

**THE EFFECTS OF WELL AND RESERVOIR
PARAMETERS ON THE PERFORMANCE OF
HORIZONTAL AND VERTICAL WELLS IN
VOLUMETRIC DRY GAS RESERVOIRS**

BY

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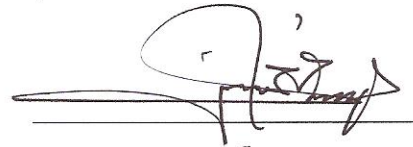
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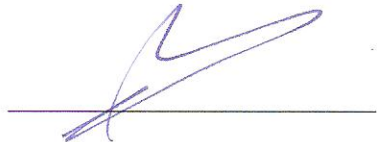
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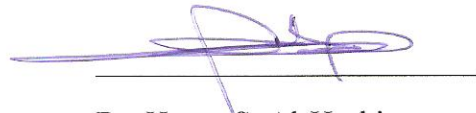
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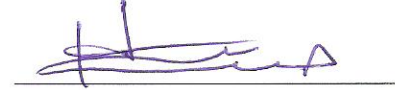


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DEDICATION

This effort is dedicated to

My loving parents, my brothers and their children, my sisters and their children and my friends whose affection, sacrifices, blessings and prayers are great source of courage in achieving this goal in my life.

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THESIS ABSTRACT (ENGLISH)

Full Name : Babar Kamal

Thesis Title : The Effects of Well and Reservoir Parameters on the Performance of Horizontal and Vertical Wells in Volumetric Dry Gas Reservoirs

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Accurate determination of abandonment pressure, ultimate recovery factor, and the time to reach abandonment condition is very important to the upstream natural gas industry. For a given reservoir fluid, it is important to determine whether or not the abandonment pressure, ultimate recovery factor, and the time to reach abandonment condition depend on well type, drainage area size and shape, and reservoir rock properties such as horizontal permeability, vertical permeability, and formation thickness. Prior to this current research, it was commonly believed that the ultimate recovery factor at abandonment condition for these reservoirs should be very high. This research studied the effects of well parameters and reservoir properties on the performance of vertical wells, horizontal wells, and hydraulically-fractured vertical wells in homogeneous and anisotropic volumetric dry-gas and wet-gas reservoirs. The effects of well parameters and reservoir properties on the abandonment pressure, the ultimate recovery factor, and the time to reach abandonment condition were investigated. The well parameters and reservoir properties that were investigated include horizontal permeability, formation thickness, vertical permeability, horizontal well penetration ratio, vertical to horizontal permeability ratio, horizontal well location with respect to the upper and lower no-flow boundaries, hydraulic fracture penetration ratio, hydraulic fracture conductivity, drainage area size and shape, gas gravity, and porosity. For each case, the average reservoir pressure at the time of abandonment and

the time to reach abandonment were determined by a minimum production rate below which it will not be economical to produce from the well. Performance of the horizontal well was compared with the performance of the un-stimulated vertical well and with the hydraulically-fractured vertical well. Guideline for the selection of the proper well type in a given reservoir is presented. The results and conclusions presented in this research have not been introduced into the petroleum engineering literature previously.

Results indicate that horizontal permeability, formation thickness, well penetration ratio, drainage area size and shape, have significant effect on the performance of these three well types while gas gravity has negligible effect. The ratio of vertical permeability to horizontal permeability and the location of the horizontal well with respect to the upper and lower no-flow boundaries have negligible effect on the performance of horizontal wells in dry-gas and wet-gas reservoirs. The value of porosity does not affect the ultimate recovery factor and the abandonment pressure but it affects the abandonment time. At low horizontal permeabilities, hydraulic fracture length has significant effect on the well performance while hydraulic fracture conductivity has no effect. As permeability increases to 1 md, both the hydraulic fracture length and conductivity affect the well performance. In general, at horizontal permeabilities of 1 md and lower, a hydraulic fracture of penetration ratio 0.2 performs almost the same as a horizontal well of penetration ratio 0.4. At high permeabilities, horizontal and vertical wells have the same ultimate recovery factor and abandonment pressure; however, horizontal wells perform better than vertical wells in terms of the abandonment time.

MASTER OF SCIENCE DEGREE

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THESIS ABSTRACT (ARABIC)

ملخص البحث

اسم الطالب	:	بابار كمال
موضوع الدراسة	:	تأثير عوامل البئر والمكمن النفطي على أدائية الآبار العمودية والأفقية في مكامن الغاز الجاف الحجمية
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التحديد الدقيق لكل من ضغط اغلاق (ترك) المكمن والحد الأقصى من الإنتاج والزمن اللازم للوصول لذلك يعتبر من أهم الحسابات في الصناعات الغازية. فإنه من الأهمية تحديد فيما إذا كان ضغط اغلاق المكمن والحد الأقصى والزمن اللازم لذلك لمكمن ما سوف يتأثر او لا يتأثر بكل من نوع البئر ومساحة التصريف وشكل المكن وخصائص الصخور ك النفاذية الأفقية والعمودية وسماكة الطبقة المنتجة. وبناء على هذه البحوث فإنه مما يستحسن الحصول على أعلى معدلات انتاج ممكنة. هذه الدراسة تبحث تأثير كلاً من العوامل المتغيرة في الآبار العمودية والأفقية على أدائية كلاً من الآبار الأفقية والعمودية في المكامن الغاز الجاف والرطب ذات الخصائص المتجانسة. بشكل محدد يعمل البحث على استنتاج علاقة تأثير هذه العوامل على ضغط اغلاق المكمن والحد الأقصى من الإنتاج والزمن اللازم لذلك. حيث تتضمن الدراسة تأثير العوامل الاتية : النفاذية الأفقية، سماكة الطبقة، النفاذية العمودية، طول الجزء الأفقي من البئر، موقع البئر بالنسبة لحدود المكمن العليا والسفلى، نسبة الشقوق الهيدروليكية ومدى اتصالها، مساحة تصريف البئر، كثافة الغاز. في كل حالة من هذه الحالات يتم تعريف ضغط اغلاق (ترك) البئر والزمن اللازم للوصول له بحسب أقل معدل إنتاج اقتصادي من هذه البئر. كذلك يتناول البحث مقارنة بين أدائية البئر الأفقي والآبار العمودية التي لم تستخدم بها طرق والتحسين بعد والتي تم تحسينها باستخدام الشقوق الهيدروليكية ليقدم البحث طريقة جديدة لم يتم التطرق لها في البحوث السابقة تساعد على اختيار نوع البئر المناسب وفقاً لخصائص المكمن المحددة.

وفقاً لنتائج هذه الدراسة تعتبر النفاذية الأفقية وسماكة الطبقة الحاوية للغاز بالإضافة إلى نسبة تثقيب البئر ومساحة تصريفها أكثر العوامل تأثيراً على أدائية ثلاثة أنواع من الآبار في الوقت الذي يعتبر تأثير كثافة الغاز بسيط جداً حيث يمكن اهماله. كما أوضحت هذه الدراسة إن نسبة النفاذية الأفقية إلى العمودية لها تأثير مهم وكذا الحال يمكن أيضاً اهمال تأثير موقع البئر الأفقي في المكمن نسبة الى حدود المكمن العلوي والسفلي في مكامن الغاز الجاف والرطب. كما أنه لا يوجد تأثير يذكر لقيمة المسامية على معدل الإنتاج وضغط اغلاق (ترك) المكمن ولكن يتضح تأثير المسامية على

زمن اللازم للوصول الى اغلاق (ترك) المكنن. في حالة النفاذيات الافقية القليلة يمثل طول الشقوق الهيدروليكية العامل الأكثر أهمية على آدائية البئر بينما يهمل تأثير مدى توصلية هذه الشقوق. بينما مع ازدياد النفاذية إلى 1 مل دارسي يظهر تأثير كلاً من توصلية هذه الشقوق وطولها على آدائية البئر. بشكل عام في المكامن ذات النفاذية الأفقية 1 مل دارسي أو أقل فإن نسبة الشقوق 0.2 يتساوى تأثيرها الى حد كبير مع نسبة الشقوق 0.4 . في حالة النفاذيات العالية فإن كلاً من الأبار الأفقية والعمودية لها معدل الإنتاج ويتساوى فية ضغط الاغلاق (الترك) بينما تعتبر آدائية الأبار الأفقية أفضل من العمودية في الزمن اللازم لترك المكنن.

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جامعة الملك فهد للبترول والمعادن
الظهران؛ المملكة العربية السعودية

CHAPTER 1

INTRODUCTION

1.1 Background

Volumetric gas reservoirs contain mixture of hydrocarbons which may be classified as dry gas, wet gas, or retrograde gas-condensate, depending on the composition of gas and the pressure and temperature at which the accumulation exists. Reservoirs that produce only gas and no appreciable hydrocarbon liquids are called dry gas reservoirs. Dry gas reservoirs may have a water influx from a nearby water bearing portion of the formation or may be volumetric. Volumetric dry gas reservoirs are completely enclosed by impermeable barriers and do not receive pressure support from surroundings. The source of reservoir energy is gas expansion resulting from gas production and subsequent pressure reduction. Gas expansion is a very efficient drive mechanism in volumetric dry gas reservoirs, resulting in high ultimate recovery.

The word “dry gas” means the reservoir is primarily made up of methane with some intermediate weight hydrocarbon molecules. There is no change in phase of dry gas and its composition remains same in the presence of significant pressure drop. Reservoir fluids remain in gas phase in the reservoir and at surface conditions. Also the word “dry

gas” does not mean that the gas is dry or it doesn’t contain water, it only indicates that no liquid hydrocarbons form in the reservoir, wellbore or surface equipment during production. In wet gas reservoirs, the primary composition of wet gas is also methane but wet gas has more of the intermediate and heavier weight hydrocarbon molecules. Because of its composition, formation of the liquid phase in the wellbore and surface production equipment accompanies pressure and temperature reduction during production. In wet gas reservoirs “wet gas” does not mean that gas is wet with water it means that hydrocarbon liquids condense at surface conditions.

Initial gas reserves should not only depend on reservoir rock and fluid properties but also on well type and characteristics. Reservoir rock and fluid properties that affect well performance include porosity, horizontal permeability, vertical permeability, initial gas saturation, rock and fluid compressibility, gas viscosity, gas gravity, z-factor, and reservoir pressure and temperature. There are three conventional methods for estimating initial gas in place, G, and gas reserves. These methods are: (a) volumetric method (b) material balance and (c) type curves. However, these methods do not describe well performance and do not properly and adequately describe the effects of rock and fluid properties on well performance.

In the last 20 years, many horizontal wells have been drilled around the world. The major purpose of horizontal wells is to increase the well’s contact with the reservoir and thereby enhance well productivity. Productivity of a horizontal well depends upon well parameters and reservoir properties. Horizontal well length depends upon the drilling technique that is used to drill the well. The major disadvantage of horizontal wells is their

cost. The cost of drilling and completion of horizontal well is more than a vertical well, depending upon drilling method and the completion technique employed.

Vertical wells are not good candidates for low permeability reservoirs but in high permeability reservoirs vertical wells perform well and in some cases even they perform better than horizontal wells such as in thick high permeability reservoirs. Hydraulic fracturing helps vertical wells to produce at a good economical rate but it is not easy to create long and highly-conductive fractures both in low and high permeability reservoirs. In high permeability gas reservoirs, wellbore turbulence limits the deliverability of vertical wells. Non-Darcy flow effects can be reduced by reducing the gas velocity near the wellbore. The most effective way of reducing the gas velocity around the wellbore is to reduce the amount of gas production per unit length of the well in contact with the reservoir. This is accomplished in horizontal wells and in long and conductive hydraulic fractures created in vertical wells.

1.2 Statement of the Problem

Volumetric and material balance (MBE) techniques do not describe well performance while decline type-curves have considerable short-comings in regards to realistic prediction of horizontal and vertical wells' performance as a function of well and reservoir rock properties described earlier. In the volumetric and material balance techniques, we assume a low abandonment pressure (such as 500 psia) and, based on this assumption, we calculate the ultimate recovery factor. When such assumption is not accurate, high ultimate recovery factor will be estimated. In addition, this research suggests that the abandonment pressure, the ultimate recovery factor, and the

abandonment time should all be expected to be a function of reservoir properties, well type, and well characteristics (i.e., well length). This research intended to find definitive and quantitative answers to the following questions:

- Does the ultimate recovery factor depend on the well type?
- For a given well type, do the average reservoir pressure at abandonment time, the ultimate recovery factor, and the abandonment time depend on reservoir properties and well parameters (i.e., well length or penetration ratio)?
- What would be the proper well type and well characteristics that should be selected in order to develop a reservoir based on reservoir properties? What should be the selection criteria?

The answers to these questions are of great importance to the natural gas industry and to the petroleum engineering discipline.

1.3 Research Objectives

The objective of this research is to study the effects of well and reservoir rock properties on the performance of horizontal and vertical wells in volumetric dry gas reservoirs. The effects of well and reservoir rock properties on the ultimate recovery and on the time to reach the economic limit will be investigated. The well and reservoir rock properties that will be investigated include horizontal permeability, vertical permeability, formation thickness, drainage area size, drainage area shape, horizontal well penetration ratio, and hydraulic fracture length and conductivity. For each case, the average reservoir pressure at the time of abandonment and the time to reach abandonment condition will be

determined by a minimum production rate below which it will not be economical to produce from the well. The minimum production rate will be referred to as abandonment condition in this research and is taken to be 50 MScf/D, regardless of the well type. Performance of the horizontal well will be compared with the performance of the vertical well and hydraulically-fractured vertical well. In case of hydraulic fractured vertical wells, the effects of fracture length and fracture conductivity are also investigated in this study in order to determine the optimum fracture parameters for volumetric dry gas reservoirs.

Therefore, the objectives of this research are to:

1. Investigate the effect of the following well parameters and reservoir properties on the performance of vertical wells, horizontal wells and hydraulically-fractured vertical wells:
 - Initial production rate
 - Horizontal permeability
 - Reservoir thickness
 - Drainage area size and shape.
 - Ratio of vertical permeability to horizontal permeability
 - Horizontal well length
 - Location of the horizontal well with respect to the upper and lower no-flow boundaries
 - Hydraulic fracture length and conductivity
 - Gas gravity

- Porosity
2. Develop and utilize appropriate and practical criteria to evaluate and to compare the performance of the three well types.
 3. Use the comparative analysis in order to select the proper well type and well penetration ratio to develop the reservoir based on reservoir properties.

The results will be used in order to select the proper well type and well penetration ratio to develop the reservoir based on reservoir properties.

CHAPTER 2

LITERATURE REVIEW

Several studies have examined the effects of different reservoir rock and fluid properties on the performance of both horizontal and vertical wells. All these studies conducted by different authors are for gas- condensate reservoirs; there are only few authors who worked in the area of dry gas reservoirs.

McGuire and Sikora¹ (1960) published a classic paper on the effects of vertical fractures on well productivity and showed that how productivity depends on the fracture penetration and conductivity. They used electric analogue computer to study the effect of finite conductivity vertical fractures on the productivity of wells in pseudo steady state behavior. Their curves are still most widely used for productivity forecasting. These curves demonstrate that the productivity increase benefits from hydraulic fracturing as a function of fracture length and relative fracture conductivity.

Parts et al.² (1961) presented an analytical model for pseudo steady state behavior for finite conductivity finite fractures. Parts et al. reservoir model was divided in to two regions of different permeabilities. Region I represents the fracture domain and region II represents the formation domain. The two more significant contributions of Parts et al.

are (1) introduction of dimensionless group of variables to describe the performance of fractured wells. This concept has been used as a dominant indicator of relative improvement in the fluid flow between fractured and non-fractured wells. (2) in case of an infinite conductivity fracture and in relatively large drainage area, the effective wellbore radius is equal to one half the fracture half lengths. In an infinite conductivity fracture, the pressure drop is negligible with respect to the formation. This situation is achieved when the dimensionless fracture conductivity is greater than 300.

Henderson and Dempsey^{3, 4} (1968) presented a case history to study the effect of well placement, operational strategies and well spacing in Oriskany sand reservoir. They varied well placement and well schedules in their study to reduce the number of wells necessary to meet the desired demand schedule. Initially the reservoir was containing 41 wells and was producing 140 MMscf/D. The objective was to increase the production to 300 MMscf/D by drilling 38 additional wells and by adding compressor horse power. When the additional wells were drilled in the high deliverability region the production was increased initially and then starts decreasing quickly due to higher drawdown, on the other hand when wells were moved out of the high deliverability region and placed in the outer portions of the reservoir the production was increased and sustained for a longer period of time than previous run. To produce more gas from the wells which are in the tighter section, the high permeability wells were down to 40% so that these wells can produce for a longer period of time. They concluded that many additional wells are required to increase production; also the proper placement of wells is very important. In addition, the use of numerical models gives engineers and his management an opportunity to evaluate the performance of wells in the reservoirs.

Coats⁵ (1969) presented a method for locating new wells in a heterogeneous field. His objective was to determine the optimum drilling program to maintain a contractual deliverability during field development. He provided a discussion of whether wells should be spaced closer together in areas of high kh or in areas of low kh . He found that when ϕh is essentially uniformly distributed, the wells should be closer together in low kh areas. On the other hand, if the variation in kh is largely caused by variations in h , or if porosity is highly correlated with permeability, wells should be closer together in areas of high kh . Coats' method assumes boundary-dominated flow throughout the reservoir.

Cinco Ley et al.⁶ (1978) demonstrated that the infinite fracture conductivity assumption is erroneous when the pressure drop along the fracture is considerable. He concluded that this would happen when the dimensionless fracture conductivity is lower than 300.

Cinco Ley et al. H. and Samaniego V. F.⁷ (1981) analyzed finite conductivity fractures and defined bilinear flow regimes which are the result of two linear flow regimes. One linear flow regime is within the fracture and other linear flow regime is into the fracture from matrix. They concluded that bilinear flow exists when most of the fluid entering the wellbore comes from the formation and the fracture tip effects haven't yet affected the well behavior.

Cinco Ley et al.⁸ (1982) introduced the concept of pseudo skin function. He presented curves for the dimensionless effective wellbore radius versus fracture conductivity and damaged fractures. The equivalent fracture skin effect for pseudo radial or pseudo steady state flow varying with fracture conductivity was also derived from their analysis.

Giger⁹ (1987) introduced new criteria such as areal productivity and replacement ratio to make comparison between vertical and horizontal wells. The replacement ratio is the number of vertical wells that will produce equal to one horizontal well at a same rate. He concluded that the productivity index of horizontal wells is higher than vertical wells because of lower drawdown; moreover, the flow entering the well per unit length is larger in horizontal wells than in vertical wells. The productivity index of both horizontal and vertical wells depends on their drainage radius. He stated that if horizontal wells are drilled at same spacing as vertical wells then they produce at a rate six times more than vertical wells.

Celier et al.¹⁰ (1989) presented a relationship to calculate the pressure drop due to non-Darcy flow effects for both horizontal and vertical wells. They showed that horizontal well performs very well in both low and high permeability gas reservoirs and that non-Darcy flow effects are almost negligible in horizontal wells. Long horizontal wells may produce less gas per unit length than a vertical well but the total horizontal well production is higher than that a vertical well because of its long length.

Renard and Dupuy¹¹ (1991) compared the performance of horizontal and vertical wells based on their flow efficiency. By comparing flow efficiency of vertical and horizontal wells, they stated that permeability reduction around the wellbore is less harmful in horizontal wells than vertical wells because of their increased contact area with the formation. He also concluded that if vertical permeability is less than horizontal permeability, then anisotropy ratio magnifies the influence of formation damage near the wellbore. In addition, another advantage in horizontal wells is that the fluid velocity at

the wellbore is much lower than vertical wells which reduce sand production in horizontal wells.

Al-Hashim, Kissami and Al-Yousef¹² (1993) studied the effect of multiple hydraulic fractures (finite or infinite conductivities) on gas well performance. Through analysis of the pressure transient behavior, they investigated the effects of induced vertical fractures of different fracture half-length ratios and different conductivities. They showed that finite conductivity fractures do not show bilinear or formation linear flow periods whereas infinite conductivity fractures showed linear flow period. They also concluded that, in case of infinite conductivity fractures, a single hydraulic fracture gave higher productivity than two fractures of same total length. However, in the case of finite conductivity fractures, two fractures gave higher productivity than a single fracture.

Muladi and Pinczewski¹³ (1999) analyzed the effects of the layering on horizontal well performance in gas-condensate reservoirs. Four cases of different reservoir heterogeneities were studied using an 11-layer reservoir. For each case, three prediction runs were made for average permeability values of 1 md, 10 md, and 100 md. The following criteria were used to compare the relative performance of the different cases studied: production rate, cumulative production, and flowing bottom-hole pressure of the well. They concluded that in tight reservoirs, the position of the horizontal well is very important, but in high permeability reservoirs, the reservoir performance would be less sensitive to the position of the horizontal well. In high permeability reservoirs, fluid mobility is much higher such that the fluid can easily move vertically to the horizontal well and the effect of heterogeneities would be less significant. They also concluded that gravity effects can influence the productivity in the case of high permeability reservoir. In

the case of reservoirs with high average permeability, horizontal wells have better performance than vertical wells. In tight reservoirs, however, the horizontal wells appear to be more sensitive to the permeability distribution. Horizontal wells achieve better performance when positioned in high permeability layer, assuming the same average permeability value.

Dashti and Kabir¹⁴ (2001) studied the effectiveness of horizontal wells in a high permeability and high anisotropy Burgan Third Middle Sand (3MS) reservoir in Kuwait. They compared the performance of horizontal and vertical wells under different scenarios such as reservoir and completion consideration, tubing size, and well length. First, they discussed the important component of horizontal well design, and then compared performance prediction of horizontal wells with their vertical counterparts under various scenarios. Performance indices, such as water breakthrough time, oil rate, water cut, and ultimate recovery are the key elements that were used to compare the performance of the wells. They concluded that horizontal well does not offer obvious advantage over its vertical counterpart in terms of water breakthrough time and ultimate recovery. They also concluded that horizontal well performance is not too different from its vertical counterpart.

Bilgesu and Ali¹⁵ (2004) studied the effect of reservoir properties on the completion strategies for fractured gas storage reservoirs. The basic objective was to maximize production with minimum cost in order to optimize production from fractured formations. Maximizing production is controlled by reservoir properties such as porosity, permeability, number of wells, line pressure, wellbore diameter, peak day requirements etc. They studied the effect of well type and reservoir permeability in a 270 acres

reservoir with 10% porosity and 20% connate water saturation by drilling 8 vertical, 3 horizontal and 1 horizontal well. Initial runs were conducted with three different permeability values 20 md, 5 md and 1 md. They concluded that the production trend of horizontal wells shows an advantage of horizontal wells over vertical wells in all cases and those vertical wells need more time to produce the same cumulative amount of gas. They also concluded that for permeabilities of 1 and 5 md, horizontal wells perform better than vertical wells and that, for higher permeability, 8 vertical wells and single horizontal well give almost similar results. Also, when formation characteristics are favorable fewer horizontal wells are needed to produce the same gas volume. This condition should be further studied in terms of economics for horizontal versus vertical well drilling and completions.

Hashemi and Gringarten¹⁶ (2005) conducted a limited reservoir simulation study to compare productivity of vertical, horizontal and hydraulically-fractured wells in gas-condensate reservoirs. They found that horizontal wells and hydraulically fractured vertical wells improve well productivity. The degree of productivity enhancement, however, depends on well and reservoir parameters such as horizontal well lengths, permeability anisotropy, fracture length, and fracture conductivity. They concluded that the well test data can be used to calibrate the parameters of empirical correlation in well performance models when experimental data are not available.

Economides and Martin¹⁷ (2007) compared the performance of horizontal transverse, horizontal longitudinal and vertical fractured gas wells using simplified analytical equations. They concluded that the main difference between oil and gas reservoirs is turbulent effects and an additional pressure drop due to small contact area between the

transverse fracture and the wellbore. They concluded that beside stimulation, hydraulic fracturing provides other benefits as well which includes sand production control, connection of layered and laminated formations by vertical penetration and also the considerable reduction of turbulence effects that dominate well performance in reservoirs with moderate to high permeability. They also concluded that for horizontal permeability less than 0.1 md, horizontal wellbores with transverse fractures or vertical wells with fractures are suitable options depending upon project economics and relative costs of vertical and horizontal wellbores. For permeability between 0.1 md and 0.5 md, horizontal wellbores with transverse fractures are recommended because, above 0.5 md, the choked connection between the fracture and the wellbore makes transverse fractures relatively inefficient. For permeability between 0.5 md and 5 md, horizontal wellbores with longitudinal fractures or vertical well with fractures are suitable candidates depending upon projects economics. For permeability greater than 5 md, horizontal wellbores with longitudinal fractures are considered.

Jamiolahmady et al¹⁸ (2007) investigated the performances of vertical, slanted, and horizontal wells productivity in layered, gas-condensate reservoirs. They used compositional reservoir simulation to conduct a series of sensitivity analysis on a single-well model. Also, the effects of relative permeability, inertial, fluid properties and reservoir anisotropy (k_v/k_h) have been studied. They concluded that for homogenous systems, a horizontal (highly-slanted) well (HW) or a slanted well (SW) have higher productivities; the improvement due to increase in lateral reach is less pronounced at lower k_v/k_h values especially for slanted well. In heterogeneous system, the horizontal or highly-slanted well improved the flow performance by reaching its total production

plateau faster than vertical well. The performance of the slanted well, on the other hand, is adversely affected by the extended cross flow from low-permeability to high-permeability layers. The impact of k_v/k_h on production is more pronounced for slanted well than for the vertical well and finally for the horizontal (highly-slanted) well especially at lower k_v/k_h ratio. Hence, the preference of having horizontal (highly-slanted) well is economically more defensible at lower k_v/k_h .

Marongiu-Porcu and Wang^{19, 20} (2009) studied and compared the performance of horizontal and vertical wells with and without fractures over a wide range of permeabilities. However, they used simplified analytical equations to conduct their study. They compared the performance of unfractured vertical well, fractured vertical well, and horizontal well with one, two, four and eight transverse fractures. They generated simplified results for 0.01 md, 0.1 md and 1 md. They concluded that for low permeability gas reservoirs, fractured vertical well performs better than a horizontal well with one or two transverse fractures for all set of permeabilities (0.01 md to 1 md). For case of 1 md permeability, fractured vertical well gives almost similar performance to a horizontal well with four transverse fractures. In case of horizontal wells with transverse fractures, horizontal wells with eight transverse fractures perform better than fractured vertical wells or horizontal wells with four transverse fractures.

Economides and Marongiu-Porcu^{21, 22} (2010) compared the performance of vertical, horizontal transverse, and horizontal longitudinal fractured wells both in oil and gas reservoirs, using simplified analytical equations. Their main objective was the selection of optimum completion type based on economic criteria. They also highlight the importance of considering the hydraulic fracturing process from the very start of wellbore

planning. They conducted a number of fracture designs for a wide range of both oil and gas wells. They used a fixed drainage area of 640 acres for this study. They concluded that a propped fracture in a gas formation will almost certainly have lower effective proppant permeability than a similar propped fracture in an oil formation due to the effects of turbulent flow within the fracture. They also concluded that for a horizontal well in oil formations, transverse fractures are very attractive for low permeability formations up to around 10 md. Above this permeability vertical fractured wells or horizontal well with longitudinal fractures should be considered. For horizontal wells in gas formations, transverse fractures are preferred for formation permeability lower than 0.5 md. Below 0.1 md, multiple vertical wellbores with fractures are preferred. In gas reservoirs with permeability above 0.5 md, horizontal wells with longitudinal fractures became more attractive than similar wells with transverse fractures. Multiple vertical fractured wells may also be more attractive than a horizontal well with multiple longitudinal fractures depending upon the relative economic of vertical and horizontal wellbores. For gas wells above 5 md, horizontal wellbores with multiple longitudinal fractures are the most attractive option.

Shelley and Soliman^{23, 24} (2010) studied the effects of well type and hydraulic fracture design on recovery for various reservoir permeabilities. The two main objective of their study was (1) To study the effects of hydraulic fracture design on hydrocarbon recovery for various permeability scenarios. (2) The effect of well type selection which includes vertical well, stimulated vertical well, horizontal well, axial stimulated horizontal well, and transverse stimulated horizontal with variations in compartment length and effective fracture length. In their research they generated results for black oil, gas condensate and

dry gas. They used a 3-D, 3-phase numerical reservoir simulator. All other parameters which include thickness, porosity, water saturation, drainage area and pore pressure are fixed except permeability, fracture half-length and fracture conductivity. They selected fracture half-length and fracture conductivity according to reservoir permeability. The highest permeability considered in their study was 0.5 md. All results were obtained only for formation thickness of 100 feet and for the wells being located in a 160-acre drainage area. They did not specify the drainage area shape for which the results were obtained. They concluded that in case of 0.5 md, well type selection and fracture area are not critical to hydrocarbon recovery. In lowest permeability cases the proper well selection and hydraulic fracture selection is very important. In case of dry gas wells with permeability below 0.01 md, a horizontal well with transverse fractures resulted in highest recovery. For permeability of 0.005 md and below, recovery is dependent on the amount of hydraulic fracturing performed.

Wang²⁵ (2012) studied the key issues in high performance natural gas wells. The objective of his study was to investigate the following two issues related to gas wells in high permeability reservoirs: (1) limitations in tubing diameter in the well (2) turbulence in the reservoir. He concluded that as reservoir permeability increases the inflow also increases and the existing tubing doesn't deliver a rate at which the reservoir is capable. For reservoirs whose permeability is more than 5 md, turbulence effect may account 20 to 60 % reduction. He also concluded that hydraulically-fractured vertical wells with better proppant selection reduce turbulence in moderate to high permeability gas reservoirs. Horizontal wells with transverse fractures have wide applications in low

permeability gas reservoirs. Horizontal wells with transverse fractures are not suitable for high permeability reservoirs because of increased turbulence effect inside the fracture.

CHAPTER 3

RESEACH METHODOLOGY

3.0 Research Methodology

A simulator is a program used to perform material balance calculations to determine pressure and saturation distribution of the reservoir as a function of time. Reservoir simulation models can be used to predict the performance of dry gas reservoirs. The commercial reservoir simulation software Eclipse will be used to model dry gas reservoirs and to evaluate the performance of both horizontal, vertical and hydraulic fractured vertical wells as a function of well and reservoir rock parameters.

The ECLIPSE simulator suite consists of two separate simulators: ECLIPSE 100 specializing in black oil modeling, and ECLIPSE 300 specializing in compositional modeling. ECLIPSE 100 is a fully-implicit, three phases, and three dimensional, general purpose black oil simulators with gas condensate options. ECLIPSE 100 is also used for dry gas simulations.

The eclipse data input section consists of eight main sections which are RUNSPEC, GRID, EDIT, PROPS, REGIONS, SOLUTION, SUMMARY and the SCHEDULE

sections. Some of these are optional and some are required. The details of these sections are described below

RUNSPEC: Runspec includes run specification, such as grid size, table sizes, number of wells and the number of phases present etc.

GRID: Defines the grid dimensions and shape, including petrophysics (porosity, permeability, net-to-gross thickness) in each grid block.

EDIT: User defined changes to the grid block centre depths, pore volumes etc. after Eclipse has processed them.

PROPS: Fluid and reservoir rock properties as a function of fluid pressures and saturations (density, viscosity, relative permeability, etc.)

REGIONS: Splits computational grid into regions for calculation of (a) PVT properties such as fluid densities and viscosities, (b) Saturation properties such as relative permeability and capillary pressure, (c) Initial conditions such as Equilibrium pressure and saturations, (d) Fluids in place.

SOLUTION: Description of equilibrium data that how the model is to be initialized. Specification of initial conditions in the reservoir may be calculated using (a) using specified fluid contact depths to give potential equilibrium (b) reading from a restart file.

RESTART: File set up by an earlier run.

SUMMARY: Result output is primarily of two types. (a) Scalar data as function of time (e.g. average field pressure). (b) Data with one value per grid cell (e.g. Oil saturation). These are only output at chosen times.

SCHEDULE: Well definitions, description of operating schedule, convergence control, control of outputs etc.

CHAPTER 4

MODEL DESCRIPTION

4.1 Reservoir Model Description

In this research, the performance of various type wells in a single-layer, a homogeneous and anisotropic reservoir is investigated. The parameters which are investigated in this study to evaluate the performance of horizontal wells, vertical wells, and hydraulically-fractured vertical wells are drainage area shape and size, formation thickness, average horizontal permeability, vertical to horizontal permeability (k_v/k_h) ratio, horizontal well penetration ratio, hydraulic fracture length, and hydraulic fracture conductivity. The values of each parameter considered in this study are shown below:

Drainage Area Shape:	Square and rectangular drainage area shapes. Length to width ratio in the rectangular case is 2:1.
Drainage Area Size:	80 acres and 160 acres.
Formation Thickness:	20 feet, 50 feet and 100 feet.
Horizontal Well Penetration Ratio:	0.2, 0.4 and 0.8.

Permeability Anisotropy ratio (k_v/k_h):	0.1, 0.5 and 1.
Horizontal Permeability:	0.01 md, 0.1 md, 1md, 10md and 100 md.
Fracture Penetration Ratio:	0.2, 0.4, and 0.8.
Fracture Conductivities:	200 md-ft, 1000 md-ft and 2000 md-ft.
Porosity:	5%-10%-20%

The reservoir top depth is 8000 feet and the initial reservoir pressure is 3,700 psia. The reservoir thickness is divided into five equal segments in the z-direction for each simulation run. Reservoir permeability in the x and y directions are equal but is different from the reservoir permeability in the z direction (vertical permeability). The vertical well is fully penetrating the entire formation thickness and is completed through the entire formation thickness. All results in this research were generated for the reservoir porosity of 20%, except for the results shown in Section 5.11 which investigates the effect of porosity. The complete details of all well and reservoir parameters used in this research are summarized in table 4.1.

Table 4.1: Reservoir rock and fluid properties

Reservoir Area	acres	80 – 160
Reservoir Thickness	ft	20 – 50 – 100
Reservoir Top Depth	ft	8000
Reservoir Porosity	%	20
Horizontal Permeabilities	md	0.01 – 0.1 – 1 – 10 – 100
k_v/k_h		0.1 – 0.5 – 1
Initial Reservoir Pressure	psia	3700
Reservoir Temperature	°F	200
Initial Oil Saturation (S_o)	%	0
Initial Water Saturation (S_w)	%	20
Initial Gas Saturation (S_g)	%	80
Vertical Well Radius (r_w)	ft	0.25
Horizontal Well Radius (r_w)	ft	0.25
Horizontal Well Penetration Ratio		0.2 – 0.4 – 0.8
Hydraulic Fractured Well Penetration Ratio		0.2 – 0.4 – 0.8
Rock Compressibility	1/psia	$4 \cdot 10^{-6}$
Water Compressibility	1/psia	$3 \cdot 10^{-6}$
Water FVF	RB/STB	1.03
Oil Density	lbs/ft ³	50.0
Water Density	lbs/ft ³	62.9549
Gas Density	lbs/ft ³	0.05365
Water viscosity	cp	0.52 @ 200 °F

4.2 Well Model Description

Cartesian coordinate grid system was used to model both horizontal and vertical wells. Vertical well model is fully penetrating and horizontal well length is calculated using the horizontal well penetration ratio and drainage area size and shape. Both horizontal and vertical wells are fully perforated. A single well model was placed in the center of the drainage volume. Horizontal well penetration ratio is defined as:

$$\text{Penetration Ratio} = \frac{L_H}{2X_e}$$

Where

L_H = Length of horizontal well

$2X_e$ = Length of the reservoir

Table 4.2 shows the lengths of horizontal wells as a function of horizontal well penetration ratios and drainage area sizes and shapes considered in this study.

Table 4.2: Length of the horizontal well L_H

Length of the horizontal well L_H , feet				
Penetration Ratio	A= 80 Acres, Square Drainage Area	A= 160 Acres, Square Drainage Area	A= 80 Acres, Rectangular Drainage Area	A= 160 Acres, Rectangular Drainage Area
0.2	360	540	540	780
0.4	780	1080	1080	1500
0.8	1500	2100	2100	3000

4.3 Grid Size Distribution

The grid sizes in both the x-direction and the y-direction is constant for all base runs and is equal to 60 feet for both rectangular and square drainage area shapes. The number of grid block NX and NY are different and vary with shape and area of the reservoir. Table 4.3 shows the number of grid blocks for each reservoir drainage area size and shape.

Table 4.3: Number of grids for each reservoir drainage area size and shape

Cartesian grid system			
A= 80 Acres, Square Drainage Area	A= 160 Acres, Square Drainage Area	A= 80 Acres, Rectangular Drainage Area	A= 160 Acres, Rectangular Drainage Area
NX= 31	NX=44	NX=44	NX=62
NY=31	NY=44	NY=22	NY=31
NZ=5	NZ=5	NZ=5	NZ=5

Figure 4.1 and 4.2 shows the grid system distribution for both rectangular and square drainage area shapes respectively.

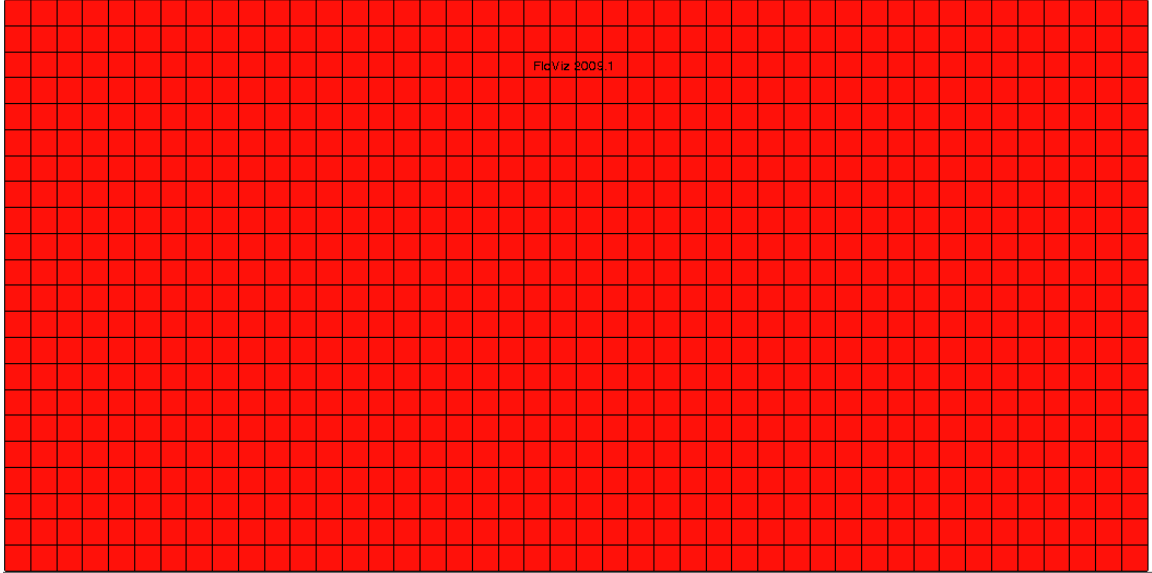


Figure 4. 1: Grid system distribution for rectangular drainage area shape

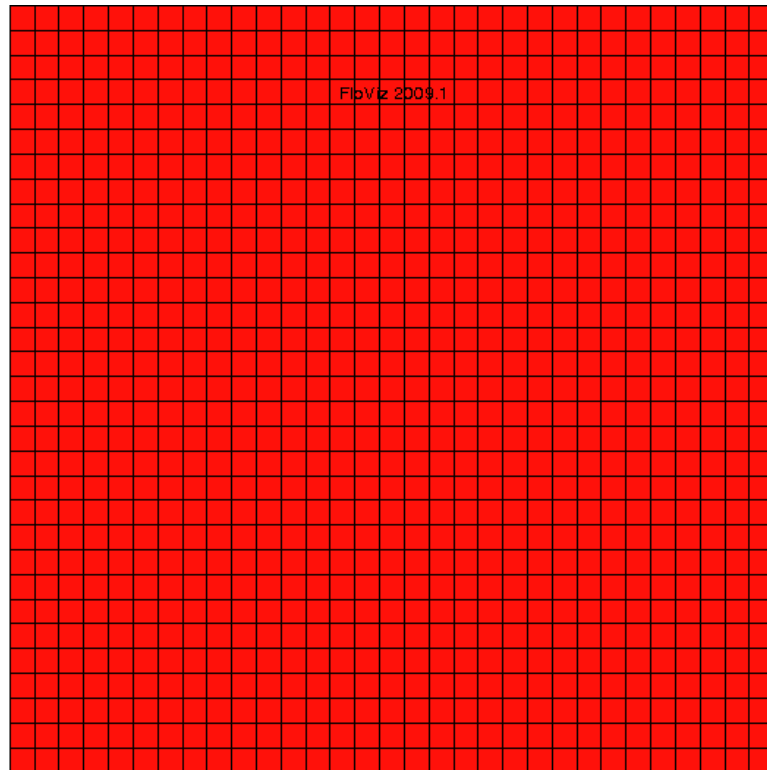


Figure 4. 2: Grid system distribution for square drainage area shape

4.4 Hydraulic Fracture Model Description

In the modeling of hydraulic fractured well, it is assumed that the well is symmetrically located in its drainage area for both square and rectangular drainage areas cases. The initial pressure in the reservoir is constant which is P_i . The width of fracture is constant which is 0.1 inch. The fracture height h_f is equal to formation thickness. Three dimensional aspect of the well and fracture position in the reservoir is presented in Figure 4.3. As shown in this figure, the vertical well is located at the center of the square drainage area and that grid block has the minimum x and y dimensions. Finite fracture is parallel to the x -axis, totally intersects the well, and is perpendicular to the y axis.

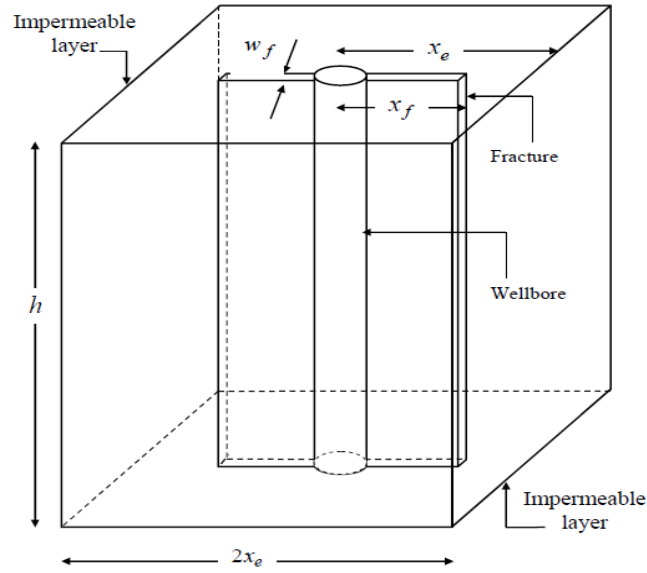


Figure 4.3: Schematic illustration of a vertical fracture in a closed square reservoir, ^{26, 27}

A variable grid size is used both in x-direction and y-direction for hydraulically-fractured vertical wells. The grid size is smaller near the wellbore and increasing to its maximum value away from the wellbore. Since the reservoir is symmetric relative to the well and fracture position, therefore the quarter of the reservoir has been observed. Figures 4.4 and 4.5 show the grid system distribution for quarter portion whereas Figure 4.6 shows the effect of fine gridding for rectangular drainage area shape. Similarly Figures 4.7 and 4.8 show the grid system distribution for quarter portion whereas Figure 4.9 shows the effect of fine gridding for square drainage area shape reservoir. All these plots are taken at initial reservoir pressure before the start of production.

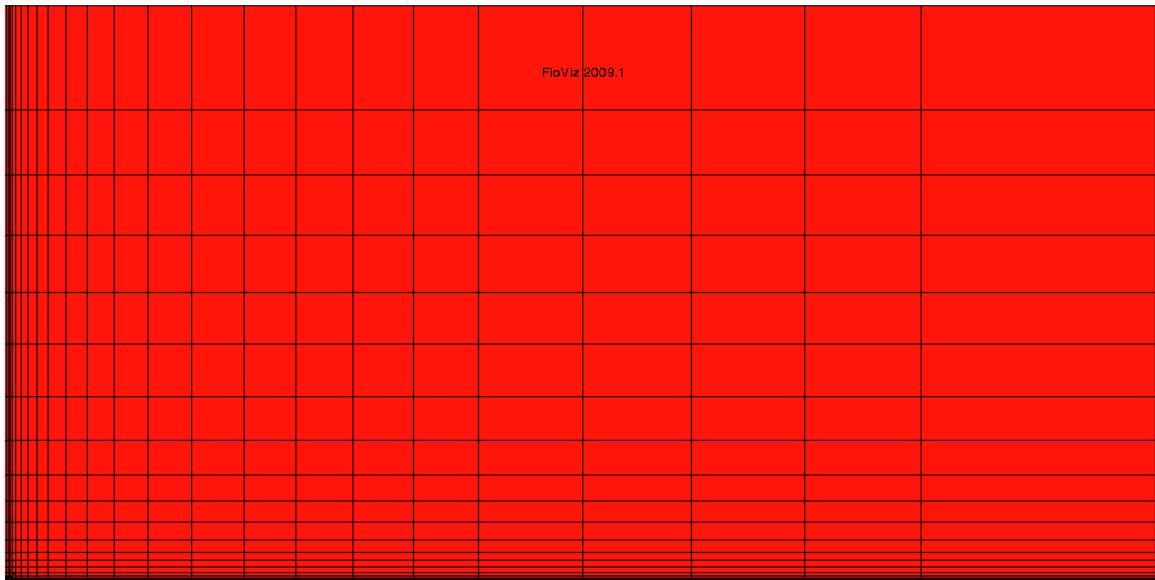


Figure 4.4: Grid system distribution for hydraulically-fractured vertical well, 80 acres, rectangular drainage area shape, quarter part of the reservoir

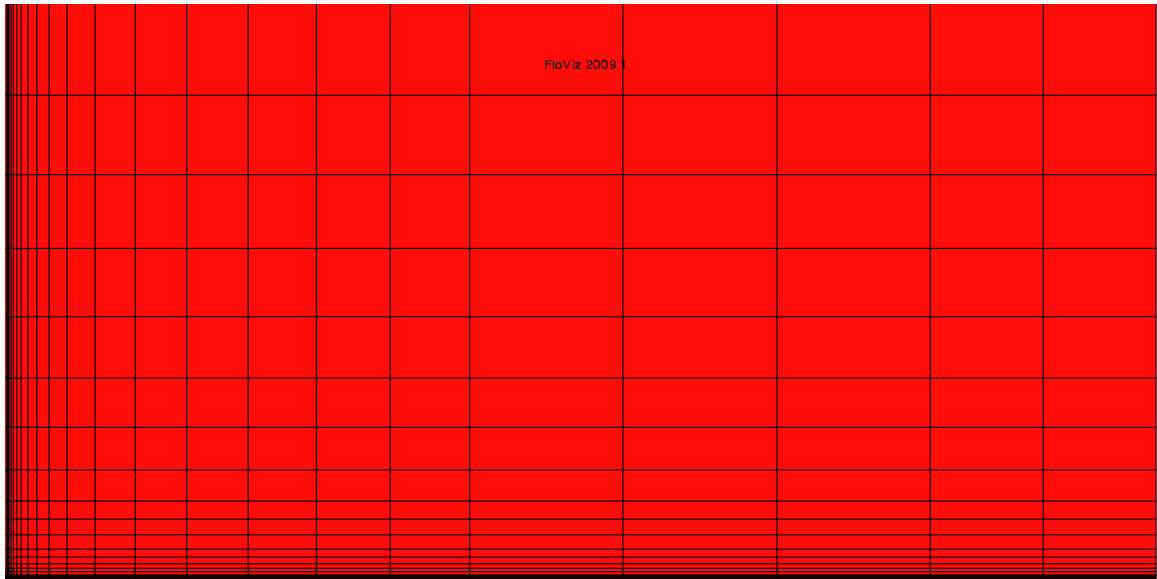


Figure 4.5: Grid system distribution for hydraulically-fractured vertical well, 160 acres, rectangular drainage area shape, quarter of the reservoir

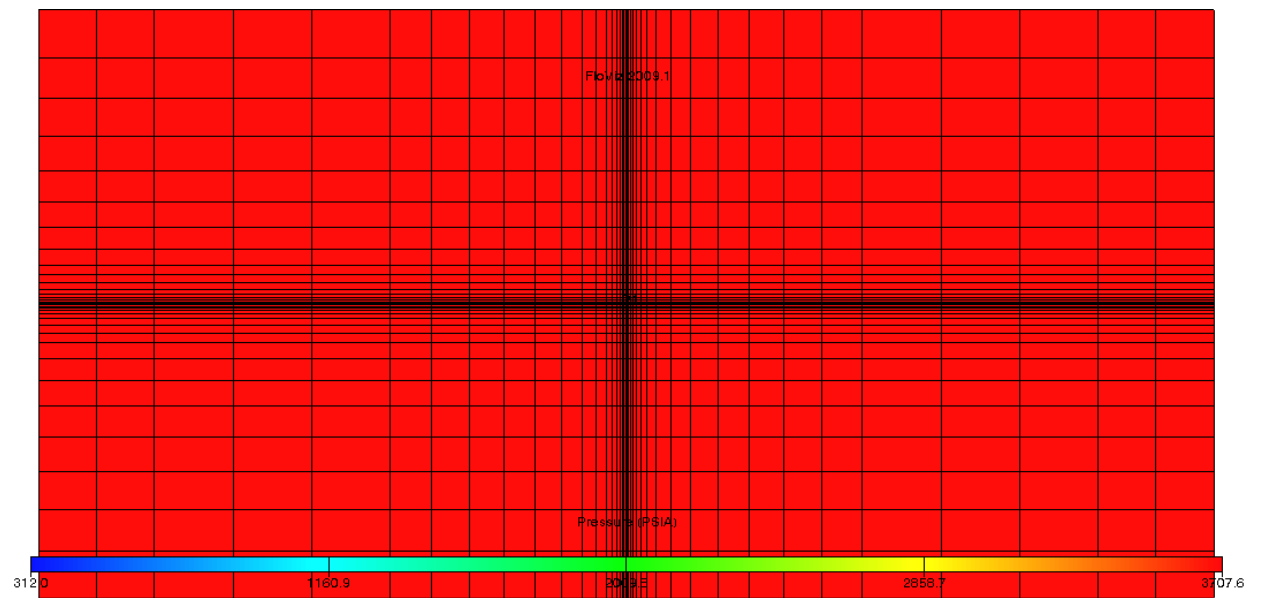


Figure 4.6: Grid system distribution for hydraulically-fractured vertical well, rectangular drainage area shape.

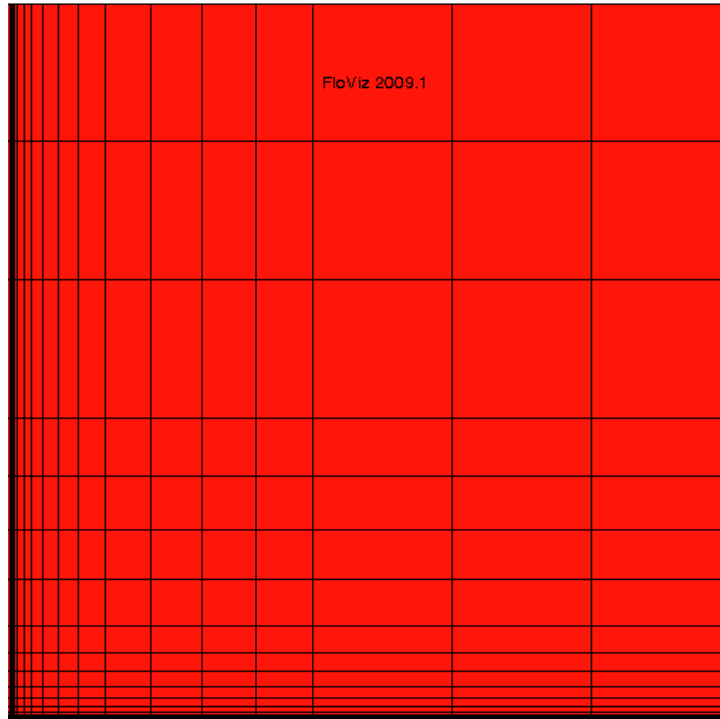


Figure 4.7: Grid system distribution for hydraulically-fractured vertical well, 80 acres, square drainage area shape, quarter part of the reservoir

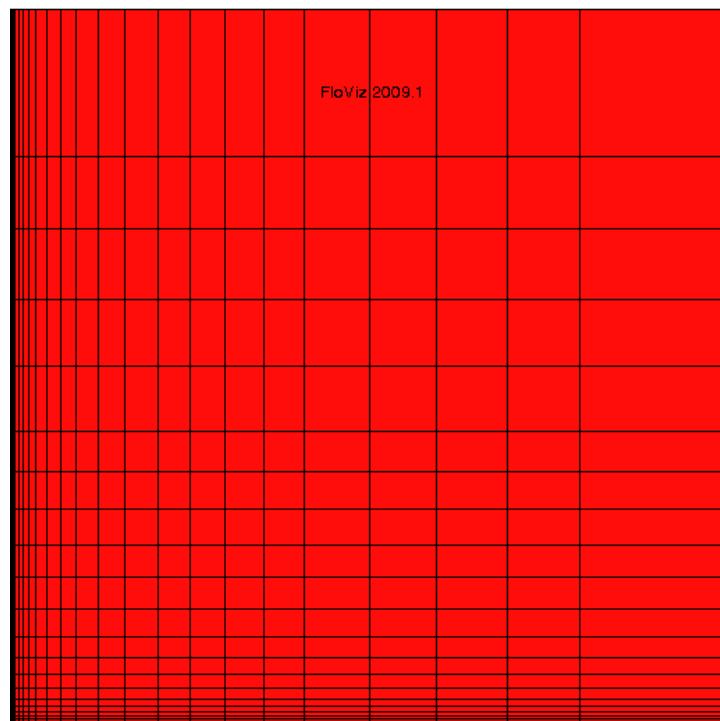


Figure 4.8: Grid system distribution for hydraulically-fractured vertical well, 160 acres, square drainage area shape, Quarter part of the reservoir

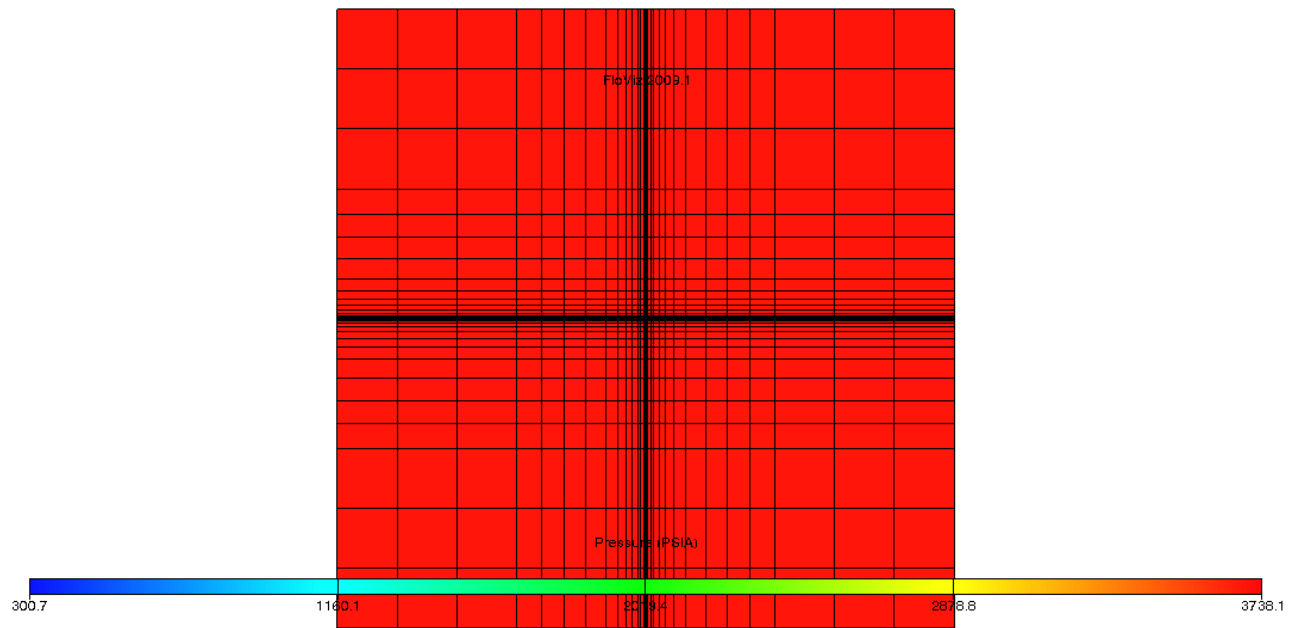


Figure 4. 9: Grid system distribution for hydraulically-fractured vertical well, square drainage area shape

Hydraulic fracturing is applied only on vertical wells for the lowest permeability cases considered in this study (i.e., 0.01 md, 0.1 md and 1md cases). Three different hydraulic fracture conductivities (200 md-feet, 1000 md-feet, 2000 md-feet) are considered in this study. Table 4.4 shows fracture lengths for both 80 and 160 square and rectangular drainage areas.

Table 4.4: Hydraulic fracture length, feet

Penetration Ratio	A= 80 Acres, Square Drainage Area	A= 160 Acres, Square Drainage Area	A= 80 Acres, Rectangular Drainage Area	A= 160 Acres, Rectangular Drainage Area
0.2	360	540	540	780
0.4	780	1080	1080	1500
0.8	1500	2100	2100	3000

The hydraulic fracture width is chosen to be 0.1 inch which is very low and unacceptable for simulator because the wellbore radius is 0.5 feet. The fracture width has to be higher than 0.5 feet; that is the reason that an equivalent fracture width of 2 feet is used for hydraulic fracturing which is equal to the dimension of the smallest grid block.

Fracture permeability is calculated by using fracture conductivity relationship.

$$k_f = \frac{F_{CD} k X_f}{w}$$

where,

F_{CD} = Dimensionless fracture conductivity

K = Formation permeability (md)

X_f = Fracture half length (feet)

W = Fracture width (feet)

The equivalent fracture permeability is calculated using

$$K_{fe} = \frac{k_f w}{w_e}$$

Where

W_e = Equivalent fracture width

k_f = Fracture permeability

The fracture porosity is 20% before and after the fracture and the equivalent fracture porosity is calculated using the below relationship.

$$\varphi_e = \frac{w \varphi_f}{w_e}$$

where,

W = Fracture width (feet)

W_e = Equivalent fracture width (feet)

φ_f =Fracture Porosity

φ_e =Equivalent fracture porosity

Using the above principals, Table 4.5 shows the values of equivalent fracture conductivity and equivalent fracture porosity.

Table 4.5: Fracture real and equivalent properties

Frac. Conductivity	Real Frac. Permeability	Equivalent Frac. Permeability	Equivalent Frac. Width	Equivalent Frac. Porosity
$k_f w$ (md-ft)	K_f (md)	K_f (md)	W_e (feet)	φ_e
200	24000	100	2	0.00083
1000	120000	500	2	0.00083
2000	240000	1000	2	0.00083

4.5 PVT Data Preparation

The PVT data of dry gas is computed by using different correlation and graphs. Gas formation volume factor B_g and gas viscosity μ_g are also important parameters in the modeling of volumetric dry gas reservoirs. Therefore, accurate calculation of these two factors is very important. The gas formation volume factor is defined as the volume of gas at reservoir condition required to produce one standard cubic foot of gas at the standard conditions. The gas formation volume factor B_g is calculated by using:

$$B_g = 0.0282 \frac{zT}{P} \frac{cu\ ft}{scf} = 0.00502 \frac{zT}{P} \frac{res.\ bbl}{scf}$$

where,

T = Temperature in degrees Rankine

P = Pressure in Psia

Z = compressibility factor

The compressibility factor of natural gases (z-factor) was calculated by using the Hall-Yarborough's equations and verified with standing and Katz chart. The specific gravity of gas is 0.7, so the pseudo reduced temperature and pseudo reduced pressure can be computed by using charts. The Hall-Yarborough method for calculation of the z-factor was developed using Starling-Carnahan equation of state. The equations presented by Hall-Yarborough are as follows:

$$z = \frac{0.06125P_{pr}te^{-1.2(1-t)^2}}{y}$$

$$y = -0.06125P_{pr}te^{-1.2(1-t)^2} + \frac{y + y^2 + y^3 - y^4}{(1 - y)^3} - (14.76t - 9.76t^2 + 4.58t^3)y^2 \\ + (90.7t - 242.2t^2 + 42.4t^3)y^{(2.18+2.82t)} = 0$$

where,

P_{pr} = Pseudo reduced pressure

t = Reciprocal of pseudo reduced temperature (T_{pc}/T)

y = Reduced Density which can be obtained as solution of above equation.

Lee, et al. (1966) correlation was used to calculate viscosity and the results are verified with the help of charts presented by Carr et al. Trans., AIME, 201,997.

$$\mu_g = K10^{-4}\exp(X\rho_g^y)$$

Where

$$K = \frac{(9.4 + 0.02M)T^{1.5}}{209 + 19M + T}$$

$$X = 3.5 + \frac{986}{T} + .01M$$

$$y = 2.4 - 0.2X$$

In all above mentioned correlations, temperature is in °R, viscosity is in centipoises, M is the molecular weight, and density is in grams per cubic centimeter. Table 4.6 shows the calculated results for B_g and μ_g as a function of pressure for a gas gravity of 0.7.

Table 4.6: PVT properties of dry gas

PRESSURE	Gas Formation Volume Factor	Gas Viscosity
Psia	RB/MSCF	CP
14.65	177.3983	0.0123
400	7.9982	0.01353
600	5.245	0.01378
800	3.8731	0.01439
1000	3.0541	0.01476
1500	1.9767	0.01599
2000	1.4458	0.01722
2500	1.1606	0.01968
3000	0.9766	0.02153
3500	0.8549	0.02276
4000	0.7701	0.02435
5000	0.6617	0.02829

CHAPTER 5

RESULTS AND DISCUSSION

In this research study more than 2000 simulation runs were made in order to investigate the effects of different well and reservoir parameters on the performance of horizontal wells, vertical wells, and hydraulically-fractured vertical wells in volumetric dry gas reservoirs. The results are plotted in terms of gas recovery factor as a function of time. All these plots are useful for evaluating and comparing the performance of horizontal, vertical and hydraulic fractured vertical wells in volumetric dry gas reservoirs.

In this chapter, reservoir simulation results are presented and detail analysis of results will be made in order to investigate the effects of several well and reservoir parameters on the performance of horizontal and vertical wells in volumetric dry gas reservoirs. Parameters investigated includes initial flow rate, horizontal permeability, reservoir thickness, vertical to horizontal permeability ratio (k_v/k_h), the length of the horizontal section of the horizontal well, drainage area size and shape, fracture conductivity and fracture length, well location and specific gravity of gas.

Table 5.1 presents the simulation results for the square drainage area cases while Table 5.2 presents the simulation results for the 2:1 rectangular drainage area cases. The results shown in these two tables include the recovery factor at abandonment time, time to reach

abandonment condition, and average reservoir pressure at abandonment time for each simulation run for vertical well, horizontal well, and hydraulically-fractured vertical well.

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X _f /X _e	K _v /K _h	h	k _h	L _H =2X _f	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
1	80	0.2	0.1	20	0.01	360	1000	3.00	2.56	3591.67	0.03	0.02	3703.26	26.75	29.90	2510.92	27.00	30.34	2494.70	27.00	30.39	2493.09
2	80	0.2	0.1	20	0.1	360	4000	29.00	70.43	1110.50	33.50	60.84	1441.41	23.50	78.43	827.88	22.75	78.95	809.04	22.75	79.12	803.01
3	80	0.2	0.1	20	1	360	8000	10.50	88.24	465.38	14.00	86.14	544.59	9.00	89.49	417.89	7.75	90.16	392.01	7.50	90.26	388.19
4	80	0.2	0.1	20	10	360	20000	2.55	91.91	321.87	3.55	91.56	335.94	N/A								
5	80	0.2	0.1	20	100	360	30000	0.65	92.40	302.26	0.83	92.36	303.91									
6	80	0.2	0.1	50	0.01	360	1500	78.75	36.22	2281.29	46.25	16.84	2998.10	84.75	57.76	1545.14	84.50	57.96	1538.31	84.50	58.01	1536.73
7	80	0.2	0.1	50	0.1	360	6000	52.25	79.99	773.15	63.50	75.21	944.62	38.00	85.36	574.77	36.75	85.67	563.33	36.50	85.70	562.21
8	80	0.2	0.1	50	1	360	13000	16.00	90.40	383.17	21.00	89.42	421.34	12.50	91.16	352.46	10.75	91.50	339.04	10.25	91.51	338.42
9	80	0.2	0.1	50	10	360	25000	3.49	92.23	309.54	4.70	92.09	315.12	N/A								
10	80	0.2	0.1	50	100	360	45000	0.81	92.44	300.97	1.01	92.42	301.67									
11	80	0.2	0.1	100	0.01	360	2000	173.25	52.72	1717.53	169.00	43.33	2031.88	145.00	70.71	1103.59	144.25	70.82	1099.71	144.25	70.86	1098.41
12	80	0.2	0.1	100	0.1	360	8000	80.25	84.08	624.07	94.25	81.81	707.69	52.25	88.42	459.89	50.50	88.62	452.58	50.25	88.65	451.38
13	80	0.2	0.1	100	1	360	17000	22.50	91.27	349.00	27.50	90.81	367.48	15.75	91.83	326.36	13.25	91.98	320.44	12.75	92.00	319.54
14	80	0.2	0.1	100	10	360	30000	4.61	92.35	305.50	5.74	92.29	307.87	N/A								
15	80	0.2	0.1	100	100	360	60000	1.01	92.47	300.55	1.19	92.46	301.03									
16	80	0.2	0.5	20	0.01	360	1000	3.25	2.79	3581.30	0.03	0.02	3703.26	26.75	29.90	2510.92	27.00	30.34	2494.70	27.00	30.39	2493.09
17	80	0.2	0.5	20	0.1	360	4000	28.75	70.62	1104.04	33.50	60.84	1441.41	23.50	78.43	827.88	22.75	78.95	809.04	22.75	79.12	803.01
18	80	0.2	0.5	20	1	360	8000	10.50	88.36	460.89	14.00	86.14	544.59	9.00	89.49	417.89	7.75	90.16	392.01	7.50	90.26	388.19
19	80	0.2	0.5	20	10	360	20000	2.52	91.92	321.68	3.55	91.56	335.94	N/A								
20	80	0.2	0.5	20	100	360	30000	0.64	92.40	302.21	0.83	92.36	303.91									
21	80	0.2	0.5	50	0.01	360	1500	81.25	38.80	2189.30	46.25	16.84	2998.10	84.75	57.76	1545.14	84.50	57.96	1538.31	84.50	58.01	1536.73

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
22	80	0.2	0.5	50	0.1	360	6000	50.50	80.59	750.95	63.50	75.21	944.62	38.00	85.36	574.77	36.75	85.67	563.33	36.50	85.70	562.21
23	80	0.2	0.5	50	1	360	13000	15.50	90.56	376.73	21.00	89.42	421.34	12.50	91.16	352.46	10.75	91.50	339.04	10.25	91.51	338.42
24	80	0.2	0.5	50	10	360	25000	3.34	92.24	309.08	4.70	92.09	315.12	N/A								
25	80	0.2	0.5	50	100	360	45000	0.79	92.44	300.91	1.01	92.42	301.67									
26	80	0.2	0.5	100	0.01	360	2000	171.25	56.46	1593.11	169.00	43.33	2031.88	145.00	70.71	1103.59	144.25	70.82	1099.71	144.25	70.86	1098.41
27	80	0.2	0.5	100	0.1	360	8000	74.50	84.96	591.36	94.25	81.81	707.69	52.25	88.42	459.89	50.50	88.62	452.58	50.25	88.65	451.38
28	80	0.2	0.5	100	1	360	17000	20.50	91.41	343.45	27.50	90.81	367.48	15.75	91.83	326.36	13.25	91.98	320.44	12.75	92.00	319.54
29	80	0.2	0.5	100	10	360	30000	4.23	92.36	304.79	5.74	92.29	307.87	N/A								
30	80	0.2	0.5	100	100	360	60000	0.96	92.47	300.48	1.19	92.46	301.03									
31	80	0.2	1	20	0.01	360	1000	3.50	2.99	3572.72	0.03	0.02	3703.26	26.75	29.90	2510.92	27.00	30.34	2494.70	27.00	30.39	2493.09
32	80	0.2	1	20	0.1	360	4000	28.75	70.67	1102.31	33.50	60.84	1441.41	23.50	78.43	827.88	22.75	78.95	809.04	22.75	79.12	803.01
33	80	0.2	1	20	1	360	8000	10.50	88.37	460.30	14.00	86.14	544.59	9.00	89.49	417.89	7.75	90.16	392.01	7.50	90.26	388.19
34	80	0.2	1	20	10	360	20000	2.52	91.92	321.55	3.55	91.56	335.94	N/A								
35	80	0.2	1	20	100	360	30000	0.64	92.40	302.27	0.83	92.36	303.91									
36	80	0.2	1	50	0.01	360	1500	81.50	39.20	2175.32	46.25	16.84	2998.10	84.75	57.76	1545.14	84.50	57.96	1538.31	84.50	58.01	1536.73
37	80	0.2	1	50	0.1	360	6000	50.00	80.63	749.48	63.50	75.21	944.62	38.00	85.36	574.77	36.75	85.67	563.33	36.50	85.70	562.21
38	80	0.2	1	50	1	360	13000	15.25	90.54	377.62	21.00	89.42	421.34	12.50	91.16	352.46	10.75	91.50	339.04	10.25	91.51	338.42
39	80	0.2	1	50	10	360	25000	3.31	92.24	309.04	4.70	92.09	315.12	N/A								
40	80	0.2	1	50	100	360	45000	0.79	92.44	300.89	1.01	92.42	301.67									
41	80	0.2	1	100	0.01	360	2000	170.50	57.31	1565.05	169.00	43.33	2031.88	145.00	70.71	1103.59	144.25	70.82	1099.71	144.25	70.86	1098.41
42	80	0.2	1	100	0.1	360	8000	73.00	85.13	584.99	94.25	81.81	707.69	52.25	88.42	459.89	50.50	88.62	452.58	50.25	88.65	451.38
43	80	0.2	1	100	1	360	17000	20.00	91.43	342.60	27.50	90.81	367.48	15.75	91.83	326.36	13.25	91.98	320.44	12.75	92.00	319.54

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
44	80	0.2	1	100	10	360	30000	4.15	92.37	304.64	5.74	92.29	307.87	N/A								
45	80	0.2	1	100	100	360	60000	0.95	92.47	300.46	1.19	92.46	301.03									
46	80	0.4	0.1	20	0.01	780	1000	25.50	26.76	2624.14	0.03	0.02	3703.26	32.75	46.79	1910.33	32.75	47.59	1882.63	32.75	47.72	1878.20
47	80	0.4	0.1	20	0.1	780	4000	23.25	77.53	860.61	33.50	60.84	1441.41	20.00	81.78	706.10	18.50	83.02	660.22	18.25	83.22	652.91
48	80	0.4	0.1	20	1	780	8000	7.75	89.91	401.90	14.00	86.14	544.59	8.75	89.84	404.63	6.75	90.80	366.63	6.25	90.98	359.24
49	80	0.4	0.1	20	10	780	20000	1.79	92.15	312.13	3.55	91.56	335.94	N/A								
50	80	0.4	0.1	20	100	780	30000	0.53	92.43	301.20	0.83	92.36	303.91									
51	80	0.4	0.1	50	0.01	780	1500	85.50	53.57	1685.40	46.25	16.84	2998.10	76.00	67.54	1210.55	75.25	67.98	1195.11	75.00	68.01	1194.09
52	80	0.4	0.1	50	0.1	780	6000	39.75	84.33	613.31	63.50	75.21	944.62	31.25	87.15	507.01	28.50	87.78	483.20	28.25	87.93	477.49
53	80	0.4	0.1	50	1	780	13000	11.50	91.32	346.00	21.00	89.42	421.34	12.00	91.30	347.08	9.00	91.73	329.42	8.25	91.81	326.44
54	80	0.4	0.1	50	10	780	25000	2.42	92.34	305.22	4.70	92.09	315.12	N/A								
55	80	0.4	0.1	50	100	780	45000	0.64	92.45	300.53	1.01	92.42	301.67									
56	80	0.4	0.1	100	0.01	780	2000	157.00	65.47	1286.00	169.00	43.33	2031.88	120.25	77.04	880.33	118.75	77.31	870.31	118.50	77.35	868.89
57	80	0.4	0.1	100	0.1	780	8000	59.25	87.16	507.83	94.25	81.81	707.69	42.25	89.52	418.09	38.50	89.91	402.93	37.75	89.95	401.58
58	80	0.4	0.1	100	1	780	17000	15.50	91.80	327.35	27.50	90.81	367.48	14.75	91.85	325.41	11.00	92.10	315.64	10.25	92.16	313.12
59	80	0.4	0.1	100	10	780	30000	3.19	92.41	302.99	5.74	92.29	307.87	N/A								
60	80	0.4	0.1	100	100	780	60000	0.80	92.48	300.29	1.19	92.46	301.03									
61	80	0.4	0.5	20	0.01	780	1000	26.00	27.47	2598.27	0.03	0.02	3703.26	32.75	46.79	1910.33	32.75	47.59	1882.63	32.75	47.72	1878.20
62	80	0.4	0.5	20	0.1	780	4000	23.25	77.79	850.95	33.50	60.84	1441.41	20.00	81.78	706.10	18.50	83.02	660.22	18.25	83.22	652.91
63	80	0.4	0.5	20	1	780	8000	7.75	89.98	399.05	14.00	86.14	544.59	8.75	89.84	404.63	6.75	90.80	366.63	6.25	90.98	359.24
64	80	0.4	0.5	20	10	780	20000	1.78	92.16	311.99	3.55	91.56	335.94	N/A								
65	80	0.4	0.5	20	100	780	30000	0.53	92.43	301.21	0.83	92.36	303.91									

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X _f /X _e	K _v /K _h	h	k _h	L _H =2X _f	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
66	80	0.4	0.5	50	0.01	780	1500	85.00	55.24	1629.66	46.25	16.84	2998.10	76.00	67.54	1210.55	75.25	67.98	1195.11	75.00	68.01	1194.09
67	80	0.4	0.5	50	0.1	780	6000	38.25	84.66	601.07	63.50	75.21	944.62	31.25	87.15	507.01	28.50	87.78	483.20	28.25	87.93	477.49
68	80	0.4	0.5	50	1	780	13000	11.00	91.36	344.36	21.00	89.42	421.34	12.00	91.30	347.08	9.00	91.73	329.42	8.25	91.81	326.44
69	80	0.4	0.5	50	10	780	25000	2.34	92.34	304.94	4.70	92.09	315.12	N/A								
70	80	0.4	0.5	50	100	780	45000	0.63	92.45	300.49	1.01	92.42	301.67									
71	80	0.4	0.5	100	0.01	780	2000	150.25	67.88	1202.47	169.00	43.33	2031.88	120.25	77.04	880.33	118.75	77.31	870.31	118.50	77.35	868.89
72	80	0.4	0.5	100	0.1	780	8000	55.00	87.73	486.37	94.25	81.81	707.69	42.25	89.52	418.09	38.50	89.91	402.93	37.75	89.95	401.58
73	80	0.4	0.5	100	1	780	17000	14.25	91.89	324.08	27.50	90.81	367.48	14.75	91.85	325.41	11.00	92.10	315.64	10.25	92.16	313.12
74	80	0.4	0.5	100	10	780	30000	2.97	92.42	302.58	5.74	92.29	307.87	N/A								
75	80	0.4	0.5	100	100	780	60000	0.77	92.48	300.26	1.19	92.46	301.03									
76	80	0.4	1	20	0.01	780	1000	26.00	27.51	2596.66	0.03	0.02	3703.26	32.75	46.79	1910.33	32.75	47.59	1882.63	32.75	47.72	1878.20
77	80	0.4	1	20	0.1	780	4000	23.25	77.83	849.66	33.50	60.84	1441.41	20.00	81.78	706.10	18.50	83.02	660.22	18.25	83.22	652.91
78	80	0.4	1	20	1	780	8000	7.75	89.99	398.67	14.00	86.14	544.59	8.75	89.84	404.63	6.75	90.80	366.63	6.25	90.98	359.24
79	80	0.4	1	20	10	780	20000	1.78	92.16	311.92	3.55	91.56	335.94	N/A								
80	80	0.4	1	20	100	780	30000	0.53	92.43	301.20	0.83	92.36	303.91									
81	80	0.4	1	50	0.01	780	1500	85.00	55.55	1619.36	46.25	16.84	2998.10	76.00	67.54	1210.55	75.25	67.98	1195.11	75.00	68.01	1194.09
82	80	0.4	1	50	0.1	780	6000	38.00	84.72	599.06	63.50	75.21	944.62	31.25	87.15	507.01	28.50	87.78	483.20	28.25	87.93	477.49
83	80	0.4	1	50	1	780	13000	11.00	91.39	343.19	21.00	89.42	421.34	12.00	91.30	347.08	9.00	91.73	329.42	8.25	91.81	326.44
84	80	0.4	1	50	10	780	25000	2.33	92.34	304.91	4.70	92.09	315.12	N/A								
85	80	0.4	1	50	100	780	45000	0.62	92.45	300.49	1.01	92.42	301.67									
86	80	0.4	1	100	0.01	780	2000	148.50	68.39	1184.73	169.00	43.33	2031.88	120.25	77.04	880.33	118.75	77.31	870.31	118.50	77.35	868.89
87	80	0.4	1	100	0.1	780	8000	54.00	87.84	482.07	94.25	81.81	707.69	42.25	89.52	418.09	38.50	89.91	402.93	37.75	89.95	401.58

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
88	80	0.4	1	100	1	780	17000	14.00	91.90	323.33	27.50	90.81	367.48	14.75	91.85	325.41	11.00	92.10	315.64	10.25	92.16	313.12
89	80	0.4	1	100	10	780	30000	2.92	92.42	302.55	5.74	92.29	307.87	N/A								
90	80	0.4	1	100	100	780	60000	0.76	92.48	300.25	1.19	92.46	301.03									
91	80	0.8	0.1	20	0.01	1500	1000	33.00	46.67	1915.96	0.03	0.02	3703.26	31.75	59.45	1482.36	31.25	60.88	1433.71	31.00	60.97	1430.50
92	80	0.8	0.1	20	0.1	1500	4000	18.00	82.52	679.15	33.50	60.84	1441.41	17.50	83.80	631.71	14.75	85.84	555.73	14.25	86.16	543.60
93	80	0.8	0.1	20	1	1500	8000	5.75	90.97	359.65	14.00	86.14	544.59	8.50	89.81	405.58	6.00	91.01	358.20	5.25	91.25	348.28
94	80	0.8	0.1	20	10	1500	20000	1.31	92.28	306.94	3.55	91.56	335.94	N/A								
95	80	0.8	0.1	20	100	1500	30000	0.47	92.44	300.65	0.83	92.36	303.91									
96	80	0.8	0.1	50	0.01	1500	1500	77.00	65.83	1270.73	46.25	16.84	2998.10	63.50	74.72	959.36	61.75	75.48	931.95	61.50	75.60	927.66
97	80	0.8	0.1	50	0.1	1500	6000	29.50	87.23	504.04	63.50	75.21	944.62	27.00	88.30	463.43	22.25	89.33	423.94	21.25	89.43	420.13
98	80	0.8	0.1	50	1	1500	13000	8.00	91.76	328.25	21.00	89.42	421.34	11.75	91.32	346.24	8.00	91.82	325.99	7.00	91.98	319.38
99	80	0.8	0.1	50	10	1500	25000	1.77	92.39	302.92	4.70	92.09	315.12	N/A								
100	80	0.8	0.1	50	100	1500	45000	0.48	92.46	300.29	1.01	92.42	301.67									
101	80	0.8	0.1	100	0.01	1500	2000	129.50	74.18	982.67	169.00	43.33	2031.88	96.25	81.72	710.14	93.00	82.15	694.22	92.50	82.21	691.97
102	80	0.8	0.1	100	0.1	1500	8000	43.25	89.21	429.94	94.25	81.81	707.69	35.75	90.17	392.99	29.25	90.77	368.85	28.00	90.84	366.39
103	80	0.8	0.1	100	1	1500	17000	10.75	92.09	315.80	27.50	90.81	367.48	14.50	91.87	324.57	10.00	92.17	312.53	8.50	92.22	310.80
104	80	0.8	0.1	100	10	1500	30000	2.34	92.44	301.66	5.74	92.29	307.87	N/A								
105	80	0.8	0.1	100	100	1500	60000	0.68	92.48	300.17	1.19	92.46	301.03									
106	80	0.8	0.5	20	0.01	1500	1000	33.25	47.27	1895.37	0.03	0.02	3703.26	31.75	59.45	1482.36	31.25	60.88	1433.71	31.00	60.97	1430.50
107	80	0.8	0.5	20	0.1	1500	4000	18.00	82.71	671.97	33.50	60.84	1441.41	17.50	83.80	631.71	14.75	85.84	555.73	14.25	86.16	543.60
108	80	0.8	0.5	20	1	1500	8000	5.75	91.01	357.88	14.00	86.14	544.59	8.50	89.81	405.58	6.00	91.01	358.20	5.25	91.25	348.28
109	80	0.8	0.5	20	10	1500	20000	1.31	92.29	306.63	3.55	91.56	335.94	N/A								

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
110	80	0.8	0.5	20	100	1500	30000	0.47	92.44	300.69	0.83	92.36	303.91	N/A								
111	80	0.8	0.5	50	0.01	1500	1500	75.25	66.89	1233.93	46.25	16.84	2998.10	63.50	74.72	959.36	61.75	75.48	931.95	61.50	75.60	927.66
112	80	0.8	0.5	50	0.1	1500	6000	28.50	87.48	494.67	63.50	75.21	944.62	27.00	88.30	463.43	22.25	89.33	423.94	21.25	89.43	420.13
113	80	0.8	0.5	50	1	1500	13000	7.75	91.81	326.57	21.00	89.42	421.34	11.75	91.32	346.24	8.00	91.82	325.99	7.00	91.98	319.38
114	80	0.8	0.5	50	10	1500	25000	1.73	92.40	302.71	4.70	92.09	315.12	N/A								
115	80	0.8	0.5	50	100	1500	45000	0.48	92.46	300.26	1.01	92.42	301.67									
116	80	0.8	0.5	100	0.01	1500	2000	122.25	75.85	923.27	169.00	43.33	2031.88	96.25	81.72	710.14	93.00	82.15	694.22	92.50	82.21	691.97
117	80	0.8	0.5	100	0.1	1500	8000	39.75	89.53	417.78	94.25	81.81	707.69	35.75	90.17	392.99	29.25	90.77	368.85	28.00	90.84	366.39
118	80	0.8	0.5	100	1	1500	17000	10.00	92.14	313.68	27.50	90.81	367.48	14.50	91.87	324.57	10.00	92.17	312.53	8.50	92.22	310.80
119	80	0.8	0.5	100	10	1500	30000	2.20	92.45	301.48	5.74	92.29	307.87	N/A								
120	80	0.8	0.5	100	100	1500	60000	0.66	92.48	300.14	1.19	92.46	301.03									
121	80	0.8	1	20	0.01	1500	1000	33.25	47.32	1893.48	0.03	0.02	3703.26	31.75	59.45	1482.36	31.25	60.88	1433.71	31.00	60.97	1430.50
122	80	0.8	1	20	0.1	1500	4000	18.00	82.74	671.02	33.50	60.84	1441.41	17.50	83.80	631.71	14.75	85.84	555.73	14.25	86.16	543.60
123	80	0.8	1	20	1	1500	8000	5.75	91.02	357.65	14.00	86.14	544.59	8.50	89.81	405.58	6.00	91.01	358.20	5.25	91.25	348.28
124	80	0.8	1	20	10	1500	20000	1.31	92.29	306.59	3.55	91.56	335.94	N/A								
125	80	0.8	1	20	100	1500	30000	0.47	92.44	300.69	0.83	92.36	303.91									
126	80	0.8	1	50	0.01	1500	1500	75.00	67.08	1227.36	46.25	16.84	2998.10	63.50	74.72	959.36	61.75	75.48	931.95	61.50	75.60	927.66
127	80	0.8	1	50	0.1	1500	6000	28.25	87.50	494.13	63.50	75.21	944.62	27.00	88.30	463.43	22.25	89.33	423.94	21.25	89.43	420.13
128	80	0.8	1	50	1	1500	13000	7.75	91.82	325.86	21.00	89.42	421.34	11.75	91.32	346.24	8.00	91.82	325.99	7.00	91.98	319.38
129	80	0.8	1	50	10	1500	25000	1.71	92.40	302.76	4.70	92.09	315.12	N/A								
130	80	0.8	1	50	100	1500	45000	0.47	92.46	300.28	1.01	92.42	301.67									

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
131	80	0.8	1	100	0.01	1500	2000	120.50	76.19	910.96	169.00	43.33	2031.88	96.25	81.72	710.14	93.00	82.15	694.22	92.50	82.21	691.97
132	80	0.8	1	100	0.1	1500	8000	39.25	89.63	413.81	94.25	81.81	707.69	35.75	90.17	392.99	29.25	90.77	368.85	28.00	90.84	366.39
133	80	0.8	1	100	1	1500	17000	9.75	92.14	313.77	27.50	90.81	367.48	14.50	91.87	324.57	10.00	92.17	312.53	8.50	92.22	310.80
134	80	0.8	1	100	10	1500	30000	2.18	92.45	301.43	5.74	92.29	307.87	N/A								
135	80	0.8	1	100	100	1500	60000	0.66	92.48	300.15	1.19	92.46	301.03									
136	160	0.2	0.1	20	0.01	540	1000	19.25	8.54	3334.77	0.03	0.01	3703.75	55.00	31.10	2467.01	55.50	31.63	2447.83	55.50	31.69	2445.81
137	160	0.2	0.1	20	0.1	540	4000	54.75	72.79	1028.48	68.00	59.72	1479.68	46.75	78.43	827.90	45.00	79.26	797.87	44.75	79.40	792.86
138	160	0.2	0.1	20	1	540	8000	18.75	88.83	443.15	28.25	85.81	557.44	18.50	89.38	421.87	15.25	90.15	392.57	14.50	90.28	387.27
139	160	0.2	0.1	20	10	540	20000	4.37	92.01	318.01	7.21	91.52	337.52	N/A								
140	160	0.2	0.1	20	100	540	30000	1.01	92.41	301.86	1.51	92.35	304.07									
141	160	0.2	0.1	50	0.01	540	1500	167.25	42.16	2070.19	81.50	14.36	3098.08	169.25	58.41	1523.31	168.75	58.70	1513.58	168.75	58.75	1511.63
142	160	0.2	0.1	50	0.1	540	6000	96.25	81.50	717.59	130.00	74.53	969.16	76.00	85.42	572.47	72.50	85.84	556.72	72.00	85.91	554.12
143	160	0.2	0.1	50	1	540	13000	28.25	90.75	368.91	42.75	89.25	427.53	25.75	91.10	355.08	21.00	91.47	339.94	19.75	91.51	338.41
144	160	0.2	0.1	50	10	540	25000	6.00	92.27	307.79	9.61	92.07	315.82	N/A								
145	160	0.2	0.1	50	100	540	45000	1.36	92.45	300.78	1.97	92.42	301.74									
146	160	0.2	0.1	100	0.01	540	2000	342.82	57.55	1556.96	336.82	41.67	2090.72	288.32	71.17	1087.70	286.92	71.35	1081.21	286.67	71.38	1080.25
147	160	0.2	0.1	100	0.1	540	8000	146.25	85.32	577.80	194.25	81.40	722.79	104.25	88.45	458.96	99.25	88.71	449.07	98.50	88.75	447.57
148	160	0.2	0.1	100	1	540	17000	38.75	91.48	340.64	56.50	90.74	370.37	32.25	91.77	328.73	26.00	91.96	321.02	24.75	92.00	319.32
149	160	0.2	0.1	100	10	540	30000	7.98	92.38	304.37	11.80	92.28	308.22	N/A								
150	160	0.2	0.1	100	100	540	60000	1.84	92.47	300.44	2.44	92.46	301.06									
151	160	0.2	0.5	20	0.01	540	1000	20.75	9.22	3306.55	0.03	0.01	3703.75	55.00	31.10	2467.01	55.50	31.63	2447.83	55.50	31.69	2445.81
152	160	0.2	0.5	20	0.1	540	4000	54.25	72.90	1024.66	68.00	59.72	1479.68	46.75	78.43	827.90	45.00	79.26	797.87	44.75	79.40	792.86

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
153	160	0.2	0.5	20	1	540	8000	18.75	88.92	439.69	28.25	85.81	557.44	18.50	89.38	421.87	15.25	90.15	392.57	14.50	90.28	387.27
154	160	0.2	0.5	20	10	540	20000	4.33	92.01	317.88	7.21	91.52	337.52	N/A								
155	160	0.2	0.5	20	100	540	30000	1.00	92.41	301.83	1.51	92.35	304.07									
156	160	0.2	0.5	50	0.01	540	1500	169.00	44.08	2003.01	81.50	14.36	3098.08	169.25	58.41	1523.31	168.75	58.70	1513.58	168.75	58.75	1511.63
157	160	0.2	0.5	50	0.1	540	6000	93.50	81.98	700.09	130.00	74.53	969.16	76.00	85.42	572.47	72.50	85.84	556.72	72.00	85.91	554.12
158	160	0.2	0.5	50	1	540	13000	27.25	90.84	365.42	42.75	89.25	427.53	25.75	91.10	355.08	21.00	91.47	339.94	19.75	91.51	338.41
159	160	0.2	0.5	50	10	540	25000	5.78	92.28	307.41	9.61	92.07	315.82	N/A								
160	160	0.2	0.5	50	100	540	45000	1.33	92.45	300.74	1.97	92.42	301.74									
161	160	0.2	0.5	100	0.01	540	2000	335.32	60.44	1459.57	336.82	41.67	2090.72	288.32	71.17	1087.70	286.92	71.35	1081.21	286.67	71.38	1080.25
162	160	0.2	0.5	100	0.1	540	8000	136.25	85.96	553.67	194.25	81.40	722.79	104.25	88.45	458.96	99.25	88.71	449.07	98.50	88.75	447.57
163	160	0.2	0.5	100	1	540	17000	35.75	91.59	336.17	56.50	90.74	370.37	32.25	91.77	328.73	26.00	91.96	321.02	24.75	92.00	319.32
164	160	0.2	0.5	100	10	540	30000	7.39	92.39	303.90	11.80	92.28	308.22	N/A								
165	160	0.2	0.5	100	100	540	60000	1.76	92.47	300.39	2.44	92.46	301.06									
166	160	0.2	1	20	0.01	540	1000	20.75	9.24	3305.88	0.03	0.01	3703.75	55.00	31.10	2467.01	55.50	31.63	2447.83	55.50	31.69	2445.81
167	160	0.2	1	20	0.1	540	4000	54.25	72.94	1023.28	68.00	59.72	1479.68	46.75	78.43	827.90	45.00	79.26	797.87	44.75	79.40	792.86
168	160	0.2	1	20	1	540	8000	18.75	88.93	439.23	28.25	85.81	557.44	18.50	89.38	421.87	15.25	90.15	392.57	14.50	90.28	387.27
169	160	0.2	1	20	10	540	20000	4.33	92.01	317.79	7.21	91.52	337.52	N/A								
170	160	0.2	1	20	100	540	30000	1.00	92.41	301.82	1.51	92.35	304.07									
171	160	0.2	1	50	0.01	540	1500	169.25	44.40	1991.86	81.50	14.36	3098.08	169.25	58.41	1523.31	168.75	58.70	1513.58	168.75	58.75	1511.63
172	160	0.2	1	50	0.1	540	6000	93.00	82.05	697.41	130.00	74.53	969.16	76.00	85.42	572.47	72.50	85.84	556.72	72.00	85.91	554.12
173	160	0.2	1	50	1	540	13000	27.00	90.84	365.37	42.75	89.25	427.53	25.75	91.10	355.08	21.00	91.47	339.94	19.75	91.51	338.41
174	160	0.2	1	50	10	540	25000	5.75	92.28	307.30	9.61	92.07	315.82	N/A								

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
175	160	0.2	1	50	100	540	45000	1.33	92.45	300.74	1.97	92.42	301.74	N/A								
176	160	0.2	1	100	0.01	540	2000	333.32	61.09	1437.57	336.82	41.67	2090.72	288.32	71.17	1087.70	286.92	71.35	1081.21	286.67	71.38	1080.25
177	160	0.2	1	100	0.1	540	8000	134.25	86.11	547.72	194.25	81.40	722.79	104.25	88.45	458.96	99.25	88.71	449.07	98.50	88.75	447.57
178	160	0.2	1	100	1	540	17000	35.00	91.60	335.53	56.50	90.74	370.37	32.25	91.77	328.73	26.00	91.96	321.02	24.75	92.00	319.32
179	160	0.2	1	100	10	540	30000	7.27	92.39	303.80	11.80	92.28	308.22	N/A								
180	160	0.2	1	100	100	540	60000	1.74	92.47	300.38	2.44	92.46	301.06									
181	160	0.4	0.1	20	0.01	1080	1000	56.00	31.04	2468.06	0.03	0.01	3703.75	65.25	46.05	1936.16	65.25	47.03	1902.10	65.25	47.19	1896.81
182	160	0.4	0.1	20	0.1	1080	4000	44.50	78.72	817.84	68.00	59.72	1479.68	41.00	81.19	727.80	37.25	82.78	668.97	36.50	82.99	661.24
183	160	0.4	0.1	20	1	1080	8000	14.25	90.24	389.05	28.25	85.81	557.44	18.00	89.52	416.89	13.50	90.57	375.80	12.25	90.82	365.61
184	160	0.4	0.1	20	10	1080	20000	3.12	92.19	310.69	7.21	91.52	337.52	N/A								
185	160	0.4	0.1	20	100	1080	30000	0.79	92.43	301.07	1.51	92.35	304.07									
186	160	0.4	0.1	50	0.01	1080	1500	170.00	56.50	1587.84	81.50	14.36	3098.08	153.25	67.09	1226.10	151.50	67.66	1206.32	151.25	67.75	1203.23
187	160	0.4	0.1	50	0.1	1080	6000	74.75	85.07	585.72	130.00	74.53	969.16	64.75	86.88	517.35	58.00	87.72	485.43	56.75	87.83	481.35
188	160	0.4	0.1	50	1	1080	13000	20.50	91.44	341.27	42.75	89.25	427.53	25.00	91.16	352.50	18.25	91.65	333.01	16.50	91.77	328.15
189	160	0.4	0.1	50	10	1080	25000	4.27	92.35	304.58	9.61	92.07	315.82	N/A								
190	160	0.4	0.1	50	100	1080	45000	1.10	92.46	300.45	1.97	92.42	301.74									
190	160	0.4	0.1	50	100	1080	45000	1.10	92.46	300.45	1.97	92.42	301.74									
191	160	0.4	0.1	100	0.01	1080	2000	303.42	67.88	1202.68	336.82	41.67	2090.72	244.00	76.80	888.85	240.25	77.15	876.31	239.75	77.20	874.28
192	160	0.4	0.1	100	0.1	1080	8000	110.25	87.79	484.02	194.25	81.40	722.79	88.00	89.37	423.77	78.00	89.85	405.27	76.25	89.91	402.92
193	160	0.4	0.1	100	1	1080	17000	27.50	91.89	323.75	56.50	90.74	370.37	31.25	91.81	327.26	22.50	92.05	317.48	20.50	92.13	314.39
194	160	0.4	0.1	100	10	1080	30000	5.76	92.42	302.52	11.80	92.28	308.22	N/A								
195	160	0.4	0.1	100	100	1080	60000	1.52	92.48	300.25	2.44	92.46	301.06									

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
196	160	0.4	0.5	20	0.01	1080	1000	56.50	31.53	2450.19	0.03	0.01	3703.75	65.25	46.05	1936.16	65.25	47.03	1902.10	65.25	47.19	1896.81
197	160	0.4	0.5	20	0.1	1080	4000	44.25	78.84	813.46	68.00	59.72	1479.68	41.00	81.19	727.80	37.25	82.78	668.97	36.50	82.99	661.24
198	160	0.4	0.5	20	1	1080	8000	14.00	90.21	390.33	28.25	85.81	557.44	18.00	89.52	416.89	13.50	90.57	375.80	12.25	90.82	365.61
199	160	0.4	0.5	20	10	1080	20000	3.11	92.20	310.46	7.21	91.52	337.52	N/A								
200	160	0.4	0.5	20	100	1080	30000	0.79	92.43	301.05	1.51	92.35	304.07									
201	160	0.4	0.5	50	0.01	1080	1500	168.50	57.79	1544.48	81.50	14.36	3098.08	153.25	67.09	1226.10	151.50	67.66	1206.32	151.25	67.75	1203.23
202	160	0.4	0.5	50	0.1	1080	6000	72.50	85.36	575.13	130.00	74.53	969.16	64.75	86.88	517.35	58.00	87.72	485.43	56.75	87.83	481.35
203	160	0.4	0.5	50	1	1080	13000	19.75	91.47	339.87	42.75	89.25	427.53	25.00	91.16	352.50	18.25	91.65	333.01	16.50	91.77	328.15
204	160	0.4	0.5	50	10	1080	25000	4.15	92.36	304.35	9.61	92.07	315.82	N/A								
205	160	0.4	0.5	50	100	1080	45000	1.08	92.46	300.44	1.97	92.42	301.74									
206	160	0.4	0.5	100	0.01	1080	2000	291.17	69.78	1136.61	336.82	41.67	2090.72	244.00	76.80	888.85	240.25	77.15	876.31	239.75	77.20	874.28
207	160	0.4	0.5	100	0.1	1080	8000	103.00	88.21	468.09	194.25	81.40	722.79	88.00	89.37	423.77	78.00	89.85	405.27	76.25	89.91	402.92
208	160	0.4	0.5	100	1	1080	17000	25.50	91.95	321.38	56.50	90.74	370.37	31.25	91.81	327.26	22.50	92.05	317.48	20.50	92.13	314.39
209	160	0.4	0.5	100	10	1080	30000	5.42	92.43	302.24	11.80	92.28	308.22	N/A								
210	160	0.4	0.5	100	100	1080	60000	1.47	92.48	300.22	2.44	92.46	301.06									
211	160	0.4	1	20	0.01	1080	1000	56.50	31.57	2448.71	0.03	0.01	3703.75	65.25	46.05	1936.16	65.25	47.03	1902.10	65.25	47.19	1896.81
212	160	0.4	1	20	0.1	1080	4000	44.25	78.87	812.43	68.00	59.72	1479.68	41.00	81.19	727.80	37.25	82.78	668.97	36.50	82.99	661.24
213	160	0.4	1	20	1	1080	8000	14.00	90.21	390.02	28.25	85.81	557.44	18.00	89.52	416.89	13.50	90.57	375.80	12.25	90.82	365.61
214	160	0.4	1	20	10	1080	20000	3.09	92.19	310.60	7.21	91.52	337.52	N/A								
215	160	0.4	1	20	100	1080	30000	0.79	92.43	301.08	1.51	92.35	304.07									
216	160	0.4	1	50	0.01	1080	1500	168.25	58.01	1537.17	81.50	14.36	3098.08	153.25	67.09	1226.10	151.50	67.66	1206.32	151.25	67.75	1203.23
217	160	0.4	1	50	0.1	1080	6000	72.25	85.42	572.71	130.00	74.53	969.16	64.75	86.88	517.35	58.00	87.72	485.43	56.75	87.83	481.35

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
218	160	0.4	1	50	1	1080	13000	19.75	91.50	338.95	42.75	89.25	427.53	25.00	91.16	352.50	18.25	91.65	333.01	16.50	91.77	328.15
219	160	0.4	1	50	10	1080	25000	4.13	92.36	304.27	9.61	92.07	315.82	N/A								
220	160	0.4	1	50	100	1080	45000	1.08	92.46	300.43	1.97	92.42	301.74									
221	160	0.4	1	100	0.01	1080	2000	288.42	70.20	1121.90	336.82	41.67	2090.72	244.00	76.80	888.85	240.25	77.15	876.31	239.75	77.20	874.28
222	160	0.4	1	100	0.1	1080	8000	101.50	88.31	464.46	194.25	81.40	722.79	88.00	89.37	423.77	78.00	89.85	405.27	76.25	89.91	402.92
223	160	0.4	1	100	1	1080	17000	25.00	91.96	321.12	56.50	90.74	370.37	31.25	91.81	327.26	22.50	92.05	317.48	20.50	92.13	314.39
224	160	0.4	1	100	10	1080	30000	5.34	92.43	302.22	11.80	92.28	308.22	N/A								
225	160	0.4	1	100	100	1080	60000	1.46	92.48	300.22	2.44	92.46	301.06									
226	160	0.8	0.1	20	0.01	2100	1000	66.50	50.11	1797.84	0.03	0.01	3703.75	64.00	58.61	1510.75	62.50	60.36	1451.06	62.25	60.63	1441.96
227	160	0.8	0.1	20	0.1	2100	4000	34.00	83.53	641.95	68.00	59.72	1479.68	36.75	82.94	663.55	30.00	85.54	566.70	28.50	85.89	553.60
228	160	0.8	0.1	20	1	2100	8000	10.25	91.18	351.07	28.25	85.81	557.44	17.75	89.54	416.11	12.50	90.78	367.23	10.75	91.15	352.30
229	160	0.8	0.1	20	10	2100	20000	2.20	92.31	305.92	7.21	91.52	337.52	N/A								
230	160	0.8	0.1	20	100	2100	30000	0.64	92.44	300.59	1.51	92.35	304.07									
231	160	0.8	0.1	50	0.01	2100	1500	148.50	68.11	1191.57	81.50	14.36	3098.08	129.50	74.29	974.55	125.00	75.29	938.77	124.25	75.42	933.89
232	160	0.8	0.1	50	0.1	2100	6000	54.50	87.81	482.34	130.00	74.53	969.16	57.25	87.85	480.57	45.25	89.15	430.95	43.25	89.38	422.14
233	160	0.8	0.1	50	1	2100	13000	14.25	91.89	323.27	42.75	89.25	427.53	24.75	91.19	351.47	16.75	91.73	329.57	14.25	91.89	323.02
234	160	0.8	0.1	50	10	2100	25000	3.05	92.40	302.52	9.61	92.07	315.82	N/A								
235	160	0.8	0.1	50	100	2100	45000	0.92	92.46	300.25	1.97	92.42	301.74									
236	160	0.8	0.1	100	0.01	2100	2000	245.25	76.11	914.10	336.82	41.67	2090.72	196.50	81.43	720.89	188.50	82.03	698.66	187.25	82.11	695.68
237	160	0.8	0.1	100	0.1	2100	8000	78.75	89.66	412.93	194.25	81.40	722.79	76.75	89.94	401.98	60.00	90.69	372.09	57.00	90.80	367.73
238	160	0.8	0.1	100	1	2100	17000	18.75	92.15	313.45	56.50	90.74	370.37	30.75	91.81	327.20	20.75	92.11	315.15	17.75	92.20	311.48
239	160	0.8	0.1	100	10	2100	30000	4.24	92.45	301.37	11.80	92.28	308.22	N/A								

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
240	160	0.8	0.1	100	100	2100	60000	1.31	92.48	300.13	2.44	92.46	301.06	N/A								
241	160	0.8	0.5	20	0.01	2100	1000	66.50	50.46	1786.17	0.03	0.01	3703.75	64.00	58.61	1510.75	62.50	60.36	1451.06	62.25	60.63	1441.96
242	160	0.8	0.5	20	0.1	2100	4000	33.75	83.58	639.78	68.00	59.72	1479.68	36.75	82.94	663.55	30.00	85.54	566.70	28.50	85.89	553.60
243	160	0.8	0.5	20	1	2100	8000	10.00	91.13	353.18	28.25	85.81	557.44	17.75	89.54	416.11	12.50	90.78	367.23	10.75	91.15	352.30
244	160	0.8	0.5	20	10	2100	20000	2.19	92.31	305.88	7.21	91.52	337.52	N/A								
245	160	0.8	0.5	20	100	2100	30000	0.64	92.44	300.59	1.51	92.35	304.07									
246	160	0.8	0.5	50	0.01	2100	1500	145.75	68.97	1161.66	81.50	14.36	3098.08	129.50	74.29	974.55	125.00	75.29	938.77	124.25	75.42	933.89
247	160	0.8	0.5	50	0.1	2100	6000	53.00	88.00	474.83	130.00	74.53	969.16	57.25	87.85	480.57	45.25	89.15	430.95	43.25	89.38	422.14
248	160	0.8	0.5	50	1	2100	13000	13.75	91.90	322.73	42.75	89.25	427.53	24.75	91.19	351.47	16.75	91.73	329.57	14.25	91.89	323.02
249	160	0.8	0.5	50	10	2100	25000	2.98	92.41	302.38	9.61	92.07	315.82	N/A								
250	160	0.8	0.5	50	100	2100	45000	0.91	92.46	300.23	1.97	92.42	301.74									
251	160	0.8	0.5	100	0.01	2100	2000	232.75	77.38	868.59	336.82	41.67	2090.72	196.50	81.43	720.89	188.50	82.03	698.66	187.25	82.11	695.68
252	160	0.8	0.5	100	0.1	2100	8000	73.50	89.91	402.95	194.25	81.40	722.79	76.75	89.94	401.98	60.00	90.69	372.09	57.00	90.80	367.73
253	160	0.8	0.5	100	1	2100	17000	17.50	92.18	312.17	56.50	90.74	370.37	30.75	91.81	327.20	20.75	92.11	315.15	17.75	92.20	311.48
254	160	0.8	0.5	100	10	2100	30000	4.04	92.45	301.25	11.80	92.28	308.22	N/A								
255	160	0.8	0.5	100	100	2100	60000	1.28	92.48	300.12	2.44	92.46	301.06									
256	160	0.8	1	20	0.01	2100	1000	66.50	50.50	1784.61	0.03	0.01	3703.75	64.00	58.61	1510.75	62.50	60.36	1451.06	62.25	60.63	1441.96
257	160	0.8	1	20	0.1	2100	4000	33.75	83.60	639.03	68.00	59.72	1479.68	36.75	82.94	663.55	30.00	85.54	566.70	28.50	85.89	553.60
258	160	0.8	1	20	1	2100	8000	10.00	91.14	353.00	28.25	85.81	557.44	17.75	89.54	416.11	12.50	90.78	367.23	10.75	91.15	352.30
259	160	0.8	1	20	10	2100	20000	2.19	92.31	305.85	7.21	91.52	337.52	N/A								
260	160	0.8	1	20	100	2100	30000	0.64	92.44	300.59	1.51	92.35	304.07									
261	160	0.8	1	50	0.01	2100	1500	145.25	69.11	1156.94	81.50	14.36	3098.08	129.50	74.29	974.55	125.00	75.29	938.77	124.25	75.42	933.89

Table 5.1: Summary of results for all cases of square drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
262	160	0.8	1	50	0.1	2100	6000	52.75	88.04	473.66	130.00	74.53	969.16	57.25	87.85	480.57	45.25	89.15	430.95	43.25	89.38	422.14
263	160	0.8	1	50	1	2100	13000	13.75	91.91	322.19	42.75	89.25	427.53	24.75	91.19	351.47	16.75	91.73	329.57	14.25	91.89	323.02
264	160	0.8	1	50	10	2100	25000	2.97	92.41	302.38	9.61	92.07	315.82	N/A								
265	160	0.8	1	50	100	2100	45000	0.91	92.46	300.23	1.97	92.42	301.74									
266	160	0.8	1	100	0.01	2100	2000	230.00	77.65	858.74	336.82	41.67	2090.72	196.50	81.43	720.89	188.50	82.03	698.66	187.25	82.11	695.68
267	160	0.8	1	100	0.1	2100	8000	72.25	89.96	401.29	194.25	81.40	722.79	76.75	89.94	401.98	60.00	90.69	372.09	57.00	90.80	367.73
268	160	0.8	1	100	1	2100	17000	17.25	92.19	311.90	56.50	90.74	370.37	30.75	91.81	327.20	20.75	92.11	315.15	17.75	92.20	311.48
269	160	0.8	1	100	10	2100	30000	4.00	92.45	301.23	11.80	92.28	308.22	N/A								
270	160	0.8	1	100	100	2100	60000	1.28	92.48	300.12	2.44	92.46	301.06									

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X _f /X _e	K _v /K _h	h	k _h	L _H =2X _f	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
1	80	0.2	0.1	20	0.01	540	1000	13.50	12.42	3178.53	0.03	0.02	3703.27	28.00	35.12	2326.14	28.25	35.72	2304.45	28.25	35.79	2301.99
2	80	0.2	0.1	20	0.1	540	4000	26.75	73.51	1003.11	34.00	60.34	1458.36	22.50	79.30	796.26	21.50	80.12	766.47	21.50	80.36	757.66
3	80	0.2	0.1	20	1	540	8000	9.50	89.11	432.52	14.25	85.98	550.73	9.25	89.58	414.58	7.50	90.29	386.93	7.25	90.54	377.08
4	80	0.2	0.1	20	10	540	20000	2.24	92.03	317.09	3.65	91.54	336.87	N/A								
5	80	0.2	0.1	20	100	540	30000	0.65	92.41	301.77	0.89	92.36	303.96									
6	80	0.2	0.1	50	0.01	540	1500	84.00	43.97	2008.77	43.50	15.65	3047.73	81.50	60.59	1447.89	81.00	60.84	1439.28	81.00	60.91	1437.10
7	80	0.2	0.1	50	0.1	540	6000	47.00	81.93	701.97	64.50	74.84	957.91	36.25	85.85	556.38	34.50	86.30	539.35	34.25	86.37	536.56
8	80	0.2	0.1	50	1	540	13000	14.00	90.83	365.83	21.50	89.36	423.62	12.75	91.16	352.36	10.25	91.53	337.83	9.75	91.60	334.77
9	80	0.2	0.1	50	10	540	25000	3.02	92.28	307.48	4.82	92.08	315.55	N/A								
10	80	0.2	0.1	50	100	540	45000	0.79	92.45	300.75	1.08	92.42	301.69									
11	80	0.2	0.1	100	0.01	540	2000	169.50	58.68	1518.61	169.00	42.48	2062.59	137.50	72.56	1038.37	136.75	72.76	1031.22	136.50	72.77	1030.79
12	80	0.2	0.1	100	0.1	540	8000	71.25	85.55	569.21	96.00	81.58	716.38	49.75	88.73	448.21	47.25	89.00	437.62	46.75	89.03	436.73
13	80	0.2	0.1	100	1	540	17000	19.25	91.53	338.54	28.25	90.78	368.46	16.00	91.83	326.54	12.75	92.00	319.57	12.00	92.02	318.62
14	80	0.2	0.1	100	10	540	30000	3.98	92.38	304.18	5.89	92.28	308.09	N/A								
15	80	0.2	0.1	100	100	540	60000	0.97	92.47	300.42	1.27	92.46	301.04									
16	80	0.2	0.5	20	0.01	540	1000	14.25	13.16	3148.97	0.03	0.02	3703.27	28.00	35.12	2326.14	28.25	35.72	2304.45	28.25	35.79	2301.99
17	80	0.2	0.5	20	0.1	540	4000	26.75	73.81	992.39	34.00	60.34	1458.36	22.50	79.30	796.26	21.50	80.12	766.47	21.50	80.36	757.66
18	80	0.2	0.5	20	1	540	8000	9.25	89.02	435.83	14.25	85.98	550.73	9.25	89.58	414.58	7.50	90.29	386.93	7.25	90.54	377.08
19	80	0.2	0.5	20	10	540	20000	2.22	92.04	316.77	3.65	91.54	336.87	N/A								
20	80	0.2	0.5	20	100	540	30000	0.65	92.41	301.77	0.89	92.36	303.96									
21	80	0.2	0.5	50	0.01	540	1500	84.75	45.97	1939.88	43.50	15.65	3047.73	81.50	60.59	1447.89	81.00	60.84	1439.28	81.00	60.91	1437.10

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
22	80	0.2	0.5	50	0.1	540	6000	45.50	82.39	685.02	64.50	74.84	957.91	36.25	85.85	556.38	34.50	86.30	539.35	34.25	86.37	536.56
23	80	0.2	0.5	50	1	540	13000	13.50	90.92	362.27	21.50	89.36	423.62	12.75	91.16	352.36	10.25	91.53	337.83	9.75	91.60	334.77
24	80	0.2	0.5	50	10	540	25000	2.91	92.29	307.12	4.82	92.08	315.55	N/A								
25	80	0.2	0.5	50	100	540	45000	0.78	92.45	300.69	1.08	92.42	301.69									
26	80	0.2	0.5	100	0.01	540	2000	165.00	61.62	1418.91	169.00	42.48	2062.59	137.50	72.56	1038.37	136.75	72.76	1031.22	136.50	72.77	1030.79
27	80	0.2	0.5	100	0.1	540	8000	66.25	86.21	544.06	96.00	81.58	716.38	49.75	88.73	448.21	47.25	89.00	437.62	46.75	89.03	436.73
28	80	0.2	0.5	100	1	540	17000	17.75	91.64	333.97	28.25	90.78	368.46	16.00	91.83	326.54	12.75	92.00	319.57	12.00	92.02	318.62
29	80	0.2	0.5	100	10	540	30000	3.69	92.39	303.68	5.89	92.28	308.09	N/A								
30	80	0.2	0.5	100	100	540	60000	0.90	92.47	300.37	1.27	92.46	301.04									
31	80	0.2	1	20	0.01	540	1000	14.25	13.19	3148.00	0.03	0.02	3703.27	28.00	35.12	2326.14	28.25	35.72	2304.45	28.25	35.79	2301.99
32	80	0.2	1	20	0.1	540	4000	26.75	73.86	990.96	34.00	60.34	1458.36	22.50	79.30	796.26	21.50	80.12	766.47	21.50	80.36	757.66
33	80	0.2	1	20	1	540	8000	9.25	89.03	435.37	14.25	85.98	550.73	9.25	89.58	414.58	7.50	90.29	386.93	7.25	90.54	377.08
34	80	0.2	1	20	10	540	20000	2.21	92.03	317.07	3.65	91.54	336.87	N/A								
35	80	0.2	1	20	100	540	30000	0.65	92.41	301.76	0.89	92.36	303.96									
36	80	0.2	1	50	0.01	540	1500	84.75	46.27	1929.48	43.50	15.65	3047.73	81.50	60.59	1447.89	81.00	60.84	1439.28	81.00	60.91	1437.10
37	80	0.2	1	50	0.1	540	6000	45.25	82.46	682.20	64.50	74.84	957.91	36.25	85.85	556.38	34.50	86.30	539.35	34.25	86.37	536.56
38	80	0.2	1	50	1	540	13000	13.50	90.96	360.76	21.50	89.36	423.62	12.75	91.16	352.36	10.25	91.53	337.83	9.75	91.60	334.77
39	80	0.2	1	50	10	540	25000	2.89	92.29	307.03	4.82	92.08	315.55	N/A								
40	80	0.2	1	50	100	540	45000	0.78	92.45	300.69	1.08	92.42	301.69									
41	80	0.2	1	100	0.01	540	2000	163.75	62.26	1396.93	169.00	42.48	2062.59	137.50	72.56	1038.37	136.75	72.76	1031.22	136.50	72.77	1030.79
42	80	0.2	1	100	0.1	540	8000	65.25	86.37	537.87	96.00	81.58	716.38	49.75	88.73	448.21	47.25	89.00	437.62	46.75	89.03	436.73
43	80	0.2	1	100	1	540	17000	17.25	91.64	334.05	28.25	90.78	368.46	16.00	91.83	326.54	12.75	92.00	319.57	12.00	92.02	318.62

