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Oil Rim Development Opportunities and Challenges: A Case Study of the Troll Oilfield in Norwegian Continental Shelf, North Sea

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ABSTRACT

The global economy is expanding at a drastic pace, and energy is fundamental to nearly all economic activities and modern living standards. Sustaining the oil supply is a profound challenge in the oil and gas industry. One of the ways the industry is now looking to sustain supply is through developing oil rims, which were once considered uncommercial because of technology. Developing oil rim has its opportunities and challenges, on which this study has focused. This study aims to investigate the feasibility and viability of oil rim development, its opportunities and challenges, and the factors affecting its economic viability. The Troll Oilfield on the Norwegian continental shelf is used as a case study because it is an oil rim field. The economic analysis is based on historical production data of the Troll oilfield. A deterministic approach is used, which involves both cash flow and sensitivity analysis. Based on the economic analysis results, oil rim development is marginally economic and viable but on certain conditions: low CAPEX and high oil price. The type of technology used in developing oil rims determines the efficiency and economic feasibility of the development. The outcome of this study shows that technology has made oil rim development possible which was once considered uncommercial in the past, and oil price is the primary determinant of the viability of oil rim development.

1. Introduction

Every minute of each day, energy powers the world, and the world populace use it without thinking. People in the world depend on energy to light up homes, commute to workplaces, travel from one location to another, and stay connected technologically without knowing where the source of energy is coming from. Most of the energy comes from fossil fuels called crude oil. According to Shell's (2011) energy scenario, oil and gas provide 80% of the world's energy. The world population is estimated

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to grow to nine billion in 2040, with two billion people added to the planet over the last forty years (ExxonMobil, 2012), as shown in Figure 1.

In addition, millions of people are enjoying a better standard of living, so energy is increasing, which may double the current rate according to projections (EIA, 2012). The current and future use of energy is very challenging. Millions of people across the developing world are improving their quality of life. Many are buying their first car, refrigerator, or computer. The global economy is expanding at a drastic pace, and energy is fundamental to nearly all economic activities and modern standards of living. According to BP (2012), China and India might become the world's largest and third-largest economies and energy consumers, jointly accounting for an estimated 35% of the global population, gross domestic product (GDP), and energy demand. If the industry does not become ready and the world continues to use energy this way without looking for new opportunities to sustain supply, it can be a risky scenario (see Figure 2). Now, there is a significant gap between energy supply and demand. This gap necessarily has to be closed. This has to be done by increasing supply, and this is a challenge that the oil and gas industry has to deal with. One way of meeting this growing demand is for the oil and gas industry to start developing all commercially viable reservoirs.

The energy demand is continuously increasing, and the sources of hydrocarbons called fossil fuels are still abundant worldwide, but this hydrocarbon is now tricky to produce. This is a profound challenge facing the oil and gas industry. The latest *BP Energy Outlook Report* stated that energy consumption is projected to grow by 1.6 per annum from 2012 to 2030, adding 39% of consumption by 2030 (BP, 2012). However, it is a requirement the oil and gas industry must meet to achieve the necessary growth in energy. In a world where oil demand will continue to increase, the industry must start looking into frontiers to maximize production. The main question is how the oil and gas industry will meet this demand.

The search for hydrocarbon reserves has remained unabated. According to ExxonMobil (2012), only 75% of oil production today was discovered before 1980, and 95% of crude oil production today was discovered before 2000 (see Figure 3). The discovery of large gushers is no longer common in many areas, and with the ever-increasing oil price, the oil and gas industry is revisiting reservoirs that were once overlooked as not commercially viable. A typical example of such reservoirs is the oil rim.

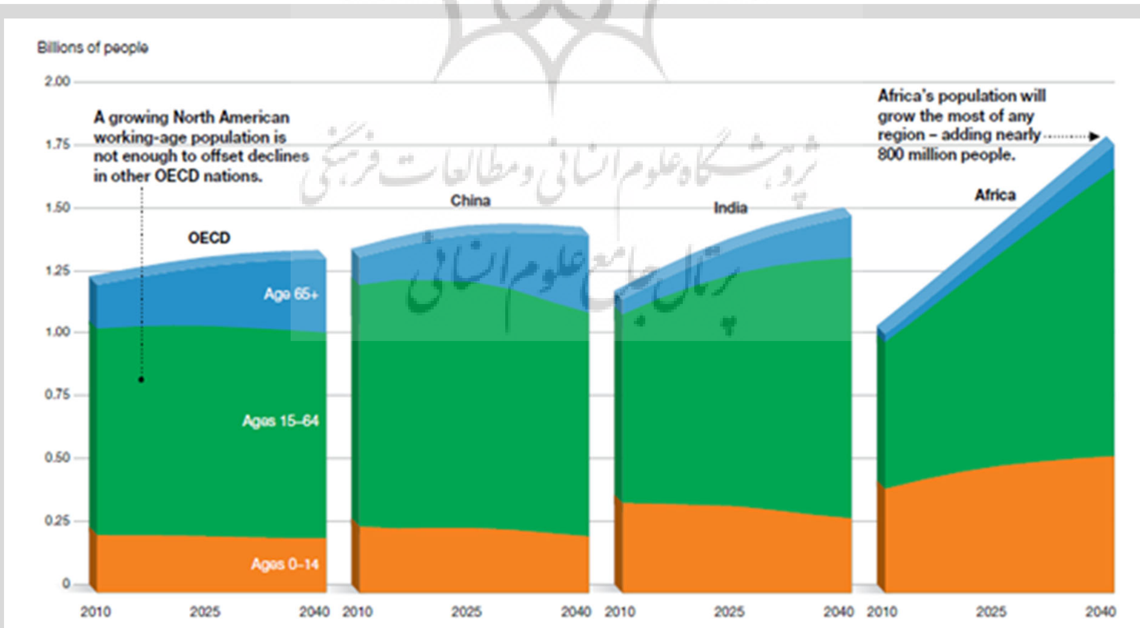

Figure 1: The increase in the world population by region (ExxonMobil, 2012)

