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GRAVEL PACK AND SCREEN DESIGN FOR SAND PRODUCTION CONTROL IN VERTICAL OIL WELLS IN THE NIGER DELTA

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INTRODUCTION

1.1 Background of the Study

Sand production is considered one of the significant production issues that reduce wellbore productivity which mainly occurs when drilling or producing from weak or unconsolidated formations. The process of sand or solids production in oil and gas production operation is a crucial operational inefficiency that can lead to various production problems including erosion of downhole tubulars; erosion of valves, fittings and surface flow lines; the wellbore filling up with sand; collapsed casing because of lack of formation support; and clogging of surface processing equipment. Discrete environmental methods are excellent tools for simulating sand production, especially for understanding the mechanism of sand formation. (Esmaeili 2018; Musa *et al.,* 2017).

Before drilling, tight formations are in the hydro-mechanical equilibrium (static equilibrium of stress and porous pressure). However, drilling hydrocarbon reservoirs to produce oil and gas causes the redistribution of stress and perforation around the well. Therefore, sand particles are separated from each other and enter the well from the formation (Uchida *et al.,* 2016). Even if sand production can be tolerated, disposal of the produced sand is a problem especially at offshore fields, thus, a means to eliminate sand production without greatly limiting production rates is desirable.

Sand production can have a significant adverse effect on oil production as it can hinder fluid flow within the reservoir and wellbore, leading to a decrease in oil production rates. As sand particles are produced along with the hydrocarbons, they can obstruct flow paths, reduce permeability, and create flow restrictions, ultimately limiting the amount of oil that can be extracted from the reservoir. Sand production can be controlled using gravel pack completion; a simple downhole filter used to control unwanted sand, slotted liner completion and sand consolidation treatments, with the gravel pack and screen design being the most common method.

Completion methods are selected based on sand characterization and failure mechanism. Laboratory testing and mathematical models used for sand prediction are selected using sand characterization. This study focuses on investigating sand production control during oil production using gravel pack placements and screen designs.

1.2 Statement of the Problem

One of the most pressing problems in the operations of oil and gas production in the Niger Delta is sand production. It is especially acute for reservoirs that are unconsolidated, which is common in the Niger Delta. The simultaneous extraction of sand and hydrocarbons uncontrollably causes numerous issues, including productivity losses, equipment abrasion, reservoir and wellbore degradation, and safety risks. When the original pressure balance around the wellbore is broken, which, in turn, leads to yielding and original structure failure of formation rock, pressure drawdown coupled with a dragging force due to the producing or injection fluid cause sand production along with oil. The main factors that lead to sand production are the case histories of sudden water breakthrough from weak- to intermediate-strength formation, changes in flow rate or high flow rate, increased number and size of surface separation facilities, clogging of choke, and surface facilities, wear and dissemination of subsurface components and drill pipe.

Although there are well-known methods such as chemical treatments; which entail introducing consolidating agents into the formation, such as resins, to cement the sand grains while leaving the pore spaces free and also increasing the formation's unconfined compressive strength in the process. Even though this method is successful, it is very expensive and not environmentally friendly as resins are highly toxic and inflammable. Also, strengthening the wellbore artificially often leads to distortion of the permeability of the compression zone through the increased formation strength.

Today, gravel packing is the most extensively utilized method of sand production control. The method's best effect is shown in initial well completions. The proper size of gravel must be determined during the design process for successful application and performance of gravel pack (Bergkvam 1997). To determine the right gravel size, the formation's median grain size must first be calculated. In the Niger Delta, there are little information available in the open literature on the design and performances of gravel pack for reservoirs that are unconsolidated.

1.3 Aim and Objectives of the Study

This project mainly focuses on the design and sizing of gravel pack and screens to control sand production in oil reservoirs using the petroleum software PROSPER.

The specific objectives;

i. To analyse the mechanisms and causes of sand production in vertical oil wells within the Niger Delta.

ii. To model and simulate gravel pack performance under Niger Delta well conditions to predict sand control effectiveness and pressure drop.

iii. To compare the performance of various gravel pack and screen configurations in minimizing sand production and maximizing oil recovery.

iv. To provide recommendation for the optimal gravel pack and screen type suitable in maximizing oil recovery in the Niger Delta.

1.4 Significance of the Study

The study is significant for the following reasons:

i. Gravel Pack and Screen Design: The main significance of this study is to provide a systematic design approach that ensures effective sand exclusion while maintaining high fluid flow, thereby reducing equipment wear and formation damage.

ii. Increased Productivity: Proper gravel packing design for sand production control increases well productivity by maintaining the integrity of the producing reservoir, preventing sand influx into the wellbore, and ensuring efficient fluid flow from the reservoir to the surface.

iii. Knowledge Transfer and Advancement: This study can contribute to knowledge transfer in the oil and gas industry by sharing insights, lessons learned and innovative solutions for sand production control.

1.5 Scope and Limitations of the Study

This study focuses mainly on the use of sand screens and gravel placement to control sand production. It encompasses the following aspects:

i. Introduction to Sand Production in Oil Wells**:** This study focuses on the definition and causes of sand production in vertical oil wells, as well as its impacts on well performance and equipment.

ii. Screen and Gravel Pack Design: This study assesses the use gravel pack and screen design as a sand control method, the criteria for selecting gravel size and screen type based on formation properties and the use petroleum software (PROSPER), to simulate sand production and control effectiveness.

iii. Geographical Scope and Data Availability: This study focuses on vertical oil wells in the Niger Delta, excluding horizontal and deviated wells.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Sand Control

Oil reservoirs are intricate structures within the Earth's crust that hold oil and natural gas. Extraction of these resources require advanced engineering techniques and management knowledge to boost production while reducing environmental impact. Sand control is a crucial process in managing oil reservoirs and increasing production. It is a technique for preventing or minimizing sand influx into the hydrocarbon flow stream which occurs when producing from an unconsolidated or weakly consolidated sand formation. Sand production can lead to various issues ranging from equipment damage to decreased productivity and the ability to predict and control sand production is a major part of the effective operation of unconsolidated oil and gas wells (Khamehchi *et al.,* 2014).

To properly mitigate these challenges, different sand control methods have been developed, with gravel packing and screen installation emerging as the primary technique for controlling sand production in vertical oil reservoirs in the Niger Delta. This literature review addresses in details, sand production problems, causes of sand production, control techniques with emphasis on the design of gravel pack placement and screens for sand production control, providing insights into methods, types of gravel pack completions and screen designs, installation techniques and design considerations for effective management in the Niger Delta.

2.2 Causes of Sand Production

Sand production occurs during hydrocarbon production from a well when the reservoir sandstone is weak enough to fail under the in situ stress conditions and the imposed stress changes due to the hydrocarbon production. The oil or gas flow transports the failed rock causing a variety of problems ranging from erosion of the surface facilities, to well integrity, and sand disposal. The following factors contribute to sand production in oil wells:

2.2.1 Weak Formation Strength

The degree of formation consolidation is a direct function of sand production in an oil reservoir. When low, the effect often causes lack of cementation between sand grains making them susceptible to erosion and tensile or compressional failure. When producing from these formations, there is increased sand mobility which facilitates sand movement towards the wellbore leading to risk of sand screen plugging and formation collapse.

2.2.2 Increasing Water Production

Water production or increase in water cut has been shown to severely limit the stability of sand around a perforation, resulting in the initiation of sand production. Many possibilities explain these occurrences. Firstly, the production of water can alter the saturation condition of a reservoir leading to changes in pore pressure and effective stress (Smith, 1988). Another way which water production can cause increase in sand production is directly related to relative permeability, increase in water cut causes reduction the permeability of an oil reservoir which increases pressure drawdown for a given oil production rates.

2.2.3 Drag Force Effects

Drag force refers to the force exerted by the flowing fluids on the particles suspended within it. This force is caused by the flowing reservoir fluid and is directly related to the velocity of the fluid flow and the viscosity of the reservoir fluid being produced. High reservoir fluid viscosity will cause a greater frictional drag forces to the formation sand grains than a reservoir fluid with low viscosity. The effect of this viscous drag causes sand to be produced from heavy oil reservoirs in the Niger Delta.

2.3 Impacts of Sand Production

Sand production in oil wells can have significant negative impacts on various aspects of oil field operations. These impacts range from operational challenges to economic losses and safety hazards. Below are the key impacts of sand production:

2.3.1 Equipment Damage

When sand production is not controlled, it causes erosion to downhole facilities such as valves, pipelines and pumps, which leads to corrosion of the equipment when exposed to hydrocarbon. Also, sand-laden fluid can cause mechanical wear on moving parts of equipment such as impellers in pumps or rotary machinery, resulting in premature failure.

2.3.2 Decreased Production

The sand accumulated in the surface tools, wellbore, pipelines, tubing and separator during sand production result in decreased production, which is not favourable to the well. Sand settles in the wellbore due to low production velocities, which slowly cover the reservoir section. If the sand trapped is not cleared, they form into sand plugs, which then fall into the wellbore and causing loss of production.

2.4 Gravel Pack Design in the Niger Delta

Gravel packing to exclude formation sand from produced fluids has been in existence for more than 30 years and now accounts for nearly 75% of all sand face treatments. However, the technology used in early gravel pack design, was borrowed from the water production industry, which for many years was using several types of mechanical sand retention and control devices to prevent sand production from produced groundwater. Early oil and gas completions, similar to those used in water wells, were what normally is referred to as open-hole gravel packs.

Gravel packing is an important sand control technique used extensively in oil and gas production to prevent or reduce sand production from unconsolidated formations. The challenges caused by sand production can be addressed by gravel packing which provide a drainage barrier around the wellbore, filtering out sand particles and enhancing hydrocarbon free flow over the well. In the process of gravel packing, specially designed gravel pack materials and graded gravel pack materials are placed in the annular space between the wellbore and the formation, this gravel pack material acts as a filter trapping sand particles and prevent the influx of sand into the production tubing during oil and gas production, the formation sand is held in place by properly sized gravel pack sand that, in turn, is held in place with a properly-sized screen.

For a successful gravel pack completion, the gravel must be adjacent to the formation without having mixed with formation sand, and the annular space between the screen and the casing or formation must be completely filled with gravel. Special equipment and procedures have been developed over the years to accomplish good gravel placement.

Water or other low viscosity fluids were first used as transporting fluids in gravel pack operations. Because these fluids could not suspend the sand, low sand concentrations and high viscosities were needed. Now, high viscosity fluids are used so that high concentration sand can be transported without settling (Scheuerman, 1984).