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
44	80	0.2	1	100	10	540	30000	3.62	92.39	303.63	5.89	92.28	308.09	N/A								
45	80	0.2	1	100	100	540	60000	0.89	92.47	300.36	1.27	92.46	301.04									
46	80	0.4	0.1	20	0.01	1080	1000	30.00	36.02	2290.16	0.03	0.02	3703.27	31.75	51.87	1739.55	31.75	53.13	1696.17	31.50	53.14	1695.83
47	80	0.4	0.1	20	0.1	1080	4000	21.25	79.93	773.63	34.00	60.34	1458.36	19.25	82.44	681.81	17.00	84.07	621.22	16.50	84.24	614.79
48	80	0.4	0.1	20	1	1080	8000	7.00	90.49	378.87	14.25	85.98	550.73	9.00	89.73	408.50	6.50	90.72	369.81	6.00	91.09	354.99
49	80	0.4	0.1	20	10	1080	20000	1.61	92.21	309.77	3.65	91.54	336.87	N/A								
50	80	0.4	0.1	20	100	1080	30000	0.58	92.43	300.92	0.89	92.36	303.96									
51	80	0.4	0.1	50	0.01	1080	1500	83.00	59.22	1496.01	43.50	15.65	3047.73	70.50	70.35	1111.89	69.25	70.95	1090.66	69.00	71.03	1088.03
52	80	0.4	0.1	50	0.1	1080	6000	35.25	85.64	564.15	64.50	74.84	957.91	30.00	87.52	493.23	26.25	88.40	459.42	25.50	88.50	455.75
53	80	0.4	0.1	50	1	1080	13000	10.00	91.55	336.70	21.50	89.36	423.62	12.25	91.22	350.25	8.75	91.73	329.65	8.00	91.88	323.60
54	80	0.4	0.1	50	10	1080	25000	2.15	92.36	304.14	4.82	92.08	315.55	N/A								
55	80	0.4	0.1	50	100	1080	45000	0.67	92.46	300.41	1.08	92.42	301.69									
56	80	0.4	0.1	100	0.01	1080	2000	146.25	69.56	1144.30	169.00	42.48	2062.59	110.50	78.88	813.25	108.25	79.26	799.43	107.75	79.29	798.25
57	80	0.4	0.1	100	0.1	1080	8000	52.25	88.14	470.60	96.00	81.58	716.38	40.50	89.74	409.38	35.00	90.23	390.27	34.00	90.28	388.05
58	80	0.4	0.1	100	1	1080	17000	13.25	91.94	322.05	28.25	90.78	368.46	15.25	91.83	326.26	11.00	92.12	314.54	9.75	92.17	312.61
59	80	0.4	0.1	100	10	1080	30000	2.84	92.43	302.30	5.89	92.28	308.09	N/A								
60	80	0.4	0.1	100	100	1080	60000	0.80	92.48	300.22	1.27	92.46	301.04									
61	80	0.4	0.5	20	0.01	1080	1000	30.25	36.58	2270.06	0.03	0.02	3703.27	31.75	51.87	1739.55	31.75	53.13	1696.17	31.50	53.14	1695.83
62	80	0.4	0.5	20	0.1	1080	4000	21.00	79.98	772.03	34.00	60.34	1458.36	19.25	82.44	681.81	17.00	84.07	621.22	16.50	84.24	614.79
63	80	0.4	0.5	20	1	1080	8000	7.00	90.55	376.65	14.25	85.98	550.73	9.00	89.73	408.50	6.50	90.72	369.81	6.00	91.09	354.99
64	80	0.4	0.5	20	10	1080	20000	1.61	92.22	309.36	3.65	91.54	336.87	N/A								
65	80	0.4	0.5	20	100	1080	30000	0.58	92.43	300.89	0.89	92.36	303.96									

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X _f /X _e	K _v /K _h	h	k _h	L _H =2X _f	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
66	80	0.4	0.5	50	0.01	1080	1500	81.75	60.54	1451.30	43.50	15.65	3047.73	70.50	70.35	1111.89	69.25	70.95	1090.66	69.00	71.03	1088.03
67	80	0.4	0.5	50	0.1	1080	6000	34.25	85.99	550.95	64.50	74.84	957.91	30.00	87.52	493.23	26.25	88.40	459.42	25.50	88.50	455.75
68	80	0.4	0.5	50	1	1080	13000	9.50	91.56	336.51	21.50	89.36	423.62	12.25	91.22	350.25	8.75	91.73	329.65	8.00	91.88	323.60
69	80	0.4	0.5	50	10	1080	25000	2.10	92.37	303.84	4.82	92.08	315.55	N/A								
70	80	0.4	0.5	50	100	1080	45000	0.67	92.46	300.40	1.08	92.42	301.69									
71	80	0.4	0.5	100	0.01	1080	2000	139.00	71.51	1076.02	169.00	42.48	2062.59	110.50	78.88	813.25	108.25	79.26	799.43	107.75	79.29	798.25
72	80	0.4	0.5	100	0.1	1080	8000	48.50	88.58	453.88	96.00	81.58	716.38	40.50	89.74	409.38	35.00	90.23	390.27	34.00	90.28	388.05
73	80	0.4	0.5	100	1	1080	17000	12.25	92.00	319.55	28.25	90.78	368.46	15.25	91.83	326.26	11.00	92.12	314.54	9.75	92.17	312.61
74	80	0.4	0.5	100	10	1080	30000	2.66	92.43	302.08	5.89	92.28	308.09	N/A								
75	80	0.4	0.5	100	100	1080	60000	0.77	92.48	300.20	1.27	92.46	301.04									
76	80	0.4	1	20	0.01	1080	1000	30.25	36.63	2268.27	0.03	0.02	3703.27	31.75	51.87	1739.55	31.75	53.13	1696.17	31.50	53.14	1695.83
77	80	0.4	1	20	0.1	1080	4000	21.00	80.01	770.93	34.00	60.34	1458.36	19.25	82.44	681.81	17.00	84.07	621.22	16.50	84.24	614.79
78	80	0.4	1	20	1	1080	8000	7.00	90.55	376.35	14.25	85.98	550.73	9.00	89.73	408.50	6.50	90.72	369.81	6.00	91.09	354.99
79	80	0.4	1	20	10	1080	20000	1.61	92.22	309.31	3.65	91.54	336.87	N/A								
80	80	0.4	1	20	100	1080	30000	0.58	92.43	300.88	0.89	92.36	303.96									
81	80	0.4	1	50	0.01	1080	1500	81.50	60.75	1444.17	43.50	15.65	3047.73	70.50	70.35	1111.89	69.25	70.95	1090.66	69.00	71.03	1088.03
82	80	0.4	1	50	0.1	1080	6000	34.00	86.03	549.72	64.50	74.84	957.91	30.00	87.52	493.23	26.25	88.40	459.42	25.50	88.50	455.75
83	80	0.4	1	50	1	1080	13000	9.50	91.58	335.58	21.50	89.36	423.62	12.25	91.22	350.25	8.75	91.73	329.65	8.00	91.88	323.60
84	80	0.4	1	50	10	1080	25000	2.09	92.37	303.85	4.82	92.08	315.55	N/A								
85	80	0.4	1	50	100	1080	45000	0.67	92.46	300.38	1.08	92.42	301.69									
86	80	0.4	1	100	0.01	1080	2000	137.50	71.97	1060.04	169.00	42.48	2062.59	110.50	78.88	813.25	108.25	79.26	799.43	107.75	79.29	798.25
87	80	0.4	1	100	0.1	1080	8000	47.50	88.65	451.31	96.00	81.58	716.38	40.50	89.74	409.38	35.00	90.23	390.27	34.00	90.28	388.05

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
88	80	0.4	1	100	1	1080	17000	12.00	92.01	319.26	28.25	90.78	368.46	15.25	91.83	326.26	11.00	92.12	314.54	9.75	92.17	312.61
89	80	0.4	1	100	10	1080	30000	2.63	92.43	301.98	5.89	92.28	308.09	N/A								
90	80	0.4	1	100	100	1080	60000	0.77	92.48	300.19	1.27	92.46	301.04									
91	80	0.8	0.1	20	0.01	2100	1000	33.50	58.31	1524.81	0.03	0.02	3703.27	29.75	68.41	1178.45	28.25	70.59	1101.73	28.00	70.92	1089.97
92	80	0.8	0.1	20	0.1	2100	4000	14.75	85.42	571.69	34.00	60.34	1458.36	16.50	84.65	600.27	12.25	87.67	486.82	11.25	88.06	471.75
93	80	0.8	0.1	20	1	2100	8000	4.75	91.57	335.57	14.25	85.98	550.73	8.75	89.71	409.60	6.00	91.08	355.15	5.00	91.52	337.57
94	80	0.8	0.1	20	10	2100	20000	1.17	92.38	303.14	3.65	91.54	336.87	N/A								
95	80	0.8	0.1	20	100	2100	30000	0.50	92.45	300.31	0.89	92.36	303.96									
96	80	0.8	0.1	50	0.01	2100	1500	67.75	72.64	1034.47	43.50	15.65	3047.73	53.75	79.78	779.13	50.25	80.98	735.39	49.75	81.16	728.60
97	80	0.8	0.1	50	0.1	2100	6000	23.50	88.81	444.30	64.50	74.84	957.91	25.25	88.78	445.46	18.00	90.27	387.78	16.50	90.48	379.78
98	80	0.8	0.1	50	1	2100	13000	6.50	92.06	316.38	21.50	89.36	423.62	12.25	91.30	346.91	8.00	91.89	323.35	6.5	92.048	316.8075
99	80	0.8	0.1	50	10	2100	25000	1.52	92.42	301.89	4.82	92.08	315.55	N/A								
100	80	0.8	0.1	50	100	2100	45000	0.59	92.46	300.17	1.08	92.42	301.69									
101	80	0.8	0.1	100	0.01	2100	2000	110.00	78.86	815.41	169.00	42.48	2062.59	78.25	84.92	592.01	72.75	85.65	564.61	72.00	85.76	560.32
102	80	0.8	0.1	100	0.1	2100	8000	34.00	90.19	392.29	96.00	81.58	716.38	33.25	90.45	381.67	23.25	91.30	347.56	21.50	91.44	342.06
103	80	0.8	0.1	100	1	2100	17000	8.50	92.23	310.23	28.25	90.78	368.46	15.00	91.85	325.62	9.75	92.18	312.34	8.00	92.27	308.60
104	80	0.8	0.1	100	10	2100	30000	2.02	92.46	301.09	5.89	92.28	308.09	N/A								
105	80	0.8	0.1	100	100	2100	60000	0.68	92.48	300.10	1.27	92.46	301.04									
106	80	0.8	0.5	20	0.01	2100	1000	33.50	58.76	1509.51	0.03	0.02	3703.27	29.75	68.41	1178.45	28.25	70.59	1101.73	28.00	70.92	1089.97
107	80	0.8	0.5	20	0.1	2100	4000	14.50	85.42	571.92	34.00	60.34	1458.36	16.50	84.65	600.27	12.25	87.67	486.82	11.25	88.06	471.75
108	80	0.8	0.5	20	1	2100	8000	4.50	91.45	340.38	14.25	85.98	550.73	8.75	89.71	409.60	6.00	91.08	355.15	5.00	91.52	337.57
109	80	0.8	0.5	20	10	2100	20000	1.17	92.38	302.97	3.65	91.54	336.87	N/A								

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
110	80	0.8	0.5	20	100	2100	30000	0.50	92.45	300.30	0.89	92.36	303.96	N/A								
111	80	0.8	0.5	50	0.01	2100	1500	65.75	73.60	1000.74	43.50	15.65	3047.73	53.75	79.78	779.13	50.25	80.98	735.39	49.75	81.16	728.60
112	80	0.8	0.5	50	0.1	2100	6000	22.50	88.99	437.32	64.50	74.84	957.91	25.25	88.78	445.46	18.00	90.27	387.78	16.50	90.48	379.78
113	80	0.8	0.5	50	1	2100	13000	6.25	92.08	315.44	21.50	89.36	423.62	12.25	91.30	346.91	8.00	91.89	323.35	6.5	92.048	316.8075
114	80	0.8	0.5	50	10	2100	25000	1.50	92.42	301.70	4.82	92.08	315.55	N/A								
115	80	0.8	0.5	50	100	2100	45000	0.60	92.46	300.16	1.08	92.42	301.69									
116	80	0.8	0.5	100	0.01	2100	2000	102.25	80.30	763.14	169.00	42.48	2062.59	78.25	84.92	592.01	72.75	85.65	564.61	72.00	85.76	560.32
117	80	0.8	0.5	100	0.1	2100	8000	34.00	90.19	392.29	96.00	81.58	716.38	33.25	90.45	381.67	23.25	91.30	347.56	21.50	91.44	342.06
118	80	0.8	0.5	100	1	2100	17000	7.75	92.25	309.30	28.25	90.78	368.46	15.00	91.85	325.62	9.75	92.18	312.34	8.00	92.27	308.60
119	80	0.8	0.5	100	10	2100	30000	1.92	92.46	300.93	5.89	92.28	308.09	N/A								
120	80	0.8	0.5	100	100	2100	60000	0.67	92.48	300.10	1.27	92.46	301.04									
121	80	0.8	1	20	0.01	2100	1000	33.50	58.82	1507.45	0.03	0.02	3703.27	29.75	68.41	1178.45	28.25	70.59	1101.73	28.00	70.92	1089.97
122	80	0.8	1	20	0.1	2100	4000	14.50	85.44	571.04	34.00	60.34	1458.36	16.50	84.65	600.27	12.25	87.67	486.82	11.25	88.06	471.75
123	80	0.8	1	20	1	2100	8000	4.50	91.46	340.18	14.25	85.98	550.73	8.75	89.71	409.60	6.00	91.08	355.15	5.00	91.52	337.57
124	80	0.8	1	20	10	2100	20000	1.17	92.38	302.94	3.65	91.54	336.87	N/A								
125	80	0.8	1	20	100	2100	30000	0.50	92.45	300.30	0.89	92.36	303.96									
126	80	0.8	1	50	0.01	2100	1500	65.50	73.79	994.26	43.50	15.65	3047.73	53.75	79.78	779.13	50.25	80.98	735.39	49.75	81.16	728.60
127	80	0.8	1	50	0.1	2100	6000	22.25	89.00	437.16	64.50	74.84	957.91	25.25	88.78	445.46	18.00	90.27	387.78	16.50	90.48	379.78
128	80	0.8	1	50	1	2100	13000	6.00	92.03	317.47	21.50	89.36	423.62	12.25	91.30	346.91	8.00	91.89	323.35	6.5	92.048	316.8075
129	80	0.8	1	50	10	2100	25000	1.48	92.42	301.77	4.82	92.08	315.55	N/A								
130	80	0.8	1	50	100	2100	45000	0.60	92.46	300.18	1.08	92.42	301.69									
131	80	0.8	1	100	0.01	2100	2000	100.25	80.57	753.23	169.00	42.48	2062.59	78.25	84.92	592.01	72.75	85.65	564.61	72.00	85.76	560.32

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X _f /X _e	K _f /K _h	h	k _h	L _H =2X _f	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
132	80	0.8	1	100	0.1	2100	8000	30.50	90.54	378.26	96.00	81.58	716.38	33.25	90.45	381.67	23.25	91.30	347.56	21.50	91.44	342.06
133	80	0.8	1	100	1	2100	17000	7.75	92.28	308.31	28.25	90.78	368.46	15.00	91.85	325.62	9.75	92.18	312.34	8.00	92.27	308.60
134	80	0.8	1	100	10	2100	30000	1.91	92.46	300.87	5.89	92.28	308.09	N/A								
135	80	0.8	1	100	100	2100	60000	0.67	92.48	300.08	1.27	92.46	301.04									
136	160	0.2	0.1	20	0.01	780	1000	36.75	18.22	2951.25	0.03	0.01	3703.75	50.75	29.49	2529.22	51.25	30.06	2508.31	51.25	30.13	2506.04
137	160	0.2	0.1	20	0.1	780	4000	50.75	75.30	939.87	68.00	59.04	1502.11	47.75	77.83	849.11	45.75	78.751	815.9775	45.25	78.83	813.13
138	160	0.2	0.1	20	1	780	8000	17.00	89.49	418.02	28.50	85.62	564.42	19.00	89.18	429.80	15.75	89.96	399.60	15.00	90.13	392.95
139	160	0.2	0.1	20	10	780	20000	3.84	92.09	314.73	7.34	91.50	338.51	N/A								
140	160	0.2	0.1	20	100	780	30000	0.97	92.42	301.49	1.60	92.35	304.17									
141	160	0.2	0.1	50	0.01	780	1500	169.67	48.22	1863.13	74.50	13.10	3150.02	167.25	57.24	1561.19	166.50	57.54	1550.92	166.50	57.61	1548.72
142	160	0.2	0.1	50	0.1	780	6000	87.25	83.05	660.60	131.25	74.18	981.27	77.75	85.01	587.68	74.00	85.50	569.32	73.50	85.59	565.97
143	160	0.2	0.1	50	1	780	13000	25.00	91.08	355.59	43.50	89.20	429.60	26.75	91.01	358.44	21.75	91.37	343.92	20.75	91.46	340.36
144	160	0.2	0.1	50	10	780	25000	5.25	92.31	306.25	9.94	92.06	316.21	N/A								
145	160	0.2	0.1	50	100	780	45000	1.24	92.45	300.63	2.33	92.43	301.41									
146	160	0.2	0.1	100	0.01	780	2000	327.67	62.14	1401.10	333.57	40.79	2122.43	290.42	70.41	1113.62	288.67	70.62	1106.44	288.42	70.65	1105.27
147	160	0.2	0.1	100	0.1	780	8000	130.50	86.45	534.97	196.42	81.18	730.88	107.50	88.21	468.13	102.00	88.50	456.84	101.00	88.54	455.55
148	160	0.2	0.1	100	1	780	17000	33.50	91.67	332.88	57.50	90.70	371.73	33.50	91.72	330.70	27.25	91.92	322.55	25.75	91.96	321.19
149	160	0.2	0.1	100	10	780	30000	6.93	92.40	303.47	12.25	92.28	308.32	N/A								
150	160	0.2	0.1	100	100	780	60000	1.69	92.47	300.35	2.75	92.46	301.07									
151	160	0.2	0.5	20	0.01	780	1000	37.75	18.81	2928.48	0.03	0.01	3703.75	50.75	29.49	2529.22	51.25	30.06	2508.31	51.25	30.13	2506.04
152	160	0.2	0.5	20	0.1	780	4000	50.50	75.45	934.70	68.00	59.04	1502.11	47.75	77.83	849.11	45.75	78.751	815.9775	45.25	78.83	813.13
153	160	0.2	0.5	20	1	780	8000	16.75	89.46	418.83	28.50	85.62	564.42	19.00	89.18	429.80	15.75	89.96	399.60	15.00	90.13	392.95

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
154	160	0.2	0.5	20	10	780	20000	3.82	92.10	314.40	7.34	91.50	338.51	N/A								
155	160	0.2	0.5	20	100	780	30000	0.96	92.42	301.49	1.60	92.35	304.17									
156	160	0.2	0.5	50	0.01	780	1500	169.92	49.76	1811.07	74.50	13.10	3150.02	167.25	57.24	1561.19	166.50	57.54	1550.92	166.50	57.61	1548.72
157	160	0.2	0.5	50	0.1	780	6000	85.00	83.42	646.96	131.25	74.18	981.27	77.75	85.01	587.68	74.00	85.50	569.32	73.50	85.59	565.97
158	160	0.2	0.5	50	1	780	13000	24.00	91.11	354.34	43.50	89.20	429.60	26.75	91.01	358.44	21.75	91.37	343.92	20.75	91.46	340.36
159	160	0.2	0.5	50	10	780	25000	5.08	92.32	306.01	9.94	92.06	316.21	N/A								
160	160	0.2	0.5	50	100	780	45000	1.22	92.45	300.60	2.33	92.43	301.41									
161	160	0.2	0.5	100	0.01	780	2000	317.92	64.39	1323.56	333.57	40.79	2122.43	290.42	70.41	1113.62	288.67	70.62	1106.44	288.42	70.65	1105.27
162	160	0.2	0.5	100	0.1	780	8000	122.50	86.96	515.67	196.42	81.18	730.88	107.50	88.21	468.13	102.00	88.50	456.84	101.00	88.54	455.55
163	160	0.2	0.5	100	1	780	17000	31.25	91.76	329.36	57.50	90.70	371.73	33.50	91.72	330.70	27.25	91.92	322.55	25.75	91.96	321.19
164	160	0.2	0.5	100	10	780	30000	6.49	92.41	303.13	12.25	92.28	308.32	N/A								
165	160	0.2	0.5	100	100	780	60000	1.62	92.48	300.31	2.75	92.46	301.07									
166	160	0.2	1	20	0.01	780	1000	37.75	18.84	2927.40	0.03	0.01	3703.75	50.75	29.49	2529.22	51.25	30.06	2508.31	51.25	30.13	2506.04
167	160	0.2	1	20	0.1	780	4000	50.25	75.39	936.87	68.00	59.04	1502.11	47.75	77.83	849.11	45.75	78.751	815.9775	45.25	78.83	813.13
168	160	0.2	1	20	1	780	8000	16.75	89.47	418.47	28.50	85.62	564.42	19.00	89.18	429.80	15.75	89.96	399.60	15.00	90.13	392.95
169	160	0.2	1	20	10	780	20000	3.81	92.09	314.53	7.34	91.50	338.51	N/A								
170	160	0.2	1	20	100	780	30000	0.96	92.42	301.48	1.60	92.35	304.17									
171	160	0.2	1	50	0.01	780	1500	169.92	50.02	1802.55	74.50	13.10	3150.02	167.25	57.24	1561.19	166.50	57.54	1550.92	166.50	57.61	1548.72
172	160	0.2	1	50	0.1	780	6000	84.50	83.46	645.42	131.25	74.18	981.27	77.75	85.01	587.68	74.00	85.50	569.32	73.50	85.59	565.97
173	160	0.2	1	50	1	780	13000	24.00	91.14	353.19	43.50	89.20	429.60	26.75	91.01	358.44	21.75	91.37	343.92	20.75	91.46	340.36
174	160	0.2	1	50	10	780	25000	5.06	92.32	305.97	9.94	92.06	316.21	N/A								
175	160	0.2	1	50	100	780	45000	1.21	92.45	300.59	2.33	92.43	301.41									

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X _f /X _e	K _v /K _h	h	k _h	L _H =2X _f	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
176	160	0.2	1	100	0.01	780	2000	315.67	64.89	1306.18	333.57	40.79	2122.43	290.42	70.41	1113.62	288.67	70.62	1106.44	288.42	70.65	1105.27
177	160	0.2	1	100	0.1	780	8000	120.75	87.07	511.50	196.42	81.18	730.88	107.50	88.21	468.13	102.00	88.50	456.84	101.00	88.54	455.55
178	160	0.2	1	100	1	780	17000	30.75	91.77	328.70	57.50	90.70	371.73	33.50	91.72	330.70	27.25	91.92	322.55	25.75	91.96	321.19
179	160	0.2	1	100	10	780	30000	6.41	92.41	303.03	12.25	92.28	308.32	N/A								
180	160	0.2	1	100	100	780	60000	1.61	92.48	300.30	2.75	92.46	301.07									
181	160	0.4	0.1	20	0.01	1500	1000	61.50	39.49	2167.46	0.03	0.01	3703.75	63.75	50.94	1771.56	63.50	52.43	1720.06	63.25	52.59	1714.77
182	160	0.4	0.1	20	0.1	1500	4000	40.00	80.83	740.93	68.00	59.04	1502.11	39.75	81.69	709.38	34.25	83.74	633.72	33.25	84.07	621.28
183	160	0.4	0.1	20	1	1500	8000	12.50	90.67	371.84	28.50	85.62	564.42	18.25	89.34	423.50	13.25	90.53	377.39	11.75	90.86	363.93
184	160	0.4	0.1	20	10	1500	20000	2.74	92.25	308.37	7.34	91.50	338.51	N/A								
185	160	0.4	0.1	20	100	1500	30000	0.79	92.44	300.84	1.60	92.35	304.17									
186	160	0.4	0.1	50	0.01	1500	1500	161.25	61.62	1414.52	74.50	13.10	3150.02	143.00	69.87	1129.05	140.00	70.67	1100.61	139.50	70.79	1096.57
187	160	0.4	0.1	50	0.1	1500	6000	66.00	86.31	539.04	131.25	74.18	981.27	62.50	87.11	508.53	53.00	88.20	467.05	51.25	88.36	461.02
188	160	0.4	0.1	50	1	1500	13000	17.75	91.65	332.68	43.50	89.20	429.60	25.75	91.11	354.39	18.25	91.66	332.57	16.00	91.79	327.16
189	160	0.4	0.1	50	10	1500	25000	3.76	92.38	303.60	9.94	92.06	316.21	N/A								
190	160	0.4	0.1	50	100	1500	45000	1.02	92.46	300.35	2.33	92.43	301.41									
191	160	0.4	0.1	100	0.01	1500	2000	278.67	71.61	1072.66	333.57	40.79	2122.43	224.42	78.57	824.58	218.42	79.05	807.12	217.67	79.13	804.16
192	160	0.4	0.1	100	0.1	1500	8000	96.25	88.66	451.06	196.42	81.18	730.88	84.75	89.49	418.95	71.00	90.11	394.77	68.75	90.21	390.88
193	160	0.4	0.1	100	1	1500	17000	23.50	92.02	318.77	57.50	90.70	371.73	32.00	91.76	329.08	22.50	92.06	317.25	19.75	92.13	314.19
194	160	0.4	0.1	100	10	1500	30000	5.04	92.43	301.99	12.25	92.28	308.32	N/A								
195	160	0.4	0.1	100	100	1500	60000	1.42	92.48	300.20	2.75	92.46	301.07									
196	160	0.4	0.5	20	0.01	1500	1000	61.50	39.82	2156.03	0.03	0.01	3703.75	63.75	50.94	1771.56	63.50	52.43	1720.06	63.25	52.59	1714.77
197	160	0.4	0.5	20	0.1	1500	4000	39.75	80.92	737.79	68.00	59.04	1502.11	39.75	81.69	709.38	34.25	83.74	633.72	33.25	84.07	621.28

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
198	160	0.4	0.5	20	1	1500	8000	12.25	90.62	373.61	28.50	85.62	564.42	18.25	89.34	423.50	13.25	90.53	377.39	11.75	90.86	363.93
199	160	0.4	0.5	20	10	1500	20000	2.72	92.25	308.46	7.34	91.50	338.51	N/A								
200	160	0.4	0.5	20	100	1500	30000	0.79	92.44	300.84	1.60	92.35	304.17									
201	160	0.4	0.5	50	0.01	1500	1500	159.00	62.66	1379.07	74.50	13.10	3150.02	143.00	69.87	1129.05	140.00	70.67	1100.61	139.50	70.79	1096.57
202	160	0.4	0.5	50	0.1	1500	6000	64.00	86.52	531.19	131.25	74.18	981.27	62.50	87.11	508.53	53.00	88.20	467.05	51.25	88.36	461.02
203	160	0.4	0.5	50	1	1500	13000	17.00	91.66	332.59	43.50	89.20	429.60	25.75	91.11	354.39	18.25	91.66	332.57	16.00	91.79	327.16
204	160	0.4	0.5	50	10	1500	25000	3.66	92.38	303.44	9.94	92.06	316.21	N/A								
205	160	0.4	0.5	50	100	1500	45000	1.00	92.46	300.34	2.33	92.43	301.41									
206	160	0.4	0.5	100	0.01	1500	2000	266.42	73.14	1018.58	333.57	40.79	2122.43	224.42	78.57	824.58	218.42	79.05	807.12	217.67	79.13	804.16
207	160	0.4	0.5	100	0.1	1500	8000	90.00	88.97	439.02	196.42	81.18	730.88	84.75	89.49	418.95	71.00	90.11	394.77	68.75	90.21	390.88
208	160	0.4	0.5	100	1	1500	17000	22.00	92.07	316.82	57.50	90.70	371.73	32.00	91.76	329.08	22.50	92.06	317.25	19.75	92.13	314.19
209	160	0.4	0.5	100	10	1500	30000	4.78	92.44	301.80	12.25	92.28	308.32	N/A								
210	160	0.4	0.5	100	100	1500	60000	1.38	92.48	300.18	2.75	92.46	301.07									
211	160	0.4	1	20	0.01	1500	1000	61.50	39.86	2154.50	0.03	0.01	3703.75	63.75	50.94	1771.56	63.50	52.43	1720.06	63.25	52.59	1714.77
212	160	0.4	1	20	0.1	1500	4000	39.75	80.94	736.93	68.00	59.04	1502.11	39.75	81.69	709.38	34.25	83.74	633.72	33.25	84.07	621.28
213	160	0.4	1	20	1	1500	8000	12.25	90.63	373.37	28.50	85.62	564.42	18.25	89.34	423.50	13.25	90.53	377.39	11.75	90.86	363.93
214	160	0.4	1	20	10	1500	20000	2.72	92.25	308.42	7.34	91.50	338.51	N/A								
215	160	0.4	1	20	100	1500	30000	0.79	92.44	300.83	1.60	92.35	304.17									
216	160	0.4	1	50	0.01	1500	1500	158.75	62.85	1372.51	74.50	13.10	3150.02	143.00	69.87	1129.05	140.00	70.67	1100.61	139.50	70.79	1096.57
217	160	0.4	1	50	0.1	1500	6000	63.75	86.56	529.47	131.25	74.18	981.27	62.50	87.11	508.53	53.00	88.20	467.05	51.25	88.36	461.02
218	160	0.4	1	50	1	1500	13000	17.00	91.67	331.88	43.50	89.20	429.60	25.75	91.11	354.39	18.25	91.66	332.57	16.00	91.79	327.16
219	160	0.4	1	50	10	1500	25000	3.65	92.38	303.41	9.94	92.06	316.21	N/A								

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
220	160	0.4	1	50	100	1500	45000	1.00	92.46	300.34	2.33	92.43	301.41	N/A								
221	160	0.4	1	100	0.01	1500	2000	263.67	73.48	1006.71	333.57	40.79	2122.43	224.42	78.57	824.58	218.42	79.05	807.12	217.67	79.13	804.16
222	160	0.4	1	100	0.1	1500	8000	88.75	89.05	436.20	196.42	81.18	730.88	84.75	89.49	418.95	71.00	90.11	394.77	68.75	90.21	390.88
223	160	0.4	1	100	1	1500	17000	21.50	92.06	316.97	57.50	90.70	371.73	32.00	91.76	329.08	22.50	92.06	317.25	19.75	92.13	314.19
224	160	0.4	1	100	10	1500	30000	4.73	92.44	301.76	12.25	92.28	308.32	N/A								
225	160	0.4	1	100	100	1500	60000	1.37	92.48	300.18	2.75	92.46	301.07									
226	160	0.8	0.1	20	0.01	3000	1000	64.50	61.80	1406.78	0.03	0.01	3703.75	60.00	67.77	1200.74	56.25	70.77	1095.70	55.50	71.17	1081.46
227	160	0.8	0.1	20	0.1	3000	4000	26.50	86.25	540.44	68.00	59.04	1502.11	35.00	83.61	638.96	24.75	87.29	501.06	22.50	87.96	475.51
228	160	0.8	0.1	20	1	3000	8000	7.75	91.62	333.42	28.50	85.62	564.42	18.00	89.36	422.85	12.25	90.76	368.28	10	91.208	350.0947
229	160	0.8	0.1	20	10	3000	20000	1.76	92.36	303.69	7.34	91.50	338.51	N/A								
230	160	0.8	0.1	20	100	3000	30000	0.66	92.45	300.38	1.60	92.35	304.17									
231	160	0.8	0.1	50	0.01	3000	1500	126.25	74.96	952.99	74.50	13.10	3150.02	109.00	79.46	790.99	100.00	81.11	730.62	98.50	81.34	722.34
232	160	0.8	0.1	50	0.1	3000	6000	41.75	89.34	424.20	131.25	74.18	981.27	54.25	88.21	466.82	36.75	90.10	394.58	33.25	90.44	381.36
233	160	0.8	0.1	50	1	3000	13000	10.75	92.10	314.77	43.50	89.20	429.60	25.50	91.14	353.37	16.75	91.76	328.38	13.50	91.95	320.60
234	160	0.8	0.1	50	10	3000	25000	2.48	92.43	301.58	9.94	92.06	316.21	N/A								
235	160	0.8	0.1	50	100	3000	45000	0.84	92.46	300.15	2.33	92.43	301.41									
236	160	0.8	0.1	100	0.01	3000	2000	200.75	80.70	748.45	333.57	40.79	2122.43	158.67	84.71	599.69	144.17	85.71	562.10	141.92	85.85	556.94
237	160	0.8	0.1	100	0.1	3000	8000	59.75	90.60	376.07	196.42	81.18	730.88	72.25	90.14	394.10	47.75	91.21	351.33	43.00	91.39	344.09
238	160	0.8	0.1	100	1	3000	17000	14.25	92.27	308.55	57.50	90.70	371.73	31.75	91.78	328.28	20.50	92.11	315.23	16.75	92.22	310.45
239	160	0.8	0.1	100	10	3000	30000	3.51	92.46	300.87	12.25	92.28	308.32	N/A								
240	160	0.8	0.1	100	100	3000	60000	1.21	92.48	300.08	2.75	92.46	301.07									
241	160	0.8	0.5	20	0.01	3000	1000	64.50	62.18	1394.13	0.03	0.01	3703.75	60.00	67.77	1200.74	56.25	70.77	1095.70	55.50	71.17	1081.46

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_f/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
242	160	0.8	0.5	20	0.1	3000	4000	26.25	86.30	538.84	68.00	59.04	1502.11	35.00	83.61	638.96	24.75	87.29	501.06	22.50	87.96	475.51
243	160	0.8	0.5	20	1	3000	8000	7.75	91.65	332.33	28.50	85.62	564.42	18.00	89.36	422.85	12.25	90.76	368.28	10	91.208	350.0947
244	160	0.8	0.5	20	10	3000	20000	1.76	92.37	303.52	7.34	91.50	338.51	N/A								
245	160	0.8	0.5	20	100	3000	30000	0.66	92.45	300.35	1.60	92.35	304.17									
246	160	0.8	0.5	50	0.01	3000	1500	123.00	75.70	926.46	74.50	13.10	3150.02	109.00	79.46	790.99	100.00	81.11	730.62	98.50	81.34	722.34
247	160	0.8	0.5	50	0.1	3000	6000	40.25	89.48	418.87	131.25	74.18	981.27	54.25	88.21	466.82	36.75	90.10	394.58	33.25	90.44	381.36
248	160	0.8	0.5	50	1	3000	13000	10.50	92.13	313.54	43.50	89.20	429.60	25.50	91.14	353.37	16.75	91.76	328.38	13.50	91.95	320.60
249	160	0.8	0.5	50	10	3000	25000	2.43	92.43	301.50	9.94	92.06	316.21	N/A								
250	160	0.8	0.5	50	100	3000	45000	0.83	92.46	300.14	2.33	92.43	301.41									
251	160	0.8	0.5	100	0.01	3000	2000	187.75	81.77	709.00	333.57	40.79	2122.43	158.67	84.71	599.69	144.17	85.71	562.10	141.92	85.85	556.94
252	160	0.8	0.5	100	0.1	3000	8000	55.25	90.80	367.75	196.42	81.18	730.88	72.25	90.14	394.10	47.75	91.21	351.33	43.00	91.39	344.09
253	160	0.8	0.5	100	1	3000	17000	13.25	92.30	307.60	57.50	90.70	371.73	31.75	91.78	328.28	20.50	92.11	315.23	16.75	92.22	310.45
254	160	0.8	0.5	100	10	3000	30000	3.36	92.46	300.77	12.25	92.28	308.32	N/A								
255	160	0.8	0.5	100	100	3000	60000	1.19	92.48	300.08	2.75	92.46	301.07									
256	160	0.8	1	20	0.01	3000	1000	64.25	62.13	1395.63	0.03	0.01	3703.75	60.00	67.77	1200.74	56.25	70.77	1095.70	55.50	71.17	1081.46
257	160	0.8	1	20	0.1	3000	4000	26.25	86.31	538.16	68.00	59.04	1502.11	35.00	83.61	638.96	24.75	87.29	501.06	22.50	87.96	475.51
258	160	0.8	1	20	1	3000	8000	7.75	91.65	332.19	28.50	85.62	564.42	18.00	89.36	422.85	12.25	90.76	368.28	10	91.208	350.0947
259	160	0.8	1	20	10	3000	20000	1.74	92.36	303.69	7.34	91.50	338.51	N/A								
260	160	0.8	1	20	100	3000	30000	0.66	92.45	300.35	1.60	92.35	304.17									
261	160	0.8	1	50	0.01	3000	1500	122.50	75.83	921.89	74.50	13.10	3150.02	109.00	79.46	790.99	100.00	81.11	730.62	98.50	81.34	722.34
262	160	0.8	1	50	0.1	3000	6000	40.00	89.50	418.05	131.25	74.18	981.27	54.25	88.21	466.82	36.75	90.10	394.58	33.25	90.44	381.36
263	160	0.8	1	50	1	3000	13000	10.25	92.11	314.50	43.50	89.20	429.60	25.50	91.14	353.37	16.75	91.76	328.38	13.50	91.95	320.60

Table 5.2: Summary of results for all cases of rectangular drainage area

Well & Reservoir Parameters								Horizontal Well			Vertical Well			Fracture Conductivity 200 md-ft			Fracture Conductivity 1000 md-ft			Fracture Conductivity 2000 md-ft		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA	YRS	%	PSIA
264	160	0.8	1	50	10	3000	25000	2.43	92.43	301.44	9.94	92.06	316.21	N/A								
265	160	0.8	1	50	100	3000	45000	0.83	92.46	300.14	2.33	92.43	301.41									
266	160	0.8	1	100	0.01	3000	2000	185.00	82.01	700.29	333.57	40.79	2122.43	158.67	84.71	599.69	144.17	85.71	562.10	141.92	85.85	556.94
267	160	0.8	1	100	0.1	3000	8000	54.25	90.84	366.19	196.42	81.18	730.88	72.25	90.14	394.10	47.75	91.21	351.33	43.00	91.39	344.09
268	160	0.8	1	100	1	3000	17000	13.00	92.30	307.53	57.50	90.70	371.73	31.75	91.78	328.28	20.50	92.11	315.23	16.75	92.22	310.45
269	160	0.8	1	100	10	3000	30000	3.33	92.47	300.74	12.25	92.28	308.32	N/A								
270	160	0.8	1	100	100	3000	60000	1.19	92.48	300.07	2.75	92.46	301.07									

Tables 5.1 and 5.2 show that the hydraulically-fractured vertical well performs better than the horizontal well of the same penetration ratio, in addition to performing better than the vertical well. This fact can also be seen in the pressure distribution in the reservoir at the time of abandonment, as shown in Figures A.1 through A.42 which are for the 80-acre square drainage area. Figures A.1 through A.21 show pressure distribution for 20-feet formation thickness whereas Figures A.22 through A.42 show pressure distribution for 100-feet formation thickness. All these figures show that hydraulically-fractured vertical well has better performance for all formation thicknesses considered, especially in low horizontal permeability reservoirs such as 0.01 md and 0.1 md; in this type of well, the average reservoir pressure reaches a low value at the end of production and thus gives the highest recovery factor. Vertical well shows poor performance in these low horizontal permeability reservoirs (such as 0.01md and 0.1 md), provides a low recovery factor in reservoirs with large formation thickness such as 100 feet, and produces only a small portion of the reservoir when formation thickness is low (20-feet thick). In all these low horizontal permeability reservoirs (0.01md and 0.1 md), horizontal well performance depends on the length of the horizontal well and thickness of the reservoir.

In this research, hydraulic fracturing is applied only on vertical wells of horizontal permeability of 0.01 md, 0.1 md and 1 md. For 1 md horizontal permeability reservoirs, the ultimate recovery factor is about the same for all 3 well types; however, it takes much less time for the HFVW to recover the reserves than it does for the VW and only slightly less time for the HFVW to recover the reserves that it does for the HW of the same penetration ratio. In such cases (horizontal permeability of 1 md), the performance of HFVW and HW are almost identical and that is the reason that simulation runs were not made for the

HFVW at horizontal permeabilities of 10 md and 100 md because its performance will be identical to the performance of HW of the same penetration ratio. For higher horizontal permeability reservoirs (such as 10 md and 100 md), both the HW and the VW show good performance; however, the abandonment time for the HW is less than the abandonment time for the VW.

In Tables 5.1 and 5.2 and in the remainder of this chapter, the abbreviations “R.F.” represent ultimate recovery factor, “Time” represent abandonment time, and “FPR” represents average reservoir pressure at abandonment time.

As shown in Table 5.1, the following statements can be made regarding the ultimate recovery factors for the three well types in square drainage area:

- For the vertical well, the lowest recovery factor is 0.02% in the 80-acre drainage area and 0.01% in the 160-acre drainage area. The highest recovery factor is 92.46% in both the 80-acre and the 160-acre drainage areas.
- For the horizontal well, the lowest recovery factor is 2.56% in the 80-acre drainage area and 8.54% in the 160-acre drainage area. The highest recovery factor is 92.48% in both the 80-acre and the 160-acre drainage areas.
- For the hydraulically-fractured vertical well, the lowest recovery factor is 29.9% in the 80-acre drainage area and 31.1% in the 160-acre drainage area. The highest recovery factor is 92.22% in the 80-acre and 92.20% in the 160-acre drainage areas.

As shown in Table 5.2, the following statements can be made regarding the ultimate recovery factors for the three well types located in 2:1 rectangular drainage area:

- For the vertical well, the lowest recovery factor is 0.02% in the 80-acre drainage area and 0.01% in the 160-acre drainage area. The highest recovery factor is 92.46% in both the 80-acre and the 160-acre drainage areas.
- For the horizontal well, the lowest recovery factor is 12.42% in the 80-acre drainage area and 18.22% in the 160-acre drainage area. The highest recovery factor is 92.48% in both the 80-acre and the 160-acre drainage areas.
- For the hydraulically-fractured vertical well, the lowest recovery factor is 35.12% in the 80-acre drainage area and 29.49% in the 160-acre drainage area. The highest recovery factor is 92.27% in the 80-acre and 92.20% in the 160-acre drainage areas.

In both the square drainage area and the 2:1 rectangular drainage areas, the lowest ultimate recovery factors mentioned above for both the 80-acre and the 160-acre drainage areas occur at a horizontal permeability of 0.01 md, formation thickness of 20 feet, k_v/k_h ratio of 0.1 (in the case of horizontal well), and well penetration ratio of 0.2 (in the case of both the horizontal well and the hydraulically-fractured vertical well).

In addition, in both the square drainage area and the 2:1 rectangular drainage areas, the highest ultimate recovery factors mentioned above for both the 80-acre and the 160-acre drainage areas occur at a horizontal permeability of 100 md (for both horizontal well and vertical well), horizontal permeability of 1 md (for the hydraulically-fractured vertical well), formation thickness of 100 feet, k_v/k_h ratio of 1.0 (in the case of horizontal well), and well penetration ratio of 0.8 (in the case of both the horizontal well and the hydraulically-fractured vertical well).

In all the plots and in the remainder of this chapter, the following abbreviations will be used: “VW” for vertical well, “HW” for horizontal well, “HFVW” for hydraulically-fractured vertical well, “SDA” for square drainage area, “RDA” for rectangular drainage area, and “P.R.” for well penetration ratio.

5.1 Effect of Initial Production Rate

Figures 5.1 through 5.20 show the effect of initial production rate of the HW on the ultimate recovery factor and on abandonment time for all the horizontal permeabilities considered in this study. These figures also show the results for production at constant bottom-hole flowing pressure. It is important to note that, in the case of initial production at constant rate, the minimum bottom-hole flowing pressure is assumed to be 300 psia and once the well is no longer able to produce at constant rate, the simulator will produce the well at constant flowing bottom-hole pressure of 300 psia which results in a decrease in production rate versus time until the minimum production rate below which it is no longer economical to produce from the well. In this research, this minimum economic rate is taken as 50 MSCF/D for all wells. In the case of initial production at constant flowing bottom-hole pressure, the well production rate will decrease with time until it reaches the minimum economic rate of 50 MSCF/D. Figures 5.1 through 5.10 are for the 20-foot formation thickness while Figures 5.11 through 5.20 are for the 100-foot formation thickness.

Figures 5.1 through 5.20 show that the initial production rate will not make any difference in terms of the ultimate recovery factor for both low and high permeability reservoirs. However, as shown in these figures, the time to reach abandonment is affected by the initial production rate, especially for reservoir with high horizontal permeability. Using the

results shown in these figures, the initial production rates for the simulation runs were chosen as a function of formation thickness and horizontal permeability and are presented in Figure 5.21.

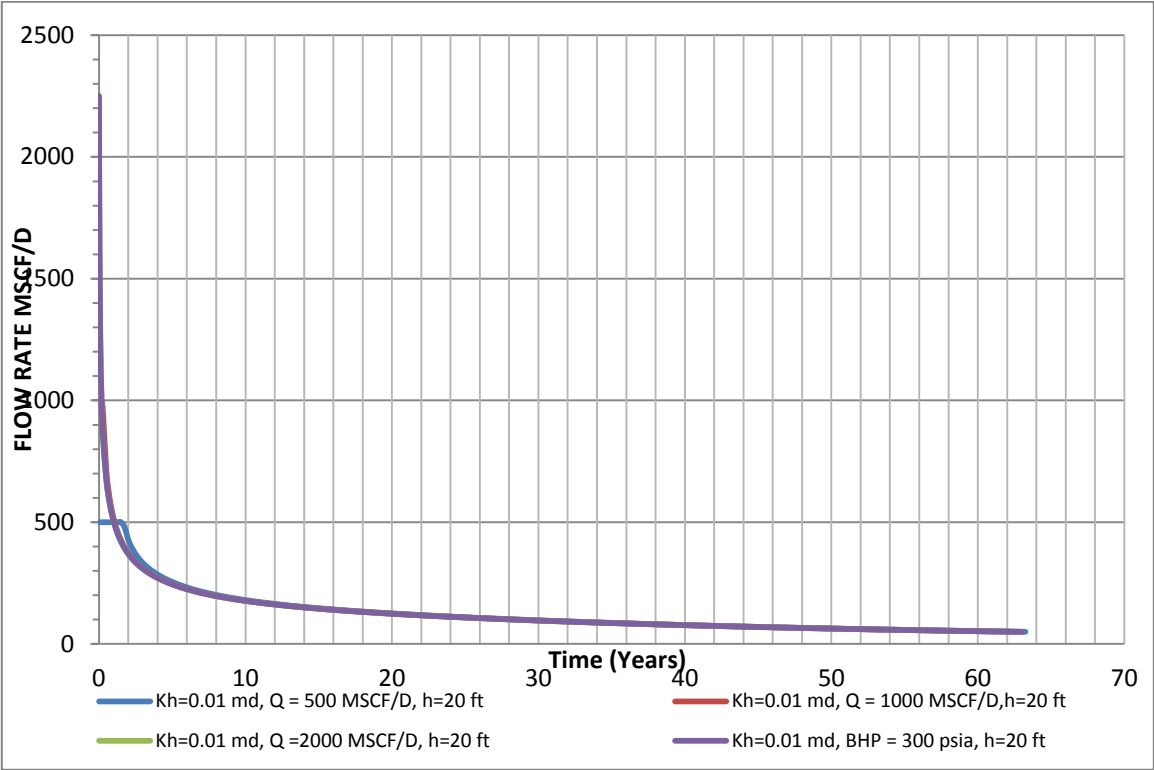


Figure 5.1: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

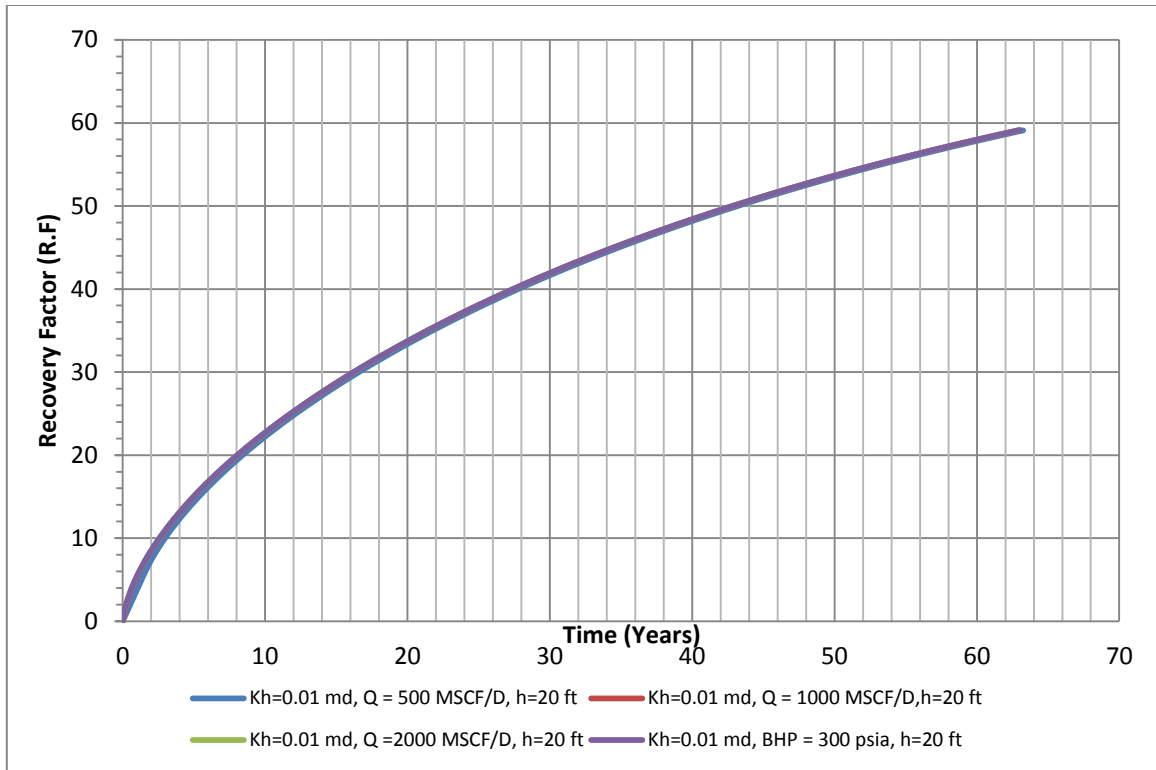


Figure 5.2: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

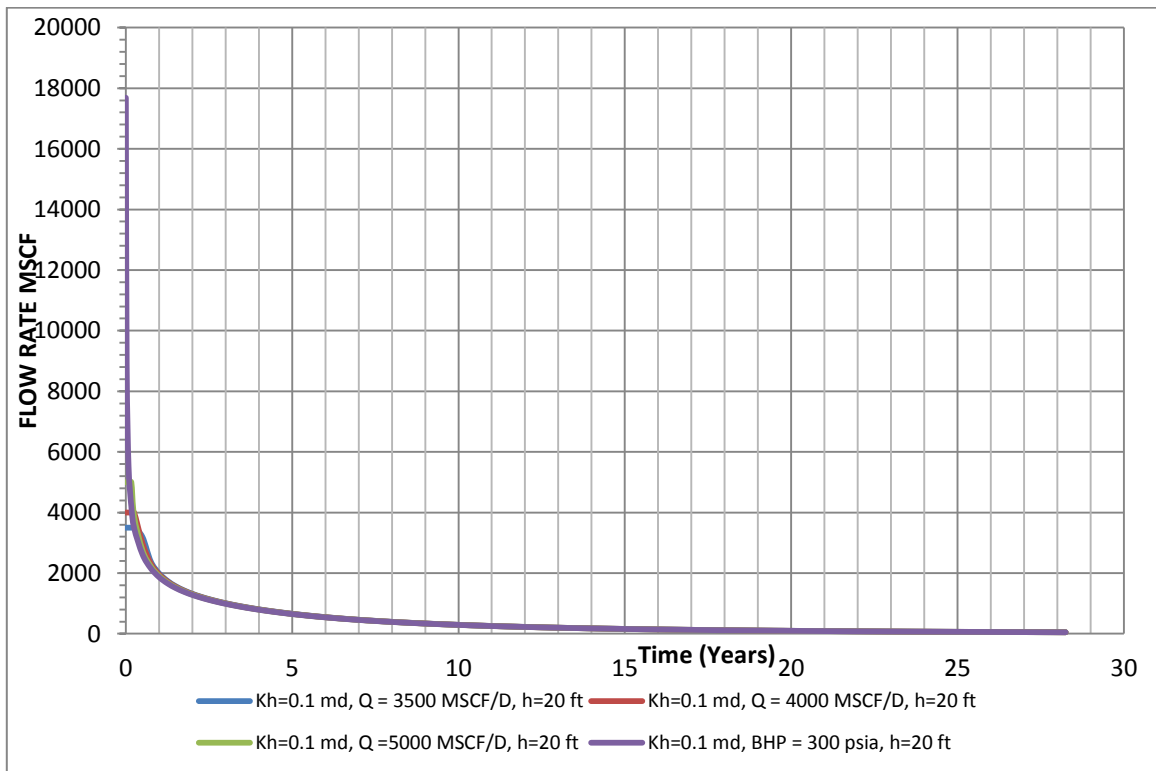


Figure 5.3: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

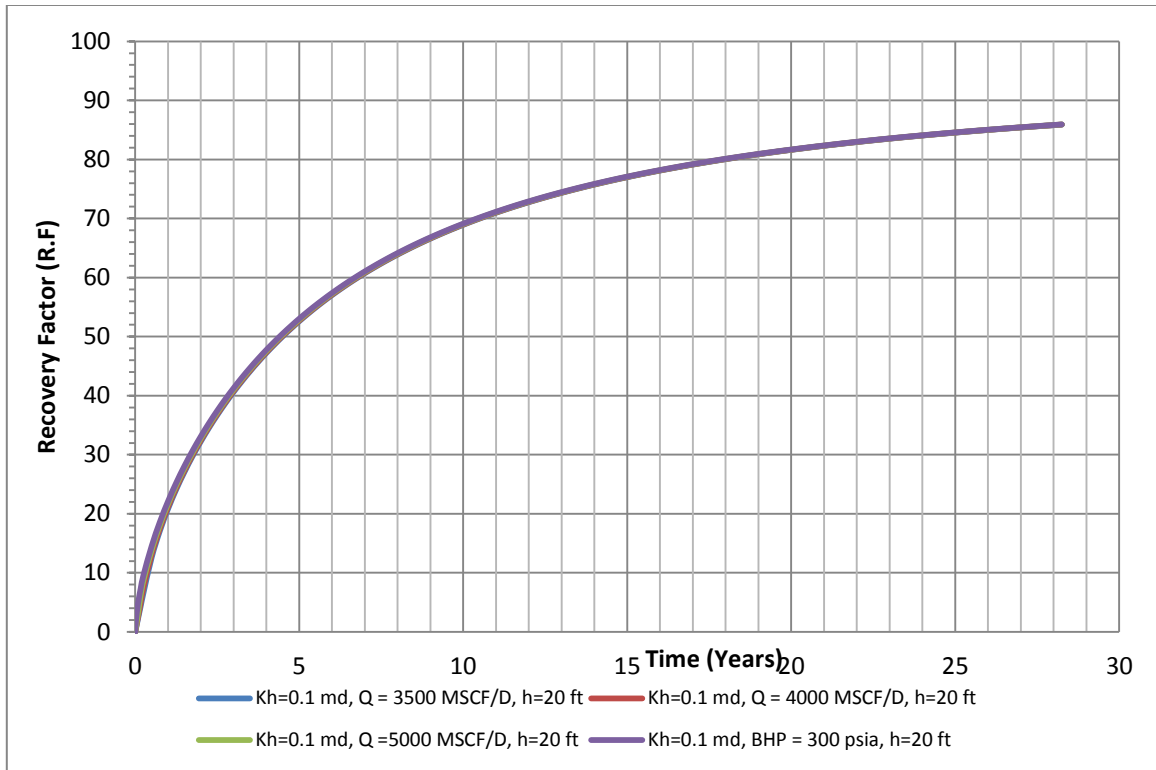


Figure 5.4: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

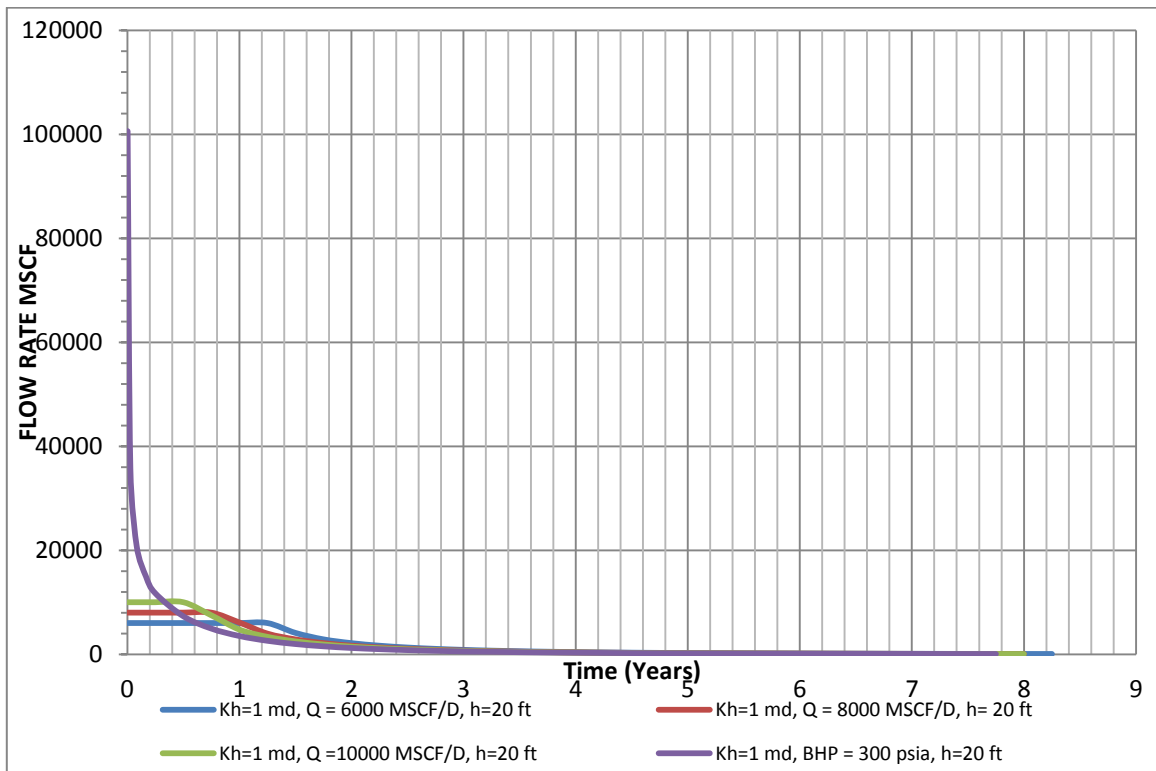


Figure 5.5: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

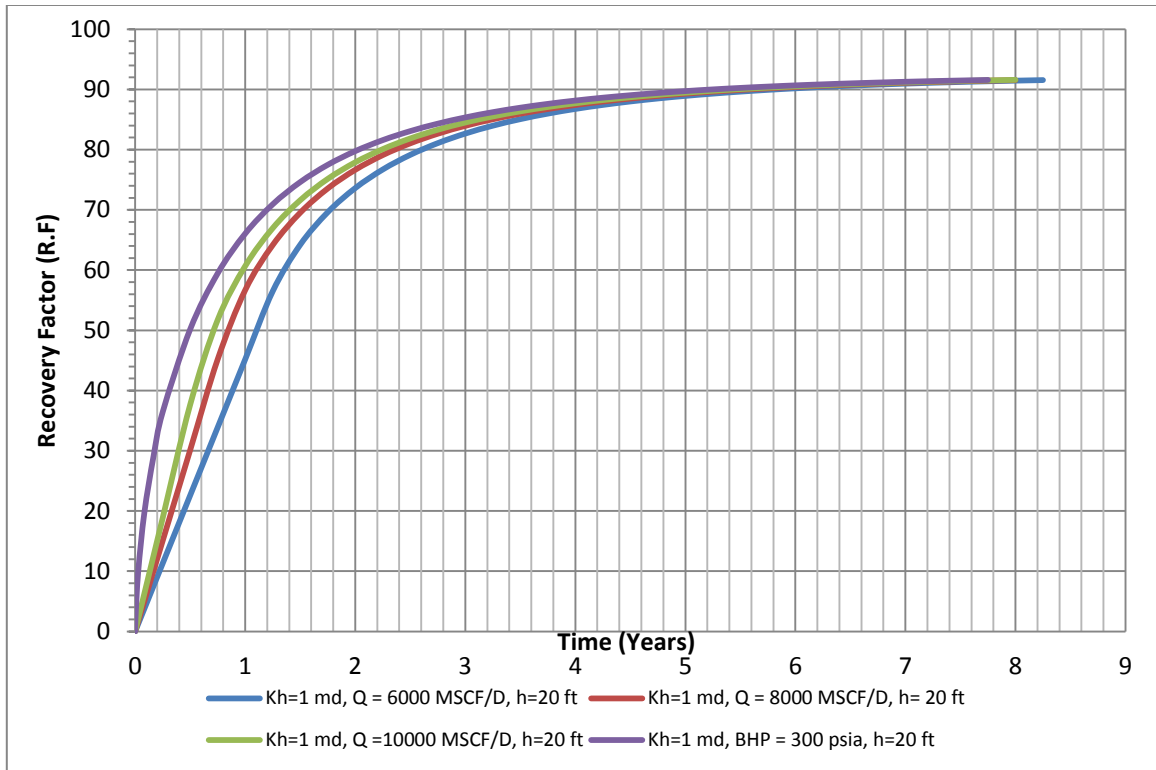


Figure 5.6: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

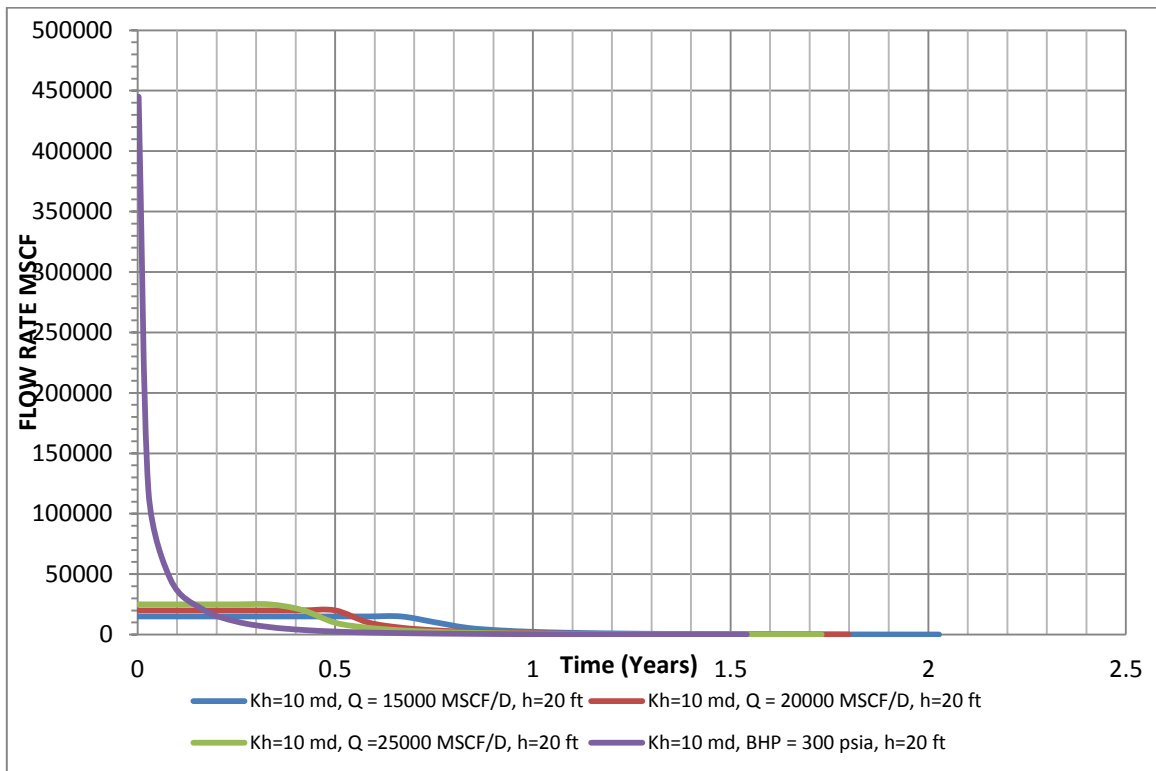


Figure 5.7: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

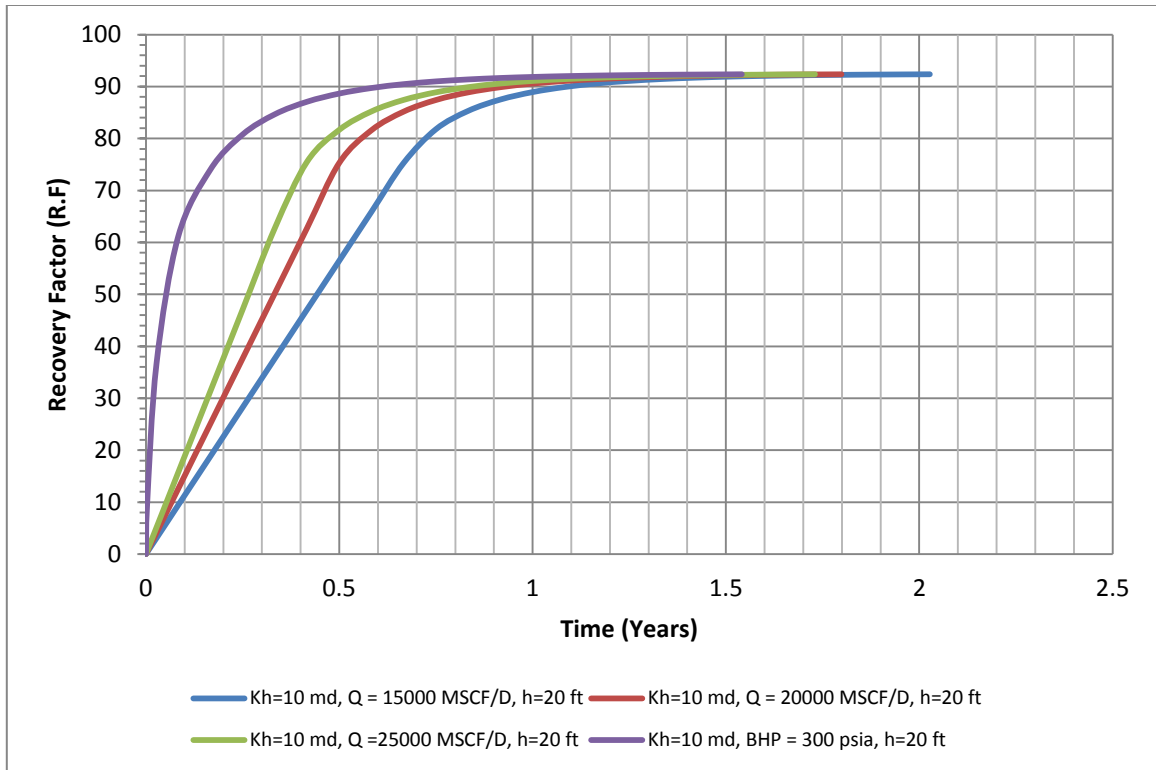


Figure 5.8: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

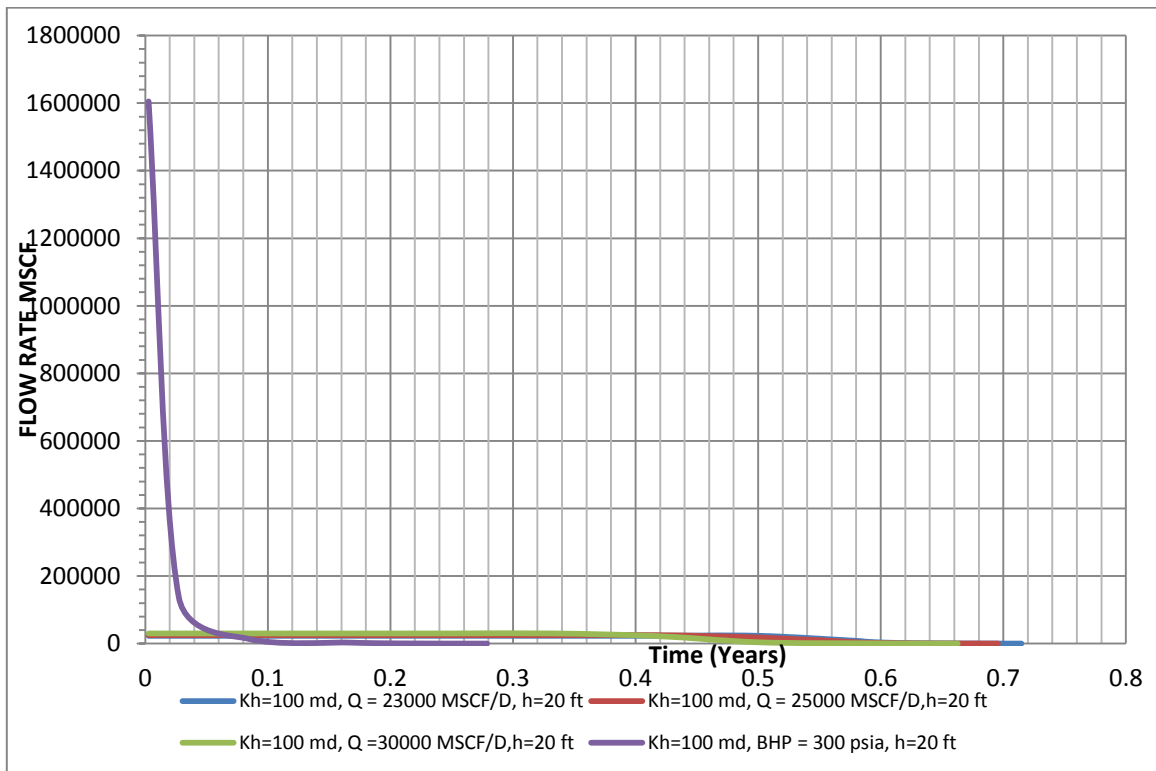


Figure 5.9: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

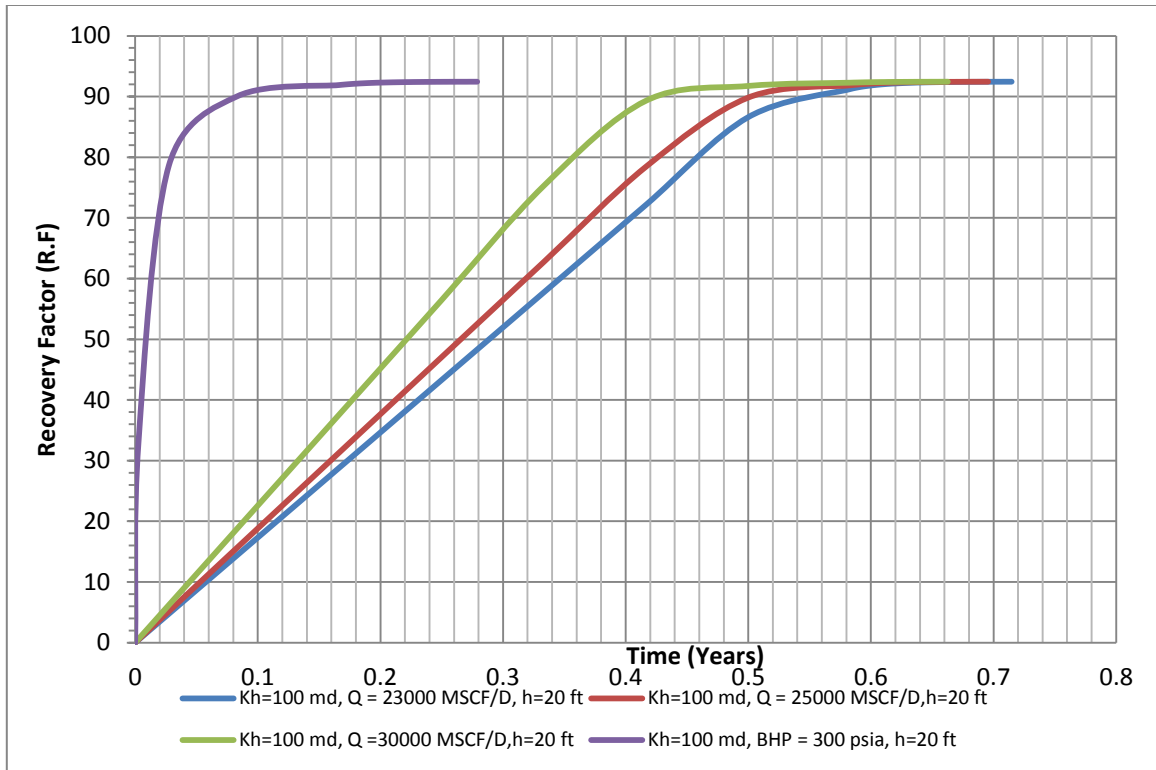


Figure 5.10: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

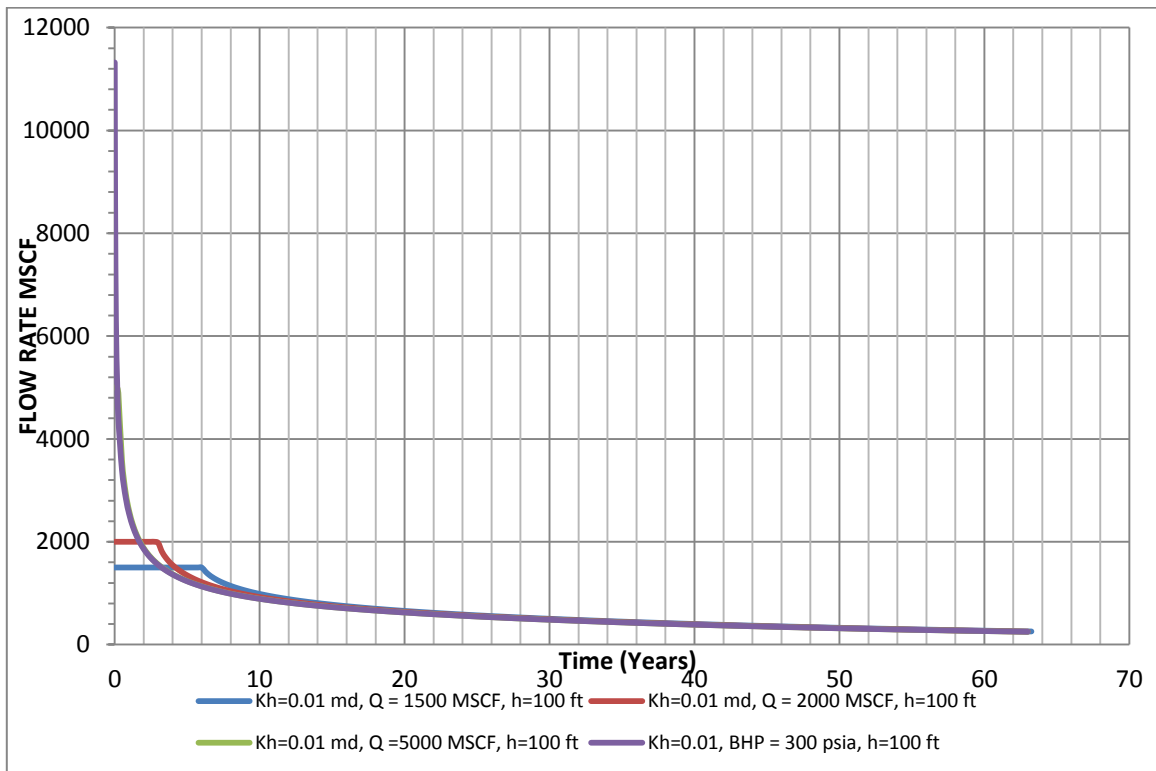


Figure 5.11: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

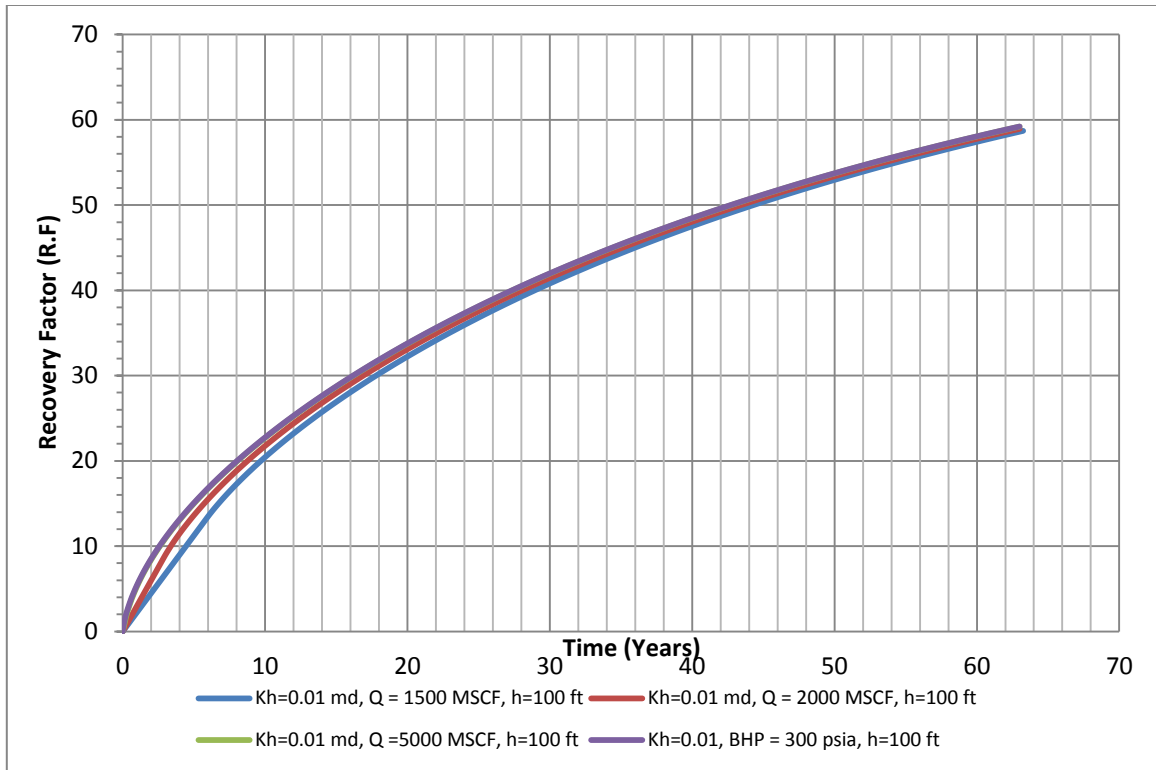


Figure 5.12: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

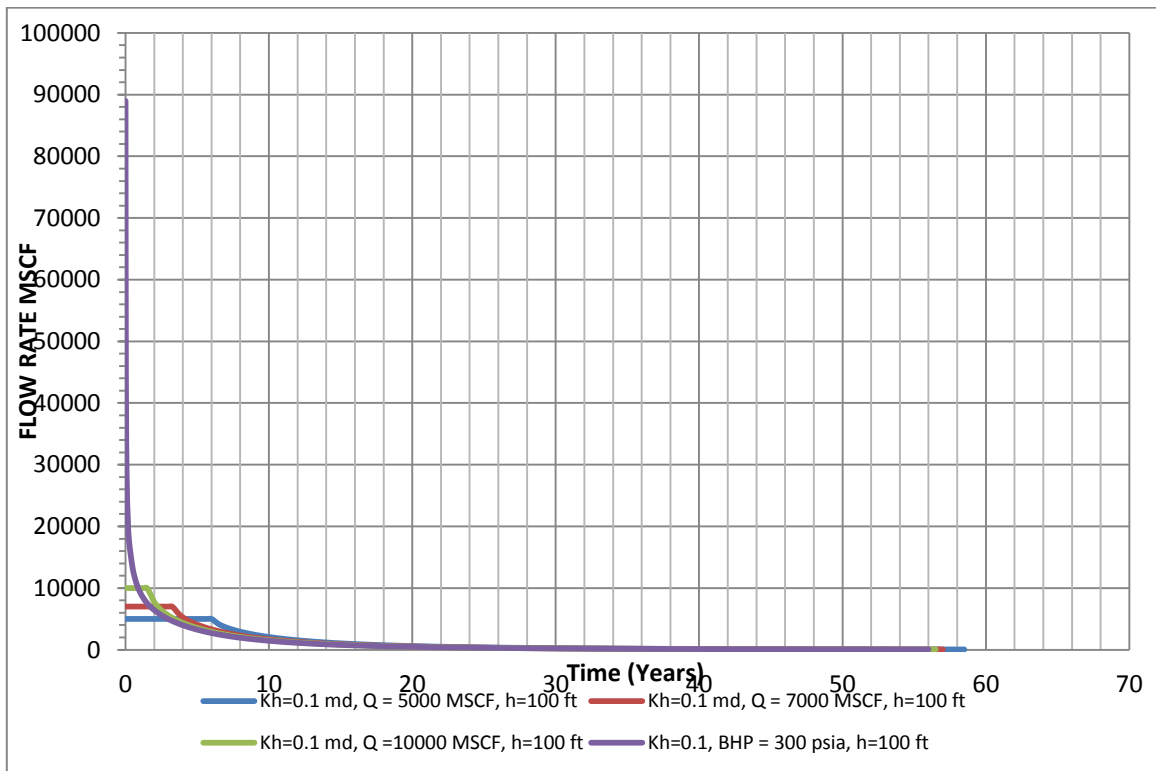


Figure 5.13: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

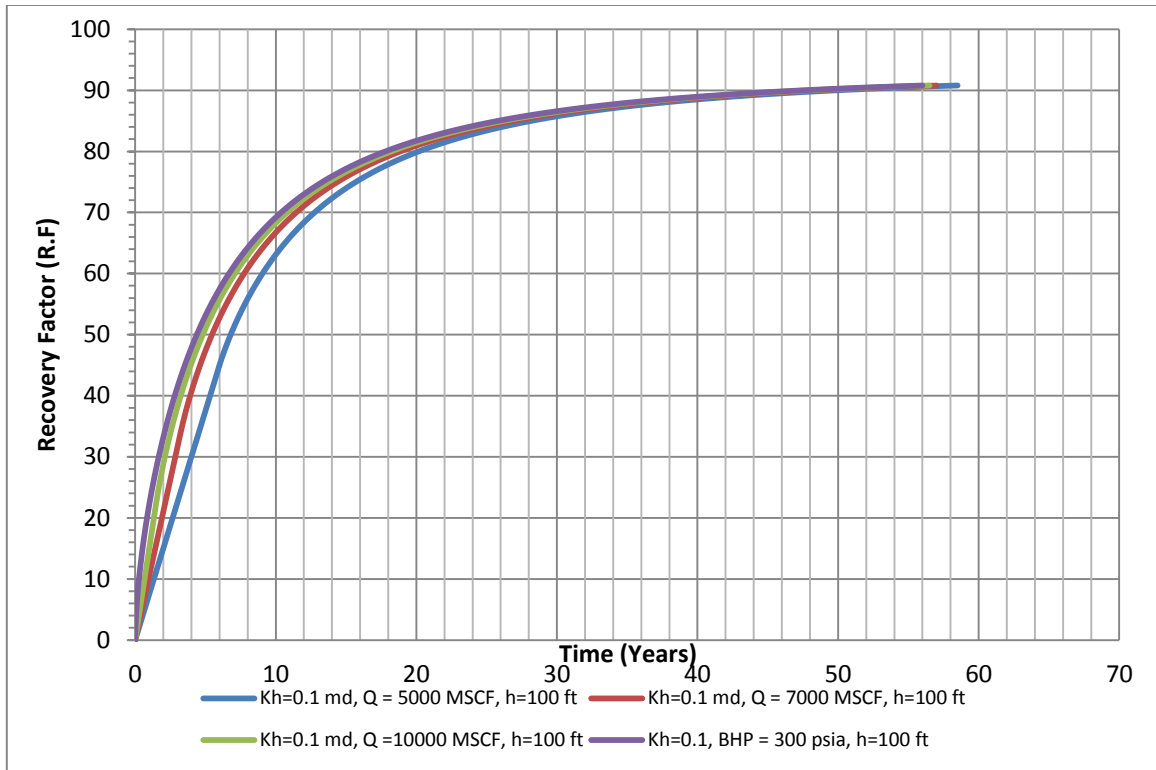


Figure 5.14: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

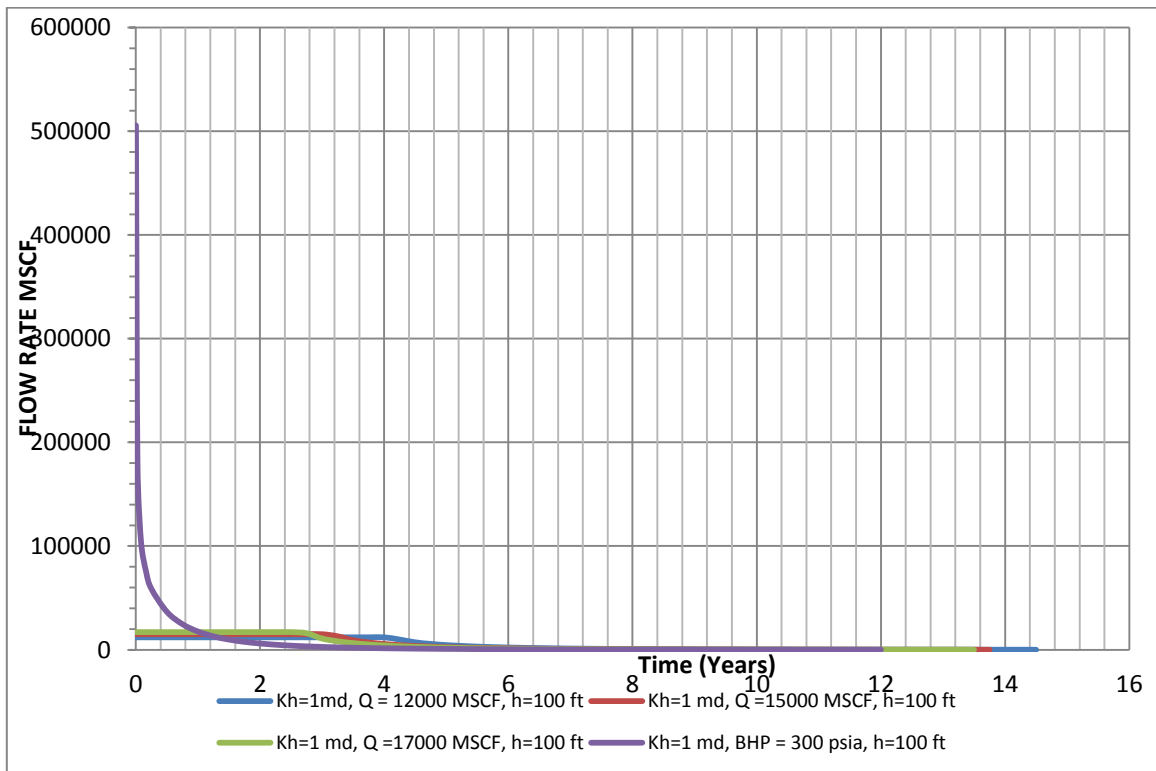


Figure 5.15: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

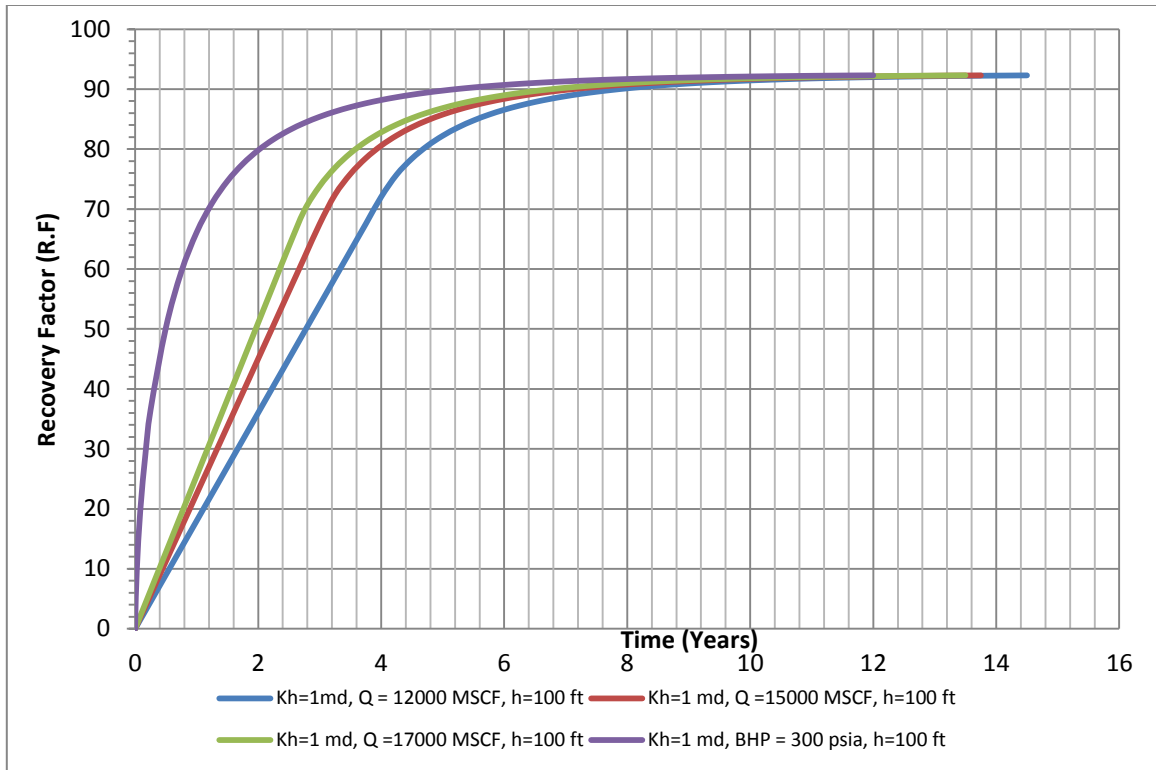


Figure 5.16: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

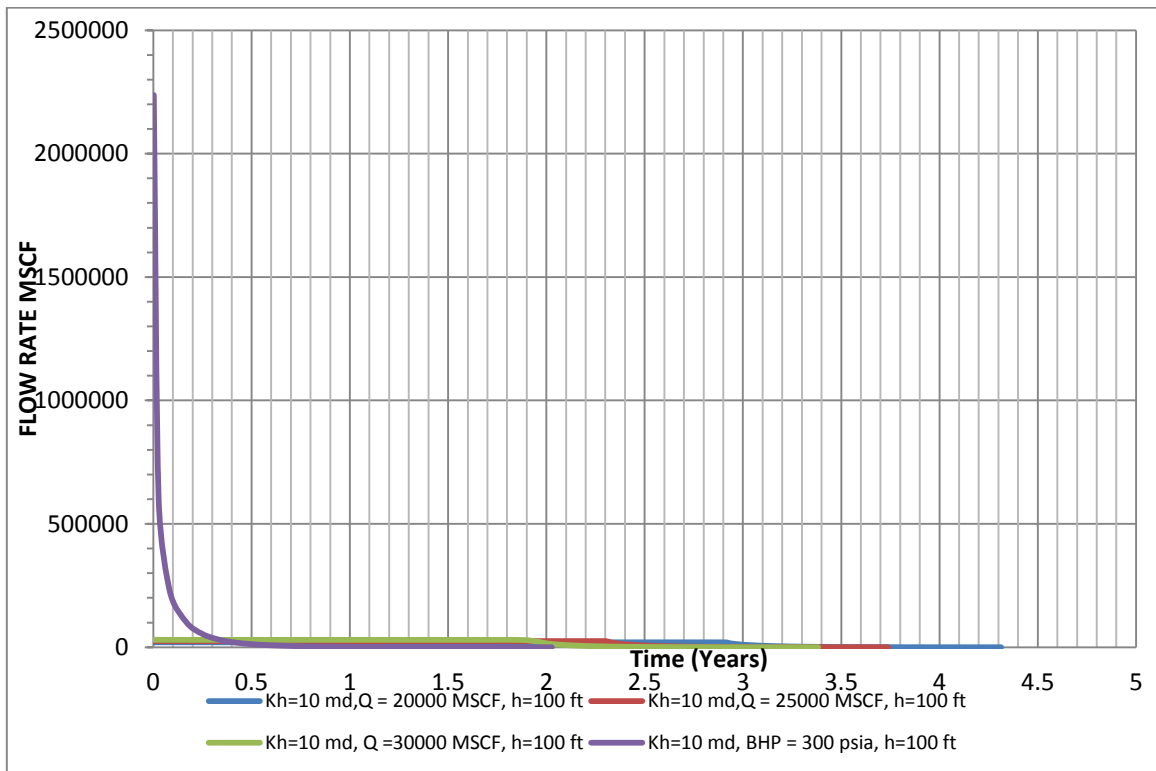


Figure 5.17: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

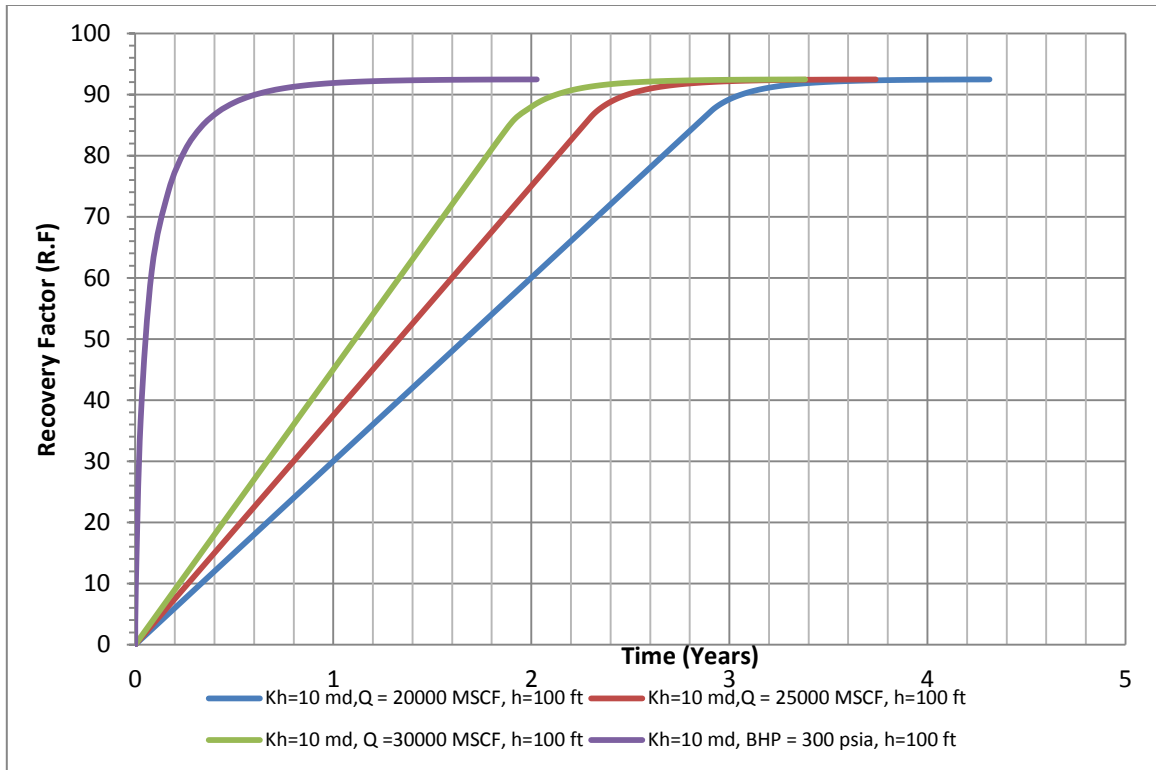


Figure 5.18: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

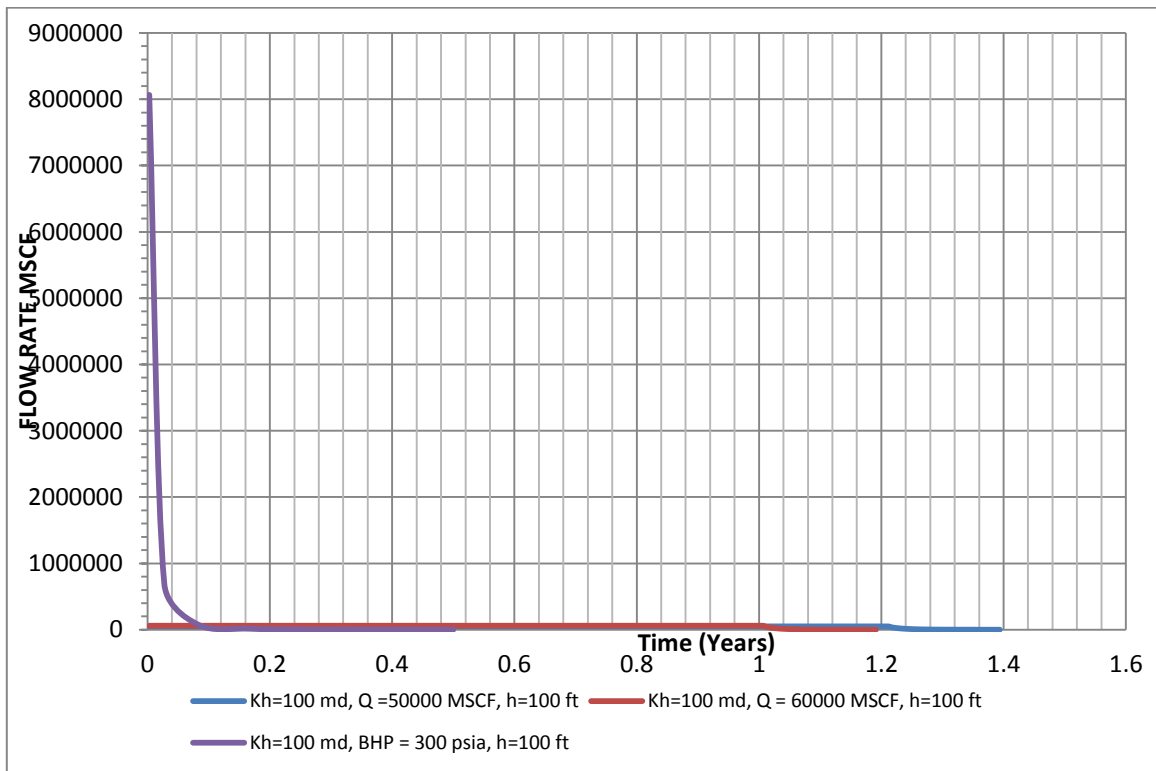


Figure 5.19: Flow rate VS time, HW, P.R=0.8, A=160 acres, SDA

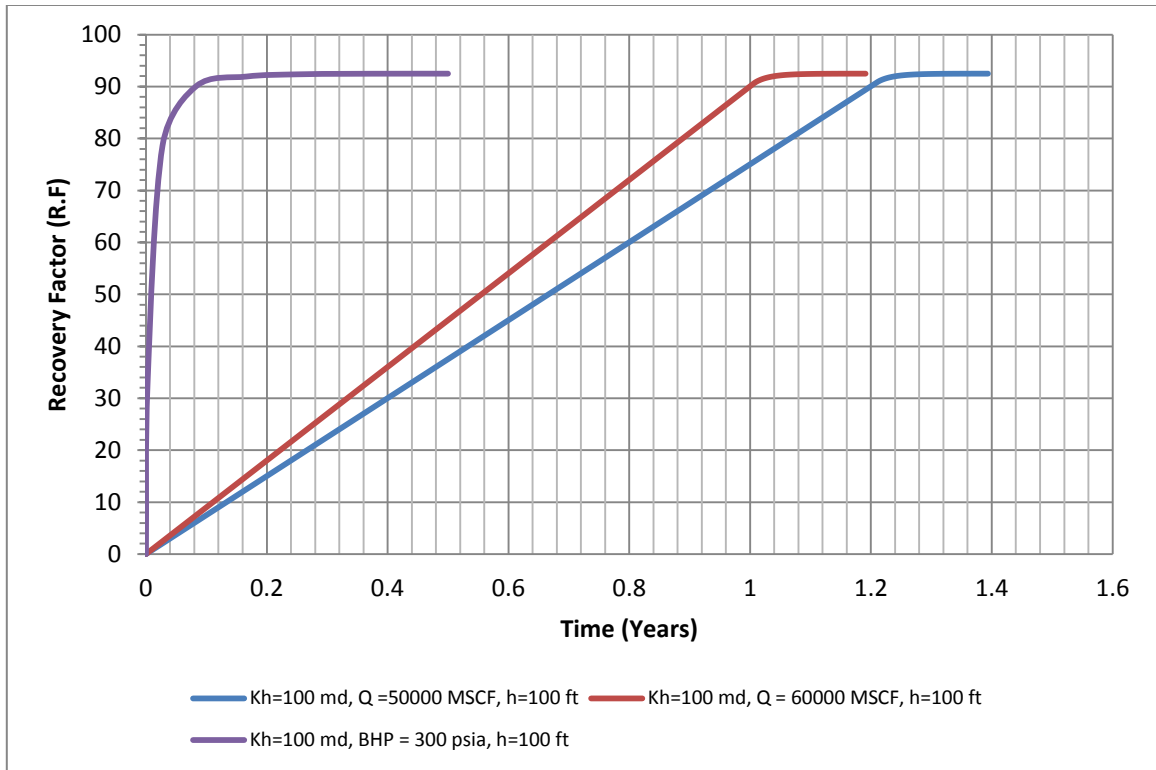


Figure 5.20: Recovery factor VS time, HW, P.R=0.8, A=160 acres, SDA

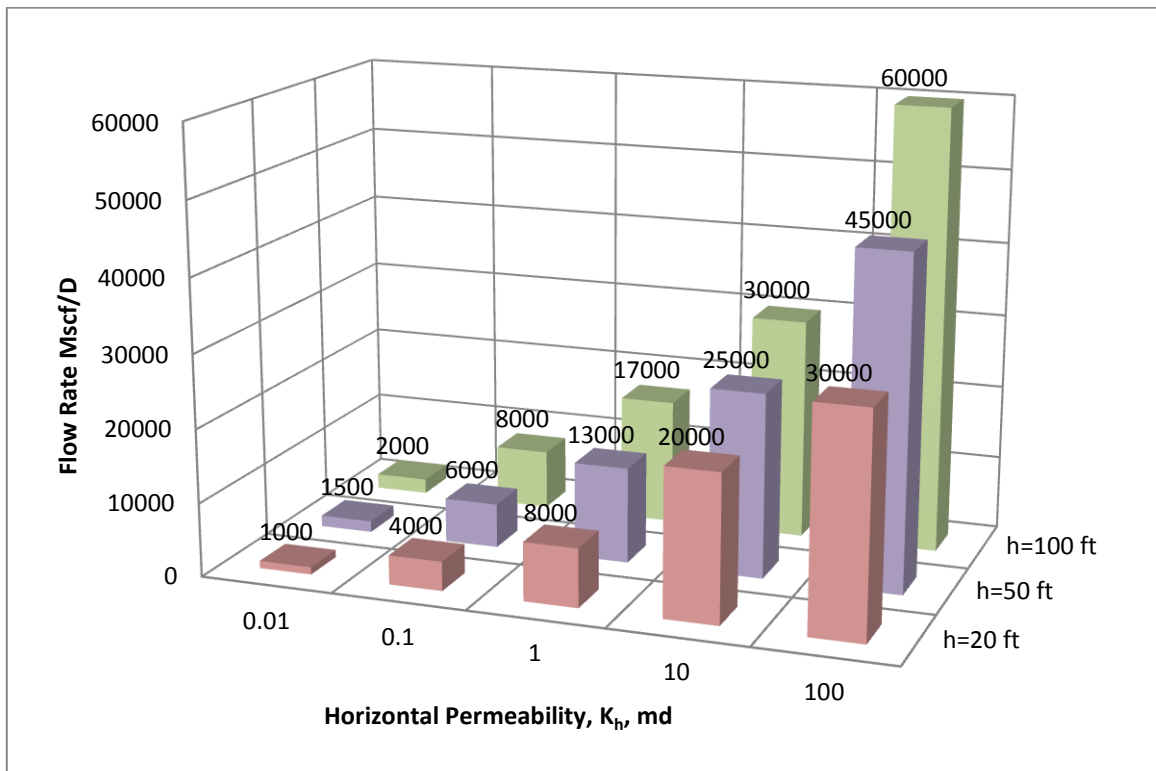


Figure 5.21: Initial production rates for both square and rectangular drainage areas.

5.2 Effect of Horizontal Permeability

Figures 5.22 through 5.57 show the effect of horizontal permeability on the performance of HW, VW, and HFVW for the 80-acre square drainage area for the five different values of horizontal permeabilities considered in this study (i.e., 0.01 md, 0.1 md, 1 md, 10 md and 100 md). The plots are arranged in the order of increasing penetration ratio for the HW and the HFVW. Figures 5.22 through 5.39 are for the k_v/k_h ratio of 0.1 and Figures 5.40 through 5.57 are for the k_v/k_h ratio of 1.0. These figures each correspond to a given value of formation thickness (20-feet, 50-feet, or 100-feet) and well penetration ratio (0.2, 0.4, or 0.8).

Figure 5.22 shows the effect of horizontal permeabilities of 0.01 md, 0.1 md and 1 md. For all the 3 well types, as horizontal permeability increases from 0.1 md to 1 md, the ultimate recovery factor increases and the abandonment time decreases. This figure indicates that for low values of penetration ratio, formation thickness, and k_v/k_h ratio, the reservoir should be developed with HFVW due to the combination of high ultimate recovery factor and low abandonment time for this type well compared to HW and VW. As the horizontal permeability increases from 0.01 md to 1 md, the advantage of the HFVW over the HW decreases both in terms of the ultimate recovery factor and the abandonment time.

Figure 5.23 shows the effect of horizontal permeabilities of 10 md and 100 md. It is clear from the results that both the HW and VW give the same ultimate recovery factor; the only difference is in the time to reach the abandonment condition. It takes VW more time to reach abandonment condition as compare to HW; however, as horizontal permeability increases from 10 md to 100 md, the difference becomes very small. Therefore, thin

reservoirs with high horizontal permeability (such as 100 md) and low value of k_v/k_h , should be developed with VW in preference to HW of low penetration ratio of 0.2.

Figure 5.26 indicates that for high value of formation thickness (such as 100 feet) and low values of penetration ratio and k_v/k_h ratio, the performance of HW and VW become somewhat closer to each other for horizontal permeability of 1 md and lower. Again HFVW always perform better than HW and VW both in terms of higher ultimate recovery factor and considerably lower abandonment time. As horizontal permeability increases from 0.01 to 1, the ultimate recovery factor for all the 3 well types become closer to each other.

Figure 5.27 indicates that for high values of formation thickness (such as 100 feet) and horizontal permeabilities (10 md and 100 md), and low values of penetration ratio (0.2) and k_v/k_h ratio, the performance of HW and VW become identical with respect to ultimate recovery factor and almost identical with respect to abandonment time.

Figure 5.34 indicates that for low values of formation thickness and k_v/k_h ratio and high value of penetration ratio (0.8), the performance of HW and HFVW become identical when horizontal permeability is 1 md; this implies that in such cases, there is no need for the HFVW and that the reservoir should be developed with HW. This figure indicates that at the lower horizontal permeabilities of 0.1 md and 0.01 md and for a penetration ratio of 0.8, HFVW should be used to develop thin reservoirs with low value of k_v/k_h ratio.

Figure 5.35 indicates that for low values of formation thickness and k_v/k_h ratio and high value of penetration ratio (0.8) and horizontal permeability (10 md and 100 md), HW and VW have the same ultimate recovery factor; however, the HW has drastically lower

abandonment time. Therefore, in such cases, the reservoir should be developed with horizontal wells. Using the results shown in Figures 5.34 and 5.35, it is interesting to note that the ultimate recovery factor is about 90% for all 3 well types when horizontal permeability is greater than 1 md.

Figure 5.38 indicates that for low value of k_v/k_h ratio and high values of formation thickness (100 feet) and penetration ratio (0.8), the performance of HW and HFVW become identical at a horizontal permeability of 1 md; however, at lower horizontal permeability (0.1 md and 0.01 md), the HFVW performs much better than the HW in terms of both the ultimate recovery factor and abandonment time. At the horizontal permeability of 1 md, the ultimate recovery factor for all 3 well types is about 92%.

Figure 5.39 indicates that for low value of k_v/k_h ratio and high values of formation thickness (100 feet) and penetration ratio (0.8), HW and VW will have the same ultimate recovery factor of about 92% when permeability is 10 md and higher; however, HW performs much better than the VW due to drastically lower abandonment time.

The same conclusions that are obtained above for the cases corresponding to k_v/k_h ratio of 0.1, as shown in Figures 5.22 through 5.39, are obtained for the cases corresponding to k_v/k_h ratio of 1, as shown in Figures 5.40 through 5.57. The only difference is that the abandonment time for the HW decreases slightly for the cases corresponding to k_v/k_h ratio of 1 compared to the cases corresponding to k_v/k_h ratio of 0.1. This shows that the value of k_v/k_h ratio has somewhat negligible effect on the performance of horizontal wells in volumetric dry gas reservoirs.