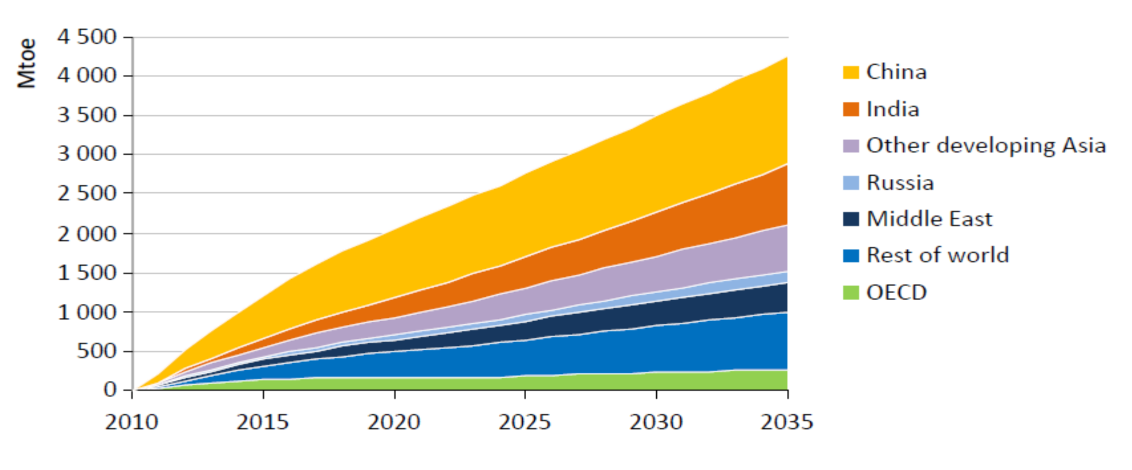

Figure 2: The growth of energy demand by region (IEA, 2011)

Closely tied to the above is that unconventional oil and gas is the key to meeting the global rise in energy demand and increasing production efficiency (Donnelly, 2012). It is now imperative to seek out oil and gas from a reservoir that was barely even considered infeasible in the past, but with the help of improved technology, it is a quest the oil and gas industry must engage in to meet the rising energy demand. One of the methods the industry is now using to achieve its quest is oil rim development.

In petroleum engineering, an oil rim is a thin oil layer below a gas cap (Kabir et al., 2008). When an oilfield contains this type of reservoir, it is called an oil rim field. This oil rim reservoir is called a saturated layer with a thickness of less than 10 m (Zakirov and Severov, 2005). Despite their low pay thickness, these reservoirs contain substantial volumes of hydrocarbons in place (Almutairi et al., 2007). Most of the oilfield in the world has reached the maturity stage, and they are also depleting in terms of production. Research has shown that most oilfield contains oil rim reservoir, but because of a lack of technology in the past, they have not been developed (Rahman et al., 2004). Developing oil rim has its opportunities and challenges on which this study focuses. Even as the industry is going into this frontier to enhance production, there is a challenge to overcome in meeting their primary aim. The primary aim of any oilfield development project is to optimize hydrocarbons production and maximize the recovery at the lowest cost (Razak et al., 2010).

In the current oil and gas industry, the discovery of huge reservoirs is no longer common in many parts of the world. With the tendency of oil prices to increase, many oil and gas industry operators are increasingly looking back at oil rims that were once seen as un-commercial because of the unconventional production method. Developing these oil rims brings about opportunities and challenges. Masoudi et al. (2011) discussed how to obtain the most out of oil rim reservoirs through reservoir management and improved enhancement initiatives. Samsunder et al. (2005) reported the effects of reservoir management in thin oil rims.

Further, Masoudi et al. (2012) investigated the continuous incremental of reserves in an oil rim marginal field through integrated technical initiative and technological advancement. Recently, Kolbikov (2012) discussed the peculiarities of rim development. This research is essential because it critically investigates the opportunities and challenges of oil rim development and its direct impact on production optimization. The Troll oilfield in the Norwegian continental shelf, an oil rim field, is used as a case study to buttress the findings of the opportunities and challenges associated with oil rim development. This study aims to critically investigate the opportunities and identify the challenges of developing oil rims. The objectives are to investigate the feasibility and viability of oil rim development, identify the development potentials of oil rim, and identify the key economic and technical factors of oil rim development.