In gravel packing, sand production can be controlled by careful selection of gravel size considering the formation sand size. The main factor that influences the sand production in gravel packed wells is the flow restriction caused by the gravel pack itself. There are three important parameters in designing and investigation of gravel packed wells that influence gravel pack permeability and cost (Khamehchi *et al.*, 2015; Deghani, 2010):

i. Selection of gravel size or mesh size to stop the movement of formation sand,
ii. Determination of gravel pack length or penetration of gravel in formation,
iii. Placement of gravel, ideally in a tight pack that has a radius as large as possible

2.5 Development Criteria for Designing Gravel Packing

i. Gravel size used should be as large as possible capable for stopping formation at the outer edge of the gravel pack.
ii. Gravel size should be less than 6 times the 40 percentile point on the sand analysis curve.
iii. More attention should be paid to the smaller sand sizes, especially those with higher flow velocity, more non-uniform, fluctuating flow rate and high gas-oil ratios, where sand grain analysis vary within the formation.
iv. Packing the gravel tightly and without contamination. Gravel to sand-ratios (G-S) should be based on tight packs and void spaces must be avoided.
v. The thickness of the pack should be at least 3-inches as thicker packs permit higher flow velocity.

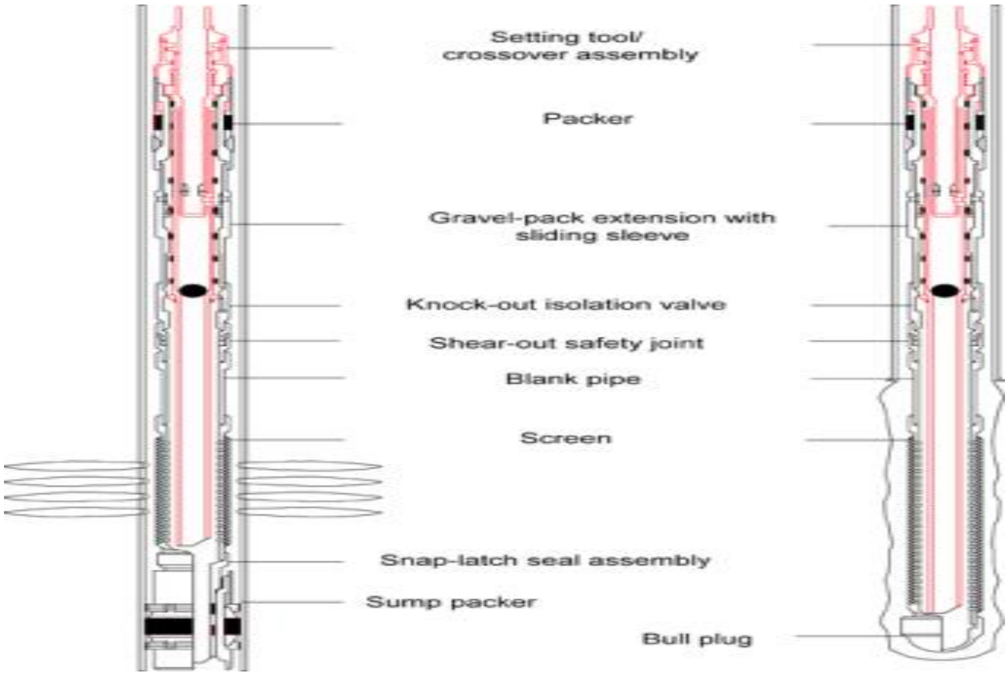

Figure 2.1: Typical gravel-pack completion equipment in cased- and openholes
Source: Penberthy (1992)

2.6 Gravel Placement Techniques

Gravel placement techniques are critical in the design and execution of gravel packs to control sand production in vertical oil and gas wells. The method chosen depends on factors such as well type, formation characteristics, and operational constraints. Here are the gravel placement techniques used in the Niger Delta:

2.6.1 Open-hole Gravel Packing

The open-hole gravel packing also referred to as underreamed-casing gravel pack has routinely been used has a sand control method in oil wells especially horizontal wells. It typically involves placing a gravel pack directly into an unconsolidated formation to prevent the production of sand while allowing the flow of hydrocarbon to the well.

In open-hole completions, the reservoir section of the well is left uncased, and the gravel-laden fluid can be pumped down the tubing casing annulus, after which the carrier fluid passes through the screen and flows back up the tubing (Suman *et al*., 1983). The underreamed-casing gravel pack provides better conductivity through the gravel, but is limited to single zone completions. Open hole packing can be done in different ways as follows:

i. Reserve-Circulation Method**:** The reserve-circulation method is a traditional open hole technique which involves pumping gravel slurry directly into the annular space between the wellbore and the formation to prevent sand and formation materials from entering the wellbore while allowing the flow of the produced fluid. The primary disadvantage of this method includes the possibility of rust, pipe dope, or other debris being swept out of the annulus and mixed with the gravel, damaging the pack permeability.

ii. Crossover Method: This method is the most common technique and involves the use of crossover tools to divert the flow of gravel slurry from the tubing to the annulus, allowing for gravel packing to be conducted efficiently. In this technique, the gravel laden fluid pumped down the tubing, crosses over to the screen open-hole annulus, and then flows up the casing tubing annulus to the surface (Suman *et al*., 1983). This method allows for more effective and efficient packing by directing the gravel slurry directly into the annular space rather than relying solely on fluid flow to carry the gravel particles into place.

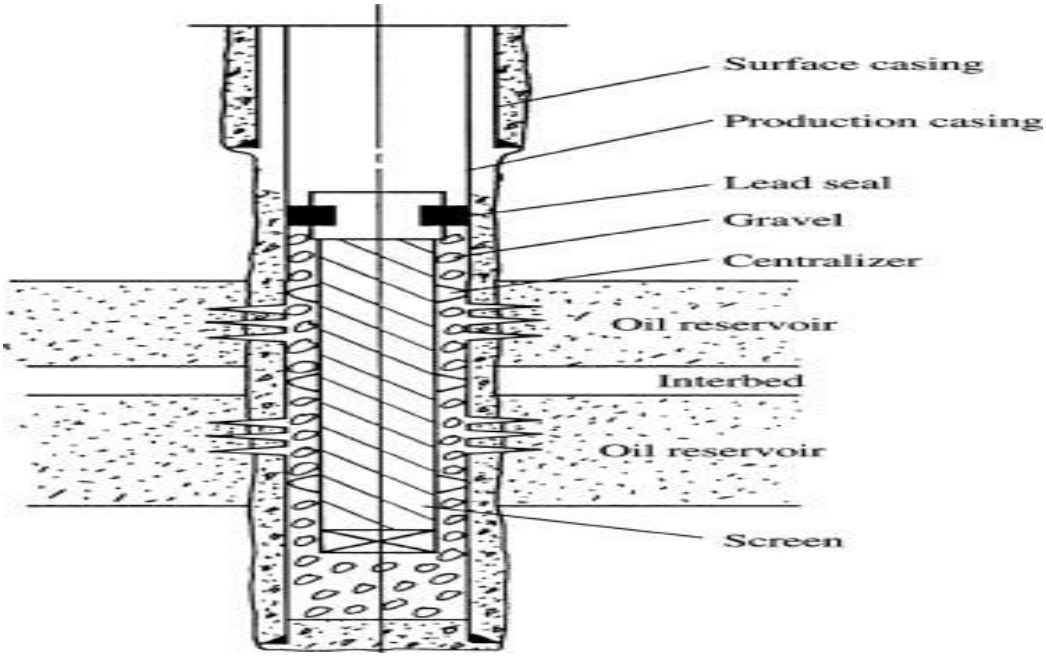

Figure 2.2: Open hole gravel packing
Source: Penberthy (1992)

2.6.2 Inside-Casing Gravel Packing

This packing technique involve placing a layer of gravel or sand around the outside of the well casing, typically in the annular space between the casing and the formation. In this technique, it must be ensured that large diameter perforations are achieved because gravel cannot be carried into the perforations that doesn't accept fluid readily. The gravel or sand used in the packing process is selected based on its size and properties to ensure optimal permeability and stability.

For the inside-casing gravel packing, the techniques used include; washdown, reverse-circulation and the conventional crossover method. The reverse- circulation and the crossover methods are analogous to those used in open holes. In the washdown method, the gravel is placed opposite the productive interval before the screen is placed, and then the screen is washed down to its final position (Suman *et al.*, 1983).

2.6.3 Fracture Pack

Fracturing and gravel packing, sometimes known as "frac-pack," has been an option for completing wells in unconsolidated sand reservoirs since the process was pioneered in the Hackberry Field (Louisiana) in 1964. In this design, the gravel-pack screen would act as a barrier to prevent proppant flow back. Backed by the support of the gravel-pack, the proppant interacts with the formation, creating an effective barrier that prevents sand production and increases effective wellbore radius (Ellis, 1998).

2.6.4 High Rate Water Pack

It is also possible to pack the perforations at a pressure higher than the fracture pressure, in which it is called a “High Rate Water Pack” (HRWP), which may be characterized as a sort of a hybrid between the conventional gravel pack and the frac-pack. The high pressure will guarantee proper packing of the perforations, but at the same time the pressure is not sufficiently high to cause any more than minimal fracture growth. The HRWP is not a very multifaceted operation; however it does require high pump rates and volumes of gravel pack fluid owing to the high leak-off into the fractures.

2.7 Sieve Analysis

A sieve analysis is a laboratory routine performed on a formation sand sample for the selection of the proper-sized gravel-pack sand. A sieve analysis consists of placing a formation sample at the top of a series of screens that have progressively smaller mesh sizes downwards in the sieve stack. Sieve analysis serves as a quality control measure during gravel packing operations. By regularly sampling and analyzing the gravel size distribution, engineers can ensure that the gravel pack meets the design specifications and performance requirements. The results of sieve analysis are usually reported as a semi-log plot of cumulative weight of formation materials retained versus grain size.

Sieving can be performed either wet or dry. In dry sieving (the most common technique), the sample is prepared by removing the fines (i.e. clays) and drying the sample in an oven. Wet sieving is used when the formation sample has extremely small grain sizes. In wet sieving, water is poured over the sample while sieving to ensure that the particles do not cling together.