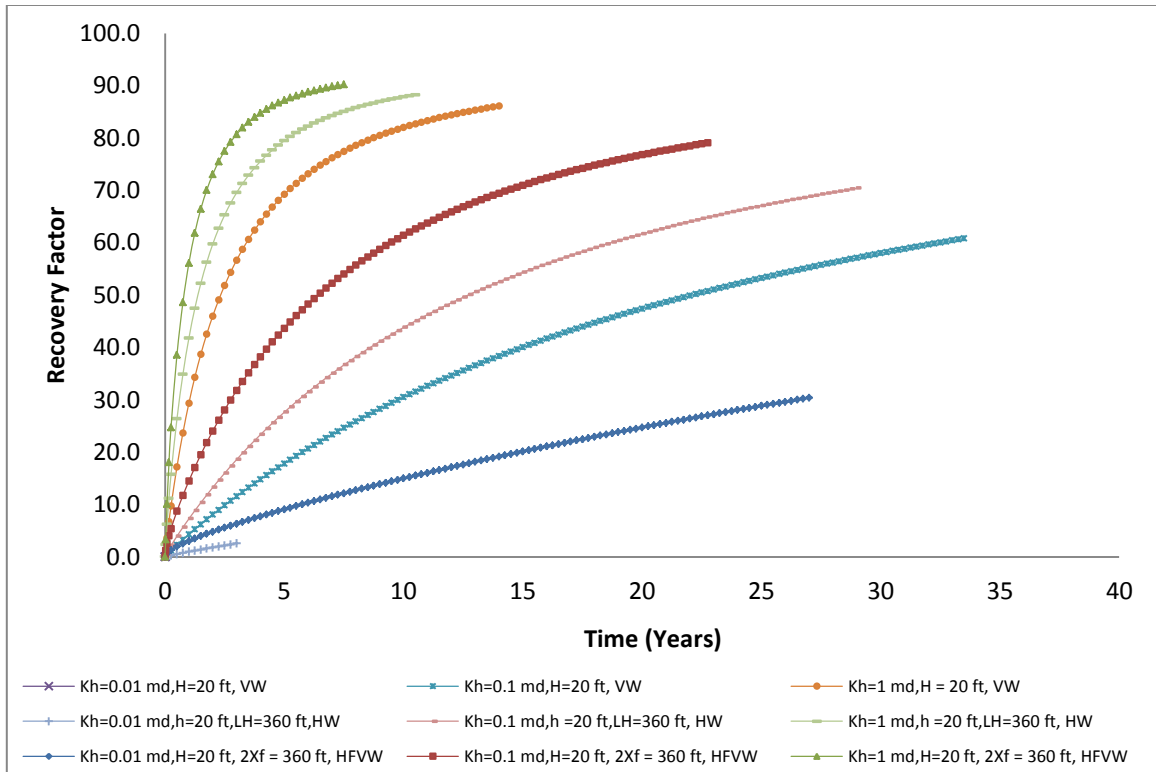


Figure 5.22: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 1-3)

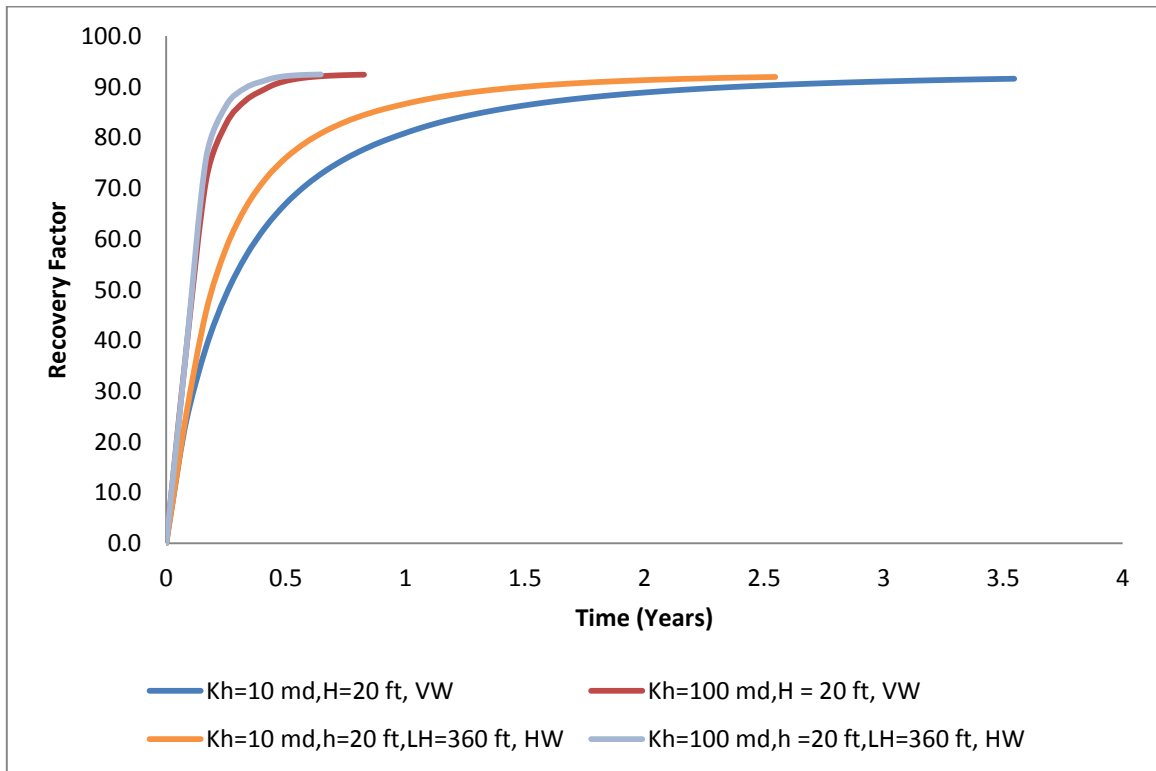


Figure 5.23: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 4-5)

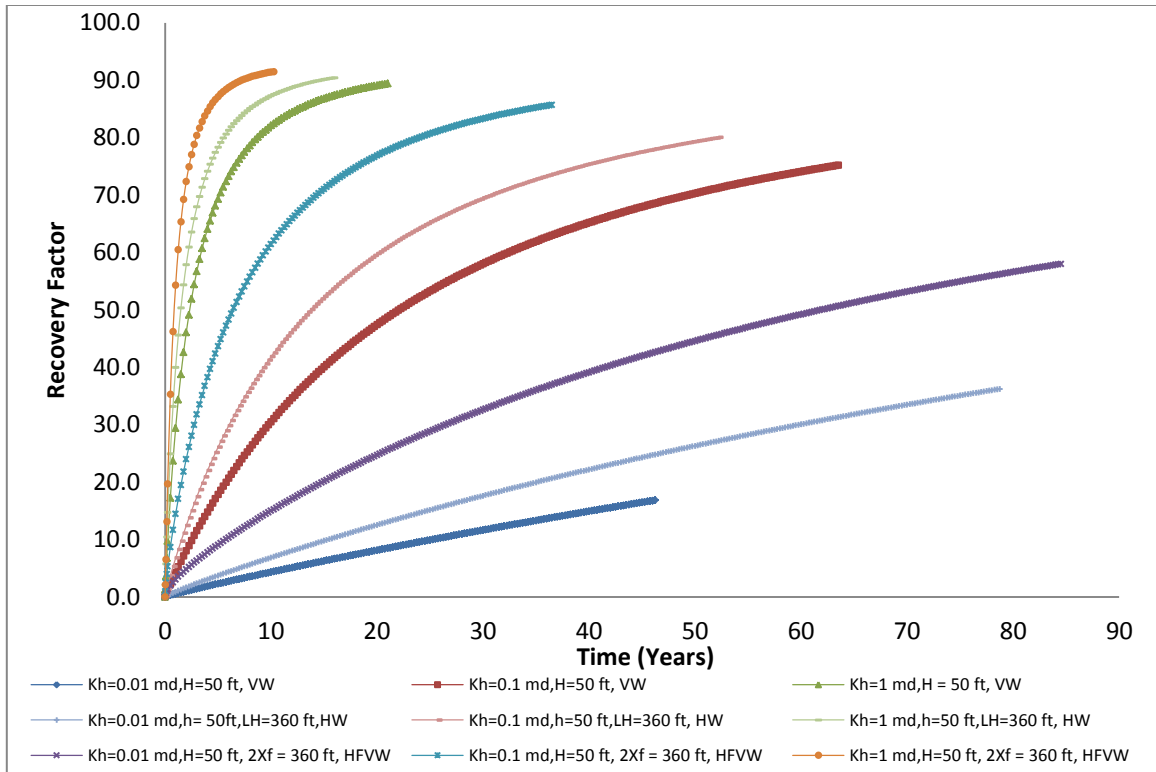


Figure 5.24: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 6-8)

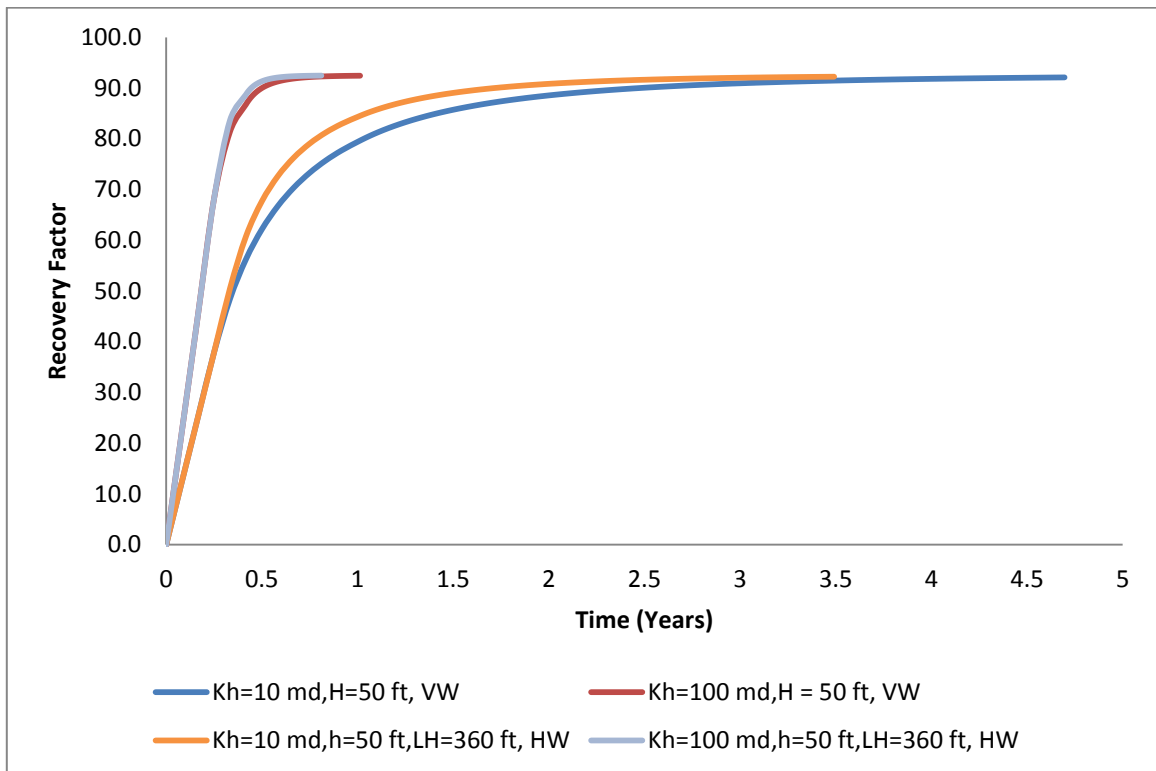


Figure 5.25: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 9-10)

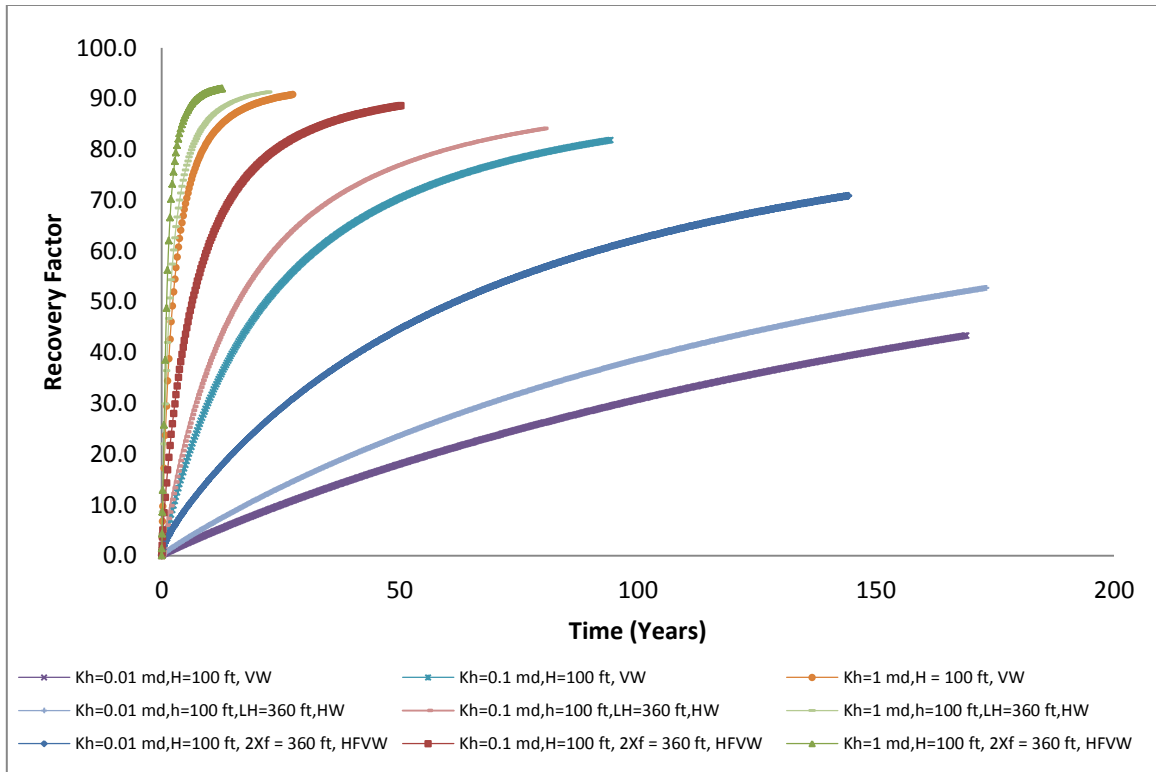


Figure 5.26: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 11-13)

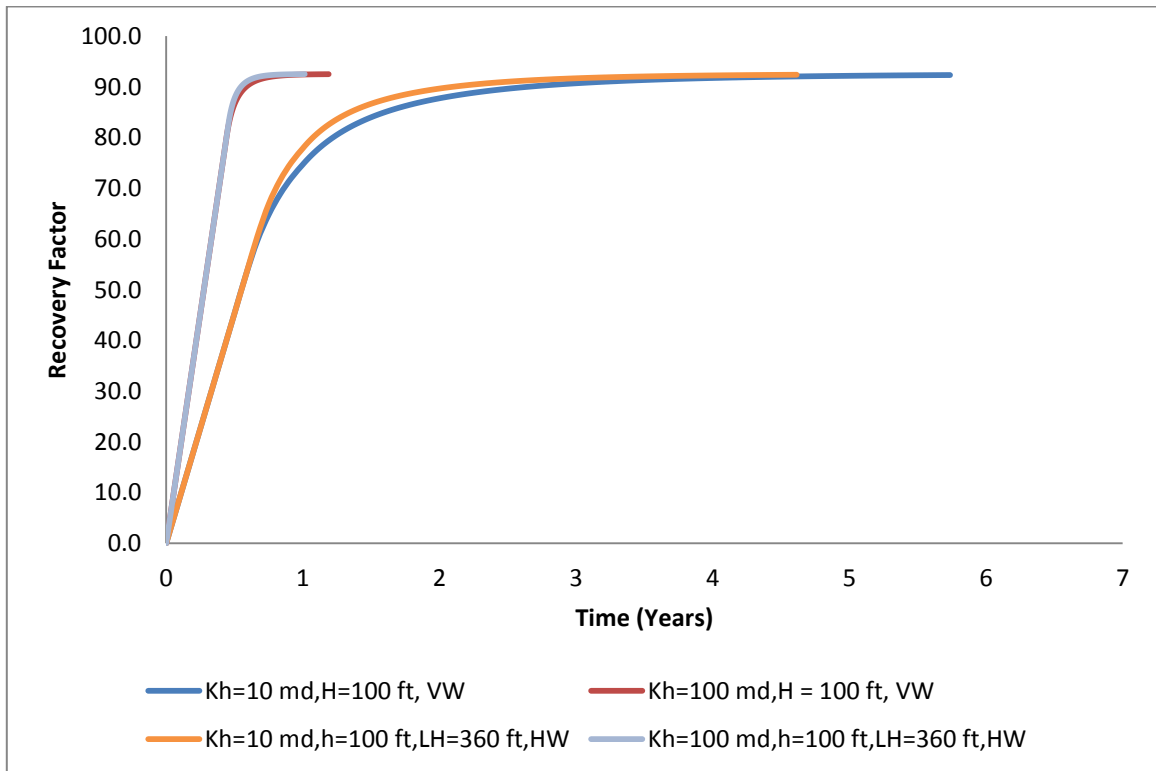


Figure 5.27: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 14-15)

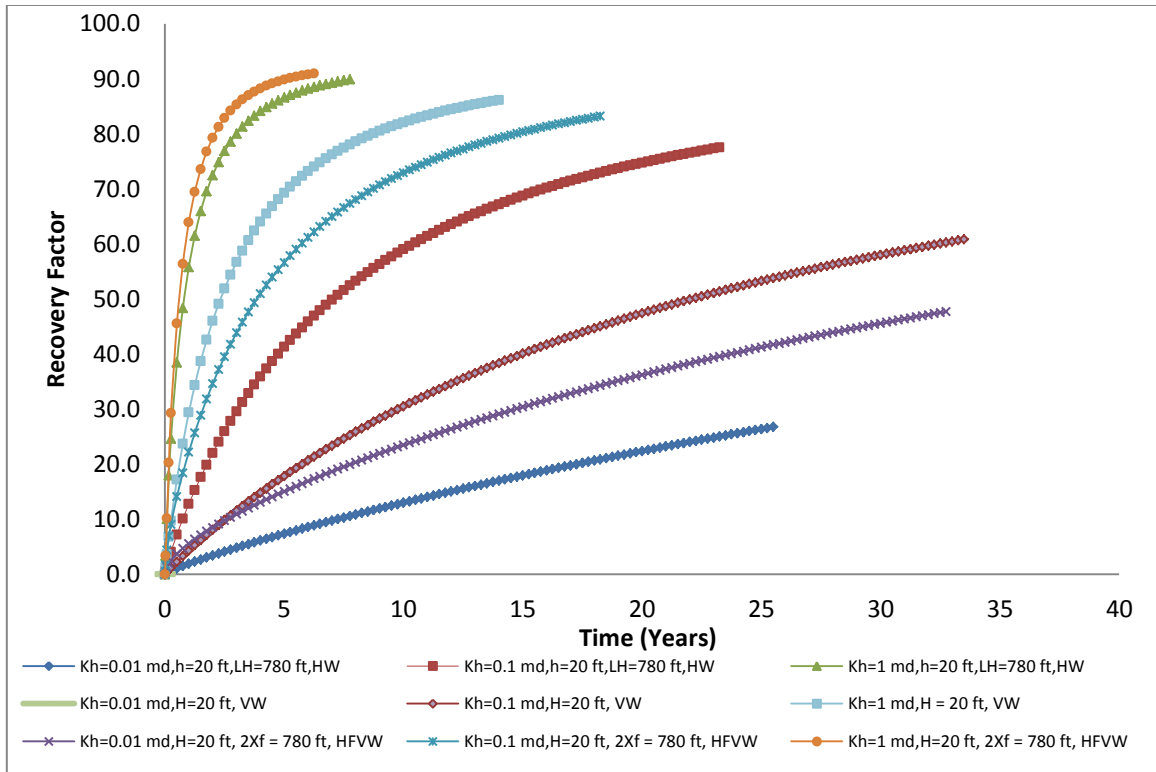


Figure 5.28: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 46-48)

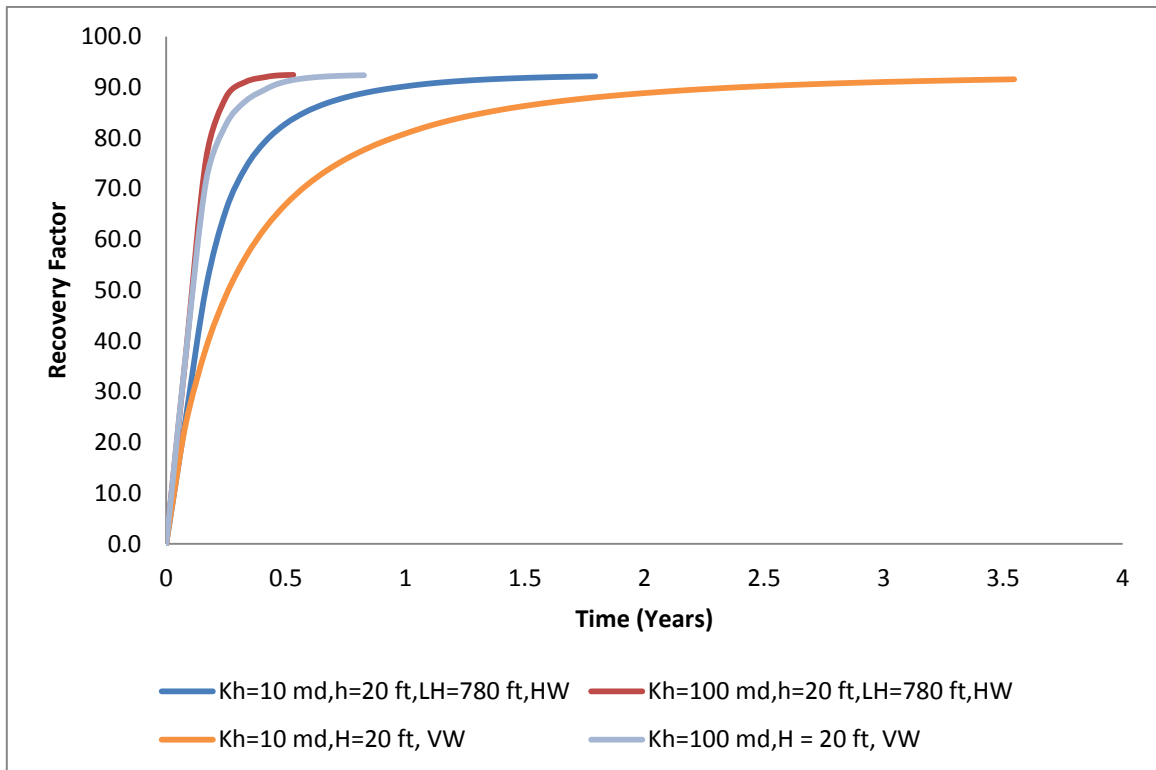


Figure 5.29: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 49-50)

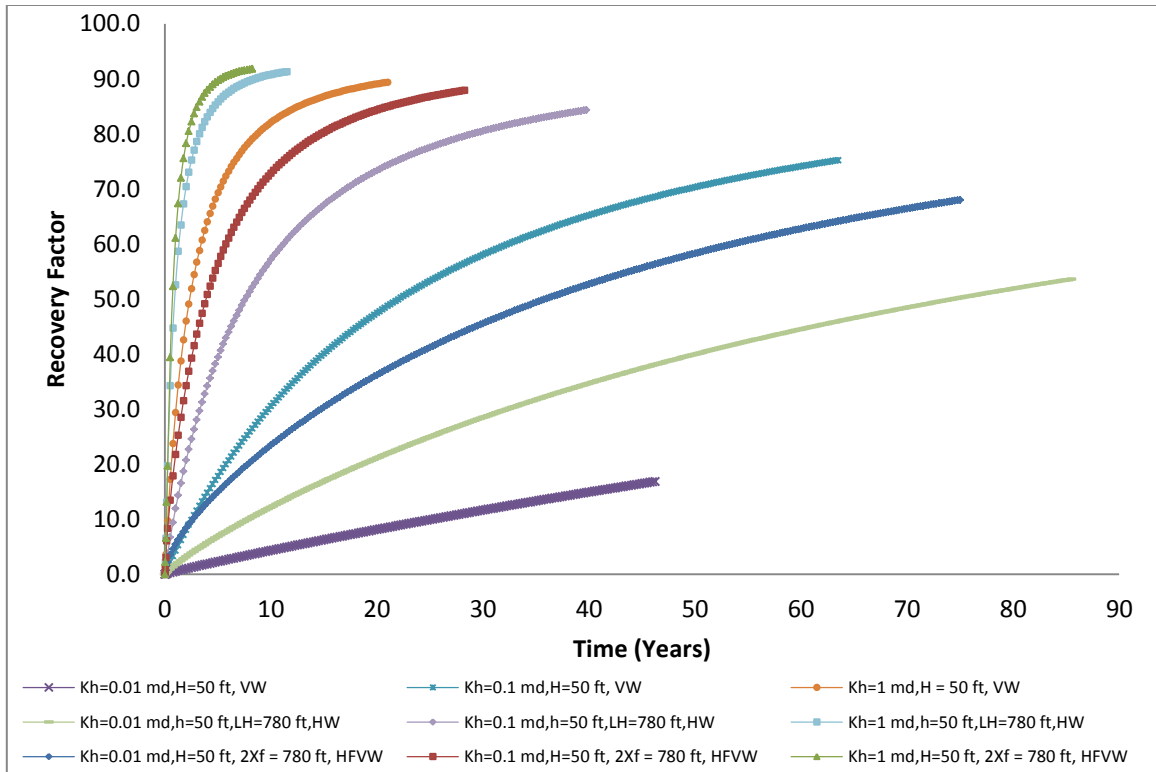


Figure 5.30: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 51-53)

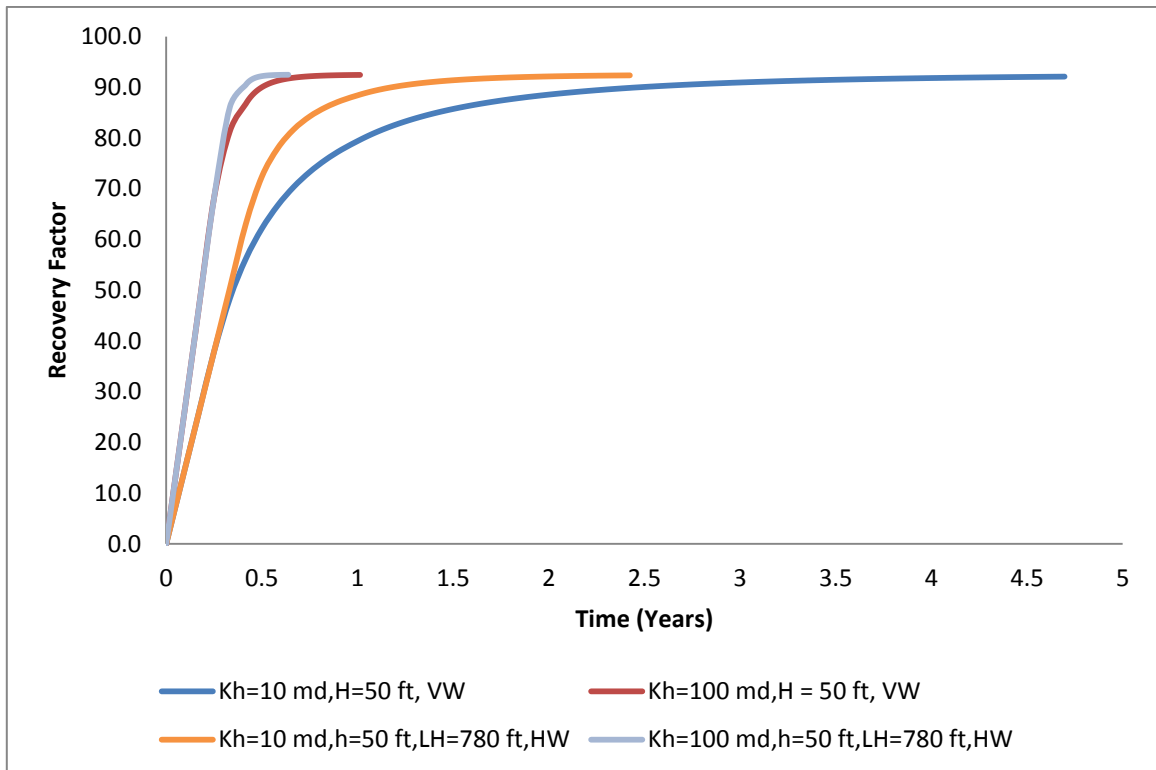


Figure 5.31: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 54-55)

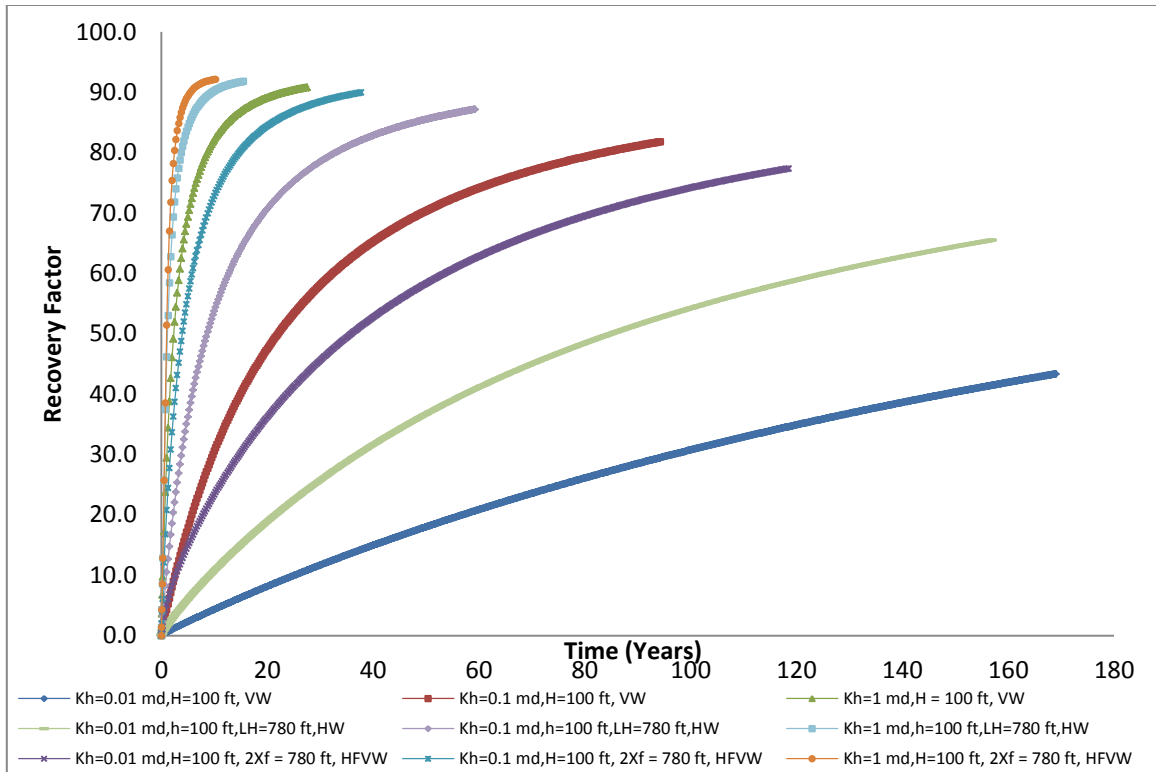


Figure 5.32: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 56-58)

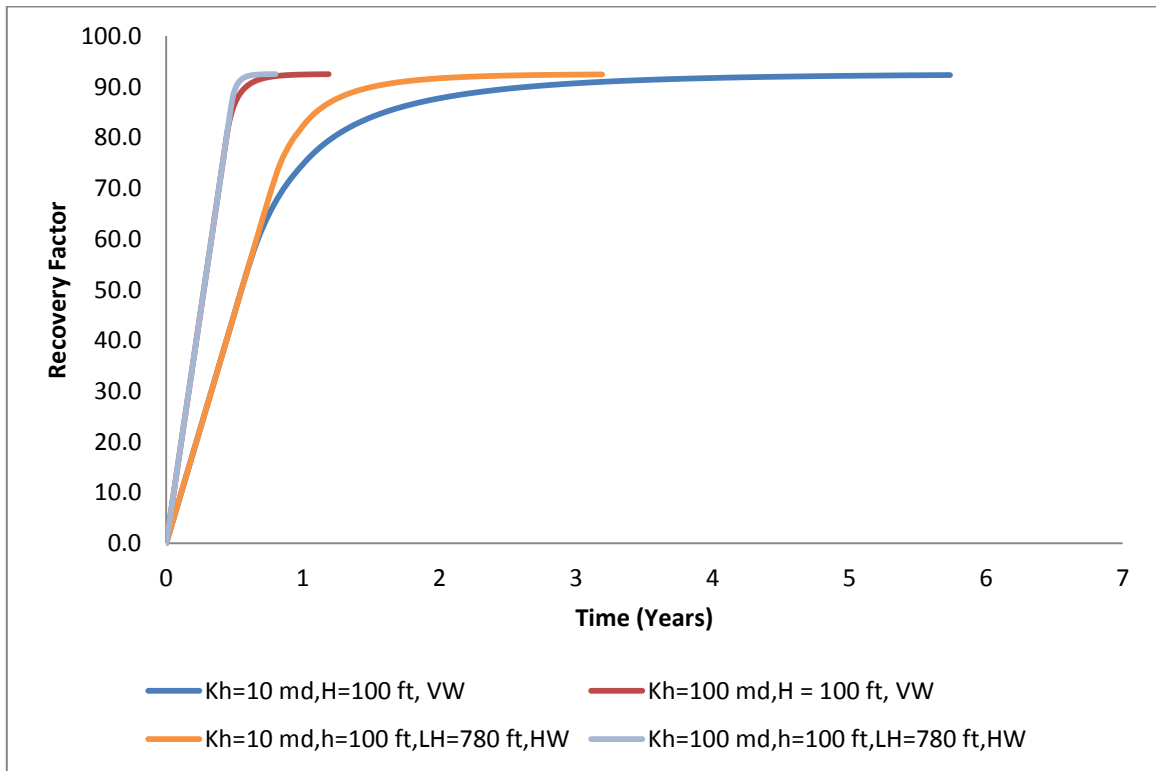


Figure 5.33: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 59-60)

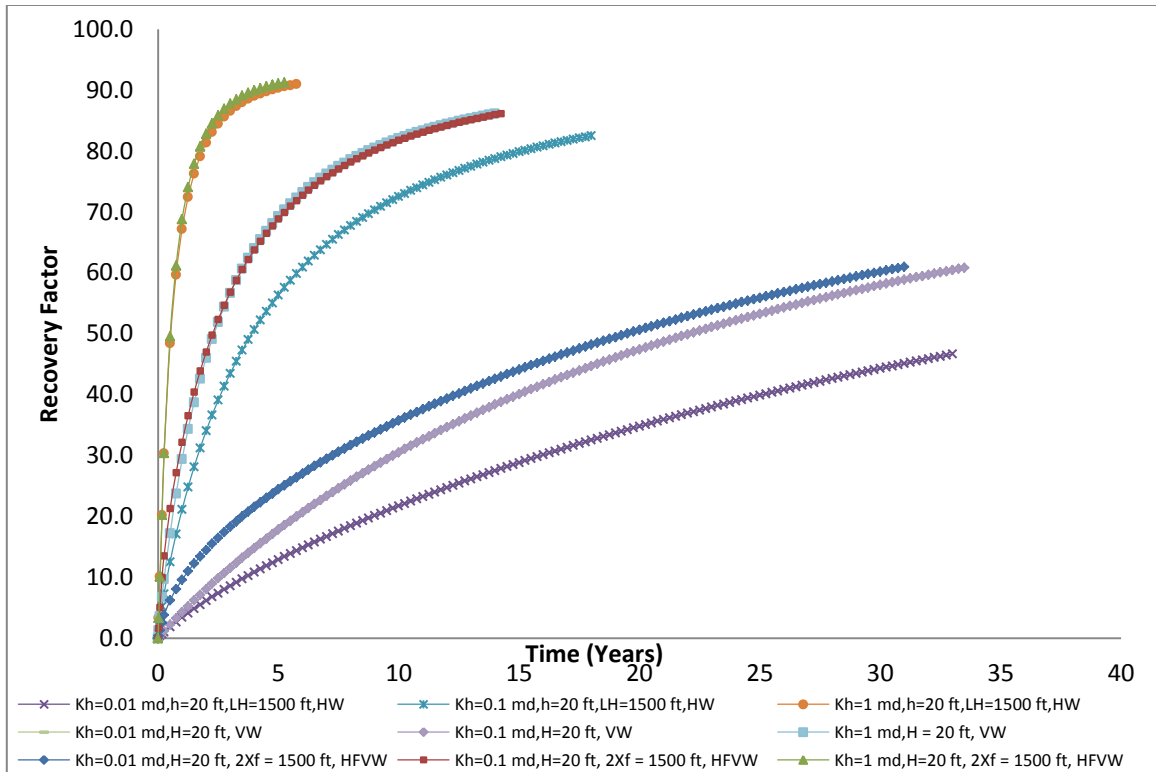


Figure 5.34: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 91-93)

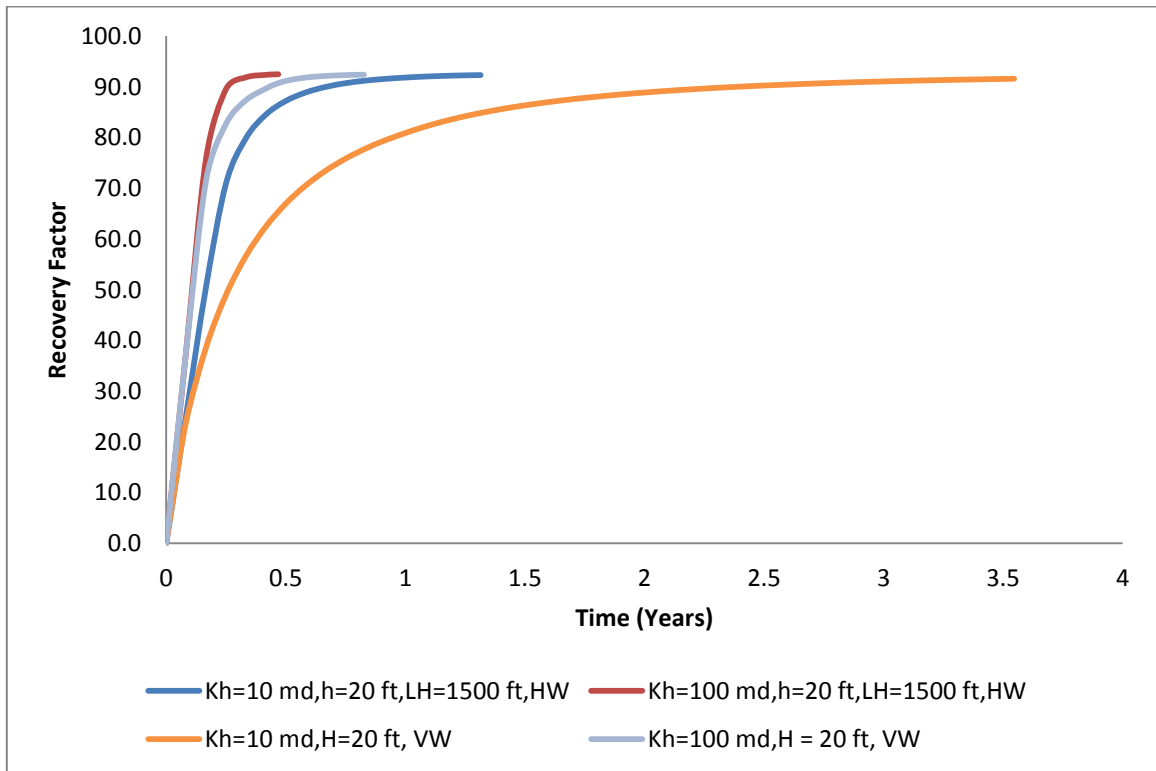


Figure 5.35: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 94-95)

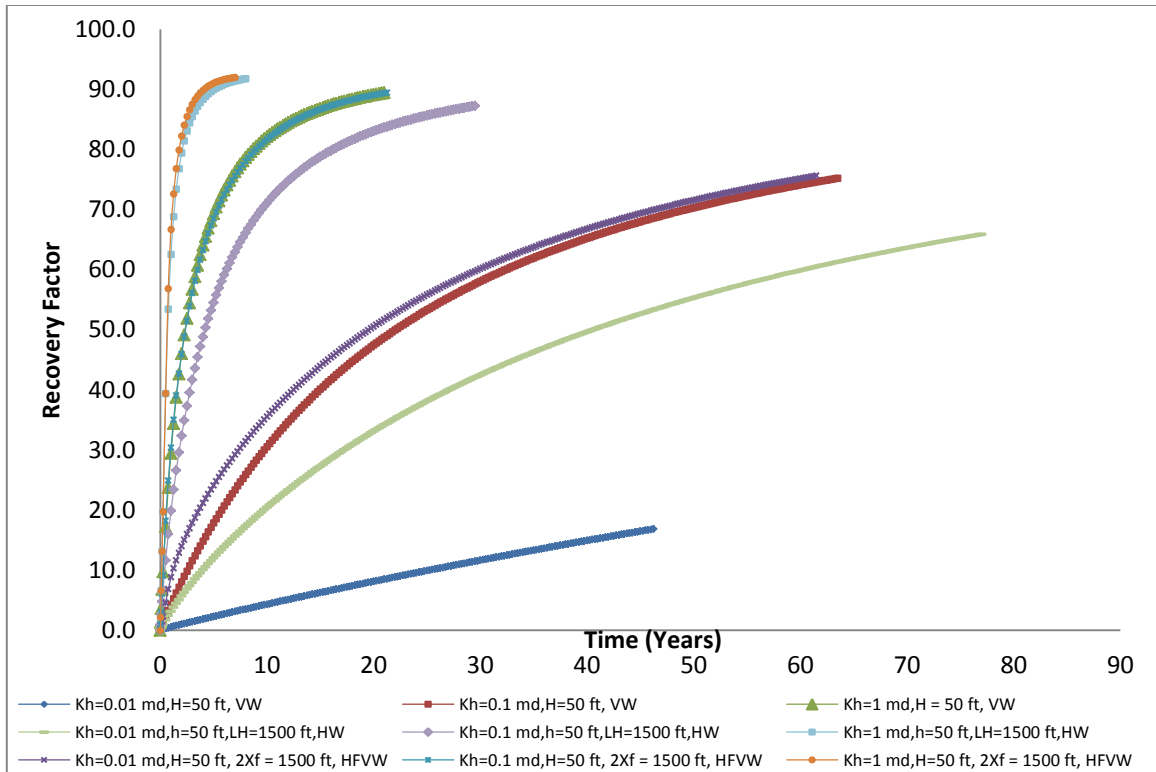


Figure 5.36: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 96-98)

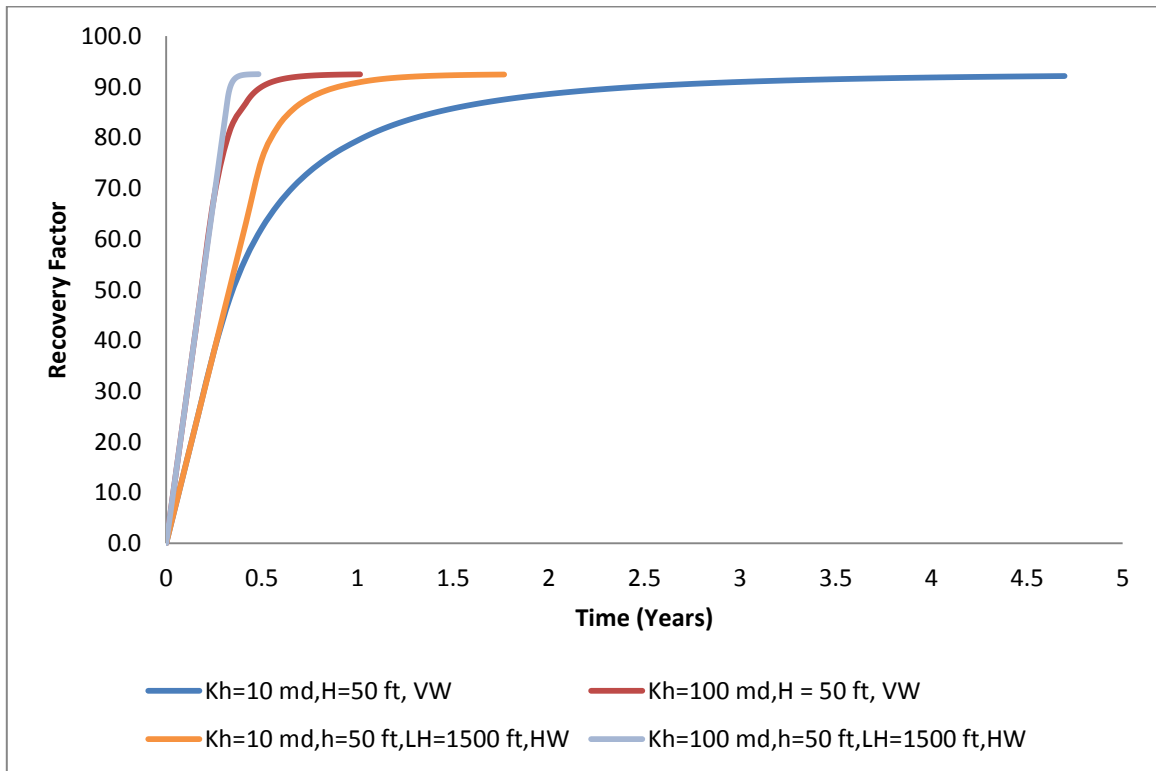


Figure 5.37: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 99-100)

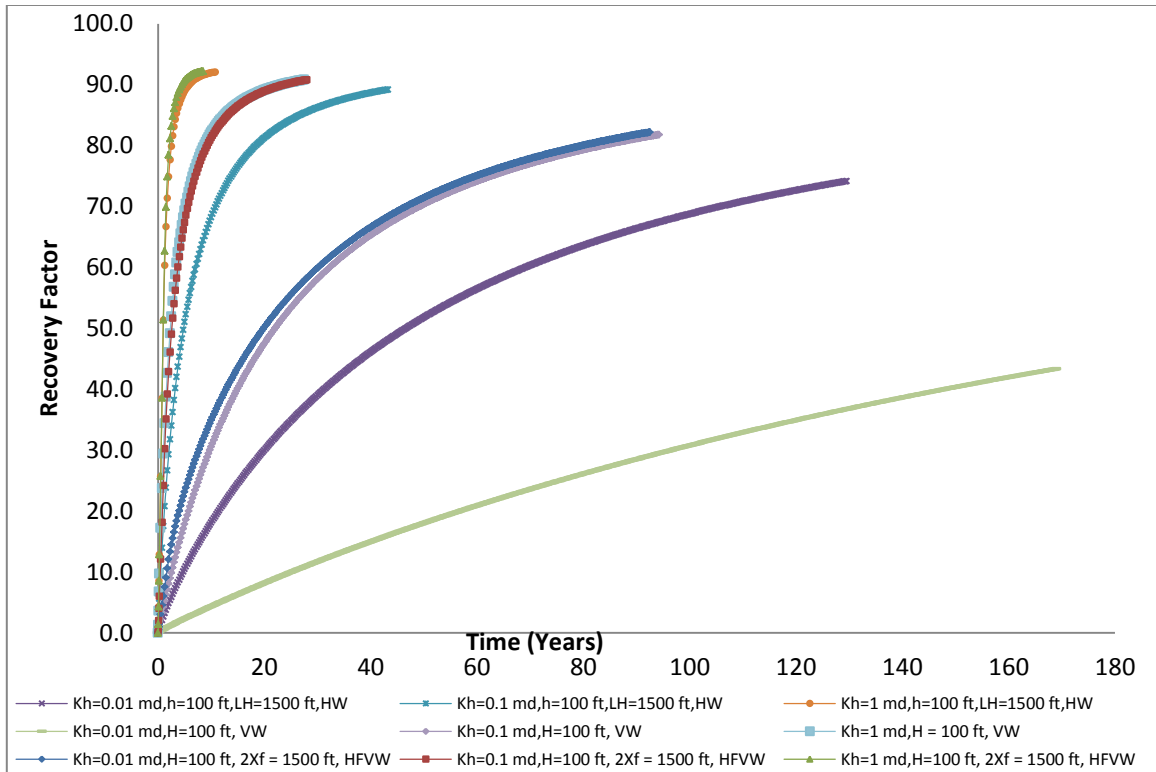


Figure 5.38: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:101-103)

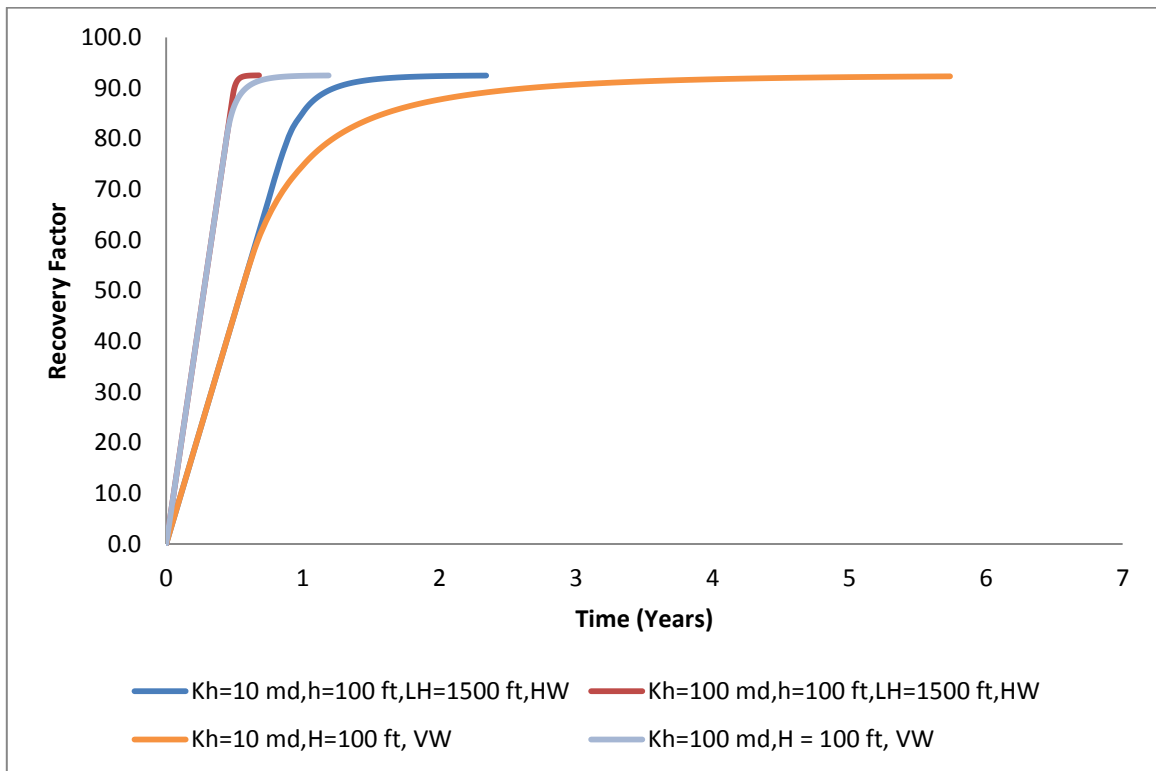


Figure 5.39: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:104-105)

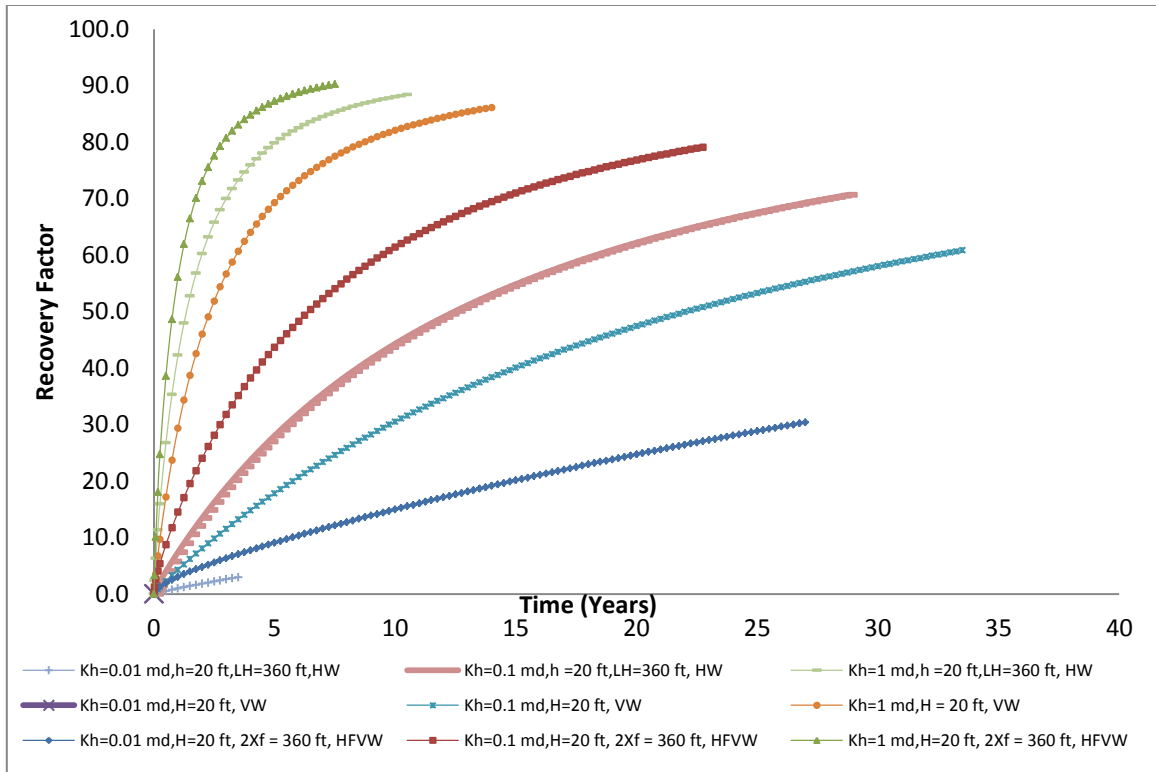


Figure 6.40: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 31-33)

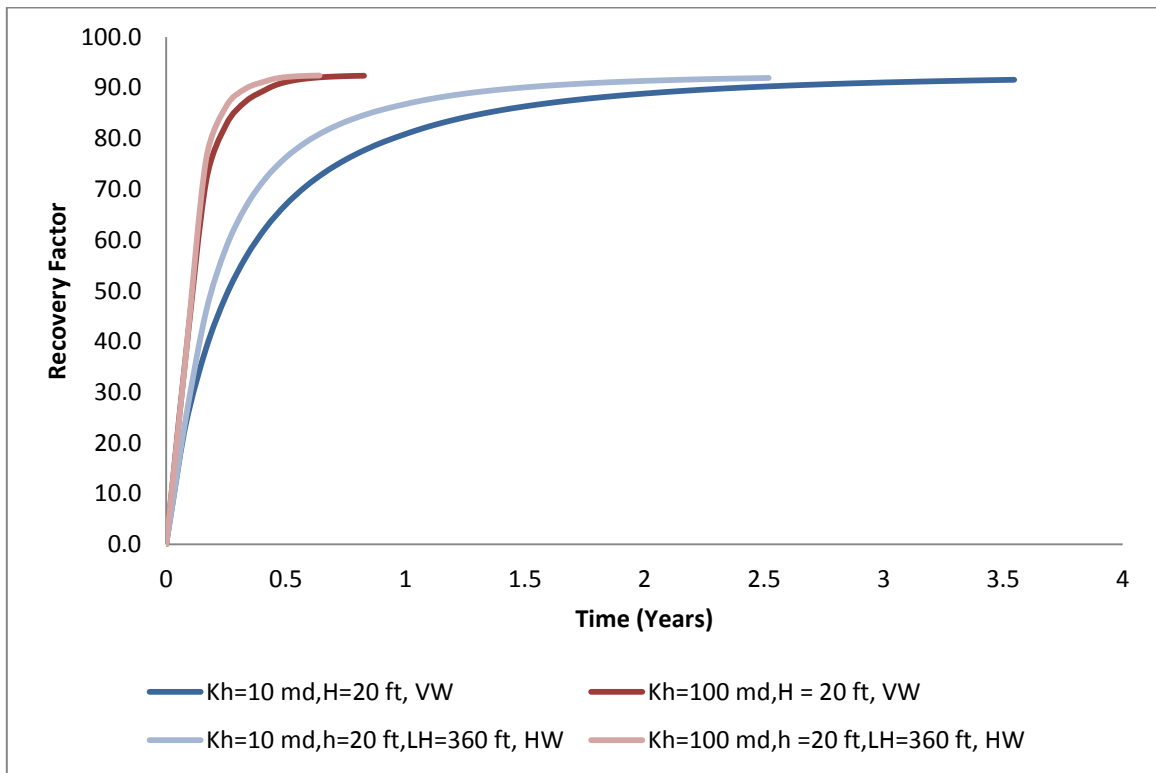


Figure 5.41: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 34-35)

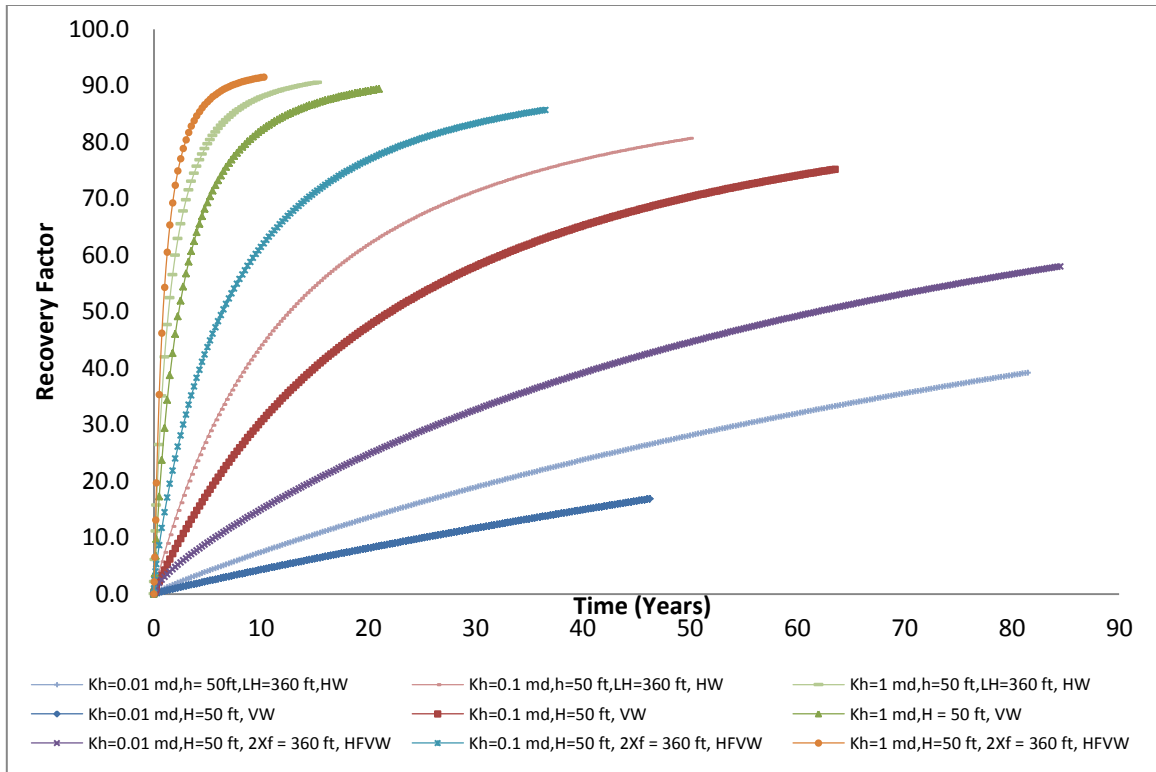


Figure 5.42: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 36-38)

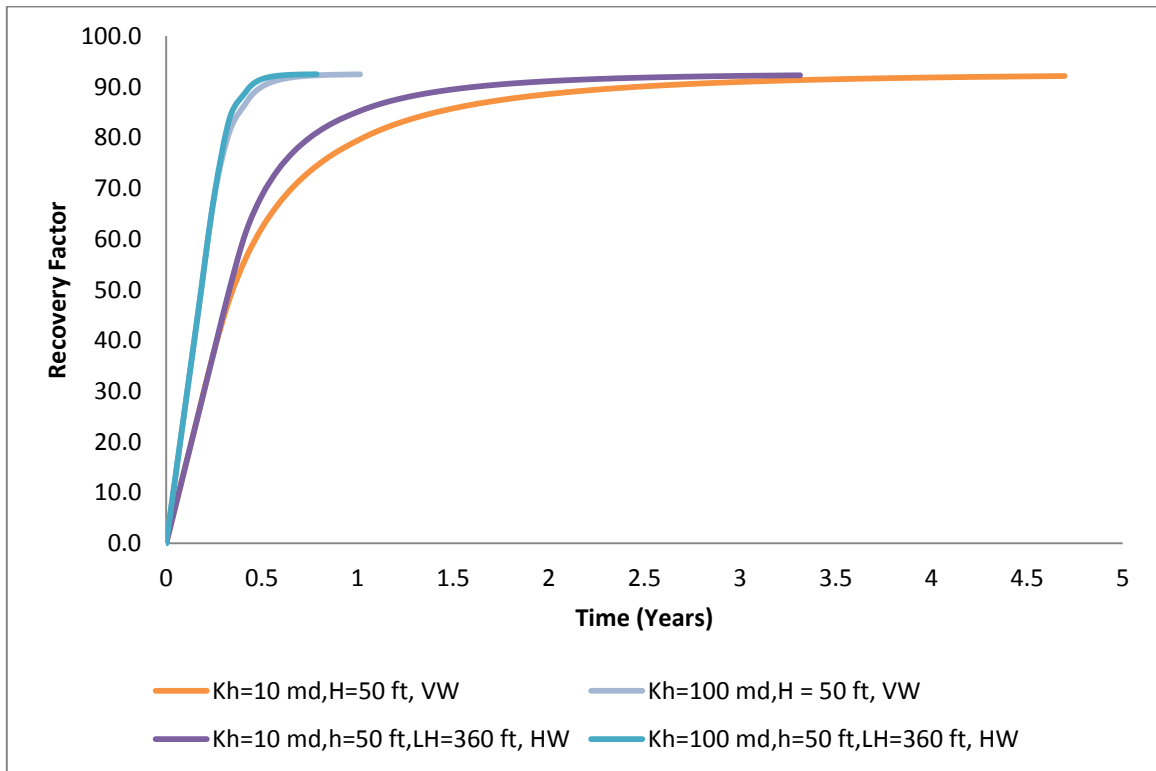


Figure 5.43: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 39-40)

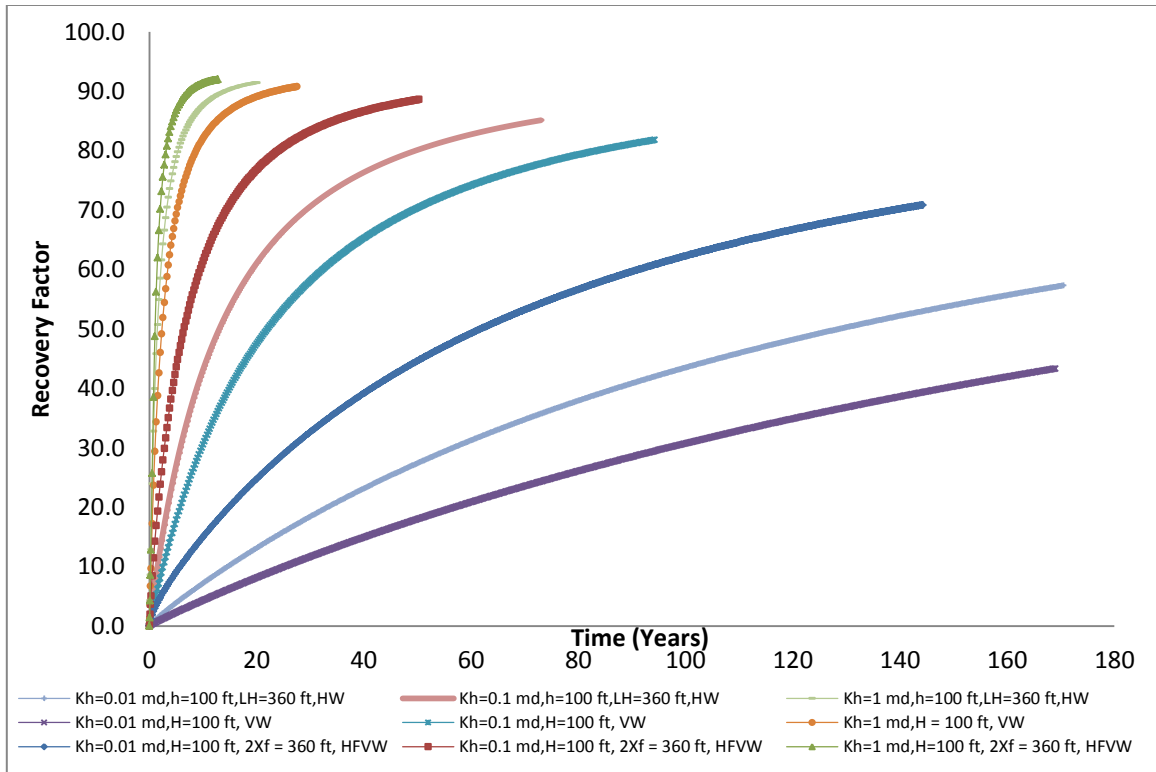


Figure 5.44: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 41-43)

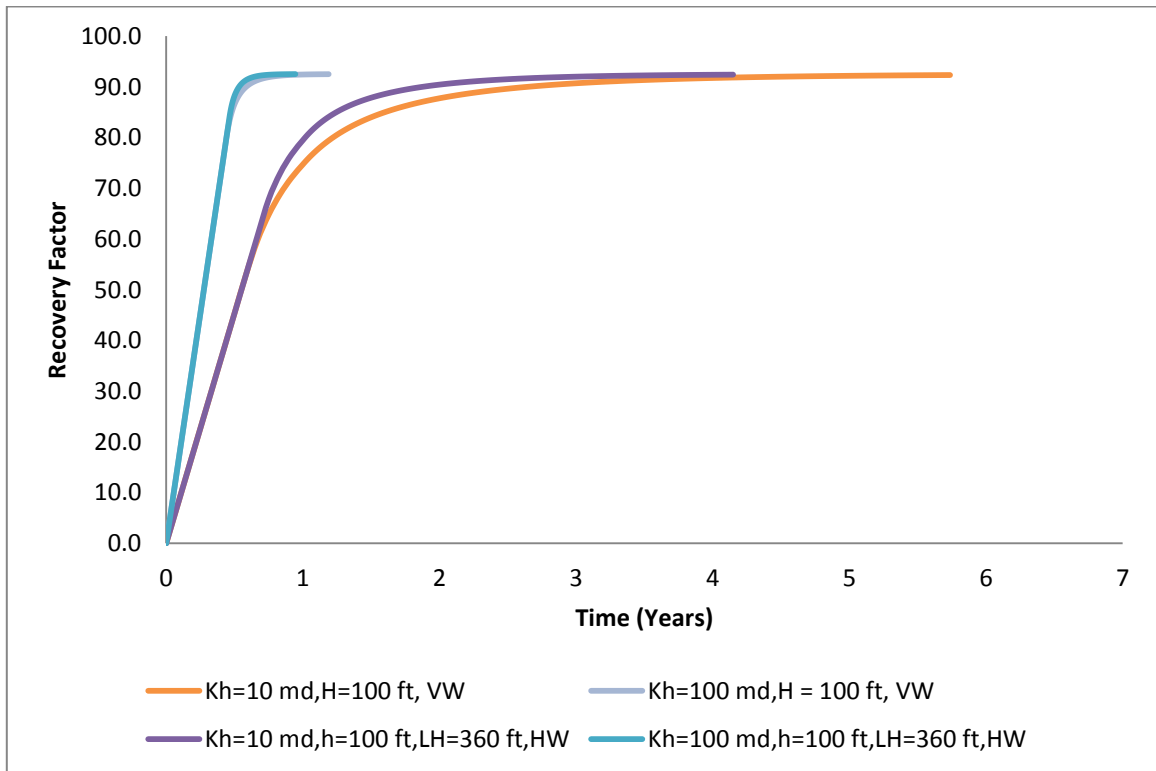


Figure 5.45: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 44-45)

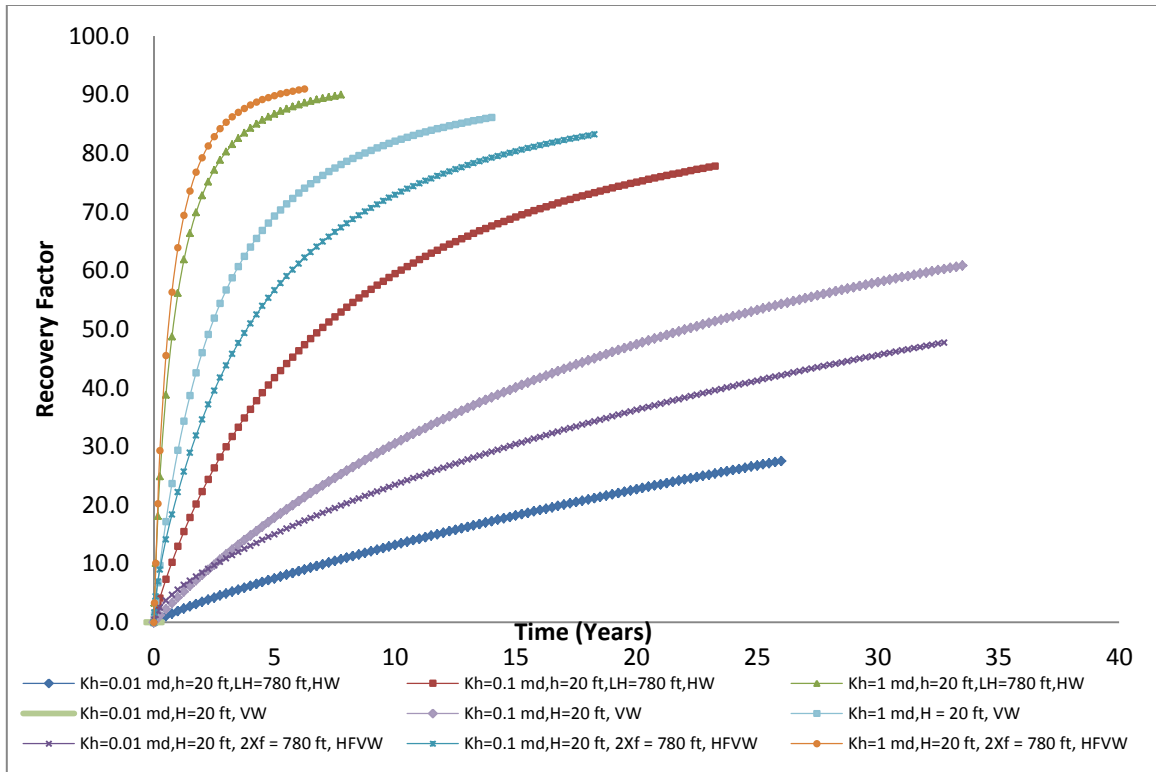


Figure 5.46: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 76-78)

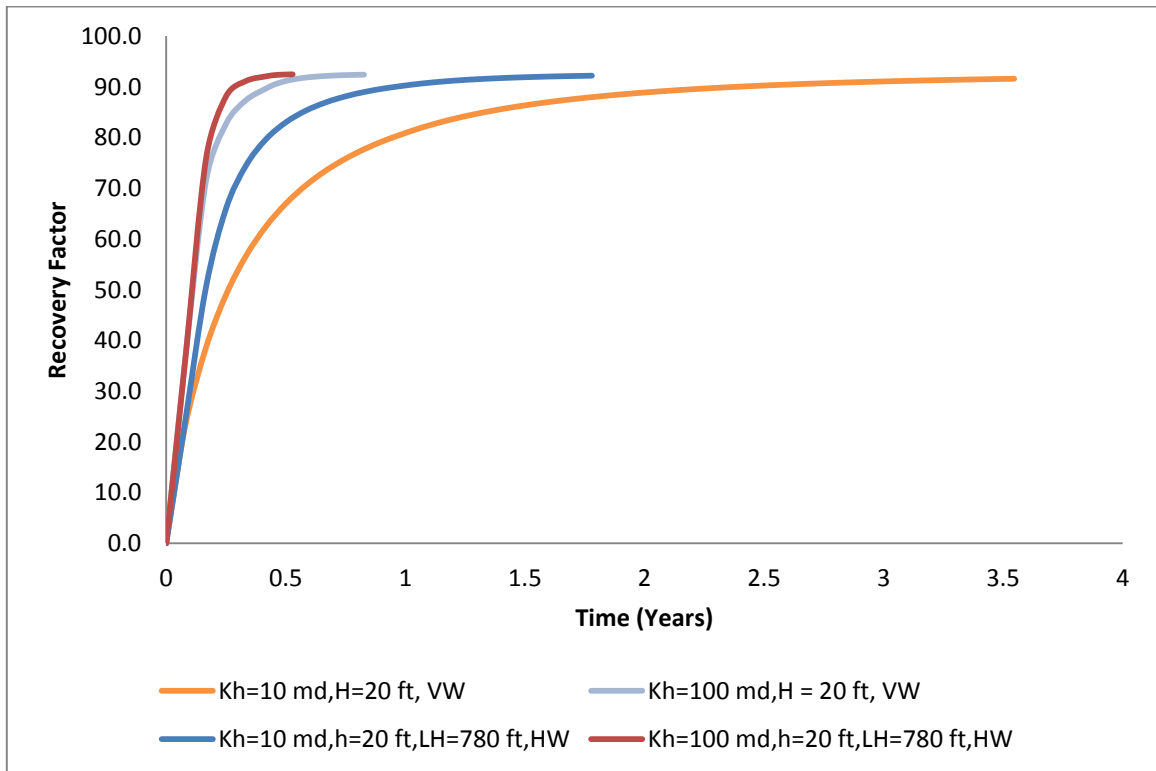


Figure 5.47: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 79-80)

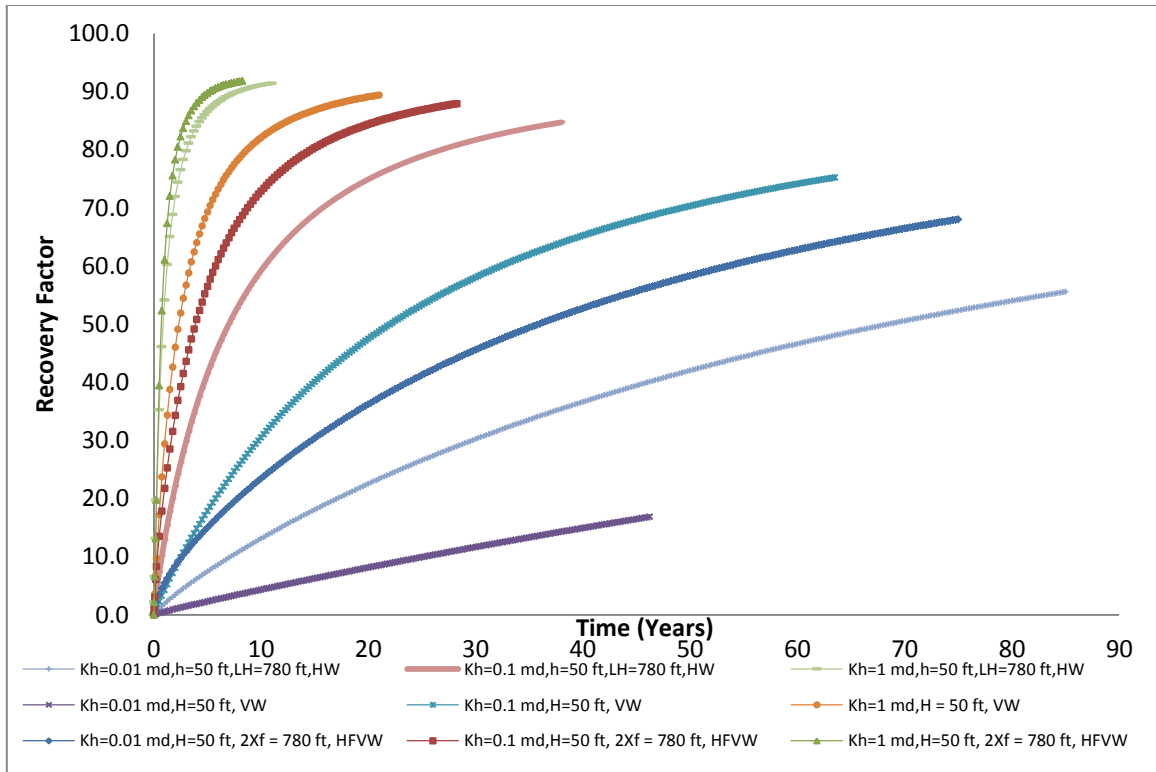


Figure 5.48: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 81-83)

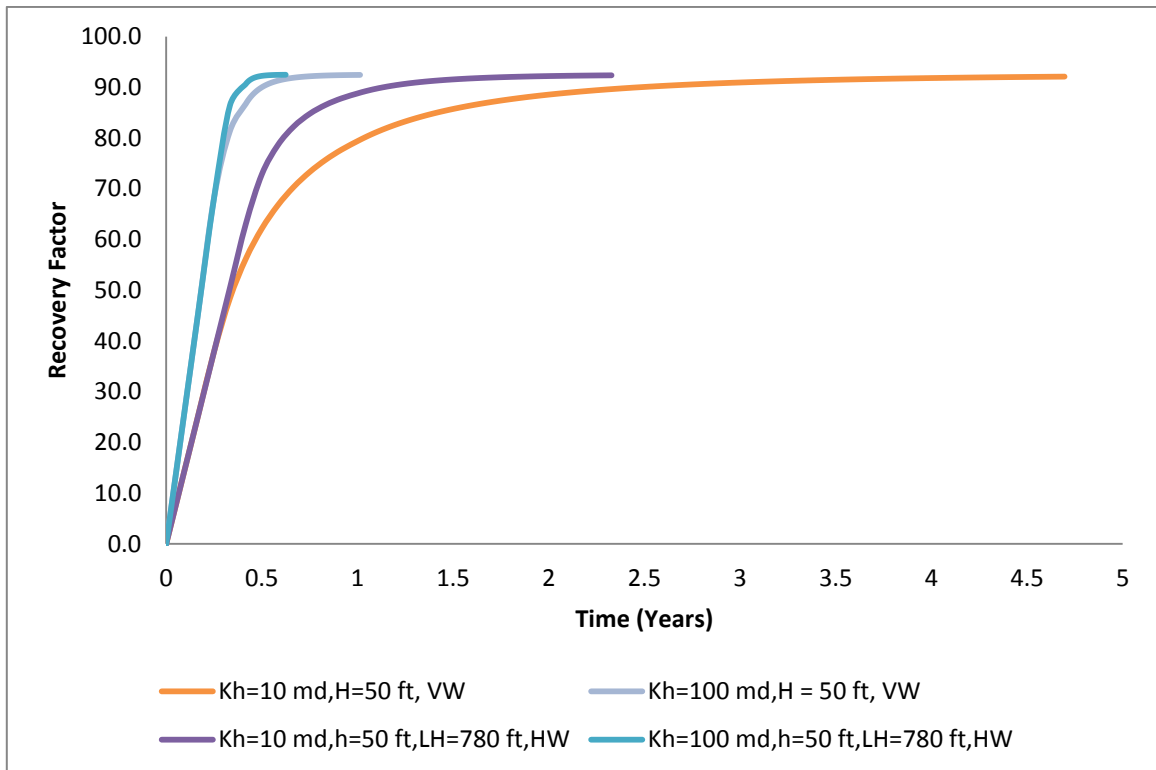


Figure 5.49: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 84-85)

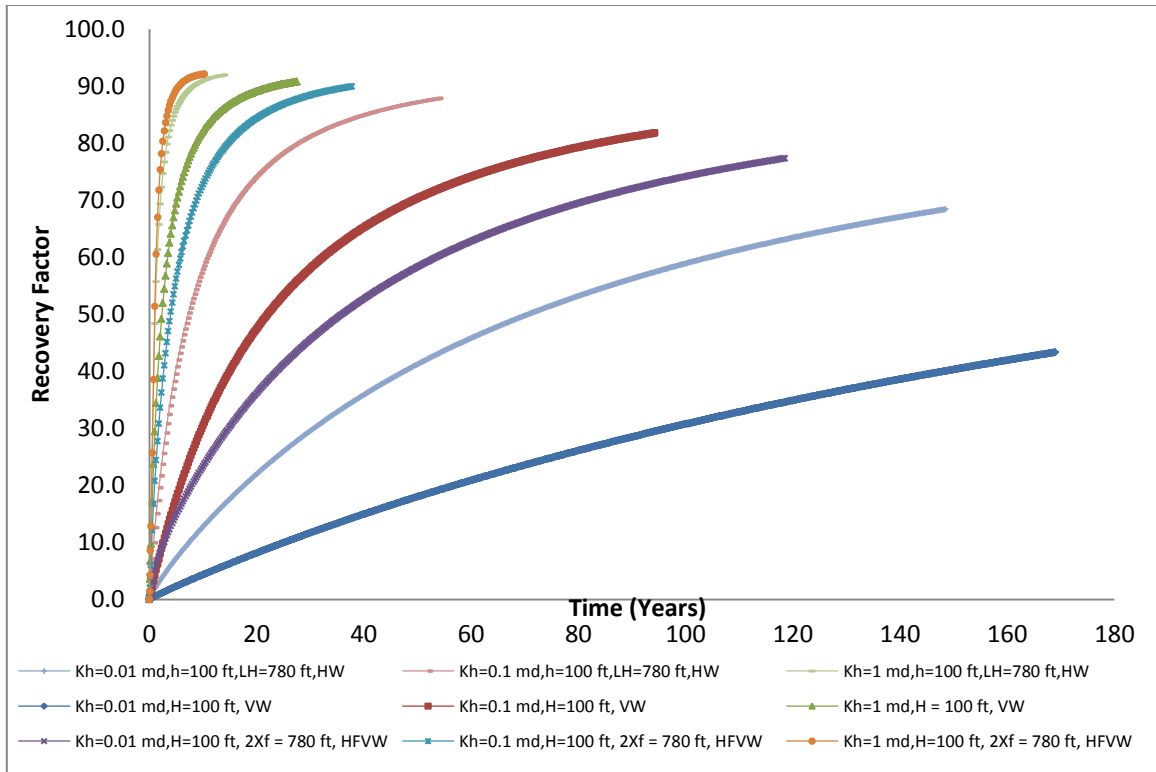


Figure 5.50: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 86-88)

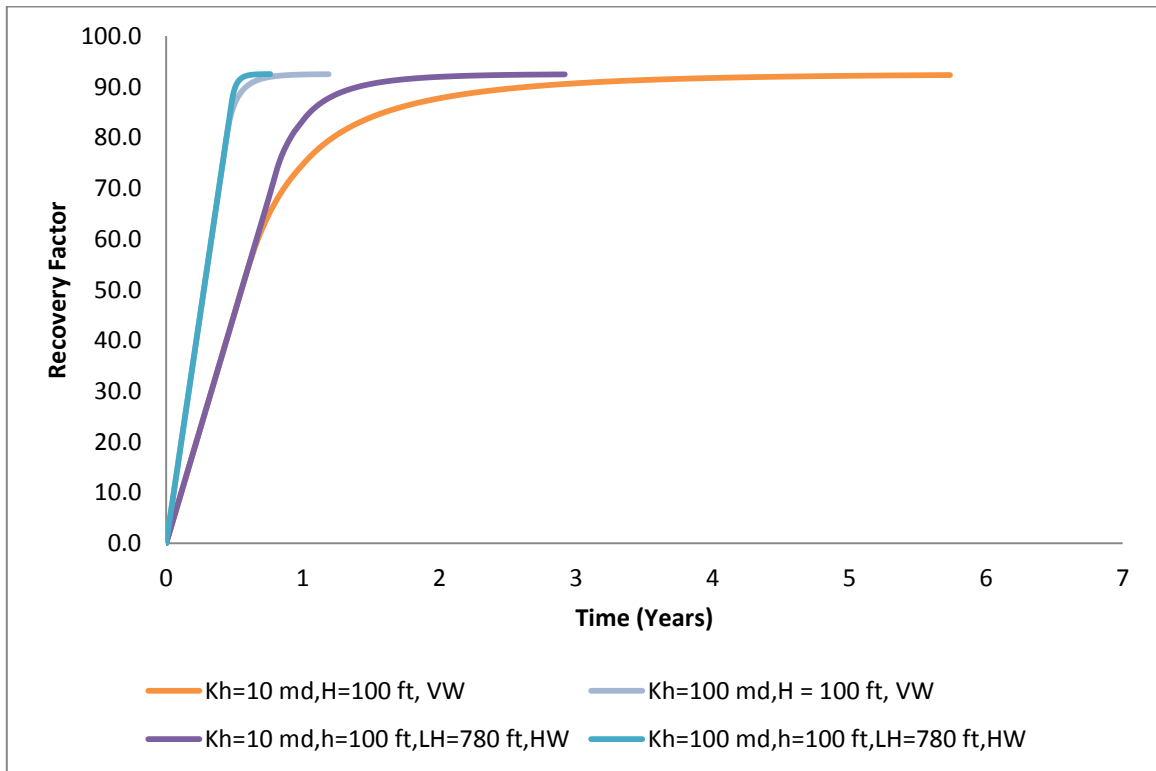


Figure 5.51: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases: 89-90)

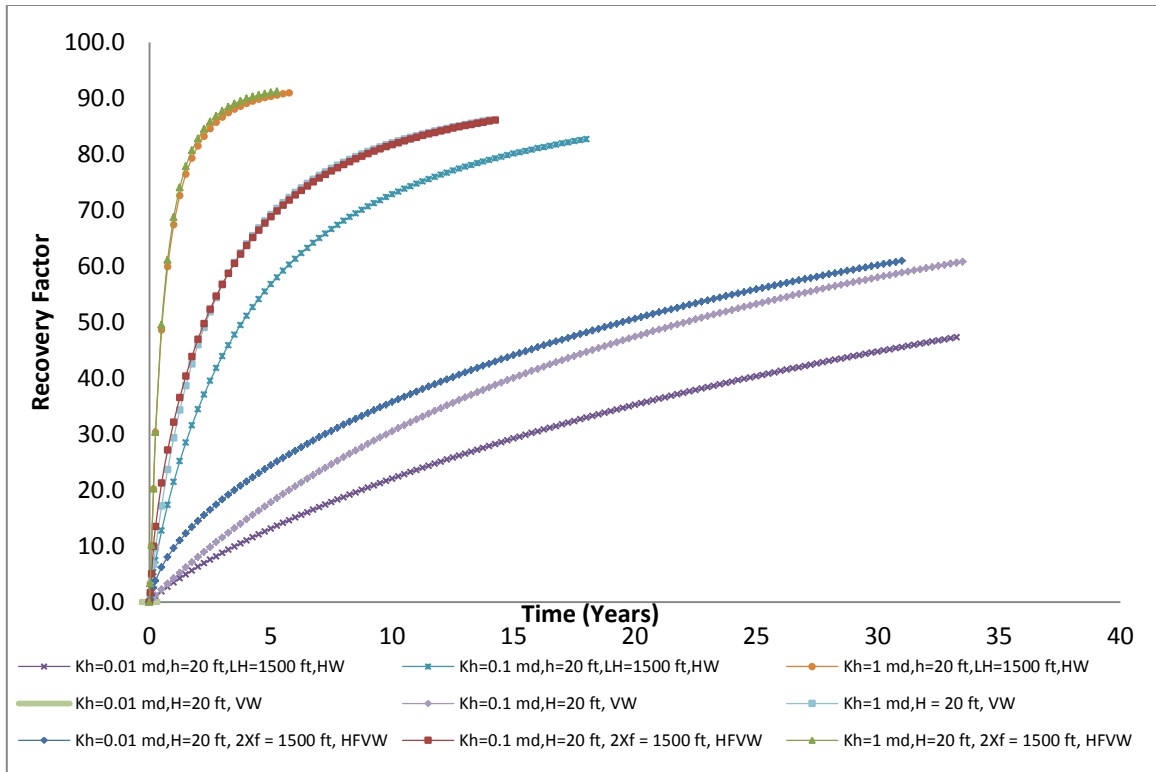


Figure 5.52: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:121-123)

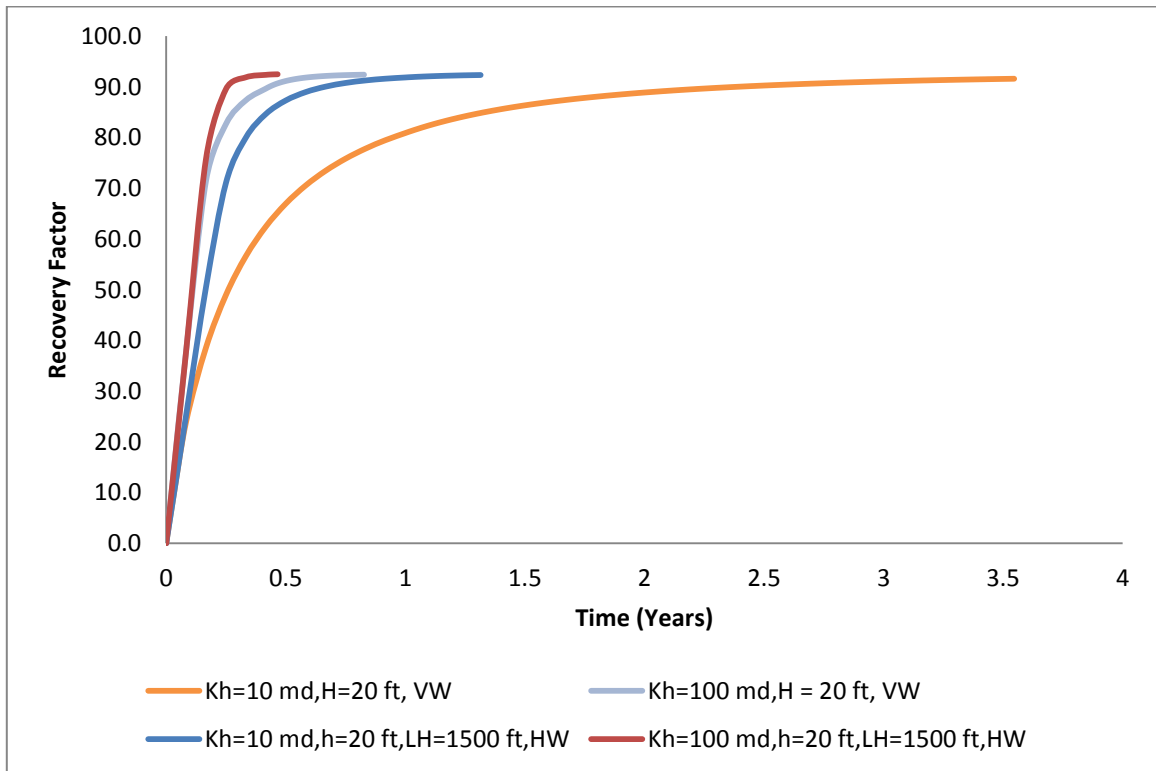


Figure 5.53: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:124-125)

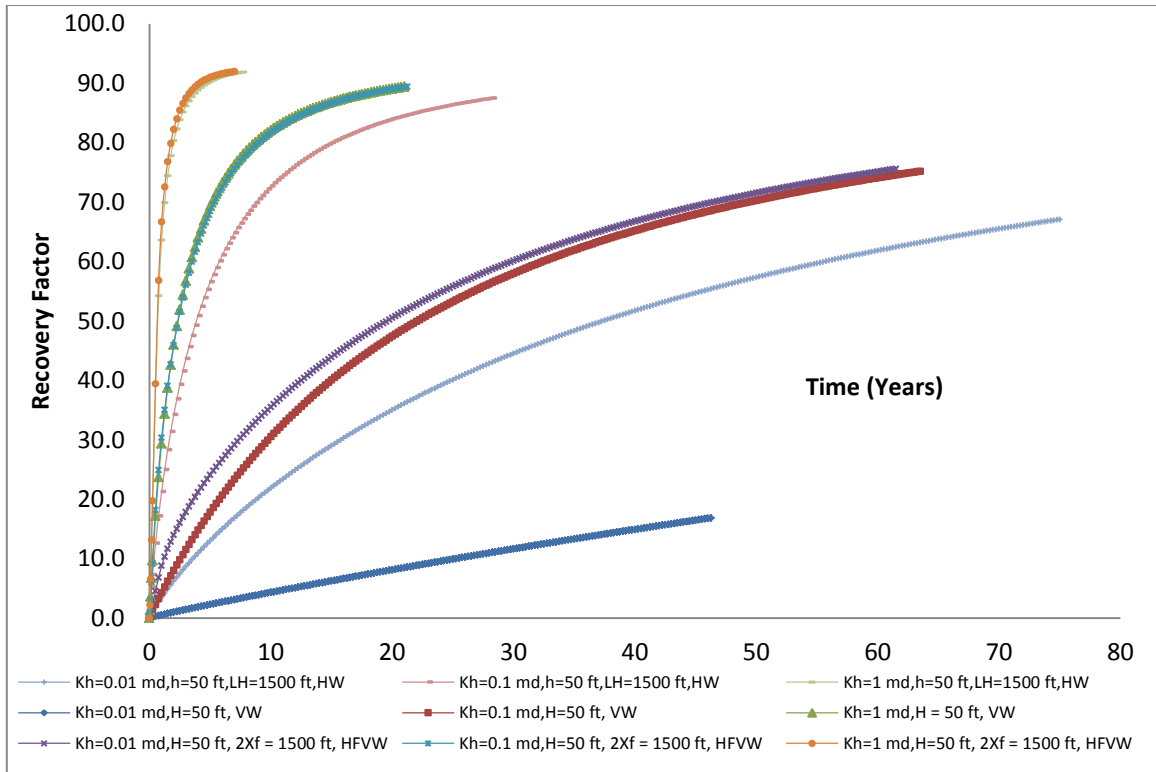


Figure 5.54: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:126-128)

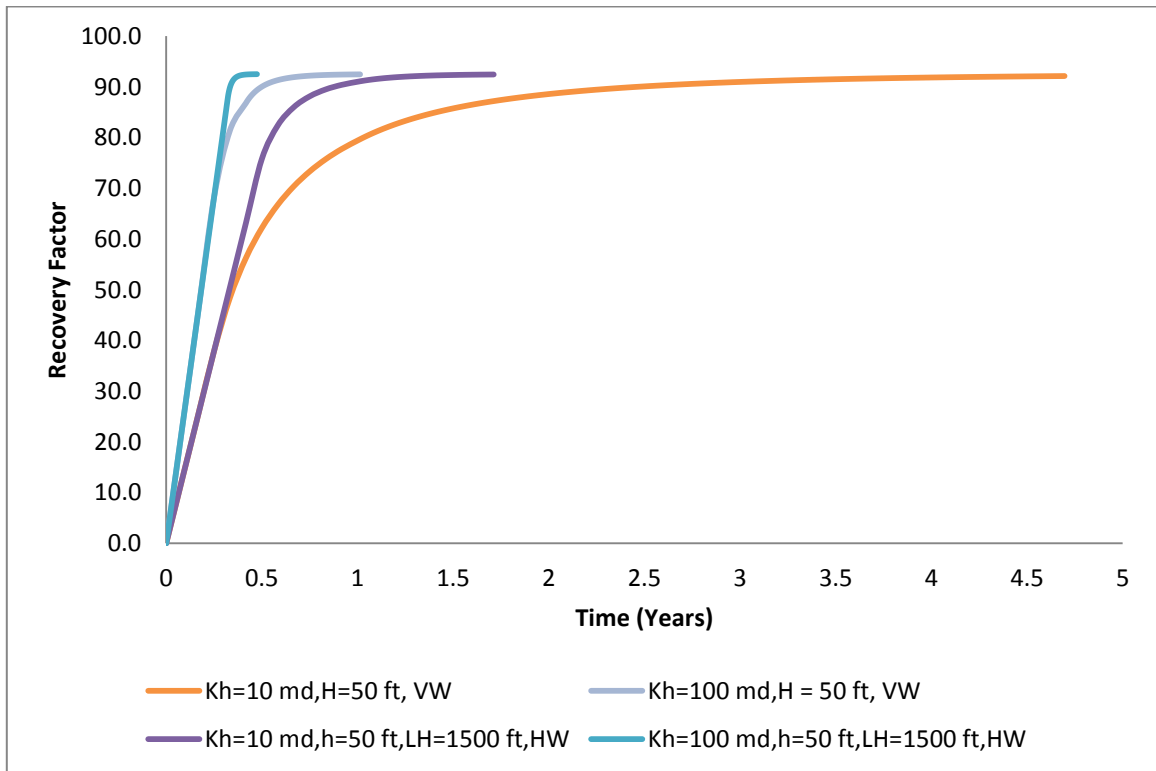


Figure 5.55: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:129-130)

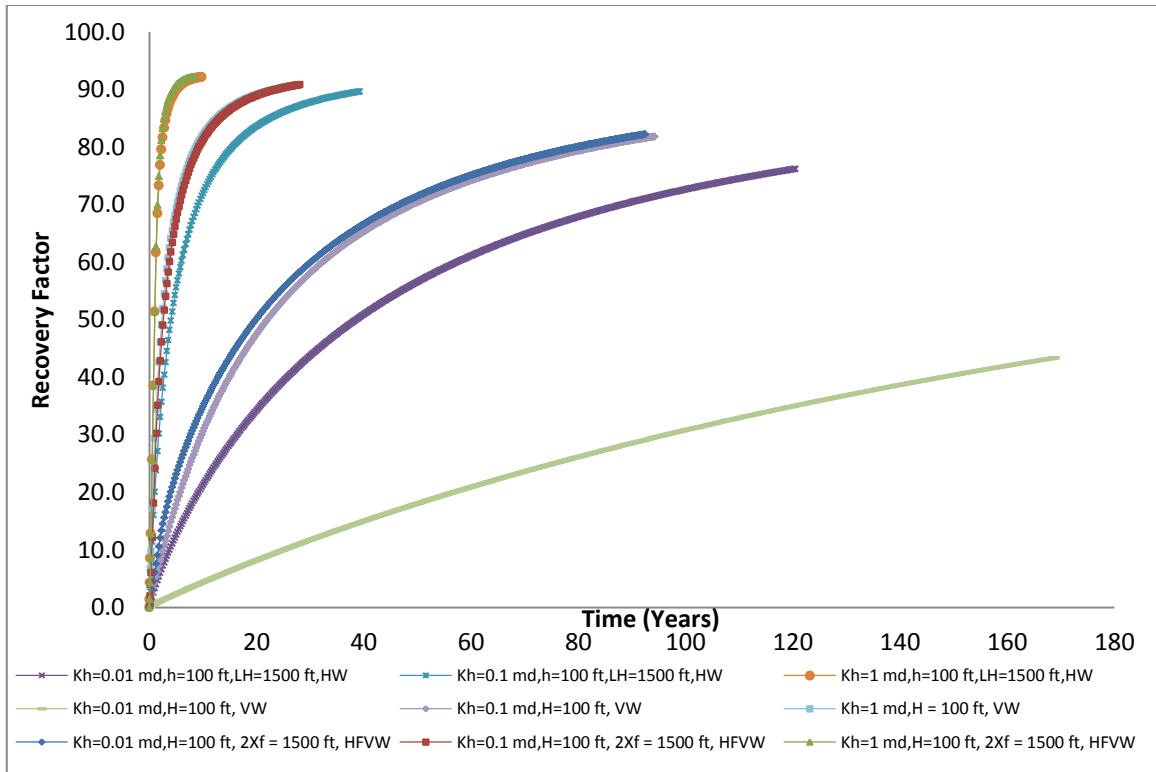


Figure 5.56: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:131-133)

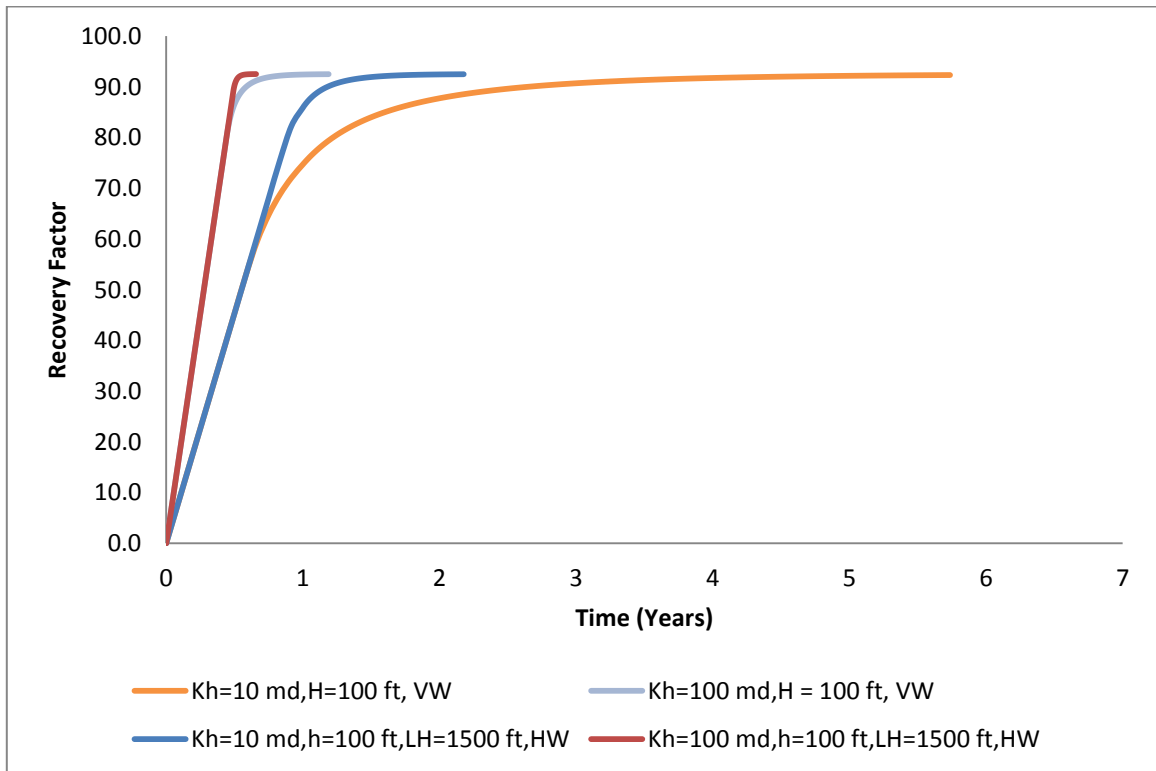


Figure 5.57: Effect of K_h on recovery factor, $A=80$ acres, SDA, $K_v/K_h=0.1$, (Cases:134-135)

5.4 Effect of Formation Thickness

Figures 5.58 through 5.87 show the effect of formation thickness on ultimate recovery factor and on abandonment time for VW, HW, and HFVW. The plots are arranged with respect to horizontal permeability and penetration ratio. Figures 5.58 through 5.72 are for the k_v/k_h ratio of 0.1 while Figures 5.73 through 5.87 are for the k_v/k_h ratio of 1.0.

Figure 5.58 shows that for low values of horizontal permeability, k_v/k_h ratio, and penetration ratio, as formation thickness increases, the recovery factor increases for all 3 well types. This figure indicates that, in such cases, HFVW should be used to develop the reservoir. As can be seen in Figures 5.58 through 5.60, HFVW perform better than the VW and HW in cases of low values of horizontal permeability, k_v/k_h ratio, and penetration ratio, regardless of the value of formation thickness.

In case of higher horizontal permeabilities 10 md, 100 md, as shown in Figures 5.61 and 5.62, the ultimate recovery factors for HW and for VW are almost identical; however, the abandonment time is slightly less for HW than for VW. Considering the values of both the ultimate recovery factor and the abandonment time, for low values of k_v/k_h ratio and penetration ratio and regardless of the value of formation thickness, Figure 5.61 indicates that the reservoir should be developed with HW when the horizontal permeability is 10 md while Figure 5.62 indicates that the reservoir should be developed with VW when the horizontal permeability is 100 md. Figures 5.61 and 5.62 show that at horizontal permeability of 10 md and higher, the formation thickness does not affect the ultimate recovery factor.

The same conclusions that are obtained above for the cases corresponding to k_v/k_h ratio of 0.1, as shown in Figures 5.58 through 5.72, are obtained for the cases corresponding to

k_v/k_h ratio of 1, as shown in Figures 5.73 through 5.87. The only difference is that the abandonment time for the HW decreases slightly for the cases corresponding to k_v/k_h ratio of 1 compared to the cases corresponding to k_v/k_h ratio of 0.1. This shows that the value of k_v/k_h ratio has somewhat negligible effect on the performance of horizontal wells in volumetric dry gas reservoirs.

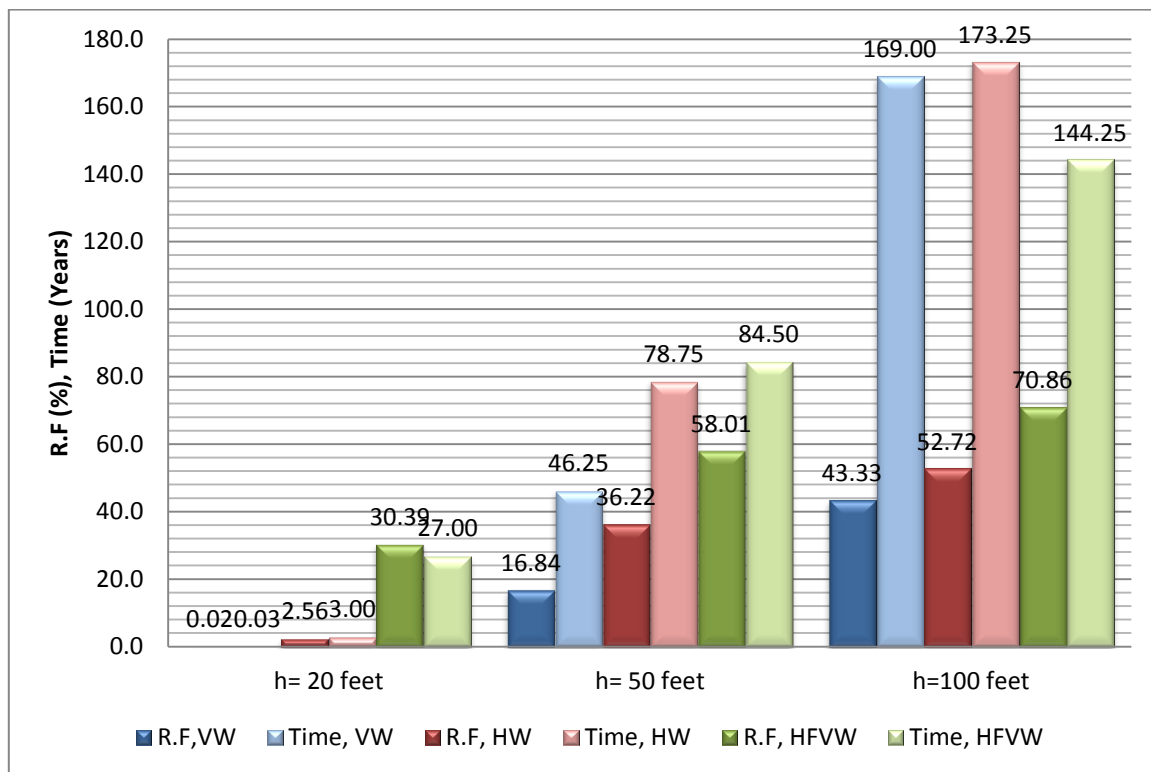


Figure 5.58: Effect of formation thickness on recovery factor, A=80 acres, $K_h=0.01$ md, SDA, P.R = 0.2, $k_v/k_h=0.1$, (Cases 1, 6, 11)

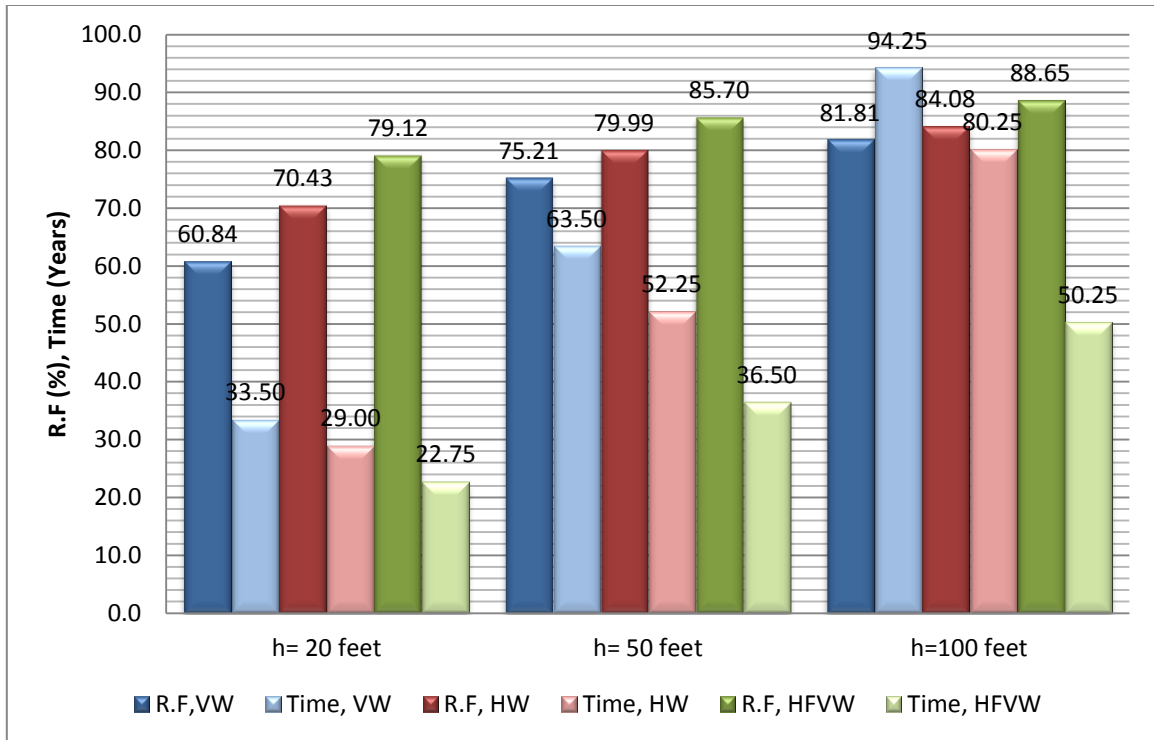


Figure 5.59: Effect of formation thickness on recovery factor, A=80 acres., $K_h = 0.1$ md, SDA, P.R = 0.2, $k_v/k_h=0.1$, (Cases 2, 7, 12)

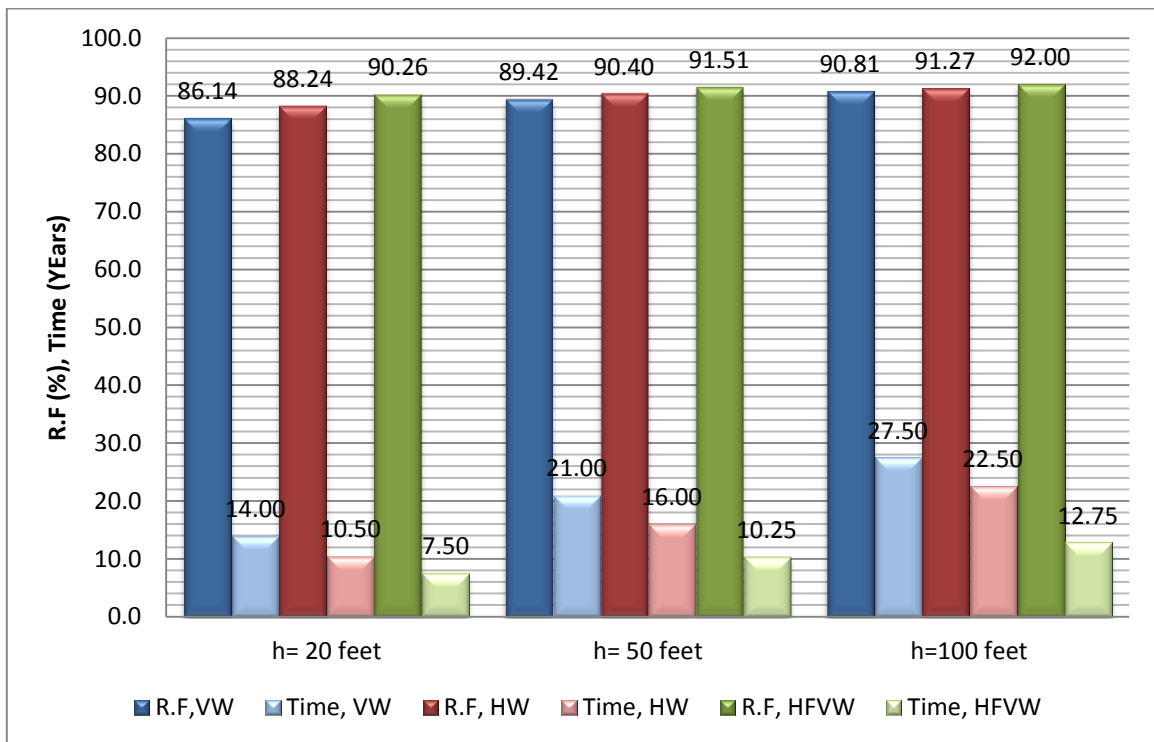


Figure 5.60: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 1$ md, SDA, P.R = 0.2, $k_v/k_h=0.1$, (Cases 3, 8, 13)

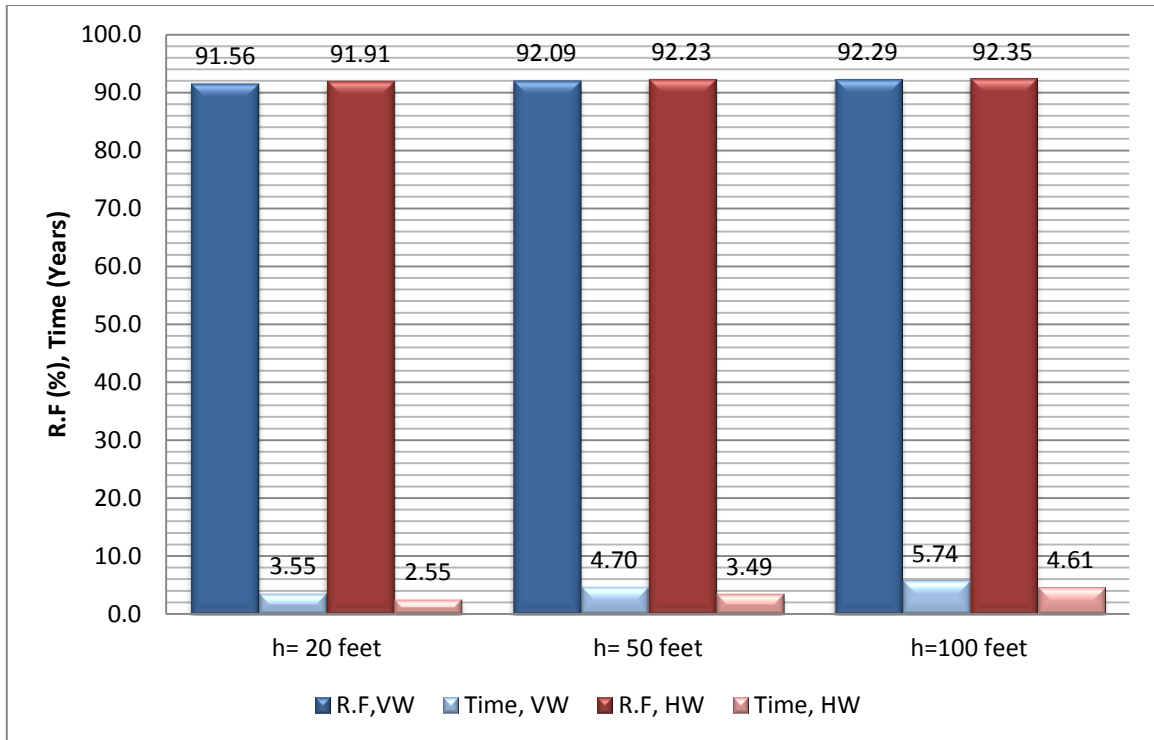


Figure 5.61: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 10$ md, SDA, P.R = 0.2, $k_v/k_h=0.1$, (Cases 4, 9, 14)

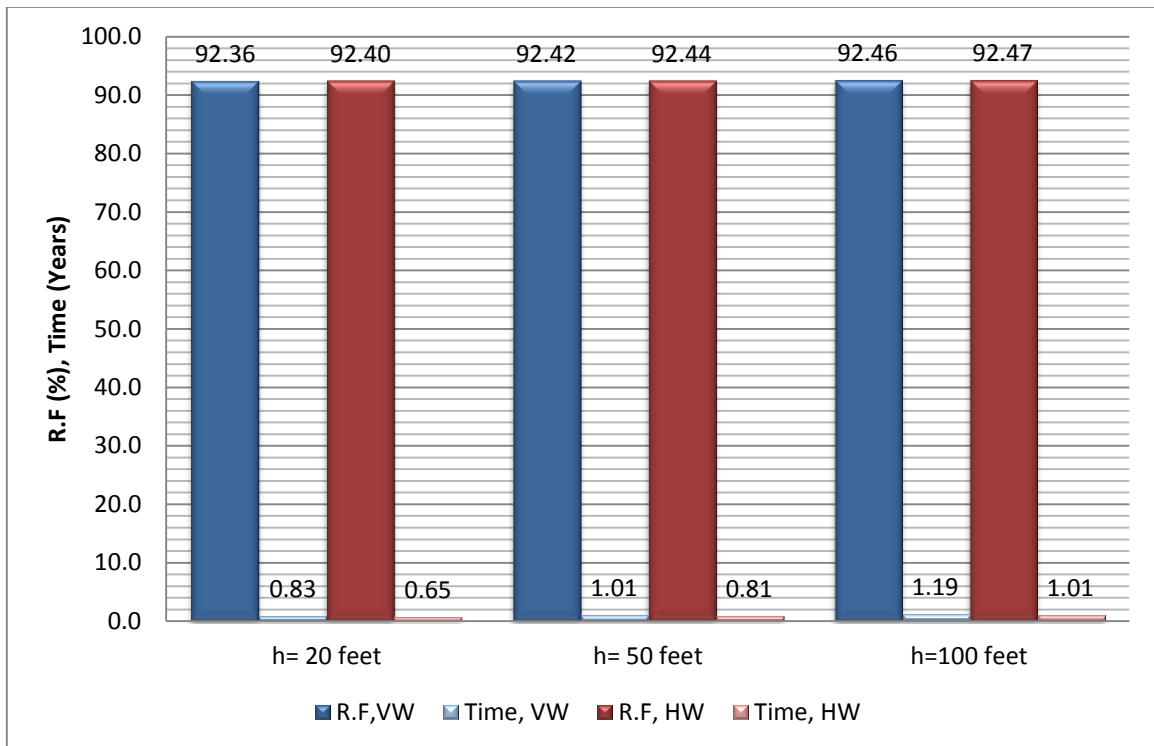


Figure 5.62: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 100$ md, SDA, P.R = 0.2, $k_v/k_h=0.1$, (Cases 5, 10, 15)

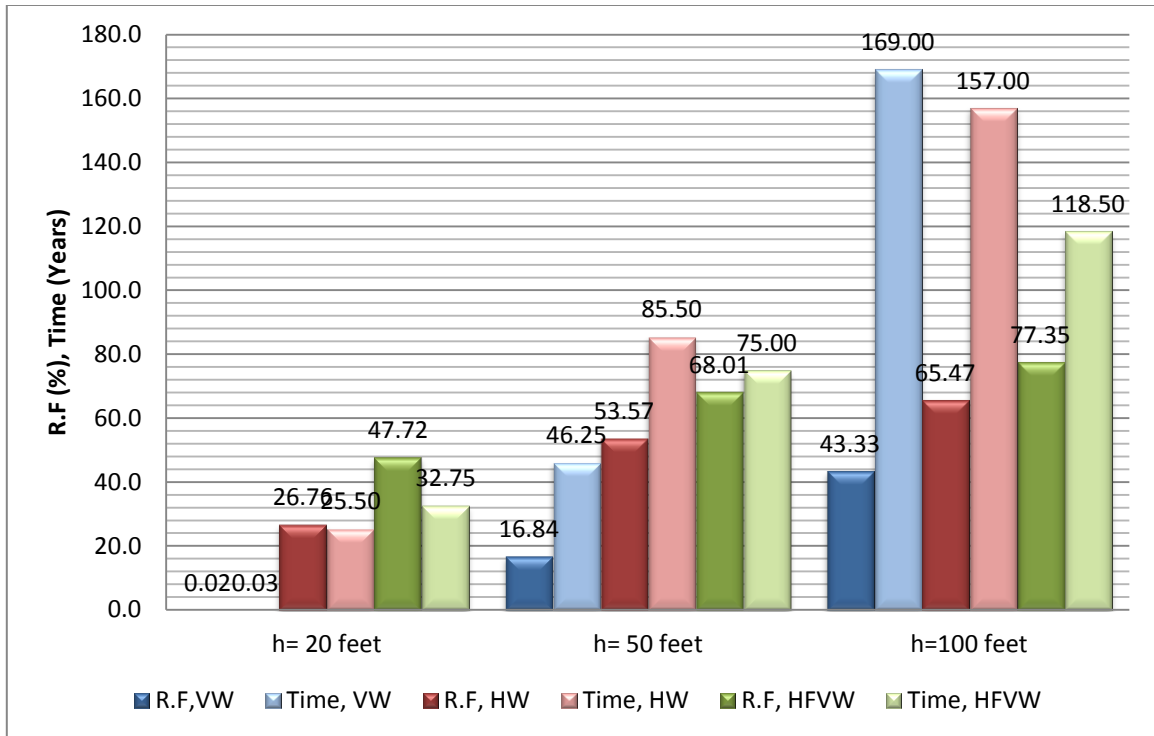


Figure 5.63: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 0.01$ md, SDA, P.R = 0.4, $k_v/k_h=0.1$, (Cases 46, 51, 56)

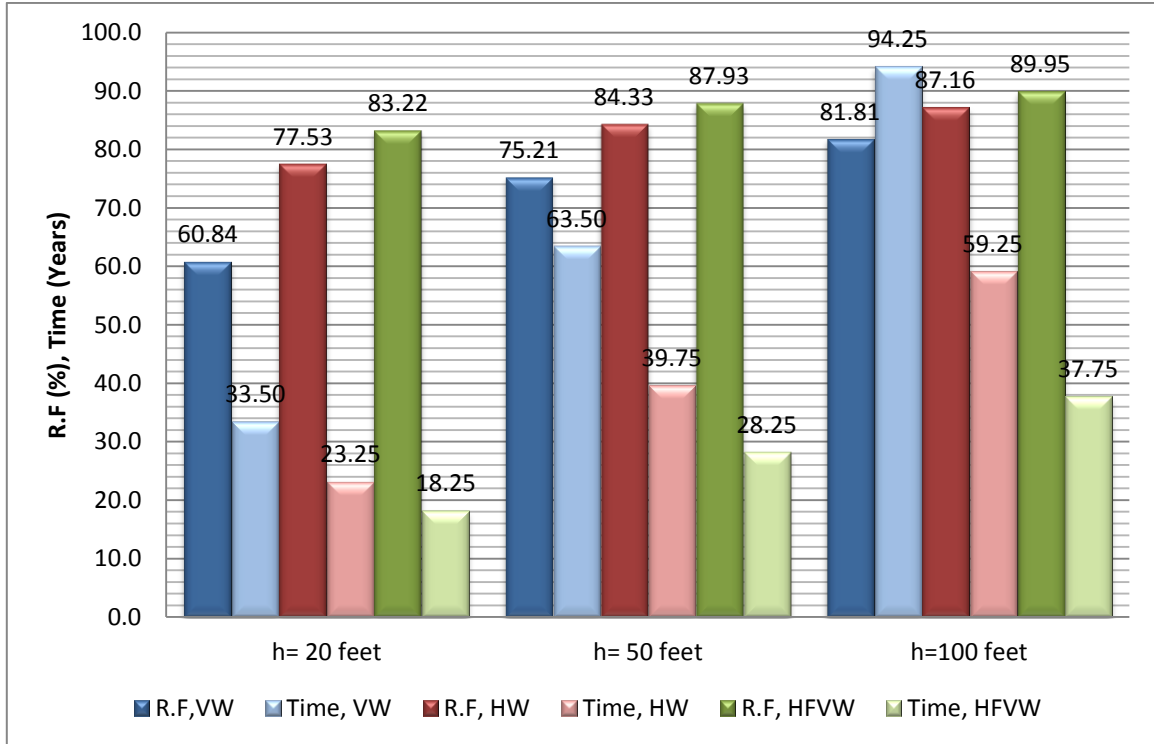


Figure 5.64: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 0.1$ md, SDA, P.R = 0.4, $k_v/k_h=0.1$, (Cases 47, 52, 57)

