COMPARATIVE ECONOMIC ANALYSIS OF WATERFLOOD AND DUMPFLOOD APPLICATIONS IN NIGER DELTA

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PETROLEUM ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY

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CERTIFICATION

This is to certify that this work was carried out by ORIAIFO PRECIOUS FAVOUR, Mat no. ENG1704428, of the Department of Petroleum Engineering, Faculty of Engineering, University of Benin, Benin City, Edo state Nigeria.

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DEDICATION

I would like to dedicate this work to God almighty, whose infinite love has been unconditional, exceptional and inestimable throughout my duration of stay in the University of Benin. Also, to my parents, Mr & Mrs Favour Oriaifo and my siblings (Oriaifo Bright, Oriaifo Purity, Oriaifo Excellence, Oriaifo Victory, Oriaifo Progress, Oriaifo Dominion), Colette Emekwuru, Lilian Ijeoma, Gift Chukwuka, Precious Godfrey Joseph Osas for their love and care. And also, to my concerned friends and course mates, I say a very big thank you to you all.

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I’ll like to start by acknowledging my heavenly father for his love and mercies, seeing me through all of my endeavours and granting me the grace to be here, a better me.

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My gratitude surely knows no bound.

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ABSTRACT

In the Niger-Delta region, one of the primary concerns for petroleum extraction is determining the most efficient and cost-effective method of oil recovery. This study focuses on comparing two popular techniques: waterflood and dumpflood. Using data from 2017 to 2020, we analyzed both methods in terms of their costs, production rates, and economic returns. The financial evaluations were conducted using metrics like Net Present Value (NPV) and Return on Investment (ROI). Results indicate that during the period studied, waterflood yielded a higher NPV and ROI than dumpflood. However, while waterflood appears to be the more economically viable option based on these metrics, other factors such as environmental impact, reservoir conditions, and operational challenges should also be considered when making a final decision. Further research and detailed examination of these techniques in different scenarios will provide a clearer picture of their long-term viability.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

The Niger-Delta region serves as the epicenter of petroleum activities in Nigeria, with petroleum playing a pivotal role in the country's economy ever since its discovery in Oloibiri, Bayelsa State, in 1956. According to data provided by OPEC, Nigeria ranks as the top oil producer in Africa, with a daily output of 1.98 million barrels. Remarkably, the oil sector contributes significantly to the nation's economic structure, constituting 95% of its export revenue, 70% of its government revenue, and 5.15% of its actual Gross Domestic Product (GDP) (Igwe, 2020).

A prominent challenge currently faced by the petroleum sector in the Niger-Delta revolves around the effective and efficient management of oil reservoirs to attain optimal oil recovery rates (Ossai et al., 2017). The continued exploration and extraction of oil in this region over the years have resulted in reservoir depletion and a decline in oil production rates (Haiyang et al., 2015). In instances where reservoirs lack aquifer or gas cap support, their energy levels diminish to the point of making production economically unviable. To combat the decline in reservoir energy, which is reflected in decreasing off-take, the injection of supplementary energy is imperative to maintain high well productivities (Shizawi et al., 2011).

Maintaining reservoir pressure can be achieved by introducing fluids into the reservoir, accomplished by extracting oil or gas through one wellbore while injecting gas or water through another. Water is the preferred fluid due to its ready availability, cost-effectiveness, and high specific gravity that facilitates injection. This process entails creating a flow and maintaining wellbore pressure by flooding the production structure with water. Remarkably, the water injection process accounts for approximately 80–85% of the surplus oil produced (Nwabueze and Ighalo, 2020). Two widely employed methods for pressure maintenance and enhancing reservoir sweep to improve oil recovery are Water flooding and Dump flooding (Zadravec & Brkić, n.d, 2011).

Water flooding stands out as a significant technique in oil production, responsible for nearly half of the total oil produced. It involves the injection of water into a series of designated injection wells, while hydrocarbons are extracted through production wells (Vladimir Vishnyakov, 2020). Water flooding is classified as a secondary recovery process, typically implemented when primary recovery methods are no longer effective. In the Niger Delta's offshore reservoirs, water flooding remains a traditional and economically viable secondary oil recovery approach. Additionally, flooding is employed to elevate reservoir pressure, consequently boosting oil recovery through pressure maintenance. The following factors make the procedure economical for use offshore:

1. In the majority of offshore reservoirs, there is an abundance of water.
2. It is well known that water works well as a displacement fluid for gravity-based oil recovery.
3. Water is also known to have high recovery factor.
4. Water can easily spread over oil formations.
5. The procedure is inexpensive and technologically simple.
6. When compared to other enhanced oil recovery (EOR) techniques, water-flooding has less injection issues and environmental pollution consequences (Ossai et al., 2018).

Dump-flooding represents a method wherein a high-pressure water-bearing formation naturally transfers water into a low-pressure oil reservoir within the same well (Alfanda et al., 2021). This process occurs as water displaces oil while preserving reservoir pressure, allowing water from a high-pressure layer to flow into a low-pressure oil layer through casing. Dump-flooding is currently employed primarily as a means to supplement energy before the application of water flooding, especially in regions where groundwater is scarce (Liu et al., 2020). Successful implementations of dump-flooding in the Niger Delta have demonstrated significant reductions in water injection costs and notable enhancements in oil recovery.

The injection process differs substantially between dump-flooding and conventional water flooding methods. Typically, seawater or treated water serves as the water source for conventional water injection projects. In a dump-flooding project, however, an oil formation within a well is allowed to crossflow into a water formation without bringing the water to the surface while maintaining reservoir conditions. The key advantages of dump flooding over water injection lie in its simplicity and cost-effectiveness. Compatibility issues with water quality are generally not a concern when using formation water for dump-flooding, eliminating the need for treatment before injection (Abdulhadi et al., 2019).

An inherent limitation of dump-flooding lies in the uncontrollable injection rate and pressure, which are constrained by the pressure differential between the water-bearing formation and the oil formation. Over time, as the water-bearing deposit is depleted or oil formation pressures rise, this pressure difference gradually diminishes (Abdulhadi et al., 2019).

Bordor demonstrated the utility of economic analysis in guiding research decisions regarding the Economics of Enhanced Oil Recovery (EOR) projects. His findings emphasized that economic analysis serves as a valuable tool for assessing whether fundamental limitations exist that hinder the development of practical processes (Zekri et al., 2000). An effective economic model should assess various production strategies and incorporate predictions under diverse economic scenarios, recognizing the inherent uncertainty in forecasting market trends. Such economic models, which simulate the initiation and management of real EOR projects, have been developed to provide valuable insights into their economic viability. The reservoir's properties and the expenses associated with extracting EOR oil from that reservoir are fed into the models, which produce estimates of:

1. The quantity of crude oil that will be produced from the project.
2. A price sufficient to reimburse all costs of the project and provide an adequate return on investment (ROI).
3. The timing at which reserves in the reservoir will be produced (Zekri et al., 2000).

The two types of EOR (Dump-flood and Water-flood) discussed in this study have both been implemented in the Niger-Delta, (Obibuike et al., 2022), although comparative economic analysis was not sufficiently investigated. This study intends to do a comparative economic analysis of the Niger-Delta's use of water floods and dump floods.

1.2 STATEMENT OF THE PROBLEM

To address the escalating demand for improved oil recovery and increased oil production rates, there is a growing necessity for secondary recovery techniques, particularly water-flooding and dump-flooding. This projection is founded on the assessment of oil recovery performance (Nwabueze and Ighalo, 2020). The suitability of candidate reservoirs for water-flooding necessitates a comprehensive evaluation of factors such as reservoir geometry, fluid properties, reservoir depth, lithology and rock properties, fluid saturations, reservoir uniformity, pay continuity, primary reservoir driving mechanisms, and other critical parameters (Nmegbu et al., 2017).