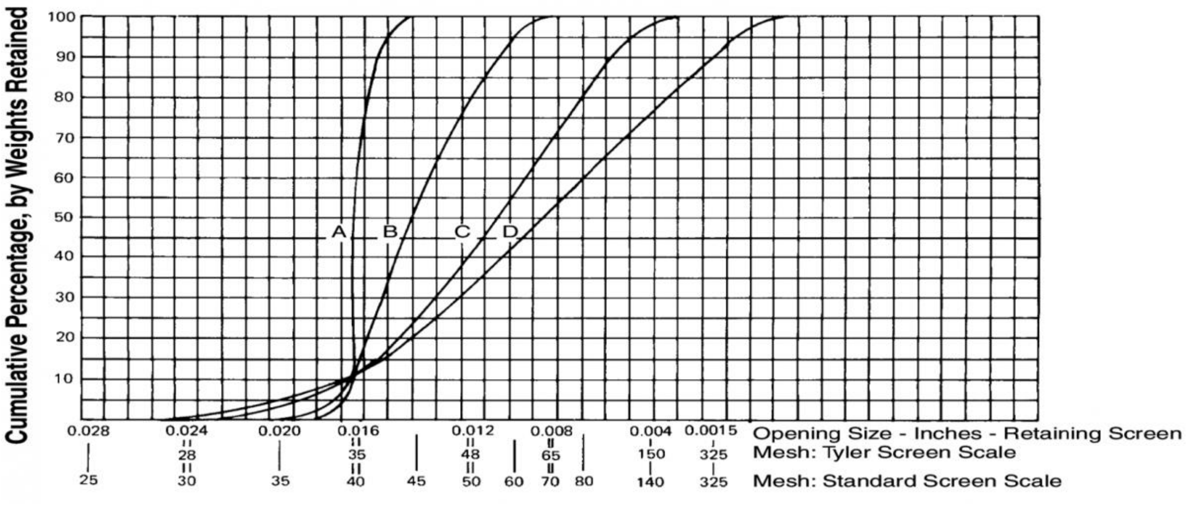

Figure 2.3: A typical sand distribution plot from sieve analysis
Source: Gurley (1977)

2.8 Gravel-Pack Screens

A gravel-pack screen or well control screen is a metal filter assembly used to support and retain the sand placed during gravel pack operations. A range of sizes and screen configurations is available to suit the characteristics of the wellbore, production fluid and the formation sand. The purpose of the gravel-pack screen is to create an annulus between the screen and the casing/open hole and to hold the gravel in place during production and to maintain open access within the aquifer ensuring that thorough development of the well is not impeded by the production of sand. They are designed with small openings that allow hydrocarbons to flow through while blocking the passage of sand and other particulates.

One of the most important items in the successful design of a well finished with a natural filter pack is the proper selection of slot opening in relation to the sizes of aquifer materials. The filter pack must be many times more permeable than the aquifer material, but the filter pack must not be coarse enough to allow the fine particles of the aquifer material to continue to wash through (Terzaghi, 1951).

2.9 Types of Sand Screens

Sand screens are an essential component of sand control systems in oil and gas wells, designed to prevent the production of formation sand while allowing hydrocarbons to flow freely. There are various types of sand screens, each suited to specific well conditions and sand control requirements. Here are the most common types:

2.9.1 Wire-Wrapped Screens

Wire-wrapped screens offer another alternative for retaining the gravel in an annular ring between the screen and the formation. Wire-wrapped screens consist of a perforated base pipe wrapped with a continuous wire that forms a precise gap (the screen opening). The wire is wound in a keystone shape, allowing for controlled filtration.

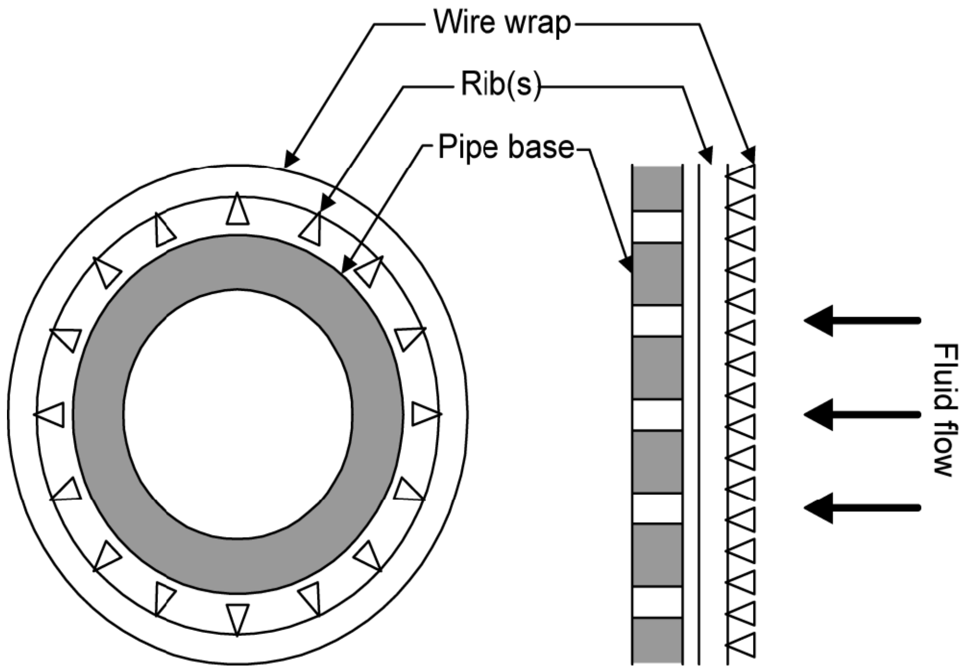

Figure 2.4: Wire-wrapped screen
Source: Sparlin (1974)

2.9.2 Slotted Liners

Slotted liners are pipes with longitudinal slots cut into them. The size and density of the slots can be customized based on the expected sand size and they are suitable for wells where the sand production is minimal or where a less expensive solution is needed.

2.9.3 Pre-packed Screens

Prepacked screens are a modification of wire-wrapped screens; they actually represent a modular gravel pack. They consist of a standard screen assembly with a layer of resin-coated gravel (consolidated) placed around it that is contained in an annular ring supported by a second screen (dual-screen prepack) or outer shroud (single-screen prepack). The gravel layer acts as an additional filtration medium.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials and Tools used

i. Integrated Production Modeling 7.5 (IPM) software – PROSPER
ii. Oil well data
iii. Well test and completion data
iv. Excel Software to manage the collected and simulated data.

3.1.1 Data Gathering

In this section, the methodology used reflects a systematic and deliberate approach to formulate and design gravel packing and sand screens in vertical oil wells for sand production control in the Niger Delta. Data variables are obtained from two (2) classified oil producing wells in the Niger Delta and it comprises of oil well data and well completion data.

3.1.2 Oil Well Data

The common well flowing data used in this simulation include:

i. Solution GOR
ii. Oil gravity
iii. Gas gravity
iv. Water salinity
v. Drainage area
vi. Reservoir Permeability

vii. Reservoir Temperature

3.1.3 Well Completion Data

Some of the well completion data which will be used to model the well using PROSPER include:

i. Gravel Packing permeability
ii. Perforation diameter
iii. Slot density
iv. Gravel pack length
v. Perforation Interval
vi. Perforation Efficiency

3.2 Research Methodology

The methodology that is used in this research involves the use of both analytical and design-based approach to evaluate gravel pack and sand screens in vertical wells in the Niger Delta. This approach include collection of data, then performing simulations using PROSPER software.

3.2.1 Data Software

PROSPER stands for Production and System Performance analysis software. It's a software package used in the oil and gas industry for the design and analysis of various components within production systems, including wells, pipelines, and surface facilities. The software allows engineers to simulate and optimize production performance, forecast production rates, analyze system behavior under different operating conditions, and evaluate the economic viability of oil and gas projects. Due to its fluid flowing modelling capability, it can be used to understand how sand control measures like screens or gravel packs affect pressure distribution and hydrocarbon production within the system. Also, PROSPER allows for sensitivity analysis, where users can assess how changes in parameters such as reservoir properties, well design, or sand control methods impact production performance. This helps in identifying the most effective sand control solutions for specific reservoir conditions.

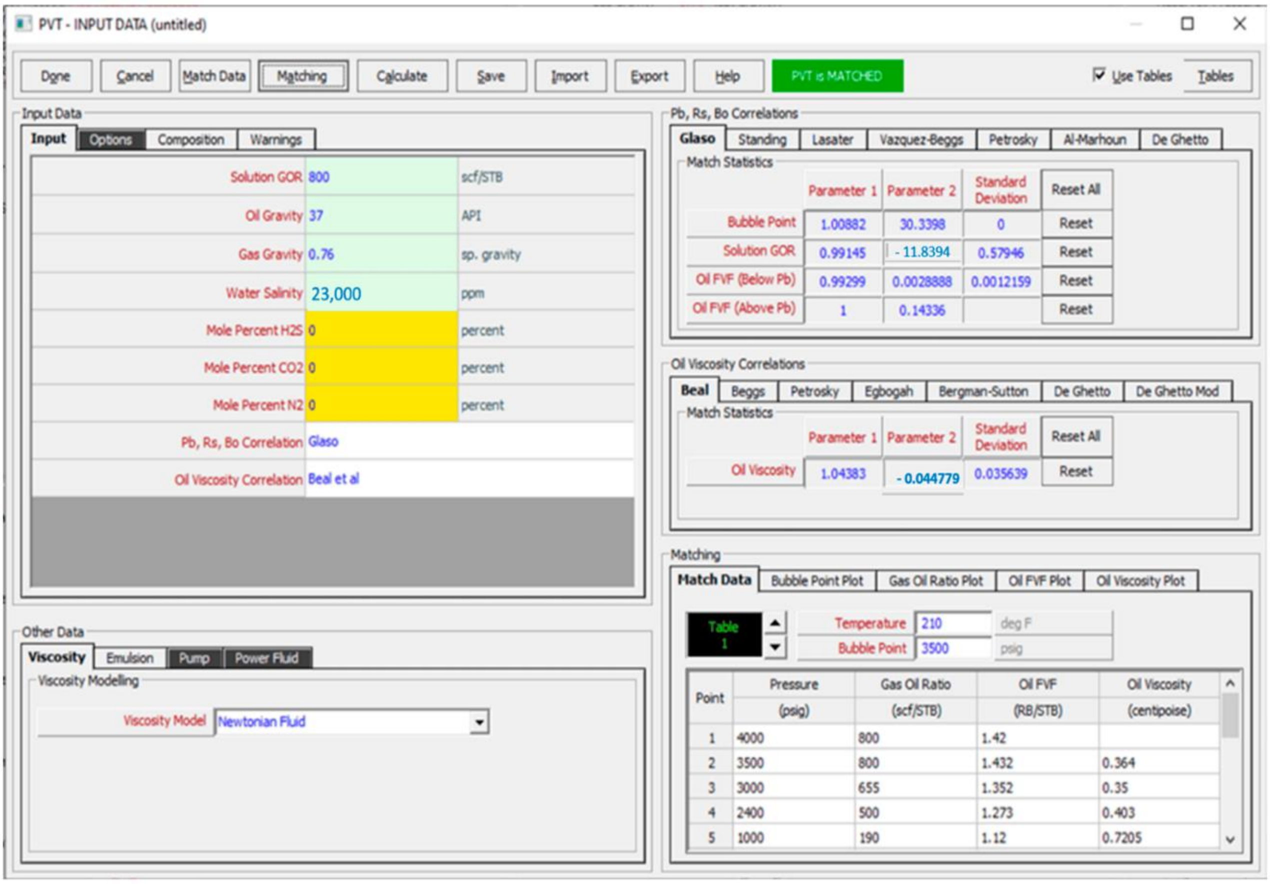

Figure 3.1 PROSPER Interface (Input Window for PVT Parameters)

3.5 WELL 1 Data

Table 3.1 through Table 3.5 shows full details of fluid and well data used for the simulations of the natural flowing case.