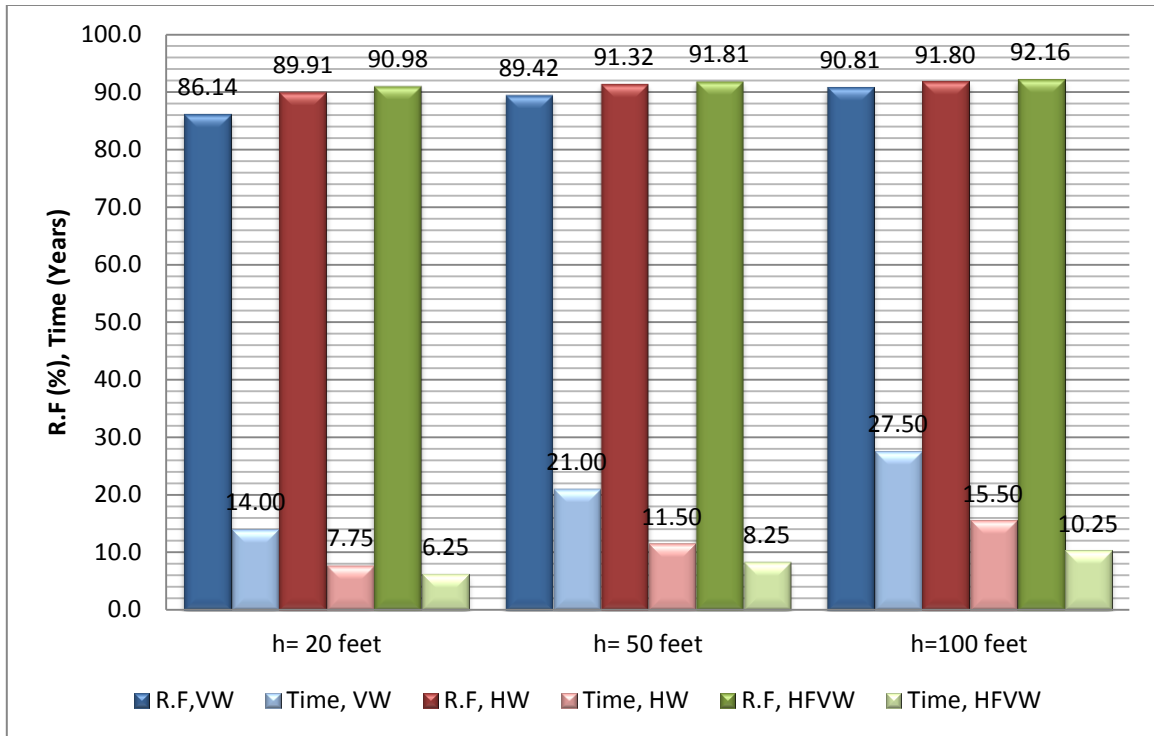


Figure 5.65: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 1$ md, SDA, P.R = 0.4, $k_v/k_h=0.1$, (Cases 48, 53, 58)

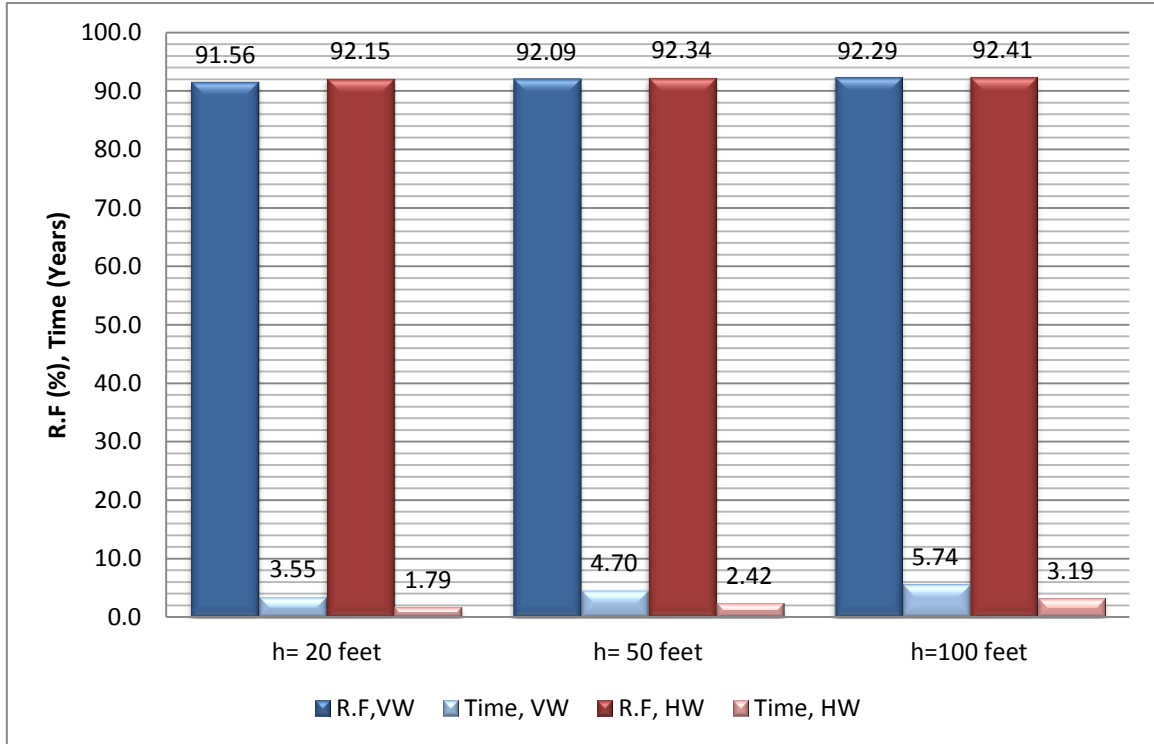


Figure 5.66: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 10$ md, SDA, P.R = 0.4, $k_v/k_h=0.1$, (Cases 49, 54, 59)

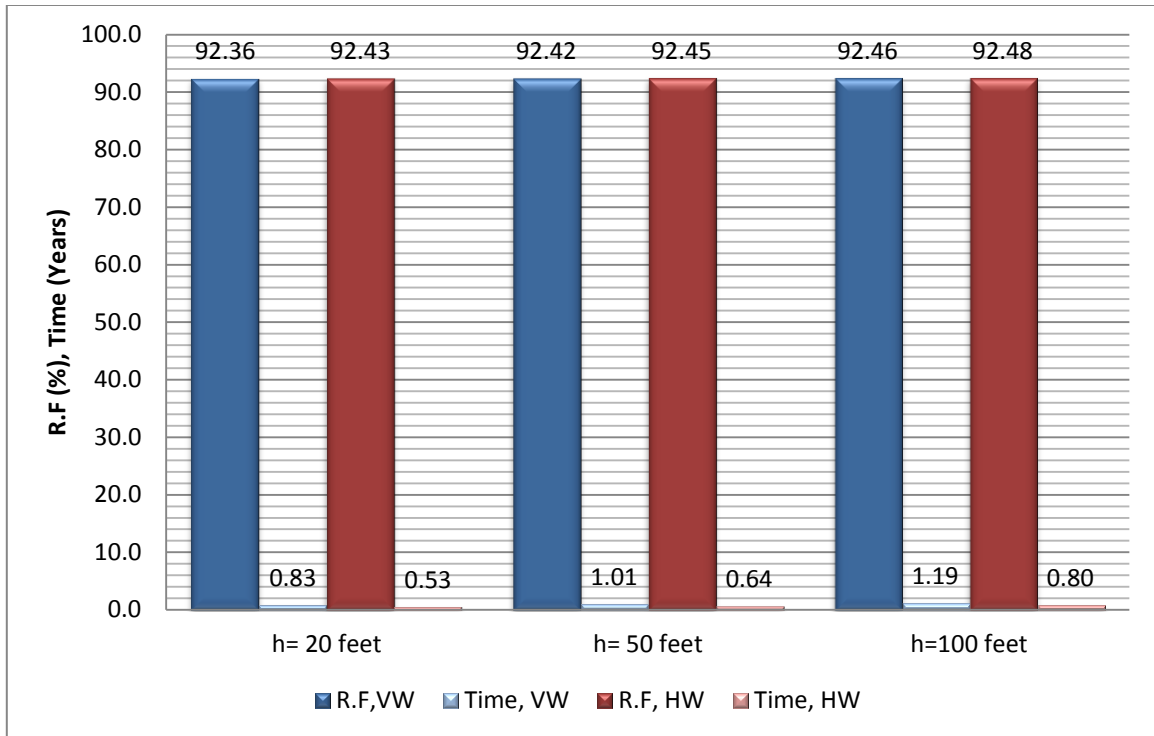


Figure 5.67: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h = 100$ md, SDA, $P.R = 0.4$, $k_v/k_h=0.1$, (Cases 50, 55, 60)

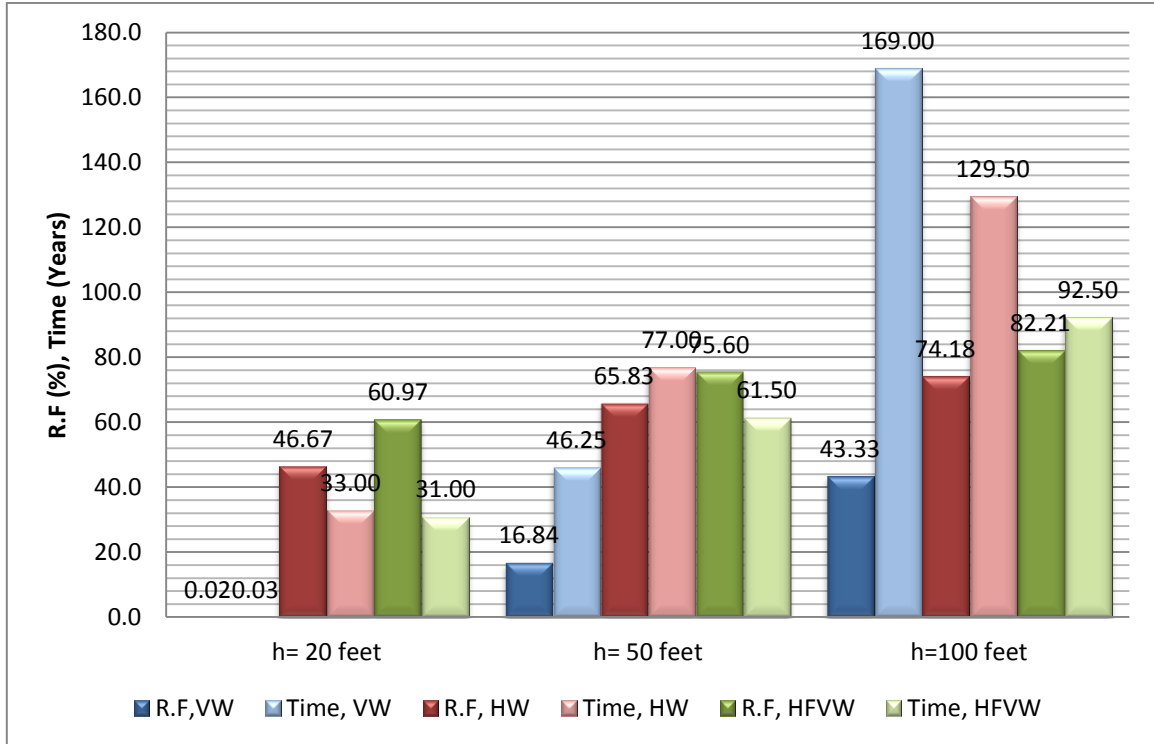


Figure 5.68: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h = 0.01$ md, SDA, $P.R = 0.8$, $k_v/k_h=0.1$, (Cases 91, 95, 101)

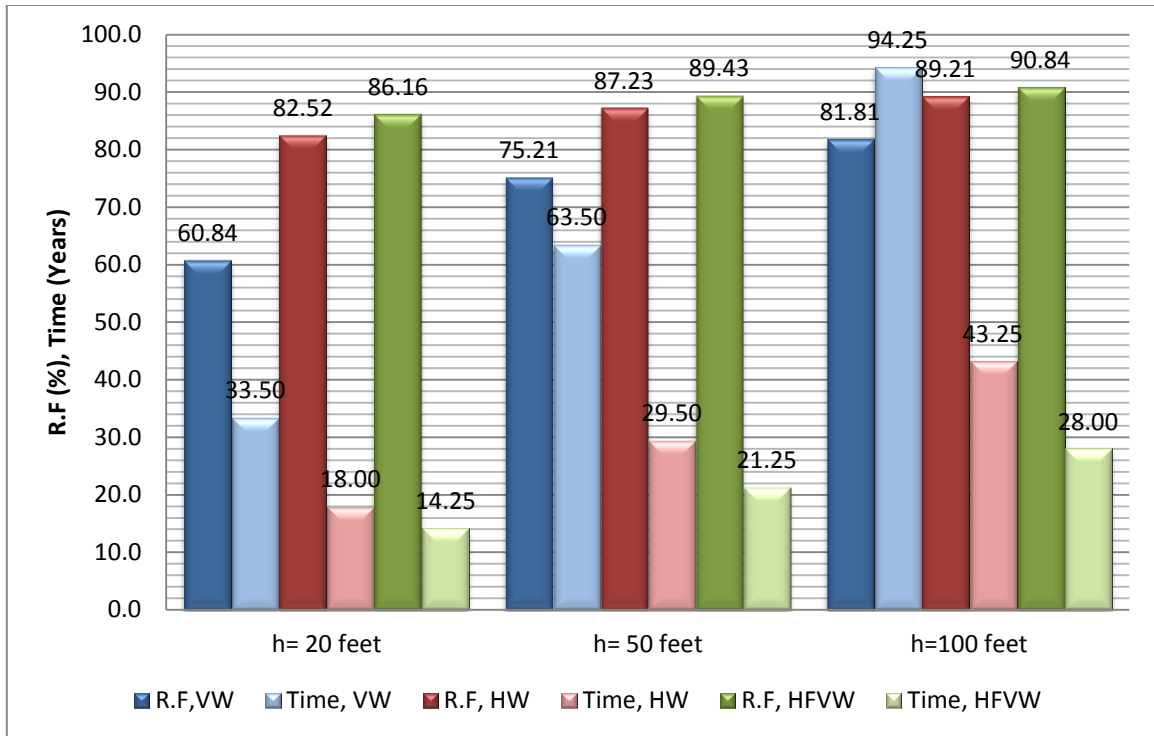


Figure 5.69: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 0.1$ md, SDA, P.R = 0.8, $k_v/k_h=0.1$, (Cases 92, 96, 102)

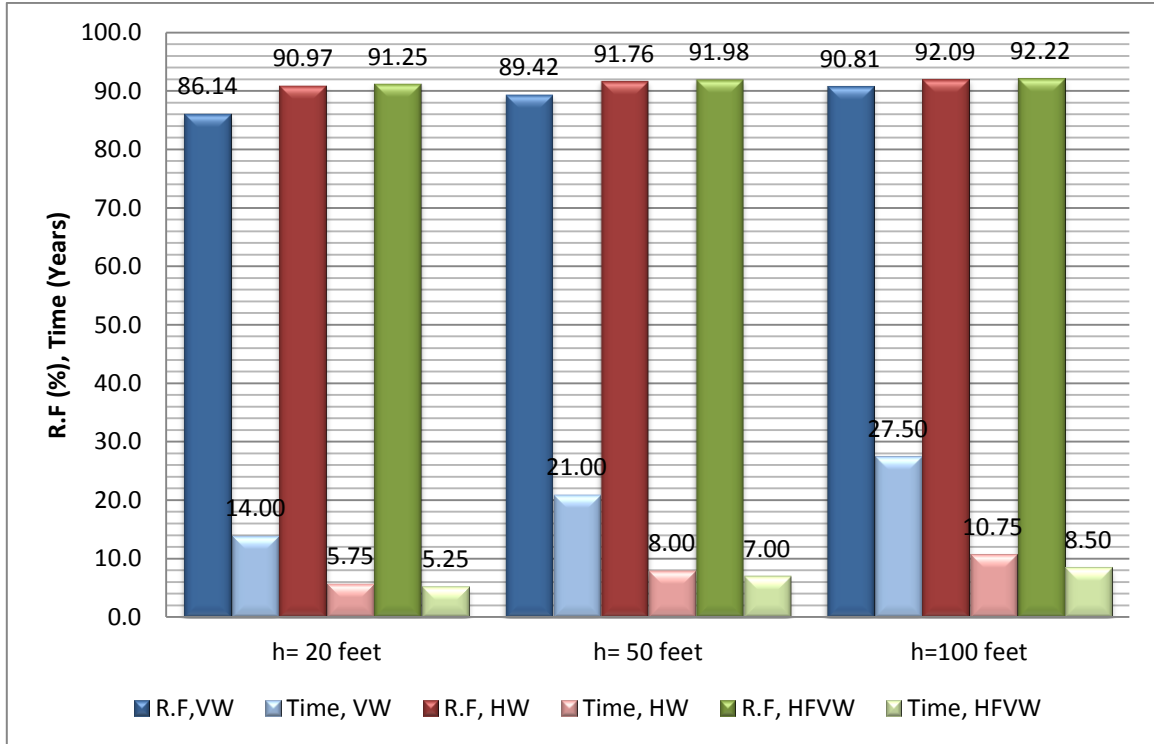


Figure 5.70: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 1$ md, SDA, P.R = 0.8, $k_v/k_h=0.1$, (Cases 93, 98, 103)

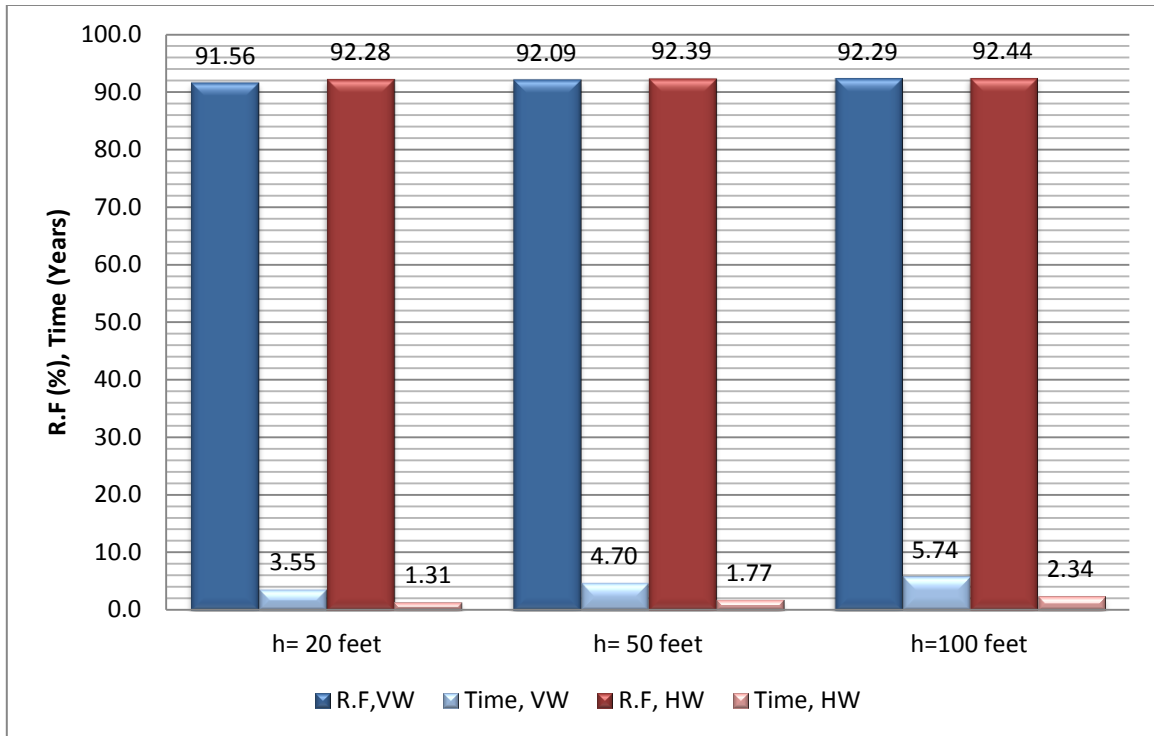


Figure 5.71: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h = 10$ md, SDA, $P.R = 0.8$, $k_v/k_h=0.1$, (Cases 94, 99, 104)

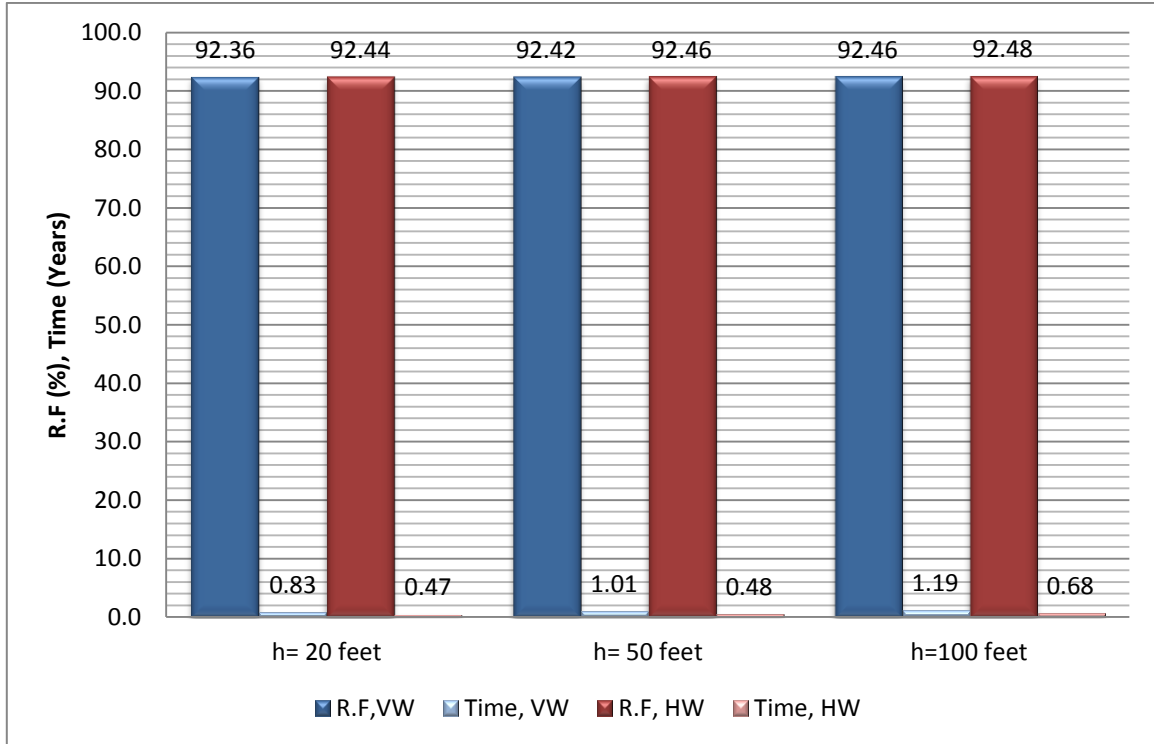


Figure 5.72: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h = 100$ md, SDA, $P.R = 0.8$, $k_v/k_h=0.1$, (Cases 95, 100, 105)

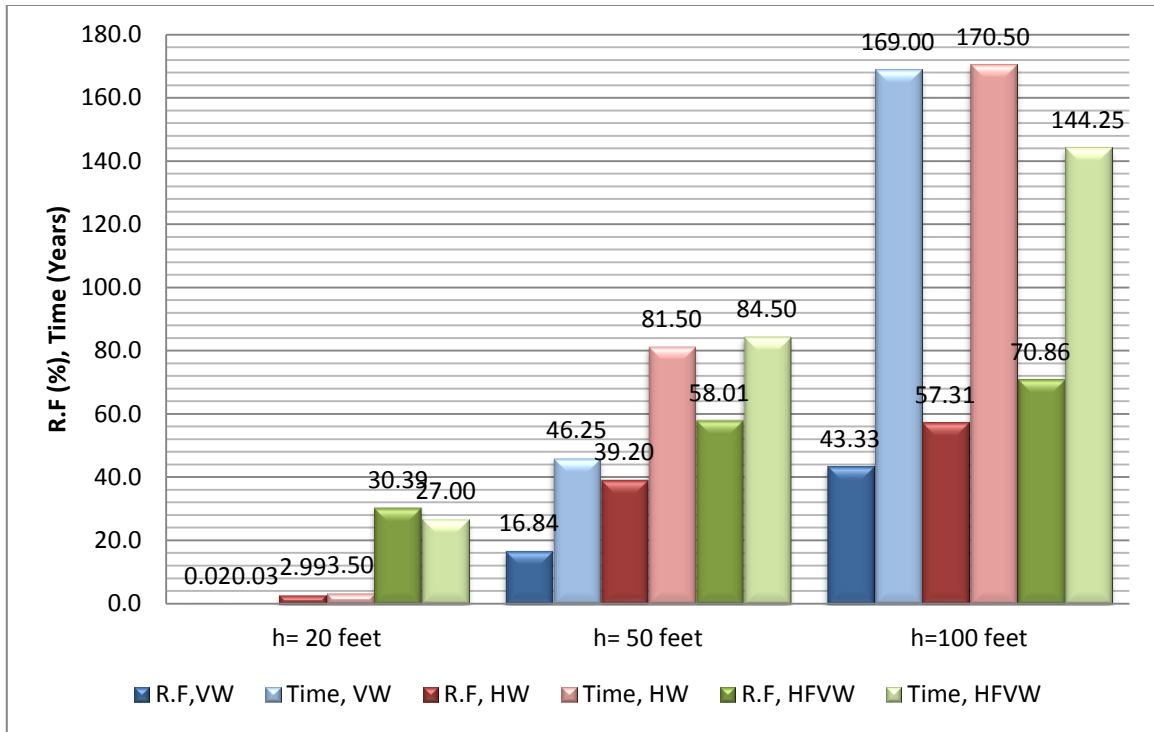


Figure 5.73: Effect of formation thickness on recovery factor, A=80 acres, $K_h=0.01$ md, SDA, P.R = 0.2, $k_v/k_h=1$, (Cases 31, 36, 41)

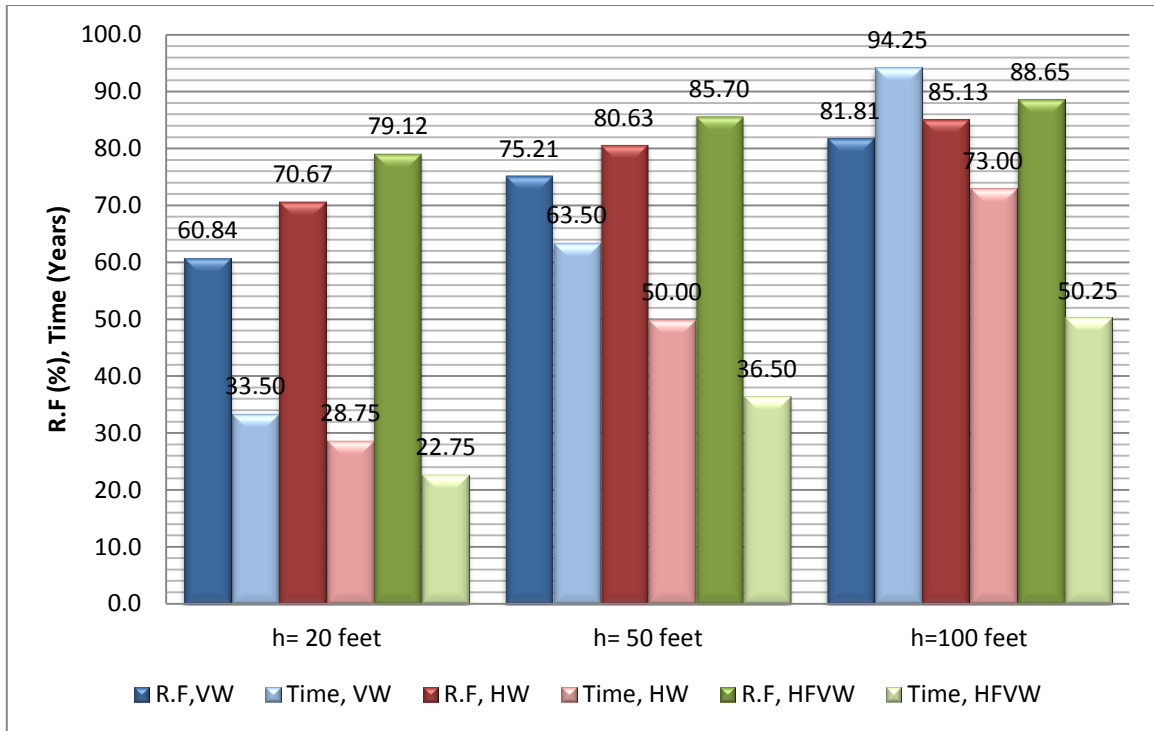


Figure 5.74: Effect of formation thickness on recovery factor, A=80 acres, $K_h=0.1$ md, SDA, P.R = 0.2, $k_v/k_h=1$, (Cases 32, 37, 42)

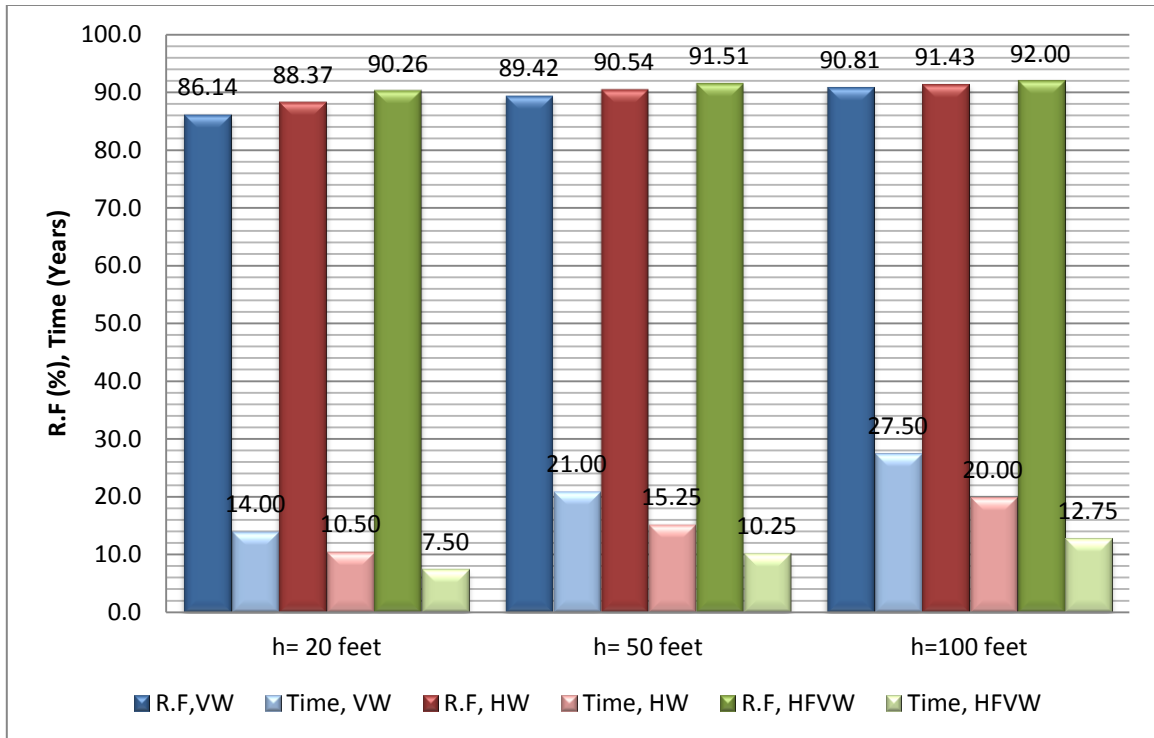


Figure 5.75: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 1$ md, SDA, P.R = 0.2, $k_v/k_h=1$, (Cases 33, 38, 43)

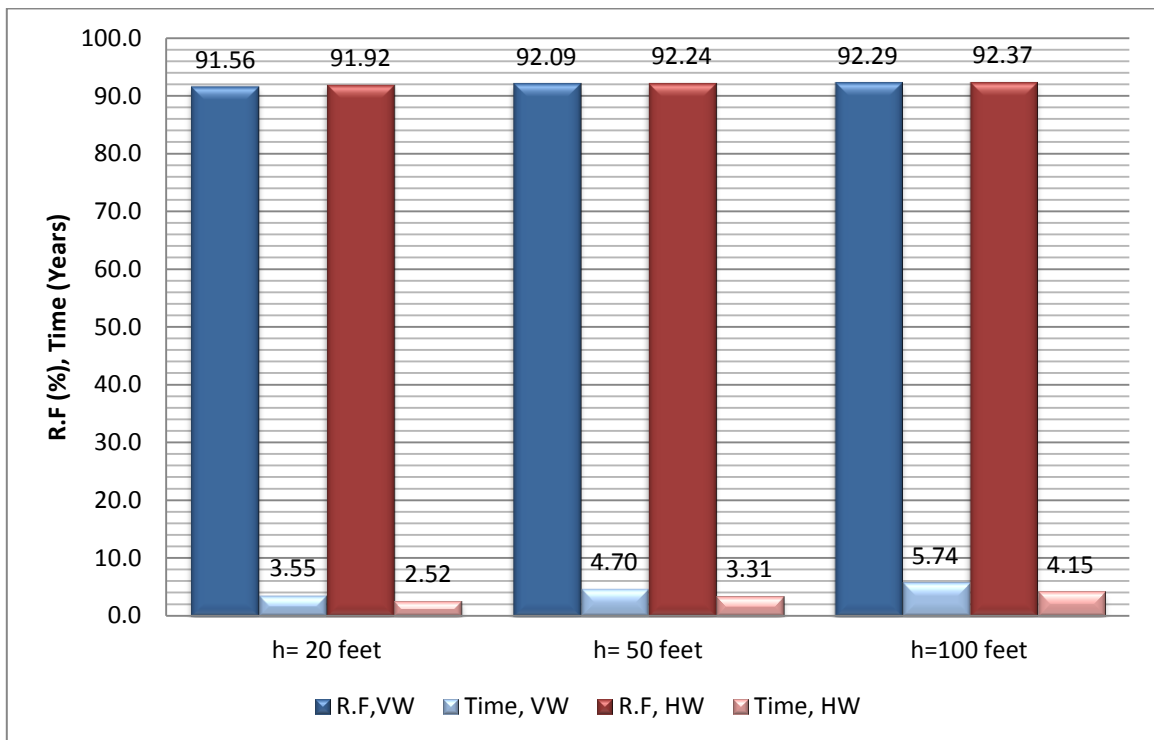


Figure 5.76: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 10$ md, SDA, P.R = 0.2, $k_v/k_h=1$, (Cases 34, 39, 44)

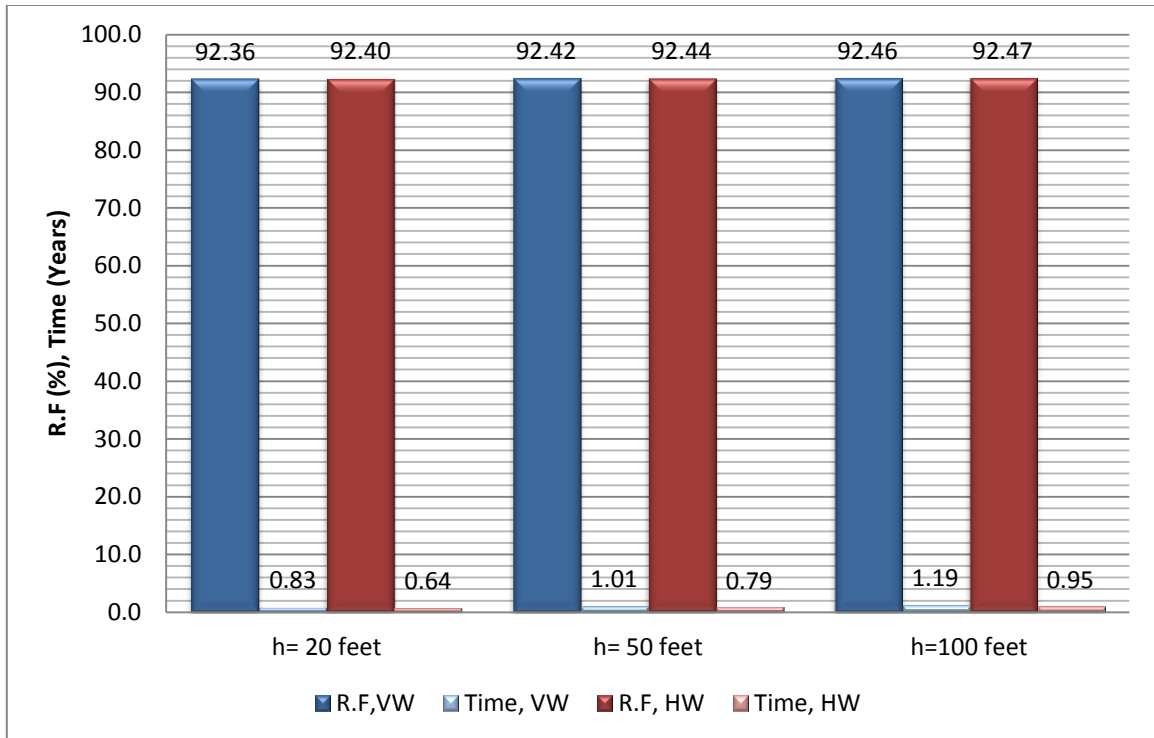


Figure 5.77: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h = 100$ md, SDA, $P.R = 0.2$, $k_v/k_h=1$, (Cases 35, 40, 45)

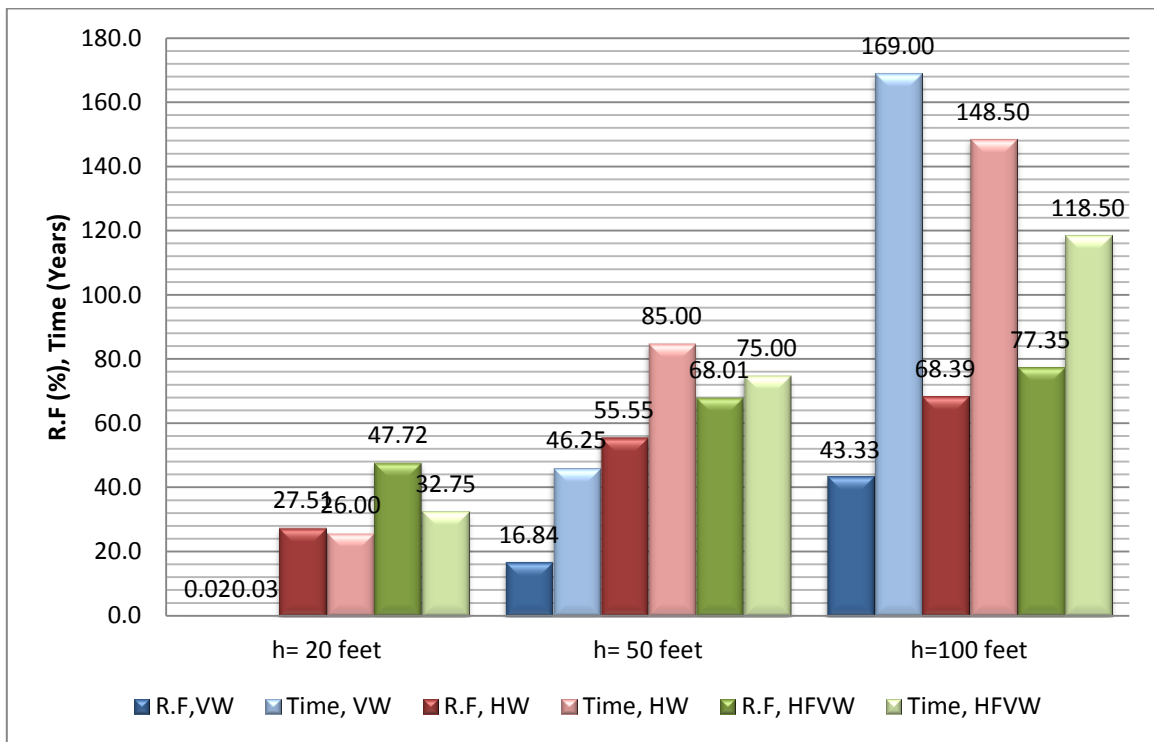


Figure 5.78: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h = 0.01$ md, SDA, $P.R = 0.4$, $k_v/k_h=1$, (Cases 76, 81, 86)

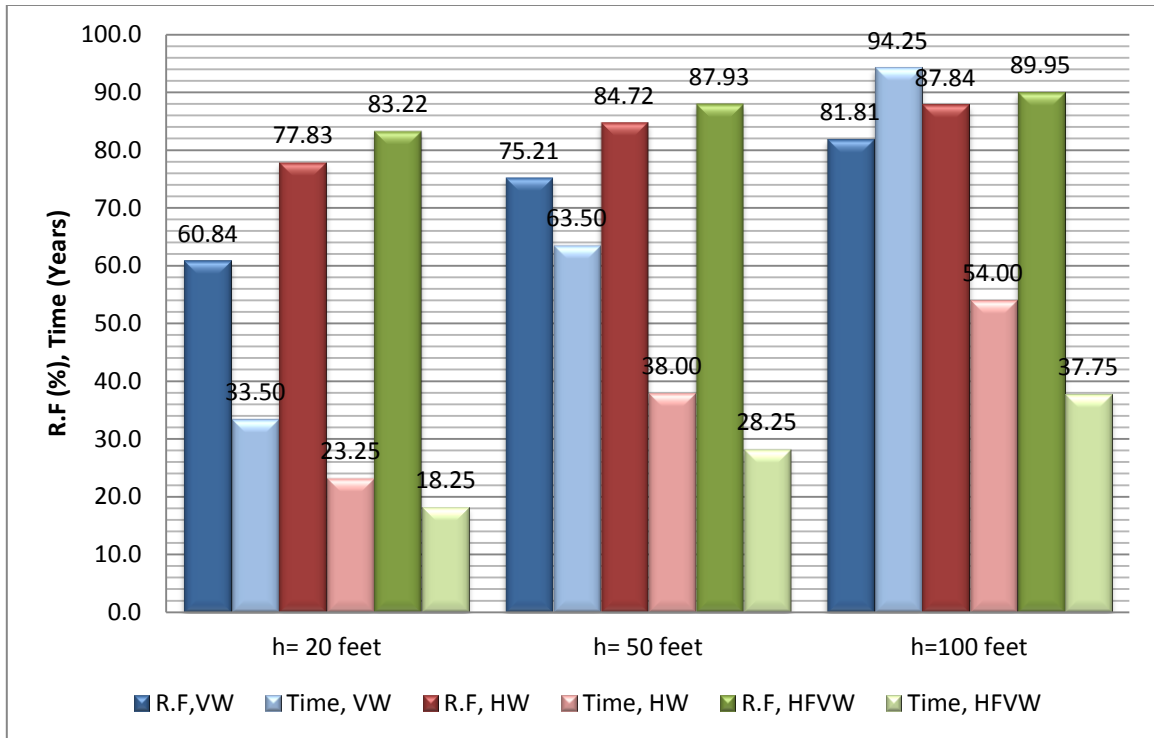


Figure 5.79: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h=0.1$ md, SDA, $P.R=0.4$, $k_v/k_h=1$, (Cases 77, 82, 87)

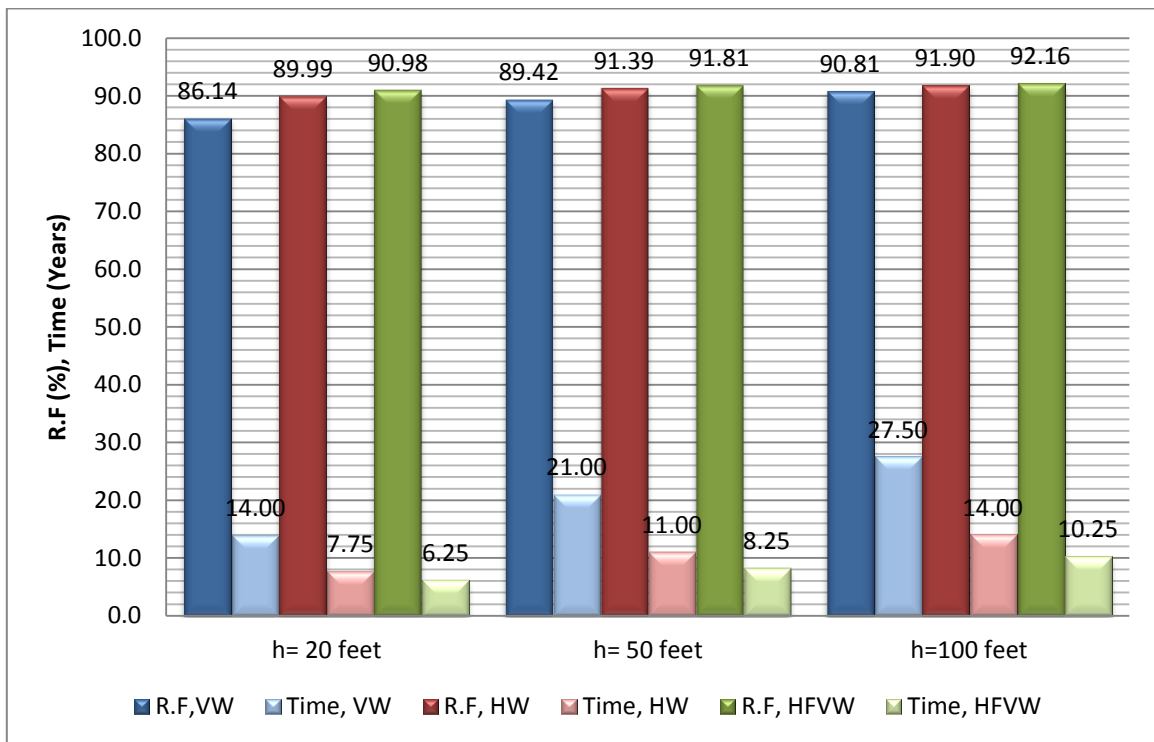


Figure 5.80: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h=1$ md, SDA, $P.R=0.4$, $k_v/k_h=1$, (Cases 78, 83, 88)

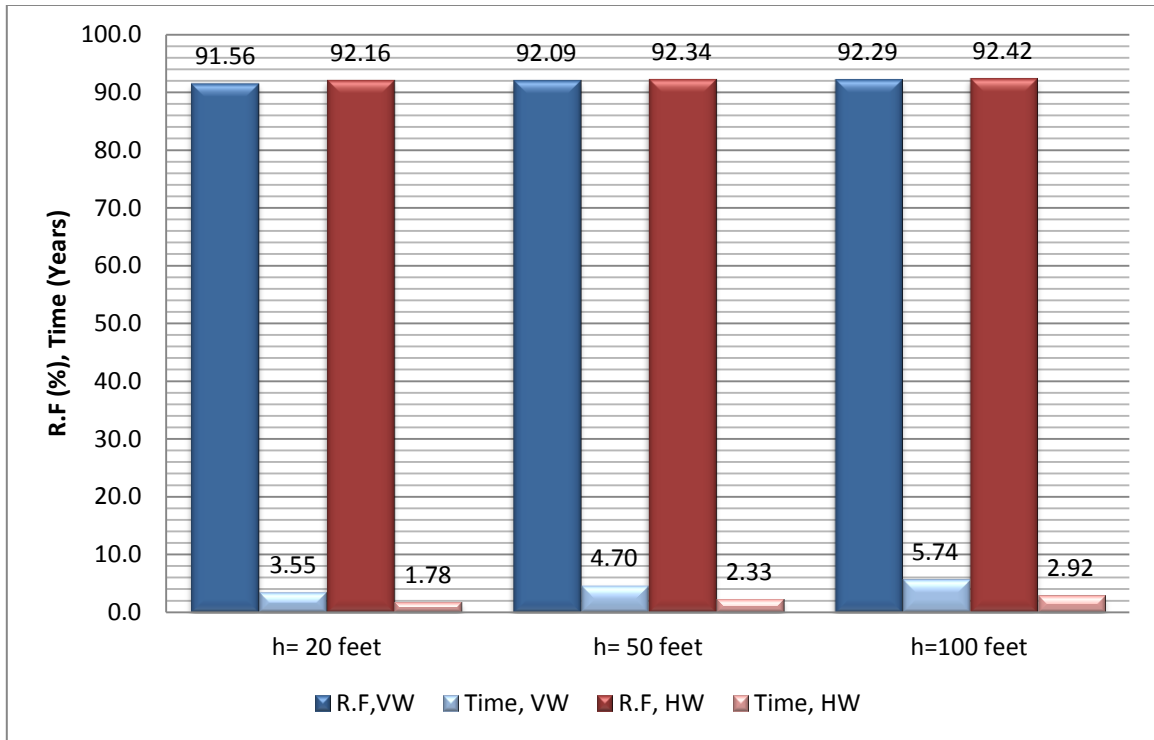


Figure 5.81: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 10$ md, SDA, P.R = 0.4, $k_v/k_h=1$, (Cases 79, 84, 89)

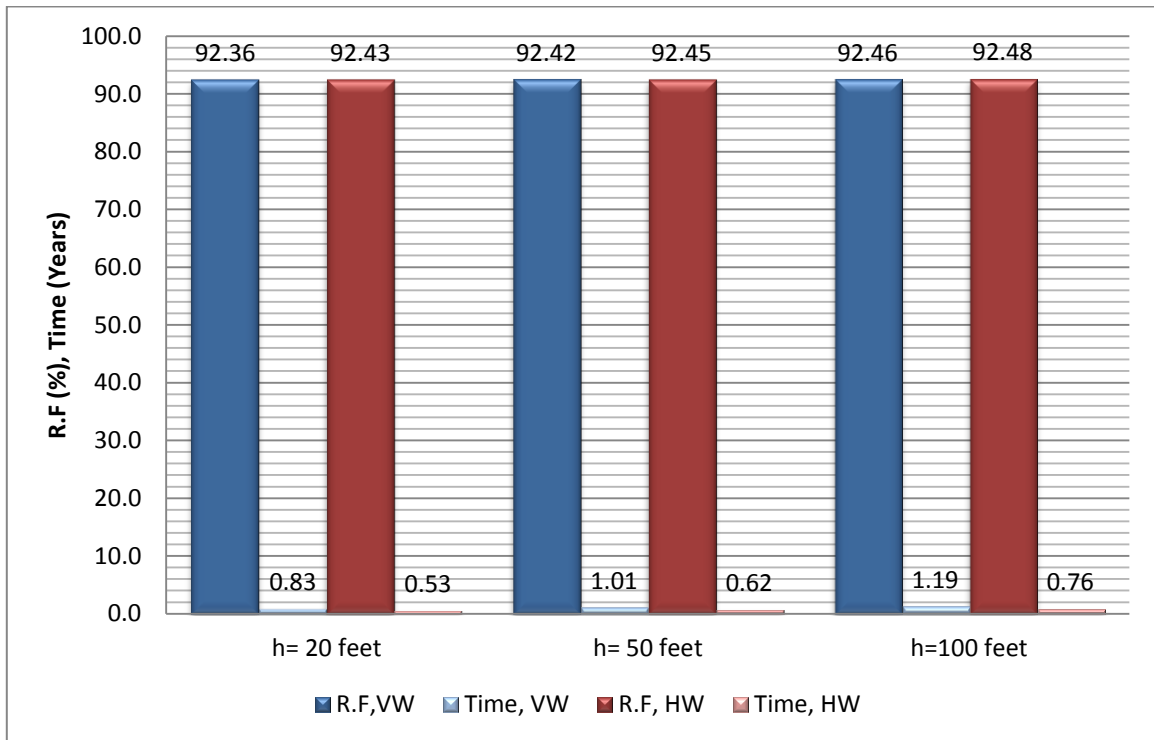


Figure 5.82: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 100$ md, SDA, P.R = 0.4, $k_v/k_h=1$, (Cases 80, 85, 90)

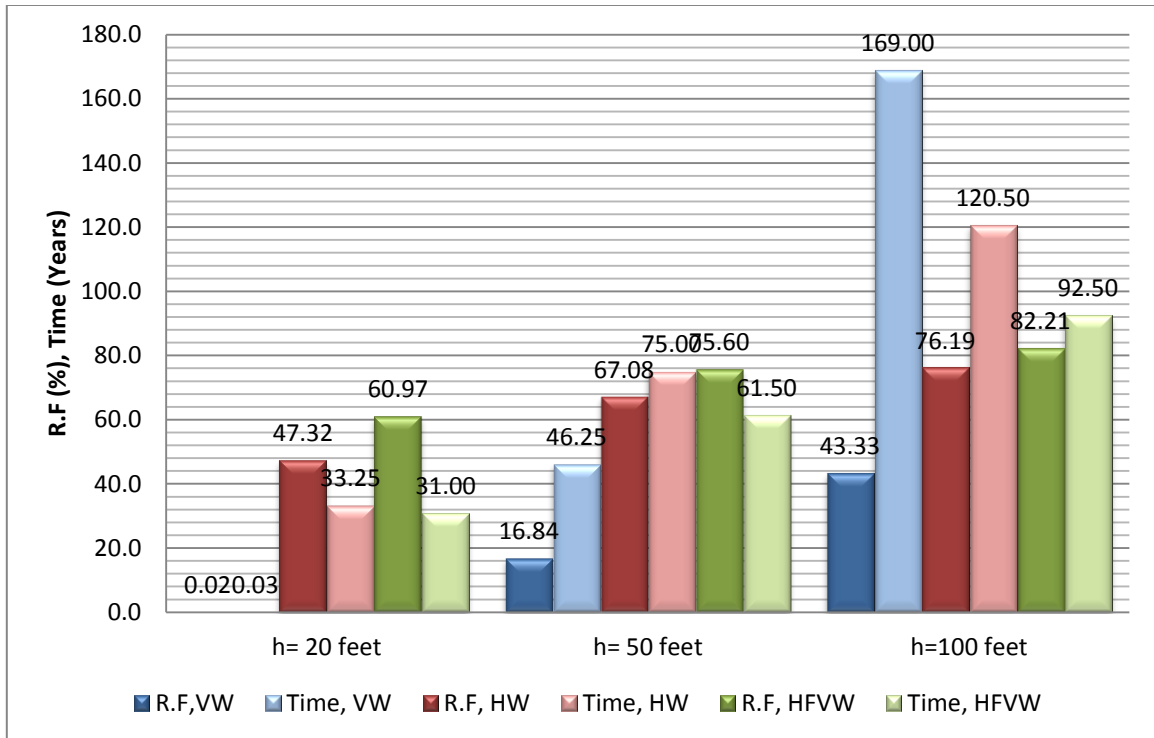


Figure 5.83: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 0.01$ md, SDA, P.R = 0.8, $k_v/k_h=1$, (Cases 121, 125, 131)

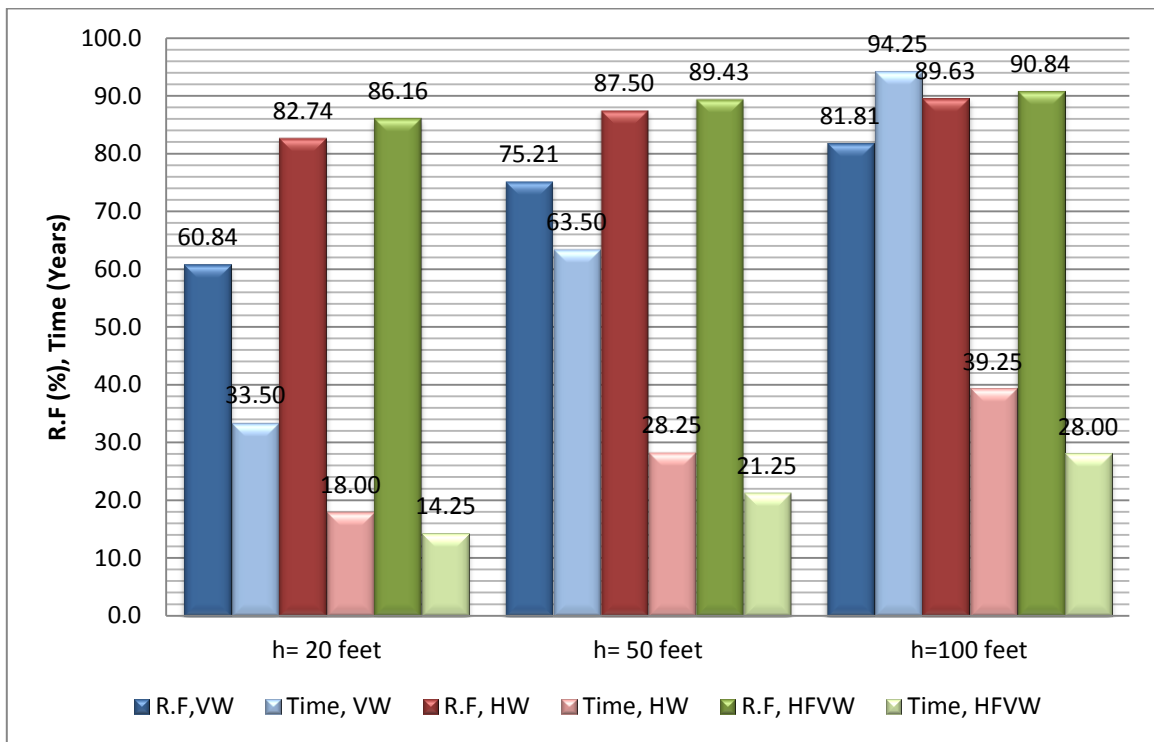


Figure 5.84: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 0.1$ md, SDA, P.R = 0.8, $k_v/k_h=1$, (Cases 122, 126, 132)

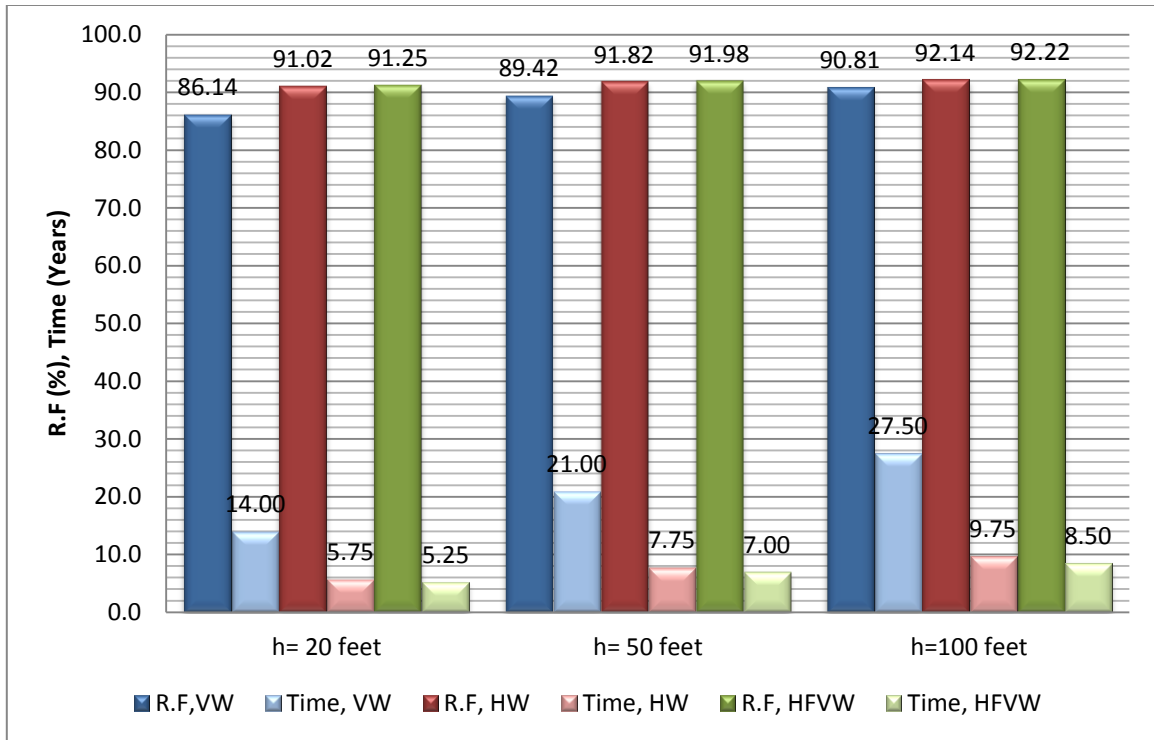


Figure 5.85: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 1$ md, SDA, P.R = 0.8, $k_v/k_h=1$, (Cases 123, 128, 133)

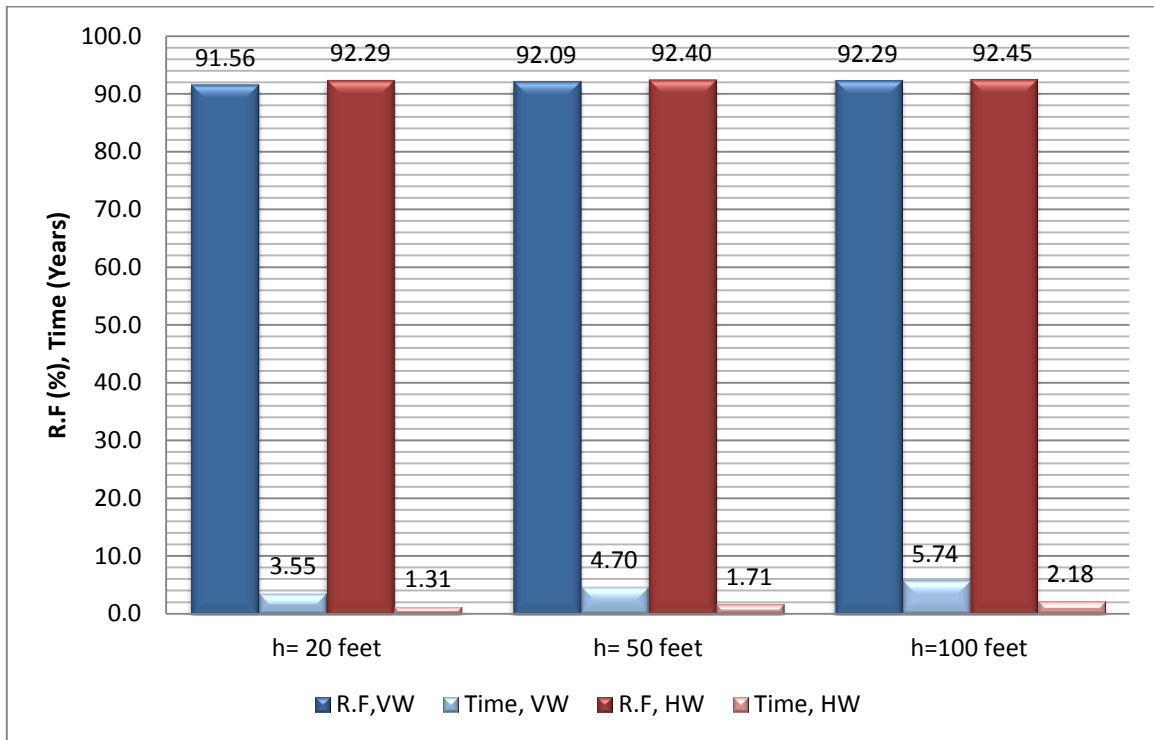


Figure 5.86: Effect of formation thickness on recovery factor, A=80 acres, $K_h = 10$ md, SDA, P.R = 0.8, $k_v/k_h=1$, (Cases 124, 129, 134)

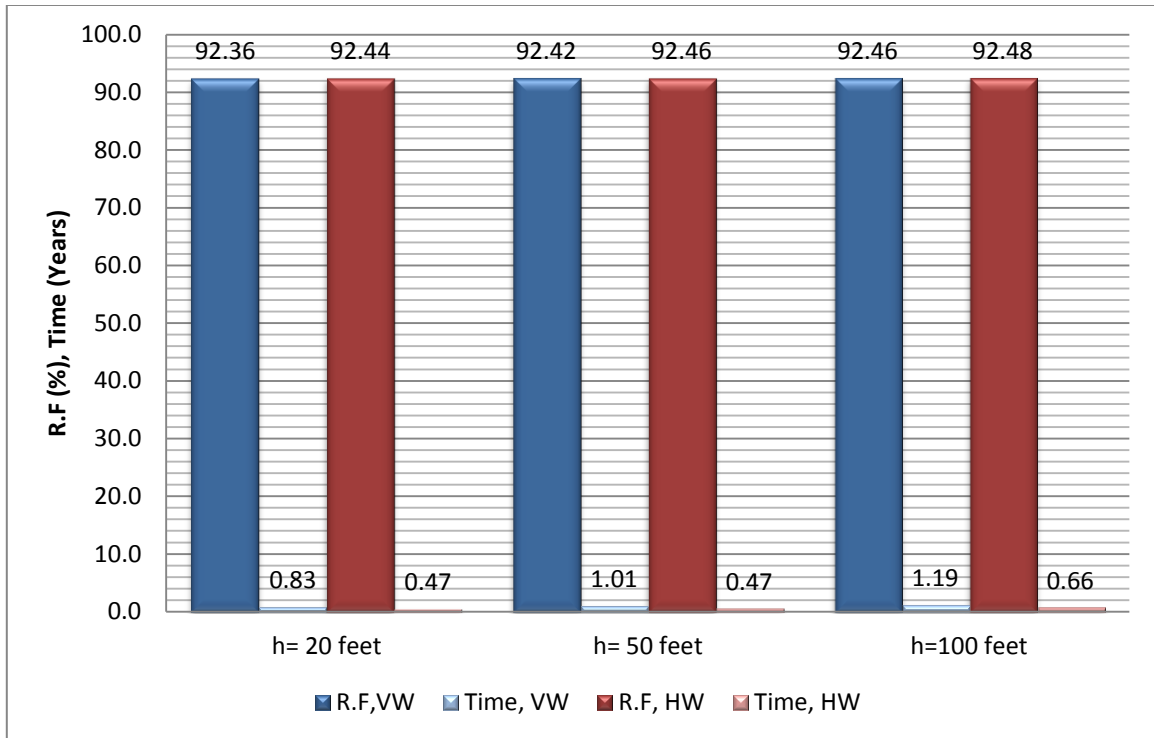


Figure 5.87: Effect of formation thickness on recovery factor, $A=80$ acres, $K_h=100$ md, SDA, $P.R=0.8$, $k_v/k_h=1$, (Cases 125, 130, 135)

5.5 Effect of Vertical to Horizontal Permeability (K_v/K_h) Ratio

Figures 5.88 through 5.107 show the effect of vertical to horizontal permeability (K_v/K_h) ratio on the performance of horizontal wells in an 80-acre square drainage area. Simulation runs were made for vertical to horizontal permeability ratios of 1, 0.5, and 0.1. Results are shown for horizontal permeabilities of 0.01 md, 0.1 md, 1 md, 10 md and 100 md and formation thicknesses of 20 feet and 100 feet.

As shown in these figures, in the case of thin reservoirs (20 feet), the value of vertical to horizontal permeability (K_v/K_h) ratio has no effect on the ultimate recovery factor and on the abandonment time, regardless of the value of the horizontal well penetration ratio and regardless of the value of horizontal permeability (except in the case of horizontal

permeability of 0.01 md and K_v/K_h ratio of 1, the horizontal well shows slightly higher ultimate recovery factor as compare to a K_v/K_h value of 0.1).

In the case of thick formations, at low horizontal permeabilities (0.01 md and 0.1 md), the value of k_v/k_h ratio slightly affects the ultimate recovery factor whereas at higher horizontal permeabilities (1 md, 10 md and 100 md), the ultimate recovery factor remains the same and the value of k_v/k_h ratio slightly affects the time to reach abandonment conditions.

In general, one can state that the value of k_v/k_h ratio has somewhat negligible effect on the performance of horizontal wells in volumetric dry gas reservoirs.

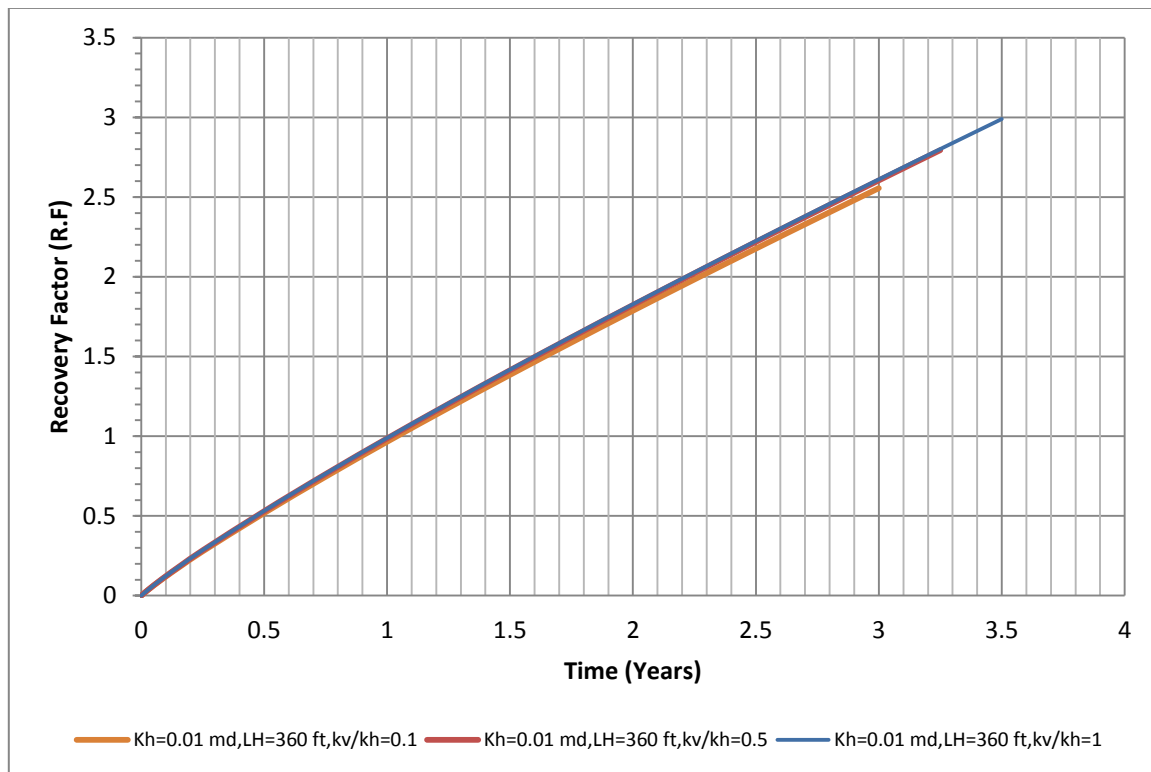


Figure 5.88: Effect of K_v/K_h on R.F, A=80 acres, h=20 feet, SDA, (Cases 1, 16, 31)

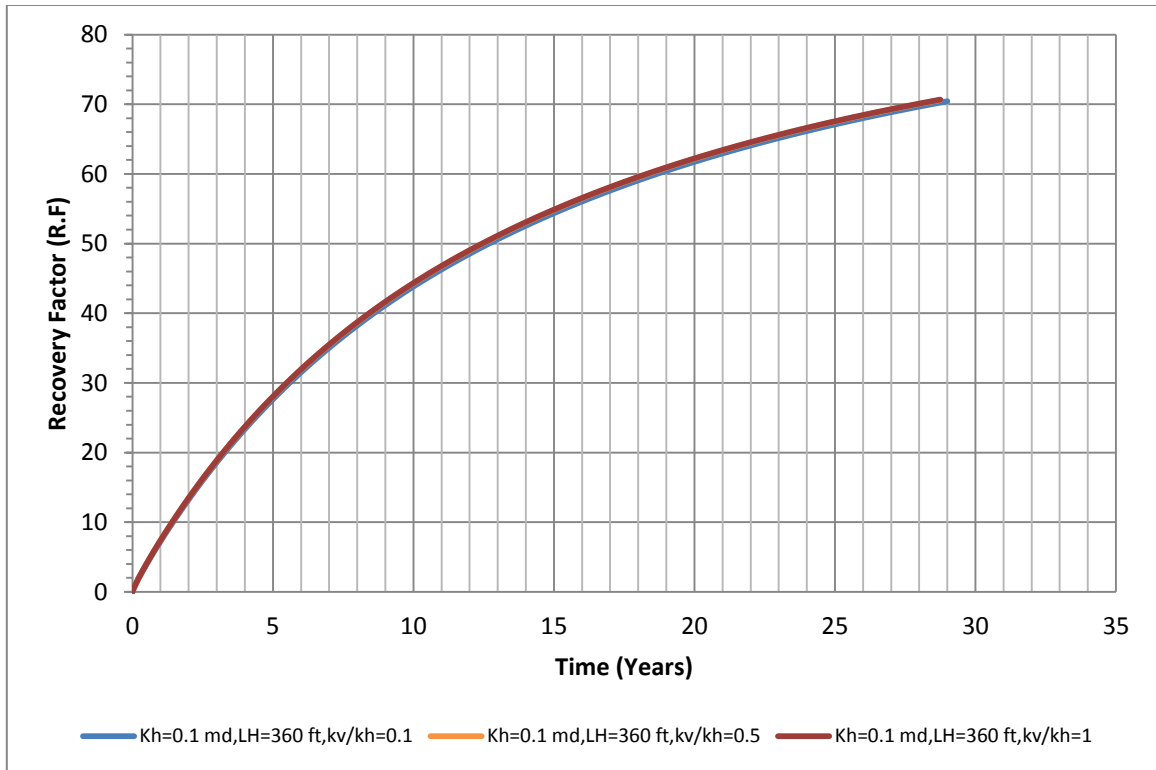


Figure 5.89: Effect of K_v/K_h on R.F, $A=80$ acres, $h=20$ feet, SDA, (Cases 2, 17, 32)

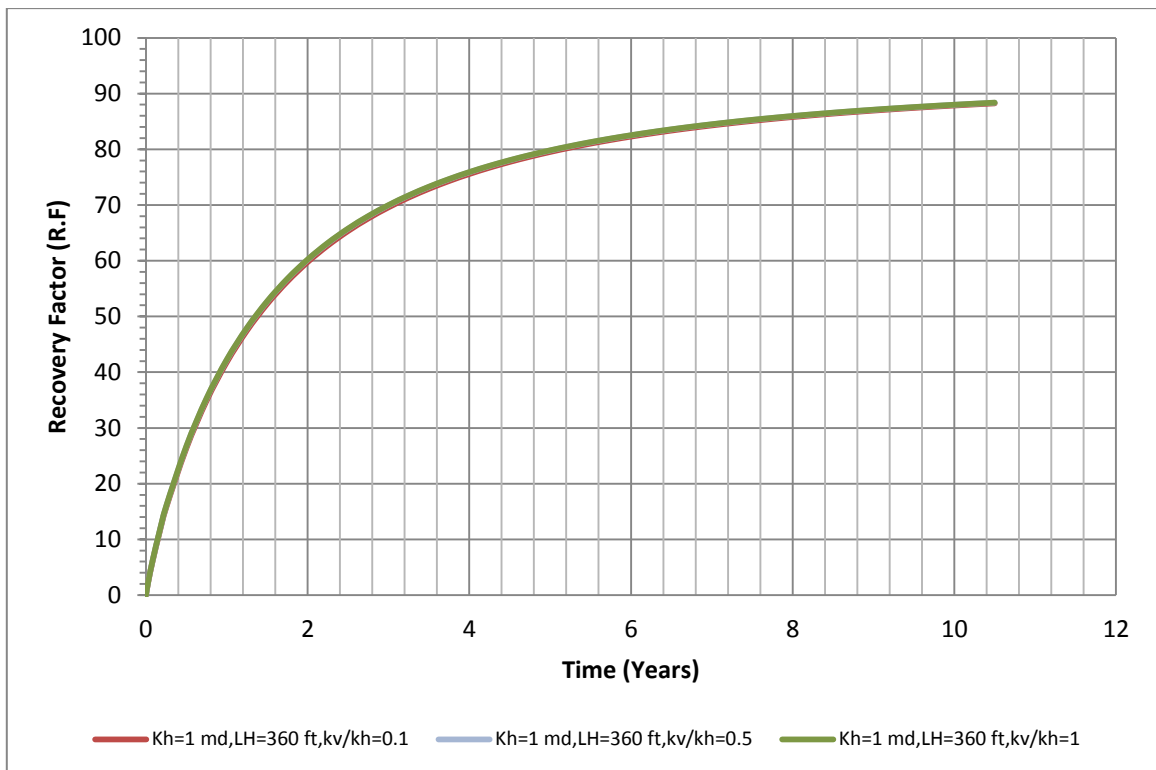


Figure 5.90: Effect of K_v/K_h on R.F, $A=80$ acres, $h=20$ feet, SDA, (Cases 3, 18, 33)

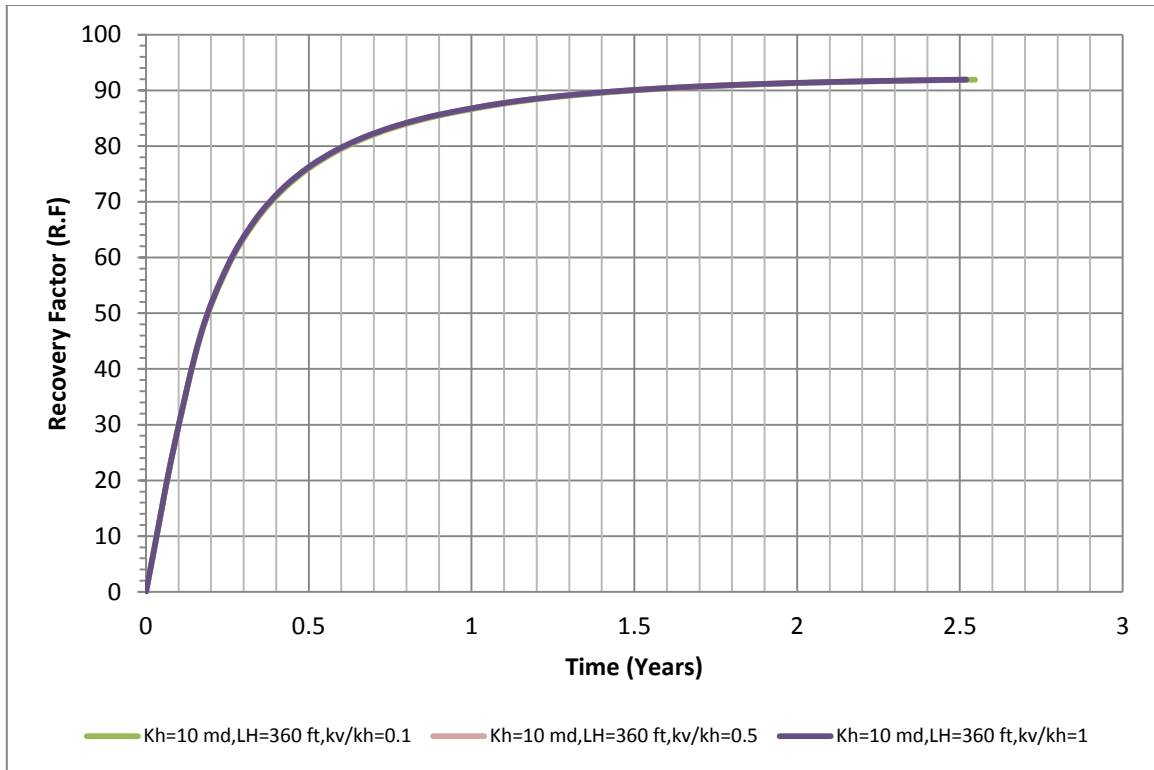


Figure 5.91: Effect of K_v/K_h on R.F, A=80 acres, h=20 feet, SDA, (Cases 4, 19, 34)

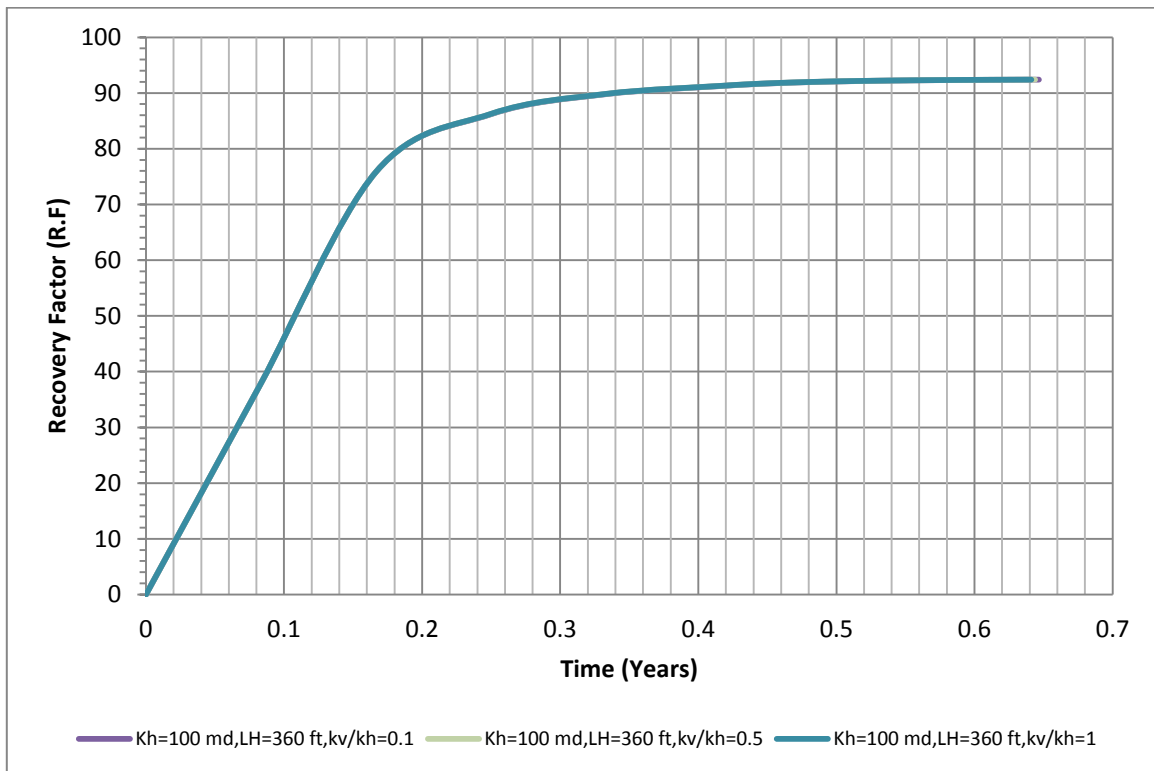


Figure 5.92: Effect of K_v/K_h on R.F, A=80 acres, h=20 feet, SDA, (Cases 5, 20, 35)

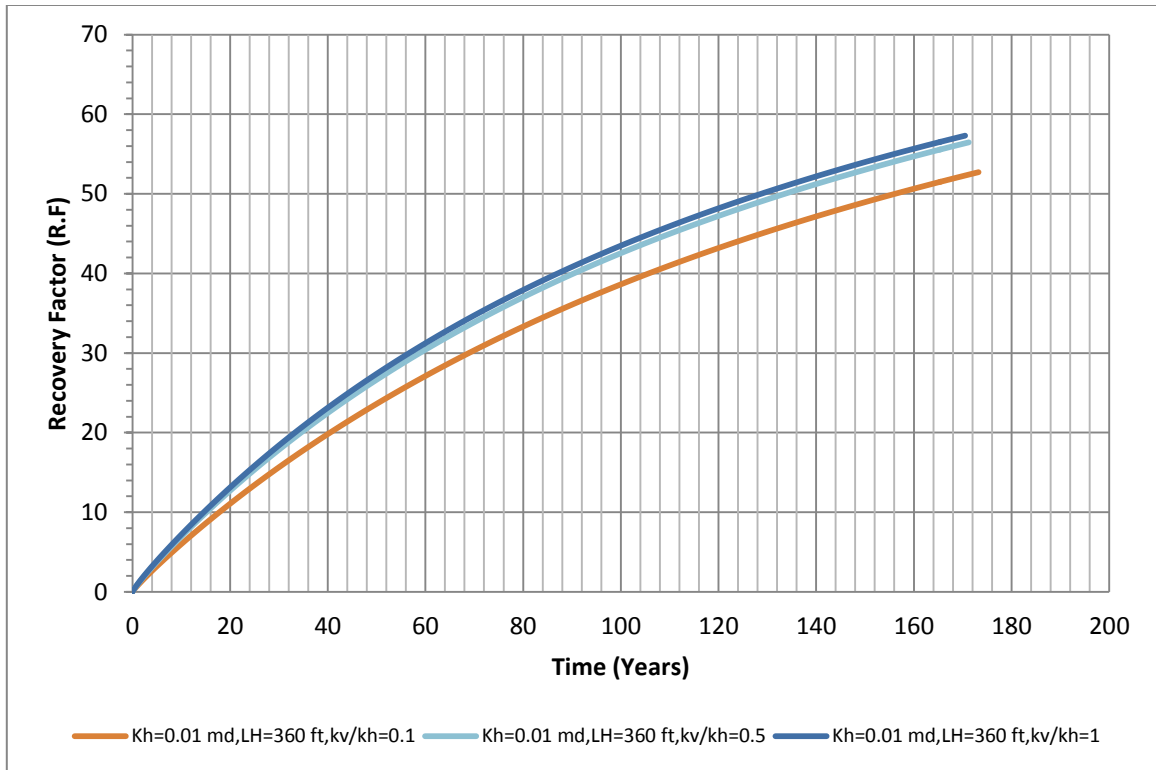


Figure 5.93: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 11, 26, 41)

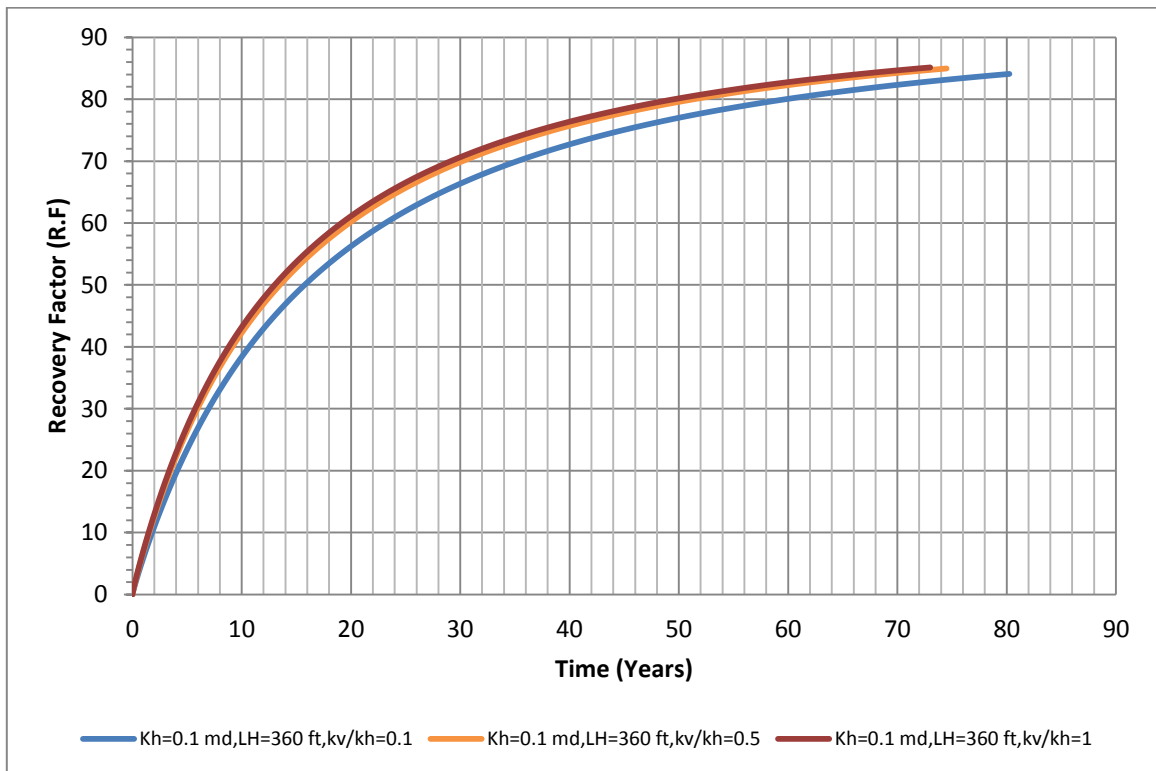


Figure 5.94: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 12, 27, 42)

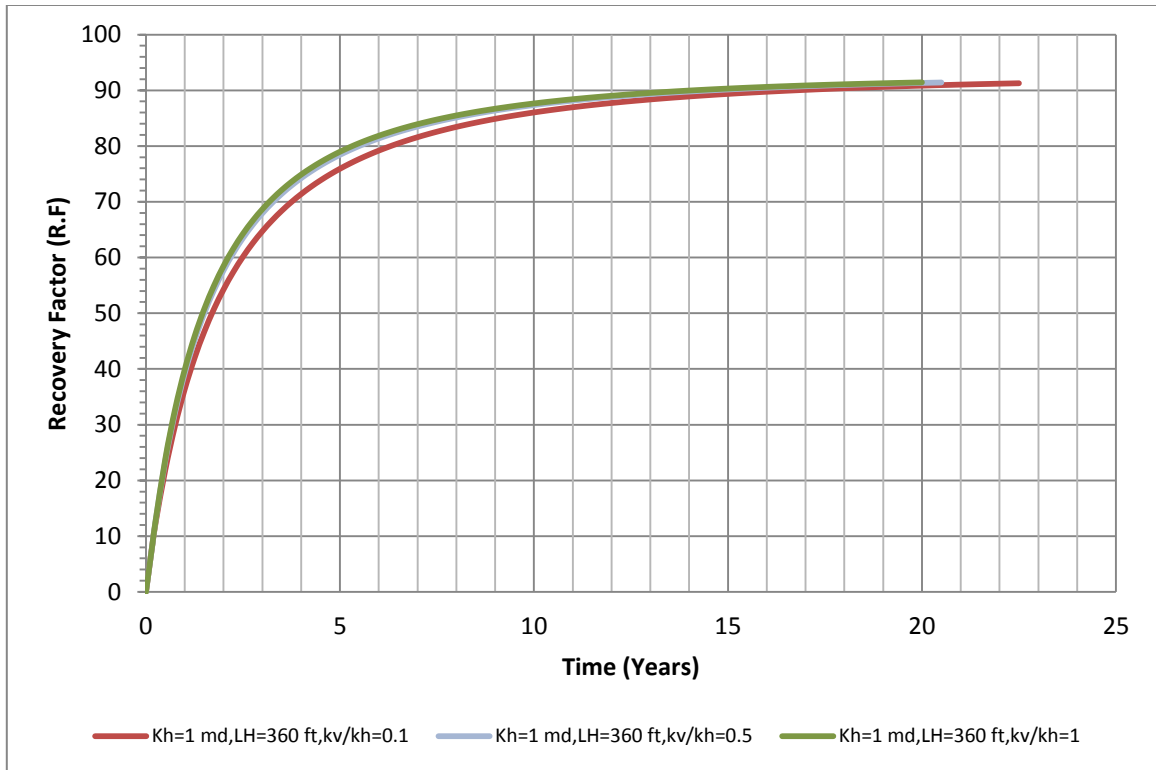


Figure 5.95: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 13, 28, 43)

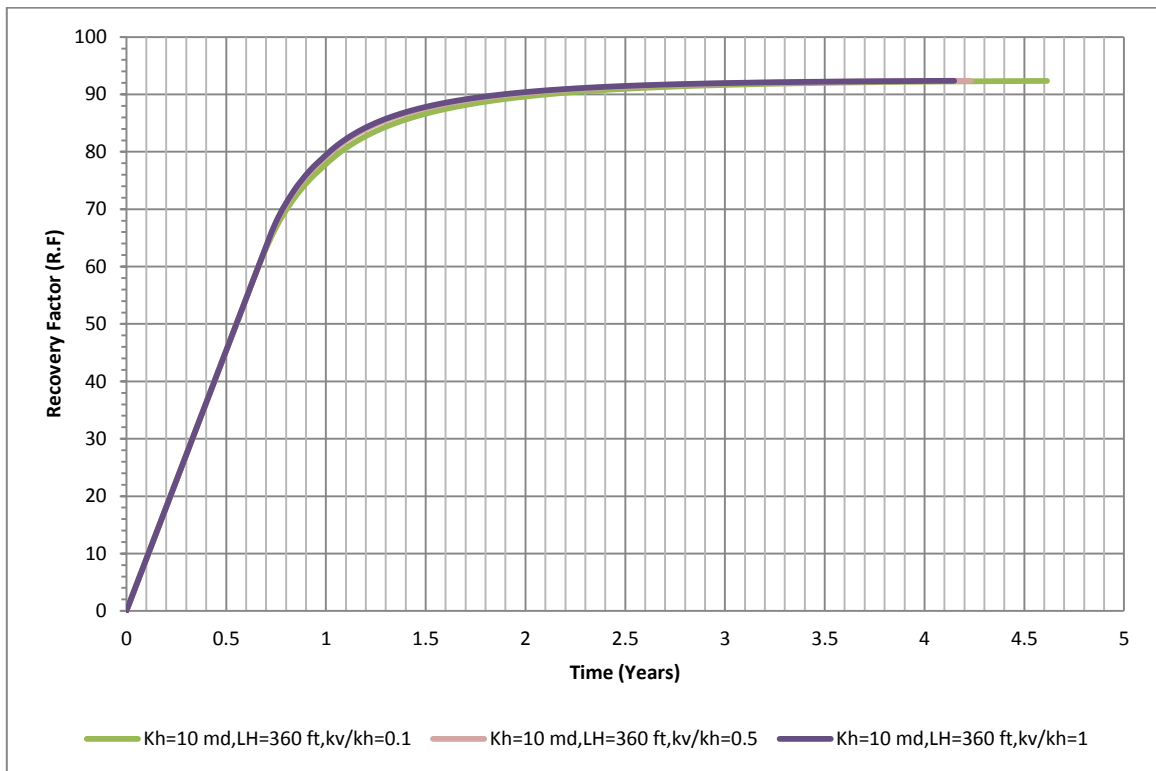


Figure 5.96: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 14, 29, 44)

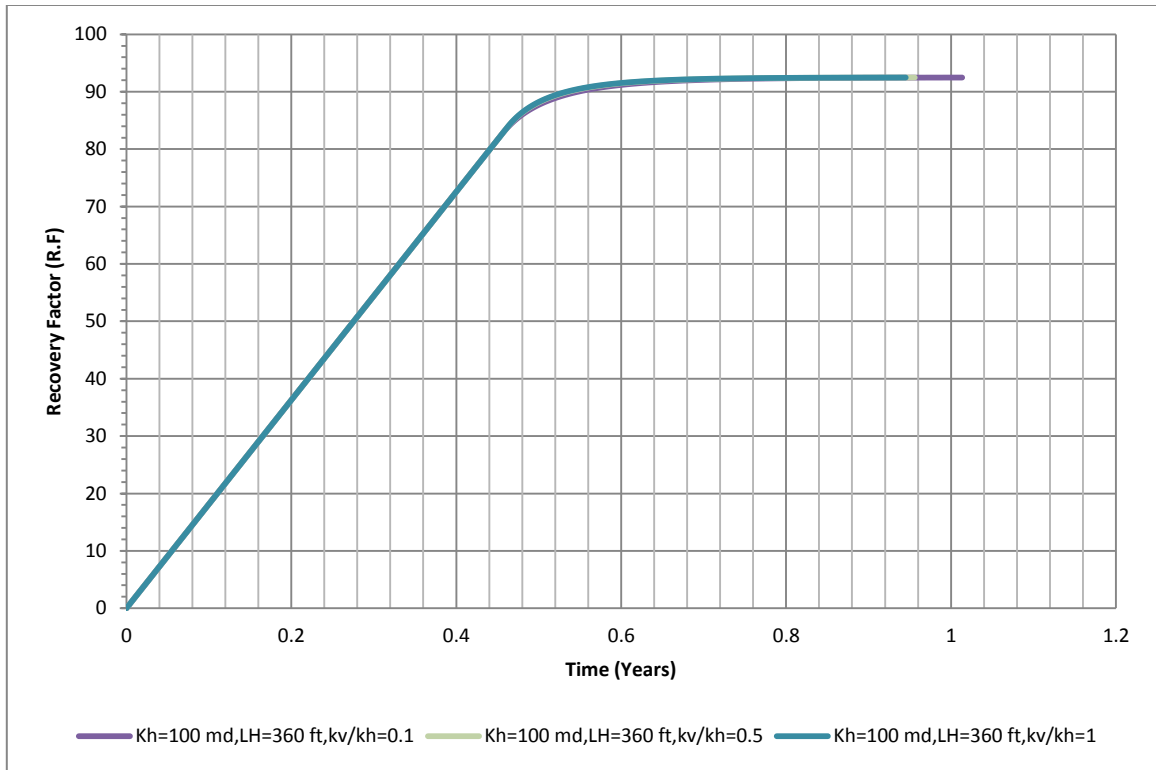


Figure 5.97: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 15, 30, 45)

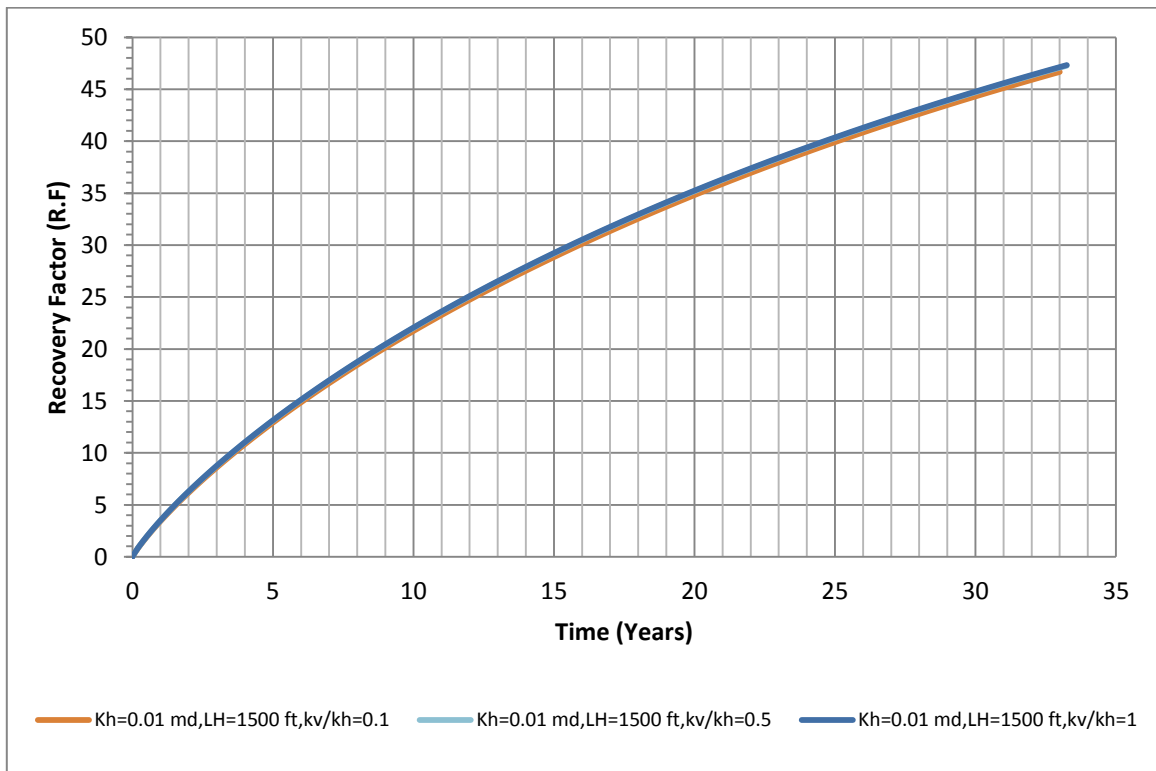


Figure 5.98: Effect of K_v/K_h on R.F, $A=80$ acres, $h=20$ feet, SDA, (Cases 91,106,121)

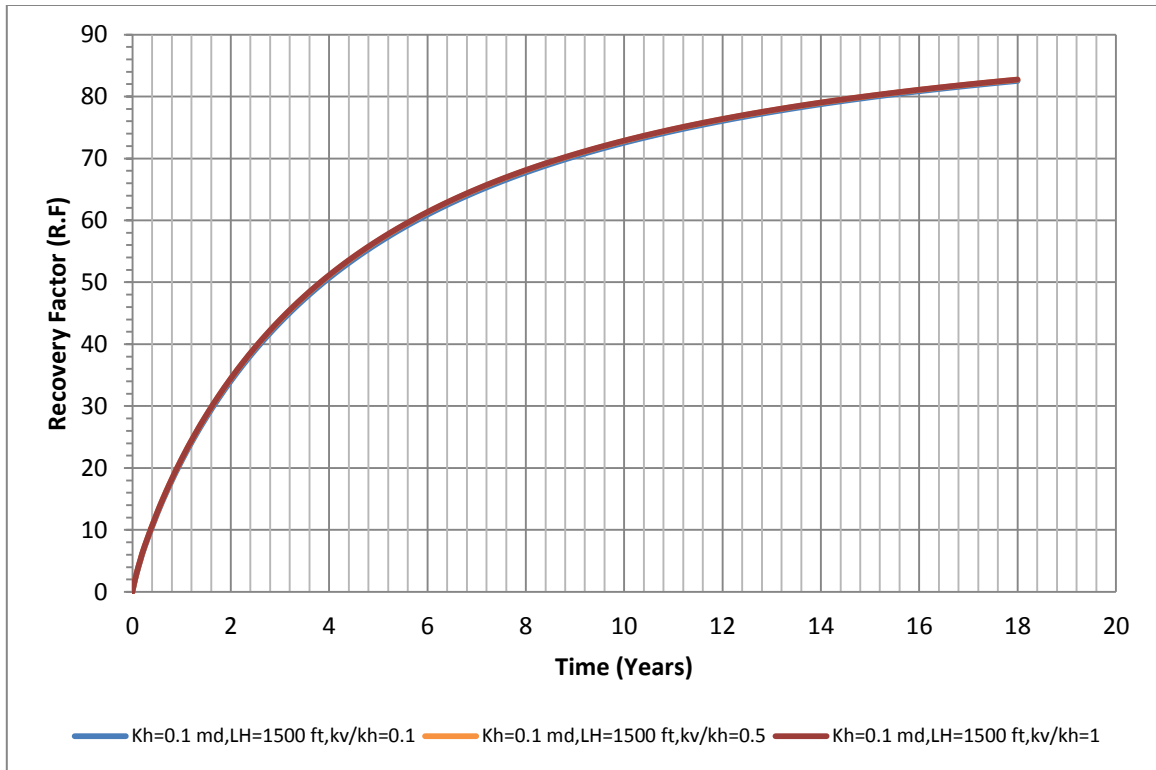


Figure 5.99: Effect of K_v/K_h on R.F, A=80 acres, h=20 feet, SDA, (Cases 92,107,122)

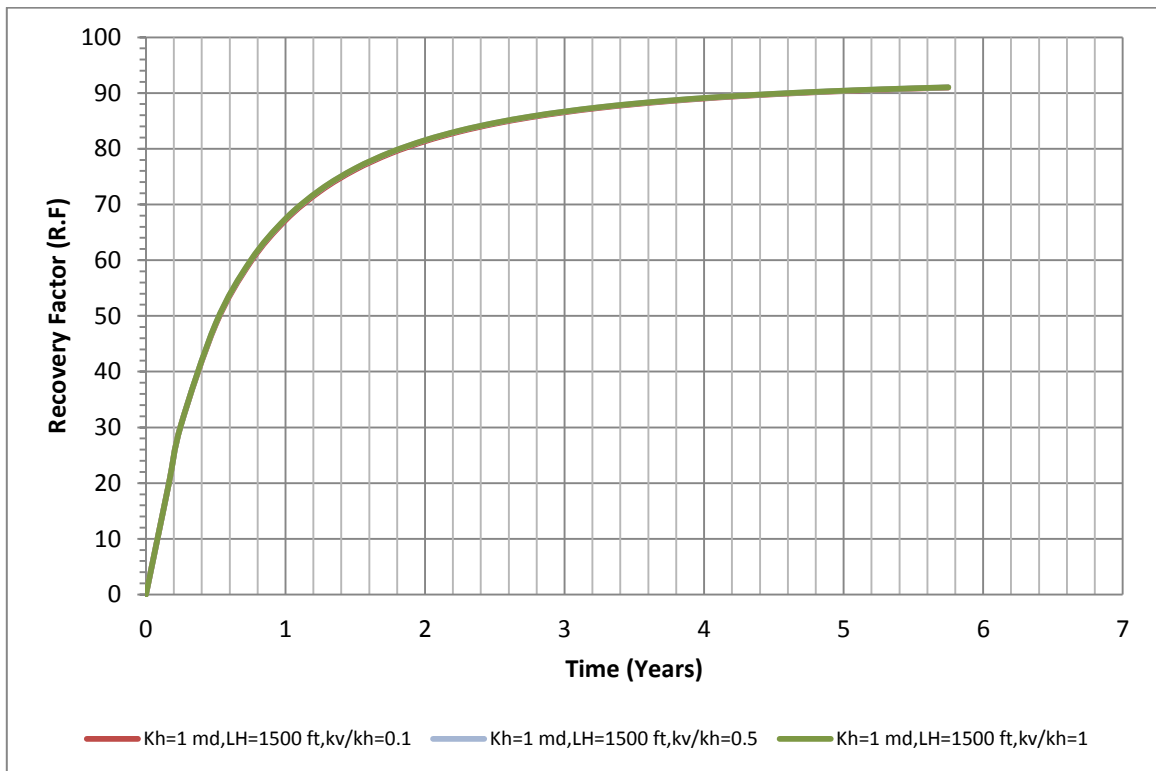


Figure 5.100: Effect of K_v/K_h on R.F, A=80 acres, h=20 feet, SDA, (Cases 93,108,123)

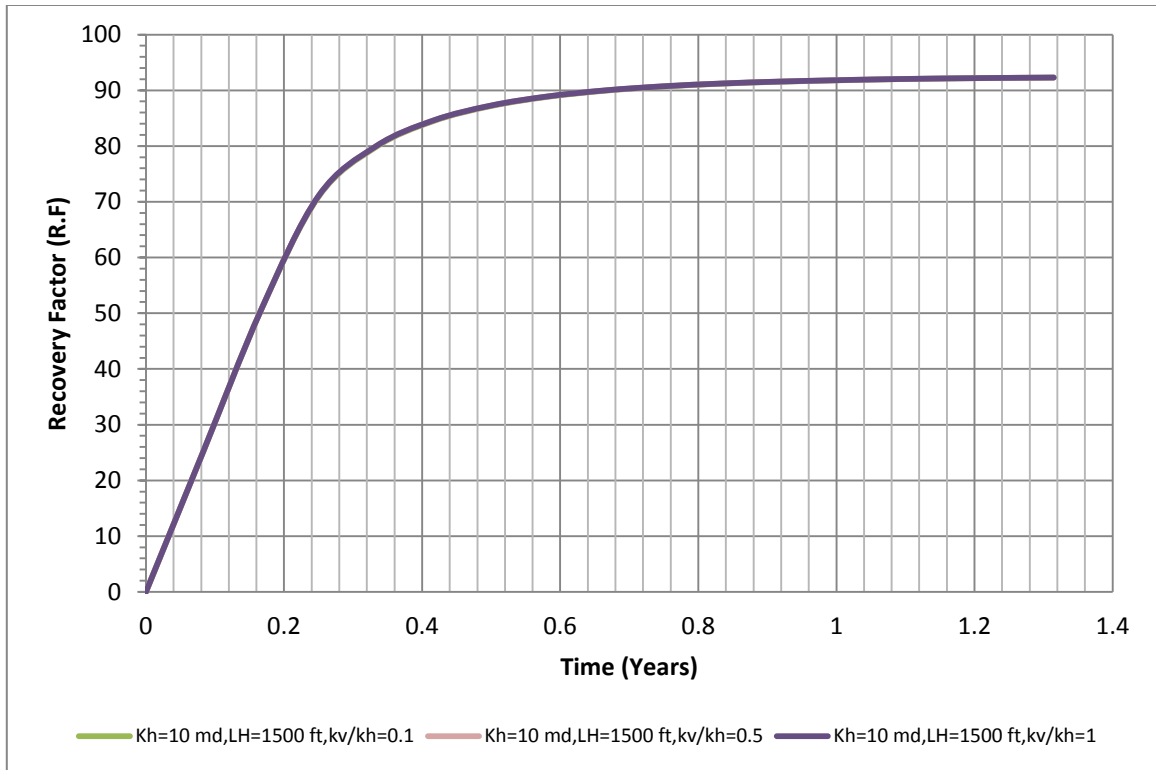


Figure 5.101: Effect of K_v/K_h on R.F, $A=80$ acres, $h=20$ feet, SDA , (Cases 94,109,124)

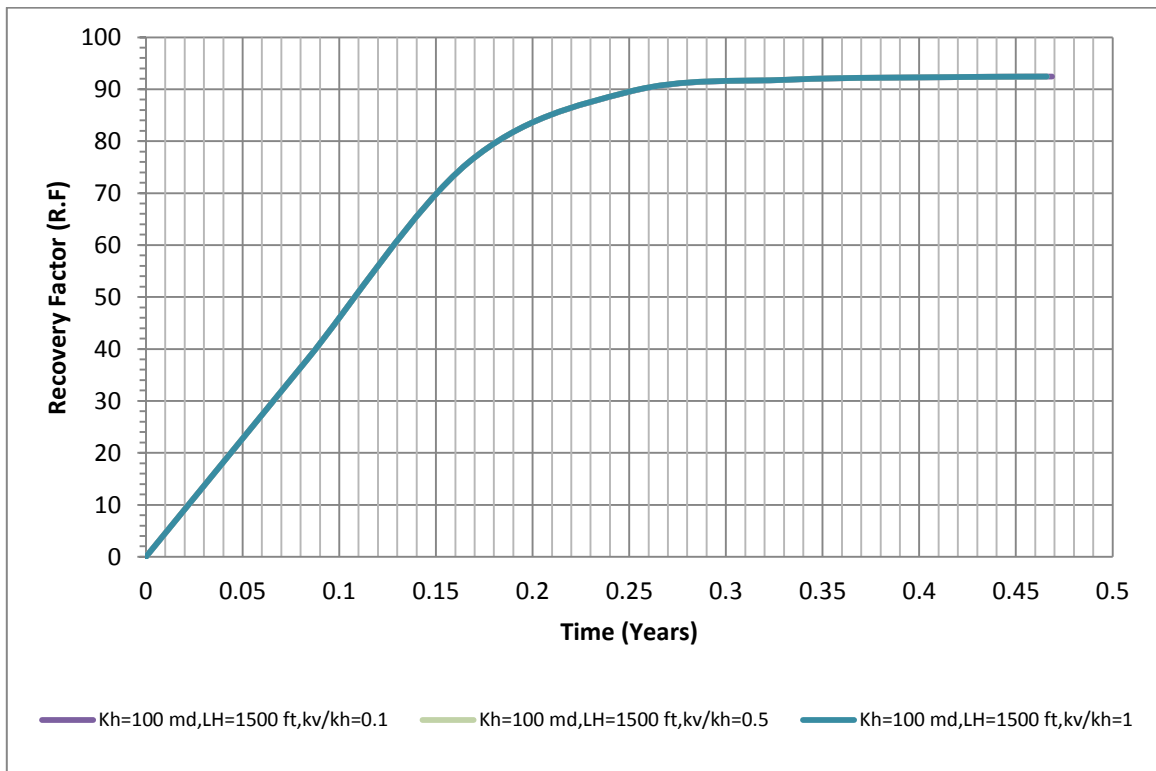


Figure 5.102: Effect of K_v/K_h on R.F, $A=80$ acres, $h=20$ feet, SDA , (Cases 95,110,125)

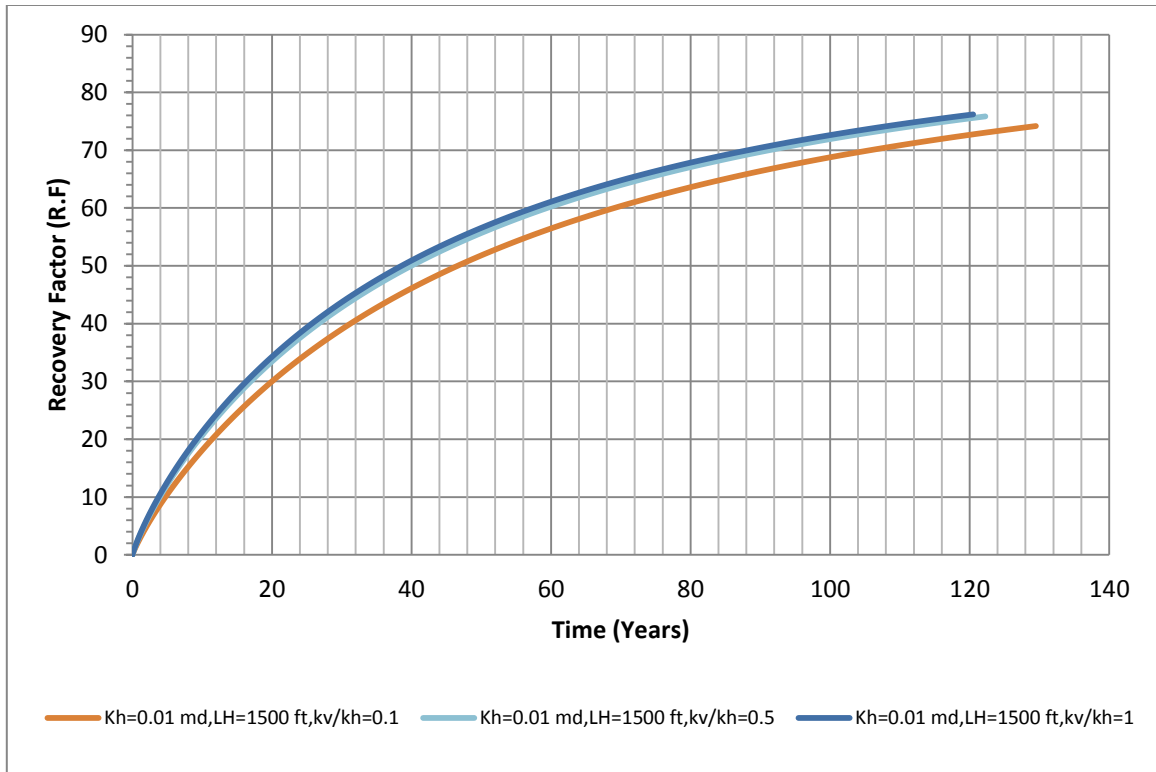


Figure 5.103: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 101,116,131)

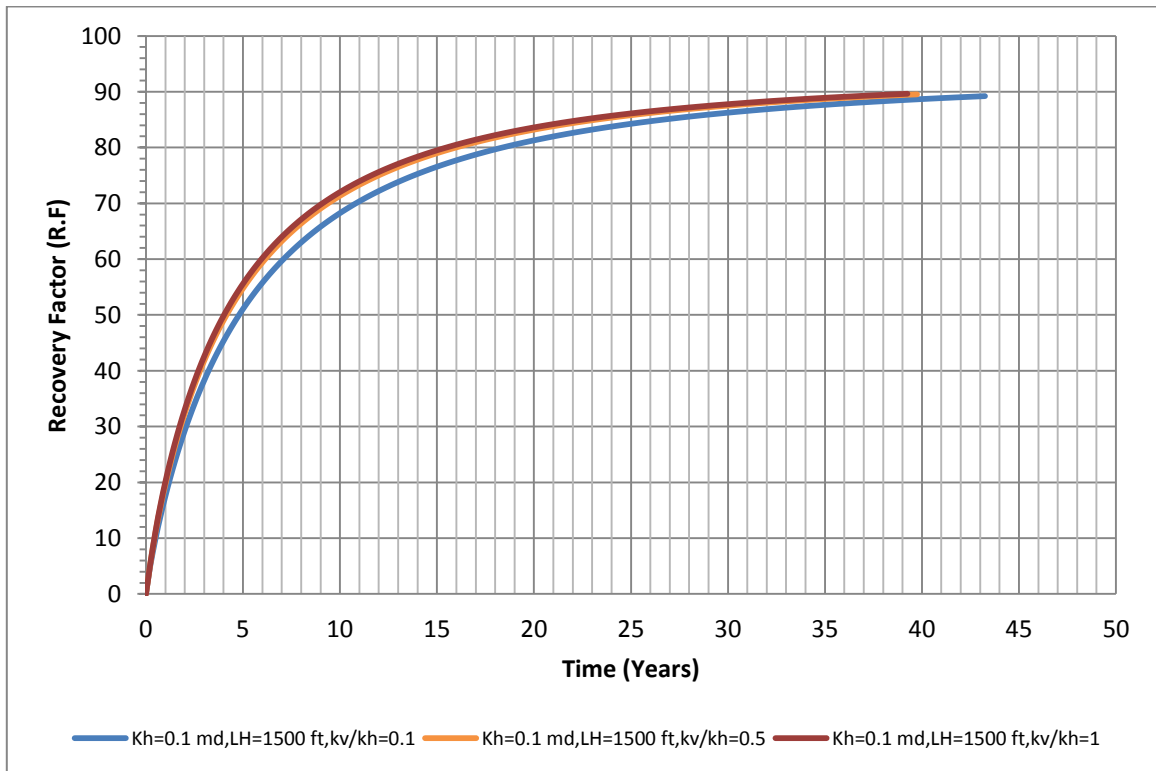


Figure 5.104: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 102,117,132)

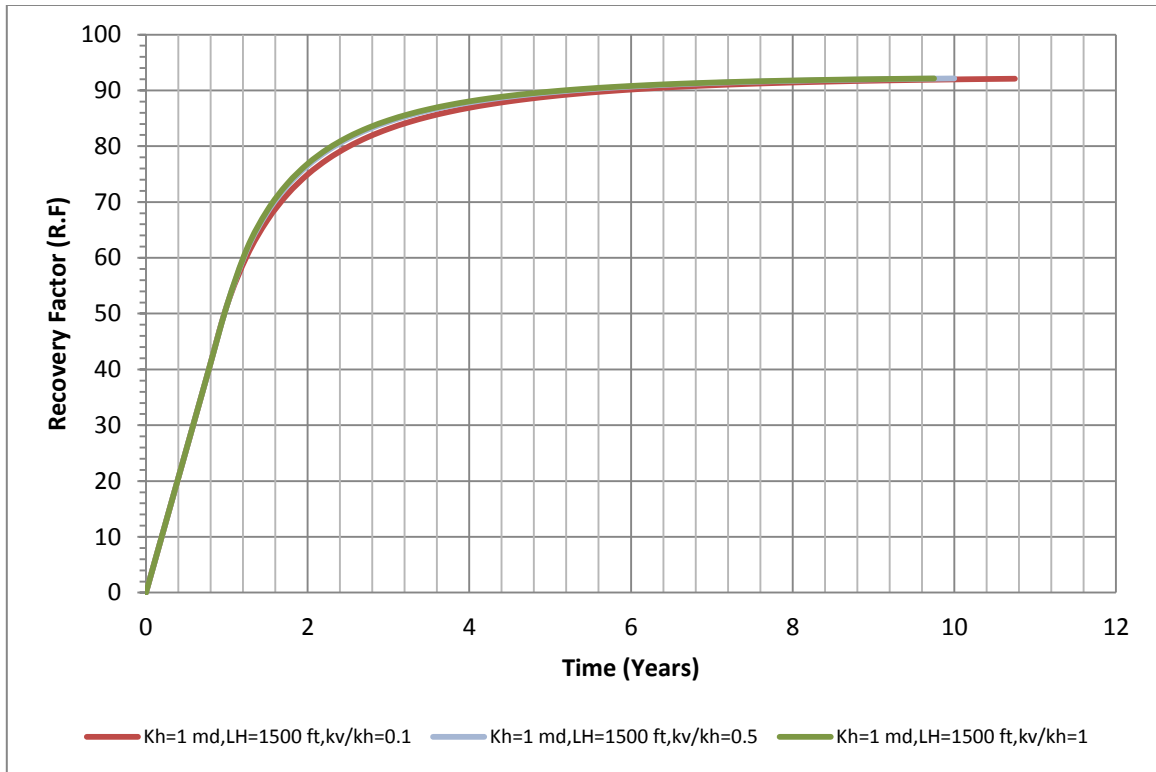


Figure 5.105: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA , (Cases 103,118,133)

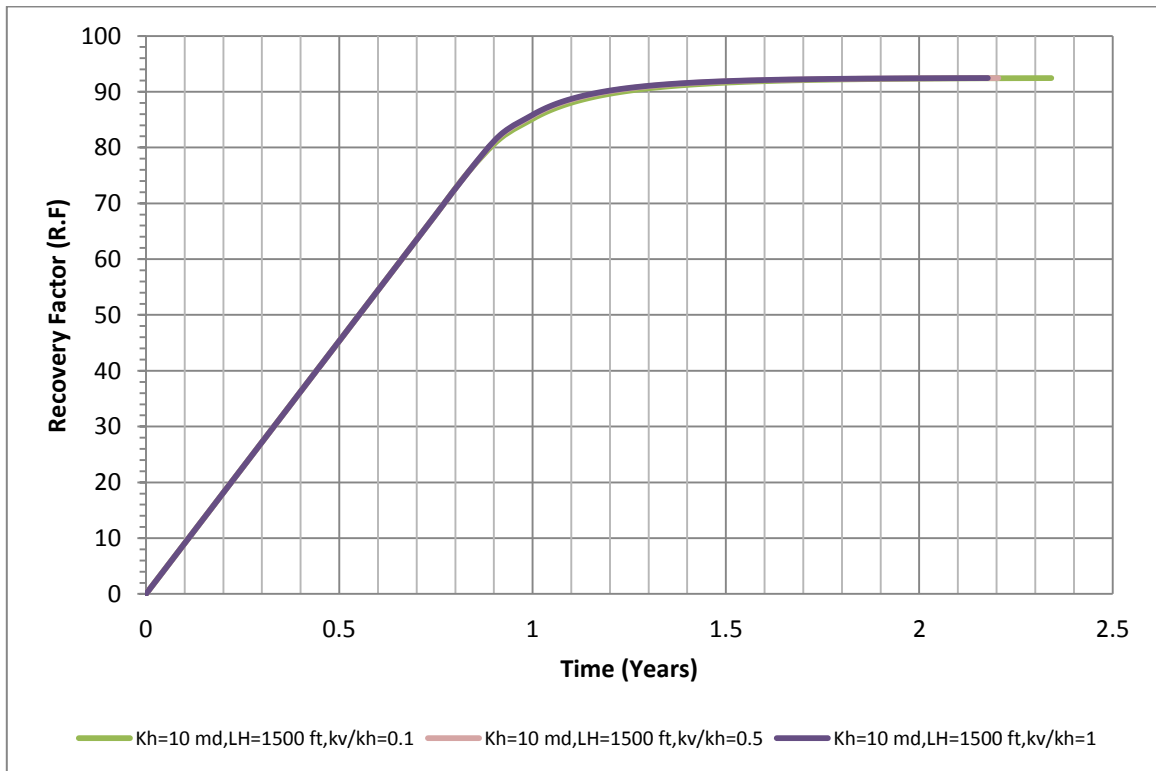


Figure 5.106: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA , (Cases 104,119,134)

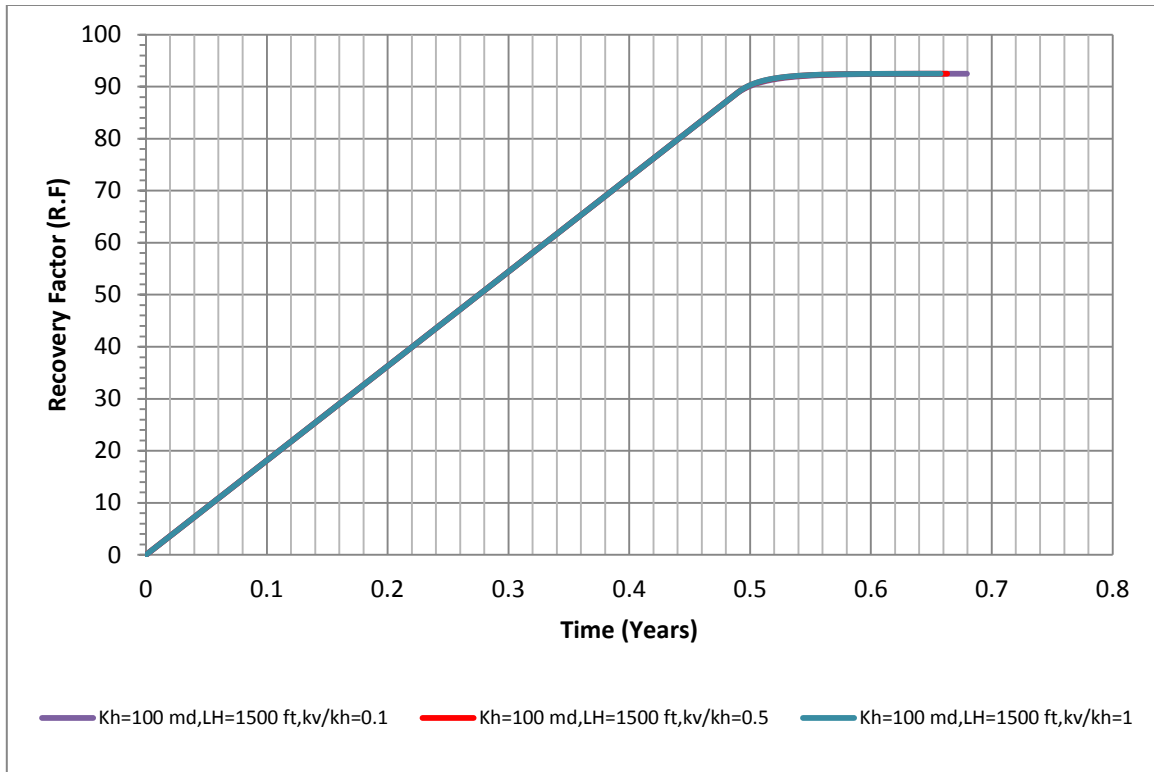


Figure 5.107: Effect of K_v/K_h on R.F, $A=80$ acres, $h=100$ feet, SDA, (Cases 105,120,135)

5.6 The Effect of Well Penetration Ratio

Figures 5.108 through 5.127 show the effect of well penetration ratio on ultimate recovery factor and on time to reach abandonment conditions. Figures 5.108 through 5.117 are for k_v/k_h ratio of 0.1 while Figures 5.118 through 5.127 Are for k_v/k_h ratio of 1.0. Each figure corresponds to a given formation thickness (20 feet, 50 feet, or 100 feet) and a given horizontal permeability (0.01 md, 0.1 md, 1 md, 10 md, or 100 md). Three penetration ratios (0.2, 0.4, and 0.8) were considered for the HW and HFVW.