Dump-flooding stands out as an exceptionally cost-effective method for maximizing reservoir oil recovery. Its simplicity lies in the fact that it only requires a zone change or an additional perforation to initiate. In contrast to water injection projects, dump-flooding entails significantly lower costs and demands minimal investment. However, it is essential to acknowledge that dump-flooding has limitations, notably the lack of control over injection rate and pressure, which are constrained by the pressure differential between the water-bearing formation and the oil formation (Zadravec and Brkić, 2020).

Efficient and effective management of oil reservoirs is imperative for the success of the petroleum industry in the Niger-Delta. However, there remains a gap in the comparative economic evaluations of systems like water flooding and dump flooding, which have been employed to enhance oil recovery. This study aims to bridge this gap by conducting an economic analysis to assess the relative advantages and efficiency of these various solutions.

1.3 AIM OF THE STUDY

The aim of this project is to assess and compare the economic implications of dump flood and water flood management techniques in the Niger-Delta region, with a focus on their cost-effectiveness and long-term sustainability. The specific objectives include:

1. To conduct a comprehensive cost-benefit analysis of both dump flood and water flood methods, considering initial investment costs, maintenance expenses, and potential economic benefits.

2. To determine the NPV of both Dumpflood and Waterflood projects

3. To determine the Return on Investment

4. (ROI) on both Dumpflood and Waterflood project

1.5 SCOPE OF THE STUDY

This research project will concentrate on conducting a comparative economic analysis of the application of dump-flooding and water-flooding techniques in the Niger-Delta region. The study will encompass a time frame from 2010 to the present day and will employ a blend of both quantitative and qualitative research methods. It is important to note that the scope of the study will be confined to specific oil reservoirs within the Niger-Delta.

1.6 SIGNIFICANCE OF THE STUDY

The outcomes of this research will shed significant light on the comparative economic analysis of conventional water flooding and dump-flooding applications in the Niger Delta. The study's findings will offer valuable insights for petroleum engineers, decision-makers, and other industry stakeholders. Additionally, this research will contribute to a greater understanding of the economic merits and drawbacks associated with dump-flooding and water-flooding systems in the Niger-Delta region. Furthermore, it will enrich the body of knowledge in the field of petroleum engineering.

CHAPTER TWO

LITERATURE REVIEW

2.1 DEFINITION OF DUMP-FLOODING

Dump-flooding is an unconventional secondary recovery technique that utilizes water from a shallow water bed located above the oil-producing pay zone. In this process, the aquifer's natural pressure, combined with the weight of the hydrostatic column, generates the necessary force to drive the water into the oil formation, displacing the oil towards the production wells in the field.

Davies offers an explanation of dump-flooding as a method where a high-pressure aquifer (water-bearing reservoir) is allowed to connect with a lower-pressure oil reservoir by establishing communication between the two zones through a casing string. The relative positions of the aquifer and oil reservoir can vary, whether the aquifer is situated above or below the oil reservoir, as long as there is sufficient pressure potential to facilitate fluid transfer. In cases where the aquifer is positioned above the oil reservoir, a downhole pump may be necessary to facilitate the flow. According to Rawding et al 2018, dump-flooding refers to a technique where fluids from one geological formation are allowed to flow into another formation, thereby providing support for reservoir pressure. This involves drilling a well that penetrates both a prolific aquifer (or gas) zone and a productive oil reservoir, and under specific conditions, with a higher-pressure aquifer (or gas) zone, significant quantities of water (or gas) flow from the aquifer (or gas) into the oil reservoir.

Quttainah and Al-Hunaif (2001) further describe dump-flooding as an operation where water is injected into the recipient reservoir from a source reservoir through the same well, driven by the natural force of gravity and the pressure differential between the two reservoirs.

2.2 REVIEW OF DUMP-FLOODING

Davies developed a theory and technique for dump-flooding which permit monitoring of the fluid injection rate as well as the determination of wellbore properties of both the source zone and the injected zone. He presented the derivations of the equations describing the fluid transfer rate and a computer program to solve the equations of flow. He applied the theory to under-saturated oil reservoir and considered four cases namely;

1. Both source and injected zones of infinite size
2. Both source and injected zones of finite size
3. Infinite injected zone and finite source zone, and
4. Infinite source zone and finite injected zone.

He prepared a dump-flood chart for monitoring dump-flood rates from the output data of the computer program comprising of lines of constant source zone's productivity and injected zone's injectivity.

Rawding et al 2018, discussed the philosophy and design of an intelligent well installation in a water dump-flood well located in West Kuwait. They detailed its application in a controlled dump-flood scenario where water from the Zubair aquifer formation is directed into the Minagish Oolite oil formation. The authors referred to the work of Quttainah and Al-Hunaif (2001), who initially pioneered a well dump-flood pilot project in the Umm Gudair field. They demonstrated that dump-flooding can be expanded as a full-field water dump-flood injection strategy to support declining reservoir pressures. Their conclusion highlighted the reliability and cost-effectiveness of using intelligent completion technology and remotely controlled hydraulic Interval Control Valves for controlled dump-flooding.

Quttainah and Al-Hunaif's (2001) paper focused on studying and analyzing the long-term effects of dump-flood operations in enhancing reservoir sweep efficiency and maintaining reservoir pressure. They initiated a dump-flood pilot project from the Umm Gudair reservoir to validate the feasibility and quantify the benefits of water injection from a source aquifer into a recipient oil reservoir. The results of the project confirmed the positive impact of water injection on the recipient reservoir, leading to the conclusion that dump-flooding could be expanded into a full-field water dump-flood injection for reservoir pressure support.

Yao et al. 2018 presented a case study involving a pilot flood with five injection wells in three carbonate reservoirs located in the Onbysk oil field. They utilized a pump-aided reverse dump-flood technique and conducted feasibility studies, including laboratory core flood tests, water-flood computer simulations using a 3-D reservoir simulator, and the implementation of a 5-injection well pilot flood across three domes. Over the course of 1-1/2 years, the reverse dump-flood pilot project demonstrated the economic feasibility of water-flooding, significantly reducing setup time and capital investment. An expected oil recovery factor of approximately 22% was anticipated.

Koot and Konopczynski 2010 designed a well production system that utilizes a single well for both hydrocarbon fluid production and water dump-flooding processes. This well system features a primary wellbore connected to first and second zones containing hydrocarbon fluid and high-pressure water, respectively. A second lateral wellbore extends from the primary wellbore and communicates with the first zone. Using a remote control system and valve production tubing structure, hydrocarbon fluid flows from the first zone to the surface via the production tubing, while simultaneously allowing dump-flood water to flow from the second zone into the first. This approach increases pressure within the first zone, resulting in an enhanced hydrocarbon fluid production rate.

2.2.1 Advantages of Dump-flooding

The advantages of dump-flooding are discussed as follows;

1. The capital costs of installing a conventional water-flooding system exceed the capital costs of dump-flooding by all the costs upstream of the injection wellhead. These capital costs include items such as flow lines, transfer pumps, water gathering systems, and water treating facilities.
2. The operating costs of maintaining a conventional water-flood exceed the dump-flood operating costs by all those costs associated with equipment maintenance.
3. In remote areas where there is inadequate ground water, dump-flooding could provide the necessary injection and avoid extremely expensive drilling of water supply wells and the installation of the necessary pumping equipment to provide the desired injection rate.
4. In areas where dump-flooding is being practiced, the injection rate could be increased by converting a watered-out producing well to dump-flooding.
5. Dump-flooding is a self-regulating process; as the oil reservoir pressure rises, the rate declines and vice versa. Hence, there should be no tendency to overpressure one area or to lower the pressure in another.
6. The casing corrosion problems are reduced since the fluid transfer occurs in a closed system preventing oxygen from accelerating any corrosion tendency. (Badusha, 2015)

2.2.2 Disadvantages of dump-flooding

The disadvantages of dump-flooding are discussed as follows;

1. It is difficult to measure the quantity of water transfer from one zone of high
2. pressure to a second zone of lower pressure. In applying the techniques offered in this work, this measuring problem will be resolved.