Table 3.1: Parameters and values for PVT data

Parameter	Value
Solution GOR	400scf/stb
Oil Gravity	40API(Air = 1)
Gas Gravity	0.8
Water Salinity	70000PPM
Impurities	None

Table 3.2: Values for deviation survey

Measured Depth (ft)	Value
0	0
8500	8500

Table 3.3: Values for downhole equipment

Equipment Type	Measured Depth (ft)	Internal Diameter	Roughness(in)	Rate Multiplier
Xmas Tree	0	N/A	N/A	N/A
Casing	8500	10.75	0.0016	1
Tubing	8000	3.96	0.0016	1

Table 3.4: Values for static geothermal gradient

Measured Depth (ft)	Static Temperature (°F)
0	60
8500	250

The overall heat transfer coefficient is 7btu/h/ft^2/F, which is the composite number that captures different heat transfer mechanisms taking place.

Average heat capacities:

i. Oil – 0.53 BTU/lb/F

ii. Gas – 0.51 BTU/lb/F

iii. Water – 1 BTU/lb/F

Table 3.5: Parameters and values for reservoir inputs

Parameter	Value
Static Reservoir Pressure	3500psig
Reservoir Temperature	250°F
Water Cut	0%
Total GOR	400scf/stb
Compaction Permeability Reduction model	No
Relative Permeability	No
Reservoir Thickness (True Strategic Thickness)	110ft
Reservoir Permeability	170mD
Drainage Area	340acres
Dietz shape factor	31.6
Wellbore radius (drill bit radius)	0.435ft
Mechanical skin	+1
Top Node pressure 250psig	250psig

3.6 WELL 2 Data

Tables 3.6 through 3.10 shows full details of fluid and well data used for the simulations of the natural flowing case.

Table 3.6: Parameters and values for PVT data

Parameter	Value
Solution GOR	350scf/stb
Oil Gravity	30API
Gas Gravity	0.75
Water Salinity	30000PPM
Impurities	None

Table 3.7: Values for deviation survey

Measured Depth (ft)	Value
0	0
6000	6000

Table 3.8: Values for downhole equipment

Equipment Type	Measured Depth (ft)	Internal Diameter	Roughness(in)	Rate Multiplier
Xmas Tree	0	N/A	N/A	N/A
Casing	6000	9.625	0.0014	1
Tubing	5500	3.92	0.0014	1

Table 3.9: Values for static geothermal gradient

Measured Depth (ft)	Static Temperature (°F)
0	60
6000	200

The overall heat transfer coefficient is 8btu/h/ft^2/F

Table 3.10: Parameters and values for reservoir input

Parameter	Value
Static Reservoir Pressure	3000psig
Reservoir Temperature	200°F
Water Cut	0%
Total GOR	350scf/stb
Compaction Permeability Reduction model	No
Relative Permeability	No
Reservoir Thickness (True Strategic Thickness)	100ft
Reservoir Permeability	150mD
Drainage Area	320acres
Dietz shape factor	31.6
Wellbore radius (drill bit radius)	0.375ft
Mechanical skin	2
Top Node pressure 250psig	250psig

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Naturally Flowing Oil Wells Results

Well completion type used in this simulation was open hole. There was no sand control method used. There was no artificial lift method in use and reservoir model used was Darcy/Enter skin by hand.

4.1.1 Well 1 Results

The results obtained using the data provided in Table 3.1 through Table 3.5 are provided below:

i. Production Rate: Oil production rate is the rate per unit of time at which oil is produced in a well. It is measure of the volume of oil extracted from a well or reservoir and it is usually reported in barrels per day. Similarly, Gas production rate is the rate per unit time in million standard cubic feet per day (MMscf/day) or thousand standard cubic feet per day (Mscf/day). The oil produced in this naturally flowing well was 15115.8 STB/day and rate of gas produced was 6.046 MMscf/day.

ii. Absolute Open Hole (AOF): This is the maximum rate that a well can produce at the lowest possible bottom-hole pressure. The AOF for this well was 89400.6 STB/day.

iii. Pressure Drop (dP) due to Sand Control: Pressure drop due to sand control was 0 because sand control method was used.

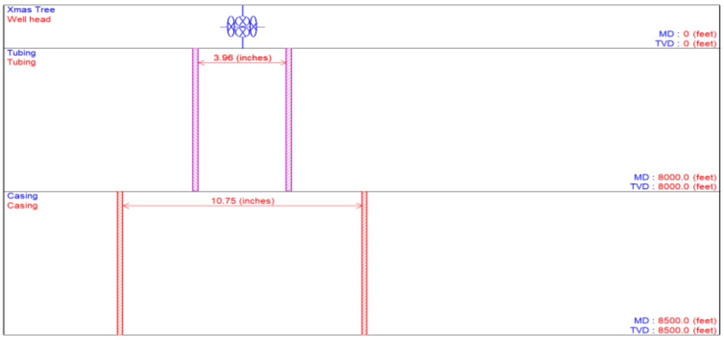

Figure 4.1: Diagram of wellbore 1

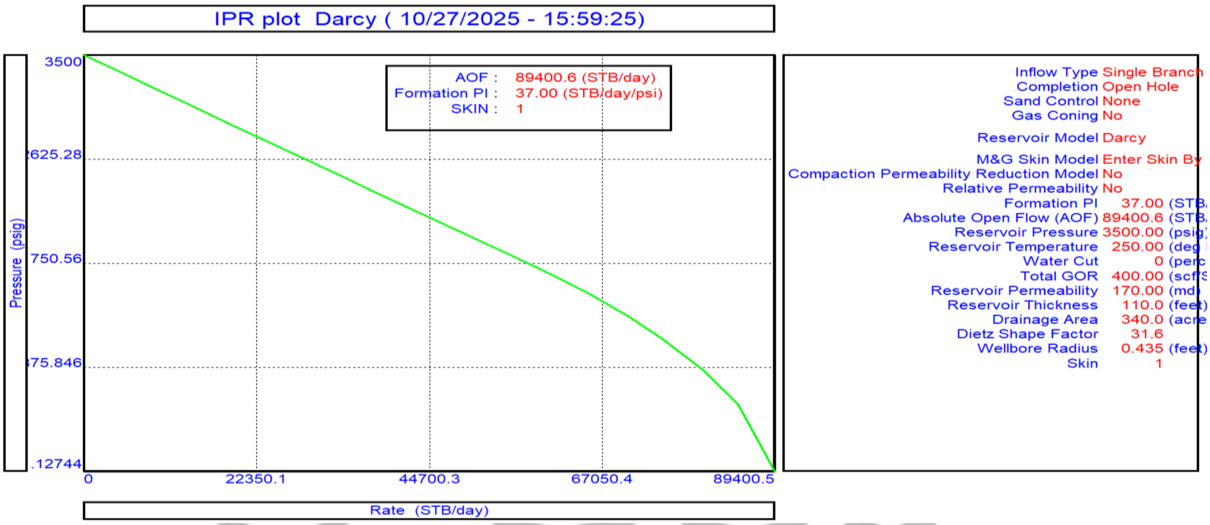

Figure 4.2 Inflow performance relationship (IPR) curve of well 1

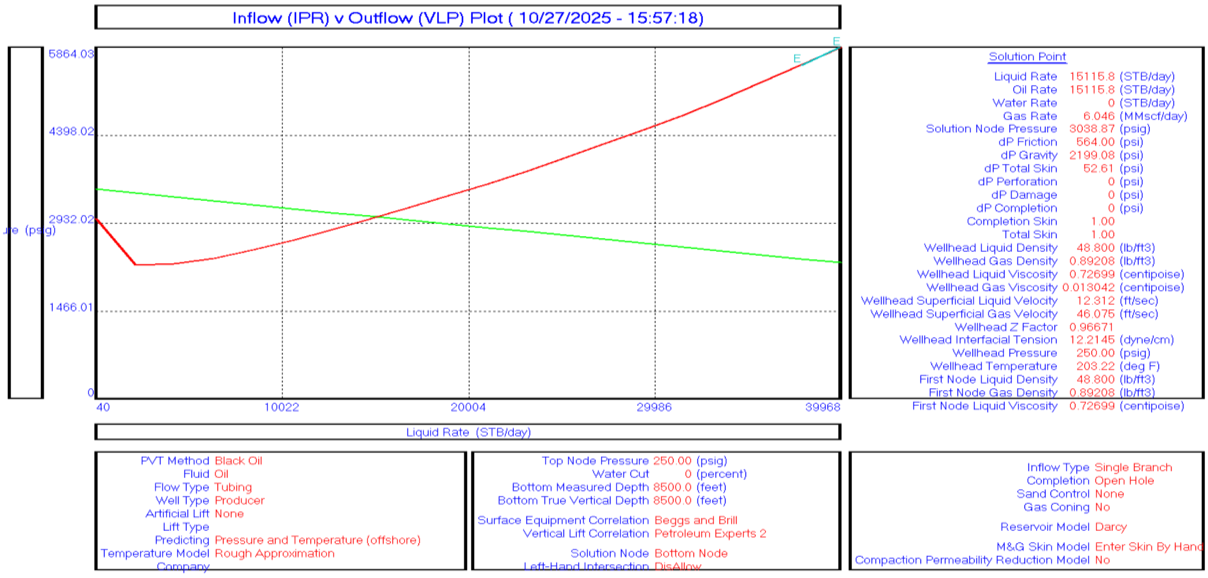

Figure 4.3 Inflow vs outflow curve of well 1

4.1.2 Well 2 Results

The results obtained using the data provided in Tables 3.1 through 3.5 are provided below:

i. Production rate: The oil produced in this naturally flowing well was 8828.7 STB/day and gas produced was 3.090MMscf/day.

ii. Absolute Open Hole (AOF): The AOF for this well was 16160.4 STB/day.

iii. Pressure Drop (dP) due to Sand Control: Pressure drop due to sand control was 0 because no gravel packing method was used.