Figures 5.108 and 5.109 show that, for low values of horizontal permeability (0.01 md and 0.1 md), formation thickness (20 feet) and k_v/k_h ratio (0.1), as the penetration ratio increases, the ultimate recovery factor for the HW and for the HFVW increases. In such

cases, the HFVW performs better than HW of the same penetration ratio, both in terms of the higher ultimate recovery factor and lower abandonment time. It is important to mention that, in such cases of low horizontal permeability (0.01 md and 0.1 md), the ultimate recovery factors for both HFVW and HW are low compared to the cases where the horizontal permeability is high (10 md and 100 md).

Figure 5.110 shows that, for horizontal permeability of 1.0 md and low values of formation thickness (20 feet) and k_v/k_h ratio (0.1), the performance of HFVW and HW become identical at high penetration ratio (0.8). In such reservoirs, at lower penetration ratios of 0.4 and 0.2, HFVW performs better than HW of the same penetration ratio only in terms of the abandonment time but not in terms of ultimate recovery; the HFVW and HW have the same ultimate recovery factor in such cases. It is important to note that it is difficult to create long conductive fractures because of the problems with proppant transport, proppant crushing, and proppant embedment. However, one can drill long horizontal wells. Figure 5.110 shows that a HW of penetration ratio of 0.8 performs better than a HFVW of penetration ratios of 0.4 and 0.2. Therefore, one can state that a HW of penetration ratio of 0.8 performs better than a HFVW because, in reality, the length of the created hydraulic fracture would not exceed a penetration ratio of 0.4 in an 80-acre square drainage area.

Figures 5.111 and 5.112 show that, for low values of formation thickness (20 feet) and k_v/k_h ratio (0.1), and high value of horizontal permeability (10 md and 100 md), the value of the penetration ratio of the HW has no effect on the ultimate recovery factor but still affects the abandonment time. In such cases, as the HW penetration ratio increases, the abandonment time decreases.

Figures 5.113 and 5.114 show that, for high values of formation thickness (100 feet) and low values of k_v/k_h ratio (0.1) and horizontal permeability (0.01 md and 0.1 md), the advantage of the HFVW over HW increases. Figure 5.113 shows that a HFVW of penetration ratio of 0.4 performs better than a HW of penetration ratio of 0.8. These two figures show that a HW of penetration ratio of 0.8 performs about the same as a HFVW of penetration ratio of about 0.3.

Figure 5.115 shows that, for high value of formation thickness (100 feet), low value of k_v/k_h ratio (0.1), and horizontal permeability of 1 md, the penetration ratio has no effect on the ultimate recovery factor but has significant effect on the abandonment time. HFVW still performs better than HW in terms of abandonment time.

Figures 5.116 and 5.117 show, that for high values of formation thickness (100 feet) and horizontal permeability (10 md and 100 md), and low value of k_v/k_h ratio (0.1), the value of HW penetration ratio has no effect on the ultimate recovery factor but still has some effect on the abandonment time.

The same conclusions that are obtained above for the cases corresponding to k_v/k_h ratio of 0.1, as shown in Figures 5.108 through 5.117, are obtained for the cases corresponding to k_v/k_h ratio of 1, as shown in Figures 5.118 through 5.127. Again, the only difference is that the abandonment time for the HW decreases slightly for the cases corresponding to k_v/k_h ratio of 1 compared to the cases corresponding to k_v/k_h ratio of 0.1. These results again show that the value of k_v/k_h ratio has somewhat negligible effect on the performance of horizontal wells in volumetric dry gas reservoirs.

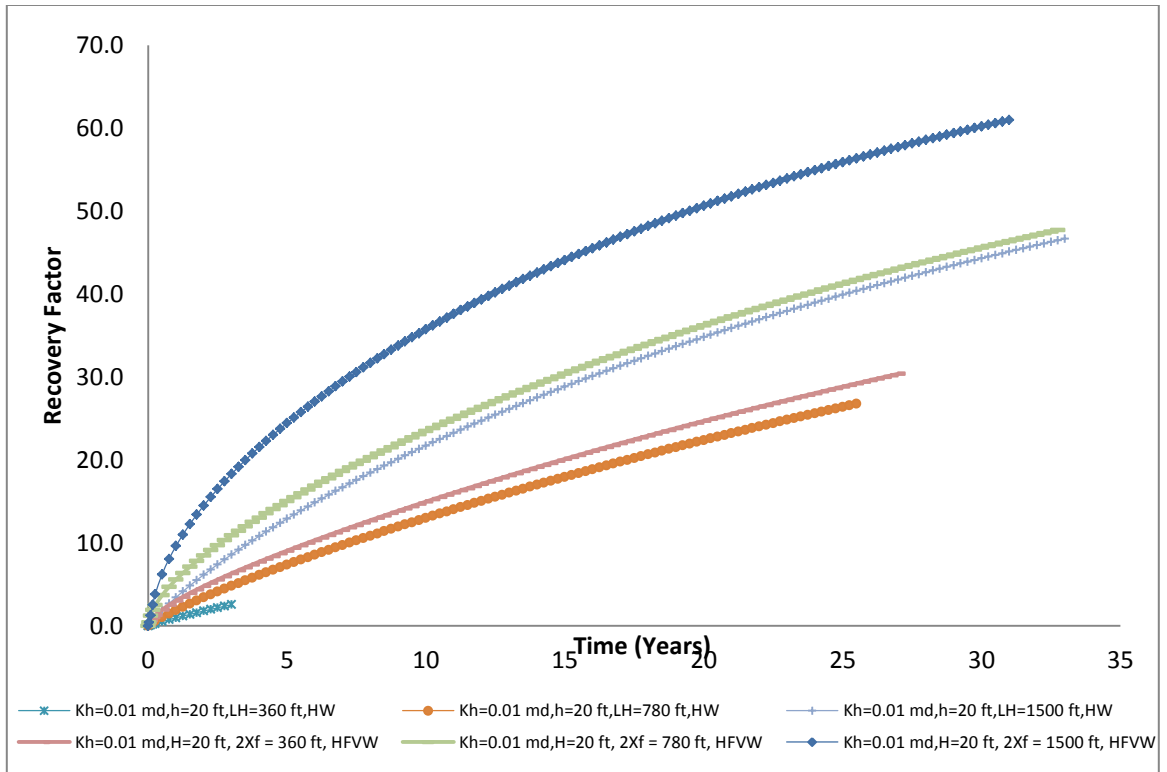


Figure 5.108: Effect of P.R on R.F, A=80 acres, h=20 ft, SDA, $K_v/K_h=0.1$, (Cases 1,46,91)

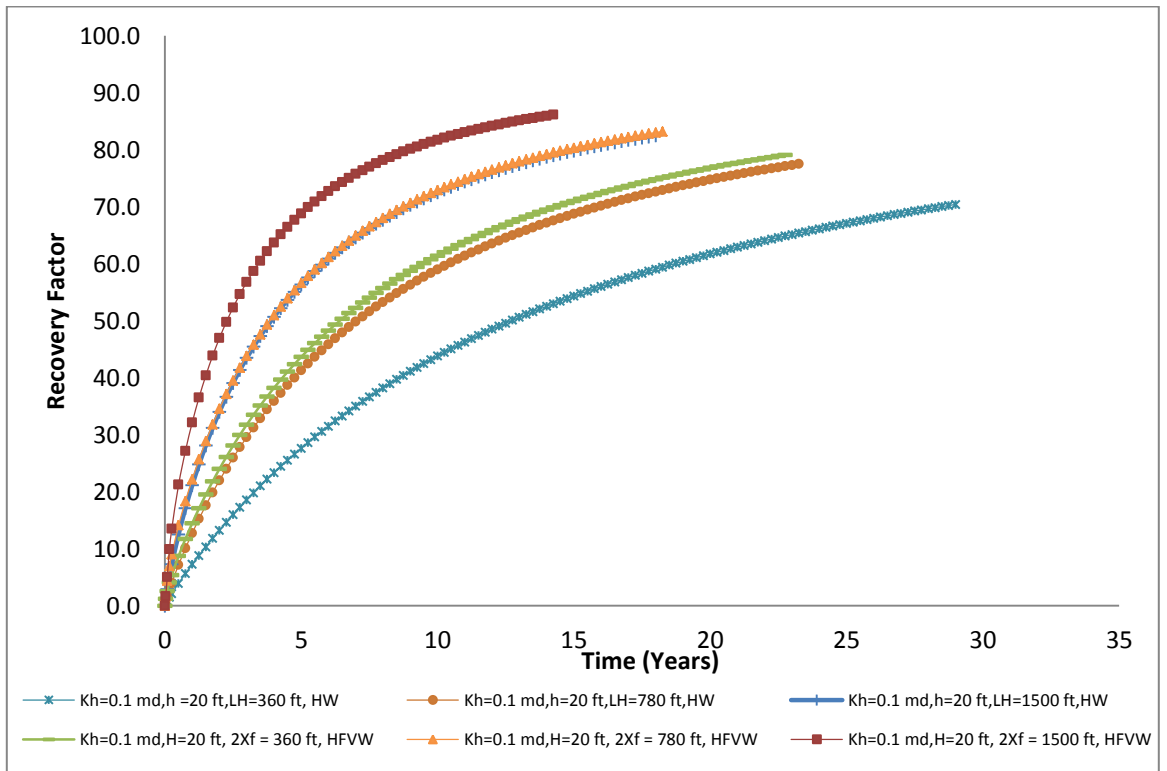


Figure 5.109: Effect of P.R on R.F, A=80 acres, h=20 ft, SDA, $K_v/K_h=0.1$, (Cases 2,47,92)

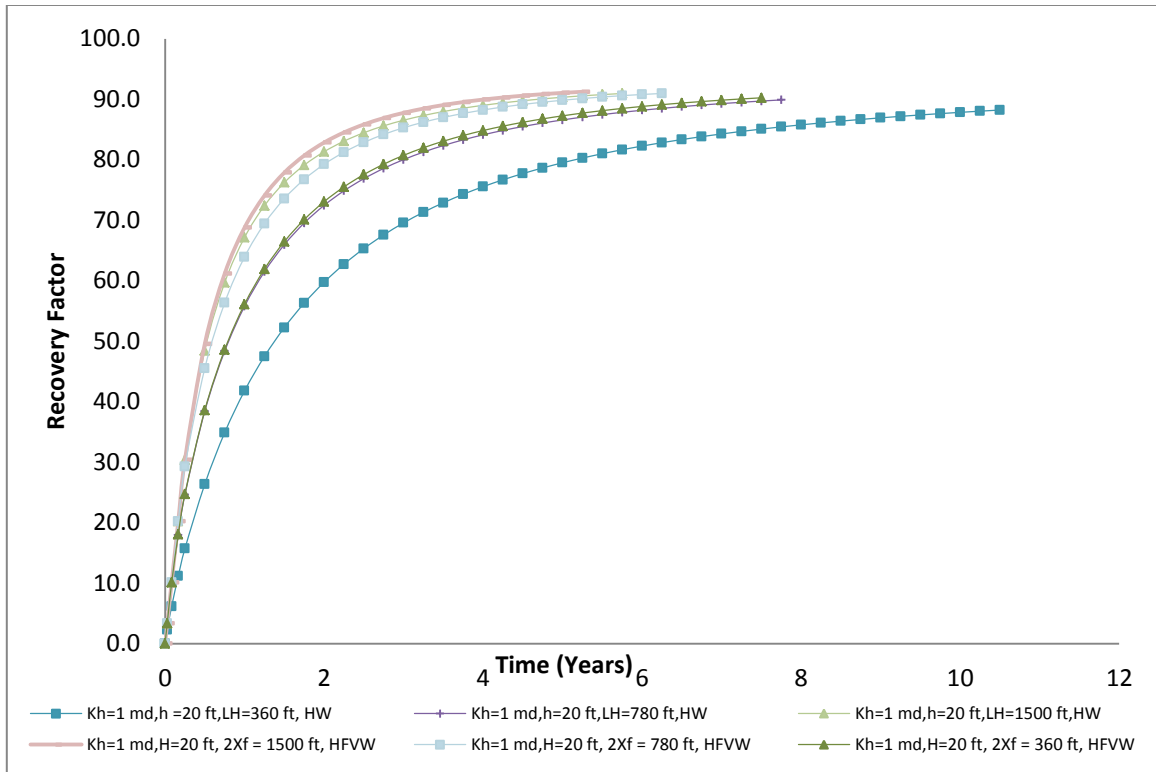


Figure 5.110: Effect of P.R on R.F, $A=80$ acres, $h=20$ ft, SDA, $K_v/K_h=0.1$, (Cases 3, 48, 93)

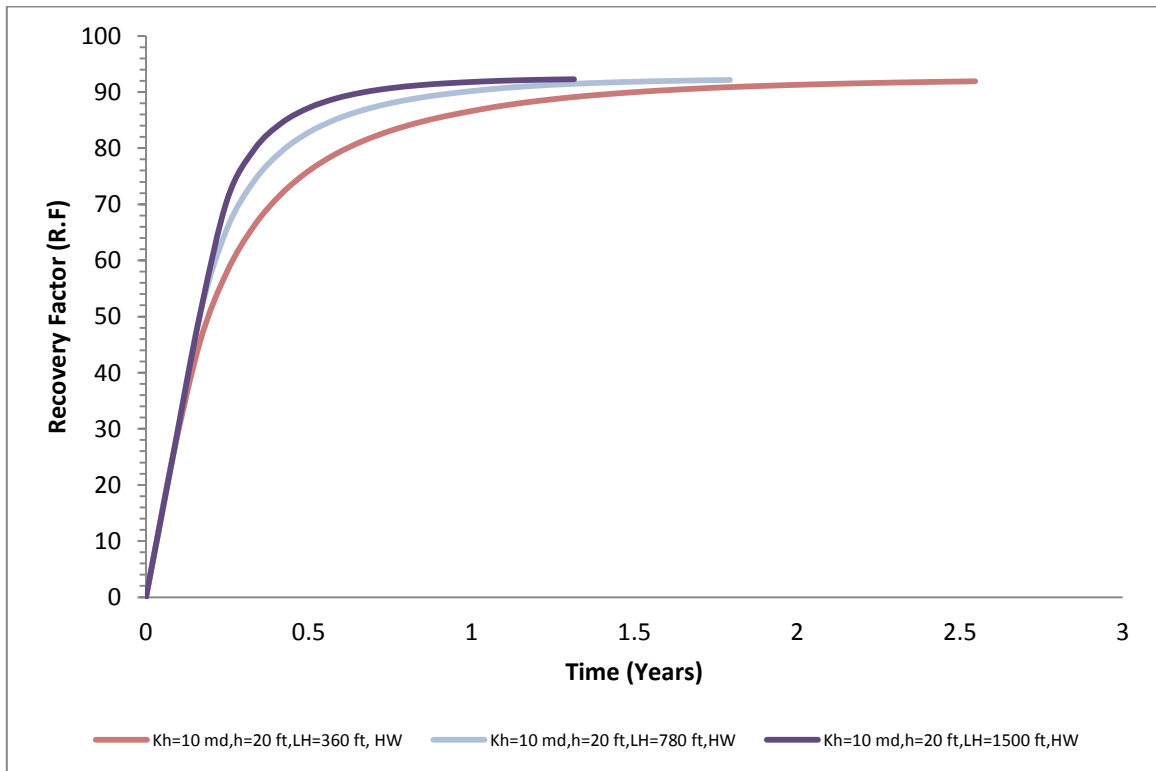


Figure 5.111: Effect of P.R on R.F, $A=80$ acres, $h=20$ ft, SDA, $K_v/K_h=0.1$, (Cases 4, 49, 94)

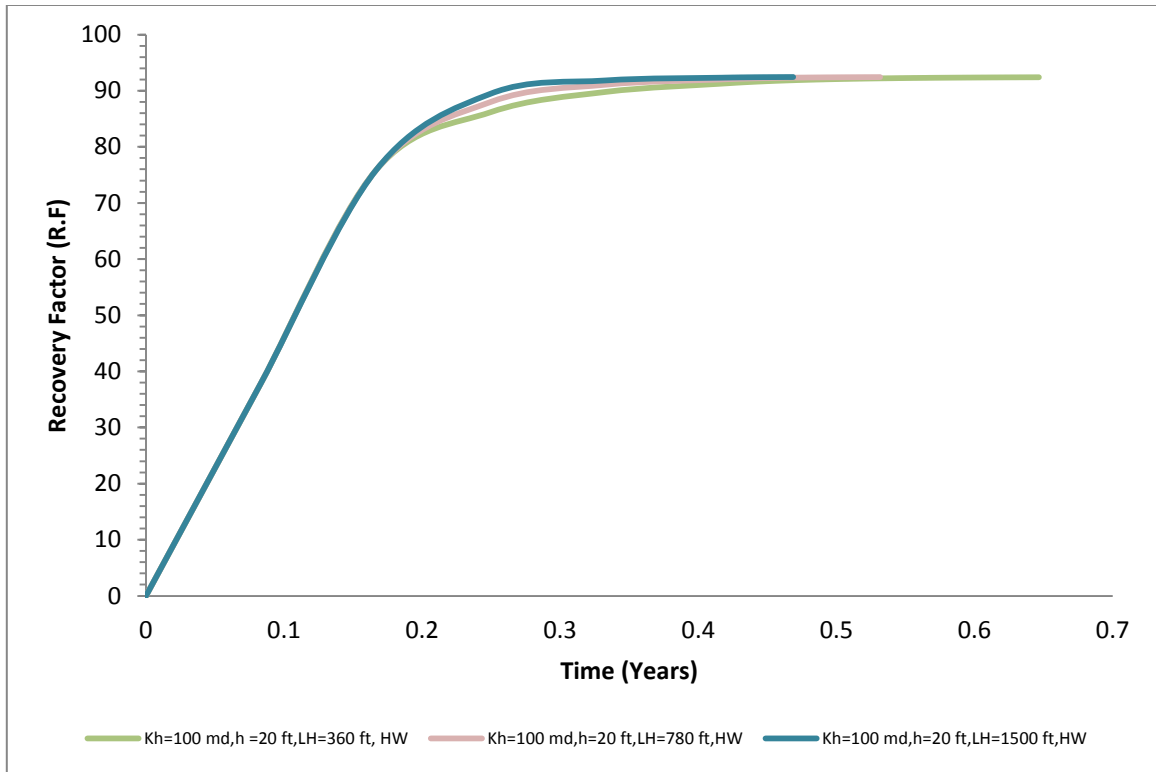


Figure 5.112: Effect of P.R on R.F, $A=80$ acres, $h=20$ ft, SDA, $K_v/K_h=0.1$, (Cases 5, 50, 95)

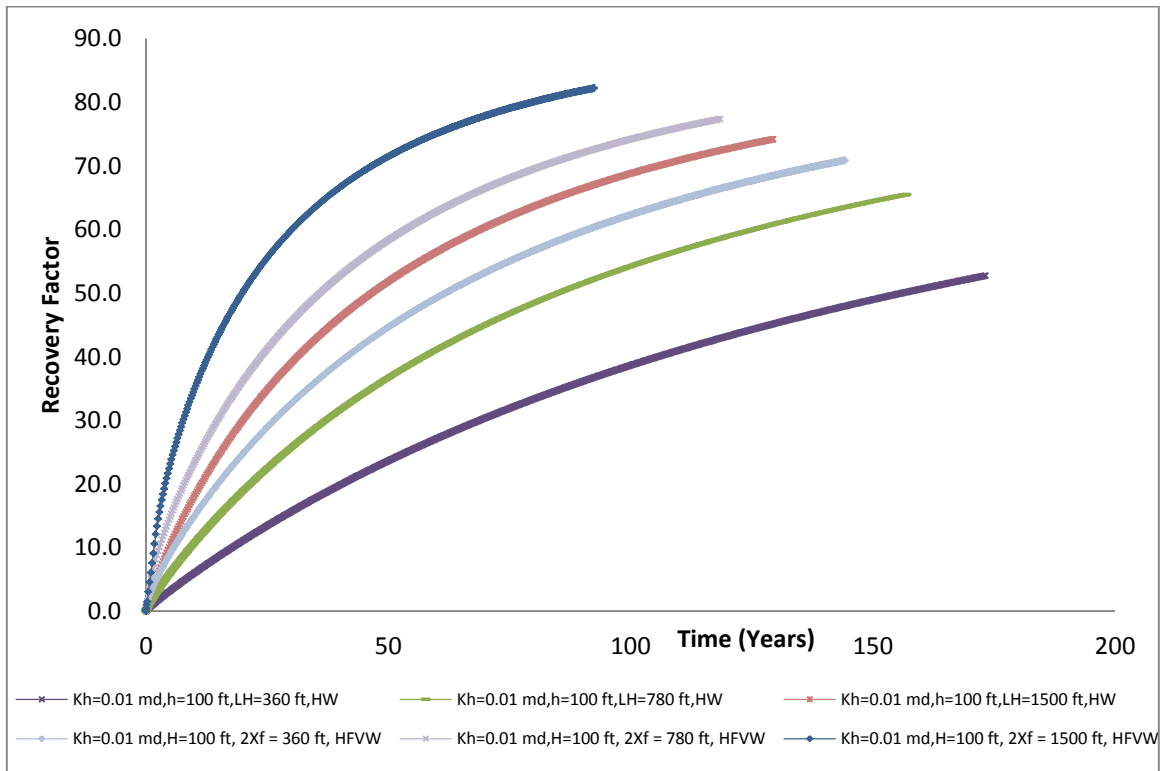


Figure 5.113: Effect of P.R on R.F, $A=80$ acres, $h=100$ ft, SDA, $K_v/K_h=0.1$ (Cases 11, 56, 101)

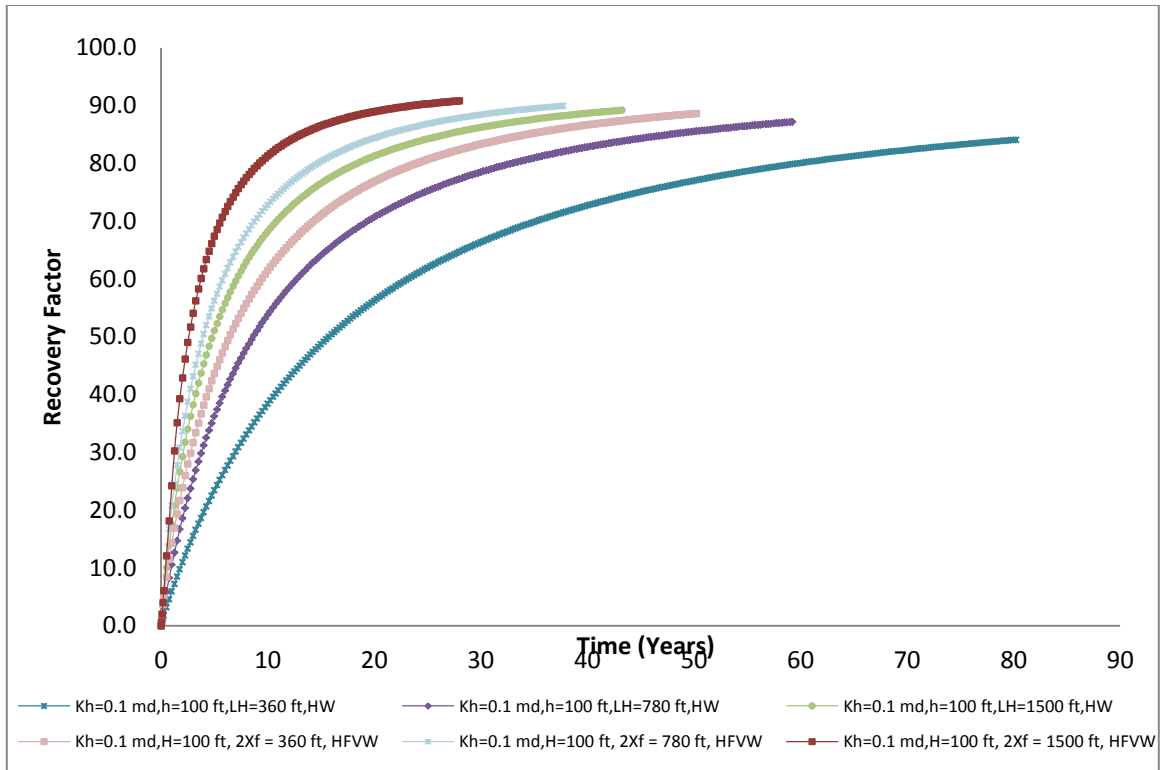


Figure 5.114: Effect of P.R on R.F, A=80 acres, h=100ft, SDA, $K_v/K_h=0.1$ (Cases 12, 57, 102)

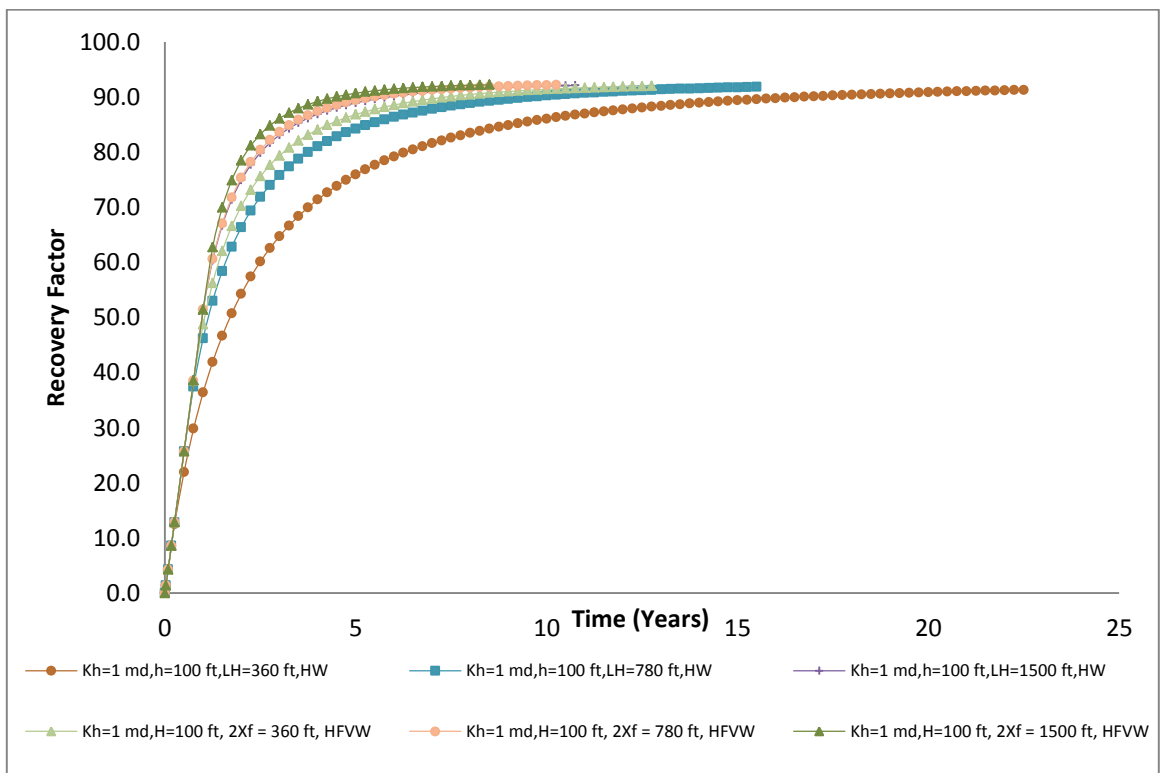


Figure 5.115: Effect of P.R on R.F, A=80 acres, h=100ft, SDA, $K_v/K_h=0.1$ (Cases 13, 58, 103)

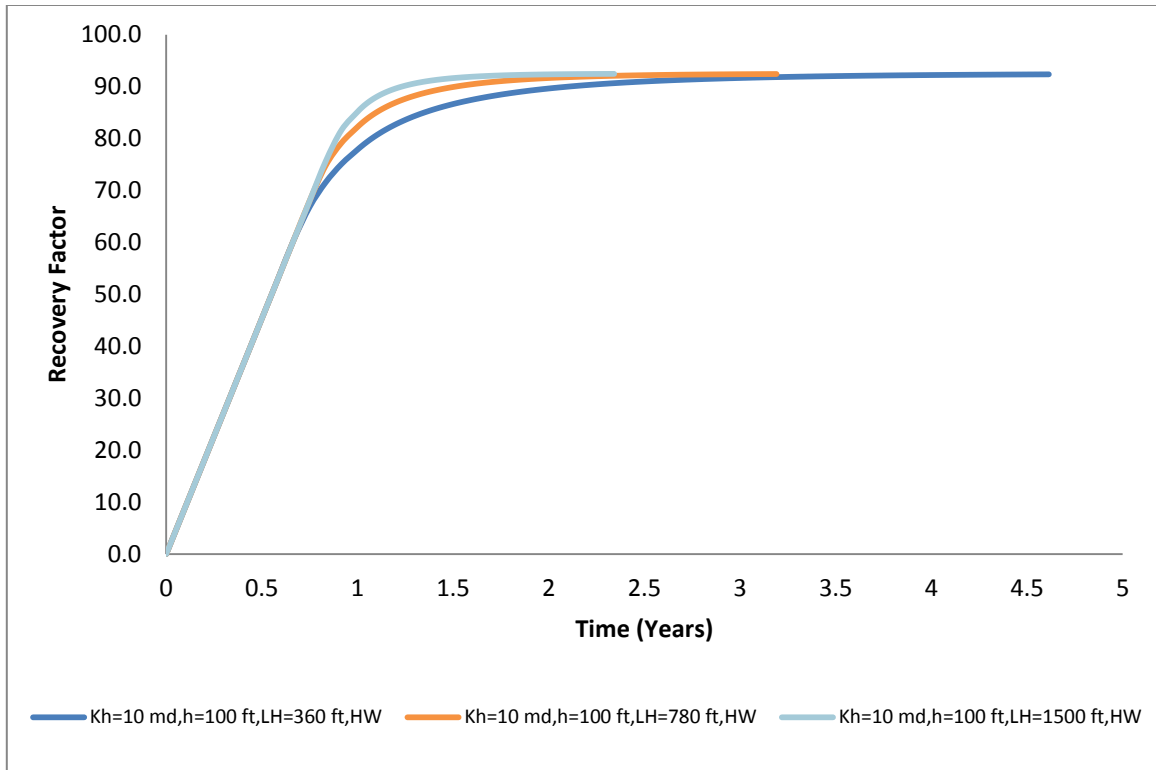


Figure 5.116: Effect of P.R on R.F, $A=80$ acres, $h=100$ ft, SDA, $K_v/K_h=0.1$ (Cases 14,59,104)

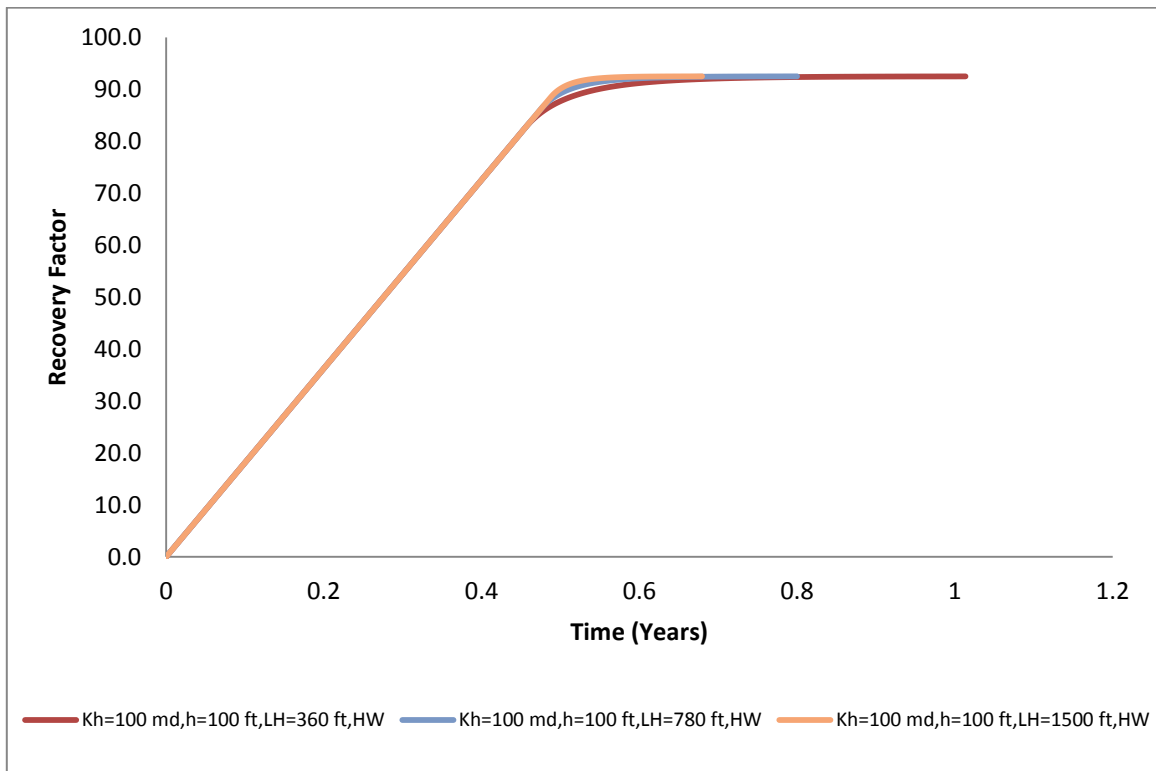


Figure 5.117: Effect of P.R on R.F, $A=80$ acres, $h=100$ ft, SDA, $K_v/K_h=0.1$ (Cases 15,60,105)

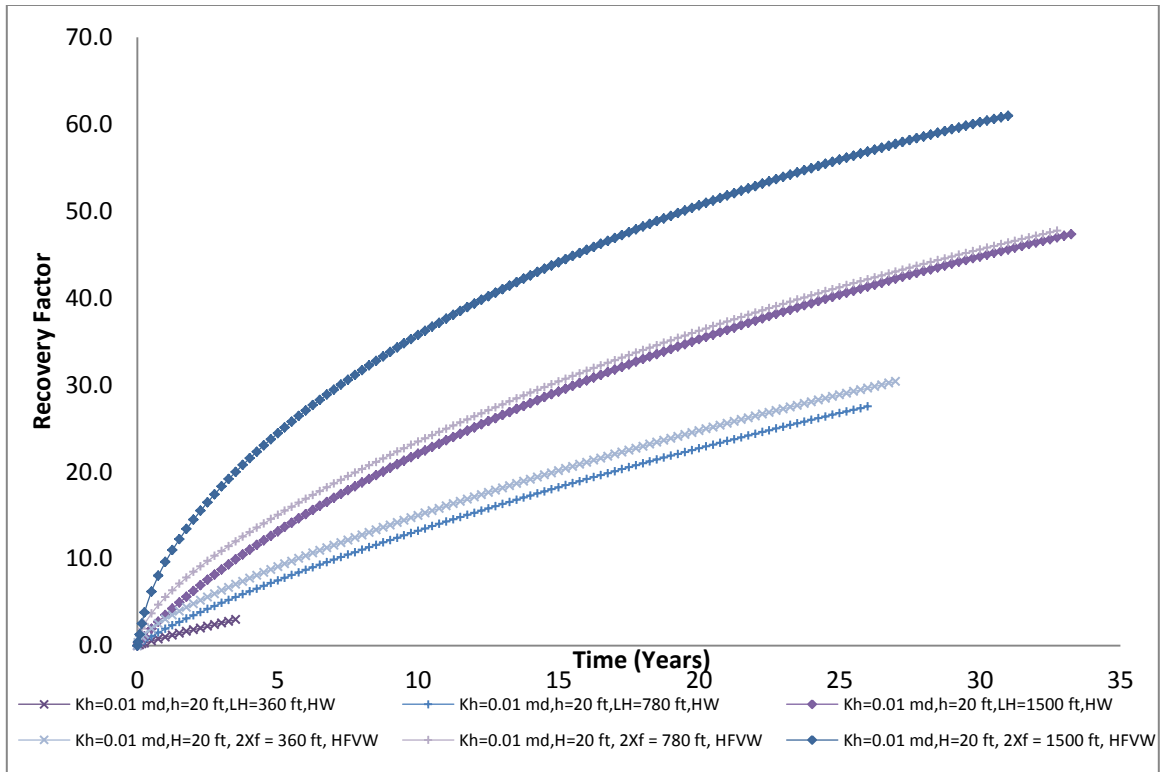


Figure 5.118: Effect of P.R on R.F, A=80 acres, h=20ft, SDA, $K_v/K_h=1$ (Cases 31, 76,121)

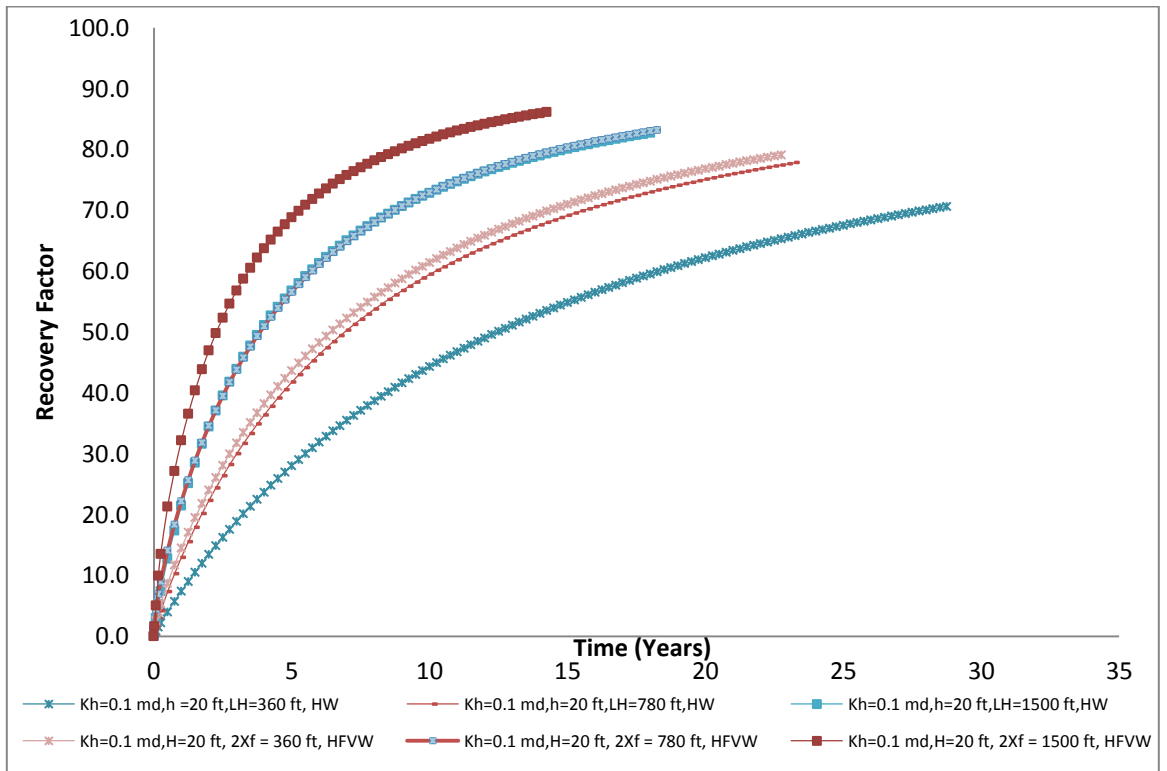


Figure 5.119: Effect of P.R on R.F, A=80 acres, h=20ft, SDA, $K_v/K_h=1$ (Cases 32, 77, 122)

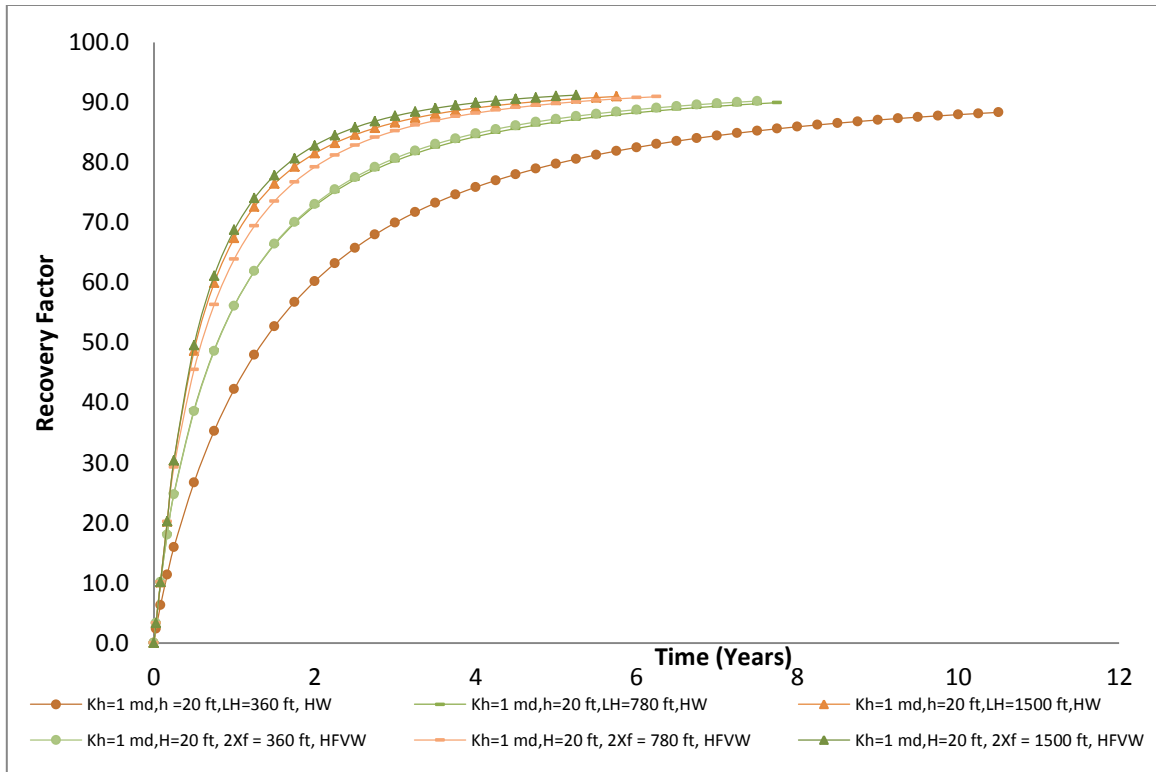


Figure 5.120: Effect of P.R on R.F, A=80 acres, h=20ft, SDA, $K_v/K_h=1$ (Cases 33, 78, 123)

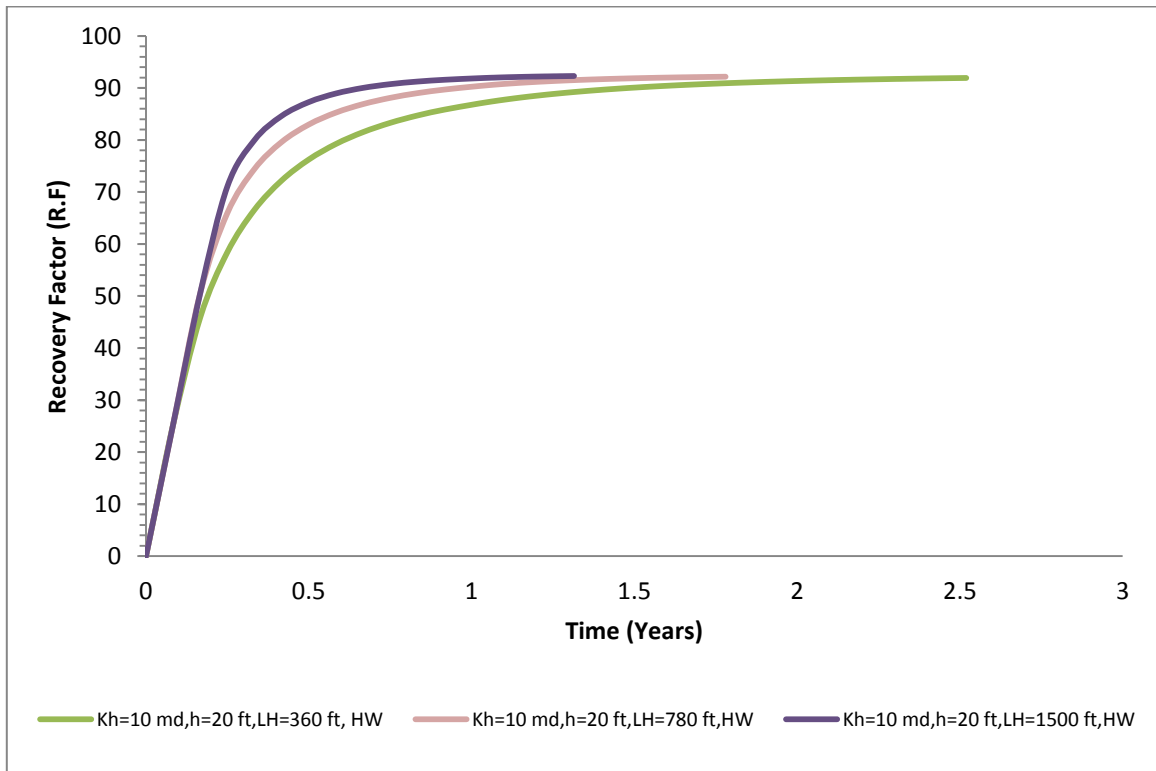


Figure 5.121: Effect of P.R on R.F, A=80 acres, h=20ft, SDA, $K_v/K_h=1$ (Cases 34, 79, 124)

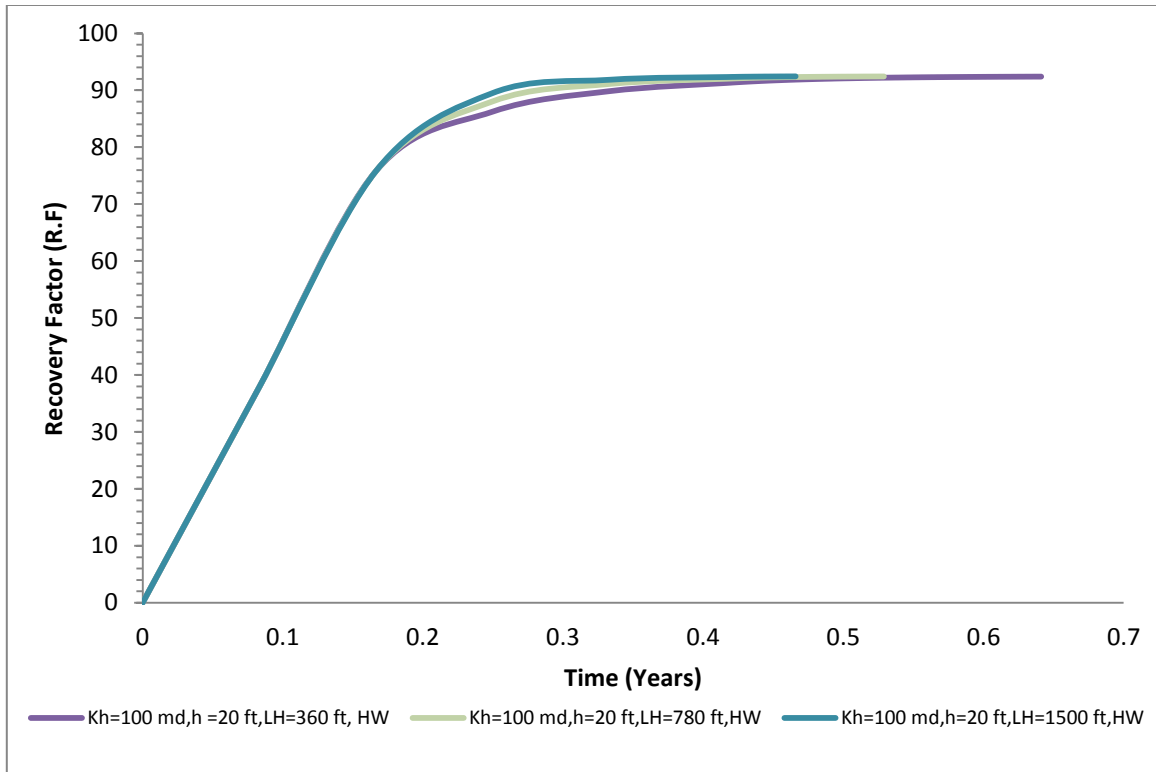


Figure 5.122: Effect of P.R on R.F, A=80 acres, h=20ft, SDA, $K_v/K_h=1$ (Cases 35, 75, 125)

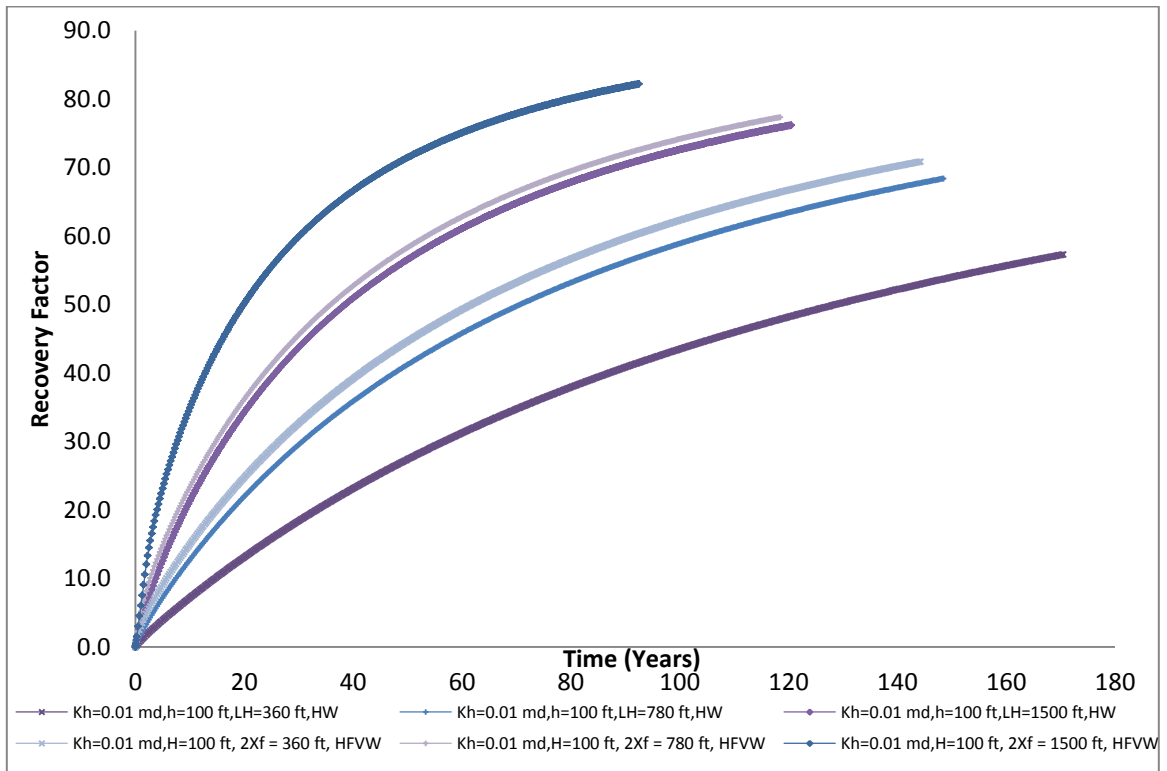


Figure 5.123: Effect of P.R on R.F, A=80 acres, h=100ft, SDA, $K_v/K_h=1$ (Cases 41, 86, 131)

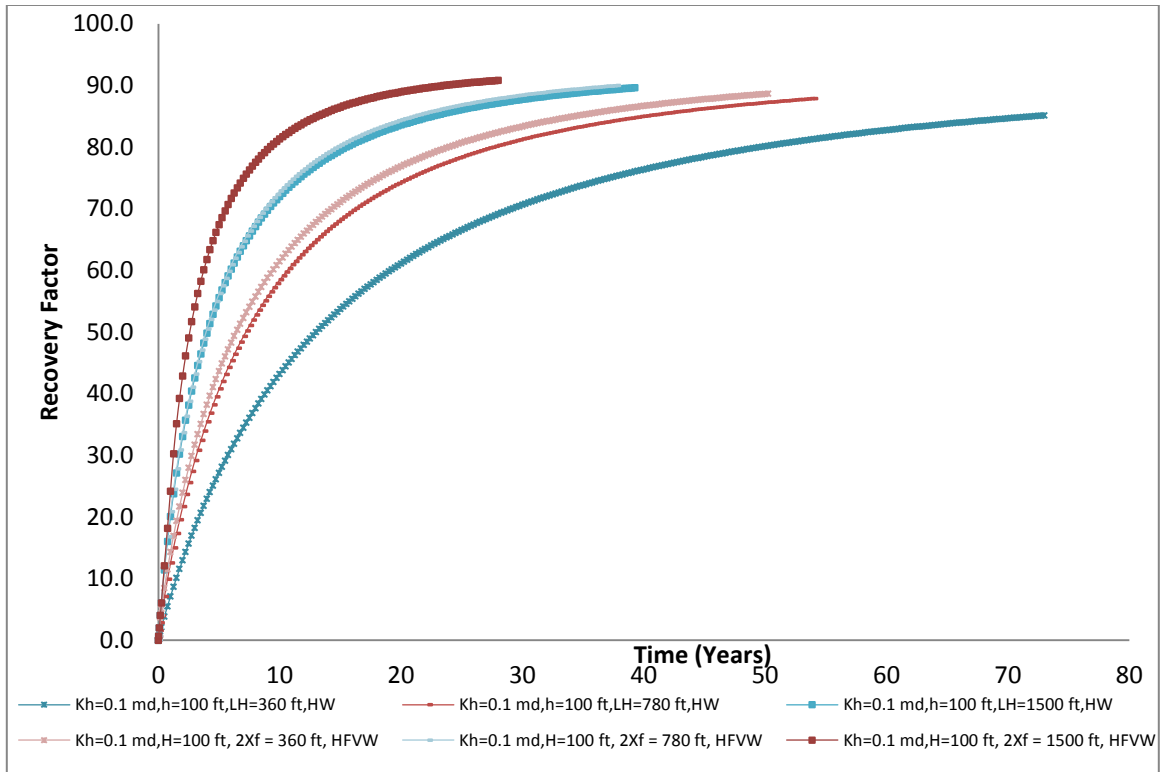


Figure 5.124: Effect of P.R on R.F, A=80 acres, h=100ft, SDA, $K_v/K_h=1$ (Cases 42, 87, 132)

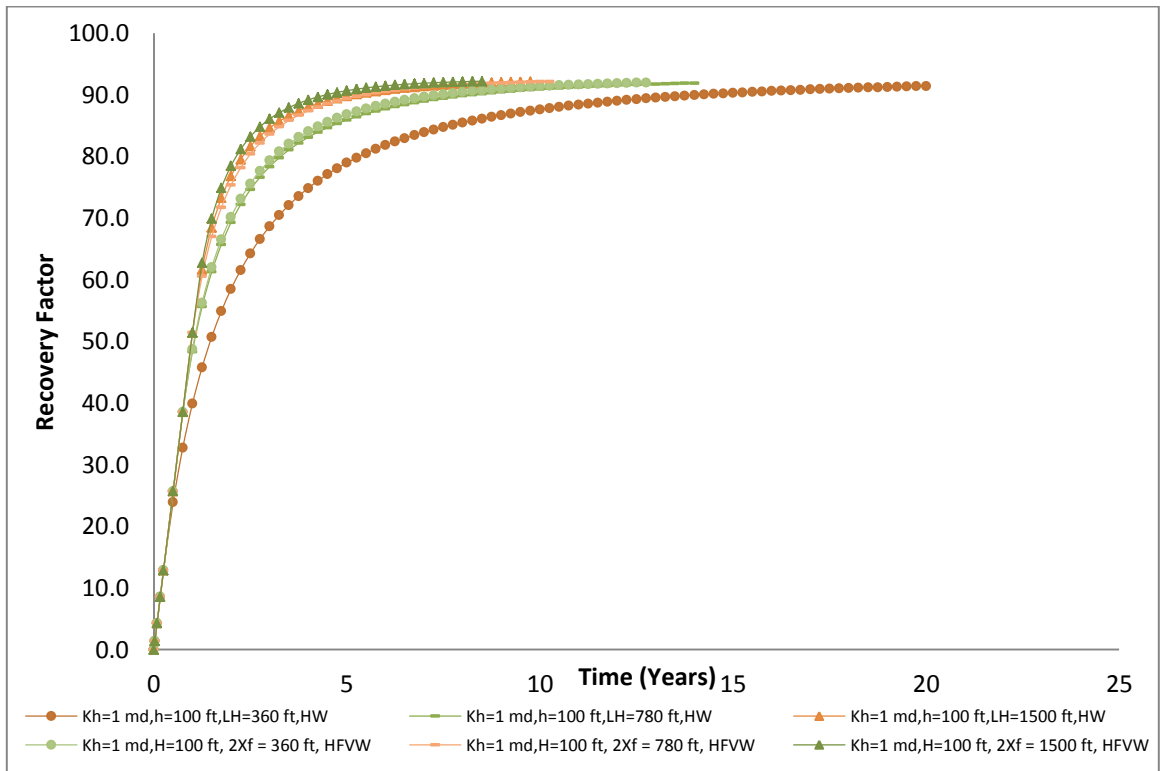


Figure 5.125: Effect of P.R on R.F, A=80 acres, h=100ft, SDA, $K_v/K_h=1$ (Cases 43, 88, 133)

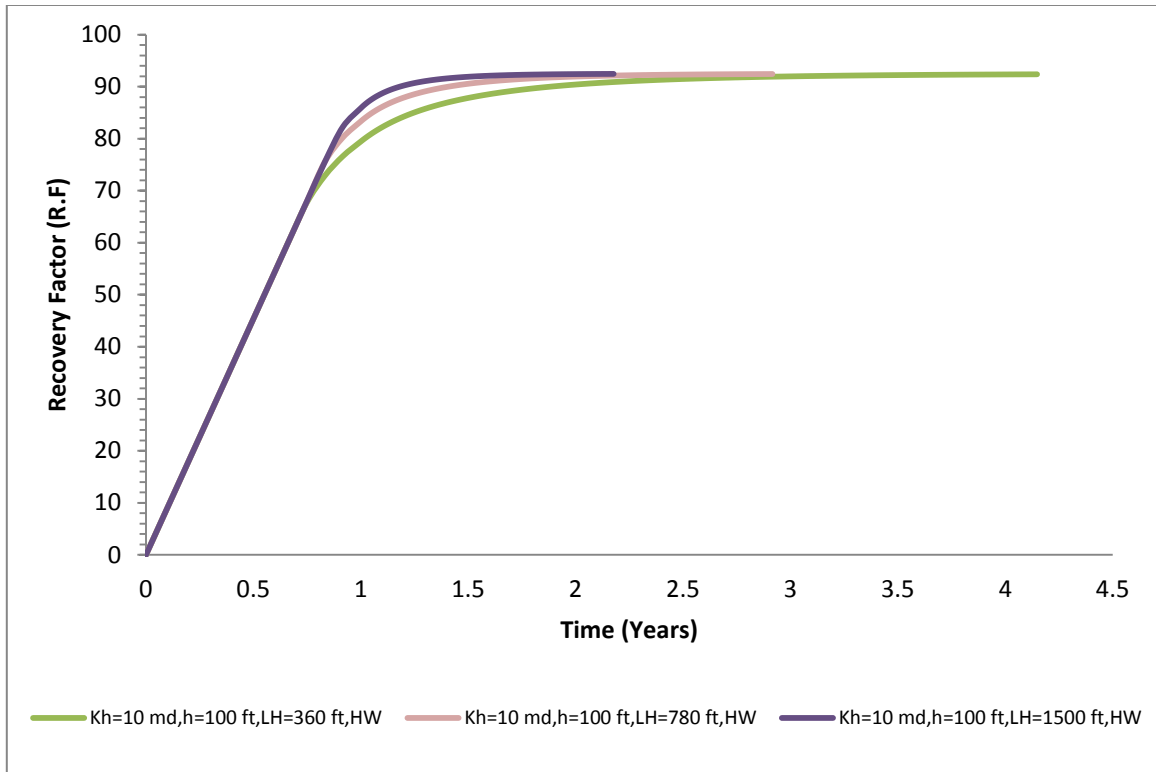


Figure 5.126: Effect of P.R on R.F, A=80 acres, h=100ft, SDA, $K_v/K_h=1$ (Cases 44, 89, 134)

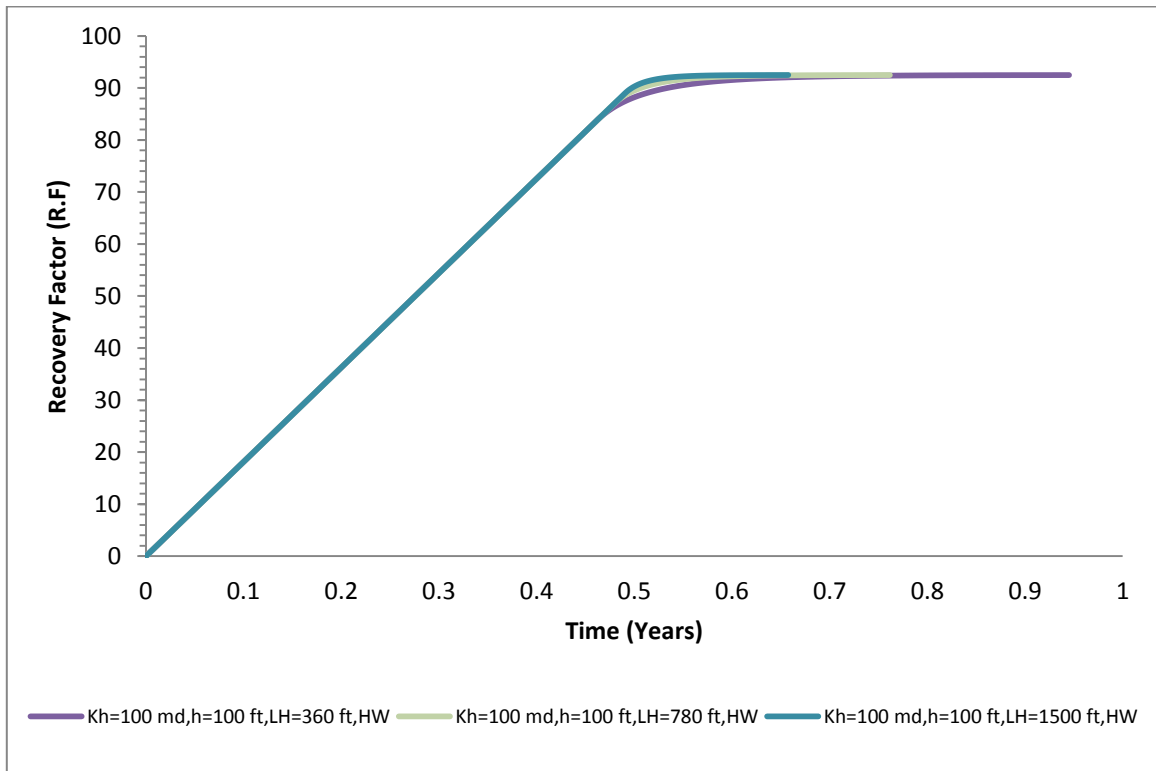


Figure 5.127: Effect of P.R on R.F, A=80 Acres, h=100ft, SDA, $K_v/K_h=1$ (Cases 45, 90, 135)

5.7 Effect of Drainage Area Size, $X_e * Y_e$

Figures 5.128 through 5.137 show the effect of drainage area size on the ultimate recovery factor and on the abandonment time. Two different drainage area sizes 80 acres and 160 acres are considered. The plots presented are for k_v/k_h ratio of 0.1. Each figure corresponds to a given formation thickness and horizontal permeability indicated in the figure.

For low values of formation thickness (20 feet) and penetration ratio (0.2):

- Figure 5.128 shows that, for horizontal permeability of 0.01 md, as the drainage area size increases from 80 acres to 160 acres, the ultimate recovery factor for both HFVW and HW increases while the abandonment time for HFVW more than doubles and for HW increases by about 6 fold.
- Figure 5.129 shows that, for horizontal permeability of 0.1 md, as the drainage area size increases from 80 acres to 160 acres, the ultimate recovery factor for both HFVW and HW increases, and the abandonment time for both HFVW and HW increases by less than two folds. For the VW, drainage area size has no effect on the ultimate recovery factor and the abandonment time for the 160 acres is almost twice the one for the 80 acres.
- Figure 5.130 shows that, for a horizontal permeability of 1 md, as the drainage area size increases from 80 acres to 160 acres, the ultimate recovery factors for HFVW remain almost the same; the same conclusion is obtained for the HW. The abandonment time for both HFVW and HW increases by less than two folds as the drainage area size doubles from 80 acres to 160 acres. For the VW, drainage area size has no effect on the ultimate recovery factor and the abandonment time for the 160 acres is almost twice the one for the 80 acres.

- Figures 5.131 and 5.132 show that, for horizontal permeabilities of 10 md and 100 md, the recovery factors of the HW and VW are about the same, regardless of the value of drainage area size. For both these type of wells, the time to reach abandonment at 160 acres is less than twice the one for the 80 acres.
- For high values of formation thickness (100 feet) and penetration ratio (0.8):
- Figure 5.133 shows that, for horizontal permeability of 0.01 md, the ultimate recovery factor for the HFVW are about the same, regardless of the value of drainage area size. The same conclusion is obtained for the HW. At 160-acres, the time to reach abandonment for the HFVW is about 2.5 times and for the HW is about 2 times the one at 80 acres.
- Figure 5.134 shows that, for horizontal permeability of 0.1 md, the ultimate recovery factor for the HFVW and HW are about the same, regardless of the value of drainage area size. In addition, each of the 3 well types has the same ultimate recovery factor at 160 acres as in 80 acres; recovery factor for the VW is still less than the ones for HW and HFVW. At 160-acres, the time to reach abandonment for the HFVW and HW is about 2 times the one at 80 acres.
- Figure 5.135 shows that, for a horizontal permeability of 1 md, the ultimate recovery factor for the HFVW, HW and VW are about the same, regardless of the value of drainage area size. In such cases, the performance of the HFVW and HW are almost identical at a given drainage area size. At 160-acres, the time to reach abandonment for the HFVW, HW and VW is about 2 times the one at 80 acres.

- Figures 5.136 and 5.137 show that, for horizontal permeabilities of 10 md and 100 md, the ultimate recovery factor for the HW and VW are about the same, regardless of the value of drainage area size. However, the time to reach abandonment time for the vertical well is much larger than the one for the HW. At 160-acres, the time to reach abandonment for the HW and VW is about 2 times the one at 80 acres.

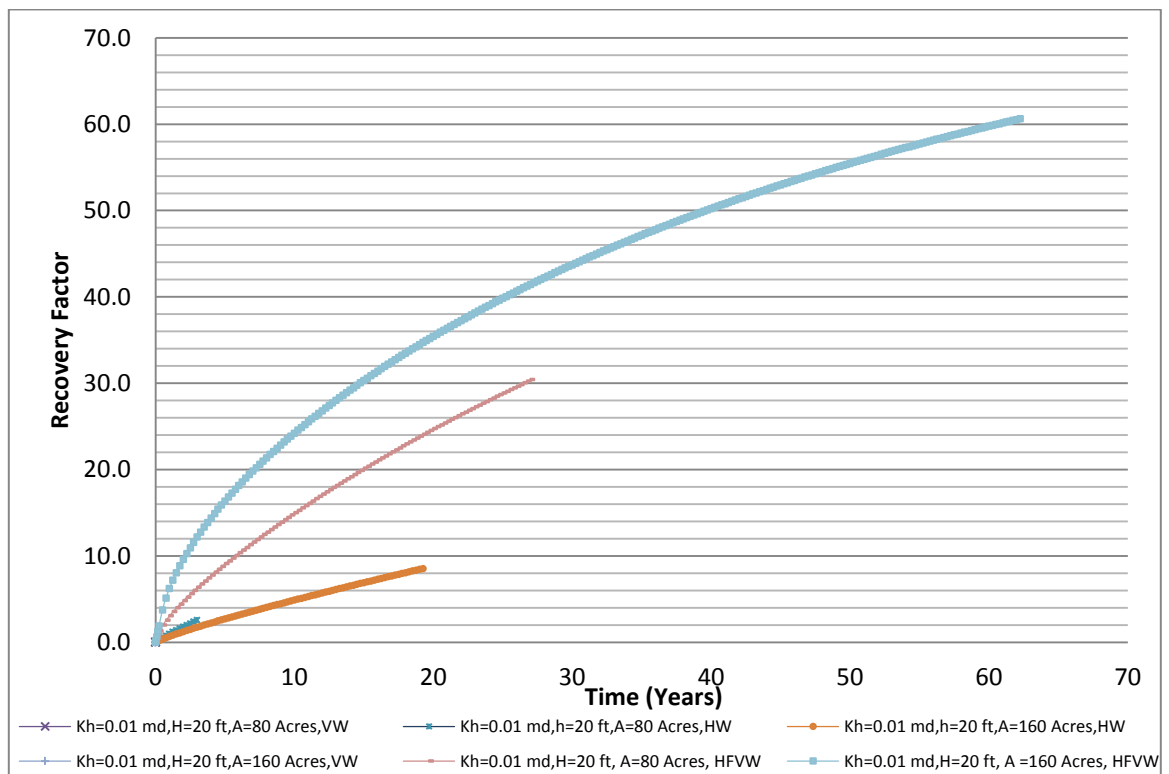


Figure 5.128: Effect of drainage area size on R.F, $K_h = 0.01$ md, $P.R = 0.2$, (Cases 1,136)

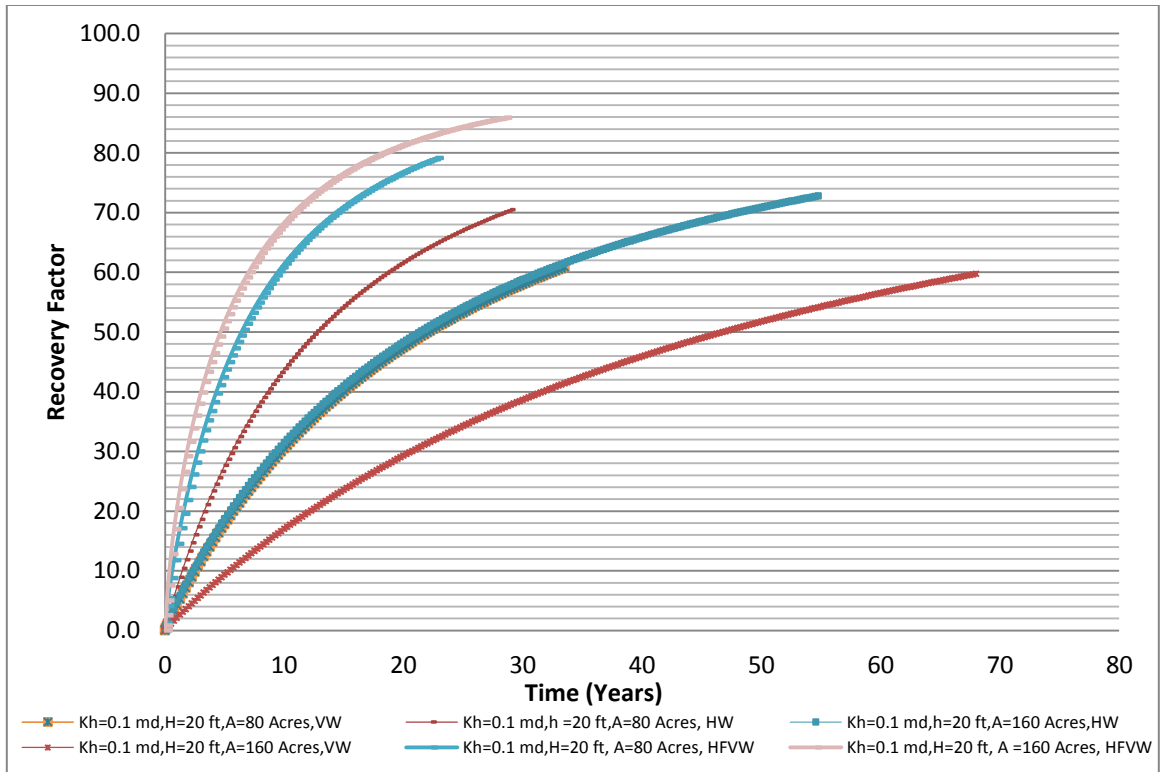


Figure 5.129: Effect of drainage area size on R.F, $K_h = 0.1$ md, $P.R. = 0.2$, (Cases 2,137)

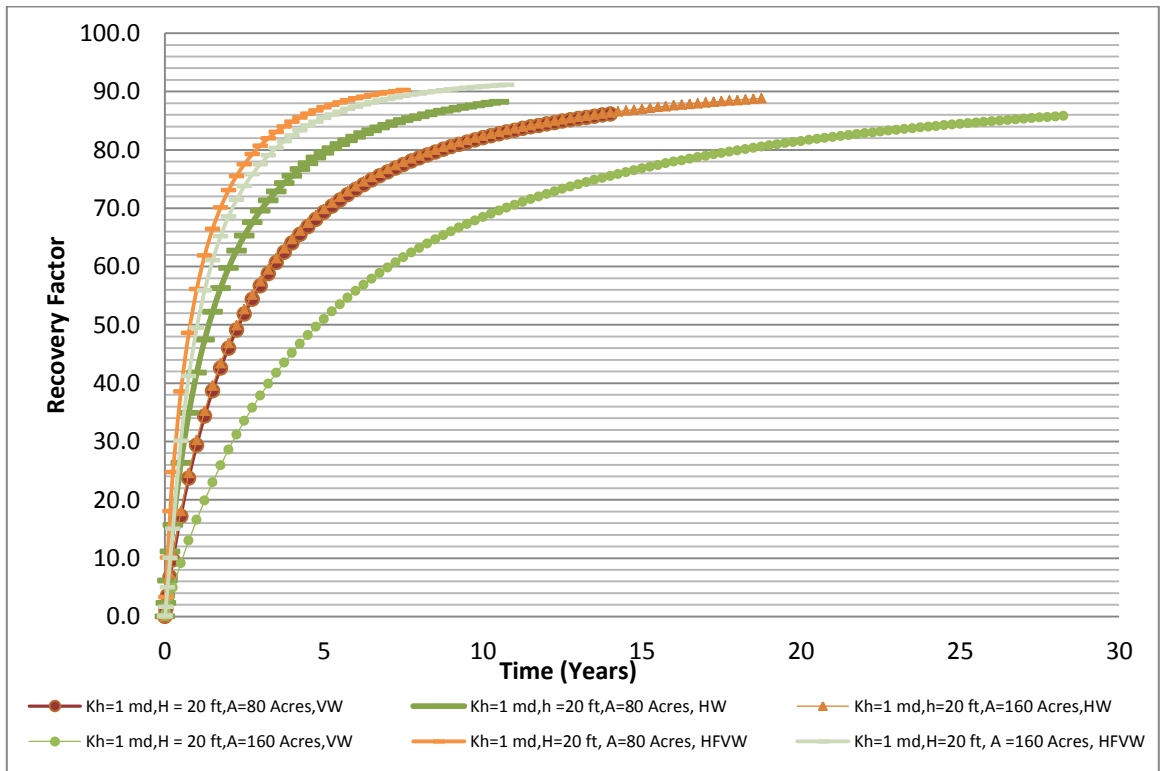


Figure 5.130: Effect of drainage area size on R.F, $K_h = 1$ md, $P.R. = 0.2$, (Cases 3,138)

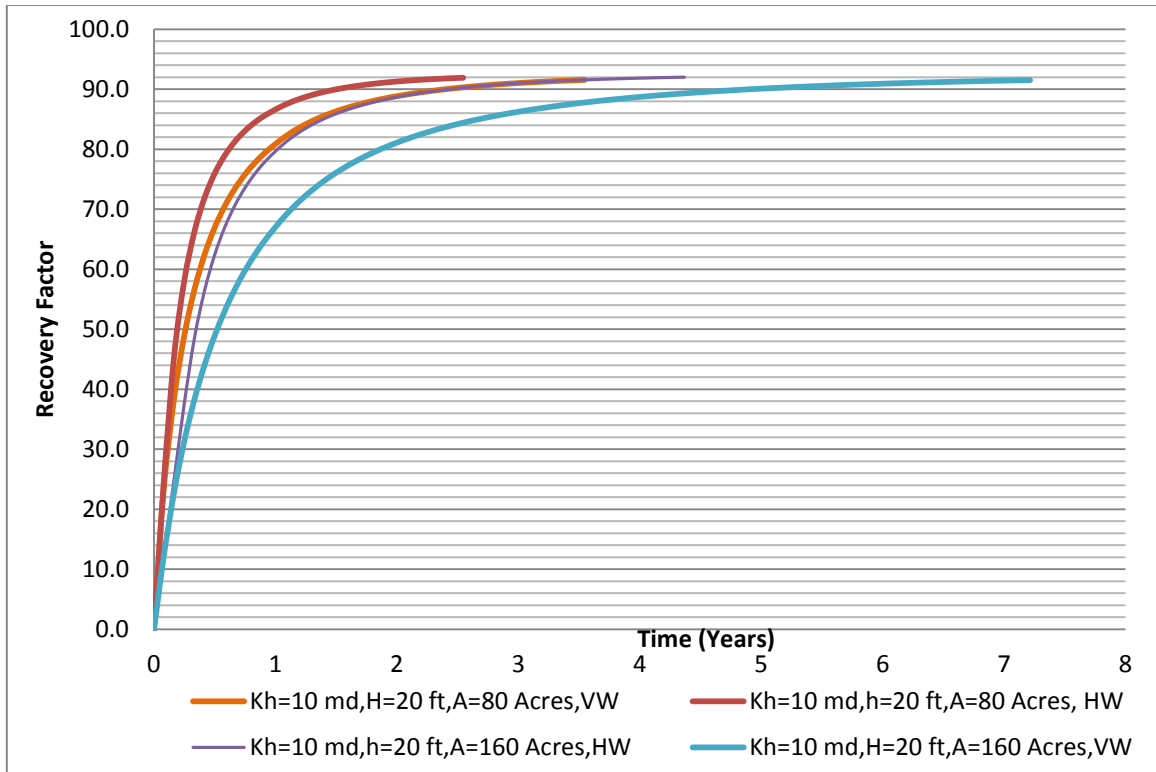


Figure 5.131: Effect of drainage area size on R.F, $K_h = 10$ md, $P.R = 0.2$, (Cases 4,139)

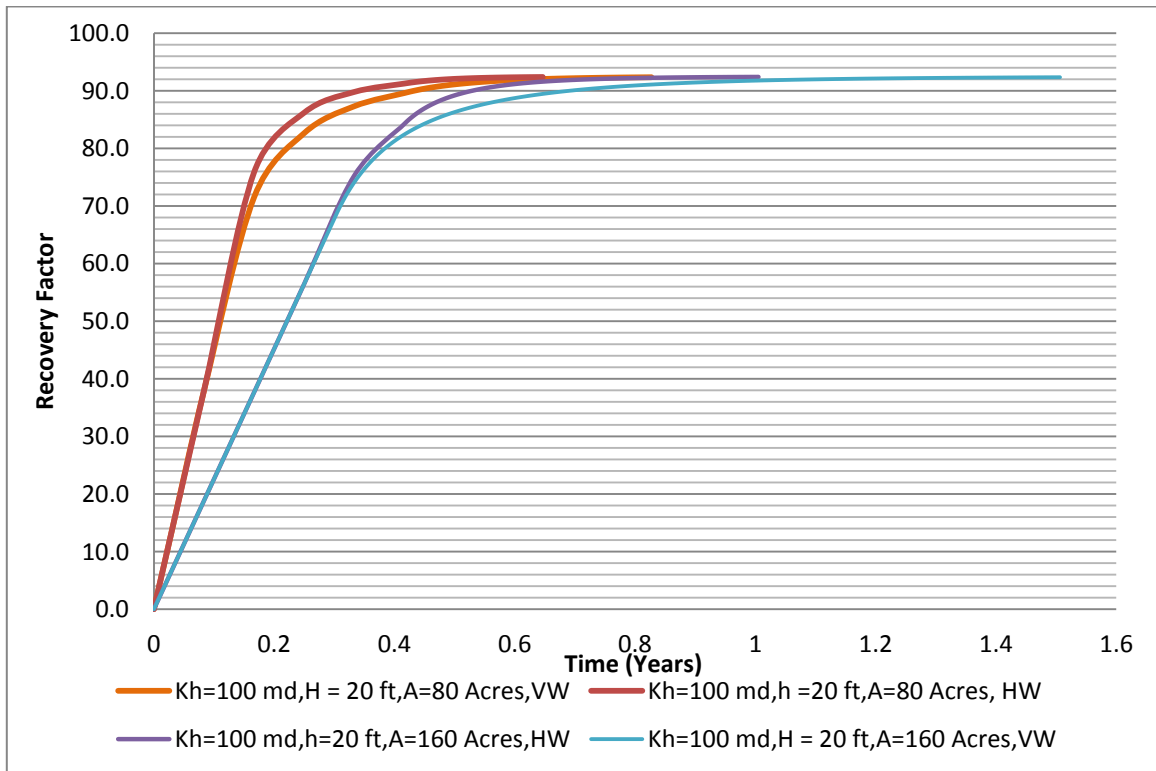


Figure 5.132: Effect of drainage area size on R.F, $K_h = 100$ md, $P.R = 0.2$, (Cases 5,140)

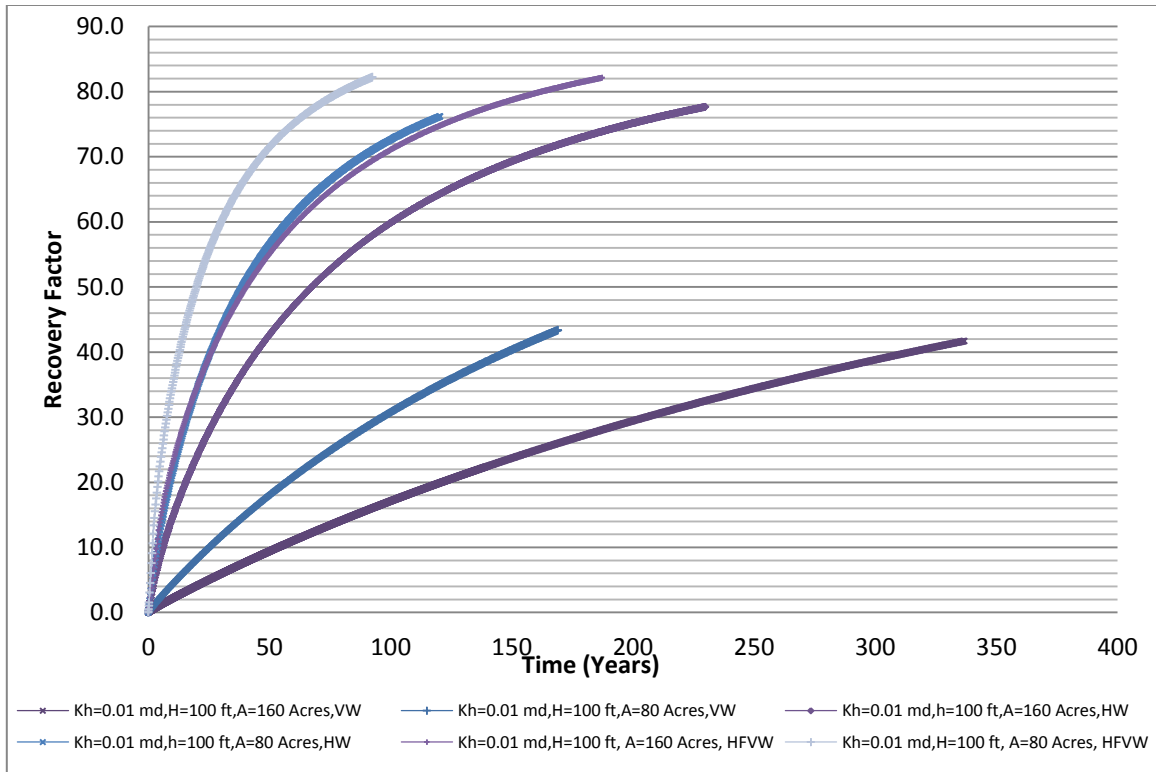


Figure 5.133: Effect of drainage area size on R.F, $K_h = 0.01$ md, $P.R = 0.8$, (Cases 131,266)

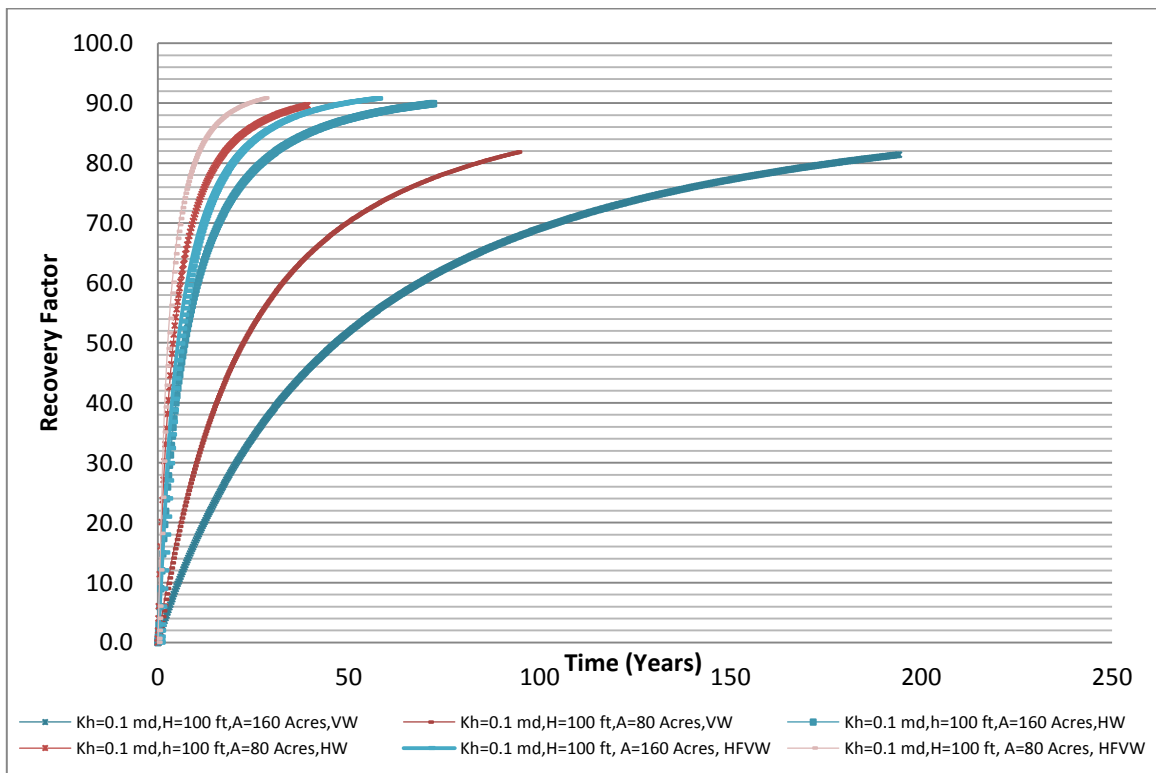


Figure 5.134: Effect of drainage area size on R.F, $K_h = 0.1$ md, $P.R = 0.8$, (Cases 132,267)

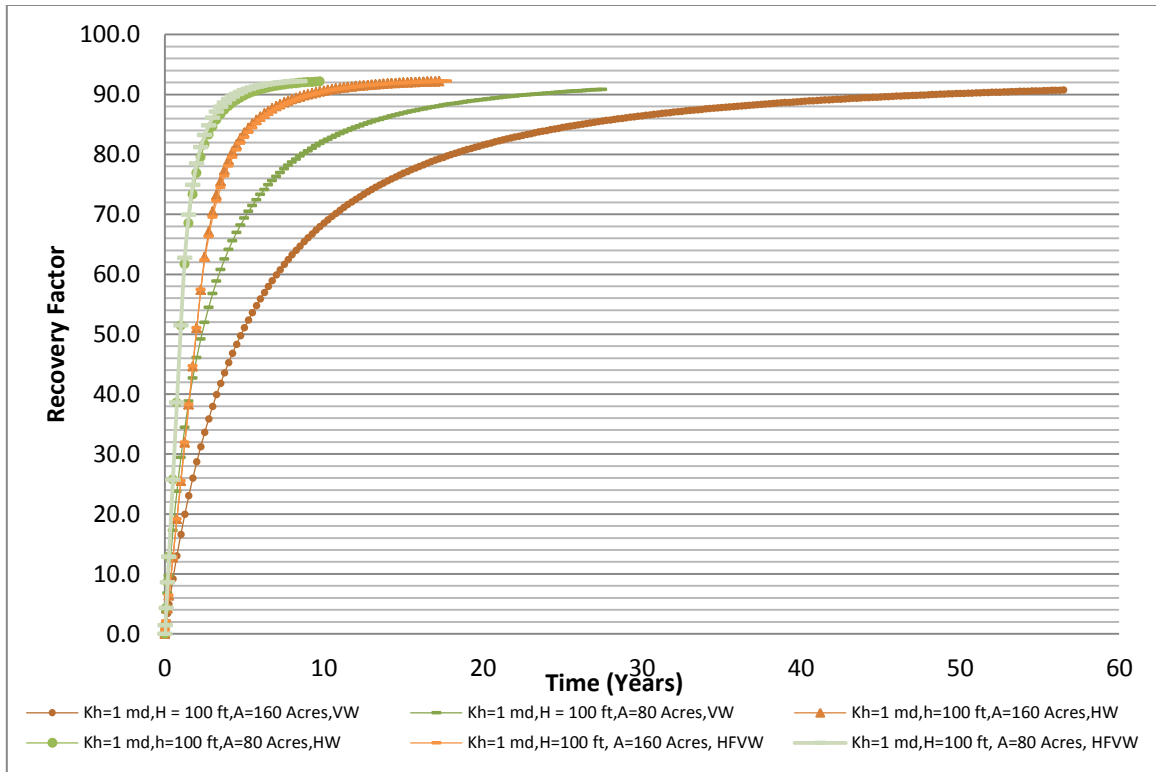


Figure 5.135: Effect of drainage area size on R.F, $K_h = 1$ md, $P.R. = 0.8$, (Cases 133,268)

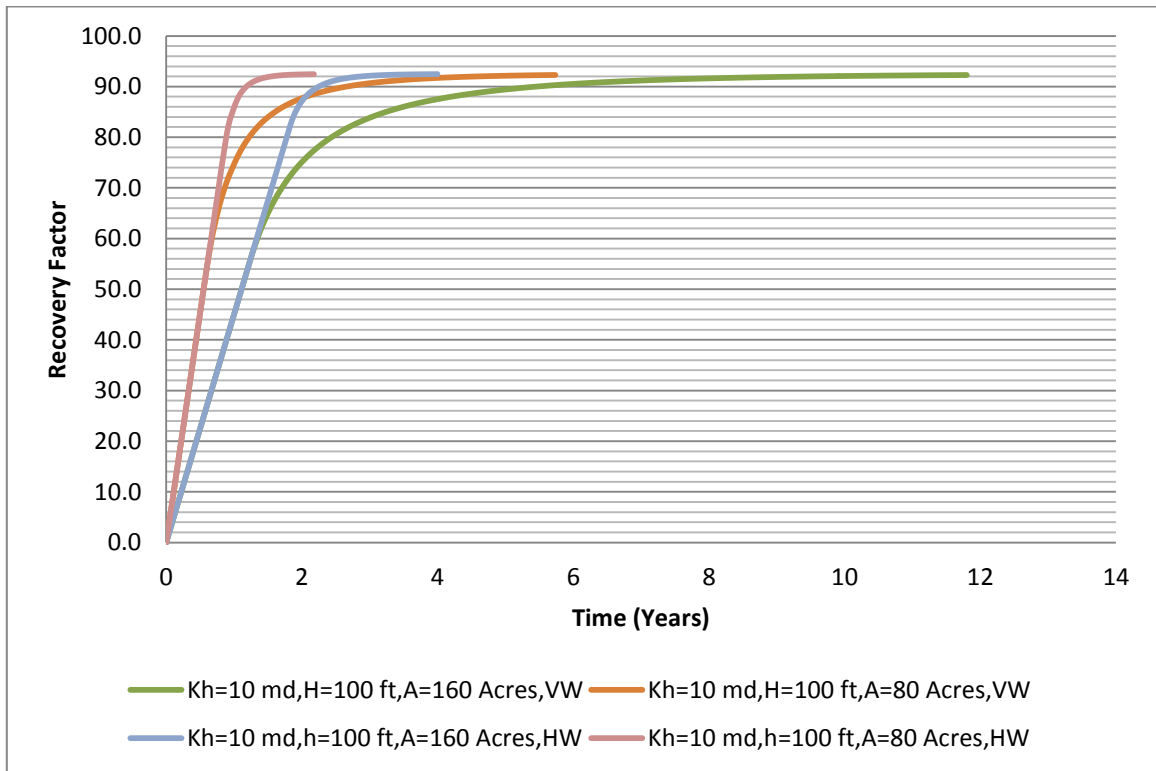


Figure 5.136: Effect of drainage area size on R.F, $K_h = 10$ md, $P.R. = 0.8$, (Cases 134,269)

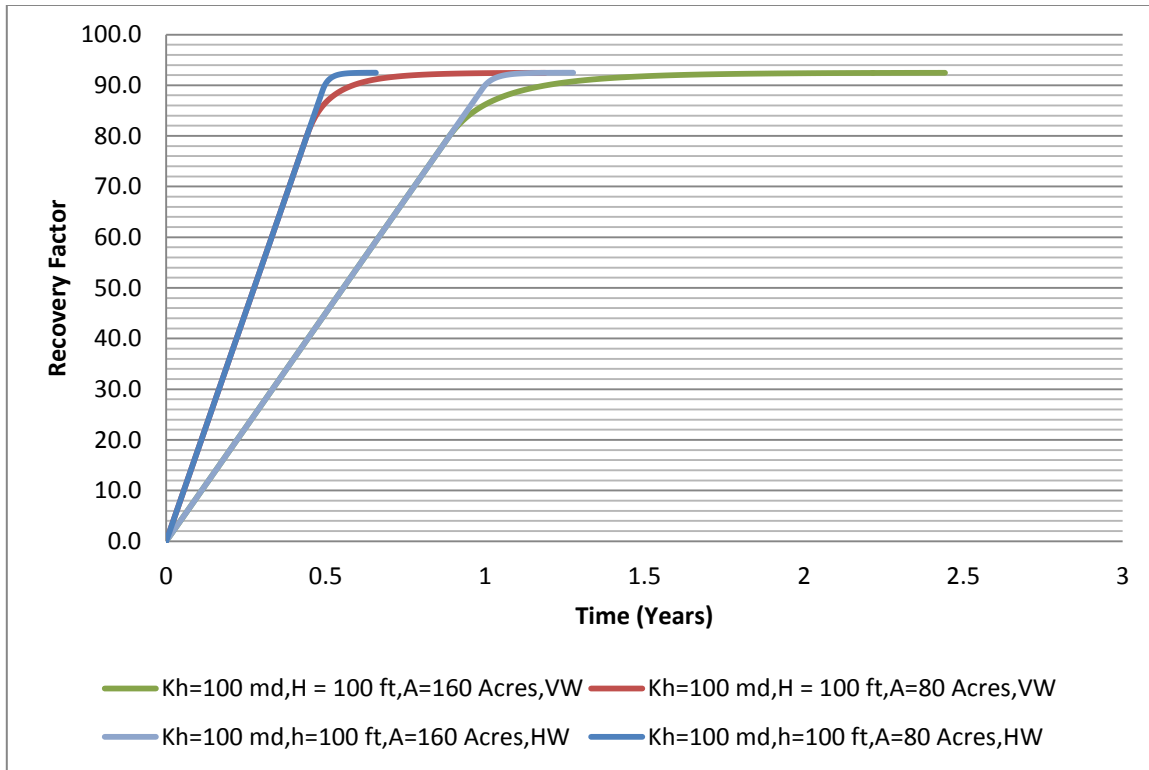


Figure 5.137: Effect of drainage area size on R.F, $K_h = 100$ md, $P.R = 0.8$, (Cases 135,270)

5.8 Effect of Drainage Area Shape, X_e/Y_e

Figures 5.138 through 5.147 show the effect of drainage area shape for k_v/k_h ratio of 0.1. Figures 5.138 through 5.142 are for formation thickness of 20 feet and penetration ratio of 0.2. Figures 5.143 through 5.147 are for formation thickness of 100 feet and penetration ratio of 0.8. Each graph corresponds to a given horizontal permeability and considers two drainage area shapes: square drainage area (SDA) and 2:1 rectangular drainage area (RDA).

For low values of formation thickness (20 feet), and penetration ratio (0.2), the following conclusions can be made:

- For horizontal permeability of 0.01 md (shown in Figure 5.138), the HFVW in RDA performs better than HFVW in SDA in terms of ultimate recovery factor but worse in terms of abandonment time. The same conclusions can be made about the HW. In such cases, the reservoir should be developed with HFVW on a RDA drilling pattern.
- For horizontal permeability of 0.1 md (shown in Figure 5.139), the HFVW in RDA performs almost identical to HFVW in SDA in terms of ultimate recovery factor and better in terms of abandonment time. The same conclusions can be made about the HW. The drainage area shape has no effect on the performance of VW in terms of both ultimate recovery factor and abandonment time. In such cases, the reservoir should be developed with HFVW on RDA drilling pattern.
- For horizontal permeability of 1 md (shown in Figure 5.140), the HFVW in RDA performs almost identical to HFVW in SDA in terms of both the ultimate recovery factor and the abandonment time. The HW in RDA also performs identical to HW in SDA in terms of both the ultimate recovery factor and the abandonment time. The drainage area shape has no effect on the performance of VW in terms of both ultimate recovery factor and abandonment time. In such cases, the reservoir should be developed with HFVW on either a SDA or a RDA drilling pattern.
- For horizontal permeability of 10 md (shown in Figure 5.141), the HW has identical performance in SDA and RDA in terms of ultimate recovery factor but better performance in RDA in terms of abandonment time. The drainage area shape has almost no effect on the performance of VW in terms of both ultimate recovery factor and abandonment time. The time to abandonment time for VW is much

larger than the one for HW. In such cases, the reservoir should be developed with HW on RDA drilling pattern.

- For horizontal permeability of 100 md (shown in Figure 5.142), the HW has almost identical performance in SDA and RDA in terms of both ultimate recovery factor and abandonment time. The drainage area shape has almost no effect on the performance of VW in terms of both the ultimate recovery factor and the abandonment time. The time to abandonment time for VW is larger than the one for HW. In such cases, the reservoir can be developed with either HW or VW.

For high values of formation thickness (100 feet) and penetration ratio (0.8), the following conclusions can be made:

- For horizontal permeability of 0.01 md (shown in Figure 5.143), the HFVW in RDA has the best performance of all other cases, both in terms of the ultimate recovery factor and the abandonment time. The HW performs better in RDA than in SDA, both in terms of the ultimate recovery factor and the abandonment time. The drainage area shape has not effect on the performance of VW, both in terms of the ultimate recovery factor and the abandonment time.
- For horizontal permeability of 0.1 md (shown in Figure 5.144), the HFVW performs almost identical in RDA and SDA in terms of the ultimate recovery factor but performs better in RDA in terms of the abandonment time. The HW performs better in RDA than in SDA in terms of the abandonment time. The drainage area shape has no effect on the performance of VW, both in terms of the ultimate recovery factor and the abandonment time.

- For horizontal permeability of 1 md (shown in Figure 5.145), the HFVW performs almost identical in RDA and SDA in terms of the ultimate recovery factor but performs better in RDA in terms of the abandonment time. The HW performs better in RDA than in SDA in terms of the abandonment time. The drainage area shape has no effect on the performance of VW, both in terms of the ultimate recovery factor and the abandonment time. HFVW in SDA and HW in RDA have almost identical performance.
- For horizontal permeability of 10 md (shown in Figure 5.146), the HW performs better in RDA than in SDA in terms of the abandonment time. The drainage area shape has no effect on the performance of VW, both in terms of the ultimate recovery factor and the abandonment time. The time to abandonment is much less for the HW than for the VW. HW should be used to develop the reservoir.
- For horizontal permeability of 100 md (shown in Figure 5.147), the drainage area shape has no effect on the performance of HW and on the performance of VW, in terms of both the ultimate recovery factor and the abandonment time. The abandonment time is much less for the HW than for the VW. HW should be used to develop the reservoir.