3. The rate of fluid transfer cannot readily be controlled below the natural transfer rate without the introduction of downhole chokes.
4. With two zones open within one well, the servicing of either zone becomes more complicated, hence more expensive.
5. Circulating the hole clean would be a problem if sand or other particles were deposited from the upper zone to the lower zone.

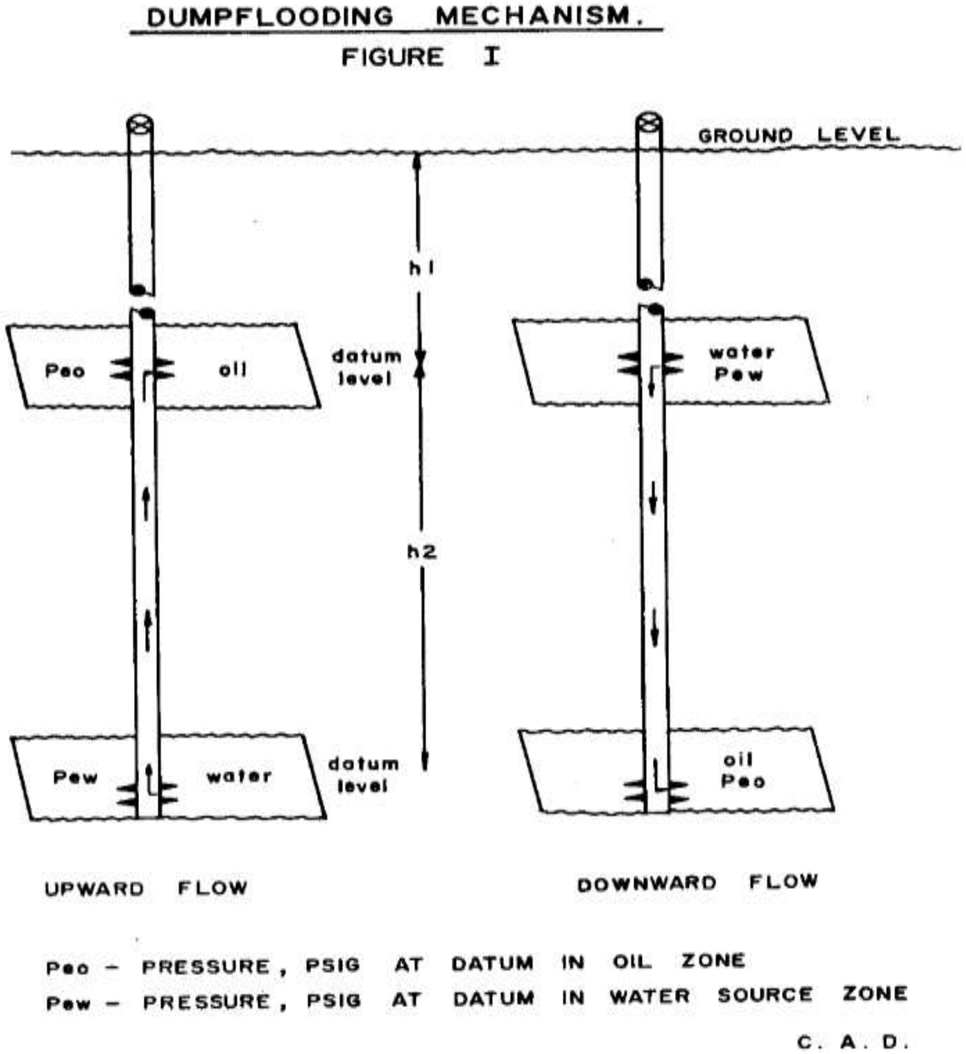

Figure 2. 1 Dump-flooding Mechanism

2.3. WATER-FLOODING

The primary purpose of water-flooding an oil reservoir is to boost the oil-production rate and ultimately enhance oil recovery (Willhite, 1986). This is achieved through a process called "voidage replacement," which involves injecting water into the reservoir to increase and maintain its pressure near its initial level. Voidage replacement essentially replaces the volume of oil, gas, and water produced from the reservoir with injected fluids. The voidage replacement ratio is a crucial metric, defined as the ratio of the barrels of injected fluid to the barrels of produced fluid from the reservoir (Kim et al., 2019).

Early in the development of oil reservoirs, it became evident that only a small percentage of the original oil in place (OOIP) could be recovered during the primary-production phase due to the natural energy depletion of the reservoirs (Craig, 1993). Dump-flooding emerged as a cost-effective method to maximize reservoir oil recovery. Its simplicity lies in the fact that it only requires a zone change or an additional perforation to initiate. In contrast to water injection projects, dump-flooding is significantly more cost-effective, demanding minimal investment. However, a key limitation of dump-flooding is its lack of control over injection rate and pressure, which is constrained by the pressure difference between the water-bearing formation and the oil formation. Over time, this pressure difference decreases as the water-bearing formation is depleted or oil formation pressures increase (Abdulhadi et al., 2019).

Since the early 1970s, in response to a rapid decline in reservoir pressure, a peripheral water-flood scheme with dump-flooding wells has been explored in various oil fields along the western coast of the Persian/Arabian Gulf, particularly utilizing overlying water-bearing layers (aquifers) as a water source for injection into dolomite and limestone oil reservoirs (AI-Siddiqi and Dawe, 1998). Simulation studies have revealed that significant volumes of oil were bypassed at the reservoir margins due to uncertainties in older completion designs and well integrity issues with existing dump-flooding wells. This led to a substantial reduction in the planned water injection volumes in certain partially depleted oil fields (AI-Siddiqi and Dawe, 1998).

Monitoring the volume of water injected into selected reservoirs has been conducted over several years through production logging campaigns (PLC), typically conducted every 3 to 4 years per well. In recent years, these logs have faced challenges such as seawater inflow during logging operations due to significant reservoir depletion, a lack of subsea and subsurface well pressure control equipment, and well integrity disturbances. Achieving total pore content replacement with the current reservoir pressure depletion in selected oil fields has not been realized over the life of the fields. Consequently, new studies and reservoir modeling have been undertaken to assess the feasibility of drilling new natural dump-flooding wells or recompleting existing wells to meet production requirements, determine voidage replacement ratios, and improve well integrity. (Craig, 1993)

Water flooding in oil reservoirs is a fundamental strategy to achieve maximum ultimate recovery from the reservoir at an optimal cost. To carry out water flooding effectively, specific considerations must be made, which are tailored to the type of reservoir and its pressure in relation to the bubble point pressure. The oil recovery process typically involves primary recovery using natural or artificial lift methods, followed by secondary recovery through water or gas injection, and ultimately, tertiary recovery or Enhanced Oil Recovery (EOR) techniques to recover the remaining oil. (Yongge L., 2015)

2.3.1. Primary Recovery of Oil

In primary recovery, there are two main types of oil recovery processes, both of which rely solely on the inherent energy within the reservoir and do not require external energy support. The source of pressure that maintains reservoir pressure depends on the specific drive mechanism operating within the reservoir. These primary recovery mechanisms can include depletion drive, gas cap drive, water drive reservoir, combination reservoir, or gravity drainage reservoir. The two primary recovery methods are as follows:

1. **Natural Flow:** In natural flow primary recovery, the reservoir pressure is sufficient to drive the oil to the surface without any artificial assistance. The energy within the reservoir, often resulting from the initial pressure built up over geological time, propels the oil towards the production well. This method is suitable when the reservoir pressure is high enough to allow for the flow of oil to the surface without any artificial lifting mechanisms.
2. **Artificial Lift:** When the natural reservoir pressure is insufficient to push the oil to the surface, artificial lift methods are employed. These techniques involve the use of equipment such as pumps or gas lift systems to artificially increase the pressure within the reservoir and lift the oil to the surface. Artificial lift methods are crucial for maintaining or enhancing production rates in reservoirs with declining natural pressures.