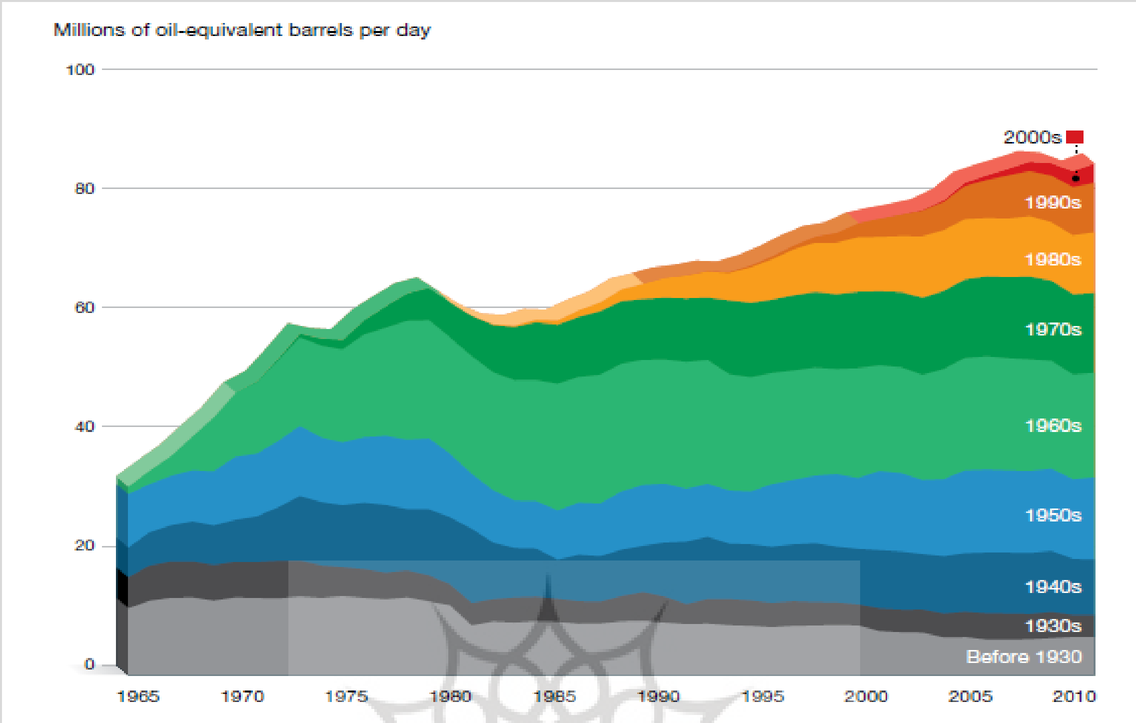

Figure 3: Discovery date of global oil production (ExxonMobil, 2012)

2. An overview of the Troll oilfield

2.1. Field description

Troll is an oil and gas field in the Norwegian continental shelf of the North Sea, located 62 miles northwest of Bergen and 31 miles west of the Island of Fedje in Norway (see Figure 4). Oil and gas were discovered in Troll in 1979. After the discovery, 20 appraisal wells were drilled between 1980 and 1993, which encountered large quantities of oil and gas (Offshore Technology 2012). The Troll field is divided into two provinces, Troll east and west, and they are structured into blocks called 31/2, 31/3, 31/5, and 31/6. Block 31/2 contains 32% of the Troll fields, while the remaining 68% lies in the three other blocks. Statoil operates the field, which has 30.58%, and other partners include Petoro AS (Norwegian) 56%, Royal Dutch Shell 8.1%, ConocoPhillips 1.62%, and Total S.A 3.69%. It is one of the North Sea's largest oil and gas fields, holding about 40% of total gas reserves in the Norwegian continental shelf (Statoil 2012). The field is estimated to have recoverable resources of 1.8 trillion standard cubic meters of natural gas and 4.0 billion barrels of oil (Mikkelsen et al., 2005).

Troll was a gas field before transforming into an oil and gas field. The field possesses large quantities of oil in thin zones under the gap cap to the west of the field. The field was initially a gas field with no commercial oil, but today, it has been developed from a gas field to an oil and gas field through the development of the thin oil column. The oil is located principally in Troll west in thin layers of 4 to 27 m thick. The most proactive part of the field is the Troll west oil province (TWOP). The gas and oil from the field are extracted through three platforms, Troll A, B, and C, but most of the gas lies in Troll east. Troll A is a gigantic platform producing gas, while Troll B is a floating processing unit and accommodation platform; Troll C is the platform produced from the thin oil column in the Troll west reservoir (Dahle, 2012). In the gas province in Troll west, the thin layer is between 11 and 13 m. Production started in the Troll field in 1995, and since then, there have been constant drilling and completion activities. The entire production well drilled in the Troll field is horizontal due to the thin formation layers (Halvorsen et al., 2012).

2.1.2. Overview

Geologically, the hydrocarbon found in this field is in a shallow marine upper Jurassic reservoir sequence with sand of good reservoir quality (Mikkelsen et al., 2005). The subsurface structure consists of three sizeable eastwardly dipping fault blocks. The formation sediments consist of alternating layers of two types of sand. The two types of sand are called clean and medium- to coarse-grained sand (C-sand), and the other is called micaceous, silty, and fine-grained sandstone (M-sand) (Mikkelsen et al., 2005). The reservoirs have gas caps varying from 0 to 160 m and a thin layer with the underlying vulnerable aquifer.

2.1.3. Field recovery strategy

The oil production in Troll has several horizon wells drilled just above the oil–water contact in the thin zone column (Figure 5). Some of the gas produced in the field supports the reservoir through gas injection (Jones et al., 2008). Currently, a total of 41 open-hole sidetracking wells have been drilled in the Troll field to recover the oil. Troll oil has over 110 horizontal subsea wells, including 53 multilateral wells (Henriksen et al., 2006). Figure 4 illustrates the field location.

2.2. An overview of the oil rim reservoir

A reservoir is any rock formation with sufficient porosity and permeability to transmit fluid from the formation to the wellbore. In petroleum geosciences, for a rock formation to be called a petroleum reservoir, it must have the ability to hold petroleum. A petroleum reservoir typically contains gas, oil, and water, which are in the order of density. These rock formations can be coarse-grained sandstones or carbonate rocks (limestones). According to Gluyas and Swarbrick (2004), petroleum reservoirs vary in internal properties, shape, and size. Economically, they must have viable oil and gas to be called a petroleum reservoir. A typical reservoir that is quite different is the oil rim reservoir. A typical petroleum reservoir is shown in Figure 6.