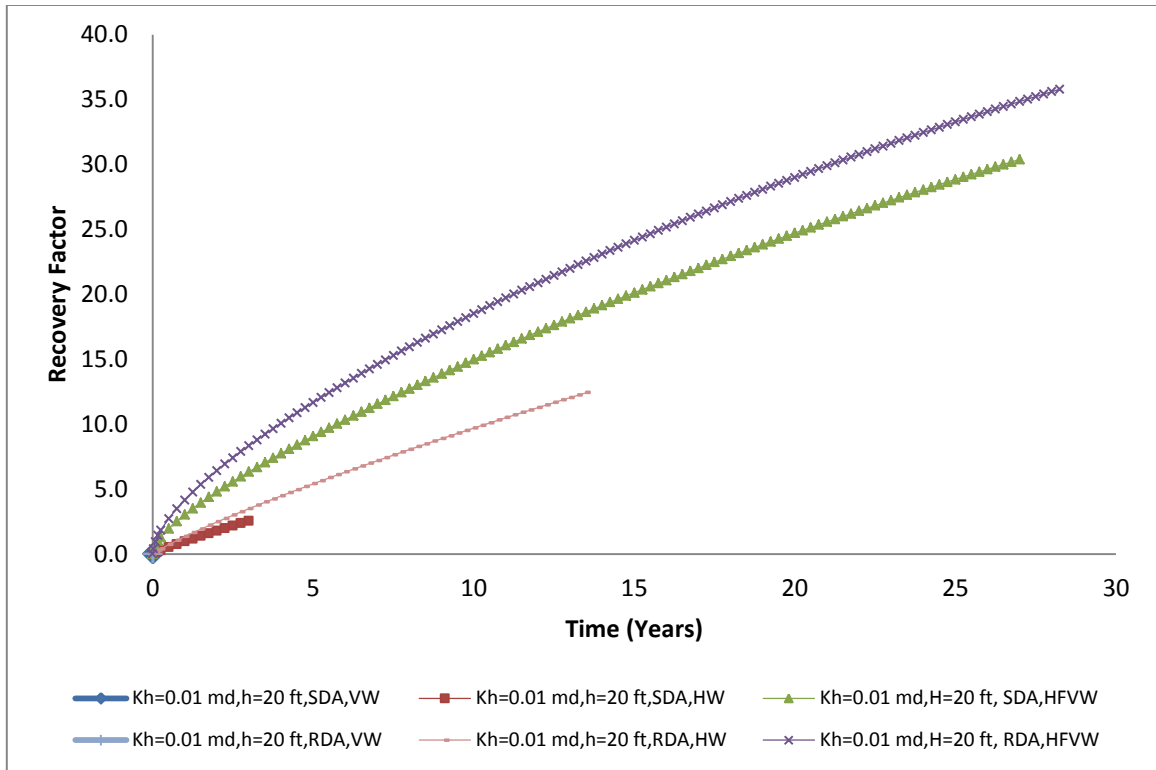


Figure 5.138: Effect of drainage area shape on R.F, $K_h = 0.01$ md, $P.R. = 0.2$, (Cases 1, 1)

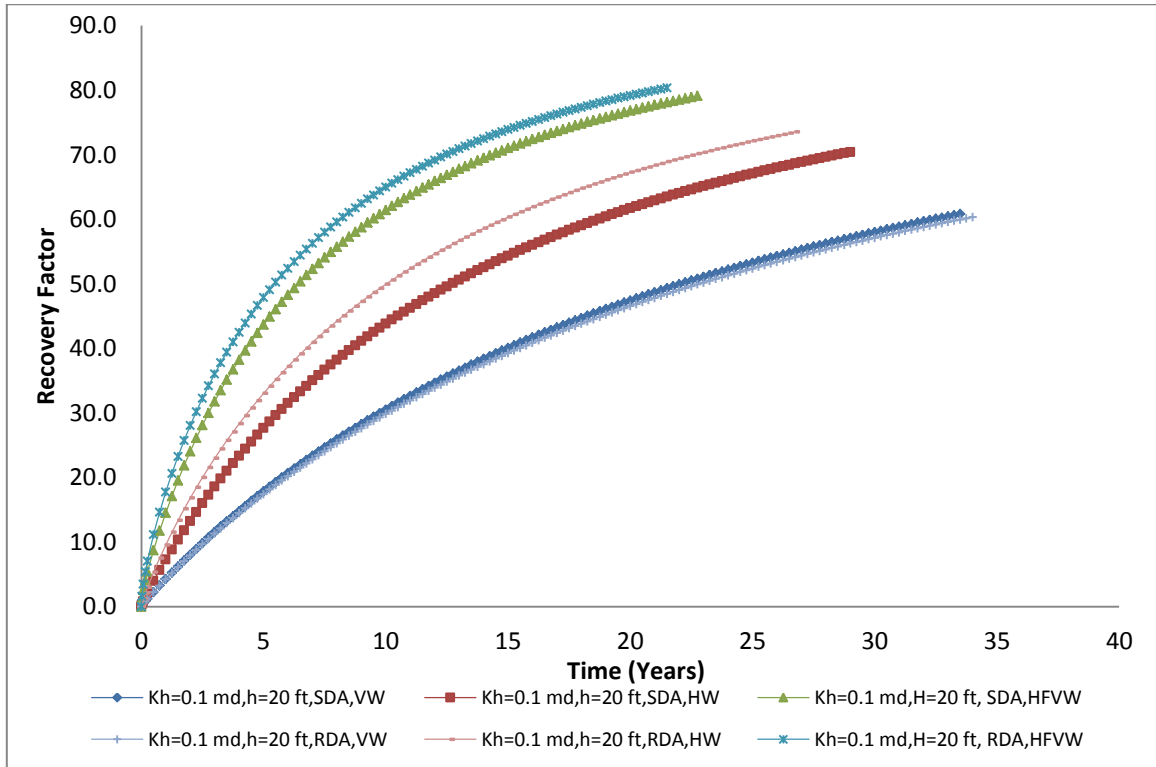


Figure 5.139: Effect of drainage area shape on R.F, $K_h = 0.1$ md, $P.R. = 0.2$, (Cases 2, 2)

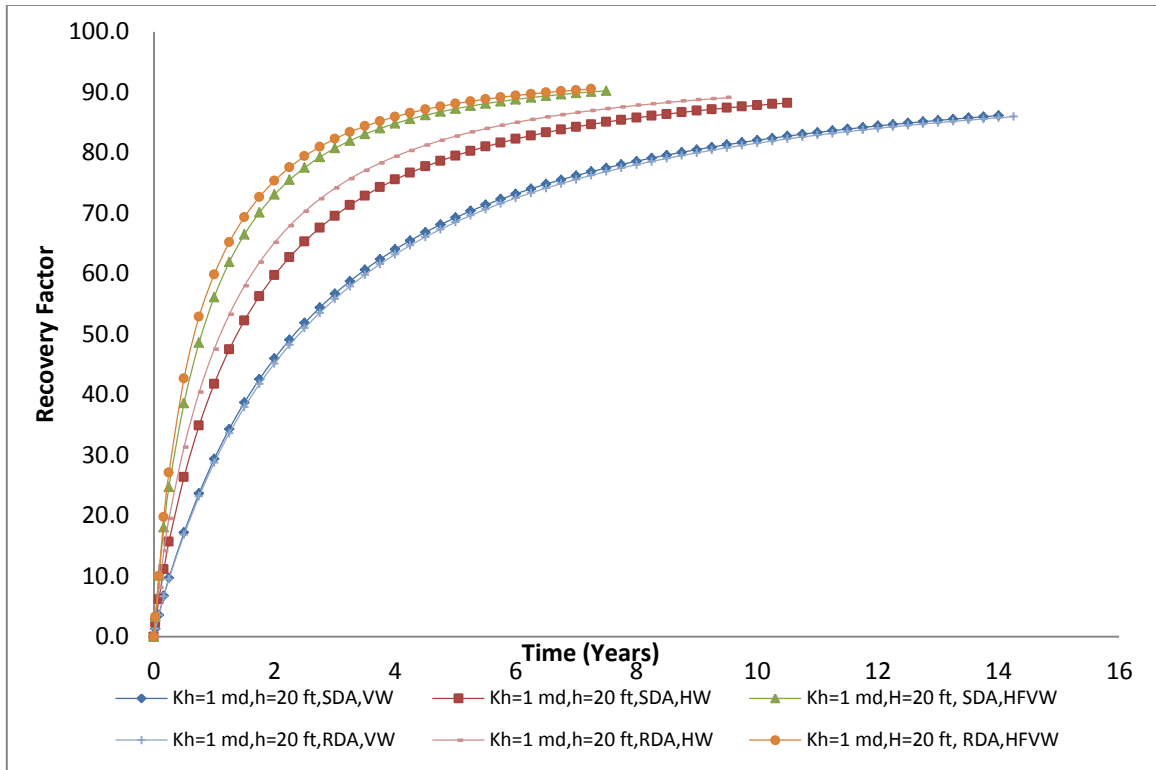


Figure 5.140: Effect of drainage area shape on R.F, $K_h = 1$ md, P.R =0.2, (Cases 3, 3)

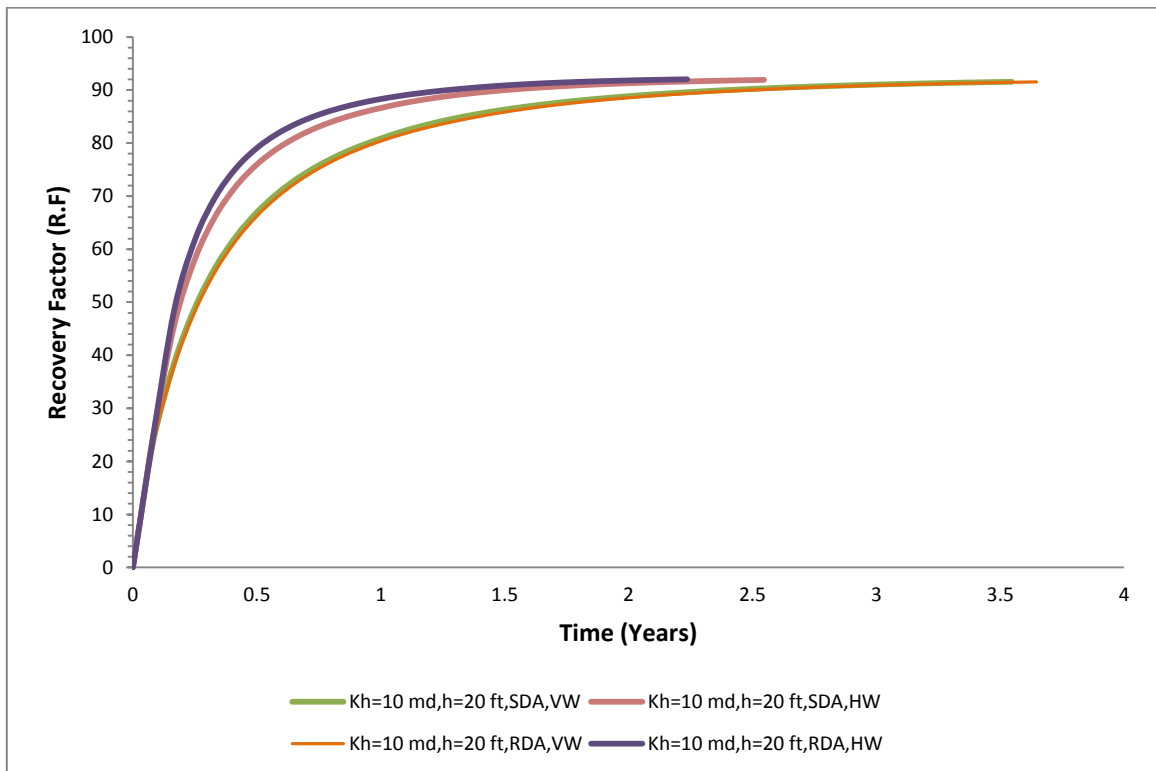


Figure 5.141: Effect of drainage area shape on R.F, $K_h = 10$ md, P.R =0.2, (Cases 4, 4)

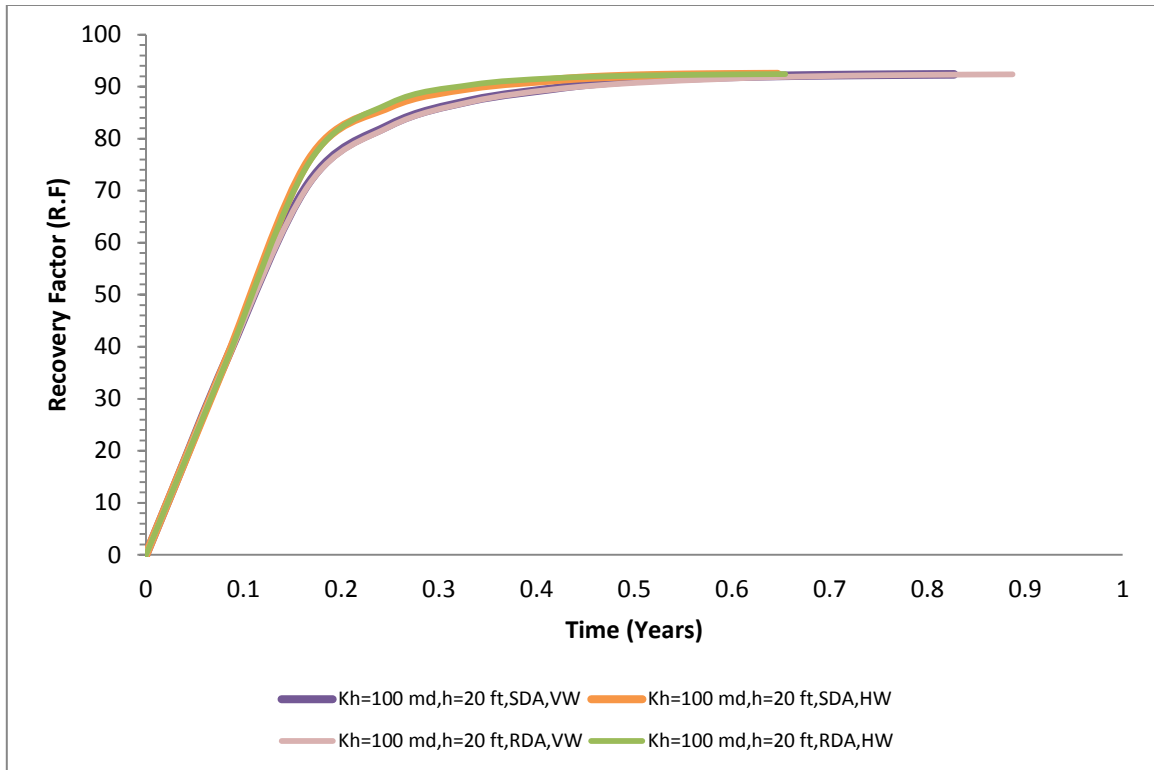


Figure 5.142: Effect of drainage area shape on R.F, $K_h = 100$ md, P.R =0.2, (Cases 5, 5)

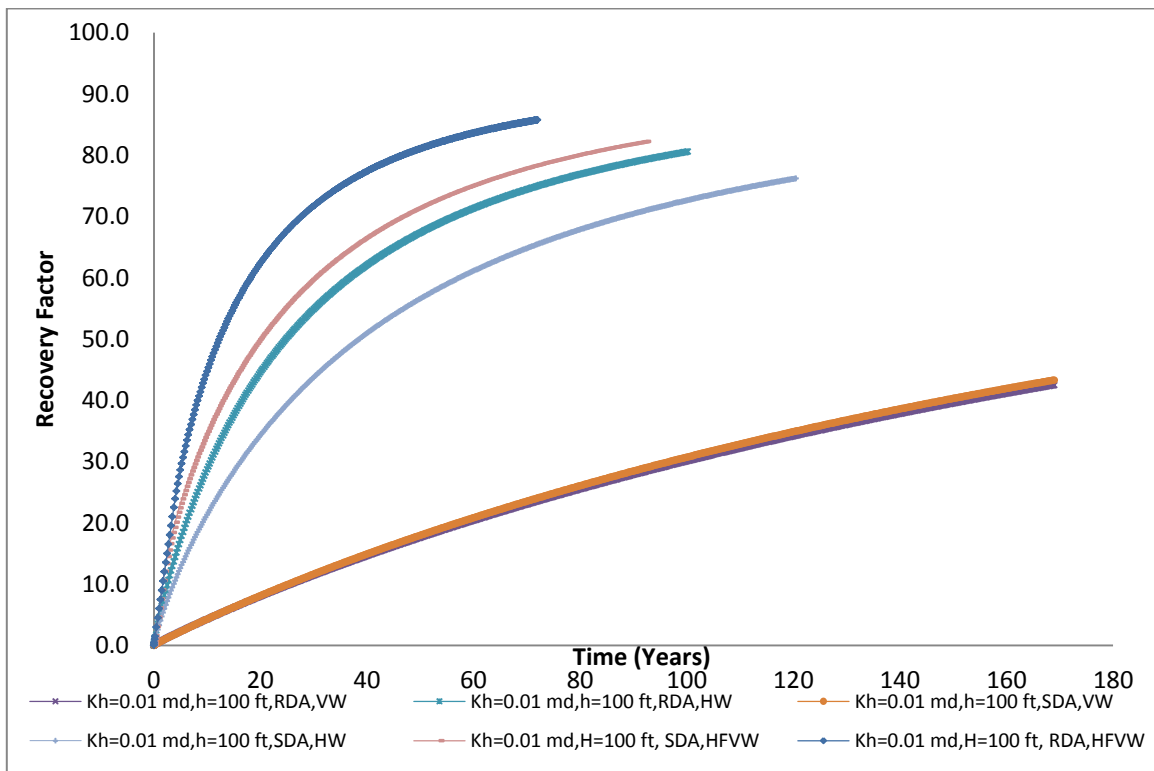


Figure 5.143: Effect of drainage area shape on R.F, $K_h = 0.01$ md, P.R =0.8, (Cases 131,131)

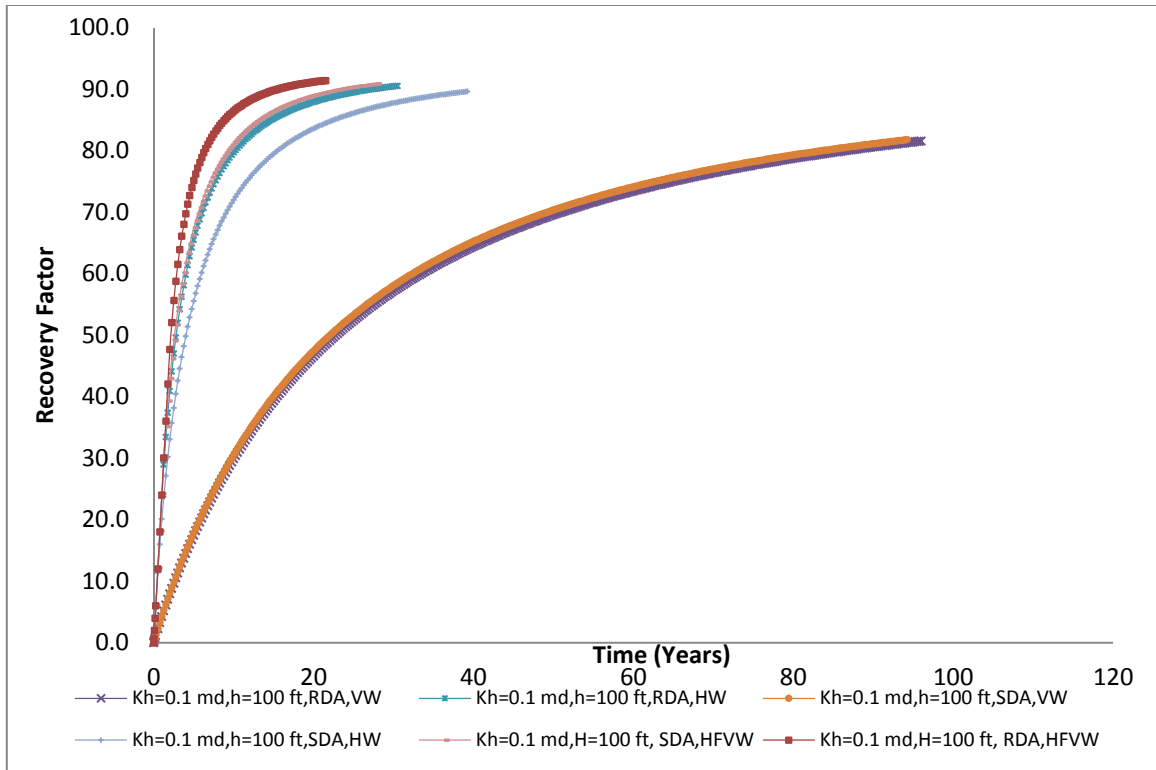


Figure 5.144: Effect of drainage area shape on R.F, $K_h = 0.1$ md, $P.R = 0.8$, (Cases 132,132)

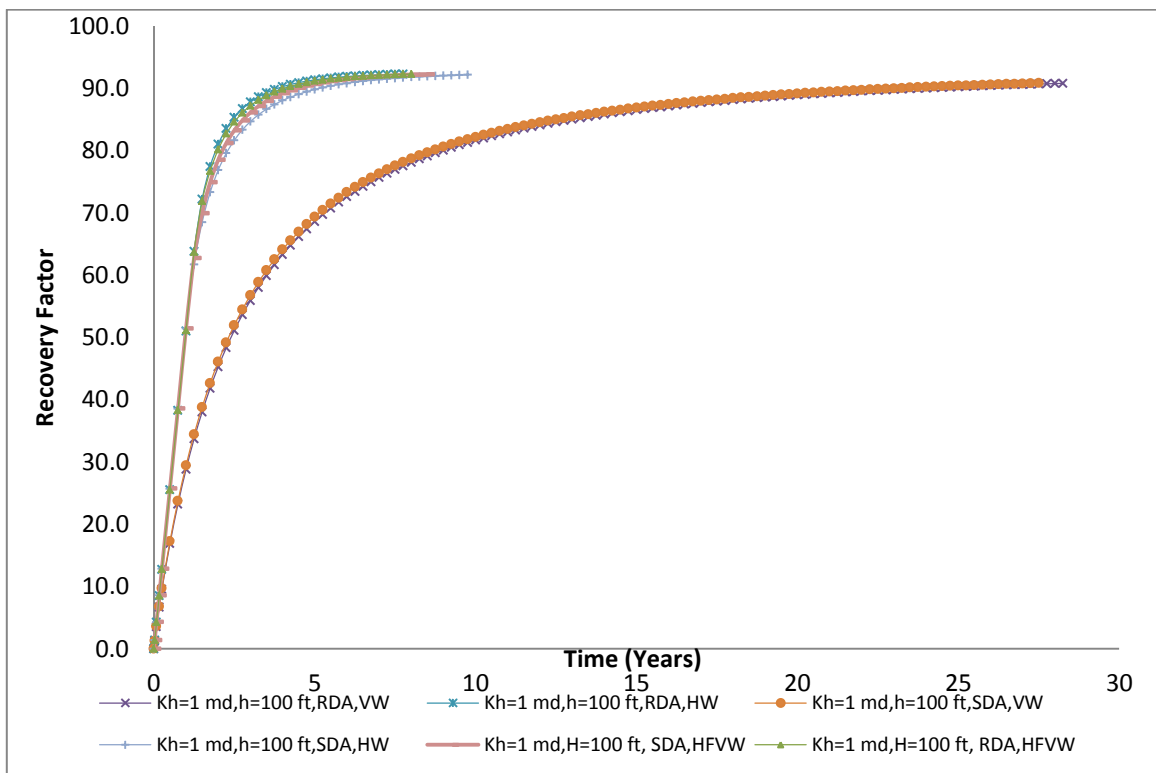


Figure 5.145: Effect of drainage area shape on R.F, $K_h = 1$ md, $P.R = 0.8$, (Cases 133,133)

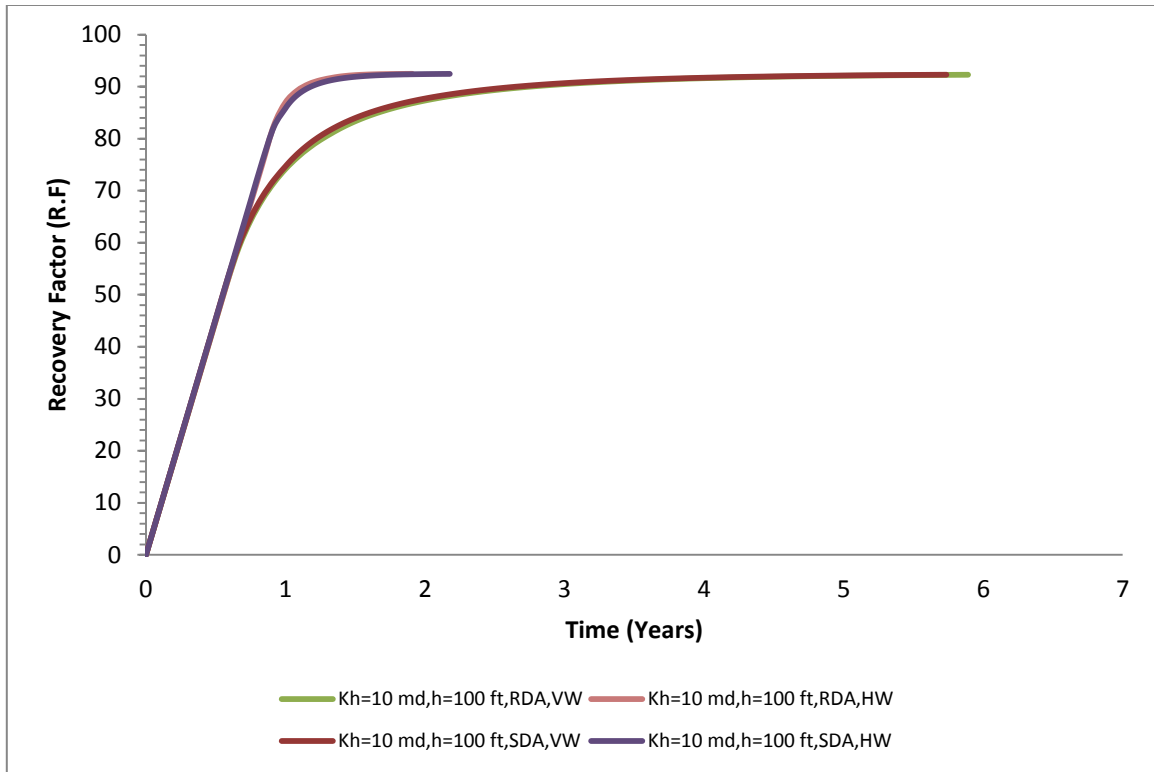


Figure 5.146: Effect of drainage area shape on R.F, $K_h = 10$ md, $P.R = 0.8$, (Cases 134,134)

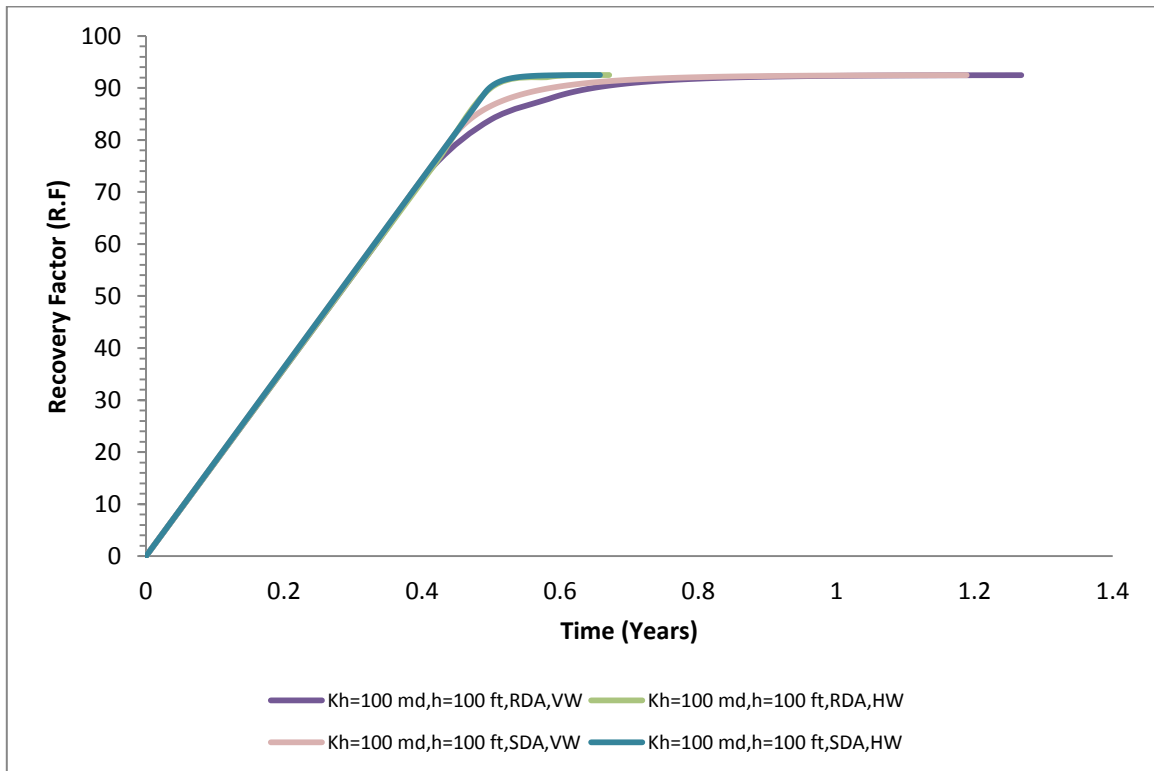


Figure 5.147: Effect of drainage area shape on R.F, $K_h = 100$ md, $P.R = 0.8$, (Cases 135,135)

5.9 Effect of Fracture Conductivity and Fracture Penetration Ratio

Figures 5.148 through 5.156 show the effect of fracture conductivity and fracture length (penetration ratios of 0.2, 0.4 and 0.8) on the performance of HFVW in an 80-acre square drainage areas. Each figure corresponds to a given horizontal permeability (0.01 md, 0.1 md, or 1.0 md) and formation thickness (20 feet, 50 feet, or 100 feet).

Figure 5.148 shows that, at low values of horizontal permeability (0.01 md) and formation thickness (20 feet), a hydraulic fracture with the highest penetration ratio gives the best well performance and that the fracture conductivity has no influence on well performance in this case. The higher the value of fracture penetration ratio, the better the well performance, irrespective of the value of fracture conductivity. Therefore, in thin formations with low horizontal permeability, hydraulic fractures with high penetration ratio (0.8) and low conductivity of 200 md-feet should be designed and created in order to reduce costs while providing excellent well performance. In the case where the horizontal permeability is 0.01 md and formation thickness is 20 feet, the hydraulic fracture of penetration ratio of 0.8 gives the highest value of abandonment time which is unique in our results. In all other results in this section, the best case scenario gives the highest ultimate recovery factor at the lowest value for the abandonment time.

Figures 5.149 and 5.150 show that, in reservoirs with the horizontal permeability of 0.01 md, as formation thickness has increased to 50 feet or 100 feet, the abandonment time in the high penetration ratio fracture case has the lowest abandonment time. Again, this figure shows that a hydraulic fracture of high penetration ratio (0.8) and low conductivity (200 md-feet) has identical performance as a hydraulic fracture of high penetration ratio (0.8) and high conductivity (2000 md-feet).

Figure 5.151 shows that, at a horizontal permeability of 0.1 md and formation thickness of 20 feet, the value of fracture conductivity starts to affect well performance. In such cases, the hydraulic fracture of high penetration ratio (0.8) and moderate conductivity (1000 md-feet) is needed to give the same performance as a hydraulic fracture of high penetration ratio (0.8) and high conductivity (2000 md-feet), thus giving the highest ultimate recovery factor and lowest abandonment time.

Figures 5.152 and 5.153 show that, for formation thicknesses of 50 feet and 100 feet, at a horizontal permeability of 0.1 md, all cases give about the same ultimate recovery factor. However, the fracture with the highest penetration ratio (0.8) and intermediate conductivity (1000 md-feet) gives the same performance as the fracture with the highest penetration ratio (0.8) and highest conductivity (2000 md-feet), resulting in lowest value for the abandonment time and highest ultimate recovery factor.

Figure 5.154 shows that at a horizontal permeability of 1 md and formation thickness of 20 feet, all fractures have the same ultimate recovery factor. However, the value of fracture conductivity becomes important at this higher horizontal permeabilities (1 md) as high fracture conductivity will decrease the value of abandonment time considerably compared to low fracture conductivity. For example, this figure shows that the hydraulic fracture of length 780 feet and of conductivity 2000 md-feet performs better than a hydraulic fracture of length 1500 feet and of conductivity 200 md-feet, both in terms of ultimate recovery factor and abandonment time.

Figures 5.155 and 5.156 show that, for a horizontal permeability of 1 md, as formation thickness increases to 50 feet or 100 feet, all fractures shown in these figures give the same ultimate recovery factor but different abandonment time. Again, in the case of 1 md, high

fracture conductivity is needed along with high to moderate penetration ratio in order to reduce the abandonment time.

Table B.1 and B.2 shows the values of dimensionless conductivity, F_{CD} , for all cases considered in this research. Table B.1 is for the square drainage area while Table B.2 is for the 2:1 rectangular drainage area. Using the values of FCD in Table B.1 and observing the behavior of HFVW shown in Figures 5.22 through 5.57 and Figures 5.148 through 5.164, one can state the following:

- In a reservoir with a given horizontal permeability, the performance of the HFVW with a given fracture conductivity improves as FCD decreases (this means that large fracture length provides better performance than a short fracture length).
- At a horizontal permeability of 0.01 md, the results show that high fracture penetration ratio (0.8) gives the best performance and that the value of FCD has no effect on the well performance. The magnitude of FCD is not a reflection of how advantageous is the HFVW over the vertical well because low value of FCD and high value of FCD provide the same performance for HFVW.
- As horizontal permeability increases from 0.01 md to 1 md, the FCD decreases, if all other well and reservoir parameters remains the same. In this case, the graphical results show that the advantage of HFVW over VW and HW of the same penetration ratio decreases.
- For the same fracture penetration ratio, the value of FCD for RDA is smaller than the value for SDA due to the longer horizontal well length for RDA.

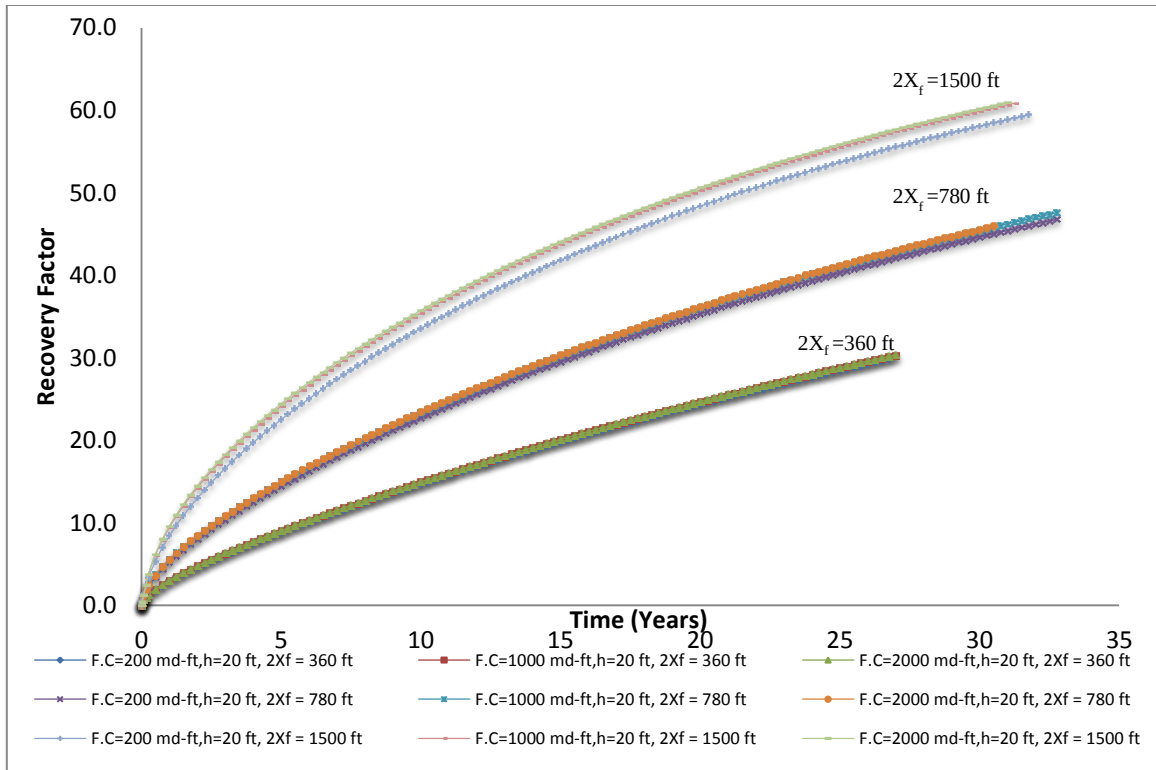


Figure 5.148: Effect of F.C & frac. length on R.F, $K_h=0.01$ md, $h=20$ ft, $A=80$ acres, SDA

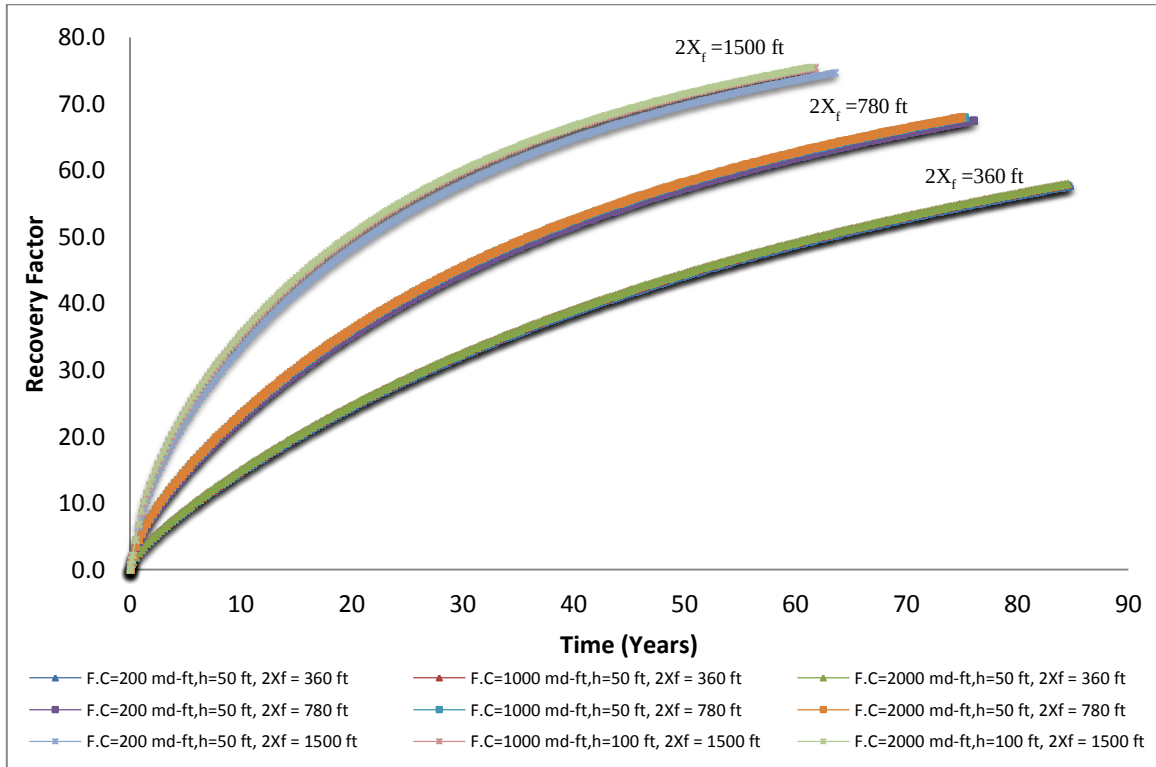


Figure 5.149: Effect of F.C & frac. length on R.F, $K_h=0.01$ md, $h=50$ ft, $A=80$ acres, SDA

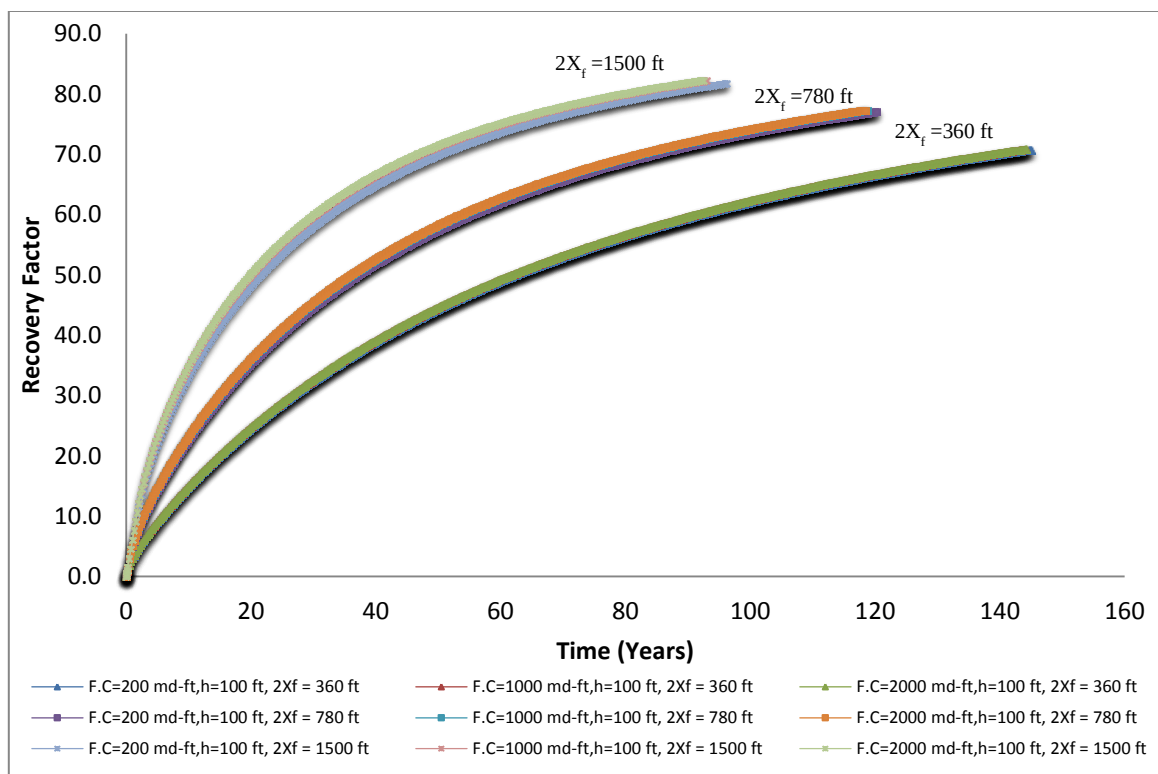


Figure 5.150: Effect of F.C & frac. length on R.F, $K_h=0.01$ md, $h=100$ ft, $A=80$ acres, SDA

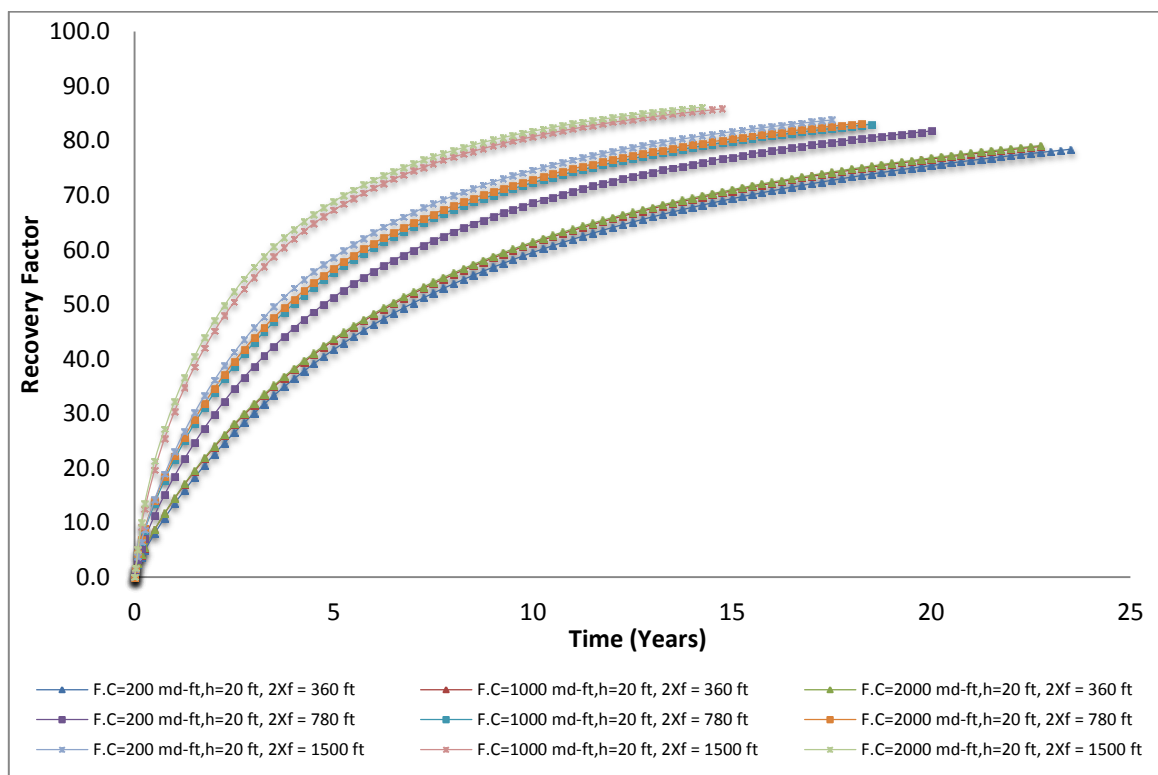


Figure 5.151: Effect of F.C & frac. length on R.F, $K_h=0.1$ md, $h=20$ ft, $A=80$ acres, SDA

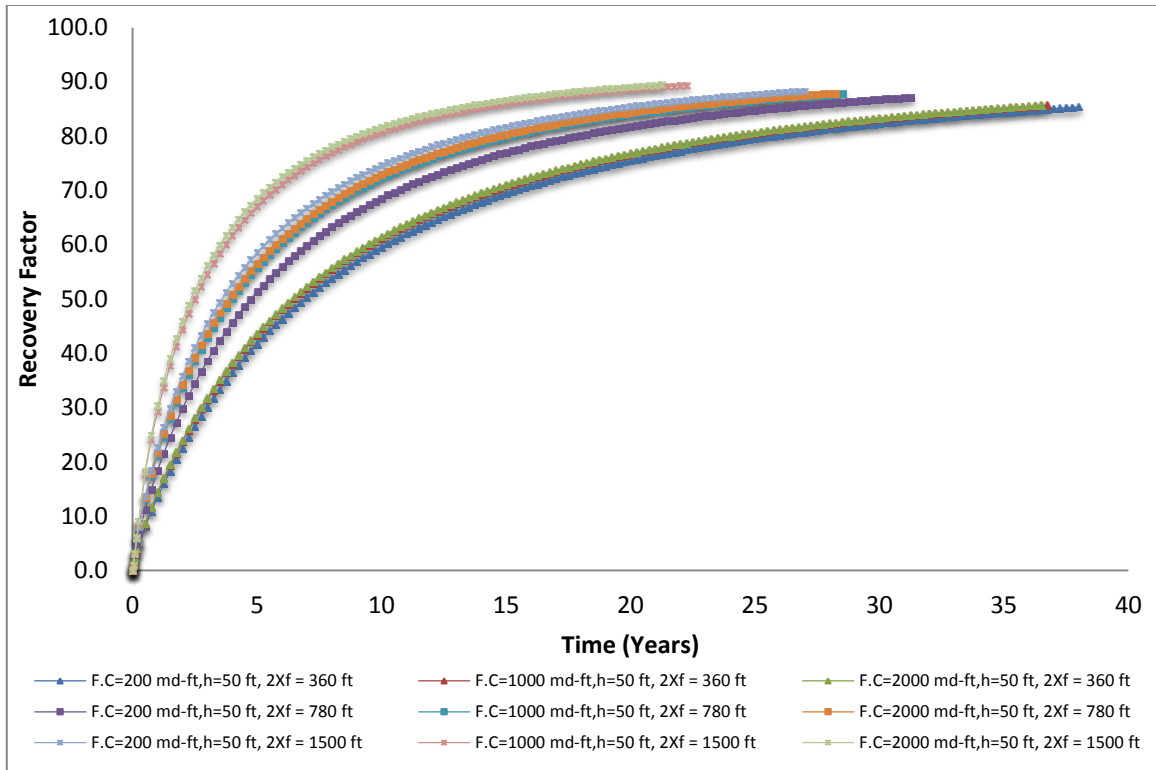


Figure 5.152: Effect of F.C & frac. length on R.F, $K_h=0.1\text{md}$, $h=50\text{ ft}$, $A=80\text{ acres}$, SDA

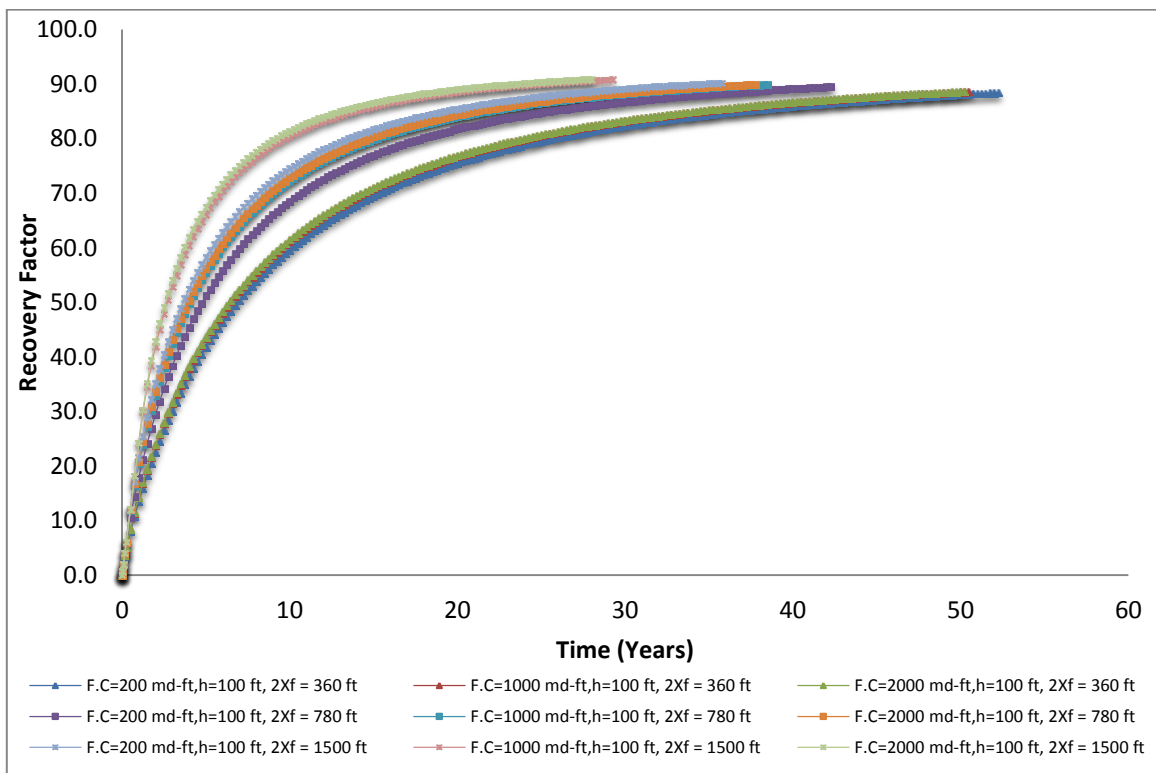


Figure 5.153: Effect of F.C & frac. length on R.F, $K_h=0.1\text{md}$, $h=100\text{ ft}$, $A=80\text{ acres}$, SDA

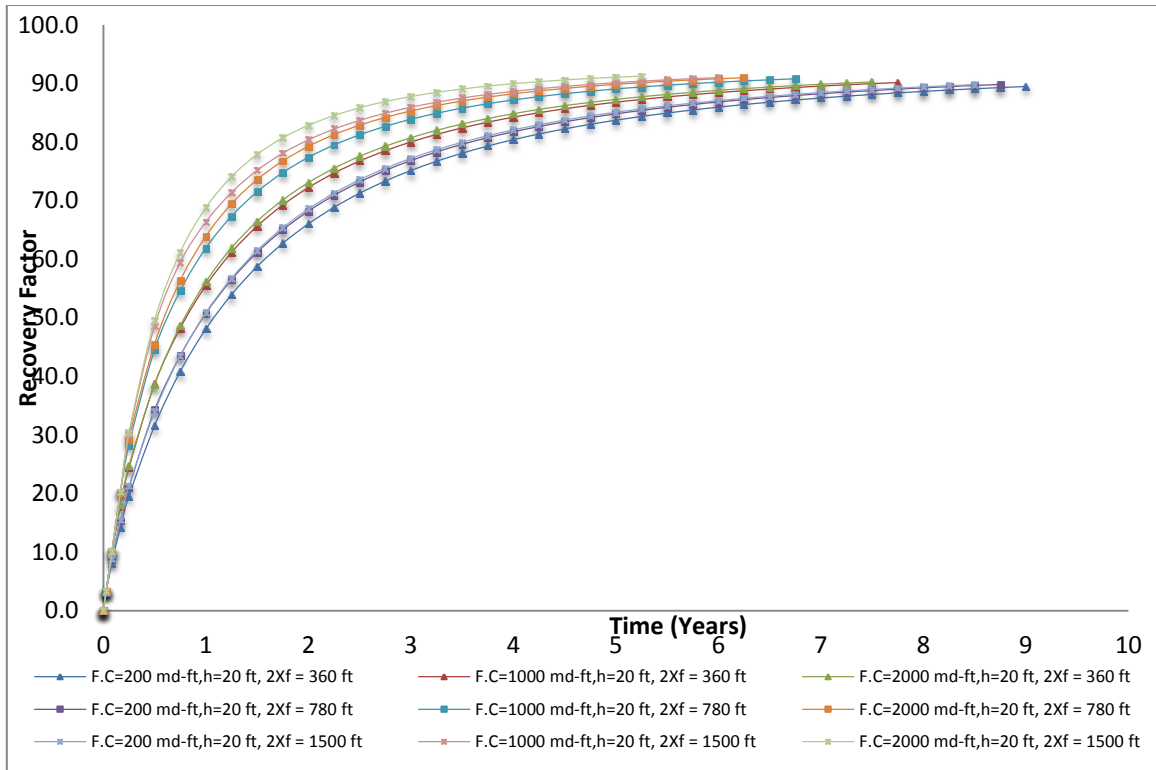


Figure 5.154: Effect of F.C & frac. length on R.F, $K_h=1\text{md}$, $h=20\text{ ft}$, $A=80\text{ acres}$, SDA

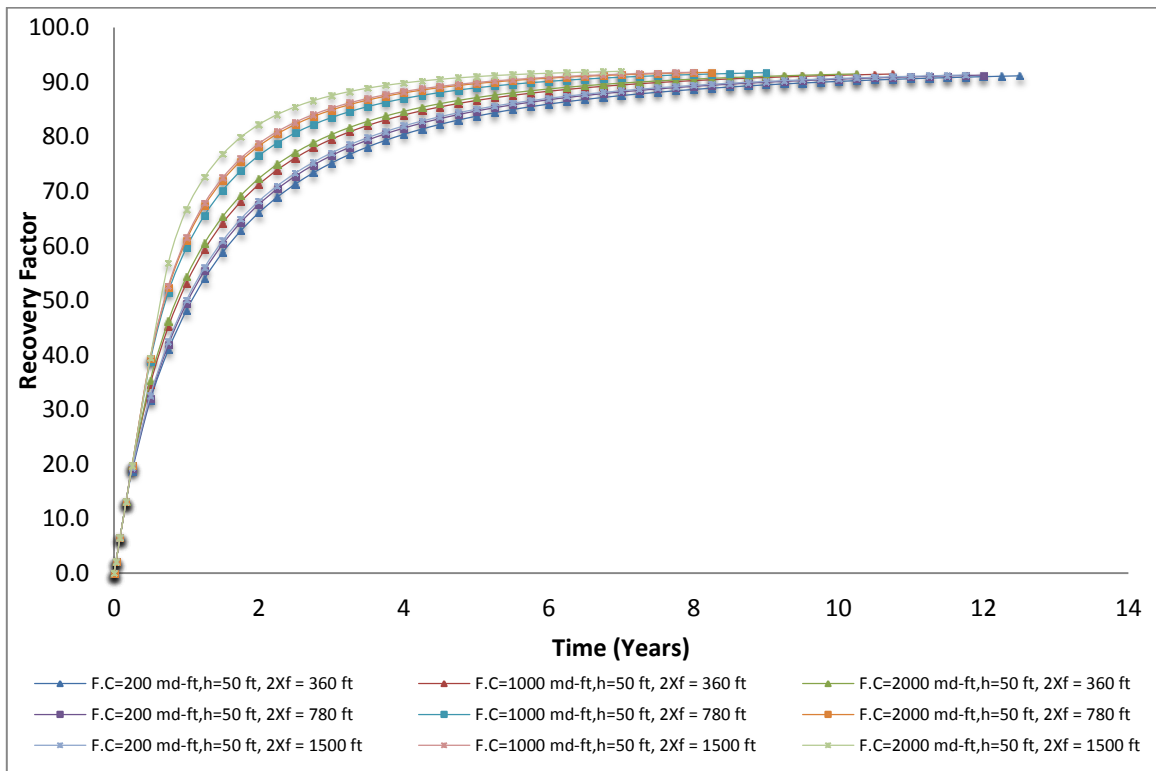


Figure 5.155: Effect of F.C & frac. length on R.F, $K_h=1\text{md}$, $h=50\text{ ft}$, $A=80\text{ acres}$, SDA

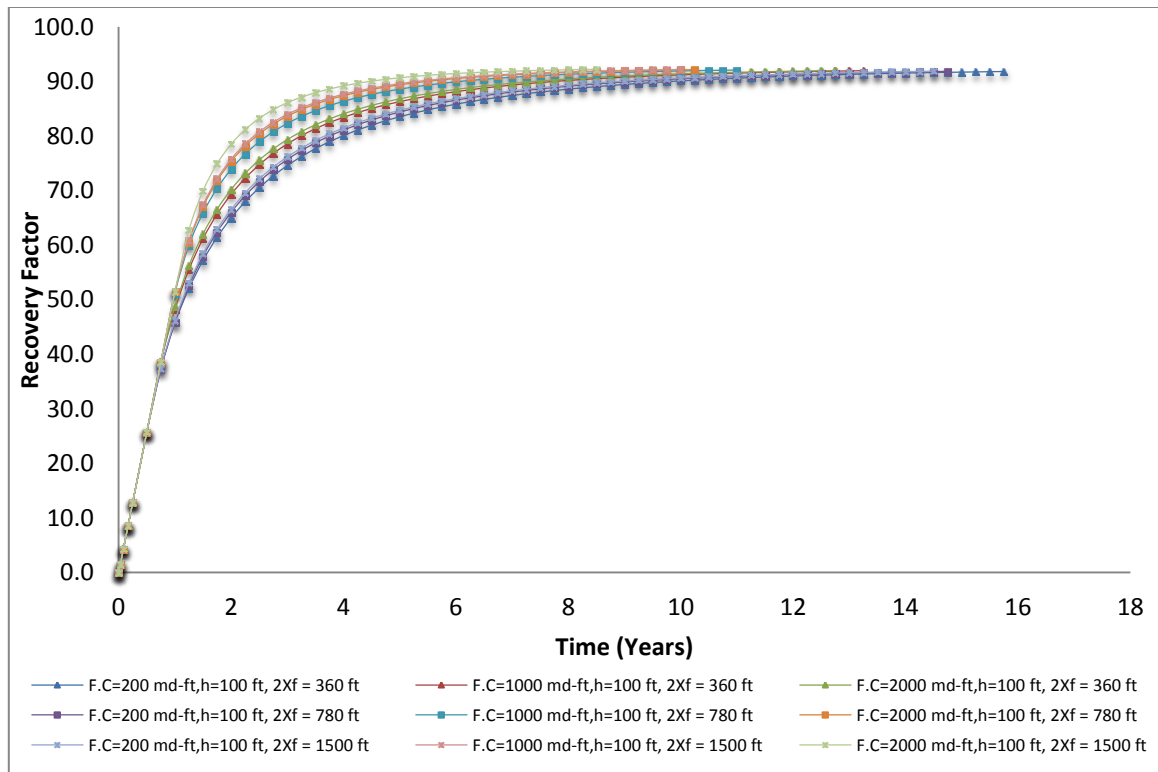


Figure 5.156: Effect of F.C. & frac. length on R.F, $K_h=1\text{md}$, $h=100\text{ ft}$, $A=80\text{ acres}$, SDA

5.10 Effect of Horizontal Well Location With Respect to the Upper and Lower No-Flow Boundary

Figures 5.157 through 5.166 show the effect of well location with respect to upper and lower no-flow boundaries on ultimate recovery factor and on abandonment time for the well located in an 80-acre, 2:1 rectangular drainage area. Figures 5.157 through 5.161 are for well penetration ratio of 0.2 and formation thickness of 20 feet while Figures 5.162 through 5.166 are for well penetration ratio of 0.8 and formation thickness of 100 feet. Each figure corresponds to a given horizontal permeability (0.01 md, 0.1 md, 1 md, 10 md, or 100 md). Results for two well locations with respect to the upper and lower no-flow boundaries are shown in each graph; one case is for the well located symmetrically with respect to the upper and lower no-flow boundaries and the other case is for the well near the upper no-flow boundary (in the grid block nearest to the upper no-flow boundary).

Results shown in these figures indicate that, for all practical purposes, the well location with respect to the upper and lower no-flow boundaries has negligible effect on horizontal well performance in volumetric dry gas reservoirs.

In all the plots of ultimate recovery factor versus time presented in this research, the linear straight line in the early portion of these plots indicates constant rate of production.

Tables B.3 and B.4 in Appendix B show the effect of the horizontal well location with respect to the upper and lower no-flow boundary on ultimate recovery factor, average reservoir pressure at abandonment time, and abandonment time for all cases considered in this research. Table B.3 is for the square drainage area while Table B.4 is for the 2:1 rectangular drainage area.

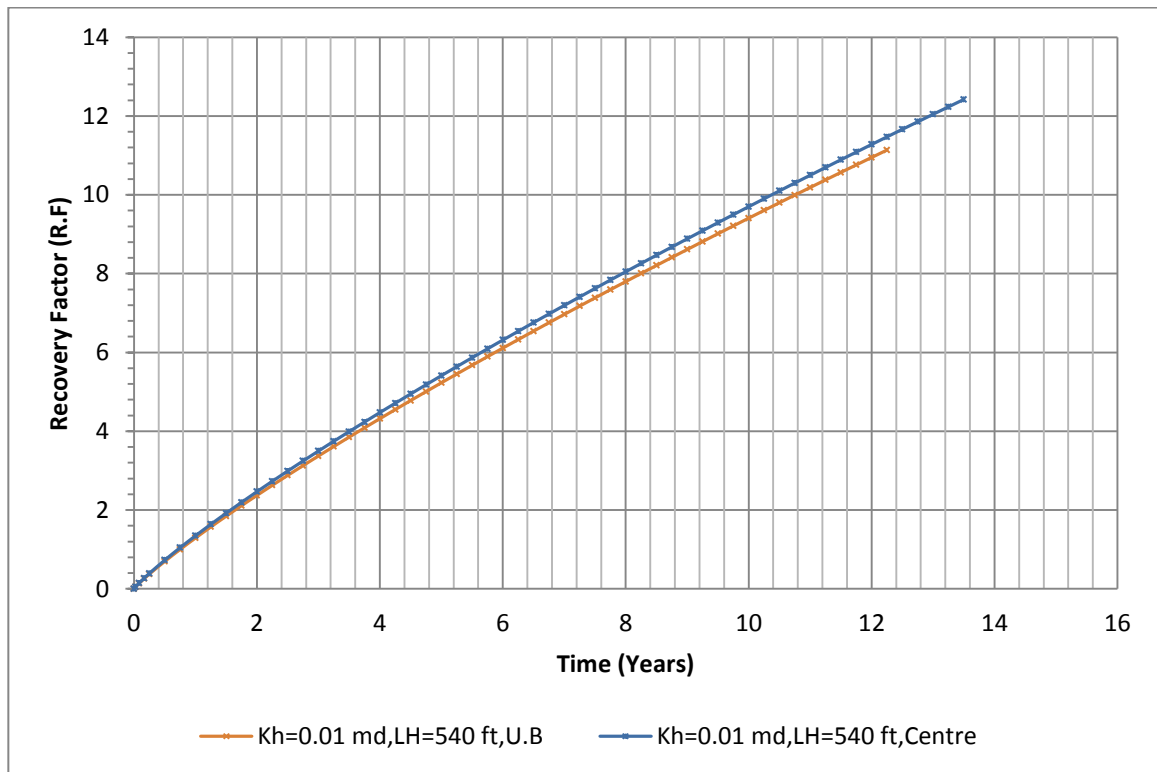


Figure 5.157: Effect of well location on recovery factor, $P.R=0.2$, $h=20$ feet, $A=80$ acres, RDA, (Case 1)

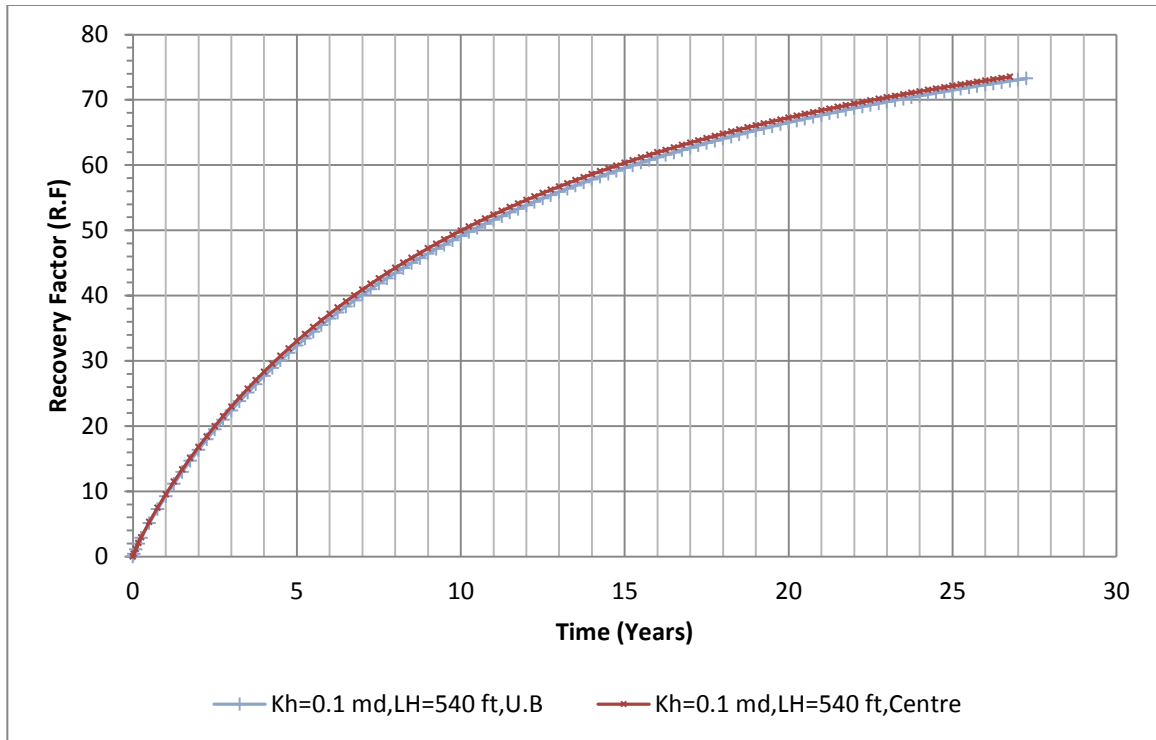


Figure 5.158: Effect of well location on recovery factor, P.R=0.2, h=20 feet, A=80 acres, RDA, (Case 2)

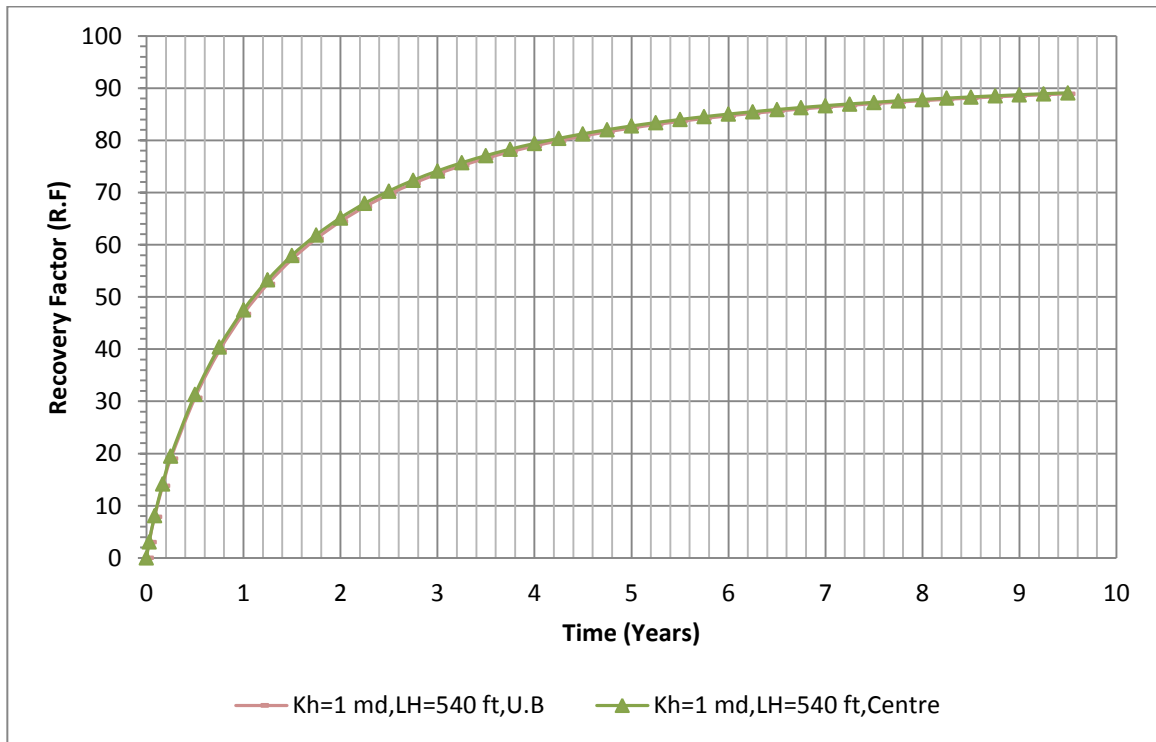


Figure 5.159: Effect of well location on recovery factor, P.R=0.2, h=20 feet, A=80 acres, RDA, (Case 3)

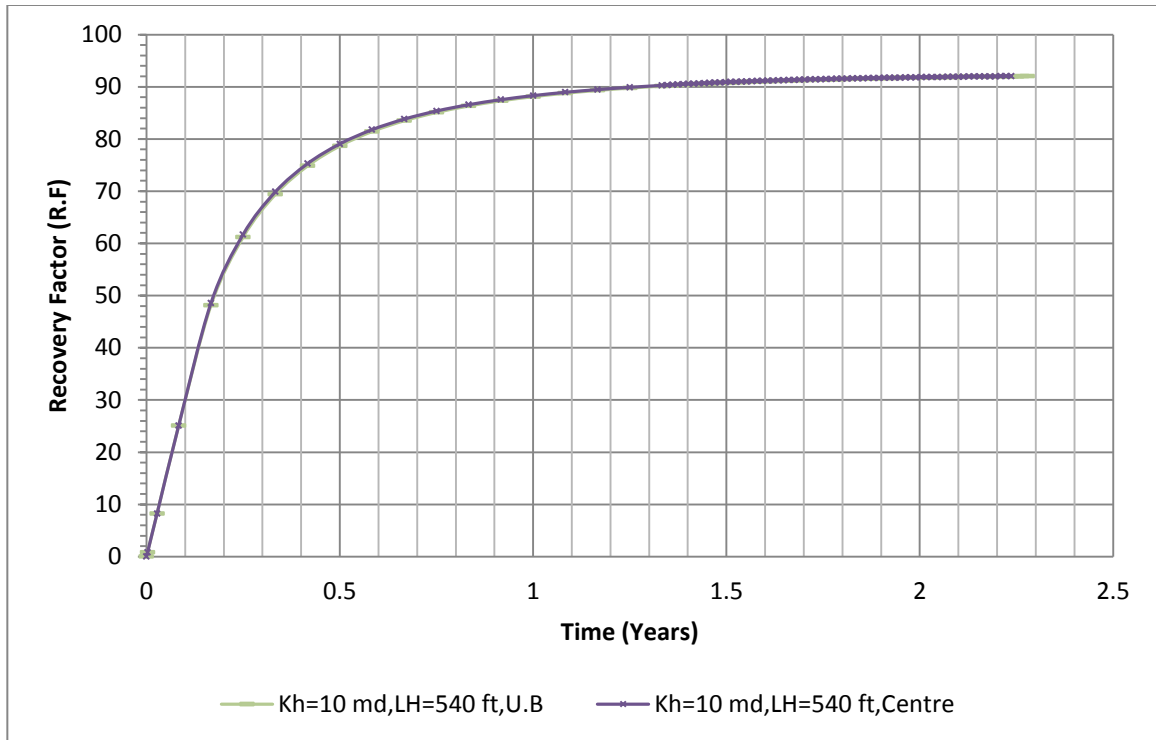


Figure 5.160: Effect of well location on recovery factor, $P.R=0.2$, $h=20$ feet, $A=80$ acres, RDA, (Case 4)

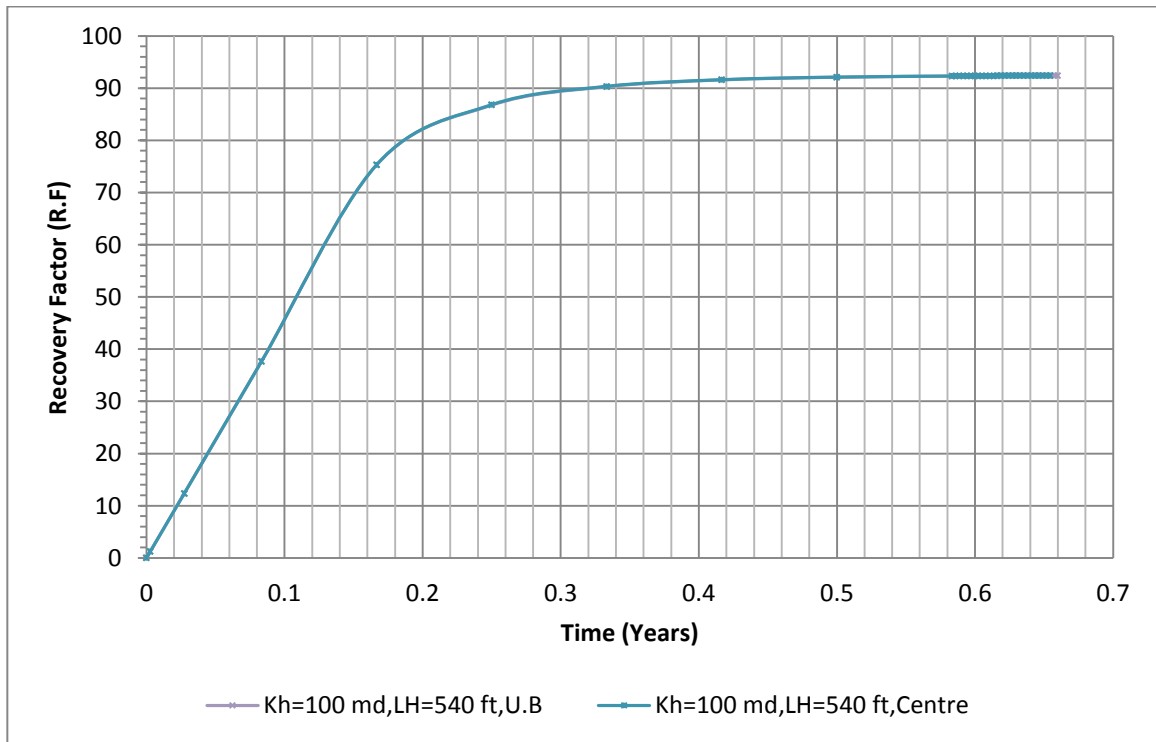


Figure 5.161: Effect of well location on recovery factor, $P.R=0.2$, $h=20$ feet, $A=80$ acres, RDA, (Case 5)

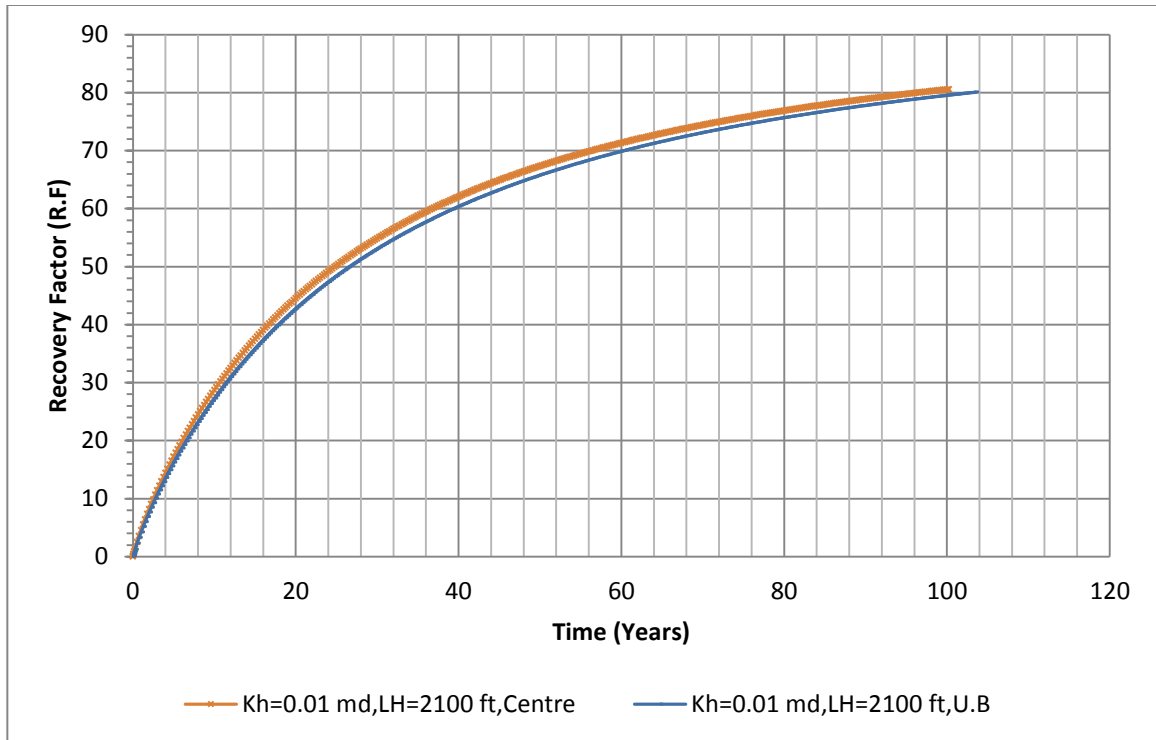


Figure 5.162: Effect of well location on recovery factor, P.R=0.8, h=100 feet, A=80 acres, RDA, (Case 131)

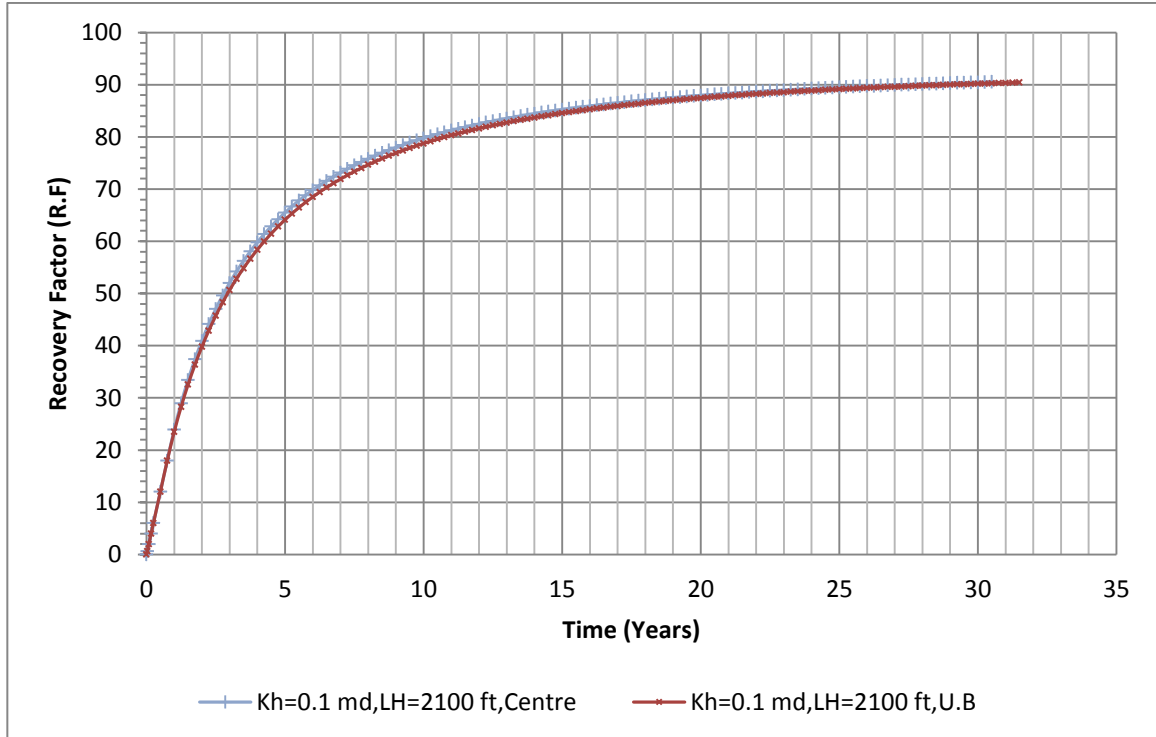


Figure 5.163: Effect of well location on recovery factor, P.R=0.8, h=100 feet, A=80 acres, RDA, (Case 132)

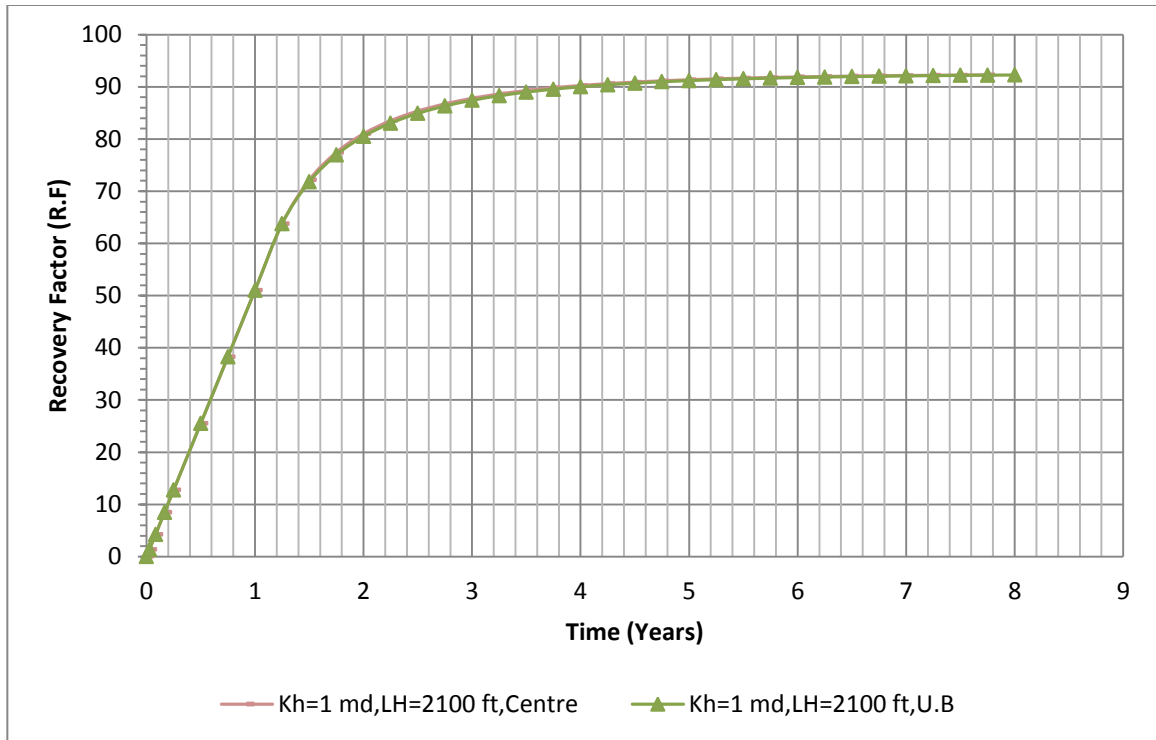


Figure 5.164: Effect of well location on recovery factor, P.R=0.8, h=100 feet, A=80 acres, RDA, (Case 133)

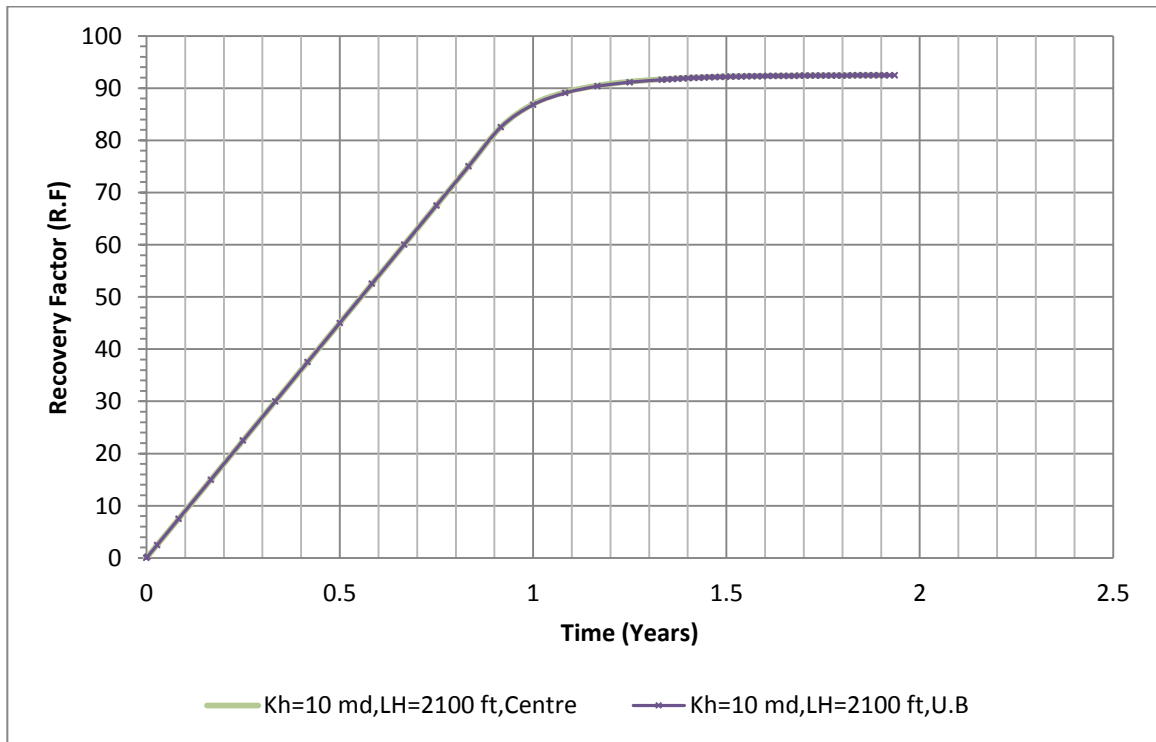


Figure 5.165: Effect of well location on recovery factor, P.R=0.8, h=100 feet, A=80 acres, RDA, (Case 134)

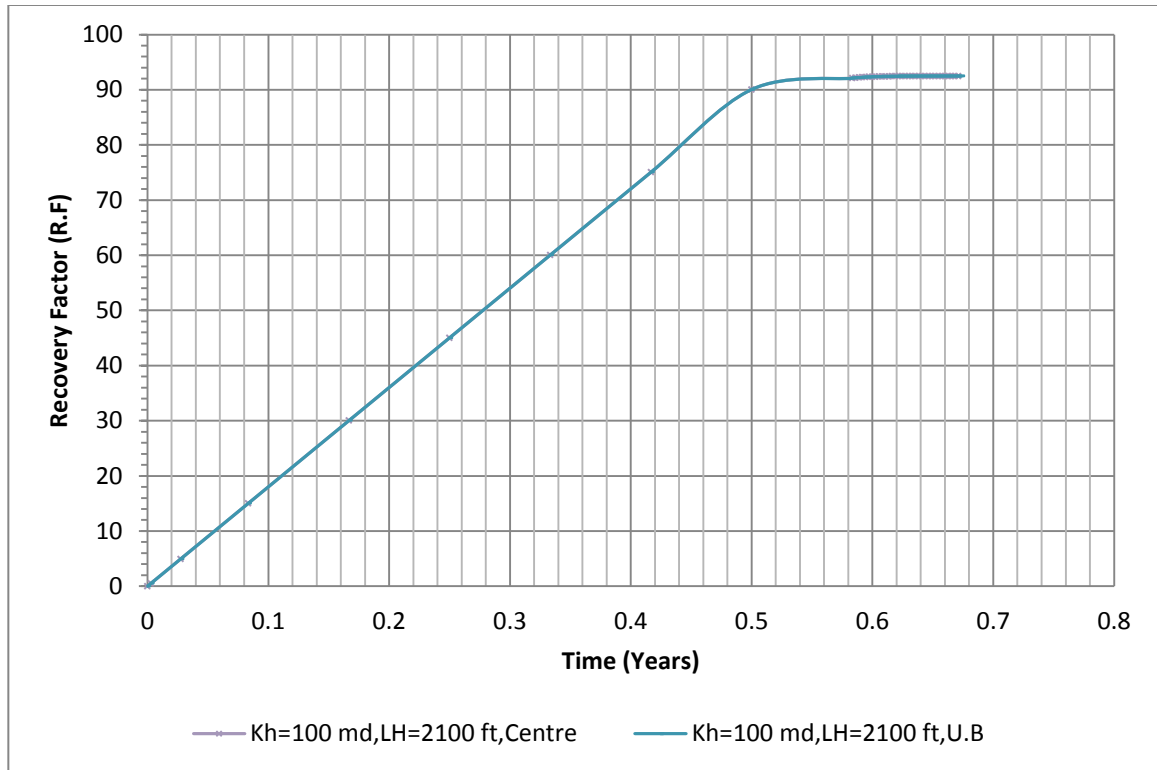


Figure 5.166: Effect of well location on recovery factor, P.R=0.8, h=100 feet, A=80 acres, RDA, (Case 135)

5.11 Effect of Natural Gas Specific Gravity

Figures 5.167 through 5.176 shows the effect of natural gas specific gravity on ultimate recovery factor and on abandonment time. Figures 5.167 through 5.171 are for horizontal well penetration ratio of 0.2 and formation thickness of 20 feet while Figures 5.172 through 5.176 are for horizontal well penetration ratio of 0.8 and formation thickness of 100 feet. The results are for the horizontal well located in an 80-acre square drainage area. Each figure is for a given horizontal permeability (0.01 md, 0.1 md, 1 md, 10 md, or 100 md). Results shown in these figures indicate that, for all practical purposes, the value of gas gravity has negligible effect on well performance in volumetric gas reservoirs. Therefore,

the results shown in Tables 5.1 and 5.2 are also applicable for volumetric wet-gas reservoirs.

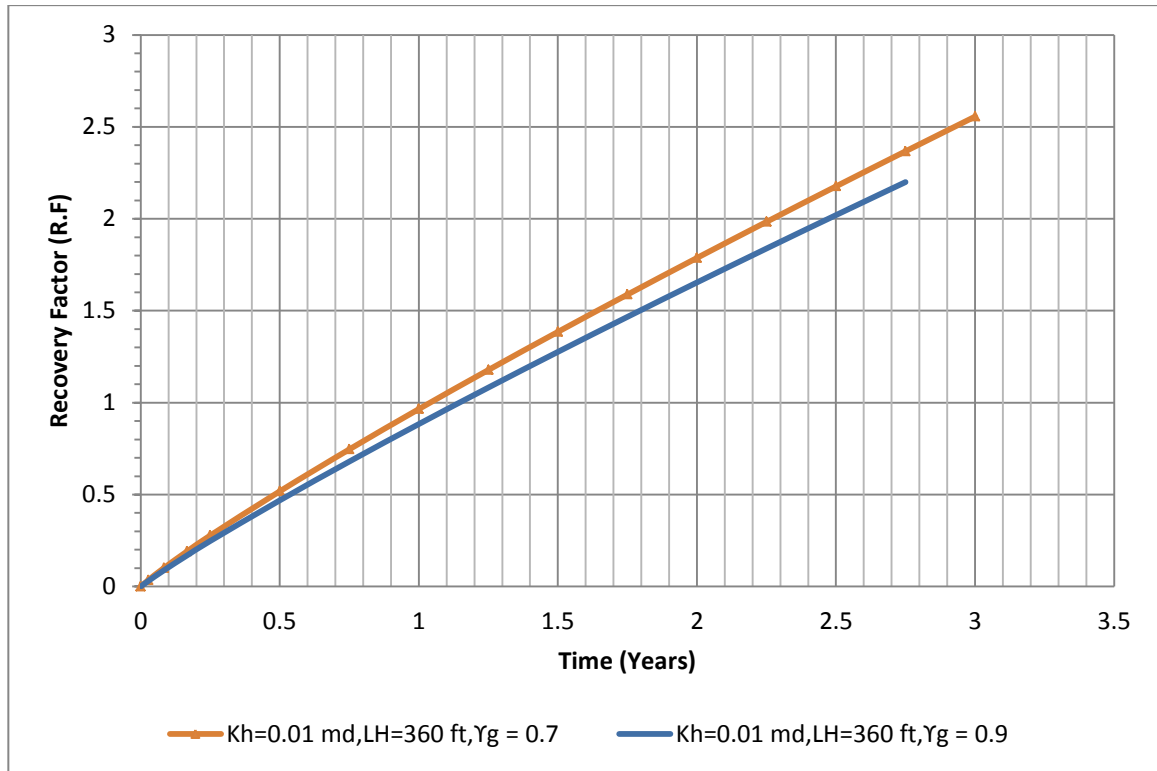


Figure 5.167: Effect of specific gravity on recovery factor, P.R=0.2, h=20 feet, A=80 acres, SDA (Case 1)

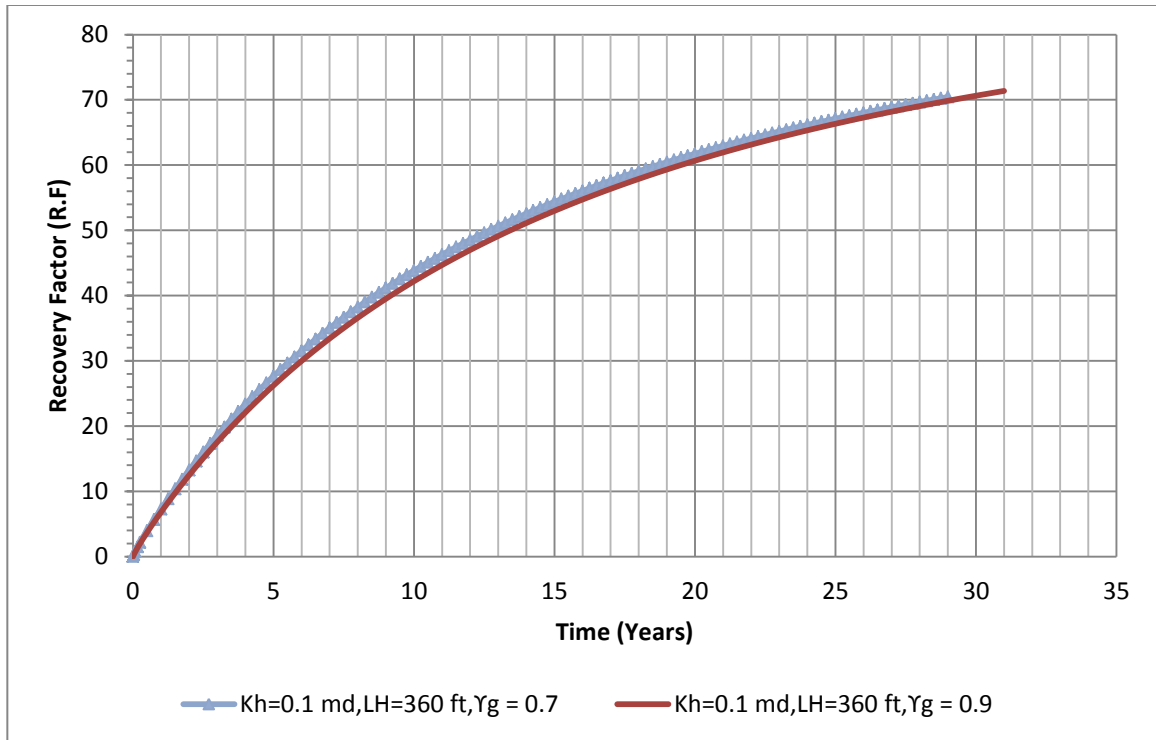


Figure 5.168: Effect of specific gravity on recovery factor, P.R=0.2, h=20 feet, A=80 acres, SDA (Case 2)

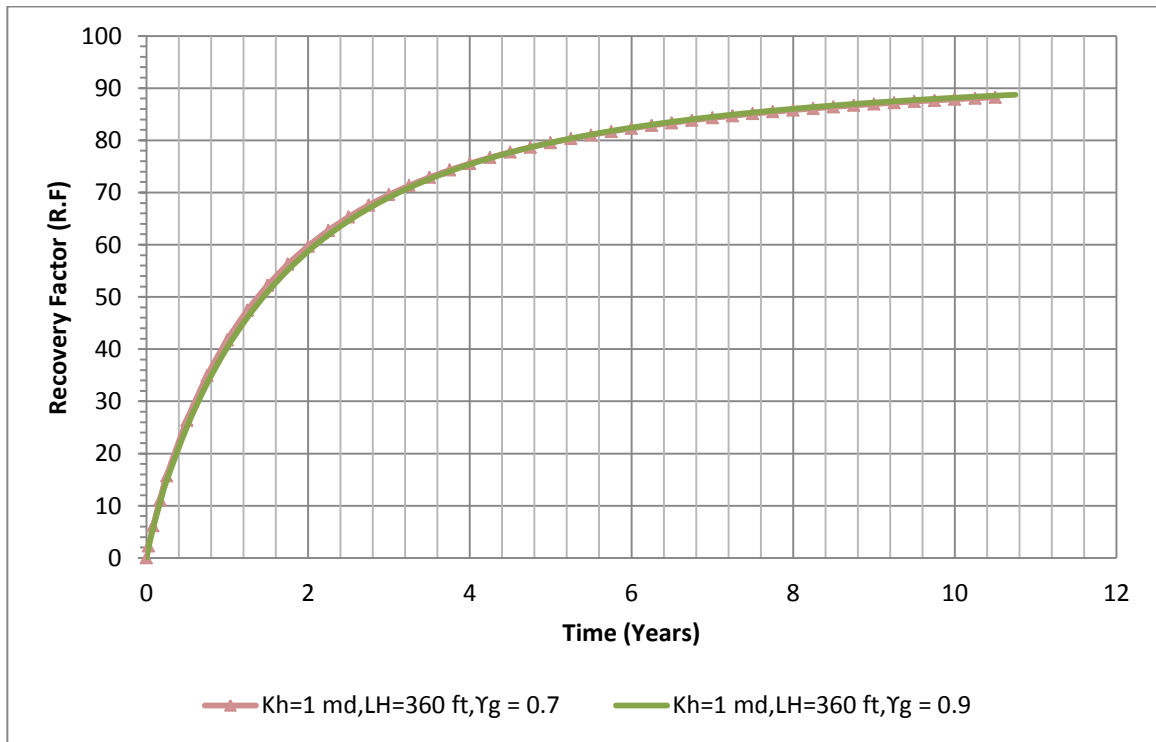


Figure 5.169: Effect of specific gravity on recovery factor, P.R=0.2, h=20 feet, A=80 acres, SDA (Case 3)

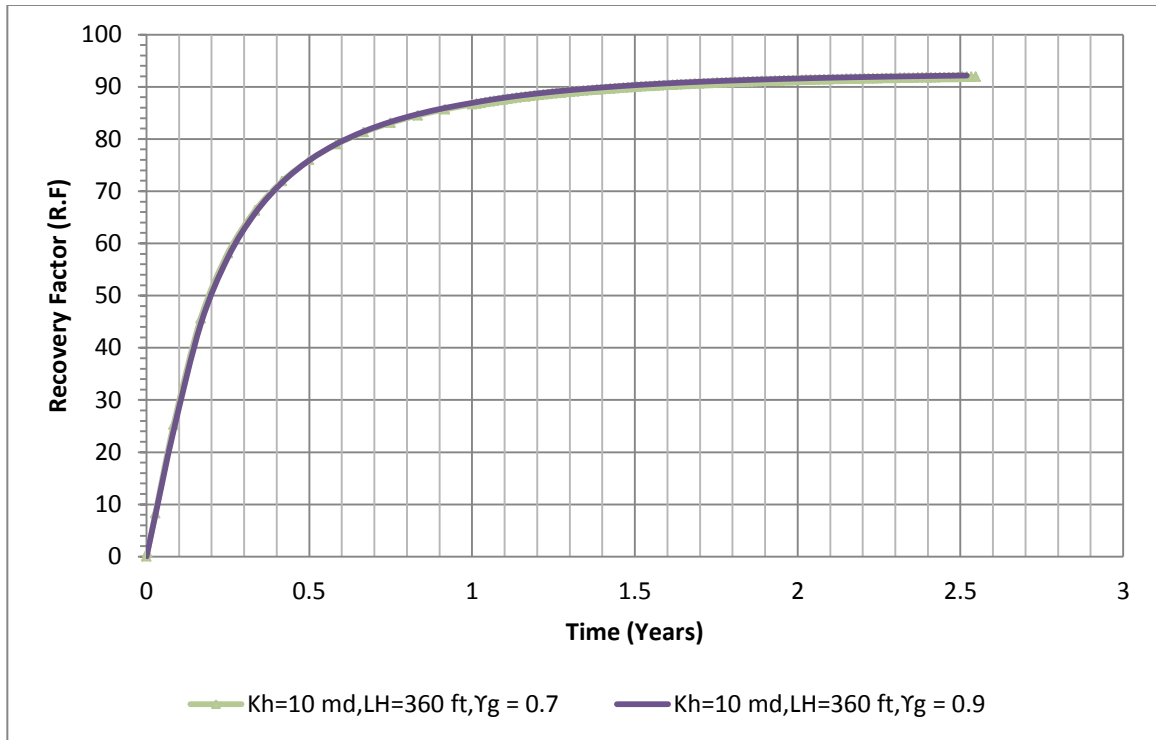


Figure 5.170: Effect of specific gravity on recovery factor, P.R=0.2, h=20 feet, A=80 acres, SDA (Case 4)

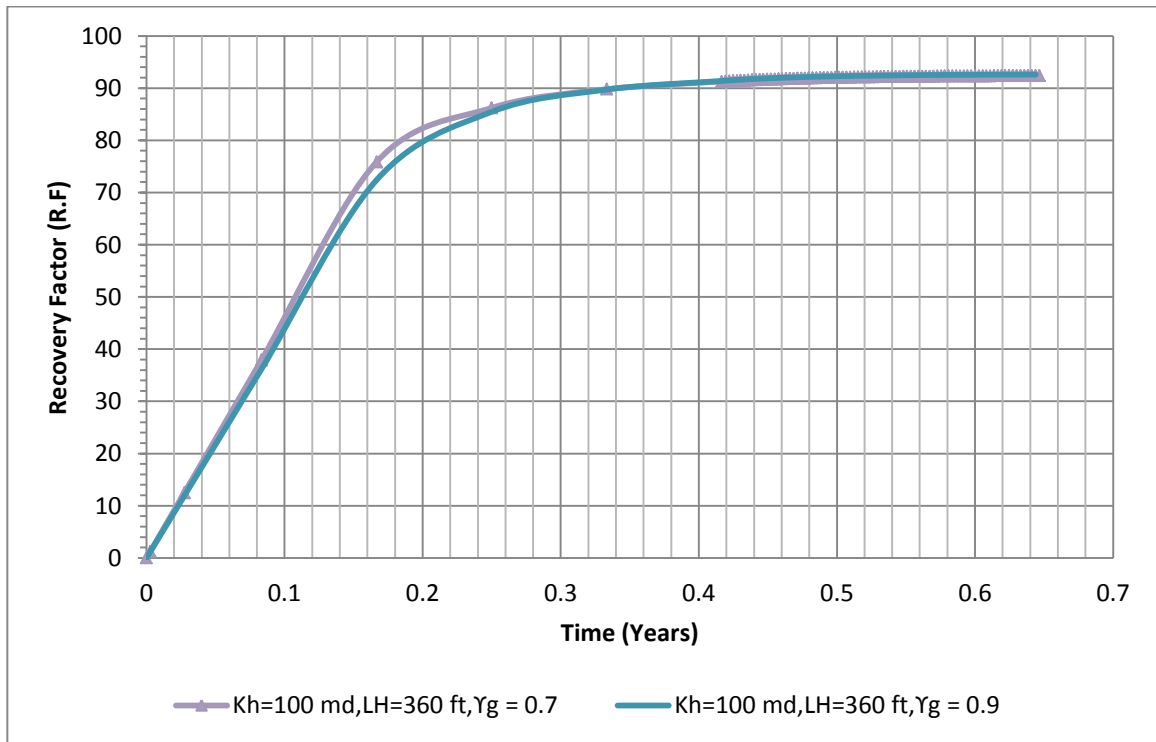


Figure 5.171: Effect of specific gravity on recovery factor, P.R=0.2, h=20 feet, A=80 acres, SDA (Case 5)

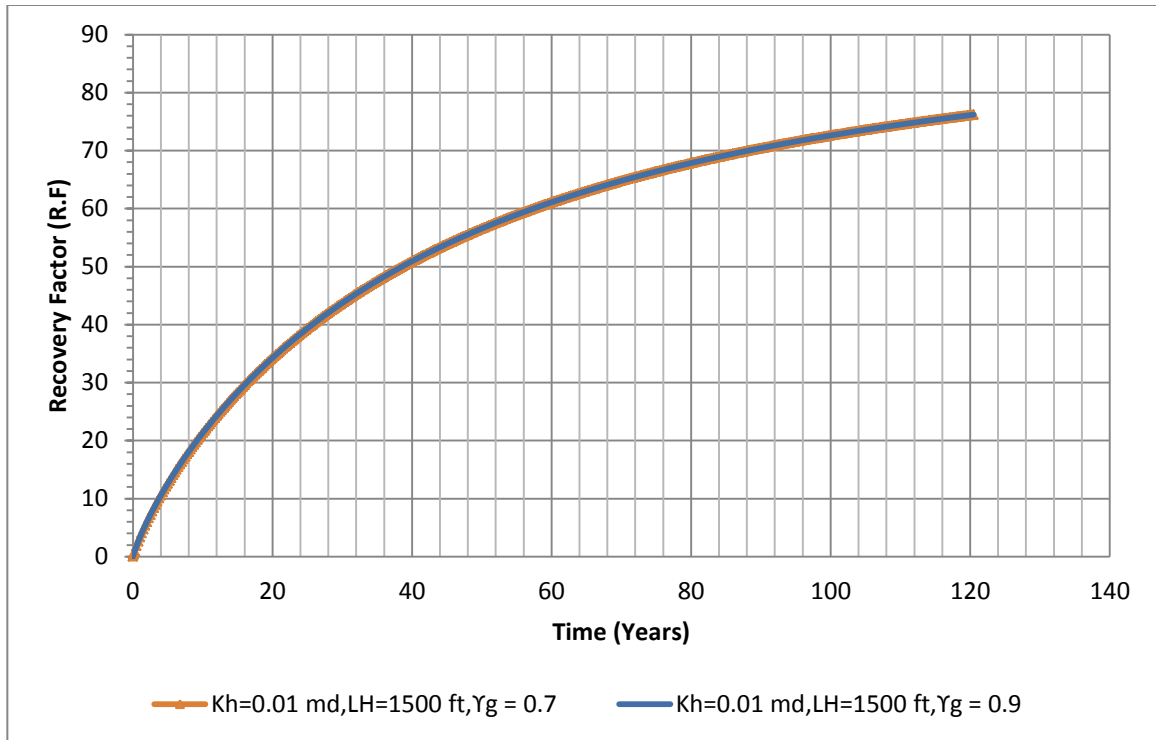


Figure 5.172: Effect of specific gravity on recovery factor, P.R=0.8, h=100 feet, A=80 acres, SDA (Case 131)

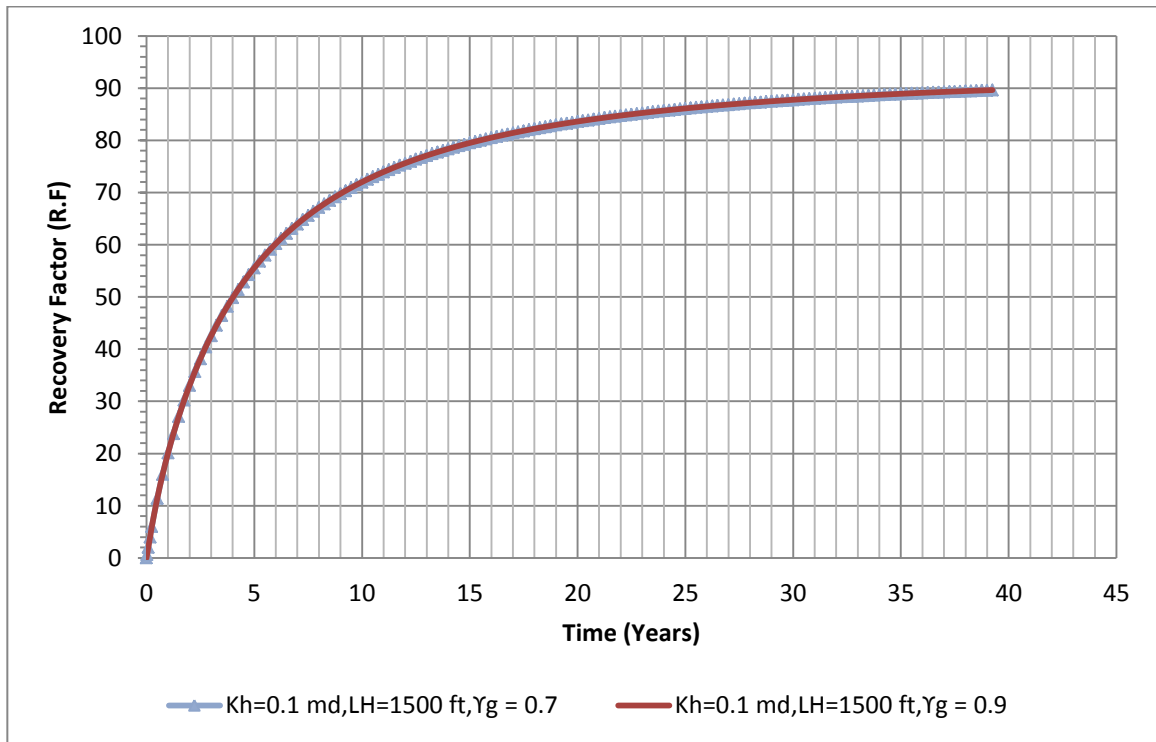


Figure 5.173: Effect of specific gravity on recovery factor, P.R=0.8, h=100 feet, A=80 acres, SDA (Case 132)

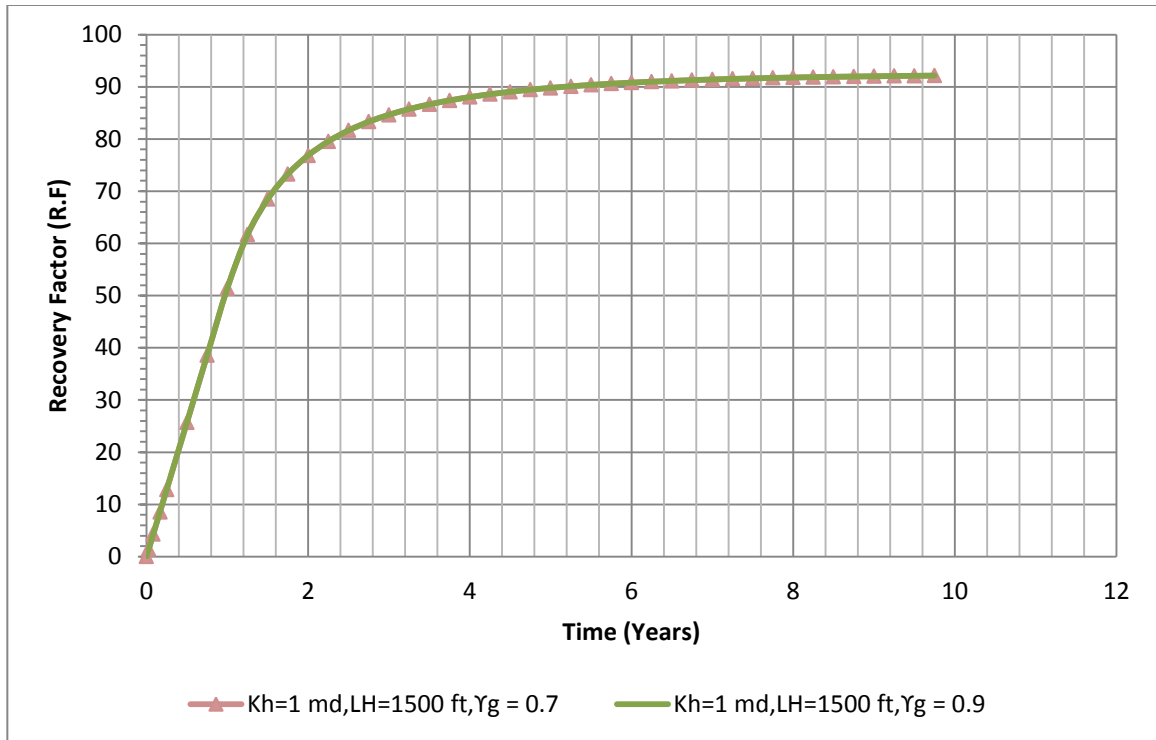


Figure 5. 174: Effect of specific gravity on recovery factor, P.R=0.8, h=100 feet, A=80 acres, SDA (Case 133)

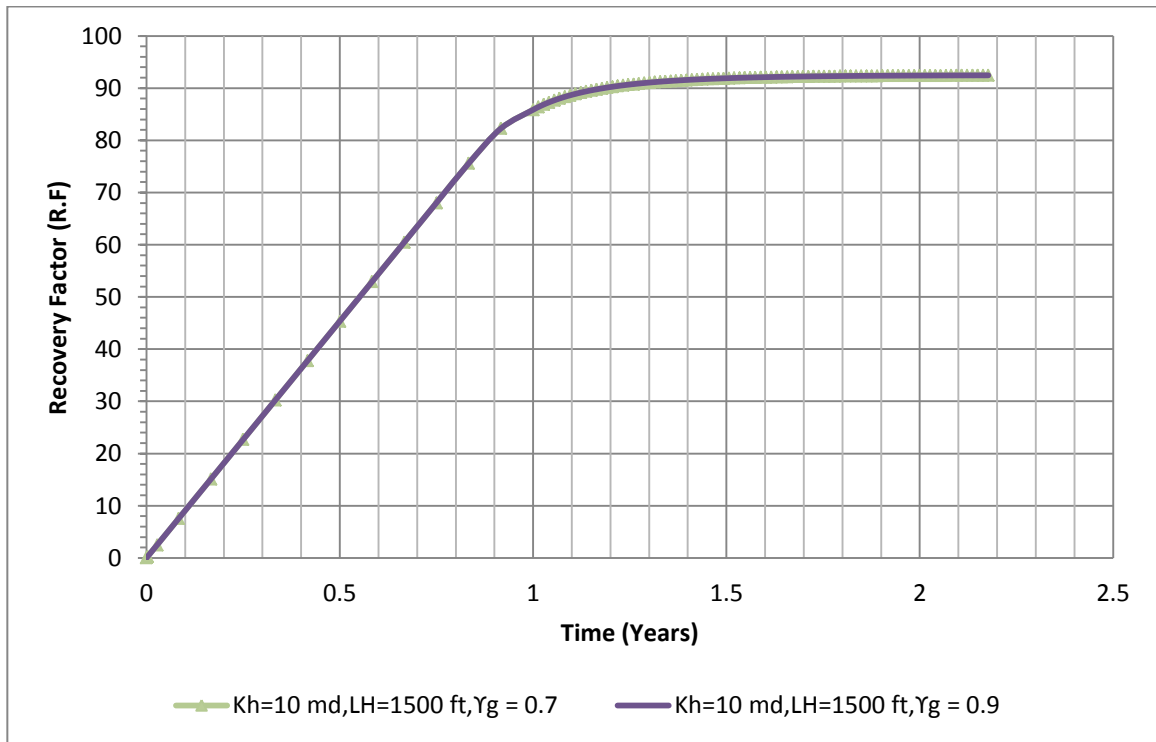


Figure 5. 175: Effect of specific gravity on recovery factor, P.R=0.8, h=100 feet, A=80 acres, SDA (Case 134)

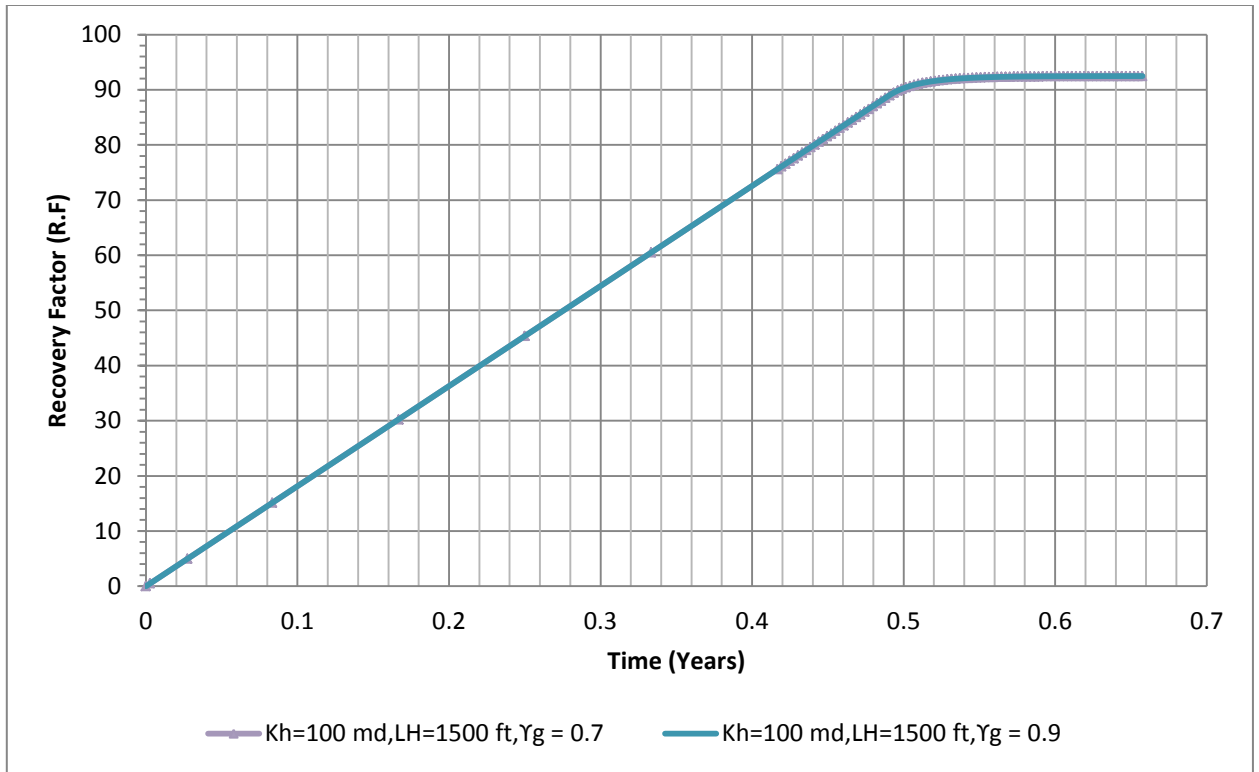


Figure 5. 176: Effect of specific gravity on recovery factor, P.R=0.8, h=100 feet, A=80 acres, SDA (Case 135)

5.11 Effect of Porosity

Except for the results shown in this section, all the results shown in this research are for the formation porosity of 20%. At low horizontal permeabilities (0.01 md, 0.1 md, and 1 md), the porosity of the hydrocarbon-bearing sedimentary rocks (sandstones and carbonates) may be much lower than 20%, depending on the pore size distribution, clay content and degree of cementation. Therefore, some additional simulation runs were made for porosities of 10% and 5% when the horizontal permeability is 0.01 md and 1 md. Figures 5.177 through 5.180 show the effect of porosity on the ultimate recovery factor and on abandonment time for a horizontal well producing in an 80-acre square drainage area. Figures 5.177 and 5.178 are for the formation thickness of 20 feet and horizontal well

penetration ratio of 0.2 while Figures 5.179 and 5.180 are for the formation thickness of 100 feet and horizontal well penetration ratio of 0.8. Figures 5.177 and 5.179 are for the horizontal permeability of 0.01 md while Figures 5.178 and 5.180 are for the horizontal permeability of 1 md.

Figures 5.177 through 5.180 show that the ultimate recovery factor does not depend on the value of porosity. However, the abandonment time depends on the value of porosity. The relevant question to which it is important to find the answer is: Does doubling the porosity double the abandonment time?

Figures 5.177 and 5.179 show that, for all practical purposes, at low horizontal permeability of 0.01 md, doubling the porosity doubles the abandonment time. Therefore, in such cases, the abandonment time ratio is equal to the porosity ratio.

However, at a horizontal permeability of 1 md, doubling the porosity does not double the abandonment time, as shown in Figures 5.178 and 5.180. Instead, these figures show that doubling the porosity results in increase in abandonment time by a value between 1.75 times to 1.91 times. Therefore, in such cases, the abandonment time ratio is equal to porosity ratio times a number between 0.875 to 0.955.

Therefore, the results, obtained for the reservoir porosity of 20% throughout this research (except in this section), can be used for a lower reservoir porosity by considering the fact that the ultimate recovery factor and the abandonment pressure will be the same but the abandonment time varies according to the above statements.