The choice between natural flow and artificial lift in primary recovery depends on the specific reservoir conditions, including the type of drive mechanism and the available reservoir pressure. Reservoir engineers assess these factors to determine the most effective and economically viable method for extracting oil during the primary recovery phase. (Kovscek, 2019)

2.3.2. Secondary Recovery for Oil

Secondary recovery methods are employed to bolster reservoir pressure and enhance oil recovery, and there are two primary types of secondary recovery: water injection and gas injection. The choice between these methods depends on the specific drive mechanism operating within the reservoir. (Rojas, D. H, 2008)

Water flooding is a common secondary recovery technique in which water is injected into the reservoir to displace more oil toward the production wells and maintain sufficient pressure to improve recovery. In some cases, water flooding can start immediately after primary depletion, particularly in reservoirs where there is a rapid decline in pressure. The timing for initiating water flooding is evaluated based on several critical factors, including:

i. **PVT Properties**: Understanding the properties of the reservoir fluids (pressure, volume, temperature) is crucial for effective water flooding.
ii. **Rock Physics**: The geological and geophysical characteristics of the reservoir rock play a significant role in determining the success of water flooding.
iii. **Reservoir Depth and Temperature**: Reservoir depth and temperature conditions influence the behavior of injected water and its interaction with the reservoir.
iv. **Reservoir Geometry**: The shape and dimensions of the reservoir impact the efficiency of water flooding.
v. **Well Locations**: The placement of producing wells and the need for support from water injection wells are considered in the planning of water flooding.
vi. **Oil Recovery Targets**: The volume of oil to be recovered and the desired recovery factor are important considerations.
vii. **Surface Facilities**: The capacity of surface facilities to handle increased water production is also a key factor.

Water Injection Wells:

Water injection wells are designed to inject water into specific zones within the reservoir. These wells are placed strategically to optimize the displacement of oil and maintain reservoir pressure. It's important to note that water injection is suitable for certain reservoirs where the presence of a water zone can effectively support the required pressure. However, in reservoirs with strong natural water drive mechanisms, the use of water injection may be unnecessary or have a negligible impact on recovery. (Leverett, M.C. and Lewis, W.B. , 1941)

Overall, the choice between water injection and gas injection as secondary recovery methods depends on a thorough assessment of reservoir conditions, including the drive mechanism, to determine the most effective approach to improve oil recovery and sustain reservoir pressure.

Types of Water Flooding Patterns

There are several types of water flooding patterns such as:

1. Peripheral Pattern for water-flooding.
2. Crystal and Basal Pattern for Water-flooding.
3. Irregular Pattern for water Injection.
4. Regular Pattern for Water-flooding.
5. Direct line pattern.
6. Staggered line pattern.
7. Regular four spot pattern
8. Five spot pattern.
9. Seven-spot pattern.

The Importance of Water Flooding due to the following considerations:

1. Maintain the reservoir pressure and prevent the rapid decline of pressure with time.
2. Displace more oil from the reservoir and increase the ultimate recovery of oil.

The success of water flooding in oil reservoirs hinges on several critical factors and data availability, including:

i. **Reservoir Data:** The amount of data available for the reservoir is crucial. This includes detailed information about the reservoir's geological and geophysical characteristics, such as heterogeneity and the extent of sand channels within the reservoir.
ii. **Well Test Data**: Data from well tests provide valuable insights into reservoir behavior and performance.
iii. **Rock and Core Properties:** Understanding the properties of the reservoir rock, as well as core analysis data, is essential for effective water flooding.
iv. **Fluid Properties**: Laboratory experiments measuring fluid properties, such as viscosity and saturation, are critical for reservoir modeling.

Water flooding as a secondary recovery technique gained prominence, especially after the 1960s when it became widely adopted in oil fields worldwide. This technique involves injecting produced water back into the reservoir to displace oil and maintain reservoir pressure, thereby increasing oil recovery. Reservoir engineers became proficient in implementing water flooding, and one essential aspect was history matching. (Olukemi Osharode, C. , 2010)

History Matching: Reservoir engineers use history matching to simulate the behavior of existing producing wells and new injection wells in the reservoir. This process helps match the historical performance of the reservoir and predict the optimal placement of wells within it.

Lake and Jensen were among the first authors to discuss reservoir performance in the context of water flooding. They predicted reservoir production performance while not accounting for reservoir heterogeneity. Dykstra introduced a graphical technique to evaluate reservoir performance. Subsequently, researchers like Turta et al. identified various factors influencing water flooding performance, including oil saturation, water saturation, production volumes, and injected water amounts. Sweep efficiency, which depends on reservoir shape and heterogeneity, also plays a significant role. (Turta et al, 2011)

Water Breakthrough: One challenge in water flooding is the early production of water, which starts at the time of breakthrough. Stimulation techniques like hydraulic fracturing can increase water production and lead to earlier breakthrough, causing operational challenges.

Kopaska-Merkel and Mann studied different water flooding patterns applicable to oil fields. These patterns are selected based on surface and subsurface topography, reservoir geometry, and the available area in relation to production wells. Common water flooding patterns include irregular, direct line spot, staggered line spot, peripheral, crestal, basal, regular (e.g., four-spot, five-spot, inverted five-spot, nine-spot) patterns. The choice of pattern depends on reservoir characteristics and well locations. (Kopaska-Merkel and Mann , 2006)

The efficiency of water flooding in improving recovery depends on several parameters, including:

Reservoir Type: Different reservoir types respond differently to water flooding.

Well Placement: The location of wells within the reservoir significantly impacts the efficiency of the chosen flooding pattern.

Pattern Selection: The specific water flooding pattern used, as well as its suitability for the reservoir shape and available area, plays a vital role in recovery efficiency.

Water flooding remains a widely used secondary recovery method in the oil industry, capable of improving recovery in various reservoirs when properly applied and managed.

2.3.3.1 Depth of Reservoir

The depth of the reservoir can affect the water flooding greatly. So, as the reservoir depth increases, the pressure required for injection increases.

2.3.3.2 Fluid Saturation

The amount of oil in the reservoir determines how much of the area floods. As there is a high level of oil saturation in the reservoir, water flooding may be used to extract additional oil and improve overall oil recovery. While the water flooding plan will fail because there is not enough oil in the reservoir to reach saturation.

2.3.3.3 Reservoir Geometry

The effectiveness of water flooding is greatly influenced by the geometry and shape of the formation. Because the reservoir geometry can predict the number of wells that can be dug, their locations, and the pattern that will govern the recovery efficiency

2.4. ECONOMIC STUDIES

It is obvious that the economics of any water flood project boil down to the simple formula: Gross Revenue Less All Costs equals Gross Profit. Using the information collected in the engineering study, the factors making up this formula can now be determined.

2.4.1 Gross Revenue

A dependable estimate of gross production can be derived from the engineering data collected and analyzed as described above. This estimate, when multiplied by the anticipated price per barrel of oil throughout the duration of the water flood, provides an estimate of the gross revenue to be expected from the reservoir. (Philips Owen, , 2009)

To ensure the success of the water flooding project, it is essential to continuously monitor and verify the production progress against established "typical" decline curves. Additionally, the ultimate recovery should be assessed continuously, taking into account new laboratory data, engineering findings, core samples, and past operational experiences.