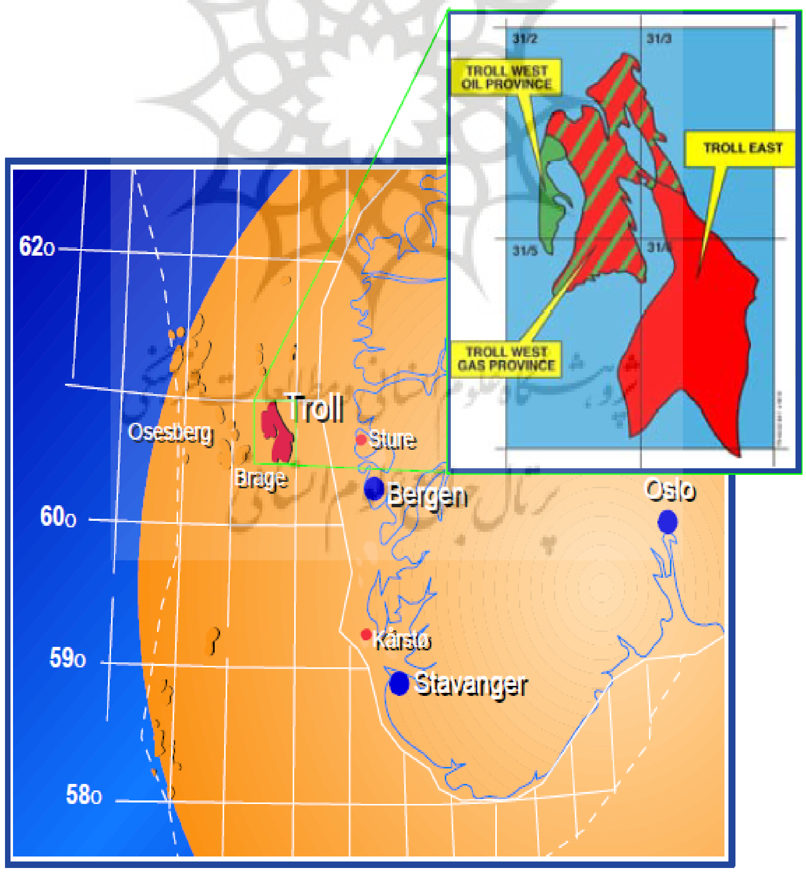

Figure 4: Map showing the field location (Leikness and Osvoll, 2005)

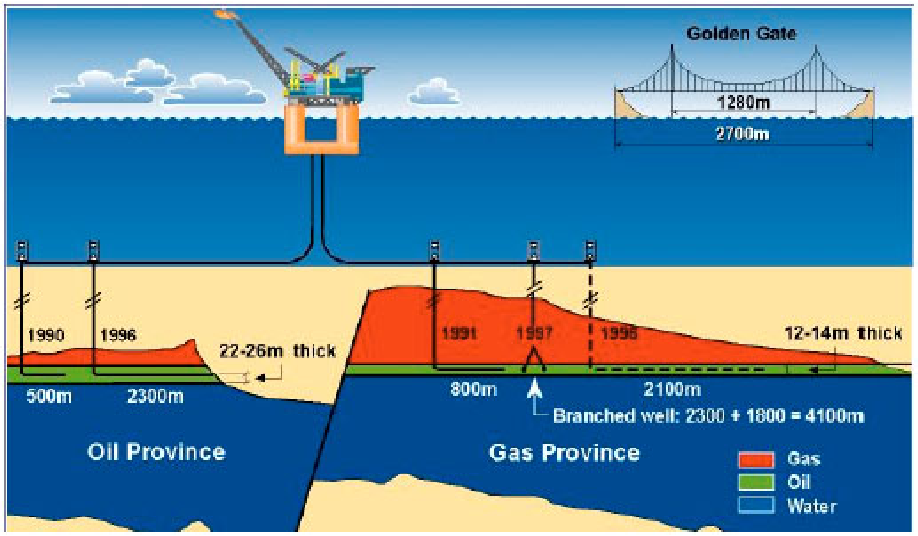

Figure 5: A schematic of the Troll production system (Alvarado et al., 2005)

An oil rim reservoir has a thin oil layer with a thickness of less than or more than 10 m between the gas cap and the aquifer (Zakirov and Severov 2005). It usually has a strong gas cap and a substantial aquifer. According to Lawal et al. (2010), an oil rim can be defined as a doughnut or pancake shape, as shown in Figure 7. When an oilfield contains this type of reservoir, it is referred to as an oil rim field. Oil rim reservoir is usually marginal, with complex, challenging scenarios, and is commercially less attractive (Masoudi et al., 2012). According to Fischbuch et al. (2010), exploring petroleum from this thin oil layer poses a distinctive challenge for reservoir development. Masoudi et al. (2011) also stated that evaluating oil rim field development is complex because conventional drilling and technologies cannot yield successful results. Oil production from oil rim reservoirs is multifaceted and challenging due to the thin oil layer and highly complex production mechanism (Silva and Dawe, 2010). If a conventional method is used to develop this type of reservoir, there might be early movement of oil/water and gas/oil which could cause early water/gas break because it is sensitive to the conventional operational systems (Onwukwe et al., 2012). Managing this complexity is a key challenge of oil recovery from oil rim reservoir. In the past, oil production volume and recovery from oil rim reservoirs were low, making oil rim development in the oil and gas industry significantly less attractive because there was no financial incentive.