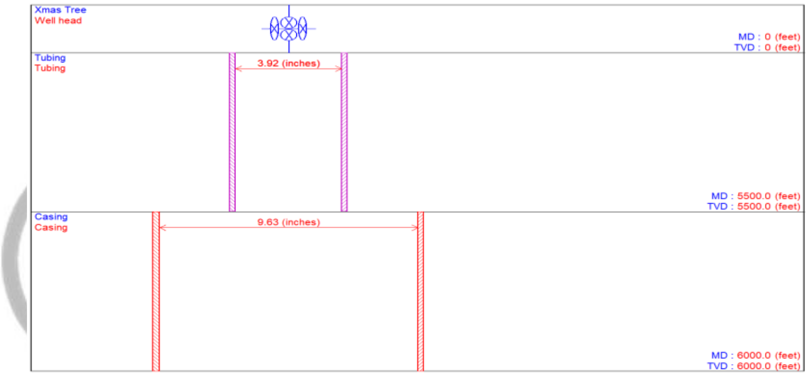

Figure 4.4 Diagram of wellbore 2

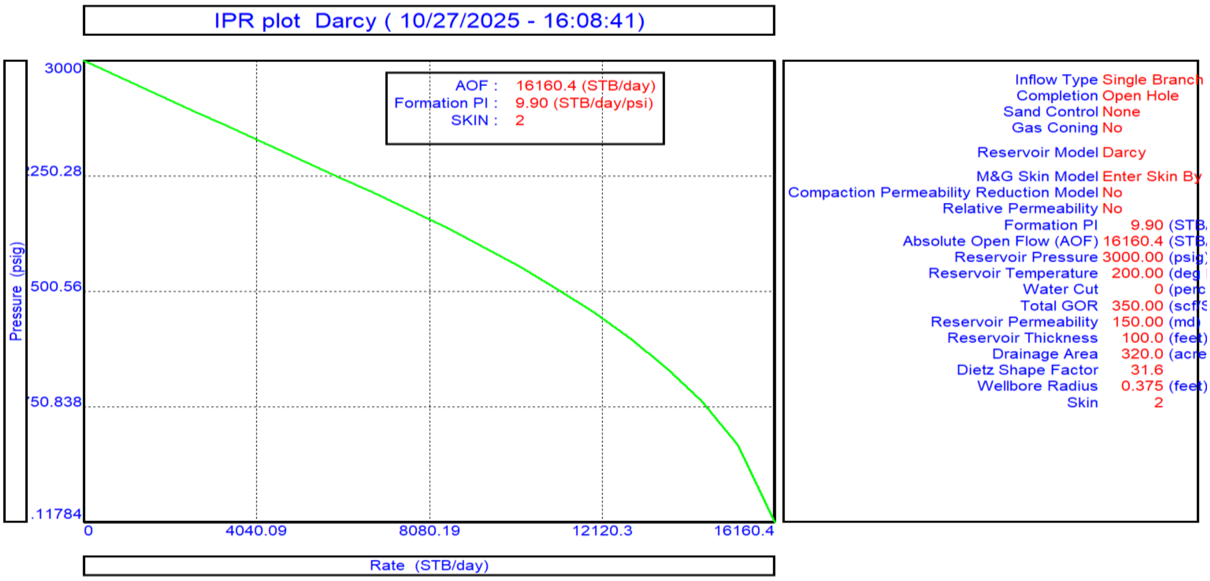

Figure 4.5 Inflow performance relationship (IPR) curve of well 2

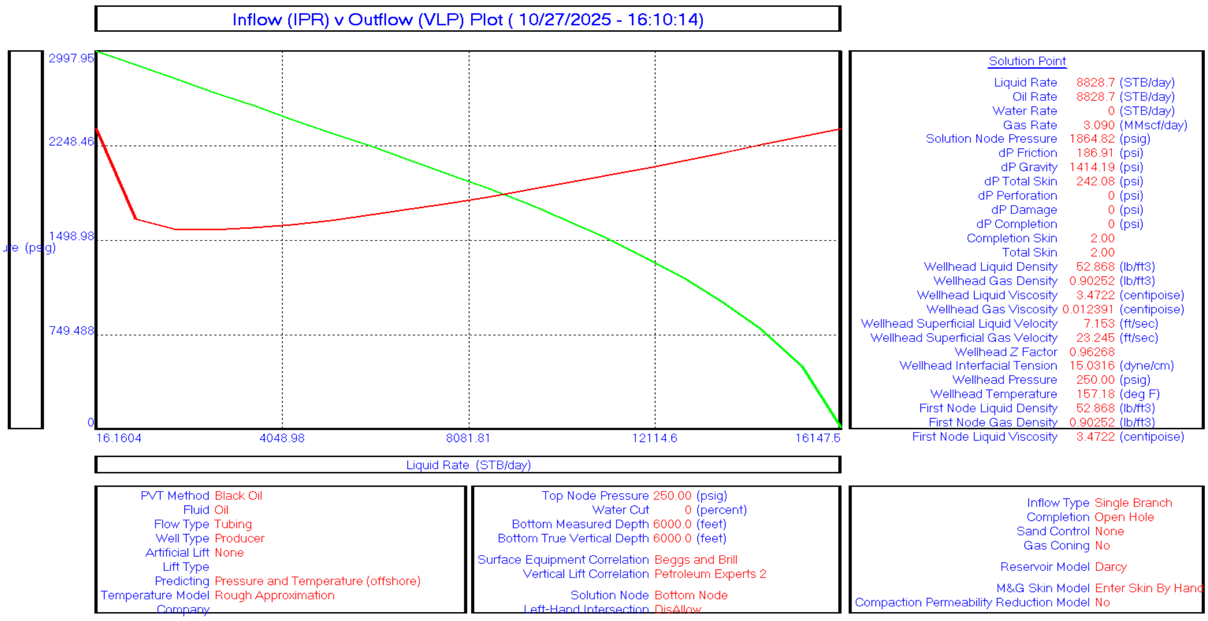

Figure 4.6 Inflow vs outflow curve of well 2

4.1.3 Gravel Pack

The data used for simulate both wells using gravel pack as sand control technique:

Table 4.1: Parameters and values for gravel pack simulation

Parameter	Value
Gravel Permeability	35000md
Gravel Pack Length	2in
Perforation Diameter	1in
Production Interval	100ft
Beta factor	Calculated
Perforation Efficiency	50%
DP Gravel Pack calculation method	Single-phase

i. Gravel Pack Results

Well completion type used in this simulation was open hole. The sand control method used was Gravel Packing. There was no artificial lift method in use and reservoir model used was Darcy/Enter skin by hand. The results obtained using gravel pack data in the tables above are stated below:

i. Production Rate: The oil produced in this gravel packed well for well 1 was 15114.9STB/day and 8827.7STB/day for well 2. Also, gas produced in well1 was 6.046MMscf/day and 3.090MMscf/day for well 2.

ii. Absolute Open Hole (AOF): The AOF for well1 was 89389.1STB/day and 16160.0STB/day for well 2.

iii. Pressure Drop (dP) due to Sand Control: Pressure drop due to sand control in well1 was 0.1092 and 0.21624psi for well 2.

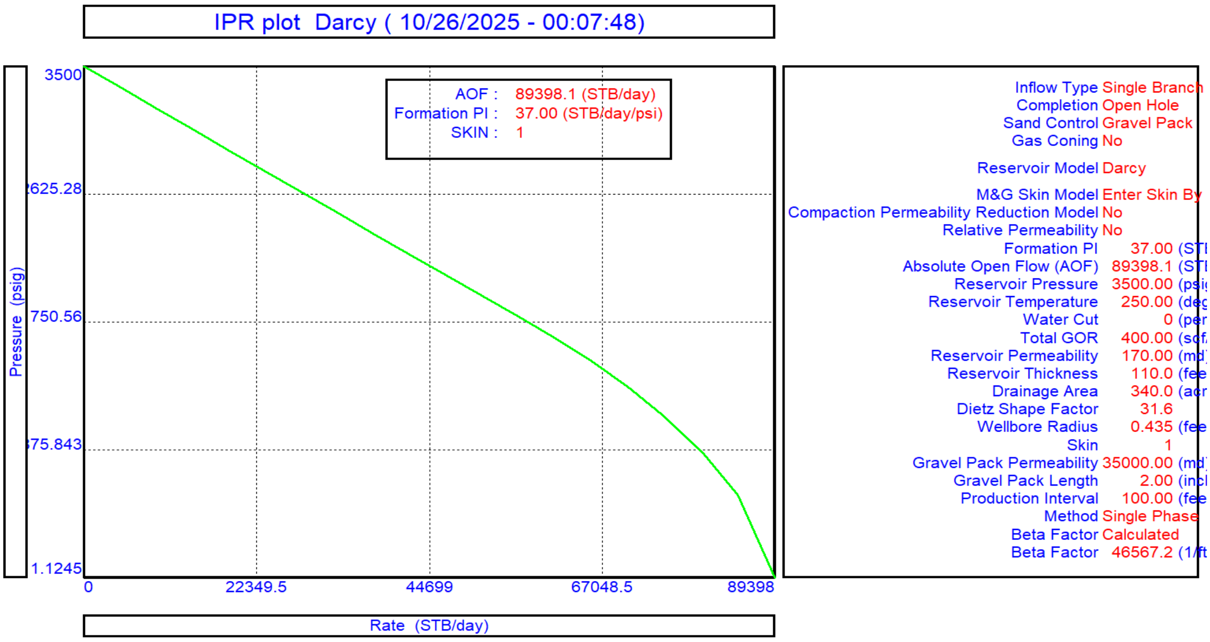

Figure 4.7: IPR curve for a gravel packed well 1

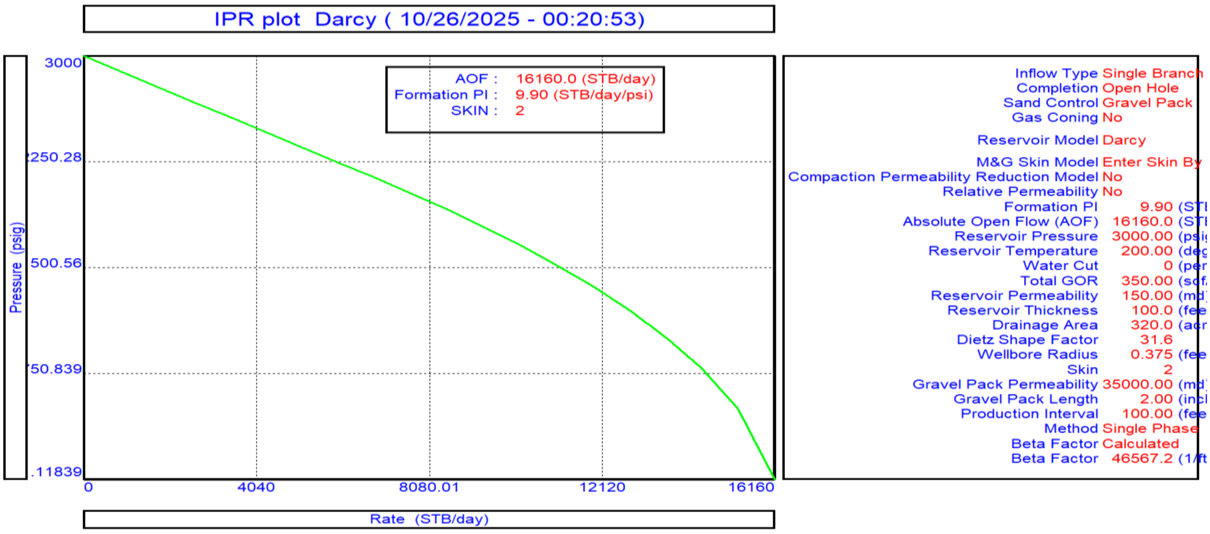

Figure 4.8: IPR curve for a gravel packed well 2

4.1.4 Frac-Pack Well Data and Results

i. Fracture Data

Table 4.2: Parameters and values for Frac and Pack Simulation

Parameter	Value
Time	2 days
Reservoir Porosity	0.3
Fracture Height	100ft
Fracture Half-Length	35ft
Dimensionless Fracture Conductivity	4500
Fracture Face Skin	2

ii. Fracture Packed Results

The reservoir model used was hydraulic fracturing and the following results were obtained for both wells:

i. Production Rate: The oil produced in this fracture packed well for well 1 was 16666.0 STB/day and 11809.2 STB/day for well 2. Also, gas produced in well1 was 6.666 MMscf/day and 4.133 MMscf/day for well 2.

ii. Absolute Open Hole (AOF): The AOF for well 1 was 140306.6STB/day and 25905.7 STB/day for well 2.