It's worth noting that water flooding often results in a 10% to 30% increase in oil gravity, which can lead to increased revenue due to the upgraded quality of the produced oil. However, the authors of this approach prefer to disregard the typical increase in revenue resulting from improved oil quality, instead treating it as an additional factor of safety in their calculations. This conservative approach helps ensure that revenue estimates are not overly optimistic and provides a margin of safety for the project's economic evaluation.

2.4.2 Costs

Water flooding, while effective for maximizing oil recovery, comes with significant costs. It's important to understand that when done correctly to achieve maximum recovery, water flooding requires substantial capital investment for development and ongoing operation. (Badusha, 2015). These costs encompass acquisition, development, and operating expenses. Here's a breakdown:

i. **Development Costs**: Developing a water flooding project can be capital-intensive, and these costs primarily cover activities related to setting up the infrastructure and injection facilities. Development costs can vary but often fall within the range of $1,500 to $5,000 per acre.

ii. **Operating Costs**: Over the life of the water flood project, operating expenses are incurred, which include maintenance, reservoir management, and operating the injection and production wells. These costs generally fall within the same range as development costs, particularly when factoring in expenses related to reopening and re-plugging old wells, which are often necessary for a successful water flood project.

iii. **Cost of Acquisition**: The cost of acquiring the property is a critical component of the overall investment. Determining the appropriate acquisition cost can be a complex process. The authors suggest valuing the property based on the assumption that an all-cash payment will be required. This cash figure serves as the foundation for all subsequent calculations. Negotiations with the seller can then explore various arrangements, such as oil payments, overriding royalties, and income guarantees, or combinations of these factors.

iv. **Negotiation Considerations**: During negotiations, it's essential to carefully evaluate and discount each proposal to present worth or back to the true value of the property. Overriding royalties, being a permanent burden on the property, are typically less desirable from the purchaser's perspective. The type of deal that can be made often depends on the financial positions of both the purchaser and the seller, as well as tax considerations.

v. **Tax Considerations**: The tax position of the seller can significantly impact the negotiation process. Sellers with low residual costs may be less interested in cash and may prefer alternative arrangements, such as fixed oil payments, especially when facing favorable tax treatment, such as a lower Capital Gains Tax rate compared to corporate income tax or individual taxes. It's advisable for both sellers and buyers to seek advice from tax attorneys to make informed decisions that align with their financial goals and tax obligations.

2.4.3 Development Cost

Determining development costs for a water flooding project involves considering various factors that can significantly impact the overall investment. These factors include spacing, the use of existing wells, the use of second-hand equipment, the type of water plant, and the decision to flow or pump. (Craig, 1993) Here's a closer look at how each of these factors influences development costs:

Spacing: Spacing refers to the distance between injection and producing wells in the reservoir. It plays a crucial role in determining the number of wells to be drilled, which in turn directly affects the development cost per acre. Spacing can vary widely based on engineering assessments and reservoir characteristics. While pressure gradient curves may suggest that spacing can be limitless, practical considerations often dictate specific spacing requirements. Factors such as the depth of the reservoir and its physical properties, oil gravity, and economic considerations all influence the choice of spacing. Engineers may have differing opinions on the "ideal spacing," and what works best can vary from one field to another. The balance between sweep efficiency (how effectively injected water displaces oil) and development and operating costs must be carefully considered when determining spacing.

Use of Existing Wells: Decisions about whether to use existing wells as part of the water flood project can be complex. Existing wells may require significant work, such as cleaning, casing replacement, or other major repairs, to be suitable for the project. The costs associated with refurbishing or converting old wells should be factored into development costs. Additionally, using such wells as input (injection) wells can involve hazards, uncertain efficiency, and potentially high conversion costs. As a result, the authors prefer to drill new input wells, with core drilling as an integral part of development costs.

Use of Second-Hand Equipment: The use of second-hand equipment, particularly pipe, is typically not recommended. Water flooding projects often have a lifespan of seven to twelve years, and second-hand materials may not last long enough to justify their use. It's generally considered false economy, except in cases where the equipment is known to be in excellent condition.

Type of Water Plant: Water plants can be of the open or closed system types. The authors prefer the open system, which includes aerators for both makeup and return waters, detention ponds with adequate chemical treatment capabilities, and visible filters for daily examination of the filtering medium. While closed systems can be cheaper, open systems offer more control over the condition of injection water, which is crucial for the operation's success. The cost of an open-type plant can vary but often ranges from $50,000 to $60,000, excluding the supply well or raw water source.

Source of Water: The source of water for injection purposes is another critical consideration. Assuming a suitable water supply is available, the cost of procuring this water should be factored into the overall plant cost.

Flow vs. Pump: The decision to flow or pump the water flood is a fundamental one and must be made when planning large-scale development. While development costs are typically lower for a flowing flood, numerous factors favor pumping. The authors recommend pumping due to the belief that recoveries under flowing conditions tend to be lower, and payouts are often delayed. Ultimate profits, determined after considering longer payout periods (which must be discounted to present worth), tend to favor pumping. This decision can vary among water flood operators.

In general, development costs can be reasonably accurately determined once the final program has been decided upon. Material costs, labor rates, and contract drilling charges are typically well-established, allowing for a more precise estimate of development expenses. It's important to strike a balance between engineering requirements and economic considerations to optimize the development strategy while managing costs effectively. (Kopaska-Merkel and Mann , 2006)

2.4.4 Operating Costs

Operating costs for a water flooding project involve several complex variables that must be carefully considered. Beyond direct labor costs and overhead, these factors should be taken into account:

1. **Water Treatment:** The cost of water treatment can vary significantly from field to field and can even fluctuate from day to day, especially if return water is mixed with makeup water. The cost of treating and pressurizing water can range from 1.25 cents per barrel (bbl.) to as much as 3 or 4 cents per bbl., depending on the required chemical treatment and the cost of producing makeup water at the surface. On average, the cost should not exceed 2 cents per bbl.
2. **Return Water:** As the flood progresses, the production of increasing quantities of return water becomes a critical issue. Plans must be made for either disposing of or reusing this water. Disposal attempts have often proven unsatisfactory and costly due to the sheer volume of water. Therefore, reusing return water, despite the additional treatment costs, is recommended. Separately treating makeup water and return water is becoming more common, allowing for better control over the combined waters. These costs form a significant portion of the overall cost of "treated and pressurized water."

3. **Corrosion:** Corrosion is a significant problem in water flooding projects. Using materials that resist or combat corrosion is essential. Materials like plastic pipe for low-pressure lines, plastic or cement-lined pipe for input strings, high-pressure water lines, and flow lines are preferred. Efforts should be made to avoid the use of dissimilar metals in contact with corrosive waters. While anti-corrosion equipment and materials may increase development costs, they lead to reduced operating costs, justifying their extensive use.
4. **Oil Treatment:** Water flooding can lead to increased oil treatment challenges, which, when they occur, contribute to higher operating costs.
5. **Cleaning Out:** Operating cost calculations should include provisions for cleaning both input and production wells periodically. Inputs, in particular, are crucial, and maintaining a clean sand face is essential to prevent clogging. Methods such as washing, acidizing, and the use of special chemicals can help keep input rates at reasonable levels.

Operating costs for a water flooding project are influenced by these factors and can vary significantly depending on the specific conditions of the field, the quality of the water used, the materials chosen, and the level of corrosion control and maintenance. Managing these costs effectively is essential for the successful and economical operation of the project. (Kovscek, 2019)

2.5.