Because of the advancement in drilling and well technology, oil rim development has resurfaced in the oil and gas industry due to the increasing energy demand. Davarpanah and Mirshekari (2018) conducted a simulation of the Iranian oil fields to control the oil production rate under different reservoir injectivity scenarios in the oil-rim reservoir. Their research aimed to simulate the six different injectivity scenarios for one of the Iranian oilfields to choose the most excellent scenario with the most oil production. According to Bakker et al. (2009), the oil rim reservoir, which was once considered uncommercial in the mid-eighties, is now seen as commercial and attractive because of integrated engineering advancement, innovative technical initiatives, and new technologies. It is now significant to develop this oil rim reservoir, but it presents new challenges and opportunities in the oil and gas industry. One of the fundamental goals of the oil and gas industry is to use all proven practices to maximize petroleum recovery and minimize cost in the long term through an integrated framework. Almutari et al. (2007) concluded that for oil rim development to become a successful story, there must be proper utilization of the technologies involved, decision-making in terms of development of the reservoir through a production technologist advice, best practice in simulation and modeling for proper modeling of the technologies involved (smart well or intelligent well completion, inflow control devices (ICDs), inflow control valves (ICVs), and tracers). This system has constant dynamics and complicated mechanisms. The oil and gas industry has been pushing to this boundary because of the increase in demand for energy, so there is no magic in meeting this demand; it is just an integration of advanced engineering and technology that can bridge this gap in which oil rim reservoir plays a role. Lawal et al. (2020) researched the rapid screening of oil□rim reservoirs for development and management, and the correlation they applied resulted in a new screening technique for both brown and green oil-rim reservoirs. Further, Olabode et al. (2021) studied the oil rim reservoirs and functional properties of the Niger Delta region. They built classic synthetic oil rim models with different reservoir parameters using an experimental design to optimize the oil rim production.

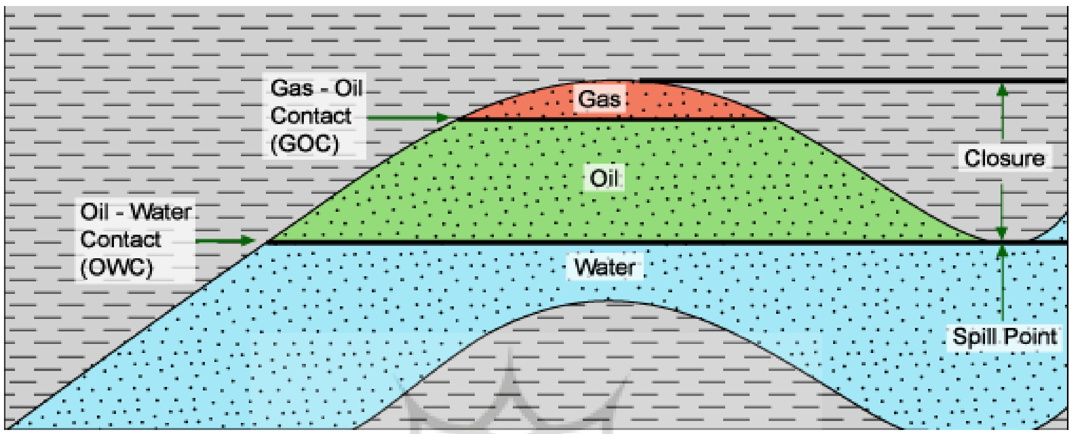

Figure 6: A schematic of a typical petroleum reservoir (International Human Resource Development Corporation, 2012).

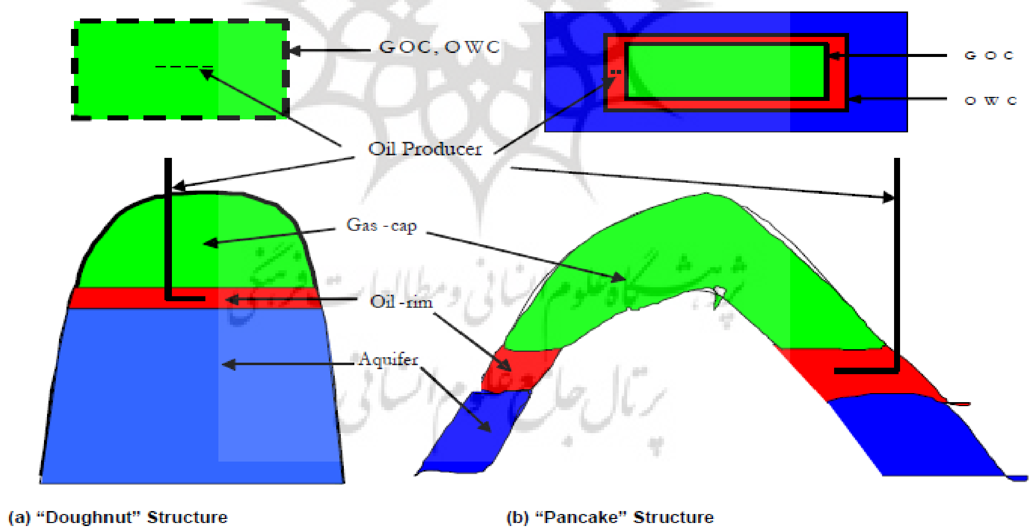

Figure 7: A typical model of an oil rim reservoir (Lawal et al., 2010)

3. Methodology

3.1. Data collection

The secondary data were collected from oil and gas articles, technical papers, oil and gas journals related to the case study, and the Norwegian Petroleum Directorate and Statistics Norway. This forms the secondary data used in this study. The historical production data used for the economic analysis of the case study were extracted from the published data of the Norwegian Petroleum Directorate. Order supportive data included produced water of the field, used to identify the coning phenomenon of the case study.

The field capital expenditure (CAPEX) and operational expenditure (OPEX) used in the economic analysis of the case study were extracted from the published data of the Norwegian Petroleum Directorate. The tax rate used in the economic analysis was extracted from Norway's historical petroleum fiscal regime published in Statistics Norway (2012).

3.2. Method for data analysis

All the data collected from the various sources were analyzed with an in-depth understanding and appreciation of all the findings, as shown in the research methodology flowchart (Figure 8). This was critically evaluated using qualitative and quantitative data analysis techniques (Grbich, 2007). The data were analyzed by critical observation of the development process and challenges involved in oil rim development. The qualitative analysis involves a nonstatistics interpretation of the theoretically based data. Quantitative analysis uses computerized mathematical models to interpret statistical data to support decision-making (Sachdeva, 2009).