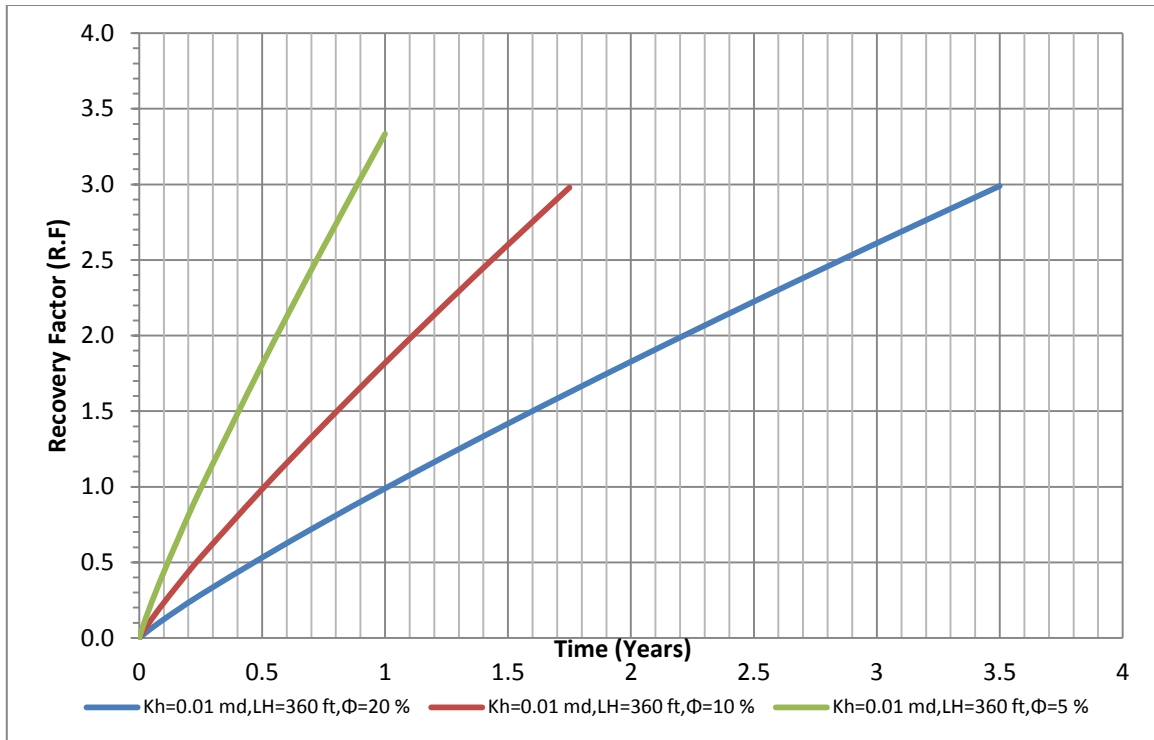


Figure 5.177: Effect of porosity on recovery factor, $K_h=0.01$ md, $h=20$ feet, $P.R = 0.2$, $A=80$ acres, SDA, (Case 31)

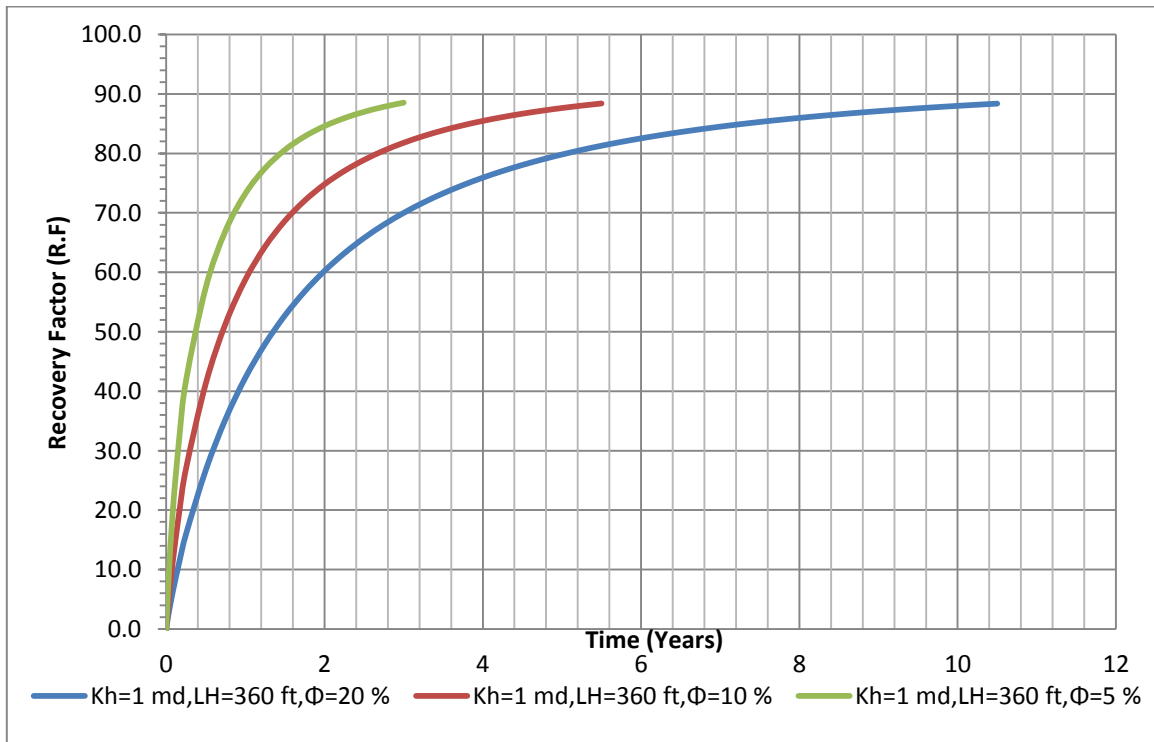


Figure 5.178: Effect of porosity on recovery factor, $K_h=1$ md, $h=20$ feet, $P.R = 0.2$, $A=80$ acres, SDA, (Case 33)

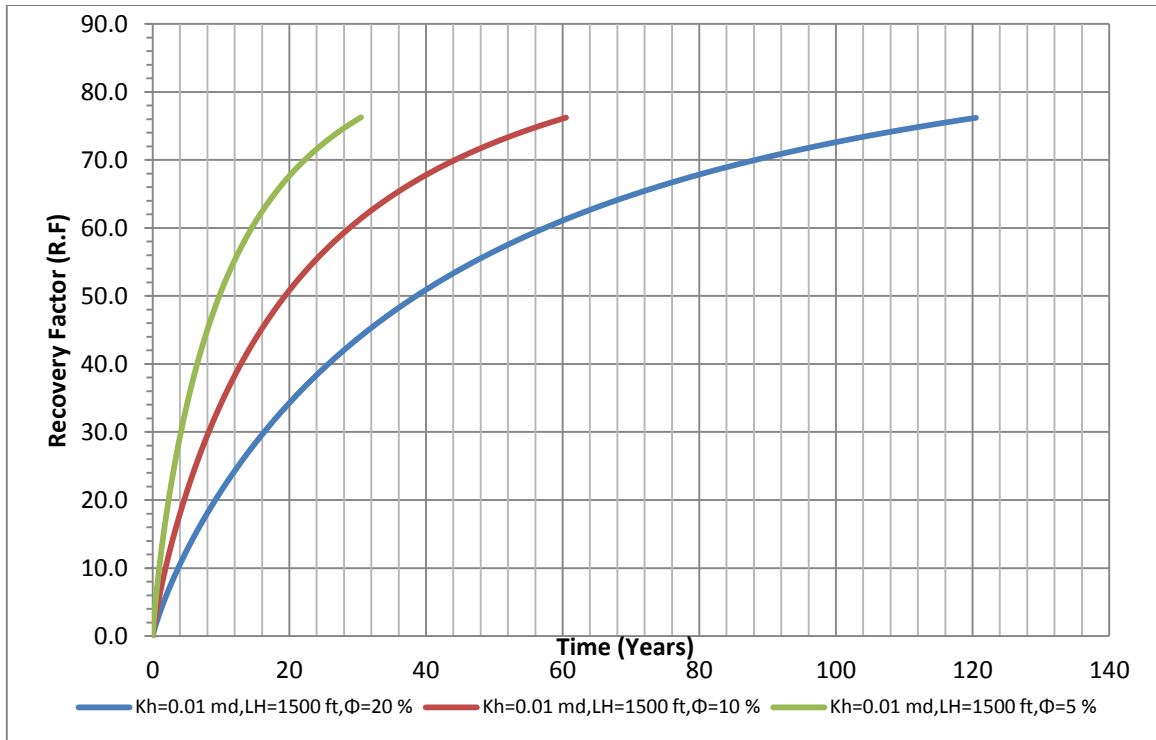


Figure 5.179: Effect of porosity on recovery factor, $K_h=0.01$ md, $h=100$ ft, P.R = 0.8, $A=80$ acres, SDA (Case 131)

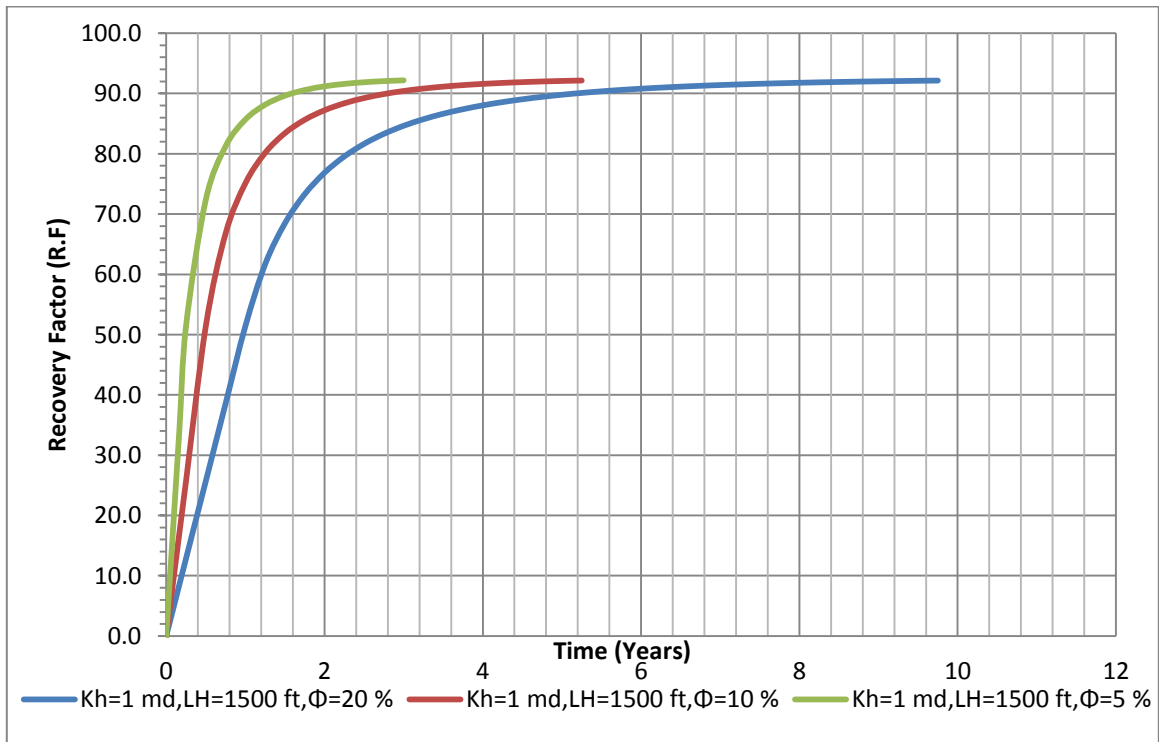


Figure 5.180: Effect of porosity on recovery factor, $K_h=1$ md, $h=100$ ft, P.R = 0.8, $A=80$ acres, SDA, (Case 133)

5.12 Selection of the Proper Well Type

The selection of well type in a given reservoir not only depends on the ultimate recovery factor but also on the time to reach abandonment conditions. Although, HFVW should perform better than a HW of the same penetration ratio, there are considerable limitations in regards to our ability to create long and conductive fractures. The following statements can be made regarding the HFVW:

- The height of fracture strongly depends upon strength of base formation and pumping rate of fracturing fluids. If the layers above or below the reservoir formation are weaker than reservoir rock than large fracture height will be obtained.
- It is desirable to obtain long infinite-conductivity fractures but in practice. However, proppant settling, Proppant crushing, proppant embedment, and problems with fracture fluid rheology and transport adversely affect our ability to create long and high-conductivity fractures.
- The effective fracture length is calculated either from pressure buildup test or from production decline history. Analysis of the pressure buildup test or production decline history has shown that, in practice, a well normally shows a 30% to 50 % smaller fracture length than the designed fracture length.
- If it is assumed that the created fracture has the same length as the designed length, then the fracture conductivity calculated from the well test is significantly smaller than the designed fracture conductivity.

- Large volume of fracture fluid is pumped in order to achieve long fracture length. In many fracture jobs very little fracture fluid is recovered. The unrecovered fluid probably accumulates in the induced fracture and reduces relative permeability to oil or gas flow.

It is important to note that it is difficult to create long and high-conductivity fractures because of the problems with proppant transport, proppant crushing, and proppant embedment. However, one can drill long horizontal wells. Thus, one can state that a HW of penetration ratio of 0.8 performs better than an actual HFVW because, in reality, the length of the created hydraulic fracture would not exceed a penetration ratio of 0.4 in an 80-acre square drainage area or in an 80-acre, 2:1 rectangular drainage area. Therefore, even in cases where the results show that a HFVW of 0.8 penetration ratio performs better than a HW of 0.8 penetration ratio both in terms of the ultimate recovery factor and abandonment time, the HW is the well type selected that gives the best performance.

Tables 5.3 through 5.6 show the selected well type in each case. Tables 5.3 and 5.4 are for the cases where the wells are located in an 80-acre, square drainage area. Tables 5.5 and 5.6 are for the cases where the wells are located in an 80-acre, 2:1 rectangular drainage area.

Tables 5.3 and 5.5 are for the selection between the horizontal well and the vertical well in the same reservoir. As shown in these two tables, the HW performs better than the vertical well in all cases, when one considers both the ultimate recovery factor and the abandonment time. In general, as the horizontal permeability increases, a HW of penetration ratio higher than 0.2 is needed in order to have sufficient improvement in well

performance over the VW to justify the development of the reservoir with the HW. In these tables, for example, a selection of “HW (0.4)” means that the horizontal well of penetration ratio of 0.4 and higher will perform better than the vertical well; in such cases, the vertical well will perform better than the horizontal well of penetration ratio of 0.2. It is important to mention that a HW of penetration ratio of 0.8 always performs better than a horizontal well of lower penetration ratio. Therefore, the selection HW (0.4) does not mean that the horizontal well of penetration ratio of 0.4 provides the best well performance among all options shown in the table. The selection “HW” means that the horizontal well of penetration ratios of 0.2, 0.4 and 0.8 all perform better than the vertical well.

Tables 5.4 and 5.6 are for the selection between the horizontal well (HW) and the hydraulically-fractured vertical well (HFVW) in the same reservoir. Only horizontal well is chosen in these tables. For example, the selection of “HW (0.4)” means that the HW of penetration ratio of 0.4 gives better performance than the HFVW of the same penetration ratio; in such cases, the selection “HW (0.4)” means that the HFVW of penetration ratio of 0.2 performs better than the HW of penetration ratio 0.2. Again, it is important to note that the HW of penetration ratio of 0.8 always performs better than a HW of lower penetration ratio. Again, it is important to emphasize that a HW of penetration ratio of 0.8 is always selected over a HFVW of penetration ratio of 0.8 because it is unrealistic to expect that one can create such a long hydraulic fracture having a penetration ratio of 0.8 in an 80-acre square drainage area or in an 80-acre, 2:1 rectangular drainage area.

For the square drainage area cases, as shown in Table 5.4, only in the case of formation thickness of 20 feet and horizontal permeability of 1 md, the HW of penetration ratio of 0.4 and higher is selected as the proper well type to develop the reservoir. In all other

formation thicknesses (50 feet and 100 feet) and horizontal permeabilities (0.01 md and 0.1 md), only a HW of penetration ratio of 0.8 is preferred over the HFVW; this means that, in these cases, the HFVW of penetration ratios of 0.2 and 0.4 should be selected in preference to HW of penetration ratios of 0.2 and 0.4, respectively.

For the rectangular drainage area cases, as shown in Table 5.6, when the horizontal permeability is 0.01 md or 0.1 md, the HW of penetration ratio of 0.8 is selected for all formation thicknesses and k_v/k_h ratios; this means that, in such cases, the HFVW of penetration ratio of 0.2 and 0.4 would be the proper well type, as compared to the HW of penetration ratio of 0.2 and 0.4, respectively. However, when the horizontal permeability is 1 md, the following selection is made: HW, HW (0.4), and HW (0.8) for formation thicknesses of 20 feet, 50 feet, and 100 feet, respectively. This means, for example, that for horizontal permeability of 1 md, a HW of penetration ratio of 0.2 and higher is selected for the formation thickness of 20 feet.

It is important to note that the value of k_v/k_h ratio has no effect on the selection of well type for the square drainage area cases and for the 2:1 rectangular drainage area cases.

Table 5.3: Well type selection between horizontal and vertical wells based on time and recovery factor ratio for 80 Acres SDA

WELL & RESERVOIR PARAMETERS					RATIO OF TIME AND RECOVERY FACTOR						WELL TYPE
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TV/TH	RH/RV	TV/TH	RH/RV	TV/TH	RH/RV	
	Acres		Feet	md							
1,46,91	80	0.1	20	0.01	0.009	115.21	0.001	1206.44	0.001	2103.83	HW
2,47,92	80	0.1	20	0.1	1.155	1.16	1.441	1.27	1.861	1.36	HW
3,48,93	80	0.1	20	1	1.333	1.02	1.806	1.04	2.435	1.06	HW
4,49,94	80	0.1	20	10	1.392	1	1.977	1.01	2.697	1.01	HW (0.4)
5,50,95	80	0.1	20	100	1.279	1	1.556	1	1.765	1	HW (0.8)
6,51,96	80	0.1	50	0.01	0.587	2.15	0.541	3.18	0.601	3.91	HW
7,52,97	80	0.1	50	0.1	1.215	1.06	1.597	1.12	2.153	1.16	HW
8,53,98	80	0.1	50	1	1.313	1.01	1.826	1.02	2.625	1.03	HW
9,54,99	80	0.1	50	10	1.345	1	1.938	1	2.658	1	HW (0.4)
10,55,100	80	0.1	50	100	1.25	1	1.588	1	2.1	1	HW (0.8)
11,56,101	80	0.1	100	0.01	0.975	1.22	1.076	1.51	1.305	1.71	HW
12,57,102	80	0.1	100	0.1	1.174	1.03	1.591	1.07	2.179	1.09	HW
13,58,103	80	0.1	100	1	1.222	1.01	1.774	1.01	2.558	1.01	HW
14,59,104	80	0.1	100	10	1.243	1	1.798	1	2.45	1	HW (0.4)
15,60,105	80	0.1	100	100	1.173	1	1.486	1	1.749	1	HW (0.8)
16,61,106	80	0.5	20	0.01	0.008	125.96	0.001	1238.24	0.001	2130.89	HW
17,62,107	80	0.5	20	0.1	1.165	1.16	1.441	1.28	1.861	1.36	HW
18,63,108	80	0.5	20	1	1.333	1.03	1.806	1.04	2.435	1.06	HW
19,64,109	80	0.5	20	10	1.407	1	1.992	1.01	2.697	1.01	HW (0.4)
20,65,110	80	0.5	20	100	1.285	1	1.564	1	1.776	1	HW (0.4)
21,66,111	80	0.5	50	0.01	0.569	2.3	0.544	3.28	0.615	3.97	HW
22,67,112	80	0.5	50	0.1	1.257	1.07	1.66	1.13	2.228	1.16	HW
23,68,113	80	0.5	50	1	1.355	1.01	1.909	1.02	2.71	1.03	HW
24,69,114	80	0.5	50	10	1.406	1	2.006	1	2.722	1	HW (0.4)
25,70,115	80	0.5	50	100	1.285	1	1.615	1	2.124	1	HW (0.4)
26,71,116	80	0.5	100	0.01	0.987	1.3	1.125	1.57	1.382	1.75	HW
27,72,117	80	0.5	100	0.1	1.265	1.04	1.714	1.07	2.371	1.09	HW
28,73,118	80	0.5	100	1	1.341	1.01	1.93	1.01	2.75	1.01	HW
29,74,119	80	0.5	100	10	1.356	1	1.931	1	2.602	1	HW
30,75,120	80	0.5	100	100	1.243	1	1.55	1	1.793	1	HW (0.4)
31,76,121	80	1	20	0.01	0.008	134.76	0.001	1240.23	0.001	2133.38	HW
32,77,122	80	1	20	0.1	1.165	1.16	1.441	1.28	1.861	1.36	HW
33,78,123	80	1	20	1	1.333	1.03	1.806	1.04	2.435	1.06	HW
34,79,124	80	1	20	10	1.407	1	1.992	1.01	2.697	1.01	HW

Table 5.3: Well type selection between horizontal and vertical wells based on time and recovery factor ratio for 80 Acres SDA (Continued)

WELL & RESERVOIR PARAMETERS					RATIO OF TIME AND RECOVERY FACTOR						WELL TYPE
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TV/TH	RH/RV	TV/TH	RH/RV	TV/TH	RH/RV	
	Acres		Feet	md							
36,81,126	80	1	50	0.01	0.567	2.33	0.544	3.3	0.617	3.98	HW
37,82,127	80	1	50	0.1	1.27	1.07	1.671	1.13	2.248	1.16	HW
38,83,128	80	1	50	1	1.377	1.01	1.909	1.02	2.71	1.03	HW
39,84,129	80	1	50	10	1.417	1	2.017	1	2.743	1	HW
40,85,130	80	1	50	100	1.289	1	1.622	1	2.136	1	HW (0.4)
41,86,131	80	1	100	0.01	0.991	1.32	1.138	1.58	1.402	1.76	HW
42,87,132	80	1	100	0.1	1.291	1.04	1.745	1.07	2.401	1.1	HW
43,88,133	80	1	100	1	1.375	1.01	1.964	1.01	2.821	1.01	HW
44,89,134	80	1	100	10	1.383	1	1.967	1	2.635	1	HW
45,90,135	80	1	100	100	1.258	1	1.561	1	1.808	1	HW (0.4)

Table 5.4: Well type selection between horizontal well and hydraulically-fractured vertical well based on time and recovery factor ratio for 80 Acres SDA

Well & Reservoir Parameters					Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Well Type
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
Cases	Area	K _v /K _h	h	k _h	TH/TF	RFF/RFH	TH/TF	RFF/RFH	TH/TF	RFF/RFH	
	Acres		Feet	md							
1,46,91	80	0.1	20	0.01	0.111	11.89	0.779	1.783	1.065	1.306	HW (0.8)
2,47,92	80	0.1	20	0.1	1.275	1.123	1.274	1.073	1.263	1.044	HW (0.8)
3,48,93	80	0.1	20	1	1.4	1.023	1.24	1.012	1.095	1.003	HW (0.4)
4,49,94	80	0.1	20	10	NA						
5,50,95	80	0.1	20	100							
6,51,96	80	0.1	50	0.01	0.932	1.601	1.14	1.27	1.252	1.148	HW (0.8)
7,52,97	80	0.1	50	0.1	1.432	1.071	1.407	1.043	1.388	1.025	HW (0.8)
8,53,98	80	0.1	50	1	1.561	1.012	1.394	1.005	1.143	1.002	HW (0.8)
9,54,99	80	0.1	50	10	NA						
10,55,100	80	0.1	50	100							
11,56,101	80	0.1	100	0.01	1.201	1.344	1.325	1.181	1.4	1.108	HW (0.8)
12,57,102	80	0.1	100	0.1	1.597	1.054	1.57	1.032	1.545	1.018	HW (0.8)
13,58,103	80	0.1	100	1	1.765	1.008	1.512	1.004	1.265	1.001	HW (0.8)
14,59,104	80	0.1	100	10	NA						
15,60,105	80	0.1	100	100							
16,61,106	80	0.5	20	0.01	0.12	10.876	0.794	1.737	1.073	1.29	HW (0.8)
17,62,107	80	0.5	20	0.1	1.264	1.12	1.274	1.07	1.263	1.042	HW (0.8)
18,63,108	80	0.5	20	1	1.4	1.022	1.24	1.011	1.095	1.003	HW (0.4)
19,64,109	80	0.5	20	10	NA						
20,65,110	80	0.5	20	100							
21,66,111	80	0.5	50	0.01	0.962	1.495	1.133	1.231	1.224	1.13	HW (0.8)
22,67,112	80	0.5	50	0.1	1.384	1.063	1.354	1.039	1.341	1.022	HW (0.8)
23,68,113	80	0.5	50	1	1.512	1.011	1.333	1.005	1.107	1.002	HW (0.8)
24,69,114	80	0.5	50	10	NA						
25,70,115	80	0.5	50	100							
26,71,116	80	0.5	100	0.01	1.187	1.255	1.268	1.14	1.322	1.084	HW (0.8)
27,72,117	80	0.5	100	0.1	1.483	1.043	1.457	1.025	1.42	1.015	HW (0.8)
28,73,118	80	0.5	100	1	1.608	1.006	1.39	1.003	1.176	1.001	HW (0.8)
29,74,119	80	0.5	100	10	NA						
30,75,120	80	0.5	100	100							
31,76,121	80	1	20	0.01	0.13	10.165	0.794	1.735	1.073	1.288	HW (0.8)
32,77,122	80	1	20	0.1	1.264	1.12	1.274	1.069	1.263	1.041	HW (0.8)
33,78,123	80	1	20	1	1.4	1.021	1.24	1.011	1.095	1.003	HW (0.4)
34,79,124	80	1	20	10	NA						

Table 5.4: Well type selection between horizontal well and hydraulically-fractured Vertical well based on time and recovery factor ratio for 80 Acres SDA (Continued)

Well & Reservoir Parameters					Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Well Type
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TH/TF	RFF/RFH	TH/TF	RFF/RFH	TH/TF	RFF/RFH	
	Acres		Feet	md							
35,80,125	80	1	20	100	NA						
36,81,126	80	1	50	0.01	0.964	1.48	1.133	1.224	1.22	1.127	HW (0.8)
37,82,127	80	1	50	0.1	1.37	1.063	1.345	1.038	1.329	1.022	HW (0.8)
38,83,128	80	1	50	1	1.488	1.011	1.333	1.005	1.107	1.002	HW (0.8)
39,84,129	80	1	50	10	NA						
40,85,130	80	1	50	100							
41,86,131	80	1	100	0.01	1.182	1.237	1.253	1.131	1.303	1.079	HW (0.8)
42,87,132	80	1	100	0.1	1.453	1.041	1.43	1.024	1.402	1.013	HW (0.8)
43,88,133	80	1	100	1	1.569	1.006	1.366	1.003	1.147	1.001	HW (0.8)
44,89,134	80	1	100	10	NA						
45,90,135	80	1	100	100							

Table 5.5: Well type selection between horizontal and vertical well based on time and recovery factor ratio for 80 Acres RDA

WELL & RESERVOIR PARAMETERS					RATIO OF TIME AND RECOVERY FACTOR						WELL TYPE
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TV/TH	RH/RV	TV/TH	RH/RV	TV/TH	RH/RV	
	Acres		Feet	md							
1,46,91	80	0.1	20	0.01	0.002	563.97	0.001	1635.61	0.001	2647.67	HW
2,47,92	80	0.1	20	0.1	1.271	1.22	1.6	1.32	2.305	1.42	HW
3,48,93	80	0.1	20	1	1.5	1.04	2.036	1.05	3	1.06	HW
4,49,94	80	0.1	20	10	1.63	1.01	2.269	1.01	3.126	1.01	HW
5,50,95	80	0.1	20	100	1.356	1	1.521	1	1.774	1	HW (0.8)
6,51,96	80	0.1	50	0.01	0.518	2.81	0.524	3.79	0.642	4.64	HW
7,52,97	80	0.1	50	0.1	1.372	1.09	1.83	1.14	2.745	1.19	HW
8,53,98	80	0.1	50	1	1.536	1.02	2.15	1.02	3.308	1.03	HW
9,54,99	80	0.1	50	10	1.599	1	2.239	1	3.163	1	HW
10,55,100	80	0.1	50	100	1.362	1	1.606	1	1.837	1	HW (0.4)
11,56,101	80	0.1	100	0.01	0.997	1.38	1.156	1.64	1.536	1.86	HW
12,57,102	80	0.1	100	0.1	1.347	1.05	1.837	1.08	2.824	1.11	HW
13,58,103	80	0.1	100	1	1.468	1.01	2.132	1.01	3.324	1.02	HW
14,59,104	80	0.1	100	10	1.482	1	2.075	1	2.92	1	HW
15,60,105	80	0.1	100	100	1.312	1	1.585	1	1.852	1	HW (0.4)
16,61,106	80	0.5	20	0.01	0.002	597.8	0.001	1661.25	0.001	2668.36	HW
17,62,107	80	0.5	20	0.1	1.271	1.22	1.619	1.33	2.345	1.42	HW
18,63,108	80	0.5	20	1	1.541	1.04	2.036	1.05	3.167	1.06	HW
19,64,109	80	0.5	20	10	1.64	1.01	2.269	1.01	3.126	1.01	HW
20,65,110	80	0.5	20	100	1.361	1	1.521	1	1.774	1	HW (0.8)
21,66,111	80	0.5	50	0.01	0.513	2.94	0.532	3.87	0.662	4.7	HW
22,67,112	80	0.5	50	0.1	1.418	1.1	1.883	1.15	2.867	1.19	HW
23,68,113	80	0.5	50	1	1.593	1.02	2.263	1.02	3.44	1.03	HW
24,69,114	80	0.5	50	10	1.659	1	2.297	1	3.221	1	HW
25,70,115	80	0.5	50	100	1.386	1	1.625	1	1.803	1	HW (0.4)
26,71,116	80	0.5	100	0.01	1.024	1.45	1.216	1.68	1.653	1.89	HW
27,72,117	80	0.5	100	0.1	1.449	1.06	1.979	1.09	2.824	1.11	HW
28,73,118	80	0.5	100	1	1.592	1.01	2.306	1.01	3.645	1.02	HW
29,74,119	80	0.5	100	10	1.598	1	2.214	1	3.066	1	HW
30,75,120	80	0.5	100	100	1.412	1	1.636	1	1.89	1	HW (0.4)
31,76,121	80	1	20	0.01	0.002	598.94	0.001	1663.55	0.001	2671.13	HW
32,77,122	80	1	20	0.1	1.271	1.22	1.619	1.33	2.345	1.42	HW
33,78,123	80	1	20	1	1.541	1.04	2.036	1.05	3.167	1.06	HW
34,79,124	80	1	20	10	1.651	1.01	2.269	1.01	3.126	1.01	HW

Table 5.5: Well type selection between horizontal and vertical well based on time and recovery factor ratio for 80 Acres RDA (Continued)

WELL & RESERVOIR PARAMETERS					RATIO OF TIME AND RECOVERY FACTOR						WELL TYPE
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TV/TH	RH/RV	TV/TH	RH/RV	TV/TH	RH/RV	
	Acres		Feet	md							
35,80,125	80	1	20	100	1.361	1	1.521	1	1.774	1	HW (0.8)
36,81,126	80	1	50	0.01	0.513	2.96	0.534	3.88	0.664	4.72	HW
37,82,127	80	1	50	0.1	1.425	1.1	1.897	1.15	2.899	1.19	HW
38,83,128	80	1	50	1	1.593	1.02	2.263	1.02	3.583	1.03	HW
39,84,129	80	1	50	10	1.667	1	2.312	1	3.251	1	HW
40,85,130	80	1	50	100	1.391	1	1.625	1	1.812	1	HW (0.4)
41,86,131	80	1	100	0.01	1.032	1.47	1.229	1.69	1.686	1.9	HW
42,87,132	80	1	100	0.1	1.471	1.06	2.021	1.09	3.148	1.11	HW
43,88,133	80	1	100	1	1.638	1.01	2.354	1.01	3.645	1.02	HW
44,89,134	80	1	100	10	1.628	1	2.237	1	3.088	1	HW
45,90,135	80	1	100	100	1.425	1	1.648	1	1.89	1	HW (0.4)

Table 5.6: Well type selection between horizontal well and hydraulic-fractured vertical well based on time and recovery factor ratio for 80 Acres RDA

Well & Reservoir Parameters					Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Well Type
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TH/TF	RFF/RFH	TH/TF	RFF/RFH	TH/TF	RFF/RFH	
	Acres		Feet	md							
1,46,91	80	0.1	20	0.01	0.478	2.882	0.952	1.475	1.196	1.216	HW (0.8)
2,47,92	80	0.1	20	0.1	1.244	1.093	1.288	1.054	1.311	1.031	HW (0.8)
3,48,93	80	0.1	20	1	1.31	1.016	1.167	1.007	0.95	0.999	HW
4,49,94	80	0.1	20	10	N/A						
5,50,95	80	0.1	20	100							
6,51,96	80	0.1	50	0.01	1.037	1.385	1.203	1.199	1.362	1.117	HW (0.8)
7,52,97	80	0.1	50	0.1	1.372	1.054	1.382	1.033	1.424	1.019	HW (0.8)
8,53,98	80	0.1	50	1	1.436	1.009	1.25	1.004	1	1	HW (0.4)
9,54,99	80	0.1	50	10	N/A						
10,55,100	80	0.1	50	100							
11,56,101	80	0.1	100	0.01	1.242	1.24	1.357	1.14	1.528	1.087	HW (0.8)
12,57,102	80	0.1	100	0.1	1.524	1.041	1.537	1.024	1.581	1.014	HW (0.8)
13,58,103	80	0.1	100	1	1.604	1.005	1.359	1.003	1.063	1	HW (0.8)
14,59,104	80	0.1	100	10	N/A						
15,60,105	80	0.1	100	100							
16,61,106	80	0.5	20	0.01	0.504	2.719	0.96	1.453	1.196	1.207	HW (0.8)
17,62,107	80	0.5	20	0.1	1.244	1.089	1.273	1.053	1.289	1.031	HW (0.8)
18,63,108	80	0.5	20	1	1.276	1.017	1.167	1.006	0.9	1.001	HW
19,64,109	80	0.5	20	10	N/A						
20,65,110	80	0.5	20	100							
21,66,111	80	0.5	50	0.01	1.046	1.325	1.185	1.173	1.322	1.103	HW (0.8)
22,67,112	80	0.5	50	0.1	1.328	1.048	1.343	1.029	1.364	1.017	HW (0.8)
23,68,113	80	0.5	50	1	1.385	1.008	1.188	1.004	0.962	1	HW (0.4)
24,69,114	80	0.5	50	10	N/A						
25,70,115	80	0.5	50	100							
26,71,116	80	0.5	100	0.01	1.209	1.181	1.29	1.109	1.42	1.068	HW (0.8)
27,72,117	80	0.5	100	0.1	1.417	1.033	1.426	1.019	1.581	1.014	HW (0.8)
28,73,118	80	0.5	100	1	1.479	1.004	1.256	1.002	0.969	1	HW (0.8)
29,74,119	80	0.5	100	10	N/A						
30,75,120	80	0.5	100	100							
31,76,121	80	1	20	0.01	0.504	2.714	0.96	1.451	1.196	1.206	HW (0.8)
32,77,122	80	1	20	0.1	1.244	1.088	1.273	1.053	1.289	1.031	HW (0.8)
33,78,123	80	1	20	1	1.276	1.017	1.167	1.006	0.9	1.001	HW
34,79,124	80	1	20	10	N/A						

Table 5.6: Well type selection between horizontal well and hydraulic-fractured vertical well based on time and recovery factor ratio for 80 Acres RDA (continued)

Well & Reservoir Parameters					Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Fracture Conductivity 2000 md-ft		Well Type
					P.R. =0.2		P.R. =0.4		P.R. =0.8		
CASES	Area	K _v /K _h	h	k _h	TH/TF	RFF/RFH	TH/TF	RFF/RFH	TH/TF	RFF/RFH	
	Acres		Feet	md							
35,80,125	80	1	20	100	N/A						
36,81,126	80	1	50	0.01	1.046	1.316	1.181	1.169	1.317	1.1	HW (0.8)
37,82,127	80	1	50	0.1	1.321	1.047	1.333	1.029	1.348	1.017	HW (0.8)
38,83,128	80	1	50	1	1.385	1.007	1.188	1.003	0.923	1	HW (0.4)
39,84,129	80	1	50	10	N/A						
40,85,130	80	1	50	100							
41,86,131	80	1	100	0.01	1.2	1.169	1.276	1.102	1.392	1.064	HW (0.8)
42,87,132	80	1	100	0.1	1.396	1.031	1.397	1.018	1.419	1.01	HW (0.8)
43,88,133	80	1	100	1	1.438	1.004	1.231	1.002	0.969	1	HW (0.8)
44,89,134	80	1	100	10	N/A						
45,90,135	80	1	100	100							

5.13 P/Z versus G_p Plot

Through the application of the material balance equation for volumetric dry-gas reservoirs, the plot of P/Z versus G_p is used in the petroleum industry in order to determine the initial gas-in-place and initial gas reserves in such reservoirs. Prior to this research, one had to assume an abandonment pressure for the reservoir in order to determine the initial gas reserves. It has been the practice in the petroleum industry and in petroleum engineering education to assume a low abandonment pressure (such as 500 psia) which was then used to determine the initial reserves. This has resulted in very high ultimate recovery factor for any type of well in volumetric dry-gas reservoirs. The current research has shown for the first time in the petroleum engineering discipline that the abandonment pressure is dependent on reservoir properties and well characteristics (well type and well penetration ratio). For the first time in the petroleum engineering discipline, the current research has determined the values of the abandonment pressure, the ultimate recovery factor, and the abandonment time as a function of well and reservoir parameters.

Figures 5.181, 5.182, and 5.183 show the plots of P/Z versus Recovery Factor (or G_p/G) for a vertical well case (case 10 in the square drainage area), a hydraulically-fractured vertical well case (case 1 in square drainage area), a horizontal well case (case 134 in 2:1 rectangular drainage area), respectively. These plots show that, for each well type, the plot of P/Z versus Recovery Factor is a perfect straight line.

Accurate values of abandonment pressure can be obtained using the results shown in Tables 5.1 and 5.2. This will enable the petroleum engineers to correctly utilize the plot of

P/Z versus G_p in order to obtain an accurate estimate of initial reserves in volumetric dry-gas and wet-gas reservoirs.

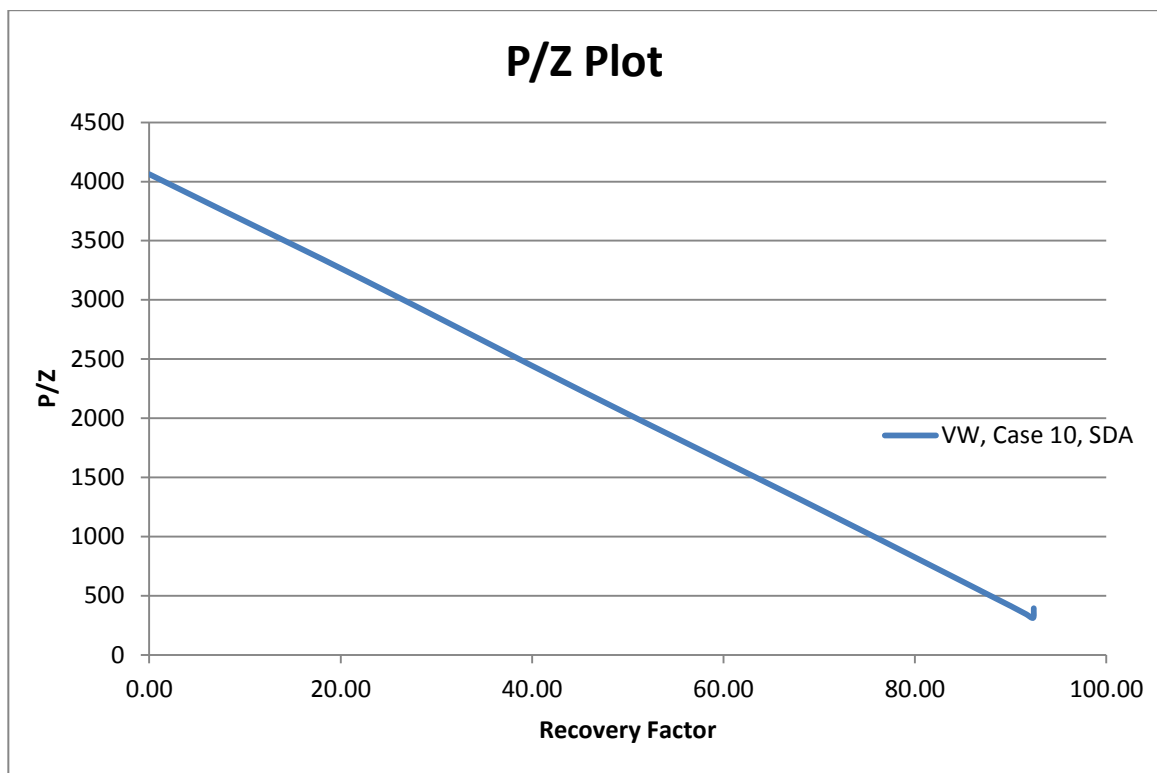


Figure 5. 181: P/Z VS R.F for VW, h= 50 feet, A=80 Acres, SDA (Case 10)

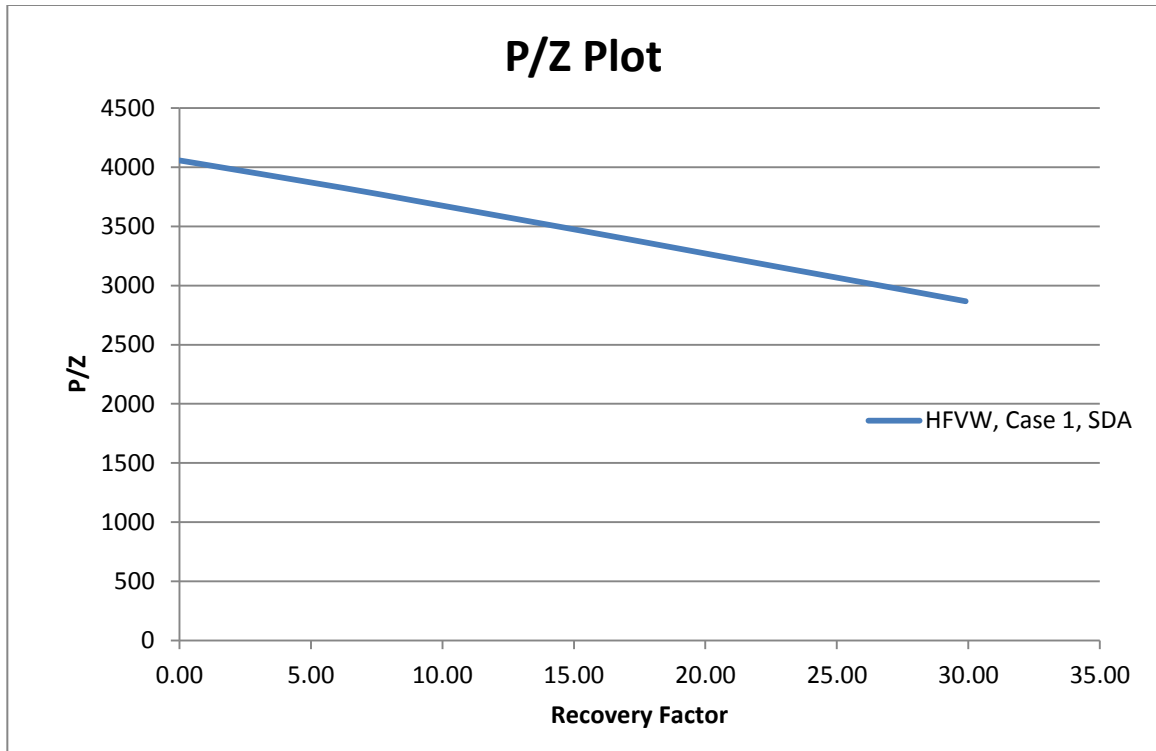


Figure 5. 182: P/Z VS R.F for HFVW, P.R =0.2, h= 20 feet, A=80 acres, SDA (Case 1)

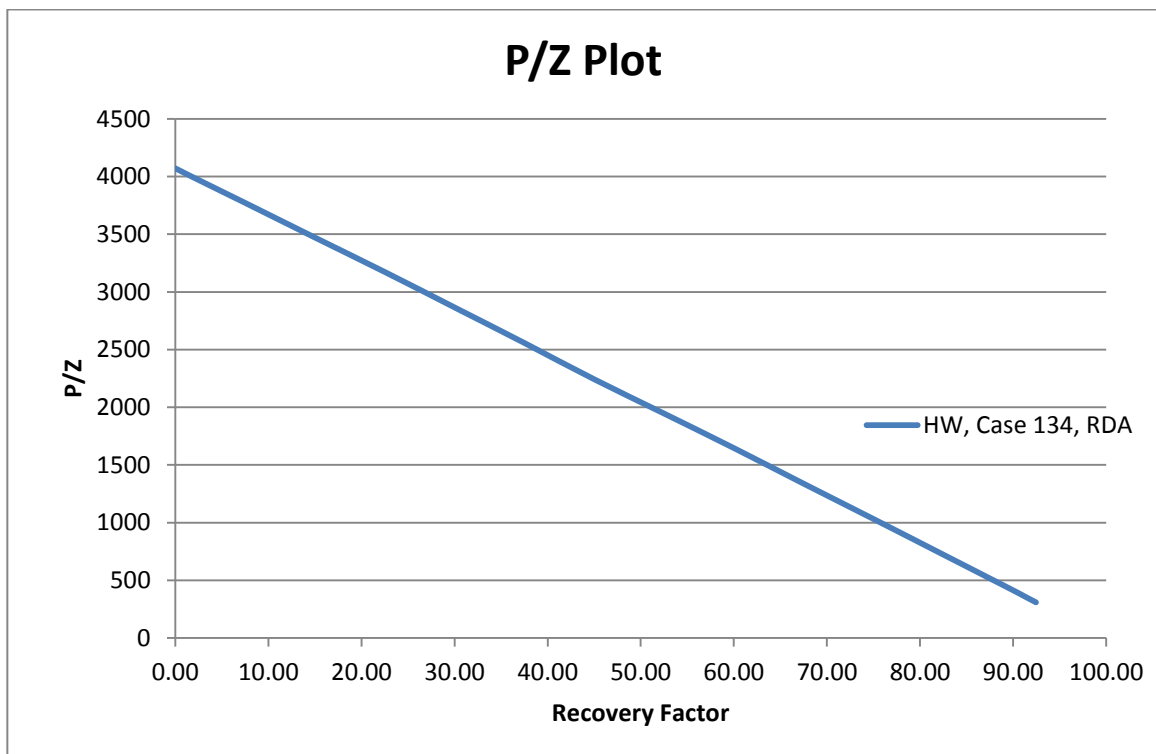


Figure 5. 183: P/Z VS recovery factor for HFVW, P.R =0.8, h= 100 feet, $K_v/K_h = 1$, A=80 acres, RDA (Case 134)

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the analysis of the results obtained in this research study, the following conclusions can be made in regards to the effects of well and reservoir parameters on the performance of vertical wells, horizontal wells, and hydraulically-fractured vertical wells in homogeneous and anisotropic volumetric dry-gas reservoirs. The average reservoir pressure at abandonment time, the ultimate recovery factor, and the time to reach abandonment condition have been determined for the three well types for wide ranges of reservoir and well parameters of practical importance. This is the first time in the petroleum engineering discipline that this has been accomplished for each well type:

1. Initial production rate of the three well types does not have any effect on the ultimate recovery factor in volumetric dry-gas reservoirs.
2. In the case of reservoirs with low horizontal permeability (such as 0.01 md and 0.1 md), initial production rate of the three well types does not have any effect on the time to reach the abandonment condition.
3. For horizontal wells, the ratio of vertical permeability to horizontal permeability (k_v/k_h ratio), gas gravity, and horizontal well location with respect to the upper and

lower no-flow boundaries have only negligible effect on the ultimate recovery factor and on the time to reach abandonment.

4. Horizontal permeability has the largest effect on the ultimate recovery factor and on the abandonment time. In general, after horizontal permeability, the well penetration ratio and then the formation thickness have the largest effect for all well types.
5. For low values of well penetration ratio (0.2) and formation thickness (20 feet), as horizontal permeability increases from 0.1 md to 1 md, the ultimate recovery factor increases and the abandonment time decreases for all three well types. In such cases, the reservoir should be developed with HFVW due to the combination of high ultimate recovery factor and low abandonment time for HFVW compared to HW and VW. As the horizontal permeability increases from 0.01 md to 1 md, the advantage of the HFVW over the HW decreases both in terms of the ultimate recovery factor and the abandonment time.
6. For thin reservoirs (20 feet) with horizontal permeabilities of 10 md and 100 md, both the HW of low penetration ratio (0.2) and the VW give the same ultimate recovery factor; the only difference is in the time to reach the abandonment condition. It takes VW more time to reach abandonment condition as compare to HW; however, as horizontal permeability increases from 10 md to 100 md, the difference becomes very small. Therefore, thin reservoirs with high horizontal permeability (such as 100 md) should be developed with VW in preference to HW of low penetration ratio of 0.2.

7. For high value of formation thickness (such as 100 feet) and low value of penetration ratio (0.2), the performance of HW and VW become somewhat closer to each other for horizontal permeability of 1 md and lower. Again HFVW always perform better than HW and VW both in terms of higher ultimate recovery factor and considerably lower abandonment time. As horizontal permeability increases from 0.01 md to 1 md, the ultimate recovery factor for all the 3 well types become closer to each other.
8. For high value of formation thickness (such as 100 feet) and horizontal permeabilities (10 md and 100 md), and low value of penetration ratio (0.2), the performance of HW and VW become identical with respect to ultimate recovery factor and almost identical with respect to abandonment time.
9. For low value of formation thickness (20 feet), and high value of penetration ratio (0.8), the performance of HW and HFVW become identical when horizontal permeability is 1 md; this implies that in such cases, there is no need for the HFVW and that the reservoir should be developed with HW. This figure indicates that at the lower horizontal permeabilities of 0.1 md and 0.01 md and for a penetration ratio of 0.8, HFVW should be used to develop thin reservoirs.
10. For low value of formation thickness (20 feet) and high values of penetration ratio (0.8) and horizontal permeability (10 md and 100 md), HW and VW have the same ultimate recovery factor; however, the HW has drastically lower abandonment time. Therefore, in such cases, the reservoir should be developed with horizontal wells. It is interesting to note that, for thin reservoirs (20 feet) and high well penetration

ratio (0.8), the ultimate recovery factor is about 90% for all 3 well types when horizontal permeability is 1 md and higher.

11. For high values of formation thickness (100 feet) and penetration ratio (0.8), the performance of HW and HFVW become identical at a horizontal permeability of 1 md; however, at lower horizontal permeabilities (0.1 md and 0.01 md), the HFVW performs much better than the HW in terms of both the ultimate recovery factor and abandonment time. At the horizontal permeability of 1 md, the ultimate recovery factor for all 3 well types is about 92%.
12. For high values of formation thickness (100 feet) and penetration ratio (0.8), HW and VW will have the same ultimate recovery factor of about 92% when permeability is 10 md and higher; however, HW performs much better than the VW due to drastically lower abandonment time.
13. The value of k_v/k_h ratio has somewhat negligible effect on the performance of horizontal wells in volumetric dry gas reservoirs. The ultimate recovery factor is about the same for all k_v/k_h ratios but the abandonment time is only slightly lower for the k_v/k_h ratio of 1 compared to the one for the k_v/k_h ratio of 0.1.
14. For low values of horizontal permeability (0.01 md, 0.1 md and 1 md) and penetration ratio (0.2), as formation thickness increases, the recovery factor increases for all 3 well types. In such cases, HFVW should be used to develop the reservoir. HFVW perform better than the VW and HW in cases of low values of horizontal permeability and penetration ratio, regardless of the value of formation thickness.

15. Considering the values of both the ultimate recovery factor and the abandonment time, for low value of penetration ratio (0.2) and for all formation thicknesses considered in this research study, the reservoir should be developed with HW when the horizontal permeability is 10 md while the reservoir should be developed with VW when the horizontal permeability is 100 md. At horizontal permeability of 10 md and higher, the formation thickness does not affect the ultimate recovery factor.
16. Drainage area size and shape have considerable effect on the ultimate recovery factor and on the abandonment time in some cases; their effects are described and quantified in this research for all the three well types considered. Conclusions 17 through 26 below describe the effects of drainage area size and shape.
17. For low value of formation thickness (20 feet) and for horizontal permeability of 0.01 md, as the drainage area size increases from 80 acres to 160 acres, the ultimate recovery factor for both HFVW and HW increases while the abandonment time for HFVW more than doubles and for HW increases by about 6 fold.
18. For low value of formation thickness (20 feet) and for horizontal permeability of 0.1 md, as the drainage area size increases from 80 acres to 160 acres, the ultimate recovery factor for both HFVW and HW increases, and the abandonment time for both HFVW and HW increases by less than two folds. For the VW, drainage area size has no effect on the ultimate recovery factor and the abandonment time for the 160 acres is almost twice the one for the 80 acres.
19. For low value of formation thickness (20 feet) and for a horizontal permeability of 1 md, as the drainage area size increases from 80 acres to 160 acres, the ultimate recovery factors for HFVW remain almost the same; the same conclusion is

obtained for the HW. The abandonment time for both HFVW and HW increases by less than two folds as the drainage area size doubles from 80 acres to 160 acres. For the VW, drainage area size has no effect on the ultimate recovery factor and the abandonment time for the 160 acres is almost twice the one for the 80 acres.

20. For low value of formation thickness (20 feet) and for horizontal permeabilities of 10 md and 100 md, the recovery factors of the HW and VW are about the same, regardless of the value of drainage area size. For both these type of wells, the time to reach abandonment for the 160-acre case is less than twice the one for the 80-acre case.
21. For high values of formation thickness (100 feet) and penetration ratio (0.8), and for horizontal permeability of 0.01 md, the ultimate recovery factor for the HFVW are about the same, regardless of the value of drainage area size. The same conclusion is obtained for the HW. At 160-acres, the time to reach abandonment for the HFVW is about 2.5 times and for the HW is about 2 times the one at 80 acres.
22. For high values of formation thickness (100 feet) and penetration ratio (0.8), and for horizontal permeability of 0.1 md, the ultimate recovery factor for the HFVW and HW are about the same, regardless of the value of drainage area size. In addition, each of the 3 well types has the same ultimate recovery factor at 160 acres as in 80 acres; recovery factor for the VW is still less than the ones for HW and HFVW. At 160 acres, the time to reach abandonment for the HFVW and HW is about 2 times the one at 80 acres.
23. For high values of formation thickness (100 feet) and penetration ratio (0.8), and for a horizontal permeability of 1 md, the ultimate recovery factor for the HFVW, HW

and VW are about the same, regardless of the value of drainage area size. In such cases, the performance of the HFVW and HW are almost identical at a given drainage area size. At 160 acres, the time to reach abandonment for the HFVW, HW and VW is about 2 times the one at 80 acres.

24. For high values of formation thickness and penetration ratio (0.8), and for horizontal permeabilities of 10 md and 100 md, the ultimate recovery factor for the HW and VW are about the same, regardless of the value of drainage area size. However, the time to reach abandonment time for the vertical well is much larger than the one for the HW. At 160 acres, the time to reach abandonment for the HW and VW is about 2 times the one at 80 acres.
25. At lower horizontal permeabilities (0.01 md and 0.1 md), the performance of both HFVW and HW is much better in 2:1 rectangular drainage area than in square drainage area.
26. At horizontal permeability of 1 md, the performance of both HFVW and HW is about the same in 2:1 rectangular drainage area than in square drainage area.
27. For the vertical well, the lower the values of horizontal permeability and formation thickness, the higher the average reservoir pressure at abandonment time.
28. For the horizontal well, the lower the values of horizontal permeability, formation thickness, and horizontal well penetration ratio, the higher the average reservoir pressure at abandonment time, the lower the ultimate recovery factor, and the higher the abandonment time.

29. The lower the values of horizontal permeability and formation thickness, and the higher horizontal well penetration ratio, the better the performance of horizontal well over the performance of vertical well.
30. Results show that at low horizontal permeabilities (0.01 md and 0.1 md), the length of the hydraulic fracture, and not the fracture conductivity, is important for improved well performance. At higher permeability (1 md), the fracture conductivity becomes more important than the fracture length for improved well performance. Results show that as the horizontal permeability increases to 1 md, the performance of hydraulically-fractured vertical wells and horizontal wells become almost similar.
31. At low horizontal permeabilities, the hydraulically-fractured vertical well of penetration ratio 0.4 has about the same performance as the horizontal well of penetration ratio 0.8. In addition, the hydraulically-fractured vertical well of penetration ratio 0.2 has about the same performance as the horizontal well of penetration ratio 0.4.
32. For low values of horizontal permeability (0.01 md and 0.1 md), formation thickness (20 feet), as the penetration ratio increases, the ultimate recovery factor for the HW and for the HFVW increases. In such cases, the HFVW performs better than HW of the same penetration ratio, both in terms of the higher ultimate recovery factor and lower abandonment time. It is important to mention that, in such cases of low horizontal permeability (0.01 md and 0.1 md), the ultimate recovery factors for both HFVW and HW are much lower compared to the cases where the horizontal permeability is high (10 md and 100 md).

33. For horizontal permeability of 1.0 md and low value of formation thickness (20 feet), the performance of HFVW and HW become identical at high penetration ratio (0.8). In such reservoirs, at lower penetration ratios of 0.4 and 0.2, HFVW performs better than HW of the same penetration ratio only in terms of the abandonment time but not in terms of ultimate recovery; the HFVW and HW have the same ultimate recovery factor in such cases. It is important to note that it is difficult to create long conductive fractures because of the problems with proppant transport, proppant crushing, and proppant embedment. However, one can drill long horizontal wells. A HW of penetration ratio of 0.8 performs better than a HFVW of penetration ratios of 0.4 and 0.2. Therefore, one can state that a HW of penetration ratio of 0.8 performs better than a HFVW because, in reality, the length of the created hydraulic fracture would not exceed a penetration ratio of 0.4 in an 80-acre square drainage area.
34. For low value of formation thickness (20 feet) and high value of horizontal permeability (10 md and 100 md), the value of the penetration ratio of the HW has no effect on the ultimate recovery factor but still affects the abandonment time. In such cases, as the HW penetration ratio increases, the abandonment time decreases.
35. For high value of formation thickness (100 feet) and low value of horizontal permeability (0.01 md and 0.1 md), the advantage of the HFVW over HW increases. A HFVW of penetration ratio of 0.4 performs better than a HW of penetration ratio of 0.8. A HW of penetration ratio of 0.8 performs about the same as a HFVW of penetration ratio of about 0.3.

36. For high value of formation thickness (100 feet) and horizontal permeability of 1 md, the penetration ratio has no effect on the ultimate recovery factor but has significant effect on the abandonment time. HFVW still performs better than HW in terms of abandonment time.
37. For high values of formation thickness (100 feet) and horizontal permeability (10 md and 100 md), the value of HW penetration ratio has no effect on the ultimate recovery factor but still has some effect on the abandonment time.
38. Based on the values of both the ultimate recovery factor and the abandonment time, this research has recommended the selection of the proper well type and well penetration ratio in order to develop a volumetric dry-gas reservoir based on reservoir properties. This is the first time that this has been presented in the petroleum engineering discipline.
39. It is confirmed that, for each well type, the plot of P/Z versus Recovery Factor is a perfect straight line.
40. For the first time in petroleum engineering discipline, accurate values of abandonment pressure can be obtained using the results shown in Tables 5.1 and 5.2. This will enable the petroleum engineers to correctly utilize the plot of P/Z versus G_p in order to obtain an accurate estimate of initial reserves in volumetric dry-gas and wet-gas reservoirs.
41. Both ultimate recovery factor and abandonment time are function of well type for low values of horizontal permeability (0.01 md, 0.1 md and 1 md).
42. For high values of horizontal permeability (10 md and 100 md) only abandonment time is a function of well type not the ultimate recovery factor.

6.2 Recommendations

I recommend that the same study that is conducted here for volumetric dry-gas and wet-gas reservoirs be conducted for volumetric, under-saturated oil reservoirs. In other words, I recommend further research in order to investigate the effects of well and reservoir parameters on the performance of vertical wells, hydraulically-fractured vertical wells, and horizontal wells in volumetric, under-saturated black-oil and volatile-oil reservoirs.

NOMENCLATURE

BHP	Bottom hole pressure, psia
B_g	Gas formation volume factor, RCF/SCF
B_o	Oil formation volume factor, RB/STB
B_w	Water formation volume factor, Res/STD
C_f	Rock Compressibility, psi^{-1}
C_w	Water compressibility, psi^{-1}
FGIP	Initial gas in place, MSCF
FGPR	Gas production rate, MSCF/D
FCD	Dimensionless fracture conductivity
F.C	Fracture Conductivity
GOR	Gas oil ratio, SCF/STB
h	Reservoir thickness, feet
HW	Horizontal well
HFVW	Hydraulic Fractured Vertical Well
K	Formation permeability (md)
K_h	Horizontal permeability, md
K_v	Vertical permeability, md
K_f	Fracture permeability
L_H	Length for horizontal well, feet
$L_H/2X_e$	Horizontal well penetration ratio
NX	Number of grids in X-direction

NY	Number of grids in Y-direction
NZ	Number of grids in Z-direction
Pi	Initial reservoir pressure, psia
Ppr	Pseudo reduced pressure
Q	Flow Rate, Mscf/Day
R.F	Recovery Factor
RH/RV	Ratio of Horizontal well and vertical well Recovery factor
RFF/RFH	Ratio of Hydraulic fractured vertical well & horizontal well Recovery factor
RDA	Rectangular drainage area shape
r_{wh}	Horizontal well radius, ft
r_{wv}	Vertical well radius, ft
SDA	Square drainage area shape
Sg	Initial gas saturation, %
So	Initial oil saturation, %
Sw	Initial water saturation, %
t	Reciprocal of pseudo reduced temperature (T_{pc}/T)
T	Initial reservoir temperature, °F
TV/TH	Ratio of Vertical well and Horizontal well Time factor
TH/TF	Ratio of horizontal well & Hydraulic fractured vertical well Time factor
U.B	Upper No-Flow Boundry
VW	Vertical Well
W	Fracture width (feet)
We	Equivalent fracture width (feet)

X_f	Fracture half length (feet)
$2X_f$	Fracture length (feet)
$2X_e$	Length of Reservoir in X-direction, feet
y	Reduced Density
Z	Compressibility factor
ρ_g	Gas density, lbs/ft ³
ρ_o	Oil density, lbs/ft ³
ρ_w	Water density, lbs/ft ³
μ_w	Water viscosity, cp
Φ	Reservoir porosity, %
Φ_f	Fracture Porosity
Φ_e	Equivalent fracture porosity
γ_g	Specific Gravity

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APPENDIX A

FIGURES

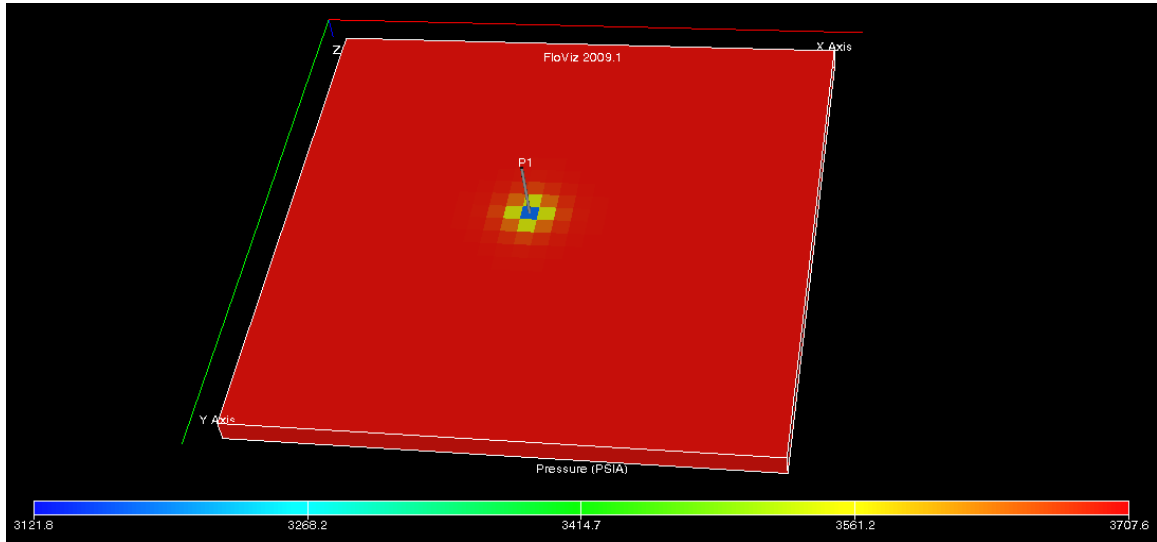


Figure A.1: Schematic 3D reservoir simulation model for vertical well at the end of production, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 1, 46, 91)

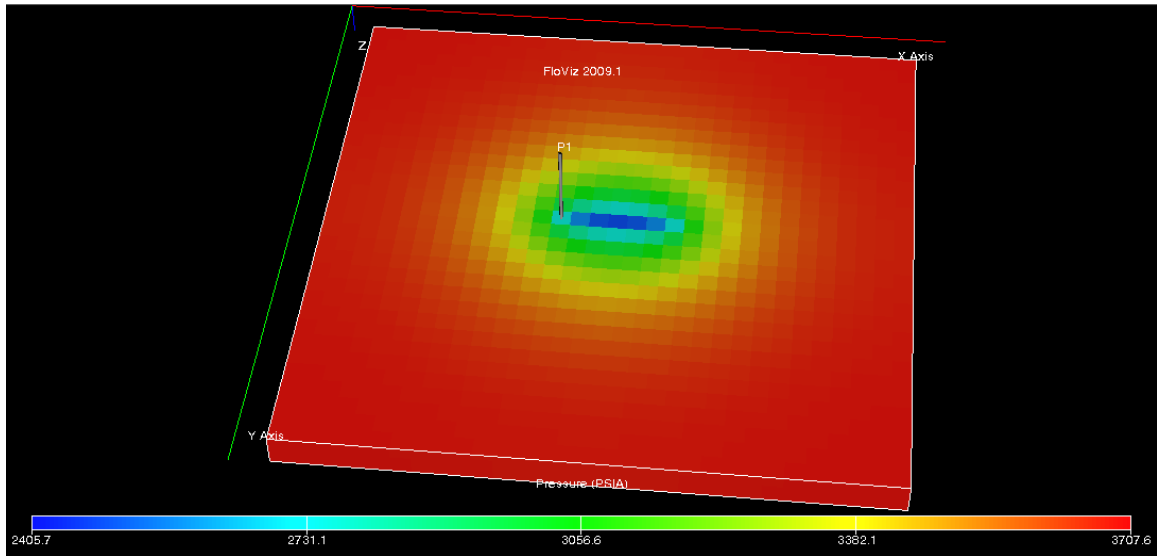


Figure A.2: Schematic 3D reservoir simulation model for horizontal well at the end of production, $P.R = 0.2$, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 1)

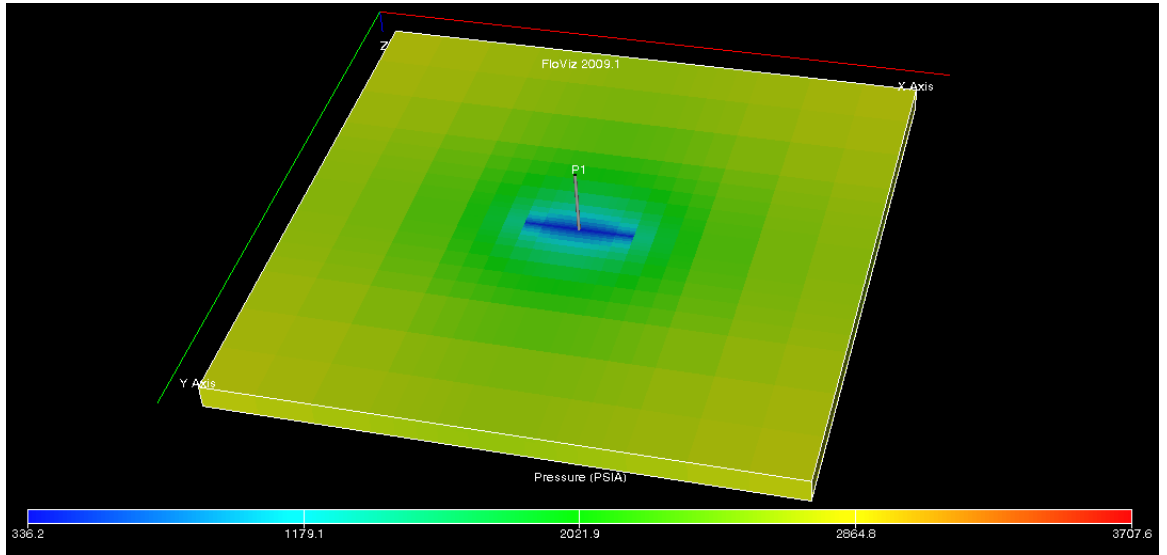


Figure A.3: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.2, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 1)

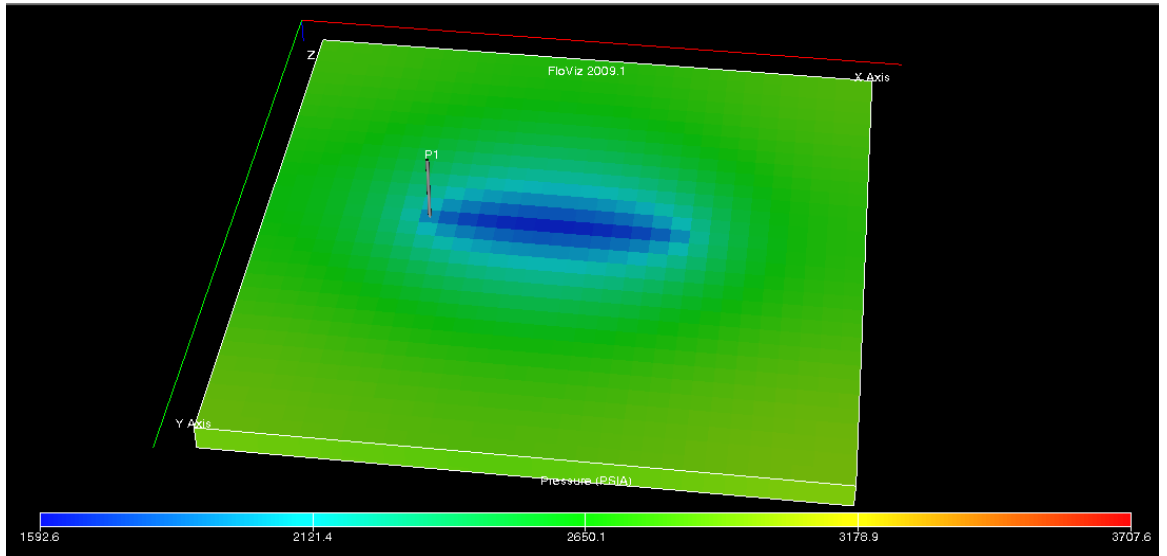


Figure A.4: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.4, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 46)

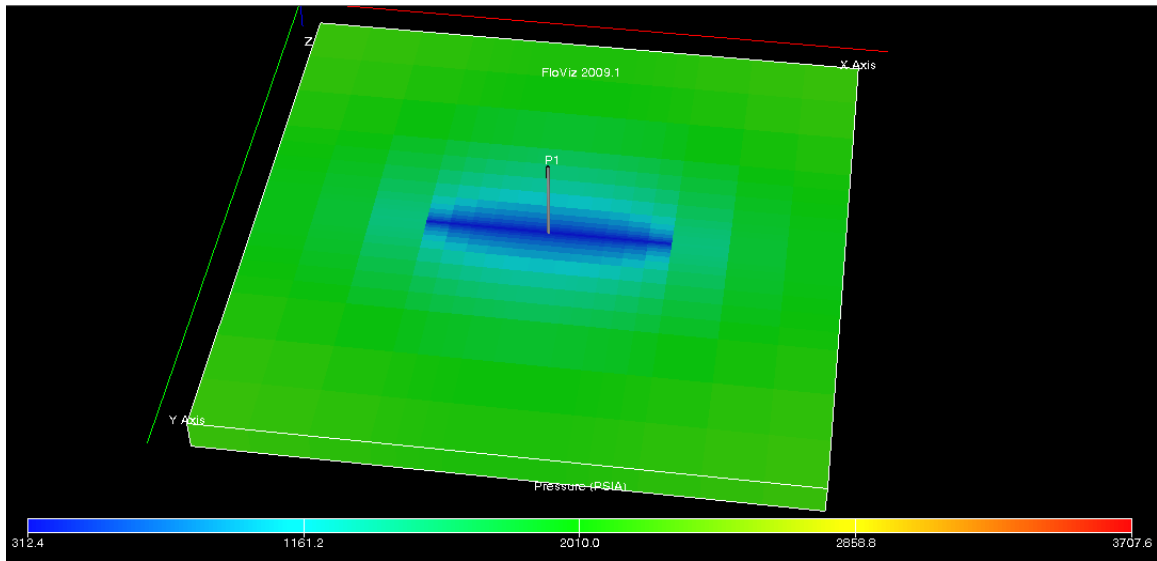


Figure A.5: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.4, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 46)

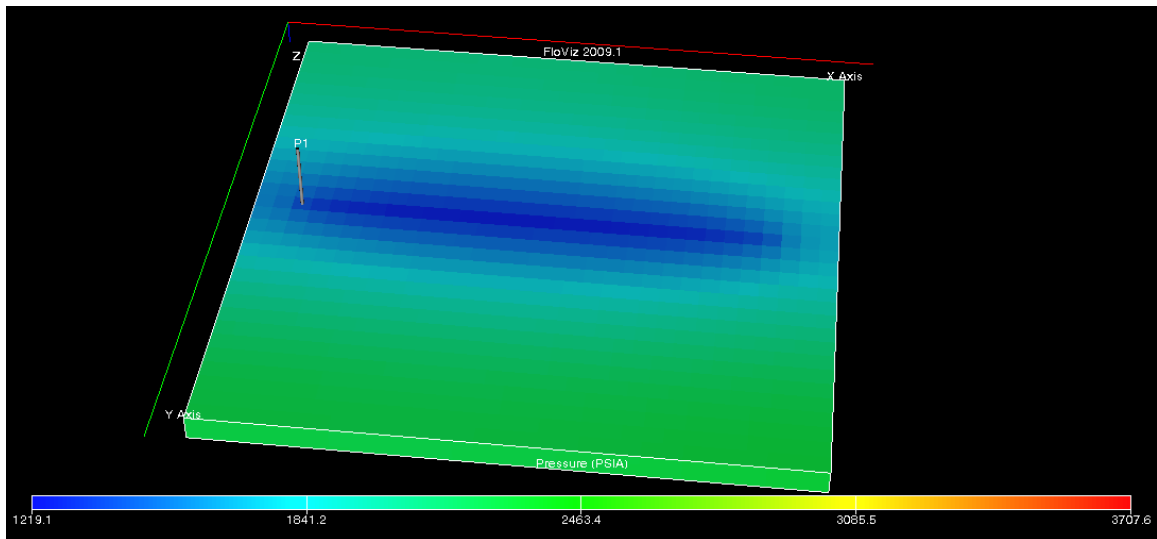


Figure A.6: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.8, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 91)

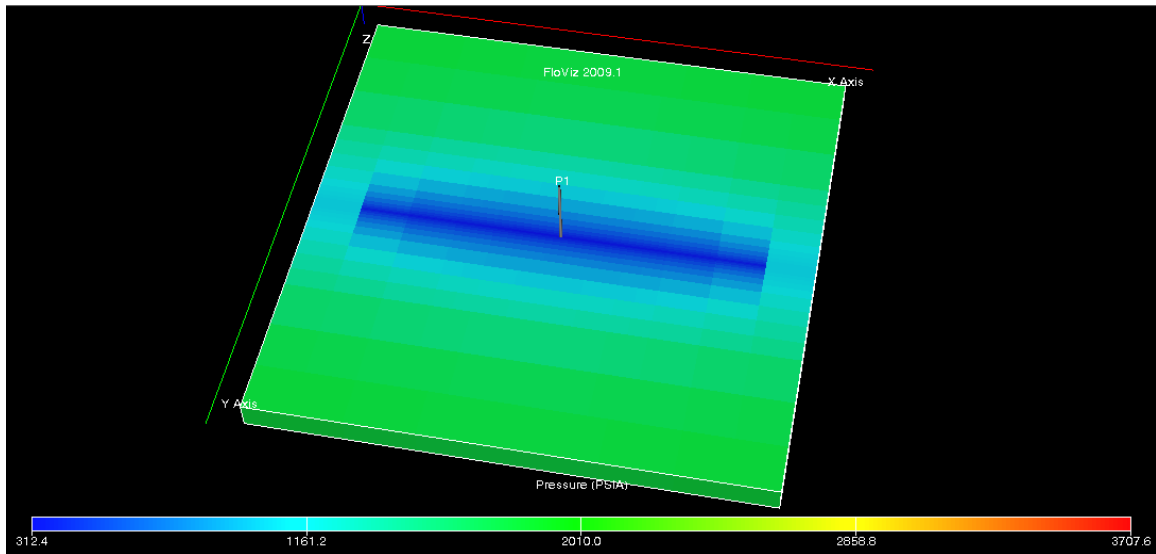


Figure A.7: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.8, $h=20$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 91)

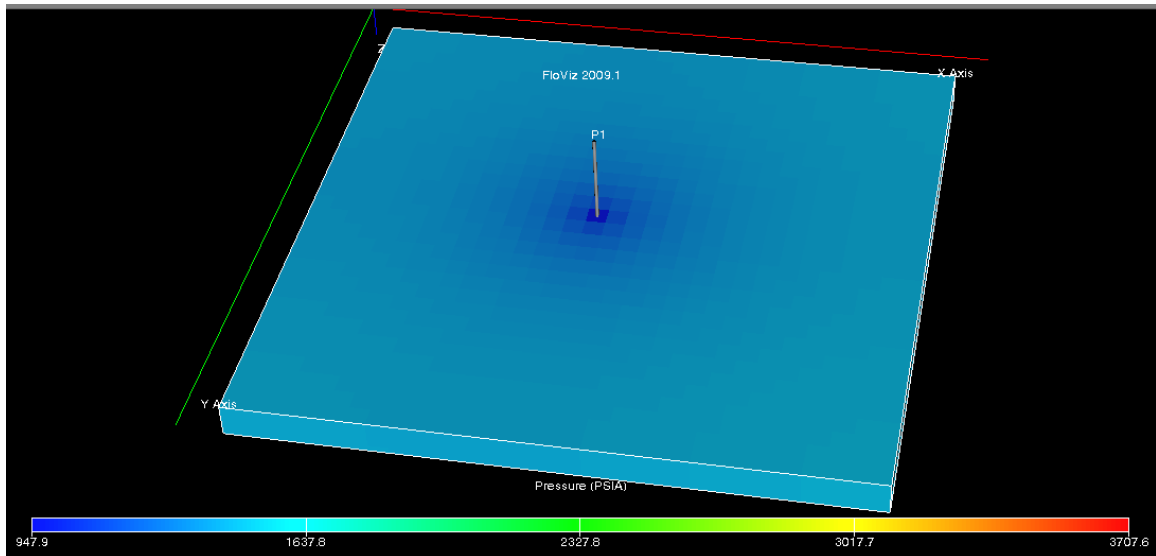


Figure A.8: Schematic 3D reservoir simulation model for vertical well at the end of production, $h=20$ ft, $A=80$ Acres, $k_h=0.1$ md, SDA, (Case 2, 47, 92)

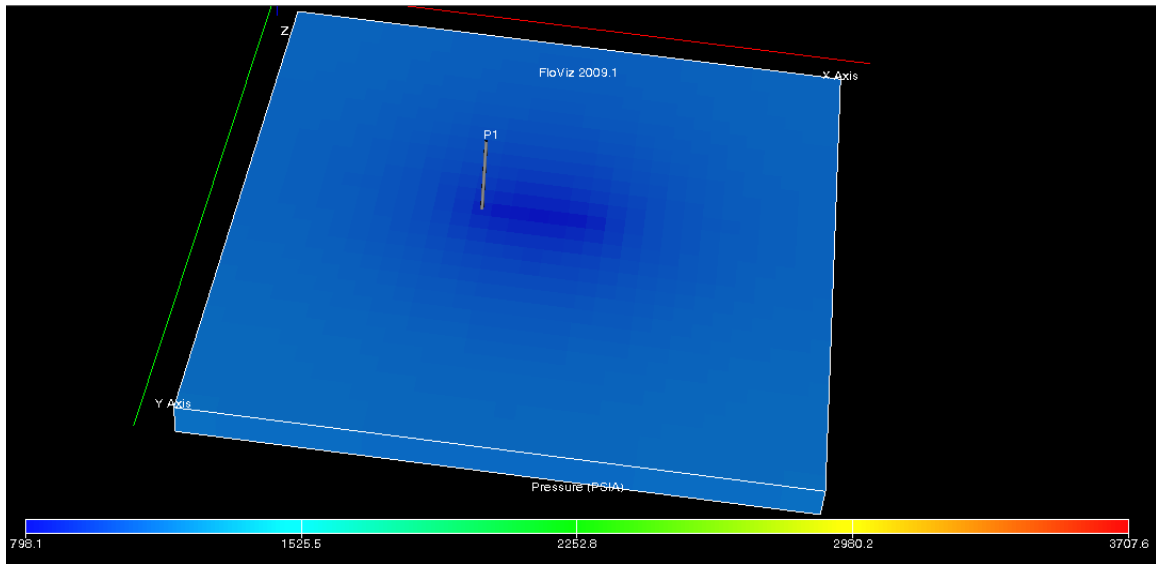


Figure A.9: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.2, h=20 ft, A=80 Acres, $k_h = 0.1$ md, SDA, (Case 2)

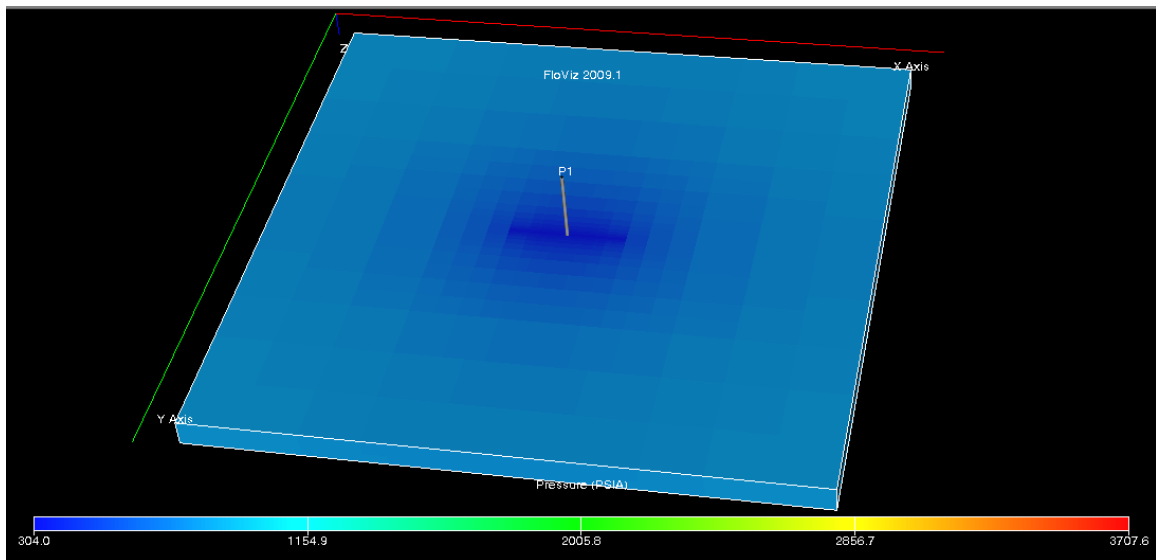


Figure A.10: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.2, h=20 ft, A=80 Acres, $k_h = 0.1$ md, SDA, (Case 2)

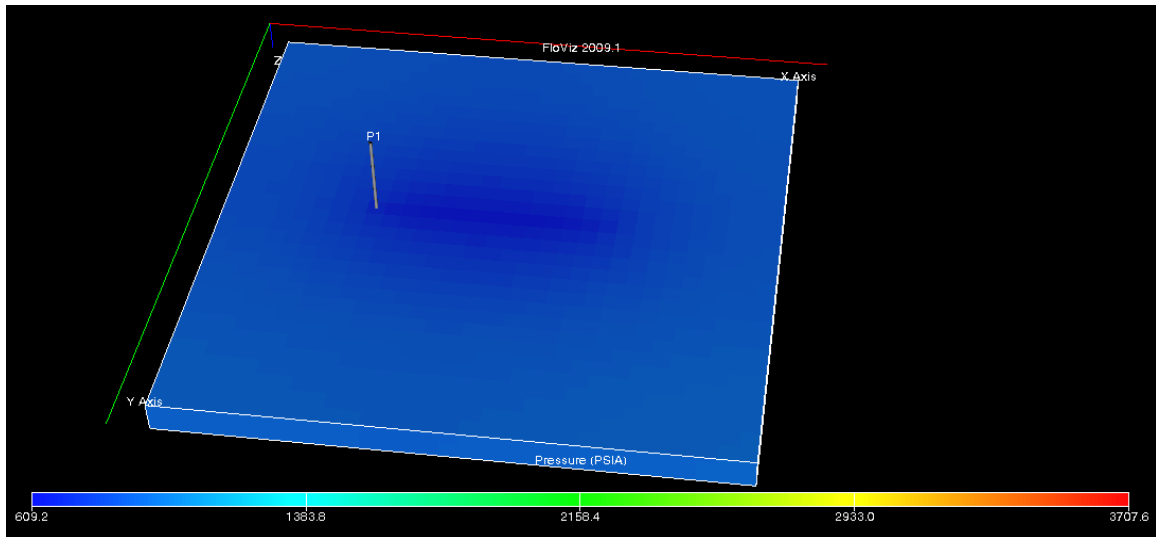


Figure A.11: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.4, h=20 ft, A=80 Acres, $k_h = 0.1$ md, SDA, (Case 47)

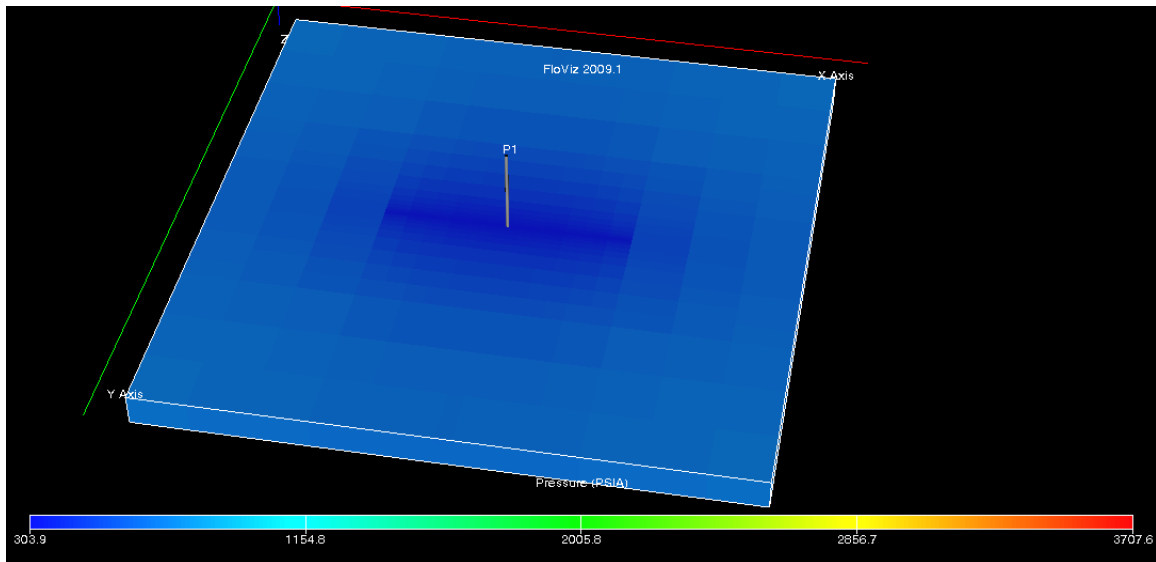


Figure A.12: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.4, h=20 ft, A=80 Acres, $k_h = 0.1$ md, SDA, (Case 47)

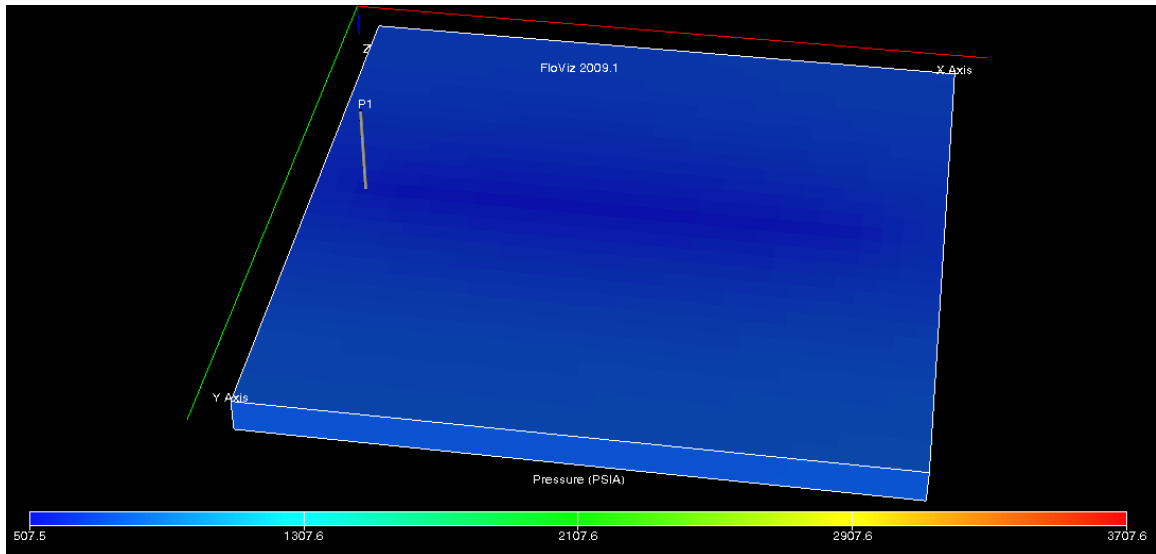


Figure A.13: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.8, h=20 ft, A=80 Acres, k_h =0.1 md, SDA, (Case 92)

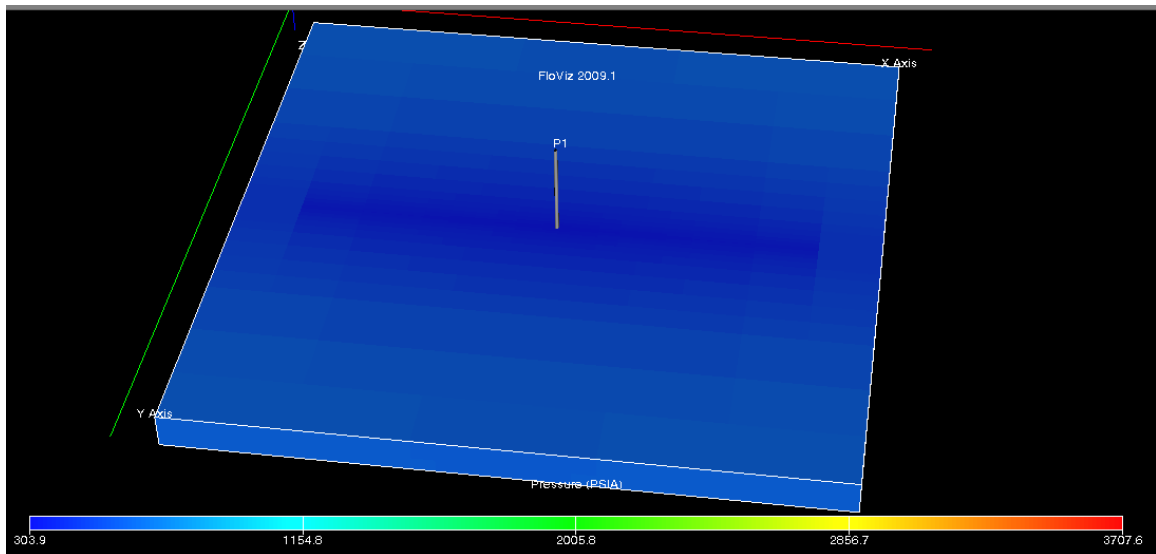


Figure A.14: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.8, h=20 ft, A=80 Acres, k_h =0.1 md, SDA, (Case 92)

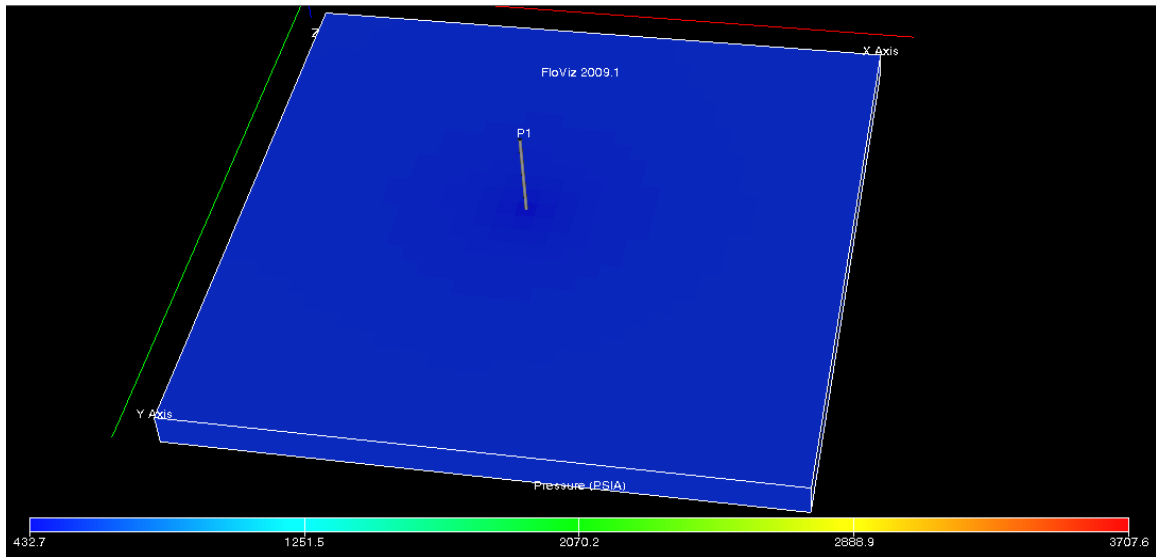


Figure A.15: Schematic 3D reservoir simulation model for vertical well at the end of production, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 3, 48, 93)

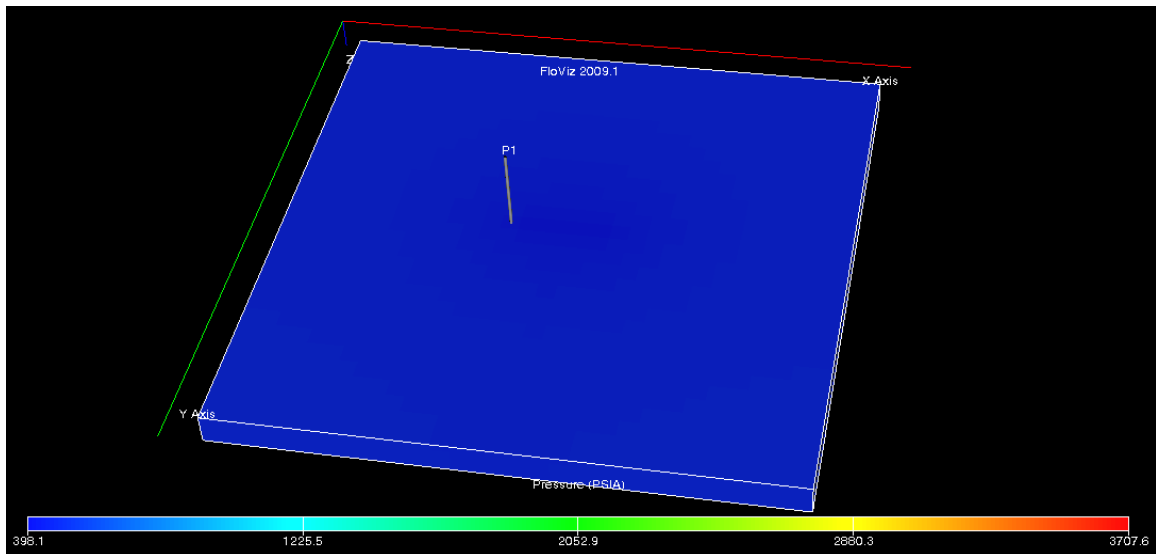


Figure A.16: Schematic 3D reservoir simulation model for horizontal well at the end of production, $P.R = 0.2$, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 3)

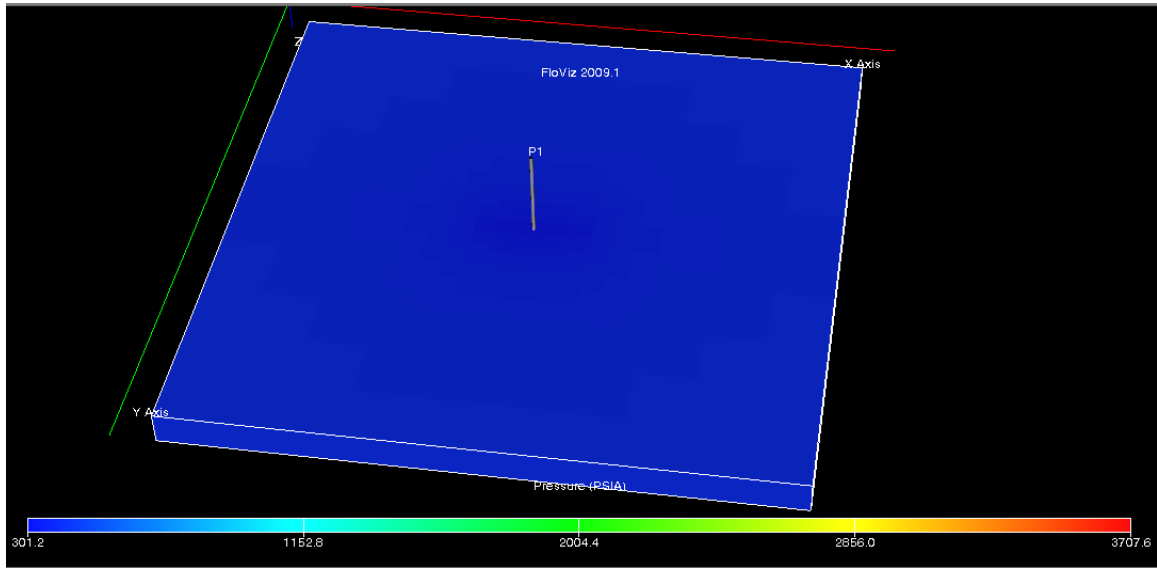


Figure A.17: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.2, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 3)

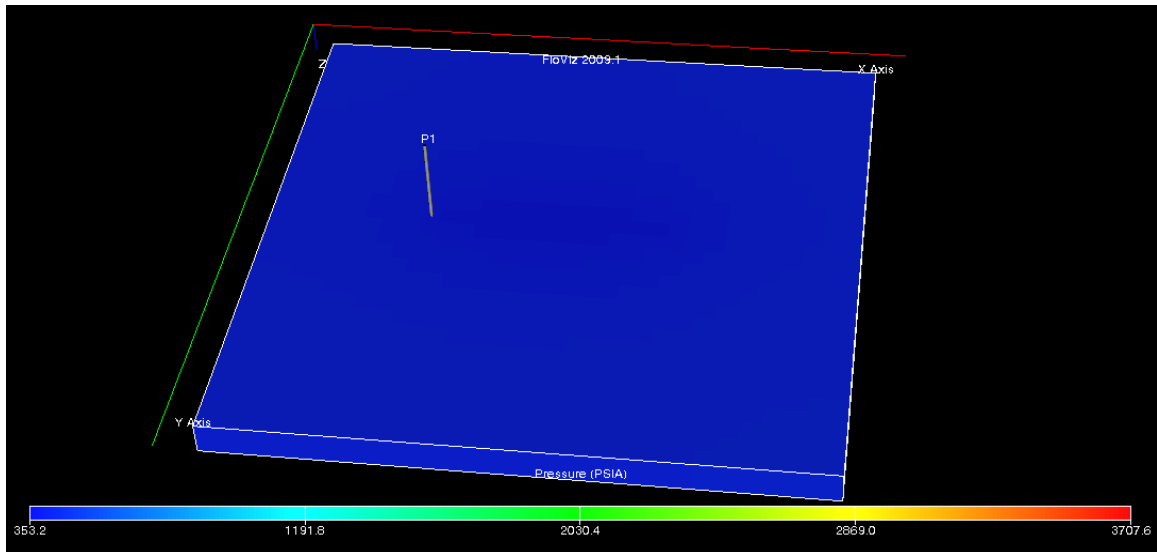


Figure A.18: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.4, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 48)

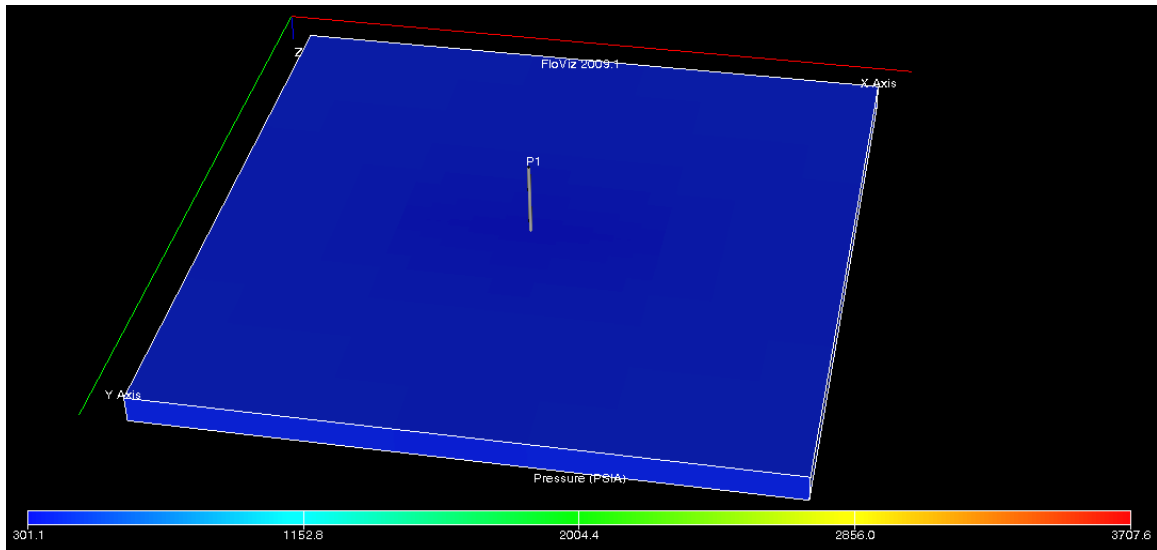


Figure A.19: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.4, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 48)

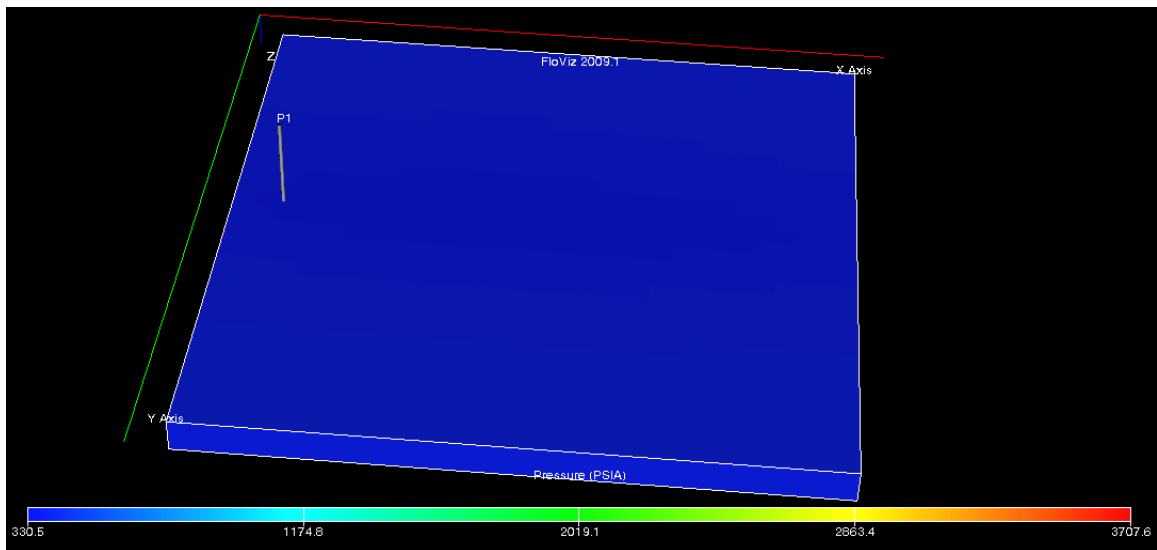


Figure A.20: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.8, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 93)

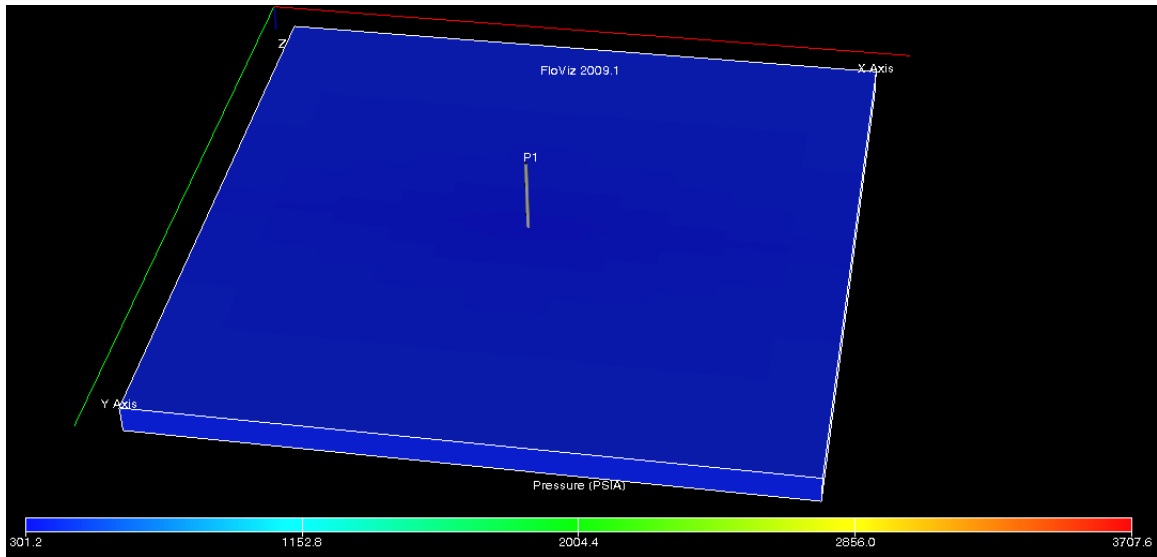


Figure A.21: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.8, $h=20$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 93)

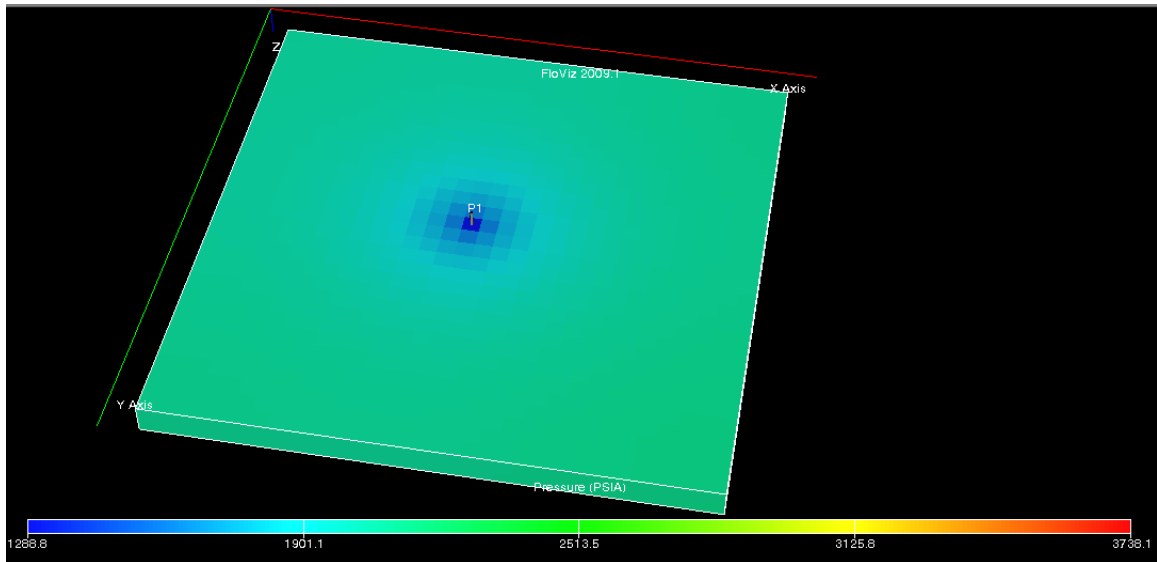


Figure A.22: Schematic 3D reservoir simulation model for vertical well at the end of production, $h=100$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 11, 56, 101)

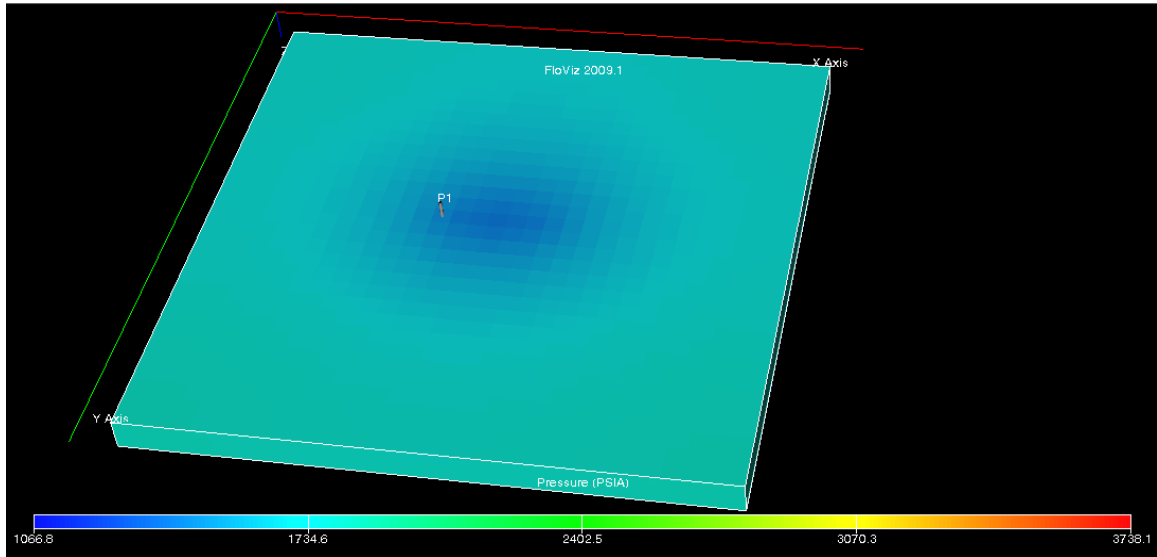


Figure A.23: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.2, $h=100$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 11)

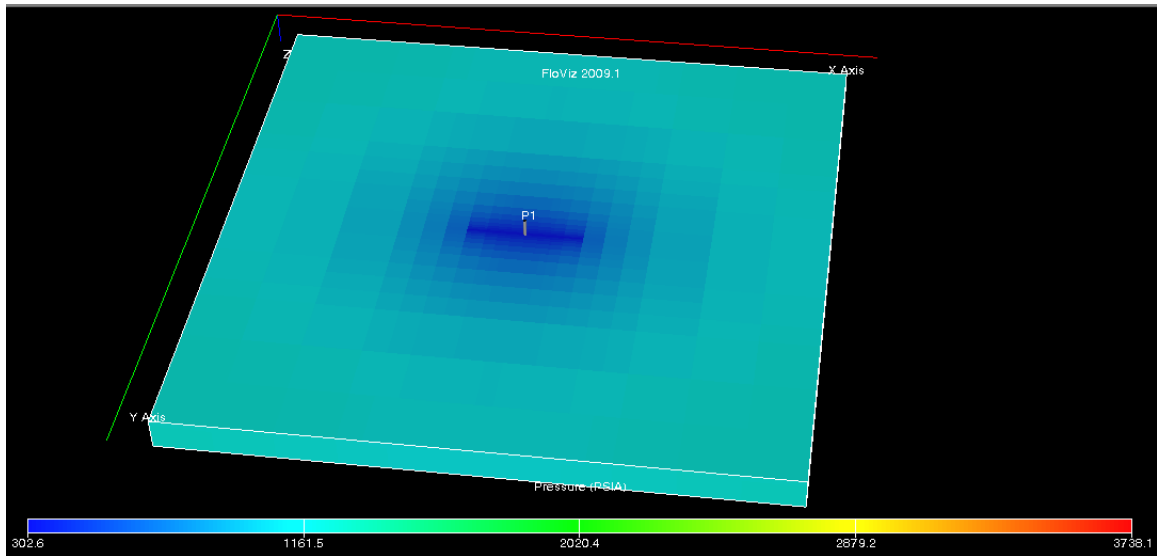


Figure A.24: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.2, $h=100$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 11)

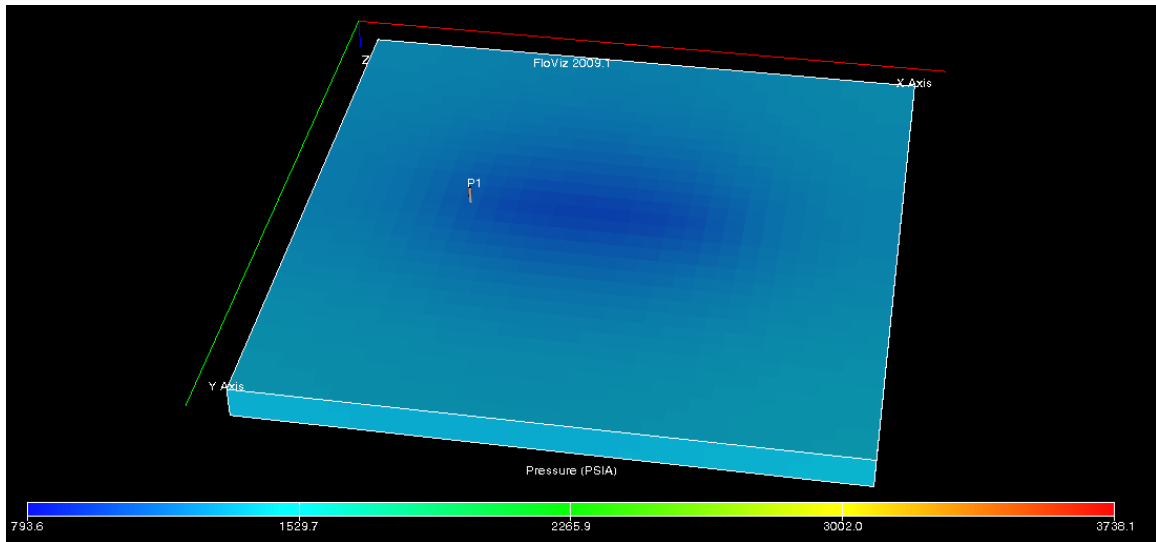


Figure A.25: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.4, $h=100$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 56)

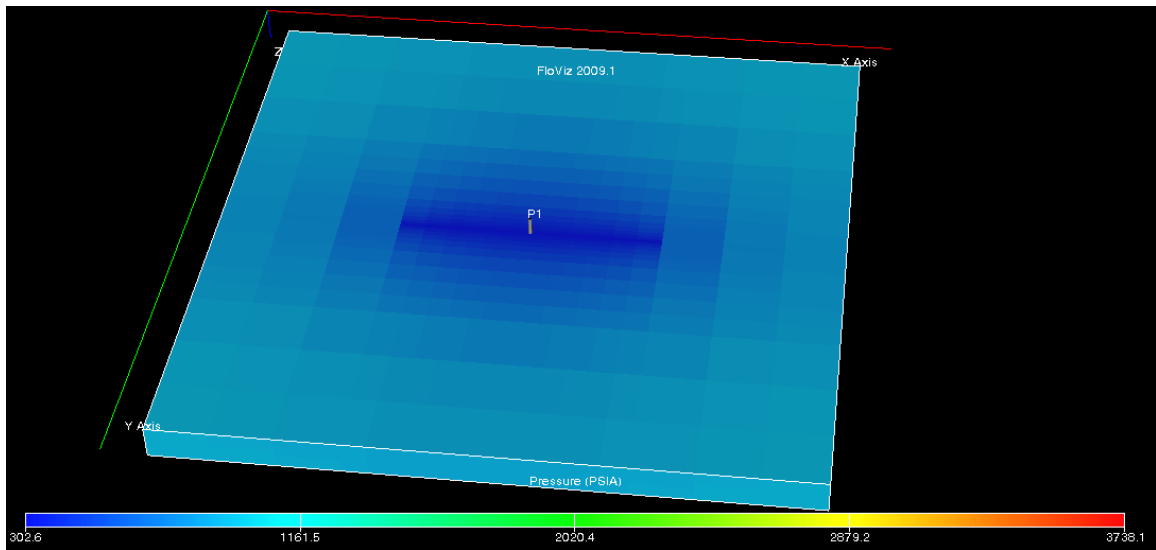


Figure A.26: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.4, $h=100$ ft, $A=80$ Acres, $k_h=0.01$ md, SDA, (Case 56)

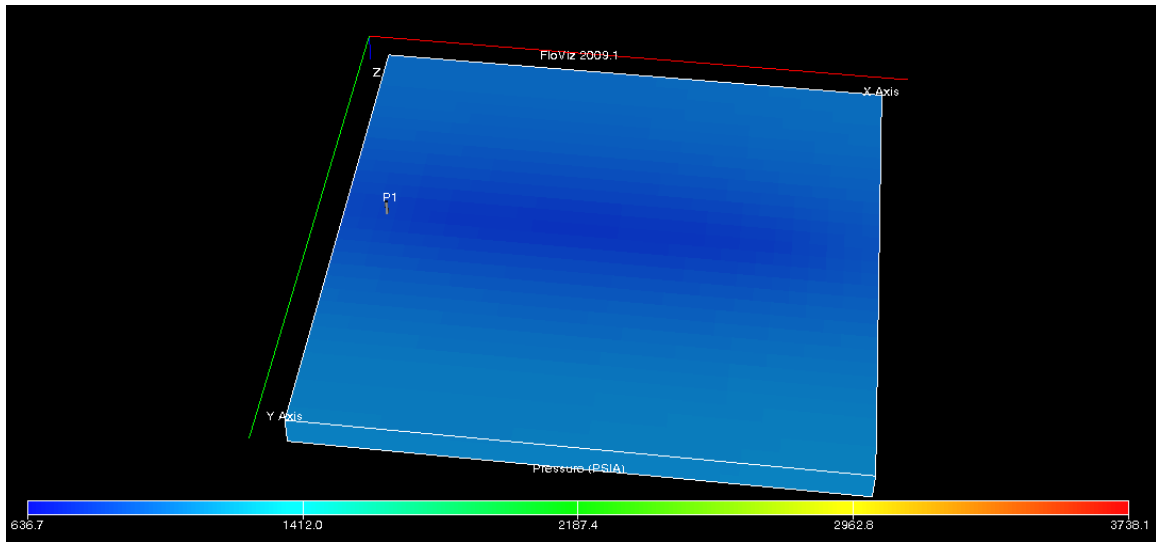


Figure A.27: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.8, h=100 ft, A=80 Acres, $k_h = 0.01$ md, SDA, (Case 101)