2.5.1. INITIAL INVESTMENT COSTS

DUMP FLOOD

- Costs for construction of dams or reservoirs.
- Equipment and labor for excavation and earthmoving.
- Land acquisition and environmental impact assessment expenses.

WATER FLOOD

- Installation of irrigation systems or pumping stations.
- Pipeline and distribution network setup.
- Equipment and labor for system installation.

2.5.2. MAINTENANCE EXPENSES

DUMP FLOOD

- Ongoing dam/reservoir maintenance.
- Sediment removal.
- Repair and replacement of infrastructure.

WATER FLOOD

- Routine maintenance of irrigation systems.
- Energy and operational costs for pumps.
- Repairs and upgrades as needed.

2.5.3. POTENTIAL ECONOMIC BENEFITS

DUMP FLOOD

- Increased agricultural productivity due to controlled water supply.
- Flood control benefits, reducing damage to properties.
- Potential for hydropower generation.

WATER FLOOD

- Enhanced agricultural yield through precise water distribution.
- Reduced water wastage and improved water use efficiency.
- Potential for increased income in agriculture.

2.5.4. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

- Evaluate the environmental impact of both methods, including habitat disruption, water quality, and long-term sustainability.
- Consider social factors such as displacement of communities, access to water resources, and impact on livelihoods.

RISK ASSESSMENT

Assess risks associated with each method, including the possibility of dam failure, climate change impacts, and regulatory changes.

TIME HORIZON

Determine the time period over which you'll evaluate costs and benefits, considering both short-term and long-term impacts.

CHAPTER THREE

METHODOLOGY

3.1 RESEARCH DESIGN

This research employs a mixed-methods design to facilitate a comprehensive understanding of the economic variables in waterflood and dumpflood applications. This integrated approach allows for both numerical quantification and in-depth qualitative understanding. The study is organized into phases for primary data collection through field surveys and secondary data collection via academic literature, industry reports, and other relevant publications.

3.2 METHOD OF DATA COLLECTION

Two Sources of data collection were used in this in project including, primary and secondary sources

3.2.1 Primary Data:

A team was dispatched to a selected oil field in the Niger-Delta where dumpflood techniques are being employed. Measurements were taken to assess operational cost, production rates and Initial Investment. These will be normalized to provide comparable metrics across both dumpflood and waterflood.

3.2.2 Secondary Data:

1. Academic Journals: Extensive literature reviews was conducted to gather existing data and findings on the economic efficacy of both waterflood and dumpflood techniques.
2. Industry Reports: Relevant industry reports were examined to extract data on costs, revenues, and other key economic indicators for both methods. These were sourced from oil industry publications and databases.

3.3 METHOD OF DATA ANALYSIS

For the analysis of this project, both qualitative and quantitative methods were used.

Quantitative method: A detailed cost-benefit analysis was conducted to assess the financial returns from waterflood and dumpflood applications. This analysis will be performed using Excel and specialized economic modeling software.

Qualitative method: For this method, a case study analysis was performed where data collected from field surveys will be compiled into individual case studies for each oil field. This will help in contextualizing the quantitative findings and enrich the overall understanding of field-specific variables

3.4 METHOD OF ECONOMIC ANALYSIS:

1. Computation of Revenue: The revenue for each year was calculated by multiplying the annual oil production (in barrels) by the oil price for that year. Then the total for each year was added together to get the sum total for the entire period
2. Net Present Value (NPV): This metric was used to evaluate the profitability of each technique, taking into account the time value of money. The discount rate (r) used was 10%. The formula for NPV is given as

   NPV = $\sum \frac{R_t}{(1+r)^t} - C_o$

   Were

   R_t= Revenue in year t

   t = Year (starting from 0 for the year 2017)

   r = Discount rate (10% or 0.10)

   C_o = Initial cost (spent in year 0 i.e., 2017)

Net Present Value of Waterflood and Dumpflood Project

Net Present Value (NPV) is a critical financial metric used to assess the profitability of a project. It involves calculating the present value (PV) of a series of cash flows, both inflows (revenues) and outflows (expenses), over a specific time period. The NPV represents the sum of the present values of these individual cash flows.

NPV is a powerful tool for evaluating the time value of money, taking into account factors like inflation and expected returns on investment. It essentially compares the value of a dollar today to its expected value in the future, considering the time value of money. If the NPV of a prospective project is positive, it indicates that the project is expected to generate more value (in today's dollars) than it costs to implement. In such cases, the project is generally considered economically viable and is typically accepted.

On the other hand, if the NPV is negative, it suggests that the project's expected cash flows are insufficient to cover its costs, and it is likely to result in a financial loss. In such cases, the project is usually discouraged or reconsidered because it would not generate a positive return on investment.

In summary, NPV is a crucial financial tool used to make informed decisions about the economic feasibility of projects, investments, or business ventures. It helps organizations assess whether the potential financial benefits of a project outweigh the associated costs, accounting for the time value of money and other relevant factors.

3. Return on Investment (ROI): ROI was computed to analyze the efficiency of the invested money. The formula for ROI is given as

   $$\text{ROI} = \frac{Total\ Revenue - Total\ cost}{Total\ cost} \times 100$$

3.5 INVESTMENT COSTS

In this context, "costs" encompass all expenses associated with both the installation and operation of the project facilities. These costs include two main categories: initial investment costs and operating costs.

To illustrate, if a five-spot pattern is selected as the water-flood configuration, there will be expenses related to drilling and completing the necessary wells for both injection and production purposes. Furthermore, costs associated with the procurement and utilization of equipment, such as injectors and water pumps (or water-flooding plants, if applicable), are also taken into account.

If the water source is situated at a distance from the project site, expenses related to water transportation and waterlines are considered. Alternatively, if it's more feasible, drilling a water well on-site might be another cost to consider. Additionally, if the injected water requires treatment before use in the project, the costs associated with water treatment processes will also be factored in when assessing the overall project costs.

1. For 5-spot pattern, the cost of drilling and completing water injection wells are given below:
    i. The cost of drilling and completing a well is $150 per foot
    ii. For a total depth of 11 000 ft, the cost of drilling and completing the well is $150 *11000 ft = $1.65 million
    iii. The cost of installation of wellhead structures is $10000 Total cost of one well is $1.65 million + $10000 = $1.66 million

Therefore, drilling cost of the 5 wells is $1.66 million * 5 = $8.3 million, (Philips, 2009).

2. The cost of installation of water injection pump for example an Elmar water/greaseinjection control module is $208 000
3. Costs of water and water lines for injection:
    i. The cost of drilling a water well to about 1500 ft is $2000, (Philips, 2009).
    ii. The cost of installing a gathering system for the water gathering is $50 000.
    iii. The cost of installing water lines for transporting the water from about 10 miles awayfrom the oil well where the water well is, execution of associated civil works and maintenance of water facility for two years is less than $866 600, (Oil Serve Nigeria, Jan, 2004).

The total cost of water and water lines is \$2000 + \$50000 + \$866 600 = \$918600. The total investment cost is the sum of the costs of drilling the water injection wells, the cost ofinstalling a water injection pump and the cost of water and water lines. The total investmentcost is \$8.3 million + \$208 000 + \$918 600 = \$9.42 million.

3.5.1 OPERATING COSTS

Operating Cost = Labour costs + Maintenance Costs + Management Costs

Labour costs: take the number of employees to be 50 and an average of \$4 000 per month per employee.

For the 50 of them, labour costs per month would be equal to 50 * \$4 000 = \$200 000.

Then labour costs annually = \$200 000 * 12 = \$2.4 million

3.5.2MAINTENANCE COSTS

These include spare parts consumption in amount of \$2.13 million peryear; fixed assets repair in amount of \$852 000/year; operating outsourced services in amount of \$4.26 million/year.