A deterministic approach or method was adopted to carry out the economic analysis of the case study. According to Sentturk (2009), this method derives three different scenarios which reflect a low, best, and high estimate of recoverable quantities. The economic analysis was divided into two groups adopted from the deterministic approach. The first is the net cash flow profile of the base case, while the second is the sensitivity analysis of the base case. The complete analysis of the deterministic method is carried out using Microsoft Excel 2007 software.

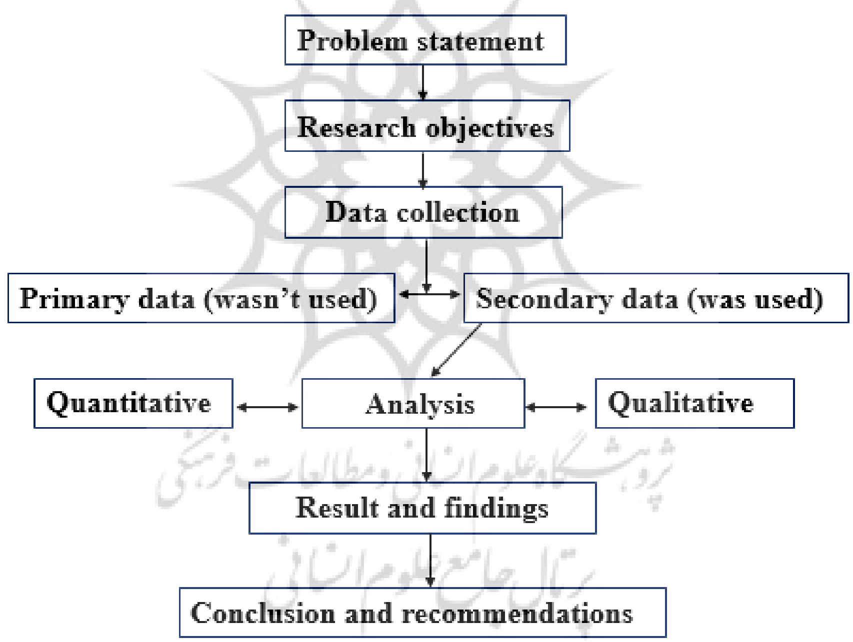

Figure 8: The research methodology flowchart

3.2.1. Net cash flow profile

This indicates how much value an investment or project could add to a firm (Mian, 2002). In its illustration, when NPV > 0, this would add value to a firm and may be accepted for investment. Further, if NPV < 0, the investment is not viable and could subtract value from the firm. While when the NPV is equal to 0, the investment neither gains nor loses. The cash flow model was built using the formula below in this analysis.

Cash flow = Revenue – expenditure

The revenue is the income from the oil sales produced in the case study. Expenditure is made-up of capital investment, operational cost, and taxes. The calculation for the revenue was done using the average yearly historical oil prices. The capital cost is the field development (drilling and completion activities), and the operational cost is the amount used in running the field. The tax is the payment attributed to the Norwegian government, including income and special taxes. The cash flow was a model built to retain accurate information from the case study to make a valid economic analysis.

3.2.2. Sensitivity analysis

The sensitivity analysis was required to understand both the upside (high) and downside (low) of the economic analysis and to identify which parameter was sensitive to oil rim development. There was a constant change of ±30% of selected parameters, including oil price, CAPEX, and OPEX of the base case to test the sensitivity analysis. The sensitivity analysis result was represented using the Tornado plot in Microsoft Excel 2007. The primary reason for the tornado plot is to determine the impact of critical uncertainties on a field (Yushkov et al., 2011).

4. Results and discussion

4.1. Results from the economic analysis

The result from the economic analysis conducted for the case study is in line with the method adopted, which is the deterministic approach or method. This approach is divided into two groups. The first is the NPV profile (base case scenario) using cash flow analysis. Historical data, which include the production rate (yearly), investment cost, operational cost, and petroleum fiscal regime for Norway, were computed using the cash flow model. See appendix 1 for a complete analysis. The second group was based on sensitivity analysis. In this scenario, the base case data were constantly changed by ±30% in selected parameters: oil price, CAPEX, and OPEX. This purpose was to analyze and determine which parameters were more sensitive to oil rim development.

4.1.1. Cash flow profile (base case scenario)

In the calculation for the computation of the cash flow model for the base case scenario, historical production data for the Troll field (case study) was used, and nominal values for both capital expenditure (CAPEX) and operating expenditure (OPEX) were used. The tax used was based on Norway's historical petroleum fiscal regime. The entire cash flow of the Troll oilfield from its production starting in 1995 until 2012 was calculated. The cumulative cash flow result plot is shown in Figure 9. See Appendix 1 for the complete table.