It is worthy of note that the Frac-Pack method comprises of a gravel packed well with a hydraulically fractured reservoir model.

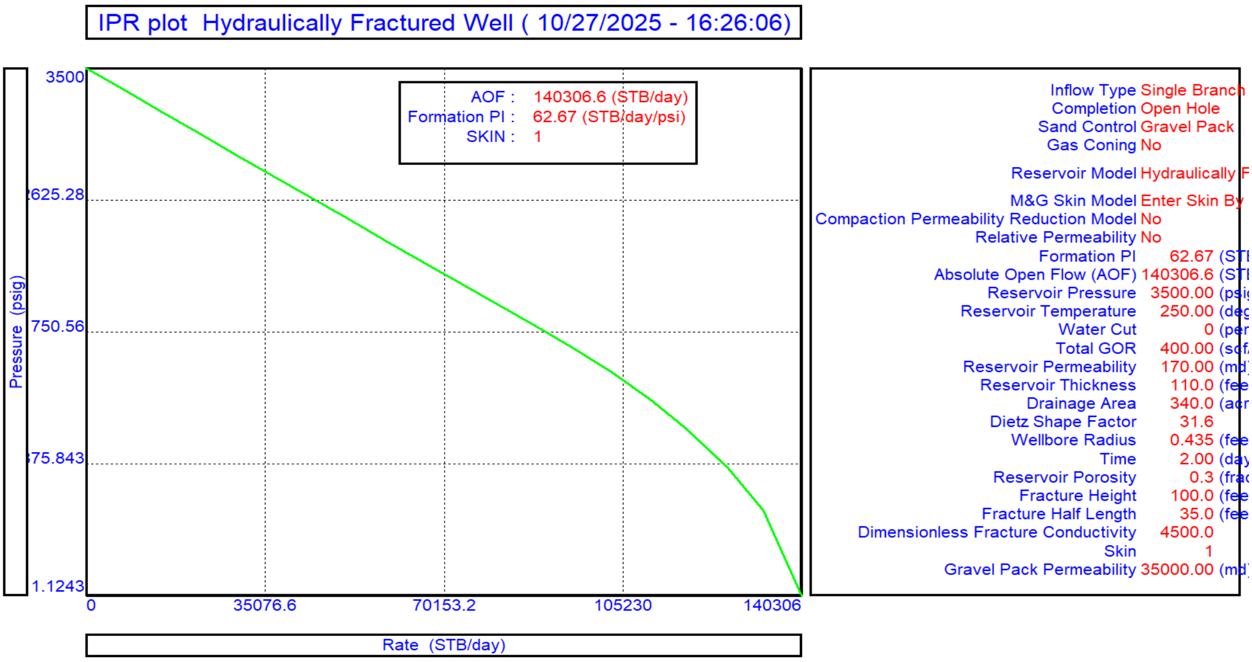

Figure 4.9: IPR curve for well 1 after frac-pack

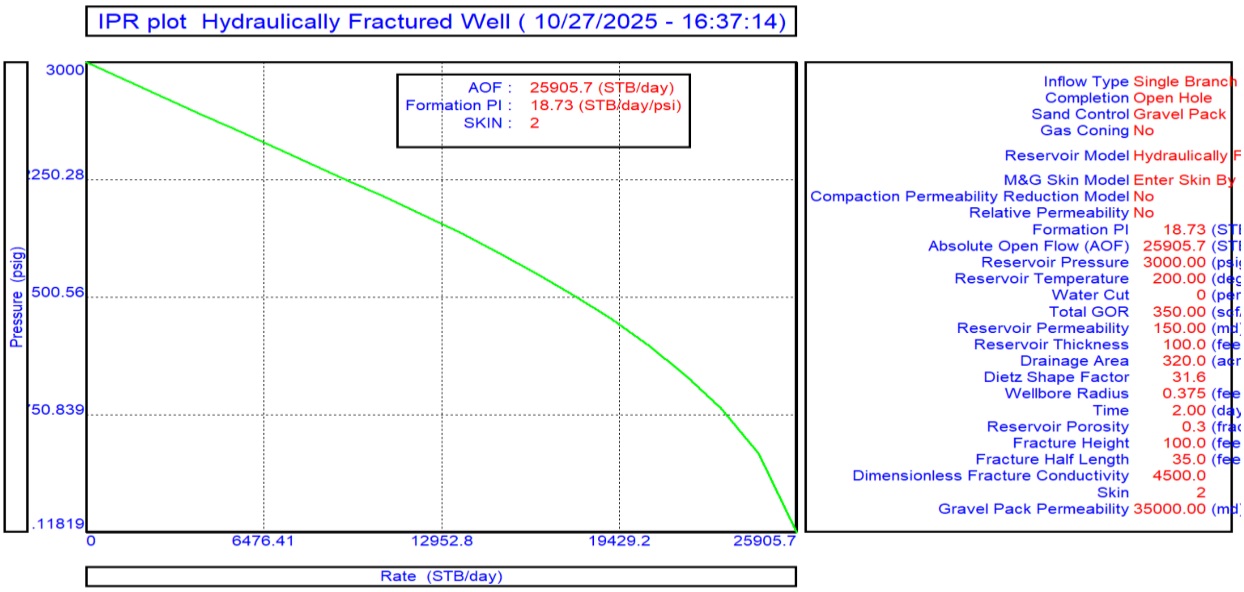

Figure 4.10: IPR curve for well 2 after frac-pack

4.1.5 Wire – Wrapped Screen

Table 4.3: Parameters and values for wire-wrapped-screen simulation

Parameter	Value
Screen outer radius	0.33
Screen Permeability	50000
Linear Outside Turbulence factor	Calculated

i. Wire-wrapped Screen Well Results

Well completion type used in this simulation was open hole. The sand control method used was Wire-Wrapped Screen. There was no artificial lift method in use and reservoir model used was Darcy/Enter skin by hand. The results obtained using the wire-wrapped well data in the tables above are stated below:

i. Production Rate: The oil produced in this gravel packed well for well 1 was 15115.4 STB/day and 8828.5STB/day for well 2. Also, gas produced in well1 was 6.046MMscf/day and 3.090MMscf/day for well 2.

ii. Absolute Open Hole (AOF): The AOF for well1 was 89399.5 STB/day and 16160.3STB/day for well 2.

iii. Pressure Drop (dP) due to Sand Control: Pressure drop due to sand control in well 1 was 0.049394 and 0.043375 psi for well 2.

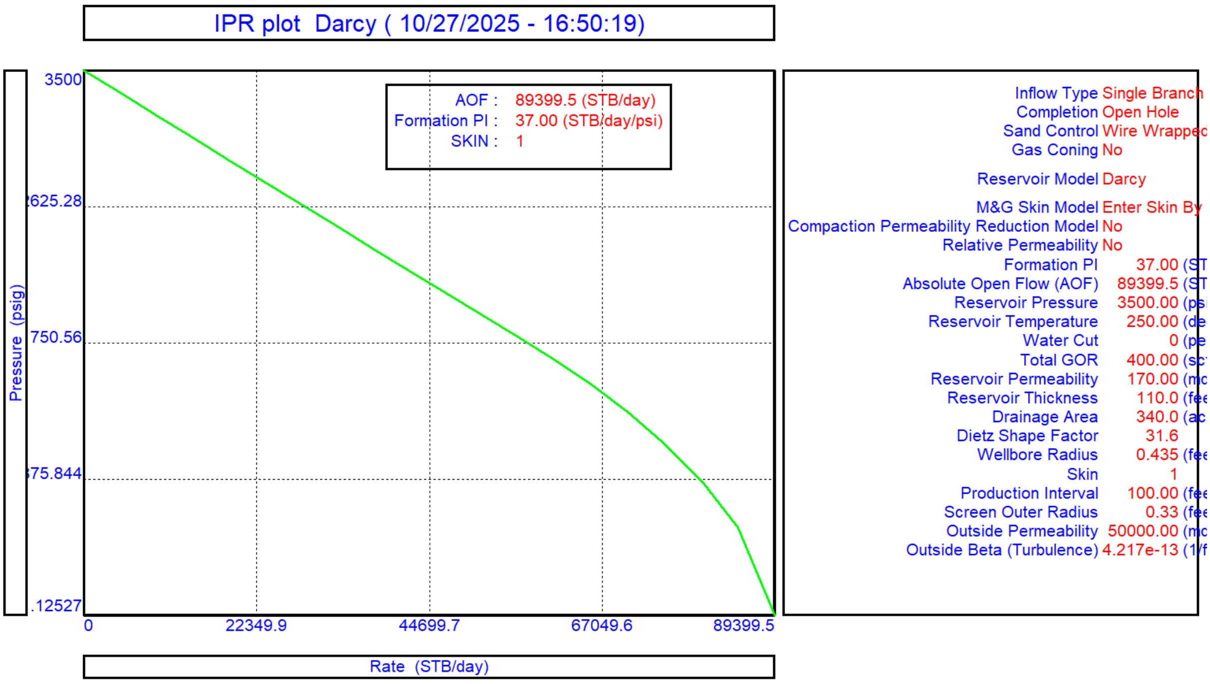

Figure 4.11: IPR curve for well 1 after wire-wrapping

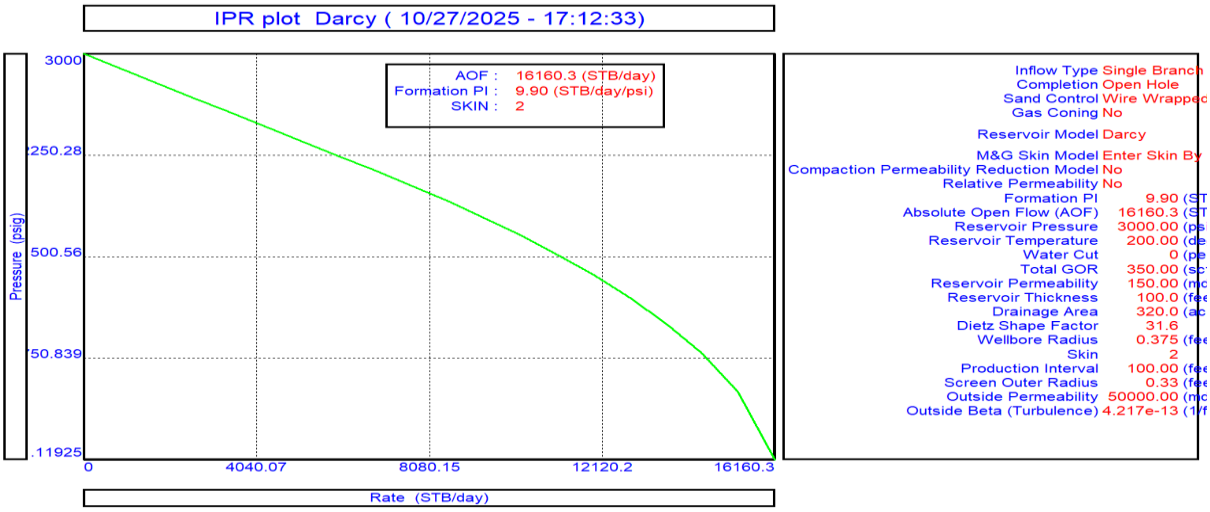

Figure 4.12: IPR curve for well 2 after wire-wrapping

4.1.6 Pre-Packed Screen

Table 4.4: Parameters and values for pre-packed screen

Parameter	Value
Screen inner radius	0.3ft
Screen Outer radius	0.33ft
Screen Turbulence factor	Calculated
Screen Outside Permeability	50000Md
Screen Outside Turbulence factor	Calculated
Perforation Interval	100ft
Slot width	0.02