Total maintenance costs per year = \$2.13 million + \$852 000 + \$4.26 million = \$7.24 million.

- Management costs = \$804 000

Annual Operating cost = \$2.4 million + \$7.24 million + \$804 000= \$10.44 million

3.5.3 PROFITABILITY ANALYSIS OF RESERVOIR OB-63

In the profitability analysis of Reservoir OB-63, the gross revenue of the project is a critical factor. The gross revenue is determined by calculating the net value of the oil recovered during the course of the project. To calculate the net value of the oil recovered, the market price of crude oil is used.

Net Value of Oil = Market Price of Crude Oil * Cumulative Oil Production at Breakthrough

Oil price forecast for the next consecutive years starting from 2017

Year	**Price**
2017	55.04
2018	71.44
2019	65.99
2020	39.53

Table 3.1 Oil price forecast for the next three consecutive years starting from 2017

Year	**Production**
2017	790000
2018	590000
2019	210000
2020	180000

Table 3.2 Oil Production forecast from 2017 to 2020

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. RECOVERY ANALYSIS FOR RESERVOIR OB-63

Water viscosity,	0.5 cp
Proposed Flood area, A	45 acres
Proposed Flood pattern	5 spot
Proposed Water Injection Rate	3000 bbl/day
Pore Volume at start of flood	$6.98 * 10^6$ bbl
Volume of oil at start of flood, N_s	3.88 MMSTB
Mobility ratio, M	0.923
Areal Sweep Efficiency at breakthrough, E_{ABT}	0.70
Cumulative PV of water injected at breakthrough, Q_{iBT}	0.467
Cumulative water injected at breakthrough, W_{iBT}	2.28 MM bbl
Time to break through, t_{BT}	760 days
Displacement efficiency at breakthrough, E_{DBT}	0.5838
Cumulative oil production at breakthrough, $[N_p]_{BT}$	1.59 MM STB

Table.4. 1 Oil Recovery Calculation Data for the Water-flooding Project of Reservoir OB-63

From the provided table, it's evident that the cumulative oil production at breakthrough, which occurs approximately 760 days into the water-flooding project, amounts to 1.59 million stock tank barrels (MMSTB). This represents around 41% of the initial volume of oil present at the beginning of the flood, which is a promising outcome. Additionally, the areal sweep efficiency at breakthrough stands at 0.70, and the displacement efficiency at breakthrough is calculated to be 0.5838. It's worth noting that even without implementing the water-flooding project, a significant volume of 1.59 MMSTB of oil would have remained trapped within the formation.

While achieving a 41% oil recovery is deemed acceptable, there are opportunities to enhance this recovery by adjusting certain parameters. For instance, by increasing the water viscosity through the addition of surface-active agents, the viscosity of the injected water could be raised to 0.65 cp. This, in turn, would reduce the mobility ratio from 0.923 to 0.709, leading to improved performance. The areal sweep efficiency would increase from 0.70 to 0.7358, and the cumulative oil production at breakthrough would consequently rise to 2.23 MMSTB, as opposed to the initial 1.59 MMSTB.

This adjustment demonstrates the potential for optimizing oil recovery by modifying key parameters in the water-flooding process. 2.23 MMSTB is about 43% of the initial volume of oil before water-flood. They are given ina table below:

Parameter	**Value at 0.5cp**	**Value at 0.65cp water**
Mobility ratio, M	0.923	0.709
Areal Sweep Efficiency at breakthrough, EABT	0.70	0.7358

Cumulative oil production at breakthrough $[N_p]_{BT}$	1.59 MMSTB	2.23 MMSTB
$[N_p]_{BT}$ as % of N_s	41%	43%

Table.4.2 Effect of change in water viscosity for oil recovery from Reservoir OB-63

4.2 ECONOMIC ANALYSIS OF SECONDARY OIL RECOVERY BY WATERFLOODING FOR RESERVOIR OB-63

4.2.1 Profitability Analysis of Reservoir OB-63

In this case, the price of crude oil is set at $30 per barrel.

Given that Reservoir OB-63 has achieved a cumulative oil production at breakthrough ([Np]BT) of 1.59 million stock tank barrels (MMSTB) within 760 days, the net value of the oil can be calculated as follows:

Net Value of Oil = Market Price of Crude Oil * Cumulative Oil Production at Breakthrough

Net Value of Oil = $30 * 1.59 MMSTB = $47.7 million

Furthermore, for the purpose of economic evaluation, it is assumed in this analysis that a year comprises 330 working days, with the remaining days allocated for equipment servicing and maintenance. After 330 days, it is estimated that an additional 690,395 STB of oil will be recovered.

This information is essential for a comprehensive economic assessment of the project, allowing for a more accurate evaluation of its profitability and financial viability.

4.2.2 Net Present Value of Reservoir OB-63

Net Present Value (NPV) is a critical financial metric used to assess the profitability of a project. It involves calculating the present value (PV) of a series of cash flows, both inflows (revenues) and outflows (expenses), over a specific time period. The NPV represents the sum of the present values of these individual cash flows.

Year	**INV**	**REV**	**EXP**	**NCR**	**CUM. NCR**	**PV @ 10%**
0	$9.42 M	-	-	($9.42 M)	($9.42 M)	($9.42 M)
1(330 days)	-	$20.7M	$10.44 M	$10.26 M	0.84M	$9.33M
2(660 days)	-	$20.7 M	$10.44 M	$10.26 M	$11.1M	$8.5M
Breakthrough (760 days)	-	$6.3M	$10.44 M	($4.14 M)	$6.96M	($3.11 M)

Table.4.3 Cash Flows for the water-flooding project, Reservoir OB-63

From table 4.3,

- Initial Investment: -$9.42 million
- Year 1 Cash Flow: $9.33 million
- Year 2 Cash Flow: $8.5 million
- Year 3 Cash Flow: -$3.11 million

NPV = Initial Investment + Year 1 Cash Flow + Year 2 Cash Flow + Year 3 Cash Flow

NPV = (-$9.42M) + $9.33M + $8.5M - $3.11M = $5.3 million

Based on this calculation, with a discount rate of 10%, the NPV of the project is $5.3 million. Since the NPV is greater than zero, the project is considered financially viable and worth investing in. A positive NPV indicates that the project is expected to generate a return that exceeds the cost of capital, making it an attractive investment opportunity.

4.2.3 The Net Present Values for the Water-flooding project on reservoir OB- 63 at variable prices of crude oil

Price of Crude Oil	NPV at the Crude Oil Price
$20/bbl	($8.28M)
$30/bbl	$5.30M
$40/bbl	$18.83M
$50/bbl	$35.83M

Table.4. 4 NPV at various crude oil prices, reservoir OB-63

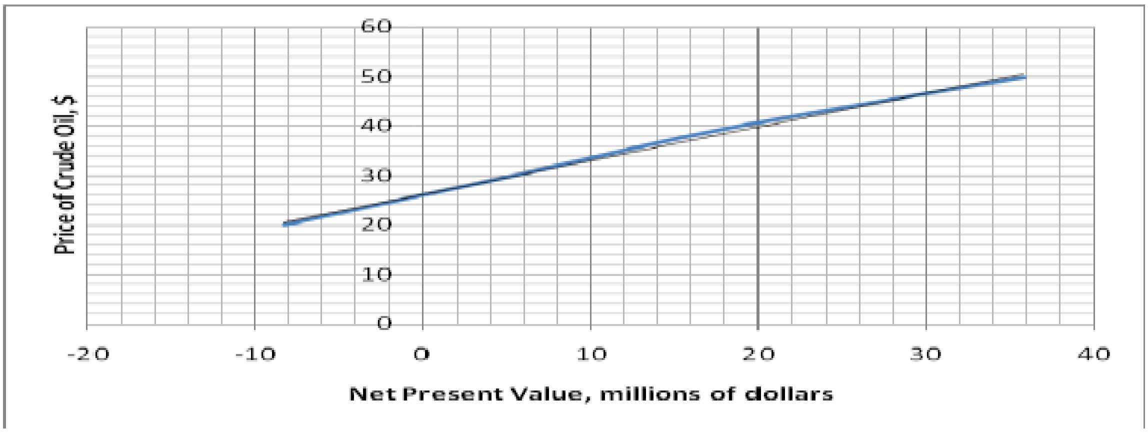

Figure 4. 1 Plot of Price of Crude oil against the NPV's at the different prices, reservoir OB-63.