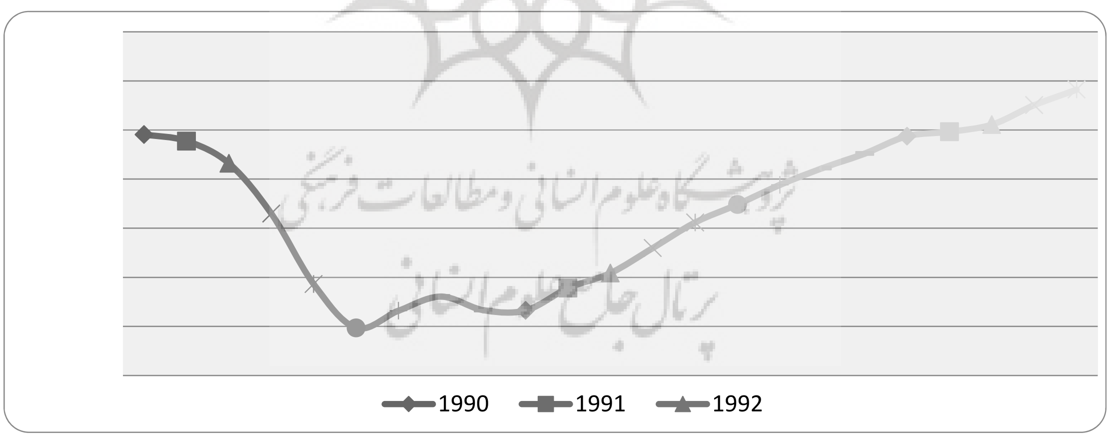

Figure 9: The result of the cumulative cash flow model for the base case

4.1.2. Sensitivity analysis

Sensitivity analysis was carried out on the base case cash flow model to investigate the feasibility and viability of oil rim development. In this scenario, the historical average oil prices from 1990 to 2012 were changed by ±30%. The sensitivity analysis results for oil prices are shown in Figure 10. The cumulative cash flow plot for these two scenarios is also shown in Figure 11.

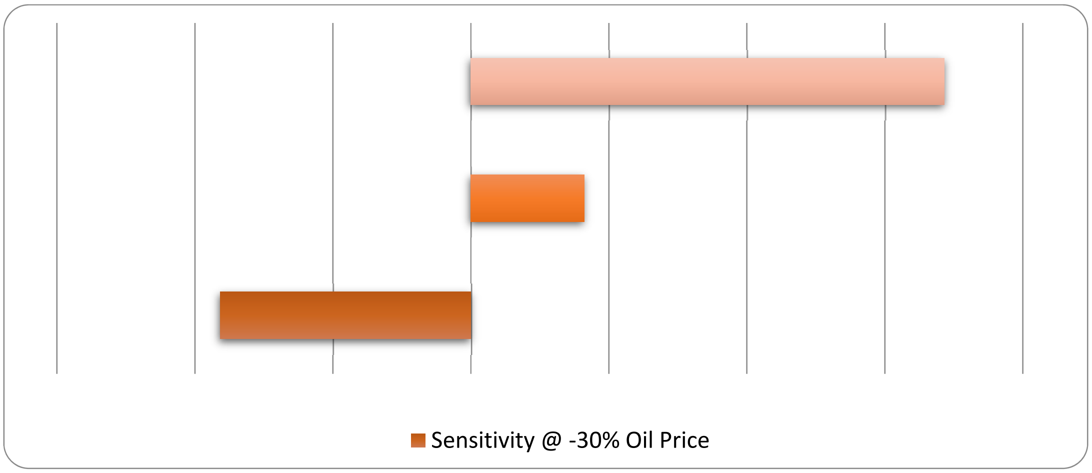

Figure 10: The sensitivity analysis of oil price at 30%

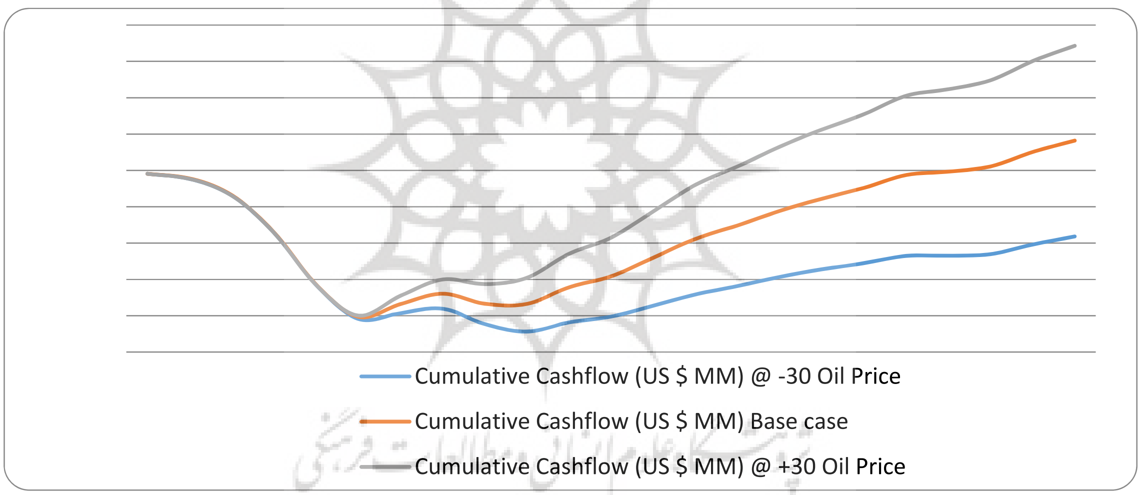

Figure 11: The cumulative cash flow for oil price showing the different breakeven points

The CAPEX sensitivity analysis was also carried out based on 30% of the nominal value, the base case. The result of the sensitivity of CAPEX is shown in Figure 12. The cumulative cash flow plot for the three scenarios is also shown in Figure 13. See appendix 2 for the computed table.

The OPEX used to compute the sensitivity analysis for this scenario was based on 30% of the base case (the nominal value). The nominal value is the historical operational cost of the case study from when it started production in 1995 until 2012. The results of the sensitivity analysis of OPEX are shown in Figure 14. The cumulative cash flow plot for these three scenarios is also shown in Figure 15. See appendix 2 for the computed table.