i. Pre-Packed Screen Results

Well completion type used in this simulation was open hole. The sand control method used was Pre-Packed Screen. There was no artificial lift method in use and reservoir model used was Darcy/Enter skin by hand. The results obtained using the Pre-Packed Screen data in the table above are stated below:

i. Production rate: The oil produced in this gravel packed well for well 1 was 15115.2 STB/day and 8828.3STB/day for well 2. Also, gas produced in well1 was 6.046MMscf/day and 3.090MMscf/day for well 2.

ii. Absolute Open Hole (AOF): The AOF for well1 was 89399.1 STB/day and 16160.3STB/day for well 2.

iii. Pressure Drop (dP) due to Sand Control: Pressure drop due to sand control in well 1 was 0.066854 psi and 0.0759 psi for well 2.

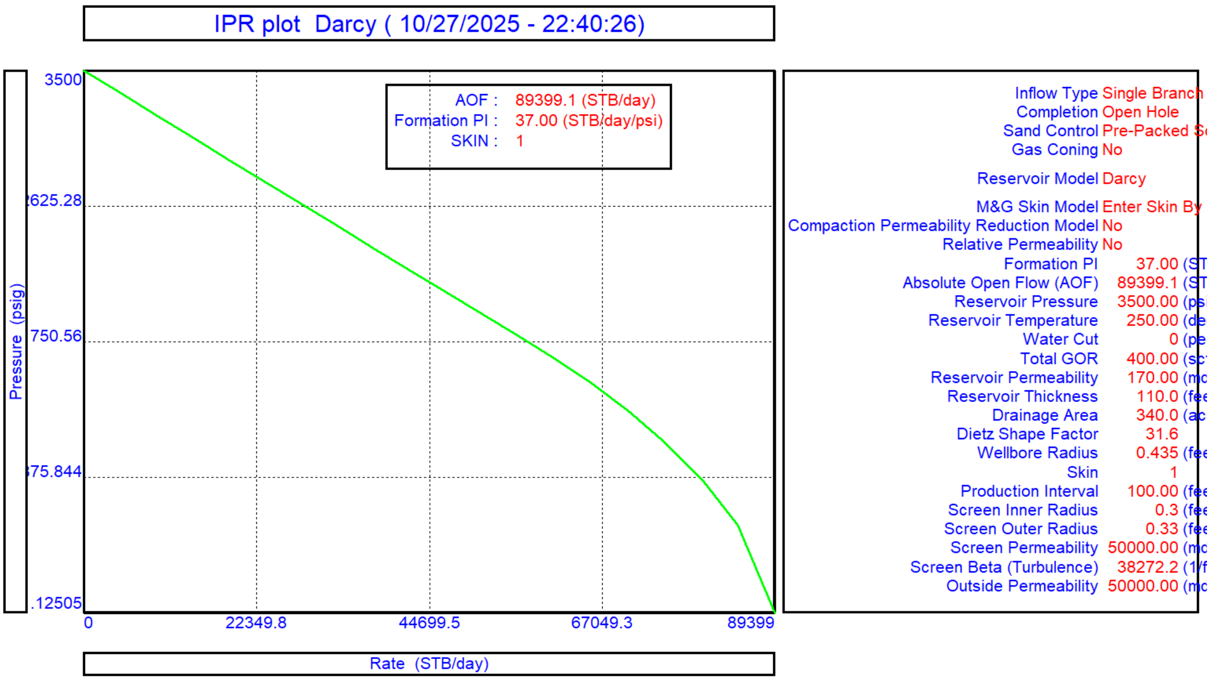

Figure 4.13: IPR curve for well 1 using pre-packed screen

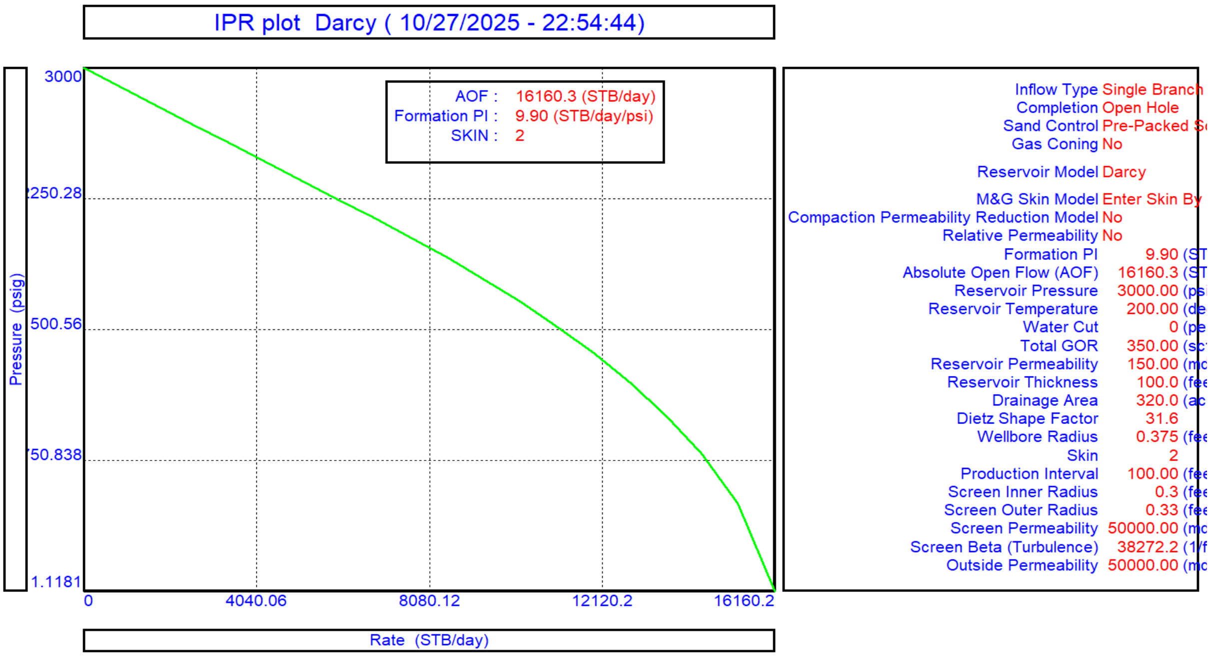

Figure 4.14: IPR curve for well 2 using pre-packed screen

4.1.7 Slotted Liners

Table 4.5 Parameters and values for slotted liner well

Parameter	Value
Linear inner radius	0.3ft
Linear Outer radius	0.35ft
Slot height	4in
Slot width	0.01in
Slot density	5 slots/ft
Outer screen thickness	-
Outside Permeability	50000Md
Outside turbulence factor	0
Perforation Interval	100ft

i. Slotted Liner Results

Well completion type used in this simulation was open hole. The sand control method used was Slotted Liner. There was no artificial lift method in use and reservoir model used was Darcy/Enter skin by hand. The results obtained using the slotted liner well data in the tables above are stated below:

i. Production Rate: The oil produced in this gravel packed well for well 1 was 2877.5STB/day and 4008.6STB/day for well 2. Also, gas produced in well1 was 1.151MMscf/day and 0.92038MMscf/day for well 2.

ii. Absolute Open Hole (AOF): The AOF for well1 was 4844.2STB/day and 2629.6STB/day for well 2.

iii. Pressure Drop (dP) due to Sand Control: Pressure drop due to sand control in well 1 was 1185.65psi and 1080.06 psi for well 2.