From the plot above it can be read that the NPV becomes negative as the price of crude oil drops below $26.

Therefore, it is concluded that for embarking on water-flooding project on reservoir OB-63to be economically viable, the price of crude oil would not fall below $26.

4.2.4 The Net Present Values for the waterflooding project on reservoir OB-63 at variable interest rates

Interest Rate	NPV at Interest Rate
10%	$5.30M
20%	$3.86
40%	$1.63
60%	($10 400)

Table.4. 5 NPV at various interest rates at oil price of $30/bbl, reservoir OB-63

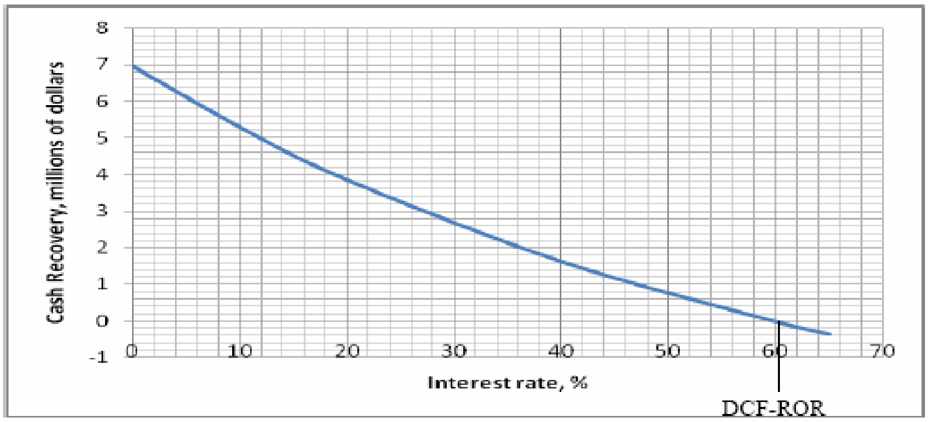

Figure 4.2 Plot of Cash Recovery against interest rates, reservoir OB-63

From the plot above it can be read that the DCF-ROR is 60%. Discounted Cash Flow Rate of Return (DCF-ROR) is a profit indicator and it is that discount rate that discounts all future revenues to just equal all future costs. It discounts the Net Present Value of the project to zero.

4.3. COMPARATIVE ECONOMIC ANALYSIS OF DUMPFLOOD AND WATERFLOOD

4.3.1 WATERFLOOD PROJECT RESERVOIR OB-63

The cost of investments is $9.42 million

Operating Cost = Labour costs + Maintenance Costs + Management Costs = $10.44 million

Oil price forecast for consecutive years

Oil price	Forecast
2017	55.04
2018	71.44
2019	65.99
2020	39.53

Production forecast for the next consecutive years

Oil price	Production forecast
2017	790000
2018	590000
2019	210000
2020	180000

Cost of investments = $9.42 million (This will be accounted for in the first year, 2017)

Operating Cost = $10.44 million/year

2017: 43,481,600 - 9.42M - 10.44M = $23,621,600

2018: 42,149,600 - 10.44M = $31,709,600

2019: 13,857,900 - 10.44M = $3,417,900

2020: 7,115,400 - 10.44M = -$3,324,600

Total Revenue (2017 - 2020): $55,424,500

NPV (2017 - 2020): $47,973,146.60

ROI: 488.77%

4.3.2 DUMPFLOOD PROJECT

Initial Investment: $26MM

Cost of Installation $4MM

Production forecast for the next consecutive years

Oil price	Production forecast
2017	101,607
2018	292,458
2019	352,181
2020	241,540

Cumulative Cash Flows for the years 2017-2020:

2017:

Revenue =101,607 barrels x $55.04 per barrel = $5,590,754.28

2018:

Revenue = 292,458 barrels x $71.44 per barrel = $20,887,743.52

2019:

Revenue = 325,181 barrels x $65.99 per barrel = $21,476,319.19

2020:

Revenue = 241,540 barrels x $39.53 per barrel = $9,547,416.20

Total Revenue (2017-2020): $57,502,233.19

NPV (2017-2020): $23,702,466.02

ROI: 121.16%

4.3.1. INITIAL INVESTMENT & ASSOCIATED COSTS

DUMPFLOOD

Initial Investment: $26MM

Cost of Installation: $4MM (Total: $30MM)

WATERFLOOD

Initial Investment: $9.42MM

Operating Cost (Yearly): $10.44MM

Waterflood requires a lower initial investment, but it incurs a consistent yearly operating cost which is significant.

4.3.2. CUMULATIVE CASH FLOWS

(2017-2020)

DUMPFLOOD

2017: $5,590,754.28

2018: $20,887,743.52

2019: $21,476,319.19

2020: $9,547,416.20

Total: $57,502,233.19

WATERFLOOD

2017: $23,621,600

2018: $31,709,600

2019: $3,417,900

2020: -$3,324,600

Total: $55,424,500

While Dumpflood has a slightly higher total revenue over four years, Waterflood shows higher yearly revenues, especially in the first two years.

4.3.4. NET PRESENT VALUE (NPV) AT A DISCOUNT RATE OF 10% (2017-2020)

Dumpflood: $23,702,466.02

Waterflood: $47,973,146.60

Waterflood's NPV is substantially higher, which means it's predicted to be more beneficial in terms of the value of money over time.

4.3.5. RETURN ON INVESTMENT (ROI) FOR THE YEARS 2017-2020:

Dumpflood: 121.16%

Waterflood: 488.77%

Waterflood has a remarkably higher ROI, indicating superior profitability when considering the investment costs.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

Initial Costs: While Waterflood requires a lower upfront cost, it has significant yearly operational costs. Dumpflood has a higher initial investment, considering both the initial cost and installation.

Revenues: Over the four-year period, the revenues are comparable, but Waterflood peaks earlier (2017-2018) while Dumpflood spreads more evenly across the years.

NPV: Waterflood demonstrates a substantially higher NPV, suggesting it's a better financial choice when considering the time value of money over the evaluated period.

ROI: With an impressive ROI of nearly 490%, Waterflood indicates a much better return on the initial and operational costs.

This study aimed to provide a comparative economic analysis between waterflood and dumpflood applications in the Niger-Delta region. The results indicate that, based on the data from 2017-2020, the waterflood technique appears more economically beneficial when considering NPV and ROI.

5.2. RECOMMENDATIONS

While the economic metrics lean towards the Waterflood method as more financially beneficial over the given timeframe, it's essential to consider other factors such as long-term viability, environmental implications, and technical constraints before making a decision.

APPENDIX

Year	**INV**	**REV**	**EXP**	**NCR**	**CUM. NCR**	**PV @ 10%**
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Breakthrough (760 days)	-	$6.3M	$10.44 M	($4.14 M)	$6.96M	($3.11 M)

Table.4.6 Cash Flows for the water-flooding project, Reservoir OB-63

Oil price forecast for consecutive years

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Production forecast for the next consecutive years

Oil price	Production forecast
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