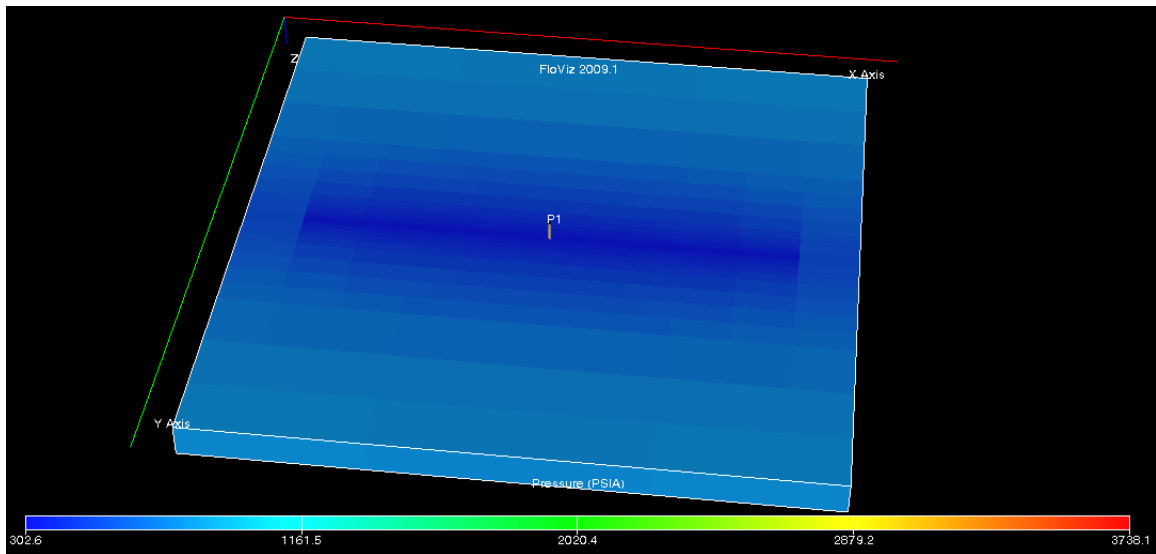


Figure A. 28: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.8, h=100 ft, A=80 Acres, $k_h = 0.01$ md, SDA, (Case 101)

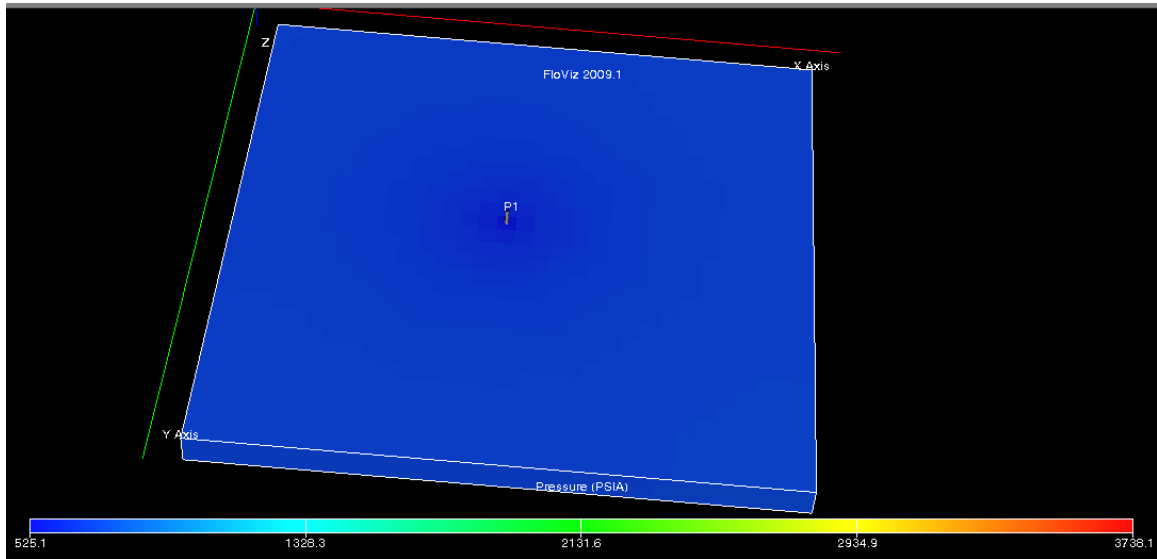


Figure A.29: Schematic 3D reservoir simulation model for vertical well at the end of production, $h=100$ ft, $A=80$ Acres, $k_h=0.1$ md, SDA, (Case 12, 57, 102)

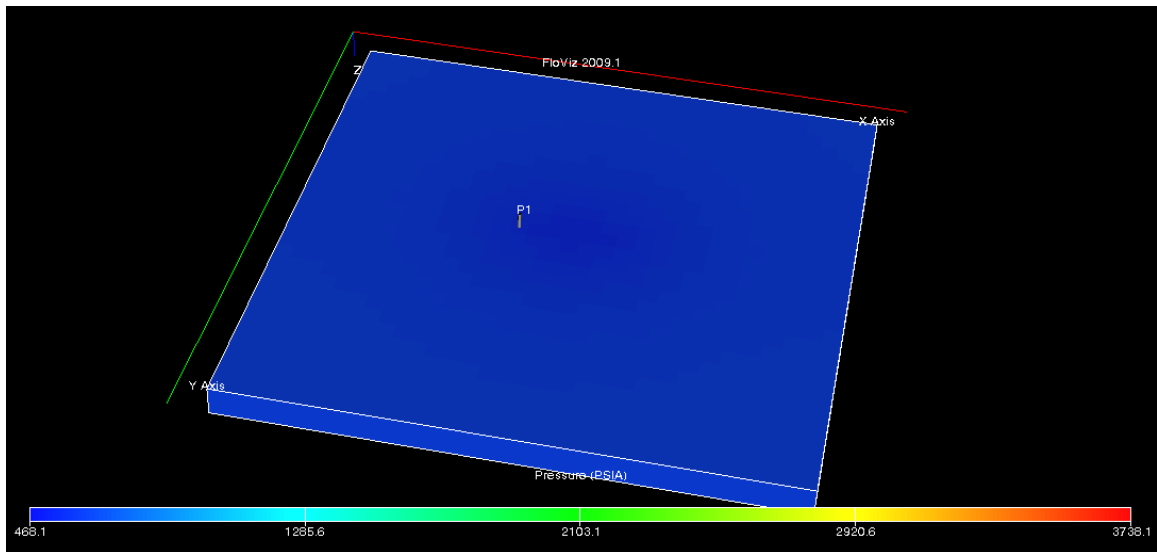


Figure A.30: Schematic 3D reservoir simulation model for horizontal well at the end of production, $P.R = 0.2$, $h=100$ ft, $A=80$ Acres, $k_h=0.1$ md, SDA, (Case 12)

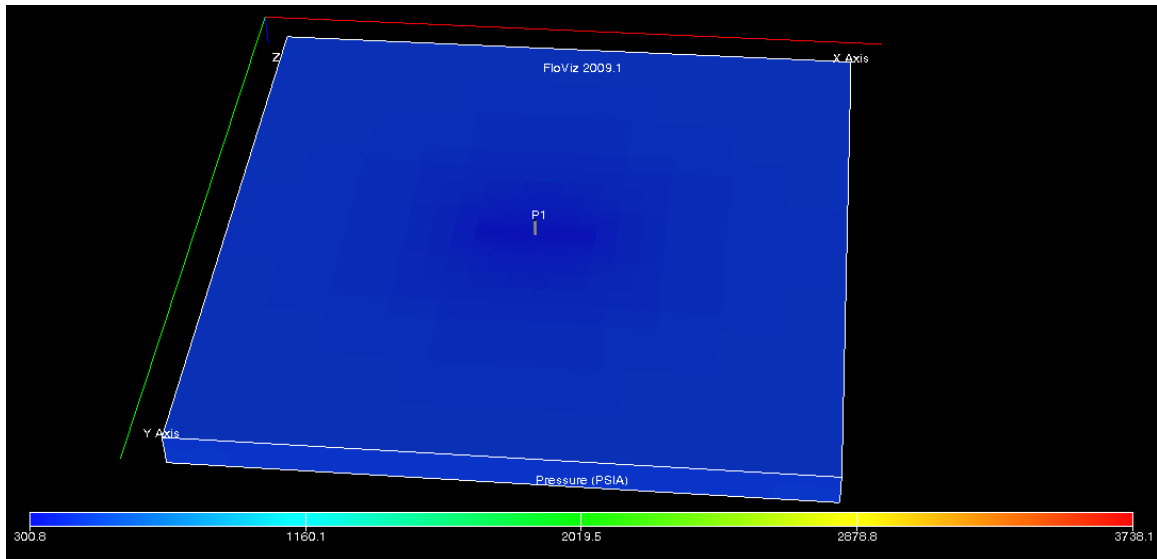


Figure A.31: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.2, $h=100$ ft, $A=80$ Acres, $k_h=0.1$ md, SDA, (Case 12)

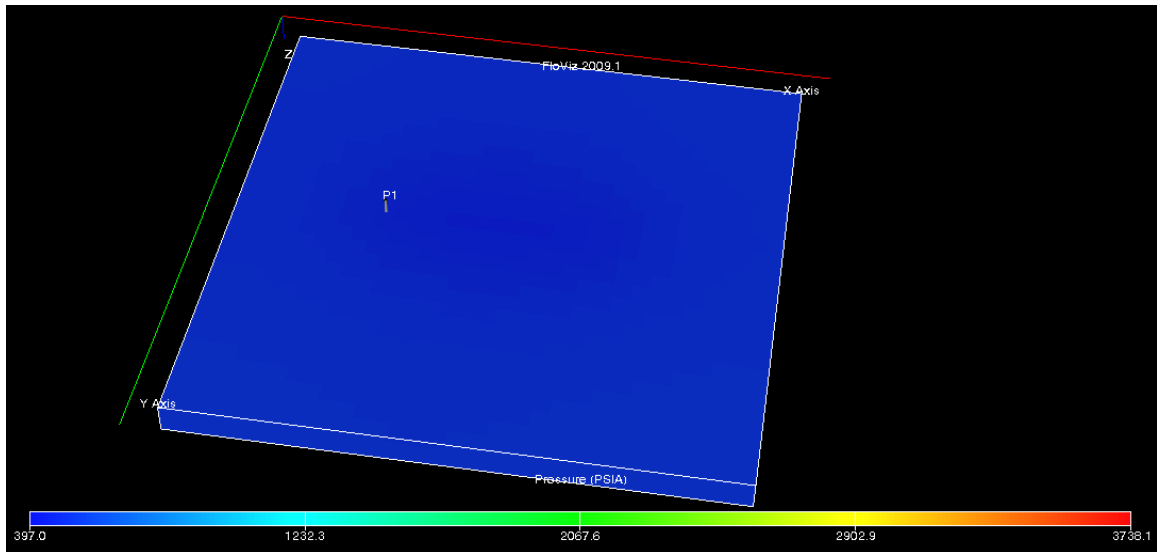


Figure A.32: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.4, $h=100$ ft, $A=80$ Acres, $k_h=0.1$ md, SDA, (Case 57)

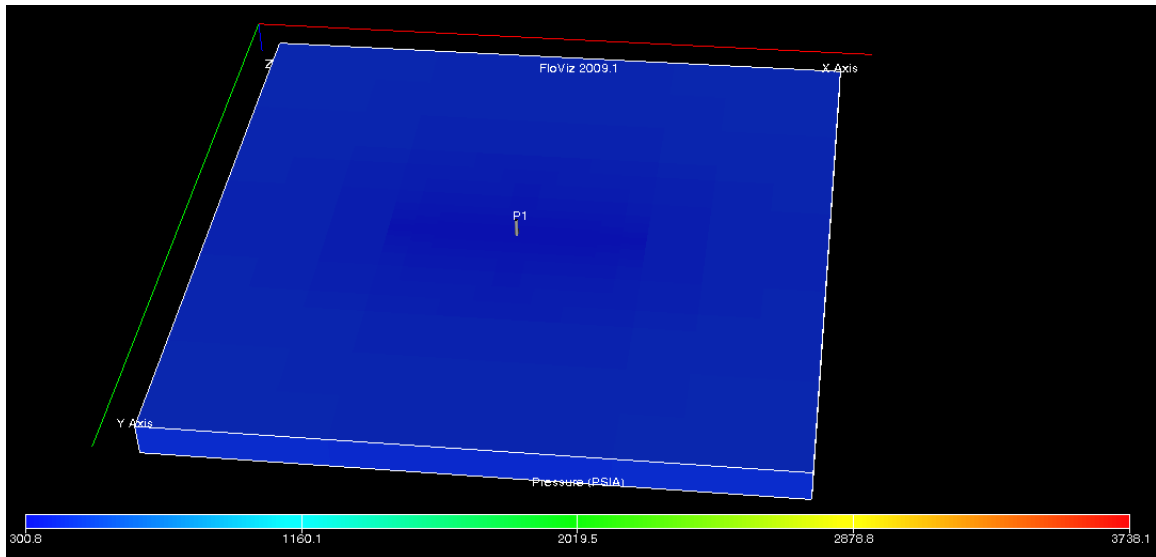


Figure A. 33: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.4, h=100 ft, A=80 Acres, k_h =0.1 md, SDA, (Case 57)

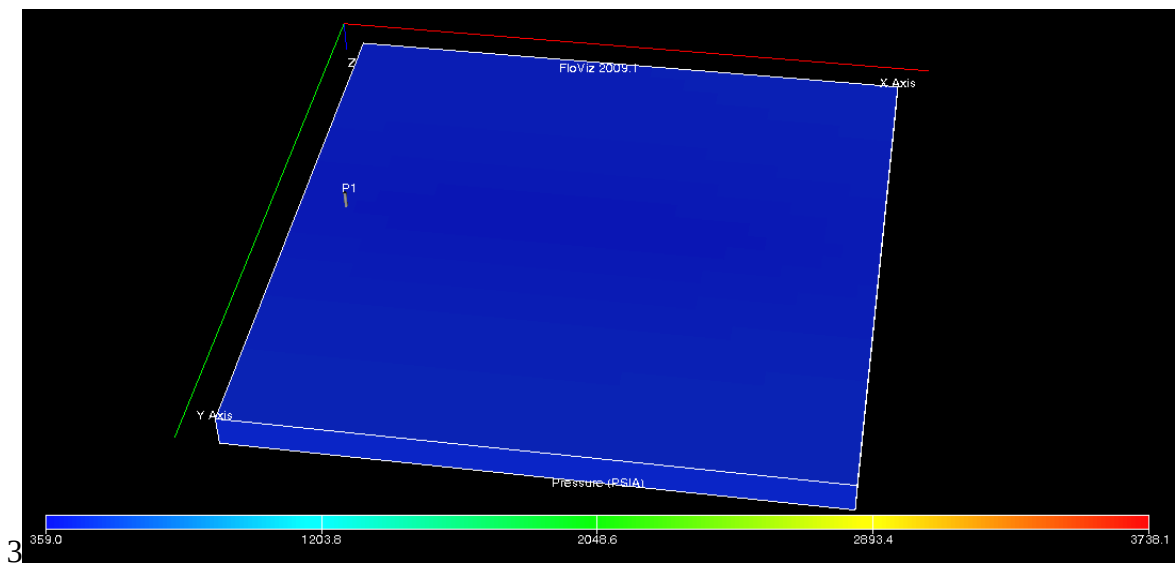


Figure A.34: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.8, h=100 ft, A=80 Acres, k_h =0.1 md, SDA, (Case 102)

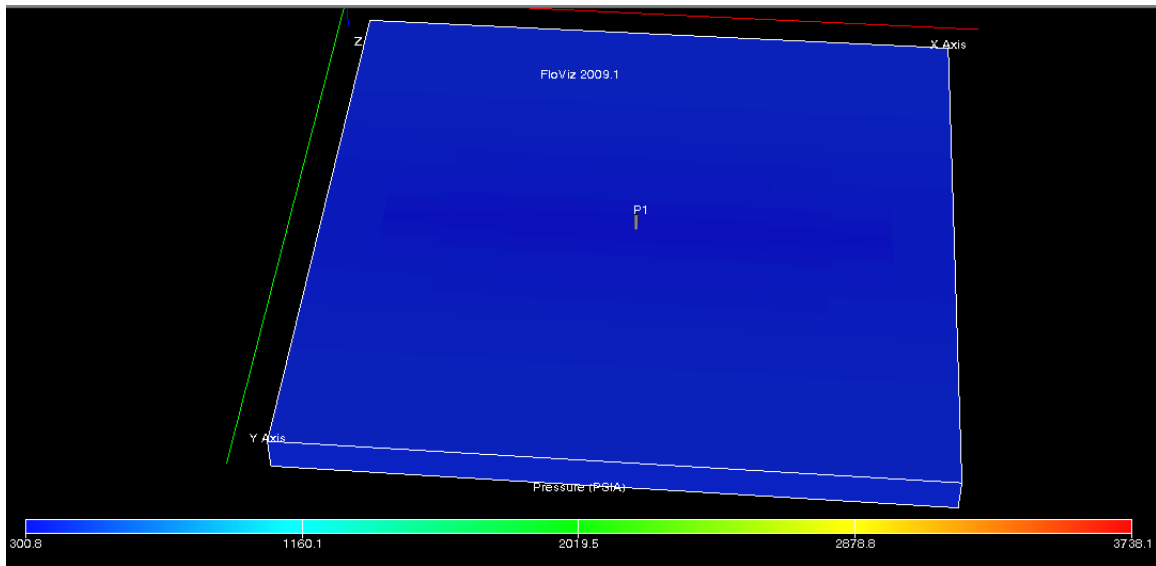


Figure A.35: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.8, $h=100$ ft, $A=80$ Acres, $k_h=0.1$ md, SDA, (Case 102)

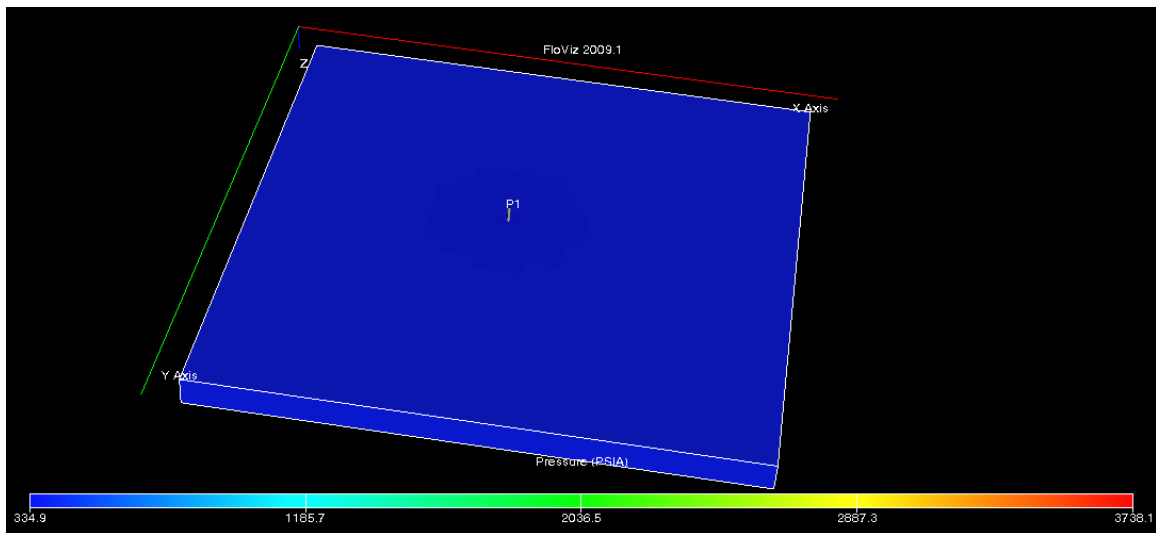


Figure A.36: Schematic 3D reservoir simulation model for vertical well at the end of production, $h=100$ ft, $A=80$ Acres, $k_h=1$ md, SDA, (Case 13, 58, 103)

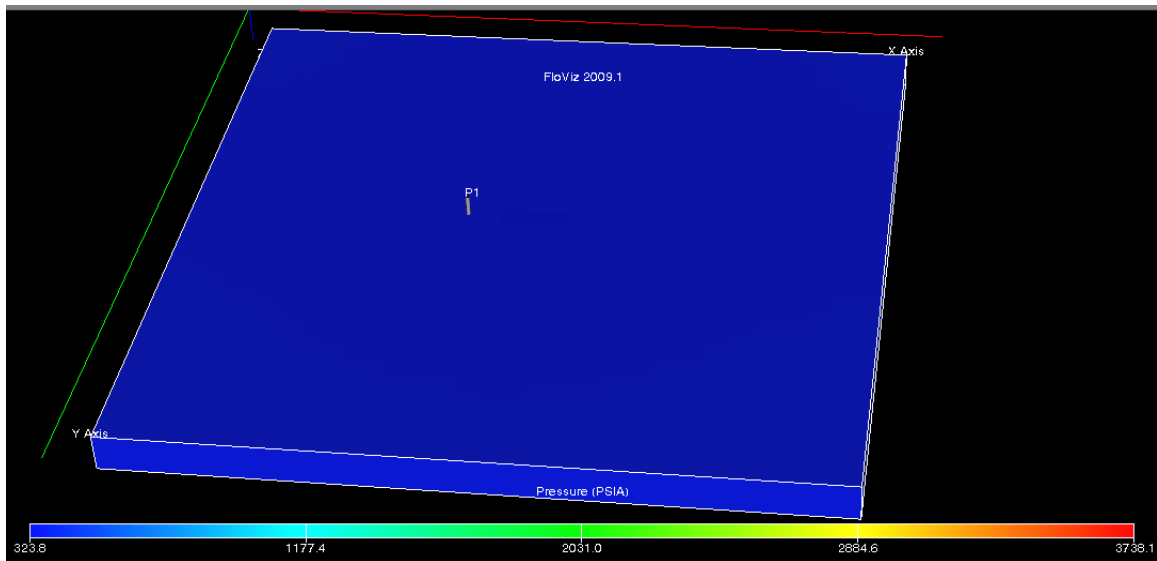


Figure A.37: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.2, h=100 ft, A=80 Acres, $k_h = 1$ md, SDA, (Case 13)

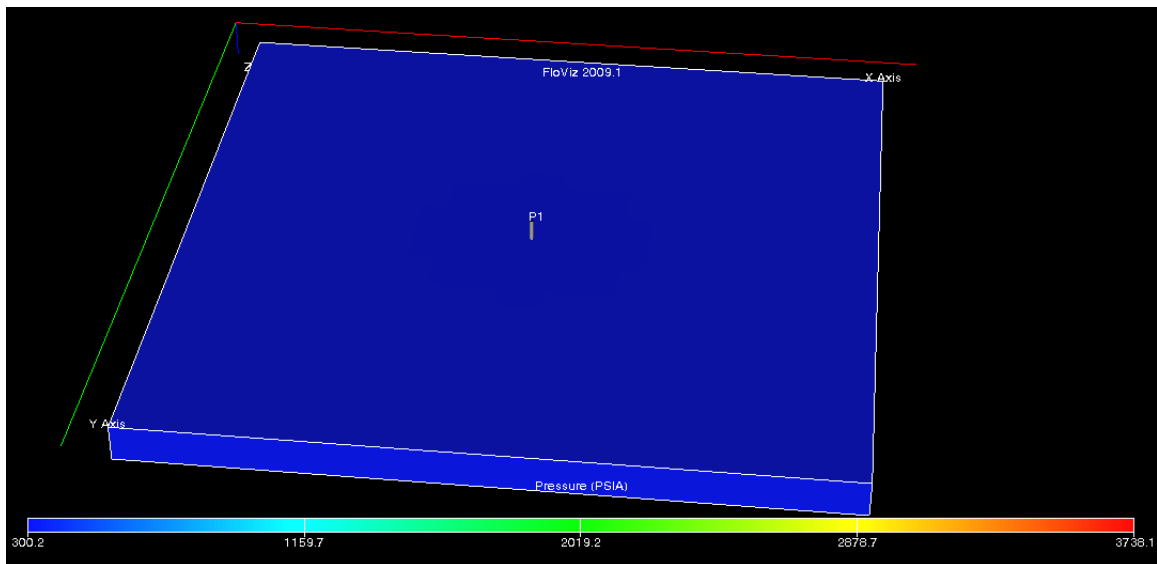


Figure A. 38: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.2, h=100 ft, A=80 Acres, $k_h = 1$ md, SDA, (Case 13)

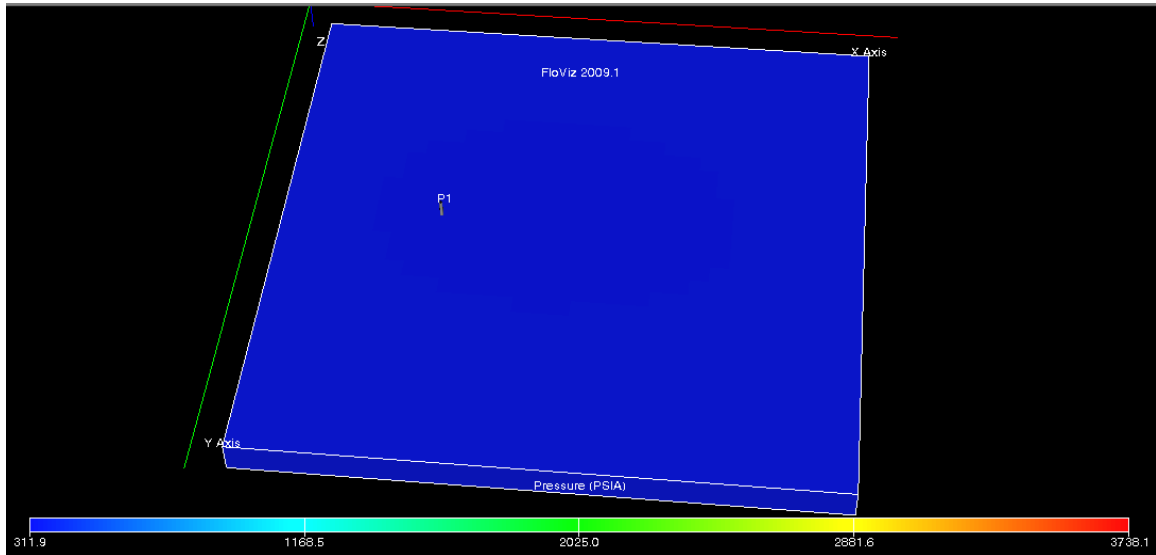


Figure A.39: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.4, h=100 ft, A=80 Acres, $k_h = 1$ md, SDA, (Case 58)

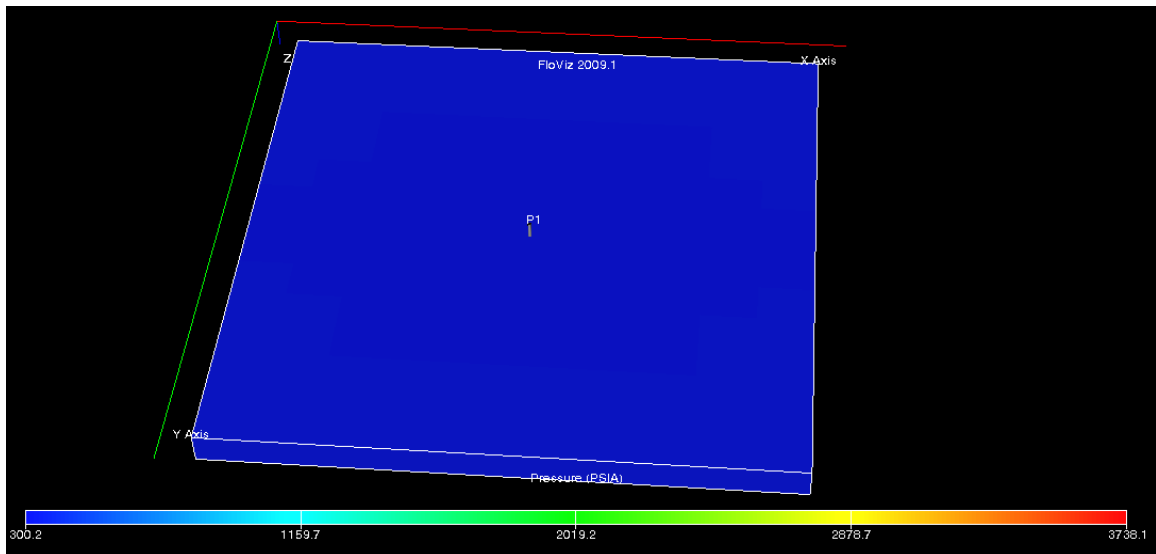


Figure A. 40: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.4, h=100 ft, A=80 Acres, $k_h = 1$ md, SDA, (Case 58)

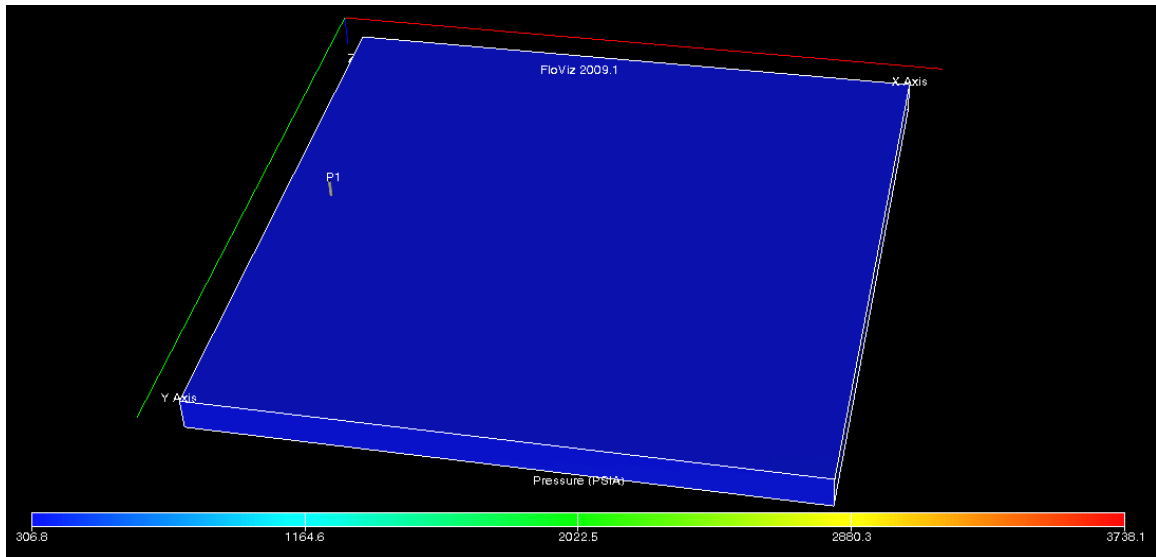


Figure A.41: Schematic 3D reservoir simulation model for horizontal well at the end of production, P.R = 0.8, h=100 ft, A=80 Acres, $k_h = 1$ md, SDA, (Case 103)



Figure A.42: Schematic 3D reservoir simulation model for hydraulic fractured vertical well at the end of production, P.R = 0.8, h=100 ft, A=80 Acres, $k_h = 1$ md, SDA, (Case 103)

APPENDIX B

TABLES

Table B.1: Well and reservoir parameters for hydraulic fracturing in SDA

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
1,16,31	80	1866.76	1866.76	0.0083	0.01	20	360	200	111.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	20		1000	555.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	20		2000	1111.1	240000	1000	0.00083
46,61,76	80	1866.76	1866.76	0.0083	0.01	20	780	200	51.3	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	20		1000	256.4	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	20		2000	512.8	240000	1000	0.00083
91,106,121	80	1866.76	1866.76	0.0083	0.01	20	1500	200	26.7	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	20		1000	133.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	20		2000	266.7	240000	1000	0.00083
6,21,36	80	1866.76	1866.76	0.0083	0.01	50	360	200	111.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	50		1000	555.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	50		2000	1111.1	240000	1000	0.00083
51,66,81	80	1866.76	1866.76	0.0083	0.01	50	780	200	51.3	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	50		1000	256.4	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	50		2000	512.8	240000	1000	0.00083
96,111,126	80	1866.76	1866.76	0.0083	0.01	50	1500	200	26.7	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	50		1000	133.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	50		2000	266.7	240000	1000	0.00083
11,26,41	80	1866.76	1866.76	0.0083	0.01	100	360	200	111.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	100		1000	555.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	100		2000	1111.1	240000	1000	0.00083
56,71,86	80	1866.76	1866.76	0.0083	0.01	100	780	200	51.3	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	100		1000	256.4	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	100		2000	512.8	240000	1000	0.00083
101,116,131	80	1866.76	1866.76	0.0083	0.01	100	1500	200	26.7	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.01	100		1000	133.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.01	100		2000	266.7	240000	1000	0.00083
2,17,32	80	1866.76	1866.76	0.0083	0.1	20	360	200	11.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	20		1000	55.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	20		2000	111.1	240000	1000	0.00083
47,62,77	80	1866.76	1866.76	0.0083	0.1	20	780	200	5.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	20		1000	25.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	20		2000	51.3	240000	1000	0.00083
92,107,122	80	1866.76	1866.76	0.0083	0.1	20	1500	200	2.7	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	20		1000	13.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	20		2000	26.7	240000	1000	0.00083

Table B.1: Well and reservoir parameters for hydraulic fracturing in SDA (continue)

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
7,22,37	80	1866.76	1866.76	0.0083	0.1	50	360	200	11.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	50		1000	55.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	50		2000	111.1	240000	1000	0.00083
52,67,82	80	1866.76	1866.76	0.0083	0.1	50	780	200	5.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	50		1000	25.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	50		2000	51.3	240000	1000	0.00083
97,112,127	80	1866.76	1866.76	0.0083	0.1	50	1500	200	2.7	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	50		1000	13.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	50		2000	26.7	240000	1000	0.00083
12,27,42	80	1866.76	1866.76	0.0083	0.1	100	360	200	11.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	100		1000	55.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	100		2000	111.1	240000	1000	0.00083
57,72,87	80	1866.76	1866.76	0.0083	0.1	100	780	200	5.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	100		1000	25.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	100		2000	51.3	240000	1000	0.00083
102,117,132	80	1866.76	1866.76	0.0083	0.1	100	1500	200	2.7	24000	100	0.00083
	80	1866.76	1866.76	0.0083	0.1	100		1000	13.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	0.1	100		2000	26.7	240000	1000	0.00083
3,18,33	80	1866.76	1866.76	0.0083	1	20	360	200	1.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	20		1000	5.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	20		2000	11.1	240000	1000	0.00083
48,63,78	80	1866.76	1866.76	0.0083	1	20	780	200	0.5	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	20		1000	2.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	20		2000	5.1	240000	1000	0.00083
93,108,123	80	1866.76	1866.76	0.0083	1	20	1500	200	0.3	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	20		1000	1.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	20		2000	2.7	240000	1000	0.00083
8,23,38	80	1866.76	1866.76	0.0083	1	50	360	200	1.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	50		1000	5.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	50		2000	11.1	240000	1000	0.00083
53,68,83	80	1866.76	1866.76	0.0083	1	50	780	200	0.5	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	50		1000	2.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	50		2000	5.1	240000	1000	0.00083
98,113,128	80	1866.76	1866.76	0.0083	1	50	1500	200	0.3	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	50		1000	1.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	50		2000	2.7	240000	1000	0.00083

Table B.1: Well and reservoir parameters for hydraulic fracturing in SDA (continue)

Cases	Area	Length	Width	b _f	k _h	h	2X _f	K _f b _f	F _{CD}	K _f	K _{fe}	φ _e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
13,28,43	80	1866.76	1866.76	0.0083	1	100	360	200	1.1	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	100		1000	5.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	100		2000	11.1	240000	1000	0.00083
58,73,88	80	1866.76	1866.76	0.0083	1	100	780	200	0.5	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	100		1000	2.6	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	100		2000	5.1	240000	1000	0.00083
103,118,133	80	1866.76	1866.76	0.0083	1	100	1500	200	0.3	24000	100	0.00083
	80	1866.76	1866.76	0.0083	1	100		1000	1.3	120000	500	0.00083
	80	1866.76	1866.76	0.0083	1	100		2000	2.7	240000	1000	0.00083
136,151,166	160	1866.76	1866.76	0.0083	0.01	20	540	200	74.1	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	20		1000	370.4	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	20		2000	740.7	240000	1000	0.00083
181,196,211	160	1866.76	1866.76	0.0083	0.01	20	1080	200	37.0	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	20		1000	185.2	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	20		2000	370.4	240000	1000	0.00083
226,241,256	160	1866.76	1866.76	0.0083	0.01	20	2100	200	19.0	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	20		1000	95.2	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	20		2000	190.5	240000	1000	0.00083
141,156,171	160	1866.76	1866.76	0.0083	0.01	50	540	200	74.1	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	50		1000	370.4	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	50		2000	740.7	240000	1000	0.00083
186,201,216	160	1866.76	1866.76	0.0083	0.01	50	1080	200	37.0	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	50		1000	185.2	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	50		2000	370.4	240000	1000	0.00083
231,246,261	160	1866.76	1866.76	0.0083	0.01	50	2100	200	19.0	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	50		1000	95.2	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	50		2000	190.5	240000	1000	0.00083
146,161,176	160	1866.76	1866.76	0.0083	0.01	100	540	200	74.1	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	100		1000	370.4	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	100		2000	740.7	240000	1000	0.00083
191,206,221	160	1866.76	1866.76	0.0083	0.01	100	1080	200	37.0	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	100		1000	185.2	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	100		2000	370.4	240000	1000	0.00083
236,251,266	160	1866.76	1866.76	0.0083	0.01	100	2100	200	19.0	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.01	100		1000	95.2	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.01	100		2000	190.5	240000	1000	0.00083

Table B.1: Well and reservoir parameters for hydraulic fracturing in SDA (continue)

Cases	Area	Length	Width	b _f	k _h	h	2X _f	K _f b _f	F _{CD}	K _f	K _{fe}	φ _e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
137,252,267	160	1866.76	1866.76	0.0083	0.1	20	540	200	7.4	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	20		1000	37.0	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	20		2000	74.1	240000	1000	0.00083
182,197,212	160	1866.76	1866.76	0.0083	0.1	20	1080	200	3.7	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	20		1000	18.5	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	20		2000	37.0	240000	1000	0.00083
227,242,257	160	1866.76	1866.76	0.0083	0.1	20	2100	200	1.9	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	20		1000	9.5	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	20		2000	19.0	240000	1000	0.00083
142,157,172	160	1866.76	1866.76	0.0083	0.1	50	540	200	7.4	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	50		1000	37.0	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	50		2000	74.1	240000	1000	0.00083
187,202,217	160	1866.76	1866.76	0.0083	0.1	50	1080	200	3.7	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	50		1000	18.5	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	50		2000	37.0	240000	1000	0.00083
232,247,262	160	1866.76	1866.76	0.0083	0.1	50	2100	200	1.9	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	50		1000	9.5	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	50		2000	19.0	240000	1000	0.00083
147,162,177	160	1866.76	1866.76	0.0083	0.1	100	540	200	7.4	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	100		1000	37.0	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	100		2000	74.1	240000	1000	0.00083
192,207,222	160	1866.76	1866.76	0.0083	0.1	100	1080	200	3.7	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	100		1000	18.5	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	100		2000	37.0	240000	1000	0.00083
237,252,267	160	1866.76	1866.76	0.0083	0.1	100	2100	200	1.9	24000	100	0.00083
	160	1866.76	1866.76	0.0083	0.1	100		1000	9.5	120000	500	0.00083
	160	1866.76	1866.76	0.0083	0.1	100		2000	19.0	240000	1000	0.00083
138,153,168	160	1866.76	1866.76	0.0083	1	20	540	200	0.7	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	20		1000	3.7	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	20		2000	7.4	240000	1000	0.00083
183,198,213	160	1866.76	1866.76	0.0083	1	20	1080	200	0.4	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	20		1000	1.9	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	20		2000	3.7	240000	1000	0.00083
228,243,258	160	1866.76	1866.76	0.0083	1	20	2100	200	0.2	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	20		1000	1.0	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	20		2000	1.9	240000	1000	0.00083

Table B.1: Well and reservoir parameters for hydraulic fracturing in SDA (continue)

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
143,158,173	160	1866.76	1866.76	0.0083	1	50	540	200	0.7	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	50		1000	3.7	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	50		2000	7.4	240000	1000	0.00083
188,203,218	160	1866.76	1866.76	0.0083	1	50	1080	200	0.4	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	50		1000	1.9	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	50		2000	3.7	240000	1000	0.00083
233,248,263	160	1866.76	1866.76	0.0083	1	50	2100	200	0.2	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	50		1000	1.0	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	50		2000	1.9	240000	1000	0.00083
148,163,178	160	1866.76	1866.76	0.0083	1	100	540	200	0.7	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	100		1000	3.7	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	100		2000	7.4	240000	1000	0.00083
193,208,223	160	1866.76	1866.76	0.0083	1	100	1080	200	0.4	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	100		1000	1.9	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	100		2000	3.7	240000	1000	0.00083
238,253,268	160	1866.76	1866.76	0.0083	1	100	2100	200	0.2	24000	100	0.00083
	160	1866.76	1866.76	0.0083	1	100		1000	1.0	120000	500	0.00083
	160	1866.76	1866.76	0.0083	1	100		2000	1.9	240000	1000	0.00083

Table B.2: Well and reservoir parameters for hydraulic fracturing in RDA

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
1,16,31	80	2640	1320	0.0083	0.01	20	540	200	74.1	24000	100	0.00083
	80	2640	1320	0.0083	0.01	20		1000	370.4	120000	500	0.00083
	80	2640	1320	0.0083	0.01	20		2000	740.7	240000	1000	0.00083
46,61,76	80	2640	1320	0.0083	0.01	20	1080	200	37.0	24000	100	0.00083
	80	2640	1320	0.0083	0.01	20		1000	185.2	120000	500	0.00083
	80	2640	1320	0.0083	0.01	20		2000	370.4	240000	1000	0.00083
91,106,121	80	2640	1320	0.0083	0.01	20	2100	200	19.0	24000	100	0.00083
	80	2640	1320	0.0083	0.01	20		1000	95.2	120000	500	0.00083
	80	2640	1320	0.0083	0.01	20		2000	190.5	240000	1000	0.00083
6,21,36	80	2640	1320	0.0083	0.01	50	540	200	74.1	24000	100	0.00083
	80	2640	1320	0.0083	0.01	50		1000	370.4	120000	500	0.00083
	80	2640	1320	0.0083	0.01	50		2000	740.7	240000	1000	0.00083
51,66,81	80	2640	1320	0.0083	0.01	50	1080	200	37.0	24000	100	0.00083
	80	2640	1320	0.0083	0.01	50		1000	185.2	120000	500	0.00083
	80	2640	1320	0.0083	0.01	50		2000	370.4	240000	1000	0.00083
96,111,126	80	2640	1320	0.0083	0.01	50	2100	200	19.0	24000	100	0.00083
	80	2640	1320	0.0083	0.01	50		1000	95.2	120000	500	0.00083
	80	2640	1320	0.0083	0.01	50		2000	190.5	240000	1000	0.00083
11,26,41	80	2640	1320	0.0083	0.01	100	540	200	74.1	24000	100	0.00083
	80	2640	1320	0.0083	0.01	100		1000	370.4	120000	500	0.00083
	80	2640	1320	0.0083	0.01	100		2000	740.7	240000	1000	0.00083
56,71,86	80	2640	1320	0.0083	0.01	100	1080	200	37.0	24000	100	0.00083
	80	2640	1320	0.0083	0.01	100		1000	185.2	120000	500	0.00083
	80	2640	1320	0.0083	0.01	100		2000	370.4	240000	1000	0.00083
101,116,131	80	2640	1320	0.0083	0.01	100	2100	200	19.0	24000	100	0.00083
	80	2640	1320	0.0083	0.01	100		1000	95.2	120000	500	0.00083
	80	2640	1320	0.0083	0.01	100		2000	190.5	240000	1000	0.00083
2,17,32	80	2640	1320	0.0083	0.1	20	540	200	7.4	24000	100	0.00083
	80	2640	1320	0.0083	0.1	20		1000	37.0	120000	500	0.00083
	80	2640	1320	0.0083	0.1	20		2000	74.1	240000	1000	0.00083
47,62,77	80	2640	1320	0.0083	0.1	20	1080	200	3.7	24000	100	0.00083
	80	2640	1320	0.0083	0.1	20		1000	18.5	120000	500	0.00083
	80	2640	1320	0.0083	0.1	20		2000	37.0	240000	1000	0.00083
92,107,122	80	2640	1320	0.0083	0.1	20	2100	200	1.9	24000	100	0.00083
	80	2640	1320	0.0083	0.1	20		1000	9.5	120000	500	0.00083
	80	2640	1320	0.0083	0.1	20		2000	19.0	240000	1000	0.00083

Table B.2: Well and reservoir parameters for hydraulic fracturing in RDA (Continue)

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
7,22,37	80	2640	1320	0.0083	0.1	50	540	200	7.4	24000	100	0.00083
	80	2640	1320	0.0083	0.1	50		1000	37.0	120000	500	0.00083
	80	2640	1320	0.0083	0.1	50		2000	74.1	240000	1000	0.00083
52,67,82	80	2640	1320	0.0083	0.1	50	1080	200	3.7	24000	100	0.00083
	80	2640	1320	0.0083	0.1	50		1000	18.5	120000	500	0.00083
	80	2640	1320	0.0083	0.1	50		2000	37.0	240000	1000	0.00083
97,112,127	80	2640	1320	0.0083	0.1	50	2100	200	1.9	24000	100	0.00083
	80	2640	1320	0.0083	0.1	50		1000	9.5	120000	500	0.00083
	80	2640	1320	0.0083	0.1	50		2000	19.0	240000	1000	0.00083
12,27,42	80	2640	1320	0.0083	0.1	100	540	200	7.4	24000	100	0.00083
	80	2640	1320	0.0083	0.1	100		1000	37.0	120000	500	0.00083
	80	2640	1320	0.0083	0.1	100		2000	74.1	240000	1000	0.00083
57,72,87	80	2640	1320	0.0083	0.1	100	1080	200	3.7	24000	100	0.00083
	80	2640	1320	0.0083	0.1	100		1000	18.5	120000	500	0.00083
	80	2640	1320	0.0083	0.1	100		2000	37.0	240000	1000	0.00083
102,117,132	80	2640	1320	0.0083	0.1	100	2100	200	1.9	24000	100	0.00083
	80	2640	1320	0.0083	0.1	100		1000	9.5	120000	500	0.00083
	80	2640	1320	0.0083	0.1	100		2000	19.0	240000	1000	0.00083
3,18,33	80	2640	1320	0.0083	1	20	540	200	0.7	24000	100	0.00083
	80	2640	1320	0.0083	1	20		1000	3.7	120000	500	0.00083
	80	2640	1320	0.0083	1	20		2000	7.4	240000	1000	0.00083
48,63,78	80	2640	1320	0.0083	1	20	1080	200	0.4	24000	100	0.00083
	80	2640	1320	0.0083	1	20		1000	1.9	120000	500	0.00083
	80	2640	1320	0.0083	1	20		2000	3.7	240000	1000	0.00083
93,108,123	80	2640	1320	0.0083	1	20	2100	200	0.2	24000	100	0.00083
	80	2640	1320	0.0083	1	20		1000	1.0	120000	500	0.00083
	80	2640	1320	0.0083	1	20		2000	1.9	240000	1000	0.00083
8,23,38	80	2640	1320	0.0083	1	50	540	200	0.7	24000	100	0.00083
	80	2640	1320	0.0083	1	50		1000	3.7	120000	500	0.00083
	80	2640	1320	0.0083	1	50		2000	7.4	240000	1000	0.00083
53,68,83	80	2640	1320	0.0083	1	50	1080	200	0.4	24000	100	0.00083
	80	2640	1320	0.0083	1	50		1000	1.9	120000	500	0.00083
	80	2640	1320	0.0083	1	50		2000	3.7	240000	1000	0.00083
98,113,128	80	2640	1320	0.0083	1	50	2100	200	0.2	24000	100	0.00083
	80	2640	1320	0.0083	1	50		1000	1.0	120000	500	0.00083
	80	2640	1320	0.0083	1	50		2000	1.9	240000	1000	0.00083
	80	2640	1320	0.0083	1	100		1000	3.7	120000	500	0.00083

Table B.2: Well and reservoir parameters for hydraulic fracturing in RDA (Continue)

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
13,28,43	80	2640	1320	0.0083	1	100	540	200	0.7	24000	100	0.00083
	80	2640	1320	0.0083	1	100		1000	3.7	120000	500	0.00083
	80	2640	1320	0.0083	1	100		2000	7.4	240000	1000	0.00083
58,73,88	80	2640	1320	0.0083	1	100	1080	200	0.4	24000	100	0.00083
	80	2640	1320	0.0083	1	100		1000	1.9	120000	500	0.00083
	80	2640	1320	0.0083	1	100		2000	3.7	240000	1000	0.00083
103,118,133	80	2640	1320	0.0083	1	100	2100	200	0.2	24000	100	0.00083
	80	2640	1320	0.0083	1	100		1000	1.0	120000	500	0.00083
	80	2640	1320	0.0083	1	100		2000	1.9	240000	1000	0.00083
136,151,166	160	3733.64	1866.82	0.0083	0.01	20	780	200	51.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	20		1000	256.4	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	20		2000	512.8	240000	1000	0.00083
181,196,211	160	3733.64	1866.82	0.0083	0.01	20	1500	200	26.7	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	20		1000	133.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	20		2000	266.7	240000	1000	0.00083
226,241,256	160	3733.64	1866.82	0.0083	0.01	20	3000	200	13.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	20		1000	66.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	20		2000	133.3	240000	1000	0.00083
141,156,171	160	3733.64	1866.82	0.0083	0.01	50	780	200	51.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	50		1000	256.4	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	50		2000	512.8	240000	1000	0.00083
186,201,216	160	3733.64	1866.82	0.0083	0.01	50	1500	200	26.7	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	50		1000	133.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	50		2000	266.7	240000	1000	0.00083
231,246,261	160	3733.64	1866.82	0.0083	0.01	50	3000	200	13.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	50		1000	66.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	50		2000	133.3	240000	1000	0.00083
146,161,176	160	3733.64	1866.82	0.0083	0.01	100	780	200	51.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	100		1000	256.4	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	100		2000	512.8	240000	1000	0.00083
191,206,221	160	3733.64	1866.82	0.0083	0.01	100	1500	200	26.7	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	100		1000	133.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	100		2000	266.7	240000	1000	0.00083
236,251,266	160	3733.64	1866.82	0.0083	0.01	100	3000	200	13.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.01	100		1000	66.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.01	100		2000	133.3	240000	1000	0.00083

Table B.2: Well and reservoir parameters for hydraulic fracturing in RDA (Continue)

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
137,252,267	160	3733.64	1866.82	0.0083	0.1	20	780	200	5.1	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	20		1000	25.6	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	20		2000	51.3	240000	1000	0.00083
182,197,212	160	3733.64	1866.82	0.0083	0.1	20	1500	200	2.7	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	20		1000	13.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	20		2000	26.7	240000	1000	0.00083
227,242,257	160	3733.64	1866.82	0.0083	0.1	20	3000	200	1.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	20		1000	6.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	20		2000	13.3	240000	1000	0.00083
142,157,172	160	3733.64	1866.82	0.0083	0.1	50	780	200	5.1	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	50		1000	25.6	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	50		2000	51.3	240000	1000	0.00083
187,202,217	160	3733.64	1866.82	0.0083	0.1	50	1500	200	2.7	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	50		1000	13.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	50		2000	26.7	240000	1000	0.00083
232,247,262	160	3733.64	1866.82	0.0083	0.1	50	3000	200	1.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	50		1000	6.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	50		2000	13.3	240000	1000	0.00083
147,162,177	160	3733.64	1866.82	0.0083	0.1	100	780	200	5.1	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	100		1000	25.6	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	100		2000	51.3	240000	1000	0.00083
192,207,222	160	3733.64	1866.82	0.0083	0.1	100	1500	200	2.7	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	100		1000	13.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	100		2000	26.7	240000	1000	0.00083
237,252,267	160	3733.64	1866.82	0.0083	0.1	100	3000	200	1.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	0.1	100		1000	6.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	0.1	100		2000	13.3	240000	1000	0.00083
138,153,168	160	3733.64	1866.82	0.0083	1	20	780	200	0.5	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	20		1000	2.6	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	20		2000	5.1	240000	1000	0.00083
183,198,213	160	3733.64	1866.82	0.0083	1	20	1500	200	0.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	20		1000	1.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	20		2000	2.7	240000	1000	0.00083
228,243,258	160	3733.64	1866.82	0.0083	1	20	3000	200	0.1	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	20		1000	0.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	20		2000	1.3	240000	1000	0.00083

Table B.2: Well and reservoir parameters for hydraulic fracturing in RDA (Continue)

Cases	Area	Length	Width	b_f	k_h	h	$2X_f$	$K_f b_f$	F_{CD}	K_f	K_{fe}	ϕ_e
	Acres	feet	feet	ft	md	ft	ft	md-ft		md	md	
143,158,173	160	3733.64	1866.82	0.0083	1	50	780	200	0.5	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	50		1000	2.6	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	50		2000	5.1	240000	1000	0.00083
188,203,218	160	3733.64	1866.82	0.0083	1	50	1500	200	0.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	50		1000	1.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	50		2000	2.7	240000	1000	0.00083
233,248,263	160	3733.64	1866.82	0.0083	1	50	3000	200	0.1	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	50		1000	0.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	50		2000	1.3	240000	1000	0.00083
148,163,178	160	3733.64	1866.82	0.0083	1	100	780	200	0.5	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	100		1000	2.6	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	100		2000	5.1	240000	1000	0.00083
193,208,223	160	3733.64	1866.82	0.0083	1	100	1500	200	0.3	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	100		1000	1.3	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	100		2000	2.7	240000	1000	0.00083
238,253,268	160	3733.64	1866.82	0.0083	1	100	3000	200	0.1	24000	100	0.00083
	160	3733.64	1866.82	0.0083	1	100		1000	0.7	120000	500	0.00083
	160	3733.64	1866.82	0.0083	1	100		2000	1.3	240000	1000	0.00083

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
1	80	0.2	0.1	20	0.01	360	1000	3.00	2.56	3591.67	3.00	2.56	3591.67
2	80	0.2	0.1	20	0.1	360	4000	29.00	70.43	1110.50	29.00	70.43	1110.50
3	80	0.2	0.1	20	1	360	8000	10.50	88.24	465.38	10.50	88.24	465.38
4	80	0.2	0.1	20	10	360	20000	2.55	91.91	321.87	2.55	91.91	321.87
5	80	0.2	0.1	20	100	360	30000	0.65	92.40	302.26	0.65	92.40	302.26
6	80	0.2	0.1	50	0.01	360	1500	78.75	36.22	2281.29	78.75	36.22	2281.29
7	80	0.2	0.1	50	0.1	360	6000	52.25	79.99	773.15	52.25	79.99	773.15
8	80	0.2	0.1	50	1	360	13000	16.00	90.40	383.17	16.00	90.40	383.17
9	80	0.2	0.1	50	10	360	25000	3.49	92.23	309.54	3.49	92.23	309.54
10	80	0.2	0.1	50	100	360	45000	0.81	92.44	300.97	0.81	92.44	300.97
11	80	0.2	0.1	100	0.01	360	2000	173.25	52.72	1717.53	173.25	52.72	1717.53
12	80	0.2	0.1	100	0.1	360	8000	80.25	84.08	624.07	80.25	84.08	624.07
13	80	0.2	0.1	100	1	360	17000	22.50	91.27	349.00	22.50	91.27	349.00
14	80	0.2	0.1	100	10	360	30000	4.61	92.35	305.50	4.61	92.35	305.50
15	80	0.2	0.1	100	100	360	60000	1.01	92.47	300.55	1.01	92.47	300.55
16	80	0.2	0.5	20	0.01	360	1000	3.25	2.79	3581.30	3.25	2.79	3581.30
17	80	0.2	0.5	20	0.1	360	4000	28.75	70.62	1104.04	28.75	70.62	1104.04
18	80	0.2	0.5	20	1	360	8000	10.50	88.36	460.89	10.50	88.36	460.89
19	80	0.2	0.5	20	10	360	20000	2.52	91.92	321.68	2.52	91.92	321.68
20	80	0.2	0.5	20	100	360	30000	0.64	92.40	302.21	0.64	92.40	302.21
21	80	0.2	0.5	50	0.01	360	1500	81.25	38.80	2189.30	81.25	38.80	2189.30
22	80	0.2	0.5	50	0.1	360	6000	50.50	80.59	750.95	50.50	80.59	750.95
23	80	0.2	0.5	50	1	360	13000	15.50	90.56	376.73	15.50	90.56	376.73
24	80	0.2	0.5	50	10	360	25000	3.34	92.24	309.08	3.34	92.24	309.08
25	80	0.2	0.5	50	100	360	45000	0.79	92.44	300.91	0.79	92.44	300.91
26	80	0.2	0.5	100	0.01	360	2000	171.25	56.46	1593.11	171.25	56.46	1593.11
27	80	0.2	0.5	100	0.1	360	8000	74.50	84.96	591.36	74.50	84.96	591.36
28	80	0.2	0.5	100	1	360	17000	20.50	91.41	343.45	20.50	91.41	343.45
29	80	0.2	0.5	100	10	360	30000	4.23	92.36	304.79	4.23	92.36	304.79
30	80	0.2	0.5	100	100	360	60000	0.96	92.47	300.48	0.96	92.47	300.48
31	80	0.2	1	20	0.01	360	1000	3.50	2.99	3572.72	3.50	2.99	3572.72
32	80	0.2	1	20	0.1	360	4000	28.75	70.67	1102.31	28.75	70.67	1102.31
33	80	0.2	1	20	1	360	8000	10.50	88.37	460.30	10.50	88.37	460.30
34	80	0.2	1	20	10	360	20000	2.52	91.92	321.55	2.52	91.92	321.55
35	80	0.2	1	20	100	360	30000	0.64	92.40	302.27	0.64	92.40	302.27

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
36	80	0.2	1	50	0.01	360	1500	81.50	39.20	2175.32	81.50	39.20	2175.32
37	80	0.2	1	50	0.1	360	6000	50.00	80.63	749.48	50.00	80.63	749.48
38	80	0.2	1	50	1	360	13000	15.25	90.54	377.62	15.25	90.54	377.62
39	80	0.2	1	50	10	360	25000	3.31	92.24	309.04	3.31	92.24	309.04
40	80	0.2	1	50	100	360	45000	0.79	92.44	300.89	0.79	92.44	300.89
41	80	0.2	1	100	0.01	360	2000	170.50	57.31	1565.05	170.50	57.31	1565.05
42	80	0.2	1	100	0.1	360	8000	73.00	85.13	584.99	73.00	85.13	584.99
43	80	0.2	1	100	1	360	17000	20.00	91.43	342.60	20.00	91.43	342.60
44	80	0.2	1	100	10	360	30000	4.15	92.37	304.64	4.15	92.37	304.64
45	80	0.2	1	100	100	360	60000	0.95	92.47	300.46	0.95	92.47	300.46
46	80	0.4	0.1	20	0.01	780	1000	25.50	26.76	2624.14	25.50	26.76	2624.14
47	80	0.4	0.1	20	0.1	780	4000	23.25	77.53	860.61	23.25	77.53	860.61
48	80	0.4	0.1	20	1	780	8000	7.75	89.91	401.90	7.75	89.91	401.90
49	80	0.4	0.1	20	10	780	20000	1.79	92.15	312.13	1.79	92.15	312.13
50	80	0.4	0.1	20	100	780	30000	0.53	92.43	301.20	0.53	92.43	301.20
51	80	0.4	0.1	50	0.01	780	1500	85.50	53.57	1685.40	85.50	53.57	1685.40
52	80	0.4	0.1	50	0.1	780	6000	39.75	84.33	613.31	39.75	84.33	613.31
53	80	0.4	0.1	50	1	780	13000	11.50	91.32	346.00	11.50	91.32	346.00
54	80	0.4	0.1	50	10	780	25000	2.42	92.34	305.22	2.42	92.34	305.22
55	80	0.4	0.1	50	100	780	45000	0.64	92.45	300.53	0.64	92.45	300.53
56	80	0.4	0.1	100	0.01	780	2000	157.00	65.47	1286.00	157.00	65.47	1286.00
57	80	0.4	0.1	100	0.1	780	8000	59.25	87.16	507.83	59.25	87.16	507.83
58	80	0.4	0.1	100	1	780	17000	15.50	91.80	327.35	15.50	91.80	327.35
59	80	0.4	0.1	100	10	780	30000	3.19	92.41	302.99	3.19	92.41	302.99
60	80	0.4	0.1	100	100	780	60000	0.80	92.48	300.29	0.80	92.48	300.29
61	80	0.4	0.5	20	0.01	780	1000	26.00	27.47	2598.27	26.00	27.47	2598.27
62	80	0.4	0.5	20	0.1	780	4000	23.25	77.79	850.95	23.25	77.79	850.95
63	80	0.4	0.5	20	1	780	8000	7.75	89.98	399.05	7.75	89.98	399.05
64	80	0.4	0.5	20	10	780	20000	1.78	92.16	311.99	1.78	92.16	311.99
65	80	0.4	0.5	20	100	780	30000	0.53	92.43	301.21	0.53	92.43	301.21
66	80	0.4	0.5	50	0.01	780	1500	85.00	55.24	1629.66	85.00	55.24	1629.66
67	80	0.4	0.5	50	0.1	780	6000	38.25	84.66	601.07	38.25	84.66	601.07
68	80	0.4	0.5	50	1	780	13000	11.00	91.36	344.36	11.00	91.36	344.36
69	80	0.4	0.5	50	10	780	25000	2.34	92.34	304.94	2.34	92.34	304.94
70	80	0.4	0.5	50	100	780	45000	0.63	92.45	300.49	0.63	92.45	300.49

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
71	80	0.4	0.5	100	0.01	780	2000	150.25	67.88	1202.47	150.25	67.88	1202.47
72	80	0.4	0.5	100	0.1	780	8000	55.00	87.73	486.37	55.00	87.73	486.37
73	80	0.4	0.5	100	1	780	17000	14.25	91.89	324.08	14.25	91.89	324.08
74	80	0.4	0.5	100	10	780	30000	2.97	92.42	302.58	2.97	92.42	302.58
75	80	0.4	0.5	100	100	780	60000	0.77	92.48	300.26	0.77	92.48	300.26
76	80	0.4	1	20	0.01	780	1000	26.00	27.51	2596.66	26.00	27.51	2596.66
77	80	0.4	1	20	0.1	780	4000	23.25	77.83	849.66	23.25	77.83	849.66
78	80	0.4	1	20	1	780	8000	7.75	89.99	398.67	7.75	89.99	398.67
79	80	0.4	1	20	10	780	20000	1.78	92.16	311.92	1.78	92.16	311.92
80	80	0.4	1	20	100	780	30000	0.53	92.43	301.20	0.53	92.43	301.20
81	80	0.4	1	50	0.01	780	1500	85.00	55.55	1619.36	85.00	55.55	1619.36
82	80	0.4	1	50	0.1	780	6000	38.00	84.72	599.06	38.00	84.72	599.06
83	80	0.4	1	50	1	780	13000	11.00	91.39	343.19	11.00	91.39	343.19
84	80	0.4	1	50	10	780	25000	2.33	92.34	304.91	2.33	92.34	304.91
85	80	0.4	1	50	100	780	45000	0.62	92.45	300.49	0.62	92.45	300.49
86	80	0.4	1	100	0.01	780	2000	148.50	68.39	1184.73	148.50	68.39	1184.73
87	80	0.4	1	100	0.1	780	8000	54.00	87.84	482.07	54.00	87.84	482.07
88	80	0.4	1	100	1	780	17000	14.00	91.90	323.33	14.00	91.90	323.33
89	80	0.4	1	100	10	780	30000	2.92	92.42	302.55	2.92	92.42	302.55
90	80	0.4	1	100	100	780	60000	0.76	92.48	300.25	0.76	92.48	300.25
91	80	0.8	0.1	20	0.01	1500	1000	33.00	46.67	1915.96	33.00	46.67	1915.96
92	80	0.8	0.1	20	0.1	1500	4000	18.00	82.52	679.15	18.00	82.52	679.15
93	80	0.8	0.1	20	1	1500	8000	5.75	90.97	359.65	5.75	90.97	359.65
94	80	0.8	0.1	20	10	1500	20000	1.31	92.28	306.94	1.31	92.28	306.94
95	80	0.8	0.1	20	100	1500	30000	0.47	92.44	300.65	0.47	92.44	300.65
96	80	0.8	0.1	50	0.01	1500	1500	77.00	65.83	1270.73	77.00	65.83	1270.73
97	80	0.8	0.1	50	0.1	1500	6000	29.50	87.23	504.04	29.50	87.23	504.04
98	80	0.8	0.1	50	1	1500	13000	8.00	91.76	328.25	8.00	91.76	328.25
99	80	0.8	0.1	50	10	1500	25000	1.77	92.39	302.92	1.77	92.39	302.92
100	80	0.8	0.1	50	100	1500	45000	0.48	92.46	300.29	0.48	92.46	300.29
101	80	0.8	0.1	100	0.01	1500	2000	129.50	74.18	982.67	129.50	74.18	982.67
102	80	0.8	0.1	100	0.1	1500	8000	43.25	89.21	429.94	43.25	89.21	429.94
103	80	0.8	0.1	100	1	1500	17000	10.75	92.09	315.80	10.75	92.09	315.80
104	80	0.8	0.1	100	10	1500	30000	2.34	92.44	301.66	2.34	92.44	301.66
105	80	0.8	0.1	100	100	1500	60000	0.68	92.48	300.17	0.68	92.48	300.17

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
106	80	0.8	0.5	20	0.01	1500	1000	33.25	47.27	1895.37	33.25	47.27	1895.37
107	80	0.8	0.5	20	0.1	1500	4000	18.00	82.71	671.97	18.00	82.71	671.97
108	80	0.8	0.5	20	1	1500	8000	5.75	91.01	357.88	5.75	91.01	357.88
110	80	0.8	0.5	20	100	1500	30000	0.47	92.44	300.69	0.47	92.44	300.69
111	80	0.8	0.5	50	0.01	1500	1500	75.25	66.89	1233.93	75.25	66.89	1233.93
112	80	0.8	0.5	50	0.1	1500	6000	28.50	87.48	494.67	28.50	87.48	494.67
113	80	0.8	0.5	50	1	1500	13000	7.75	91.81	326.57	7.75	91.81	326.57
114	80	0.8	0.5	50	10	1500	25000	1.73	92.40	302.71	1.73	92.40	302.71
115	80	0.8	0.5	50	100	1500	45000	0.48	92.46	300.26	0.48	92.46	300.26
116	80	0.8	0.5	100	0.01	1500	2000	122.25	75.85	923.27	122.25	75.85	923.27
117	80	0.8	0.5	100	0.1	1500	8000	39.75	89.53	417.78	39.75	89.53	417.78
118	80	0.8	0.5	100	1	1500	17000	10.00	92.14	313.68	10.00	92.14	313.68
119	80	0.8	0.5	100	10	1500	30000	2.20	92.45	301.48	2.20	92.45	301.48
120	80	0.8	0.5	100	100	1500	60000	0.66	92.48	300.14	0.66	92.48	300.14
121	80	0.8	1	20	0.01	1500	1000	33.25	47.32	1893.48	33.25	47.32	1893.48
122	80	0.8	1	20	0.1	1500	4000	18.00	82.74	671.02	18.00	82.74	671.02
123	80	0.8	1	20	1	1500	8000	5.75	91.02	357.65	5.75	91.02	357.65
124	80	0.8	1	20	10	1500	20000	1.31	92.29	306.59	1.31	92.29	306.59
125	80	0.8	1	20	100	1500	30000	0.47	92.44	300.69	0.47	92.44	300.69
126	80	0.8	1	50	0.01	1500	1500	75.00	67.08	1227.36	75.00	67.08	1227.36
127	80	0.8	1	50	0.1	1500	6000	28.25	87.50	494.13	28.25	87.50	494.13
128	80	0.8	1	50	1	1500	13000	7.75	91.82	325.86	7.75	91.82	325.86
129	80	0.8	1	50	10	1500	25000	1.71	92.40	302.76	1.71	92.40	302.76
130	80	0.8	1	50	100	1500	45000	0.47	92.46	300.28	0.47	92.46	300.28
131	80	0.8	1	100	0.01	1500	2000	120.50	76.19	910.96	120.50	76.19	910.96
132	80	0.8	1	100	0.1	1500	8000	39.25	89.63	413.81	39.25	89.63	413.81
133	80	0.8	1	100	1	1500	17000	9.75	92.14	313.77	9.75	92.14	313.77
134	80	0.8	1	100	10	1500	30000	2.18	92.45	301.43	2.18	92.45	301.43
135	80	0.8	1	100	100	1500	60000	0.66	92.48	300.15	0.66	92.48	300.15
136	160	0.2	0.1	20	0.01	540	1000	19.25	8.54	3334.77	19.25	8.54	3334.77
137	160	0.2	0.1	20	0.1	540	4000	54.75	72.79	1028.48	54.75	72.79	1028.48
138	160	0.2	0.1	20	1	540	8000	18.75	88.83	443.15	18.75	88.83	443.15
139	160	0.2	0.1	20	10	540	20000	4.37	92.01	318.01	4.37	92.01	318.01
140	160	0.2	0.1	20	100	540	30000	1.01	92.41	301.86	1.01	92.41	301.86
141	160	0.2	0.1	50	0.01	540	1500	167.25	42.16	2070.19	167.25	42.16	2070.19

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md		MSCF/D	YRS	%	PSIA	YRS	%	PSIA
142	160	0.2	0.1	50	0.1	540	6000	96.25	81.50	717.59	96.25	81.50	717.59
143	160	0.2	0.1	50	1	540	13000	28.25	90.75	368.91	28.25	90.75	368.91
144	160	0.2	0.1	50	10	540	25000	6.00	92.27	307.79	6.00	92.27	307.79
145	160	0.2	0.1	50	100	540	45000	1.36	92.45	300.78	1.36	92.45	300.78
146	160	0.2	0.1	100	0.01	540	2000	342.82	57.55	1556.96	342.82	57.55	1556.96
147	160	0.2	0.1	100	0.1	540	8000	146.25	85.32	577.80	146.25	85.32	577.80
148	160	0.2	0.1	100	1	540	17000	38.75	91.48	340.64	38.75	91.48	340.64
149	160	0.2	0.1	100	10	540	30000	7.98	92.38	304.37	7.98	92.38	304.37
150	160	0.2	0.1	100	100	540	60000	1.84	92.47	300.44	1.84	92.47	300.44
151	160	0.2	0.5	20	0.01	540	1000	20.75	9.22	3306.55	20.75	9.22	3306.55
152	160	0.2	0.5	20	0.1	540	4000	54.25	72.90	1024.66	54.25	72.90	1024.66
153	160	0.2	0.5	20	1	540	8000	18.75	88.92	439.69	18.75	88.92	439.69
154	160	0.2	0.5	20	10	540	20000	4.33	92.01	317.88	4.33	92.01	317.88
155	160	0.2	0.5	20	100	540	30000	1.00	92.41	301.83	1.00	92.41	301.83
156	160	0.2	0.5	50	0.01	540	1500	169.00	44.08	2003.01	169.00	44.08	2003.01
157	160	0.2	0.5	50	0.1	540	6000	93.50	81.98	700.09	93.50	81.98	700.09
158	160	0.2	0.5	50	1	540	13000	27.25	90.84	365.42	27.25	90.84	365.42
159	160	0.2	0.5	50	10	540	25000	5.78	92.28	307.41	5.78	92.28	307.41
160	160	0.2	0.5	50	100	540	45000	1.33	92.45	300.74	1.33	92.45	300.74
161	160	0.2	0.5	100	0.01	540	2000	335.32	60.44	1459.57	335.32	60.44	1459.57
162	160	0.2	0.5	100	0.1	540	8000	136.25	85.96	553.67	136.25	85.96	553.67
163	160	0.2	0.5	100	1	540	17000	35.75	91.59	336.17	35.75	91.59	336.17
164	160	0.2	0.5	100	10	540	30000	7.39	92.39	303.90	7.39	92.39	303.90
165	160	0.2	0.5	100	100	540	60000	1.76	92.47	300.39	1.76	92.47	300.39
166	160	0.2	1	20	0.01	540	1000	20.75	9.24	3305.88	20.75	9.24	3305.88
167	160	0.2	1	20	0.1	540	4000	54.25	72.94	1023.28	54.25	72.94	1023.28
168	160	0.2	1	20	1	540	8000	18.75	88.93	439.23	18.75	88.93	439.23
169	160	0.2	1	20	10	540	20000	4.33	92.01	317.79	4.33	92.01	317.79
170	160	0.2	1	20	100	540	30000	1.00	92.41	301.82	1.00	92.41	301.82
171	160	0.2	1	50	0.01	540	1500	169.25	44.40	1991.86	169.25	44.40	1991.86
172	160	0.2	1	50	0.1	540	6000	93.00	82.05	697.41	93.00	82.05	697.41
173	160	0.2	1	50	1	540	13000	27.00	90.84	365.37	27.00	90.84	365.37
174	160	0.2	1	50	10	540	25000	5.75	92.28	307.30	5.75	92.28	307.30
175	160	0.2	1	50	100	540	45000	1.33	92.45	300.74	1.33	92.45	300.74
176	160	0.2	1	100	0.01	540	2000	333.32	61.09	1437.57	333.32	61.09	1437.57

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
177	160	0.2	1	100	0.1	540	8000	134.25	86.11	547.72	134.25	86.11	547.72
178	160	0.2	1	100	1	540	17000	35.00	91.60	335.53	35.00	91.60	335.53
179	160	0.2	1	100	10	540	30000	7.27	92.39	303.80	7.27	92.39	303.80
180	160	0.2	1	100	100	540	60000	1.74	92.47	300.38	1.74	92.47	300.38
181	160	0.4	0.1	20	0.01	1080	1000	56.00	31.04	2468.06	56.00	31.04	2468.06
182	160	0.4	0.1	20	0.1	1080	4000	44.50	78.72	817.84	44.50	78.72	817.84
183	160	0.4	0.1	20	1	1080	8000	14.25	90.24	389.05	14.25	90.24	389.05
184	160	0.4	0.1	20	10	1080	20000	3.12	92.19	310.69	3.12	92.19	310.69
185	160	0.4	0.1	20	100	1080	30000	0.79	92.43	301.07	0.79	92.43	301.07
186	160	0.4	0.1	50	0.01	1080	1500	170.00	56.50	1587.84	170.00	56.50	1587.84
187	160	0.4	0.1	50	0.1	1080	6000	74.75	85.07	585.72	74.75	85.07	585.72
188	160	0.4	0.1	50	1	1080	13000	20.50	91.44	341.27	20.50	91.44	341.27
189	160	0.4	0.1	50	10	1080	25000	4.27	92.35	304.58	4.27	92.35	304.58
190	160	0.4	0.1	50	100	1080	45000	1.10	92.46	300.45	1.10	92.46	300.45
190	160	0.4	0.1	50	100	1080	45000	1.10	92.46	300.45	1.10	92.46	300.45
191	160	0.4	0.1	100	0.01	1080	2000	303.42	67.88	1202.68	303.42	67.88	1202.68
192	160	0.4	0.1	100	0.1	1080	8000	110.25	87.79	484.02	110.25	87.79	484.02
193	160	0.4	0.1	100	1	1080	17000	27.50	91.89	323.75	27.50	91.89	323.75
194	160	0.4	0.1	100	10	1080	30000	5.76	92.42	302.52	5.76	92.42	302.52
195	160	0.4	0.1	100	100	1080	60000	1.52	92.48	300.25	1.52	92.48	300.25
196	160	0.4	0.5	20	0.01	1080	1000	56.50	31.53	2450.19	56.50	31.53	2450.19
197	160	0.4	0.5	20	0.1	1080	4000	44.25	78.84	813.46	44.25	78.84	813.46
198	160	0.4	0.5	20	1	1080	8000	14.00	90.21	390.33	14.00	90.21	390.33
199	160	0.4	0.5	20	10	1080	20000	3.11	92.20	310.46	3.11	92.20	310.46
200	160	0.4	0.5	20	100	1080	30000	0.79	92.43	301.05	0.79	92.43	301.05
201	160	0.4	0.5	50	0.01	1080	1500	168.50	57.79	1544.48	168.50	57.79	1544.48
202	160	0.4	0.5	50	0.1	1080	6000	72.50	85.36	575.13	72.50	85.36	575.13
203	160	0.4	0.5	50	1	1080	13000	19.75	91.47	339.87	19.75	91.47	339.87
204	160	0.4	0.5	50	10	1080	25000	4.15	92.36	304.35	4.15	92.36	304.35
205	160	0.4	0.5	50	100	1080	45000	1.08	92.46	300.44	1.08	92.46	300.44
206	160	0.4	0.5	100	0.01	1080	2000	291.17	69.78	1136.61	291.17	69.78	1136.61
207	160	0.4	0.5	100	0.1	1080	8000	103.00	88.21	468.09	103.00	88.21	468.09
208	160	0.4	0.5	100	1	1080	17000	25.50	91.95	321.38	25.50	91.95	321.38
209	160	0.4	0.5	100	10	1080	30000	5.42	92.43	302.24	5.42	92.43	302.24
210	160	0.4	0.5	100	100	1080	60000	1.47	92.48	300.22	1.47	92.48	300.22

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
211	160	0.4	1	20	0.01	1080	1000	56.50	31.57	2448.71	56.50	31.57	2448.71
212	160	0.4	1	20	0.1	1080	4000	44.25	78.87	812.43	44.25	78.87	812.43
213	160	0.4	1	20	1	1080	8000	14.00	90.21	390.02	14.00	90.21	390.02
214	160	0.4	1	20	10	1080	20000	3.09	92.19	310.60	3.09	92.19	310.60
215	160	0.4	1	20	100	1080	30000	0.79	92.43	301.08	0.79	92.43	301.08
216	160	0.4	1	50	0.01	1080	1500	168.25	58.01	1537.17	168.25	58.01	1537.17
217	160	0.4	1	50	0.1	1080	6000	72.25	85.42	572.71	72.25	85.42	572.71
218	160	0.4	1	50	1	1080	13000	19.75	91.50	338.95	19.75	91.50	338.95
219	160	0.4	1	50	10	1080	25000	4.13	92.36	304.27	4.13	92.36	304.27
220	160	0.4	1	50	100	1080	45000	1.08	92.46	300.43	1.08	92.46	300.43
221	160	0.4	1	100	0.01	1080	2000	288.42	70.20	1121.90	288.42	70.20	1121.90
222	160	0.4	1	100	0.1	1080	8000	101.50	88.31	464.46	101.50	88.31	464.46
223	160	0.4	1	100	1	1080	17000	25.00	91.96	321.12	25.00	91.96	321.12
224	160	0.4	1	100	10	1080	30000	5.34	92.43	302.22	5.34	92.43	302.22
225	160	0.4	1	100	100	1080	60000	1.46	92.48	300.22	1.46	92.48	300.22
226	160	0.8	0.1	20	0.01	2100	1000	66.50	50.11	1797.84	66.50	50.11	1797.84
227	160	0.8	0.1	20	0.1	2100	4000	34.00	83.53	641.95	34.00	83.53	641.95
228	160	0.8	0.1	20	1	2100	8000	10.25	91.18	351.07	10.25	91.18	351.07
229	160	0.8	0.1	20	10	2100	20000	2.20	92.31	305.92	2.20	92.31	305.92
230	160	0.8	0.1	20	100	2100	30000	0.64	92.44	300.59	0.64	92.44	300.59
231	160	0.8	0.1	50	0.01	2100	1500	148.50	68.11	1191.57	148.50	68.11	1191.57
232	160	0.8	0.1	50	0.1	2100	6000	54.50	87.81	482.34	54.50	87.81	482.34
233	160	0.8	0.1	50	1	2100	13000	14.25	91.89	323.27	14.25	91.89	323.27
234	160	0.8	0.1	50	10	2100	25000	3.05	92.40	302.52	3.05	92.40	302.52
235	160	0.8	0.1	50	100	2100	45000	0.92	92.46	300.25	0.92	92.46	300.25
236	160	0.8	0.1	100	0.01	2100	2000	245.25	76.11	914.10	245.25	76.11	914.10
237	160	0.8	0.1	100	0.1	2100	8000	78.75	89.66	412.93	78.75	89.66	412.93
238	160	0.8	0.1	100	1	2100	17000	18.75	92.15	313.45	18.75	92.15	313.45
239	160	0.8	0.1	100	10	2100	30000	4.24	92.45	301.37	4.24	92.45	301.37
240	160	0.8	0.1	100	100	2100	60000	1.31	92.48	300.13	1.31	92.48	300.13
241	160	0.8	0.5	20	0.01	2100	1000	66.50	50.46	1786.17	66.50	50.46	1786.17
242	160	0.8	0.5	20	0.1	2100	4000	33.75	83.58	639.78	33.75	83.58	639.78
243	160	0.8	0.5	20	1	2100	8000	10.00	91.13	353.18	10.00	91.13	353.18
244	160	0.8	0.5	20	10	2100	20000	2.19	92.31	305.88	2.19	92.31	305.88
245	160	0.8	0.5	20	100	2100	30000	0.64	92.44	300.59	0.64	92.44	300.59

Table B.3: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in SDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
246	160	0.8	0.5	50	0.01	2100	1500	145.75	68.97	1161.66	145.75	68.97	1161.66
247	160	0.8	0.5	50	0.1	2100	6000	53.00	88.00	474.83	53.00	88.00	474.83
248	160	0.8	0.5	50	1	2100	13000	13.75	91.90	322.73	13.75	91.90	322.73
249	160	0.8	0.5	50	10	2100	25000	2.98	92.41	302.38	2.98	92.41	302.38
250	160	0.8	0.5	50	100	2100	45000	0.91	92.46	300.23	0.91	92.46	300.23
251	160	0.8	0.5	100	0.01	2100	2000	232.75	77.38	868.59	232.75	77.38	868.59
252	160	0.8	0.5	100	0.1	2100	8000	73.50	89.91	402.95	73.50	89.91	402.95
253	160	0.8	0.5	100	1	2100	17000	17.50	92.18	312.17	17.50	92.18	312.17
254	160	0.8	0.5	100	10	2100	30000	4.04	92.45	301.25	4.04	92.45	301.25
255	160	0.8	0.5	100	100	2100	60000	1.28	92.48	300.12	1.28	92.48	300.12
256	160	0.8	1	20	0.01	2100	1000	66.50	50.50	1784.61	66.50	50.50	1784.61
257	160	0.8	1	20	0.1	2100	4000	33.75	83.60	639.03	33.75	83.60	639.03
258	160	0.8	1	20	1	2100	8000	10.00	91.14	353.00	10.00	91.14	353.00
259	160	0.8	1	20	10	2100	20000	2.19	92.31	305.85	2.19	92.31	305.85
260	160	0.8	1	20	100	2100	30000	0.64	92.44	300.59	0.64	92.44	300.59
261	160	0.8	1	50	0.01	2100	1500	145.25	69.11	1156.94	145.25	69.11	1156.94
262	160	0.8	1	50	0.1	2100	6000	52.75	88.04	473.66	52.75	88.04	473.66
263	160	0.8	1	50	1	2100	13000	13.75	91.91	322.19	13.75	91.91	322.19
264	160	0.8	1	50	10	2100	25000	2.97	92.41	302.38	2.97	92.41	302.38
265	160	0.8	1	50	100	2100	45000	0.91	92.46	300.23	0.91	92.46	300.23
266	160	0.8	1	100	0.01	2100	2000	230.00	77.65	858.74	230.00	77.65	858.74
267	160	0.8	1	100	0.1	2100	8000	72.25	89.96	401.29	72.25	89.96	401.29
268	160	0.8	1	100	1	2100	17000	17.25	92.19	311.90	17.25	92.19	311.90
269	160	0.8	1	100	10	2100	30000	4.00	92.45	301.23	4.00	92.45	301.23
270	160	0.8	1	100	100	2100	60000	1.28	92.48	300.12	1.28	92.48	300.12

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
1	80	0.2	0.1	20	0.01	540	1000	13.50	12.42	3178.5	12.25	11.1	3230.2
2	80	0.2	0.1	20	0.1	540	4000	26.75	73.51	1003.1	27.25	73.3	1011.9
3	80	0.2	0.1	20	1	540	8000	9.50	89.11	432.52	9.5	88.9	439.64
4	80	0.2	0.1	20	10	540	20000	2.24	92.03	317.09	2.278	92	317.45
5	80	0.2	0.1	20	100	540	30000	0.65	92.41	301.77	0.66	92.4	301.84
6	80	0.2	0.1	50	0.01	540	1500	84.00	43.97	2008.8	82.5	41.2	2105
7	80	0.2	0.1	50	0.1	540	6000	47.00	81.93	701.97	49	81.3	725.92
8	80	0.2	0.1	50	1	540	13000	14.00	90.83	365.83	14.75	90.7	370.38
9	80	0.2	0.1	50	10	540	25000	3.02	92.28	307.48	3.168	92.3	308.2
10	80	0.2	0.1	50	100	540	45000	0.79	92.45	300.75	0.816	92.4	300.92
11	80	0.2	0.1	100	0.01	540	2000	169.50	58.68	1518.6	172.8	55.5	1624.2
12	80	0.2	0.1	100	0.1	540	8000	71.25	85.55	569.21	76.5	84.8	596.11
13	80	0.2	0.1	100	1	540	17000	19.25	91.53	338.54	21	91.4	343.01
14	80	0.2	0.1	100	10	540	30000	3.98	92.38	304.18	4.29	92.4	304.99
15	80	0.2	0.1	100	100	540	60000	0.97	92.47	300.42	1.013	92.5	300.72
16	80	0.2	0.5	20	0.01	540	1000	14.25	13.16	3149	13.75	12.7	3167.7
17	80	0.2	0.5	20	0.1	540	4000	26.75	73.81	992.39	26.75	73.7	997.98
18	80	0.2	0.5	20	1	540	8000	9.25	89.02	435.83	9.5	89.1	430.92
19	80	0.2	0.5	20	10	540	20000	2.22	92.04	316.77	2.223	92	317.19
20	80	0.2	0.5	20	100	540	30000	0.65	92.41	301.77	0.655	92.4	301.78
21	80	0.2	0.5	50	0.01	540	1500	84.75	45.97	1939.9	84.25	44.8	1978.4
22	80	0.2	0.5	50	0.1	540	6000	45.50	82.39	685.02	46.50	82.19	692.18
23	80	0.2	0.5	50	1	540	13000	13.50	90.92	362.27	13.75	90.86	364.48
24	80	0.2	0.5	50	10	540	25000	2.91	92.29	307.12	2.98	92.28	307.30
25	80	0.2	0.5	50	100	540	45000	0.78	92.45	300.69	0.79	92.44	300.86
26	80	0.2	0.5	100	0.01	540	2000	165.00	61.62	1418.91	167.75	59.97	1475.08
27	80	0.2	0.5	100	0.1	540	8000	66.25	86.21	544.06	69.25	85.86	557.28
28	80	0.2	0.5	100	1	540	17000	17.75	91.64	333.97	18.50	91.56	337.15
29	80	0.2	0.5	100	10	540	30000	3.69	92.39	303.68	3.84	92.38	304.23
30	80	0.2	0.5	100	100	540	60000	0.90	92.47	300.37	0.95	92.47	300.64
31	80	0.2	1	20	0.01	540	1000	14.25	13.19	3148.00	14.00	12.95	3157.46
32	80	0.2	1	20	0.1	540	4000	26.75	73.86	990.96	26.75	73.77	993.91
33	80	0.2	1	20	1	540	8000	9.25	89.03	435.37	9.50	89.18	429.64
34	80	0.2	1	20	10	540	20000	2.21	92.03	317.07	2.22	92.03	316.91

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
35	80	0.2	1	20	100	540	30000	0.65	92.41	301.76	0.65	92.41	301.75
36	80	0.2	1	50	0.01	540	1500	84.75	46.27	1929.48	84.50	45.62	1951.90
37	80	0.2	1	50	0.1	540	6000	45.25	82.46	682.20	45.75	82.32	687.41
38	80	0.2	1	50	1	540	13000	13.50	90.96	360.76	13.50	90.88	363.77
39	80	0.2	1	50	10	540	25000	2.89	92.29	307.03	2.93	92.29	307.16
40	80	0.2	1	50	100	540	45000	0.78	92.45	300.69	0.78	92.45	300.85
41	80	0.2	1	100	0.01	540	2000	163.75	62.26	1396.93	165.75	61.12	1436.04
42	80	0.2	1	100	0.1	540	8000	65.25	86.37	537.87	67.25	86.12	547.36
43	80	0.2	1	100	1	540	17000	17.25	91.64	334.05	18.00	91.62	334.83
44	80	0.2	1	100	10	540	30000	3.62	92.39	303.63	3.73	92.38	304.03
45	80	0.2	1	100	100	540	60000	0.89	92.47	300.36	0.90	92.47	300.63
46	80	0.4	0.1	20	0.01	1080	1000	30.00	36.02	2290.16	29.50	34.89	2330.54
47	80	0.4	0.1	20	0.1	1080	4000	21.25	79.93	773.63	21.50	79.65	783.89
48	80	0.4	0.1	20	1	1080	8000	7.00	90.49	378.87	7.00	90.37	383.63
49	80	0.4	0.1	20	10	1080	20000	1.61	92.21	309.77	1.63	92.21	309.88
50	80	0.4	0.1	20	100	1080	30000	0.58	92.43	300.92	0.58	92.43	301.05
51	80	0.4	0.1	50	0.01	1080	1500	83.00	59.22	1496.01	84.25	57.29	1561.01
52	80	0.4	0.1	50	0.1	1080	6000	35.25	85.64	564.15	37.00	85.25	578.85
53	80	0.4	0.1	50	1	1080	13000	10.00	91.55	336.70	10.50	91.48	339.51
54	80	0.4	0.1	50	10	1080	25000	2.15	92.36	304.14	2.25	92.35	304.52
55	80	0.4	0.1	50	100	1080	45000	0.67	92.46	300.41	0.68	92.45	300.57
56	80	0.4	0.1	100	0.01	1080	2000	146.25	69.56	1144.30	153.25	67.35	1220.98
57	80	0.4	0.1	100	0.1	1080	8000	52.25	88.14	470.60	56.50	87.67	488.71
58	80	0.4	0.1	100	1	1080	17000	13.25	91.94	322.05	14.50	91.88	324.41
59	80	0.4	0.1	100	10	1080	30000	2.84	92.43	302.30	3.03	92.41	302.88
60	80	0.4	0.1	100	100	1080	60000	0.80	92.48	300.22	0.83	92.47	300.50
61	80	0.4	0.5	20	0.01	1080	1000	30.25	36.58	2270.06	30.00	36.20	2283.76
62	80	0.4	0.5	20	0.1	1080	4000	21.00	79.98	772.03	21.00	79.86	776.37
63	80	0.4	0.5	20	1	1080	8000	7.00	90.55	376.65	7.00	90.52	377.83
64	80	0.4	0.5	20	10	1080	20000	1.61	92.22	309.36	1.61	92.22	309.62
65	80	0.4	0.5	20	100	1080	30000	0.58	92.43	300.89	0.58	92.43	300.96
66	80	0.4	0.5	50	0.01	1080	1500	81.75	60.54	1451.30	82.50	59.84	1474.97
67	80	0.4	0.5	50	0.1	1080	6000	34.25	85.99	550.95	34.75	85.79	558.57
68	80	0.4	0.5	50	1	1080	13000	9.50	91.56	336.51	9.75	91.55	336.90
69	80	0.4	0.5	50	10	1080	25000	2.10	92.37	303.84	2.13	92.36	304.13

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
70	80	0.4	0.5	50	100	1080	45000	0.67	92.46	300.40	0.67	92.45	300.52
71	80	0.4	0.5	100	0.01	1080	2000	139.00	71.51	1076.02	143.25	70.42	1114.18
72	80	0.4	0.5	100	0.1	1080	8000	48.50	88.58	453.88	50.50	88.32	463.93
76	80	0.4	1	20	0.01	1080	1000	30.25	36.63	2268.27	30.00	36.34	2278.68
77	80	0.4	1	20	0.1	1080	4000	21.00	80.01	770.93	21.00	79.94	773.22
78	80	0.4	1	20	1	1080	8000	7.00	90.55	376.35	7.00	90.54	376.99
79	80	0.4	1	20	10	1080	20000	1.61	92.22	309.31	1.61	92.22	309.46
80	80	0.4	1	20	100	1080	30000	0.58	92.43	300.88	0.58	92.43	300.94
81	80	0.4	1	50	0.01	1080	1500	81.50	60.75	1444.17	82.00	60.35	1457.59
82	80	0.4	1	50	0.1	1080	6000	34.00	86.03	549.72	34.25	85.90	554.69
83	80	0.4	1	50	1	1080	13000	9.50	91.58	335.58	9.75	91.60	334.71
84	80	0.4	1	50	10	1080	25000	2.09	92.37	303.85	2.10	92.36	304.09
85	80	0.4	1	50	100	1080	45000	0.67	92.46	300.38	0.67	92.45	300.51
86	80	0.4	1	100	0.01	1080	2000	137.50	71.97	1060.04	140.25	71.19	1087.40
87	80	0.4	1	100	0.1	1080	8000	47.50	88.65	451.31	49.00	88.49	457.39
88	80	0.4	1	100	1	1080	17000	12.00	92.01	319.26	12.50	92.00	319.65
89	80	0.4	1	100	10	1080	30000	2.63	92.43	301.98	2.69	92.42	302.36
90	80	0.4	1	100	100	1080	60000	0.77	92.48	300.19	0.78	92.47	300.46
91	80	0.8	0.1	20	0.01	2100	1000	33.50	58.31	1524.81	33.75	57.57	1549.69
92	80	0.8	0.1	20	0.1	2100	4000	14.75	85.42	571.69	15.00	85.24	578.50
93	80	0.8	0.1	20	1	2100	8000	4.75	91.57	335.57	4.75	91.50	338.51
94	80	0.8	0.1	20	10	2100	20000	1.17	92.38	303.14	1.17	92.37	303.57
95	80	0.8	0.1	20	100	2100	30000	0.50	92.45	300.31	0.50	92.45	300.39
96	80	0.8	0.1	50	0.01	2100	1500	67.75	72.64	1034.47	70.50	71.29	1081.64
97	80	0.8	0.1	50	0.1	2100	6000	23.50	88.81	444.30	24.75	88.49	456.45
98	80	0.8	0.1	50	1	2100	13000	6.50	92.06	316.38	6.75	91.99	319.02
99	80	0.8	0.1	50	10	2100	25000	1.52	92.42	301.89	1.58	92.41	302.14
100	80	0.8	0.1	50	100	2100	45000	0.59	92.46	300.17	0.59	92.46	300.33
101	80	0.8	0.1	100	0.01	2100	2000	110.00	78.86	815.41	118.25	77.22	874.59
102	80	0.8	0.1	100	0.1	2100	8000	34.00	90.19	392.29	37.50	89.88	404.52
103	80	0.8	0.1	100	1	2100	17000	8.50	92.23	310.23	9.25	92.18	312.30
104	80	0.8	0.1	100	10	2100	30000	2.02	92.46	301.09	2.14	92.45	301.49
105	80	0.8	0.1	100	100	2100	60000	0.68	92.48	300.10	0.70	92.47	300.37
106	80	0.8	0.5	20	0.01	2100	1000	33.50	58.76	1509.51	33.50	58.52	1517.48
107	80	0.8	0.5	20	0.1	2100	4000	14.50	85.42	571.92	14.75	85.51	568.56

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
108	80	0.8	0.5	20	1	2100	8000	4.50	91.45	340.38	4.50	91.43	341.20
109	80	0.8	0.5	20	10	2100	20000	1.17	92.38	302.97	1.17	92.38	303.10
110	80	0.8	0.5	20	100	2100	30000	0.50	92.45	300.30	0.50	92.45	300.36
111	80	0.8	0.5	50	0.01	2100	1500	65.75	73.60	1000.74	67.00	73.13	1017.37
112	80	0.8	0.5	50	0.1	2100	6000	22.50	88.99	437.32	23.00	88.88	441.57
113	80	0.8	0.5	50	1	2100	13000	6.25	92.08	315.44	6.25	92.03	317.40
114	80	0.8	0.5	50	10	2100	25000	1.50	92.42	301.70	1.51	92.42	301.93
115	80	0.8	0.5	50	100	2100	45000	0.60	92.46	300.16	0.59	92.46	300.30
116	80	0.8	0.5	100	0.01	2100	2000	102.25	80.30	763.14	106.75	79.50	792.21
117	80	0.8	0.5	100	0.1	2100	8000	34.00	90.19	392.29	37.50	89.88	404.52
118	80	0.8	0.5	100	1	2100	17000	7.75	92.25	309.30	8.25	92.25	309.53
119	80	0.8	0.5	100	10	2100	30000	1.92	92.46	300.93	1.98	92.45	301.24
120	80	0.8	0.5	100	100	2100	60000	0.67	92.48	300.10	0.68	92.47	300.34
121	80	0.8	1	20	0.01	2100	1000	33.50	58.82	1507.45	33.50	58.70	1511.66
122	80	0.8	1	20	0.1	2100	4000	14.50	85.44	571.04	14.50	85.39	572.87
123	80	0.8	1	20	1	2100	8000	4.50	91.46	340.18	4.50	91.44	340.63
124	80	0.8	1	20	10	2100	20000	1.17	92.38	302.94	1.17	92.38	303.04
125	80	0.8	1	20	100	2100	30000	0.50	92.45	300.30	0.50	92.45	300.35
126	80	0.8	1	50	0.01	2100	1500	65.50	73.79	994.26	66.00	73.44	1006.49
127	80	0.8	1	50	0.1	2100	6000	22.25	89.00	437.16	22.75	88.99	437.33
128	80	0.8	1	50	1	2100	13000	6.00	92.03	317.47	6.25	92.07	316.06
129	80	0.8	1	50	10	2100	25000	1.48	92.42	301.77	1.50	92.42	301.89
130	80	0.8	1	50	100	2100	45000	0.60	92.46	300.18	0.60	92.46	300.29
131	80	0.8	1	100	0.01	2100	2000	100.25	80.57	753.23	103.50	80.05	772.18
132	80	0.8	1	100	0.1	2100	8000	30.50	90.54	378.26	31.50	90.42	383.23
133	80	0.8	1	100	1	2100	17000	7.75	92.28	308.31	8.00	92.26	308.97
134	80	0.8	1	100	10	2100	30000	1.91	92.46	300.87	1.94	92.45	301.20
135	80	0.8	1	100	100	2100	60000	0.67	92.48	300.08	0.67	92.48	300.34
136	160	0.2	0.1	20	0.01	780	1000	36.75	18.22	2951.25	35.00	17.15	2992.96
137	160	0.2	0.1	20	0.1	780	4000	50.75	75.30	939.87	51.25	75.00	950.59
138	160	0.2	0.1	20	1	780	8000	17.00	89.49	418.02	17.25	89.43	420.08
139	160	0.2	0.1	20	10	780	20000	3.84	92.09	314.73	3.91	92.09	314.88
140	160	0.2	0.1	20	100	780	30000	0.97	92.42	301.49	0.97	92.42	301.57
141	160	0.2	0.1	50	0.01	780	1500	169.67	48.22	1863.13	168.92	46.08	1935.92
142	160	0.2	0.1	50	0.1	780	6000	87.25	83.05	660.60	90.50	82.55	679.12

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
143	160	0.2	0.1	50	1	780	13000	25.00	91.08	355.59	26.00	90.97	359.98
144	160	0.2	0.1	50	10	780	25000	5.25	92.31	306.25	5.48	92.30	306.76
145	160	0.2	0.1	50	100	780	45000	1.24	92.45	300.63	1.27	92.45	300.80
146	160	0.2	0.1	100	0.01	780	2000	327.67	62.14	1401.10	336.17	59.64	1486.29
147	160	0.2	0.1	100	0.1	780	8000	130.50	86.45	534.97	139.00	85.87	556.96
148	160	0.2	0.1	100	1	780	17000	33.50	91.67	332.88	36.25	91.58	336.35
149	160	0.2	0.1	100	10	780	30000	6.93	92.40	303.47	7.43	92.38	304.12
150	160	0.2	0.1	100	100	780	60000	1.69	92.47	300.35	1.76	92.47	300.64
151	160	0.2	0.5	20	0.01	780	1000	37.75	18.81	2928.48	37.25	18.51	2940.04
152	160	0.2	0.5	20	0.1	780	4000	50.50	75.45	934.70	50.50	75.32	939.12
153	160	0.2	0.5	20	1	780	8000	16.75	89.46	418.83	16.75	89.43	420.25
154	160	0.2	0.5	20	10	780	20000	3.82	92.10	314.40	3.84	92.09	314.52
155	160	0.2	0.5	20	100	780	30000	0.96	92.42	301.49	0.96	92.42	301.54
156	160	0.2	0.5	50	0.01	780	1500	169.92	49.76	1811.07	169.92	48.94	1838.69
157	160	0.2	0.5	50	0.1	780	6000	85.00	83.42	646.96	86.25	83.22	654.18
158	160	0.2	0.5	50	1	780	13000	24.00	91.11	354.34	24.50	91.09	355.31
159	160	0.2	0.5	50	10	780	25000	5.08	92.32	306.01	5.17	92.31	306.29
160	160	0.2	0.5	50	100	780	45000	1.22	92.45	300.60	1.23	92.45	300.74
161	160	0.2	0.5	100	0.01	780	2000	317.92	64.39	1323.56	323.67	63.12	1367.30
162	160	0.2	0.5	100	0.1	780	8000	122.50	86.96	515.67	127.00	86.67	526.56
163	160	0.2	0.5	100	1	780	17000	31.25	91.76	329.36	32.50	91.70	331.47
164	160	0.2	0.5	100	10	780	30000	6.49	92.41	303.13	6.73	92.39	303.57
165	160	0.2	0.5	100	100	780	60000	1.62	92.48	300.31	1.66	92.47	300.58
166	160	0.2	1	20	0.01	780	1000	37.75	18.84	2927.40	37.50	18.69	2933.30
167	160	0.2	1	20	0.1	780	4000	50.25	75.39	936.87	50.50	75.41	935.91
168	160	0.2	1	20	1	780	8000	16.75	89.47	418.47	16.75	89.45	419.23
169	160	0.2	1	20	10	780	20000	3.81	92.09	314.53	3.82	92.09	314.52
170	160	0.2	1	20	100	780	30000	0.96	92.42	301.48	0.96	92.42	301.51
171	160	0.2	1	50	0.01	780	1500	169.92	50.02	1802.55	169.92	49.53	1818.85
172	160	0.2	1	50	0.1	780	6000	84.50	83.46	645.42	85.25	83.35	649.57
173	160	0.2	1	50	1	780	13000	24.00	91.14	353.19	24.25	91.12	354.03
174	160	0.2	1	50	10	780	25000	5.06	92.32	305.97	5.11	92.31	306.14
175	160	0.2	1	50	100	780	45000	1.21	92.45	300.59	1.22	92.45	300.72
176	160	0.2	1	100	0.01	780	2000	315.67	64.89	1306.18	319.67	64.01	1336.43
177	160	0.2	1	100	0.1	780	8000	120.75	87.07	511.50	123.75	86.87	519.14

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

CASES	Well & Reservoir Parameters							Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
178	160	0.2	1	100	1	780	17000	30.75	91.77	328.70	31.50	91.73	330.44
179	160	0.2	1	100	10	780	30000	6.41	92.41	303.03	6.56	92.40	303.42
180	160	0.2	1	100	100	780	60000	1.61	92.48	300.30	1.63	92.47	300.56
181	160	0.4	0.1	20	0.01	1500	1000	61.50	39.49	2167.46	61.00	38.64	2197.32
182	160	0.4	0.1	20	0.1	1500	4000	40.00	80.83	740.93	40.50	80.65	747.58
183	160	0.4	0.1	20	1	1500	8000	12.50	90.67	371.84	12.50	90.57	375.63
184	160	0.4	0.1	20	10	1500	20000	2.74	92.25	308.37	2.77	92.24	308.67
185	160	0.4	0.1	20	100	1500	30000	0.79	92.44	300.84	0.80	92.43	300.94
186	160	0.4	0.1	50	0.01	1500	1500	161.25	61.62	1414.52	164.00	60.13	1465.12
187	160	0.4	0.1	50	0.1	1500	6000	66.00	86.31	539.04	68.50	85.96	552.17
188	160	0.4	0.1	50	1	1500	13000	17.75	91.65	332.68	18.50	91.60	334.91
189	160	0.4	0.1	50	10	1500	25000	3.76	92.38	303.60	3.89	92.37	303.98
190	160	0.4	0.1	50	100	1500	45000	1.02	92.46	300.35	1.04	92.45	300.50
191	160	0.4	0.1	100	0.01	1500	2000	278.67	71.61	1072.66	291.17	69.85	1134.01
192	160	0.4	0.1	100	0.1	1500	8000	96.25	88.66	451.06	103.00	88.27	465.63
193	160	0.4	0.1	100	1	1500	17000	23.50	92.02	318.77	25.25	91.96	321.15
194	160	0.4	0.1	100	10	1500	30000	5.04	92.43	301.99	5.36	92.42	302.43
195	160	0.4	0.1	100	100	1500	60000	1.42	92.48	300.20	1.46	92.47	300.47
196	160	0.4	0.5	20	0.01	1500	1000	61.50	39.82	2156.03	61.50	39.65	2161.98
197	160	0.4	0.5	20	0.1	1500	4000	39.75	80.92	737.79	39.75	80.82	741.20
198	160	0.4	0.5	20	1	1500	8000	12.25	90.62	373.61	12.25	90.60	374.59
199	160	0.4	0.5	20	10	1500	20000	2.72	92.25	308.46	2.73	92.25	308.47
200	160	0.4	0.5	20	100	1500	30000	0.79	92.44	300.84	0.79	92.43	300.91
201	160	0.4	0.5	50	0.01	1500	1500	159.00	62.66	1379.07	160.25	62.10	1398.21
202	160	0.4	0.5	50	0.1	1500	6000	64.00	86.52	531.19	65.00	86.39	535.91
203	160	0.4	0.5	50	1	1500	13000	17.00	91.66	332.59	17.50	91.67	332.14
204	160	0.4	0.5	50	10	1500	25000	3.66	92.38	303.44	3.72	92.38	303.62
205	160	0.4	0.5	50	100	1500	45000	1.00	92.46	300.34	1.01	92.45	300.48
206	160	0.4	0.5	100	0.01	1500	2000	266.42	73.14	1018.58	273.42	72.28	1049.09
207	160	0.4	0.5	100	0.1	1500	8000	90.00	88.97	439.02	93.50	88.79	445.82
208	160	0.4	0.5	100	1	1500	17000	22.00	92.07	316.82	22.75	92.03	318.31
209	160	0.4	0.5	100	10	1500	30000	4.78	92.44	301.80	4.93	92.43	302.12
210	160	0.4	0.5	100	100	1500	60000	1.38	92.48	300.18	1.40	92.47	300.44
211	160	0.4	1	20	0.01	1500	1000	61.50	39.86	2154.50	61.50	39.77	2157.65
212	160	0.4	1	20	0.1	1500	4000	39.75	80.94	736.93	39.75	80.89	738.73
213	160	0.4	1	20	1	1500	8000	12.25	90.63	373.37	12.25	90.62	373.90

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
214	160	0.4	1	20	10	1500	20000	2.72	92.25	308.42	2.72	92.24	308.55
215	160	0.4	1	20	100	1500	30000	0.79	92.44	300.83	0.79	92.43	300.89
216	160	0.4	1	50	0.01	1500	1500	158.75	62.85	1372.51	159.25	62.49	1384.98
217	160	0.4	1	50	0.1	1500	6000	63.75	86.56	529.47	64.25	86.48	532.72
218	160	0.4	1	50	1	1500	13000	17.00	91.67	331.88	17.25	91.67	331.89
219	160	0.4	1	50	10	1500	25000	3.65	92.38	303.41	3.67	92.38	303.59
220	160	0.4	1	50	100	1500	45000	1.00	92.46	300.34	1.00	92.45	300.47
221	160	0.4	1	100	0.01	1500	2000	263.67	73.48	1006.71	268.42	72.88	1027.79
222	160	0.4	1	100	0.1	1500	8000	88.75	89.05	436.20	91.00	88.92	441.15
223	160	0.4	1	100	1	1500	17000	21.50	92.06	316.97	22.25	92.05	317.30
224	160	0.4	1	100	10	1500	30000	4.73	92.44	301.76	4.82	92.43	302.07
225	160	0.4	1	100	100	1500	60000	1.37	92.48	300.18	1.39	92.47	300.43
226	160	0.8	0.1	20	0.01	3000	1000	64.50	61.80	1406.78	65.00	61.23	1426.31
227	160	0.8	0.1	20	0.1	3000	4000	26.50	86.25	540.44	27.00	86.16	544.07
228	160	0.8	0.1	20	1	3000	8000	7.75	91.62	333.42	8.00	91.65	332.41
229	160	0.8	0.1	20	10	3000	20000	1.76	92.36	303.69	1.79	92.36	303.71
230	160	0.8	0.1	20	100	3000	30000	0.66	92.45	300.38	0.66	92.45	300.43
231	160	0.8	0.1	50	0.01	3000	1500	126.25	74.96	952.99	131.00	73.93	989.42
232	160	0.8	0.1	50	0.1	3000	6000	41.75	89.34	424.20	44.00	89.14	431.65
233	160	0.8	0.1	50	1	3000	13000	10.75	92.10	314.77	11.25	92.07	316.00
234	160	0.8	0.1	50	10	3000	25000	2.48	92.43	301.58	2.57	92.42	301.82
235	160	0.8	0.1	50	100	3000	45000	0.84	92.46	300.15	0.85	92.46	300.28
236	160	0.8	0.1	100	0.01	3000	2000	200.75	80.70	748.45	214.75	79.44	794.60
237	160	0.8	0.1	100	0.1	3000	8000	59.75	90.60	376.07	65.25	90.37	385.20
238	160	0.8	0.1	100	1	3000	17000	14.25	92.27	308.55	15.50	92.24	309.70
239	160	0.8	0.1	100	10	3000	30000	3.51	92.46	300.87	3.69	92.45	301.24
240	160	0.8	0.1	100	100	3000	60000	1.21	92.48	300.08	1.23	92.47	300.34
241	160	0.8	0.5	20	0.01	3000	1000	64.50	62.18	1394.13	64.50	61.98	1400.73
242	160	0.8	0.5	20	0.1	3000	4000	26.25	86.30	538.84	26.50	86.32	538.02
243	160	0.8	0.5	20	1	3000	8000	7.75	91.65	332.33	7.75	91.64	332.93
244	160	0.8	0.5	20	10	3000	20000	1.76	92.37	303.52	1.76	92.36	303.66
245	160	0.8	0.5	20	100	3000	30000	0.66	92.45	300.35	0.66	92.45	300.41
246	160	0.8	0.5	50	0.01	3000	1500	123.00	75.70	926.46	124.75	75.30	940.93
247	160	0.8	0.5	50	0.1	3000	6000	40.25	89.48	418.87	41.25	89.43	420.70
248	160	0.8	0.5	50	1	3000	13000	10.50	92.13	313.54	10.50	92.09	315.04

Table B.4: Summary of results for well placement in the middle and close to upper no-flow boundary of the reservoir in RDA (Continued)

Well & Reservoir Parameters								Horizontal Well in the Middle of the Reservoir			Horizontal Well close to upper No-Flow Boundary		
CASES	Area	X_f/X_e	K_v/K_h	h	k_h	$L_H=2X_f$	Q	TIME	R.F	FPR	TIME	R.F	FPR
	Acres			Ft	md	Feet	MSCF/D	YRS	%	PSIA	YRS	%	PSIA
249	160	0.8	0.5	50	10	3000	25000	2.43	92.43	301.50	2.46	92.42	301.68
250	160	0.8	0.5	50	100	3000	45000	0.83	92.46	300.14	0.84	92.46	300.28
251	160	0.8	0.5	100	0.01	3000	2000	187.75	81.77	709.00	195.25	81.18	730.84
252	160	0.8	0.5	100	0.1	3000	8000	55.25	90.80	367.75	57.75	90.68	372.51
253	160	0.8	0.5	100	1	3000	17000	13.25	92.30	307.60	13.75	92.27	308.48
254	160	0.8	0.5	100	10	3000	30000	3.36	92.46	300.77	3.44	92.46	301.07
255	160	0.8	0.5	100	100	3000	60000	1.19	92.48	300.08	1.20	92.48	300.33
256	160	0.8	1	20	0.01	3000	1000	64.25	62.13	1395.63	64.50	62.12	1395.92
257	160	0.8	1	20	0.1	3000	4000	26.25	86.31	538.16	26.25	86.28	539.58
258	160	0.8	1	20	1	3000	8000	7.75	91.65	332.19	7.75	91.65	332.52
259	160	0.8	1	20	10	3000	20000	1.74	92.36	303.69	1.76	92.37	303.59
260	160	0.8	1	20	100	3000	30000	0.66	92.45	300.35	0.66	92.45	300.41
261	160	0.8	1	50	0.01	3000	1500	122.50	75.83	921.89	123.50	75.59	930.49
262	160	0.8	1	50	0.1	3000	6000	40.00	89.50	418.05	40.50	89.46	419.60
263	160	0.8	1	50	1	3000	13000	10.25	92.11	314.50	10.50	92.12	314.03
264	160	0.8	1	50	10	3000	25000	2.43	92.43	301.44	2.44	92.43	301.60
265	160	0.8	1	50	100	3000	45000	0.83	92.46	300.14	0.84	92.46	300.26
266	160	0.8	1	100	0.01	3000	2000	185.00	82.01	700.29	190.00	81.60	715.32
267	160	0.8	1	100	0.1	3000	8000	54.25	90.84	366.19	56.00	90.77	369.18
268	160	0.8	1	100	1	3000	17000	13.00	92.30	307.53	13.50	92.29	307.72
269	160	0.8	1	100	10	3000	30000	3.33	92.47	300.74	3.36	92.46	301.04
270	160	0.8	1	100	100	3000	60000	1.19	92.48	300.07	1.19	92.48	300.33

RESUME

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QUALIFICATIONS

King Fahd University of Petroleum and Minerals, Dhahran Saudi Arabia

- **MSc Petroleum Engineering (2012)** CGPA 3.563 out of 4.

NED University of Engineering and Technology Karachi, Pakistan

- **BE Mechanical (2009)** Aggregate percentage: 75%

PRESENTATIONS AND CONFERENCES

- 3rd prize, 2011 MEOS Regional Education Week Workshop Competition, “Role of Technology in Oil and Gas Industry in the Middle East, Manama, Bahrain,(23-26 September 2011).
- 3rd prize, Technical Paper Presentation, 2nd All Pakistan Mechanical Engineering Conference, GIKI (Ghulam Ishaq Khan Institute of Science and Technology, Swabi 10-12 April, 2009) for the paper “Feasibility of Solar Streetlights in Pakistan”
- Participation in, SPE Middle East Sub-Regional student paper contest Saudi Arabia-Bahrain region, “Selection between Active and Passive Inflow Control Completions in Horizontal Wells”, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia, (December 22,2011)

PROFESSIONAL AFFILIATIONS

- General Secretary for the SPE (Society of Petroleum Engineers) KFUPM Student Chapter (April 2012 – September 2012).
- Coordinator of Conference & Exhibition for the SPE (Society of Petroleum Engineers) KFUPM Student Chapter (January 2011 – April 2012).
- Founder & Administrative committee member of Graduate student club (GSC) KFUPM (November 2011-Present).
- Professional member of SPE SAS (Saudi Arabia Section).
- President, ASHRAE NED University of Engineering & Technology Student Chapter (American Society of Heating Refrigeration Air-conditioning Engineers) (January 2009 - December 2009).
- Vice-President, ASHRAE NED Student Chapter (January 2008 - December 2008).
- Student member, Pakistan HVACR (Heating Ventilation Air Conditioning & Refrigeration Society) (September 2007 – December 2010).
- Student member, ASME (American Society of Mechanical Engineers) (January 2008 to December 2009).

EXTRA CURRICULAR ACTIVITIES

Playing cricket, travelling, Attending social events, swimming, etc.