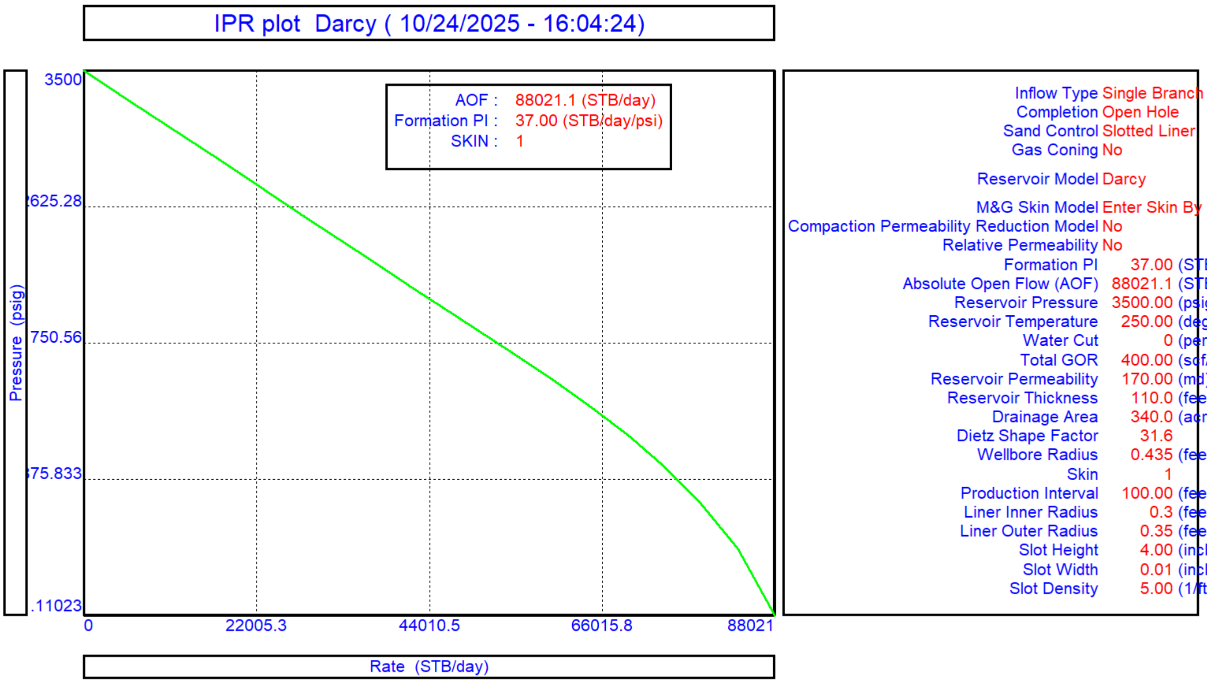

Figure 4.15: IPR curve for well 1 using slotted liner

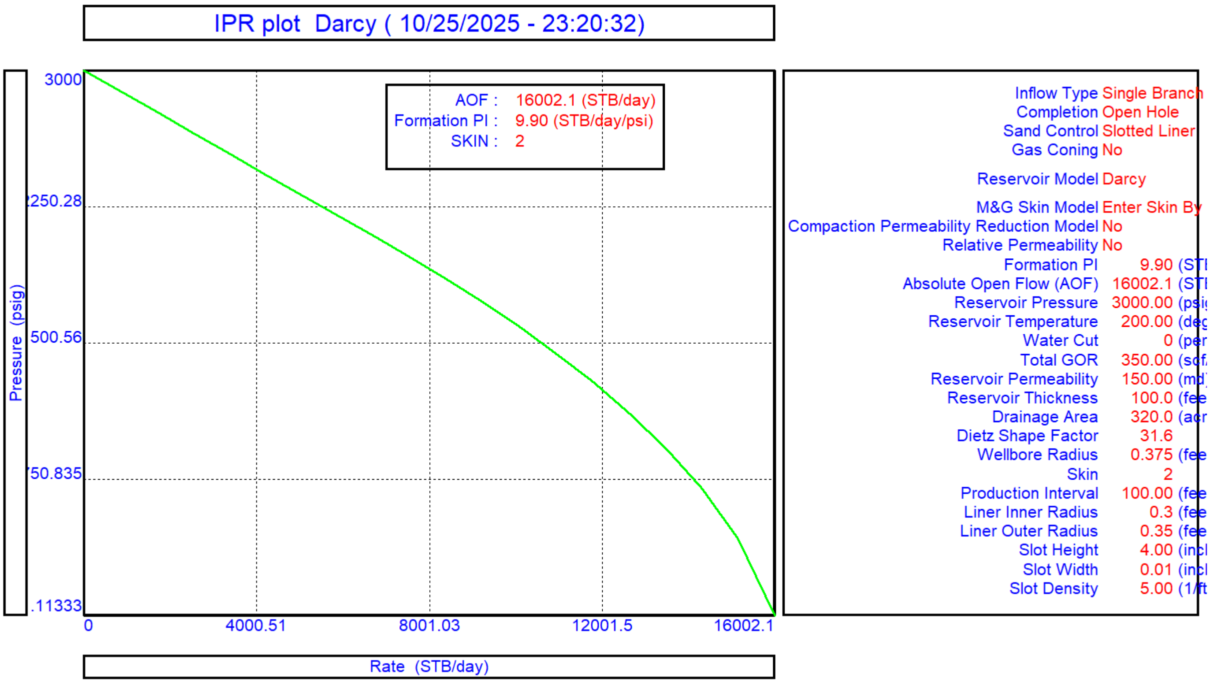

Figure 4.16: IPR curve for well 2 using slotted liner

4.1.8 Comparison of Results for the Various Completion methods

Table 4.6: Tabular comparison of results obtained from well 1 simulations

Parameters	Absolute Open Flow (STB/Day)	Oil Flow Rates (STB/Day)	Gas Flow Rates (Mscf/Day)	Skin	Pressure Drop due to Sand Control (psi)
Naturally Flowing Oil well	89400.6	15115.8	6046	1	0
Gravel Packed well	89389.1	15114.9	6046	1	0.11
Frac and Packed well	140306.6	16666	6670	1	0.126
Slotted Liner	88021.1	14773.7	5909	1	40.69
Wire-Wrapped screen	89386.9	15111.4	6045	1	0.52
Pre-Packed screen	89399.1	15115.2	6046	1	0.067

Table 4.7: Tabular comparison of results obtained from well 2 simulations

Parameters	Absolute Open Flow (STB/day)	Oil Flow rates (STB/day)	Gas Flow rates (Mscf/day)	Skin	Pressure Drop due to Sand Control (psi)
Naturally Flowing Oil well	16160.4	8828.7	3090	2	0
Gravel Packed well	16160	8827.7	3090	2	0.22
Frac and Packed well	25905.7	11809.2	4133	2	0.29
Slotted Liner	16002.1	10626.2	3719	2	94.41
Wire- Wrapped screen	16160.3	8828.5	3090	2	0.048
Pre-Packed screen	16160.3	8828.4	3090	2	0.076

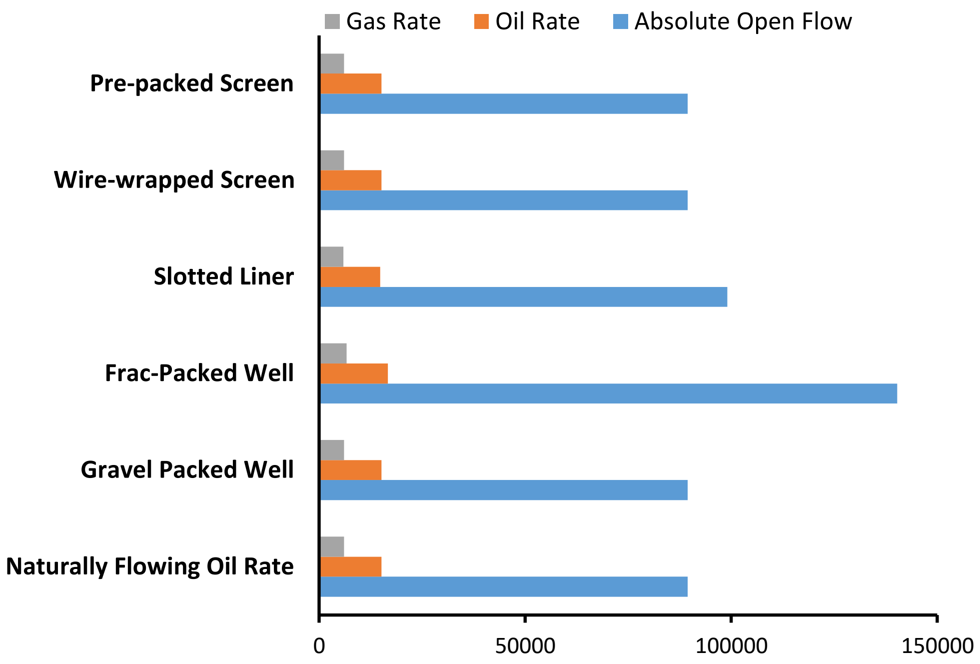

Figure 4.17: A Bar chart comparing flow rates and AOF for well 1

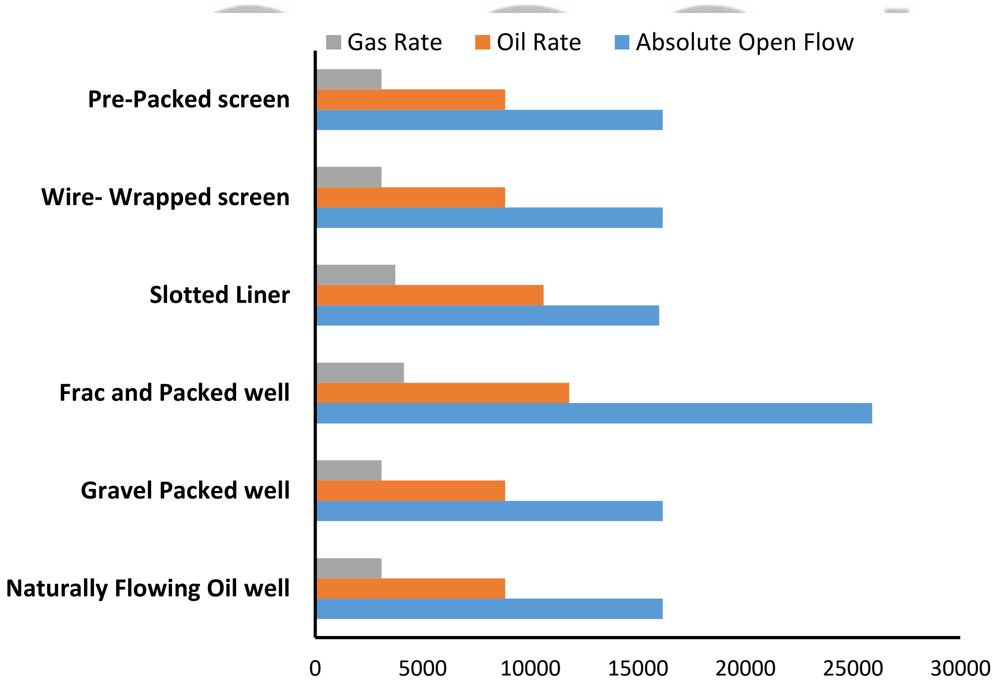

Figure 4.18: A Bar chart comparing flow rates and AOF for well 2

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The workflow uses Inflow Performance Relationship curves to analyze the effect of different sand control techniques on the performance of two (2) wells case study.

Based on this study, the following conclusions were arrived at:

i. Reservoirs with weakly cemented or unconsolidated sandstones are prone to sand production. The lack of cementation between sand grains allows them to be easily dislodged when oil or gas is extracted.

ii. Predictions with this model will aid planning capital sanding related investments such as postponement of sand control installation, recompletion schedule, drilling disposal wells, and installation (or cancellation) of capacities of sand handling facilities.

iii. Fracturing and Packing (Frac-Pack) had the biggest positive impact on the production of both wells as it involves hydraulic fracturing of the formation to improve its permeability before gravel pack placement.

iv. Among the various screen types evaluated, the pre-packed screen which combines the screen and gravel pack in one assembly consistently provided the most efficient and reliable performance under Niger Delta reservoir conditions.

5.2 Recommendations

The following recommendations are presented:

i. Thick-Wall-Cylinder (TWC) test should be carried out to have a more accurate measure of the formation strength.

ii. Gravel packing technique for sand control should be preferred to the sand consolidation technique for sand control in oil wells in the Niger-Delta because gravel packed wells are more durable and have better sand control effectiveness.

iii. Future study should incorporate the variability of rock mechanics properties of the investigated reservoir and this topic is proposed for future research.

5.3 Contribution to Knowledge

This project contributes to the body of knowledge by providing long-term data on the effectiveness and durability of sand control systems, informing future designs and operational practices.

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