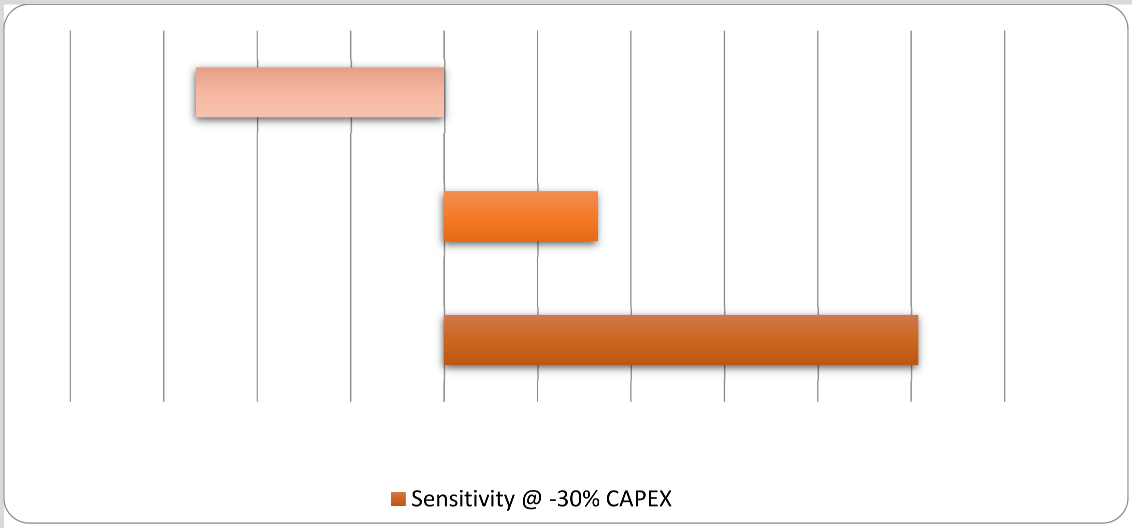

Figure 12: The sensitivity analysis of CAPEX at 30%

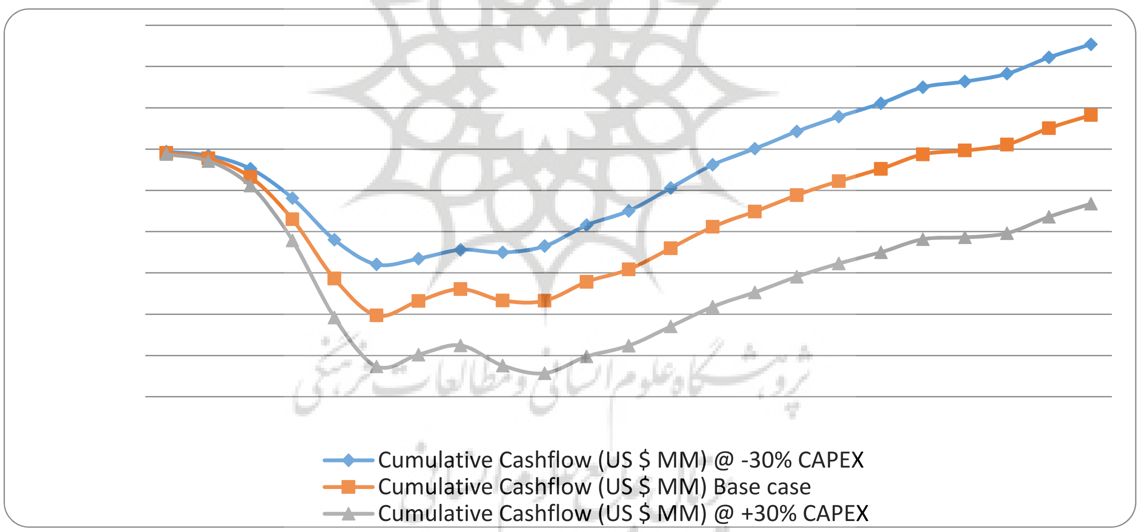

Figure 13: The cumulative cash flow for CAPEX showing the different breakeven points

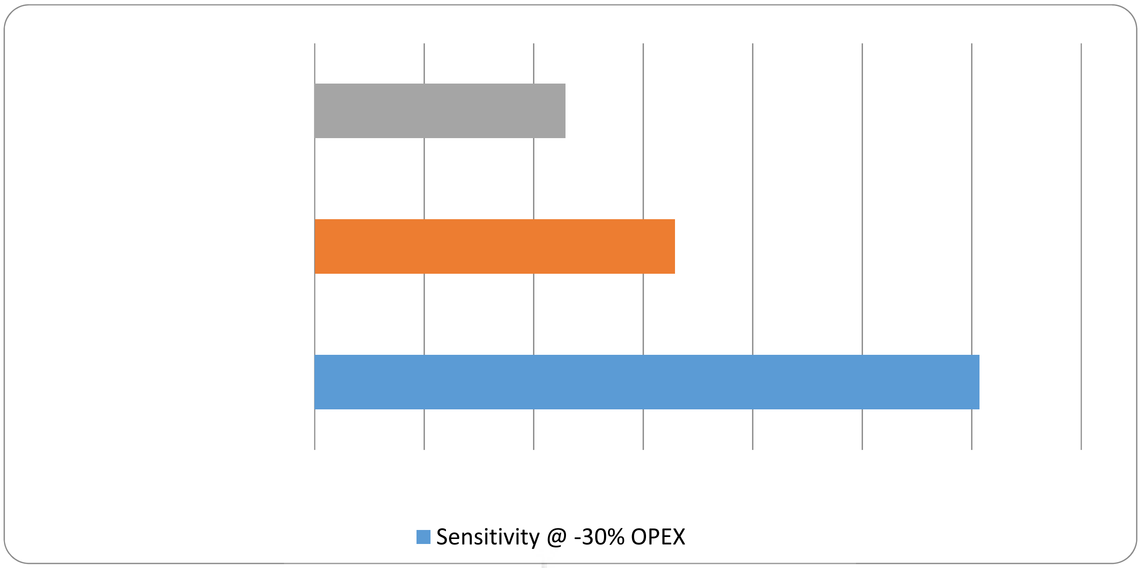

Figure 14: The sensitivity analysis of OPEX at 30%

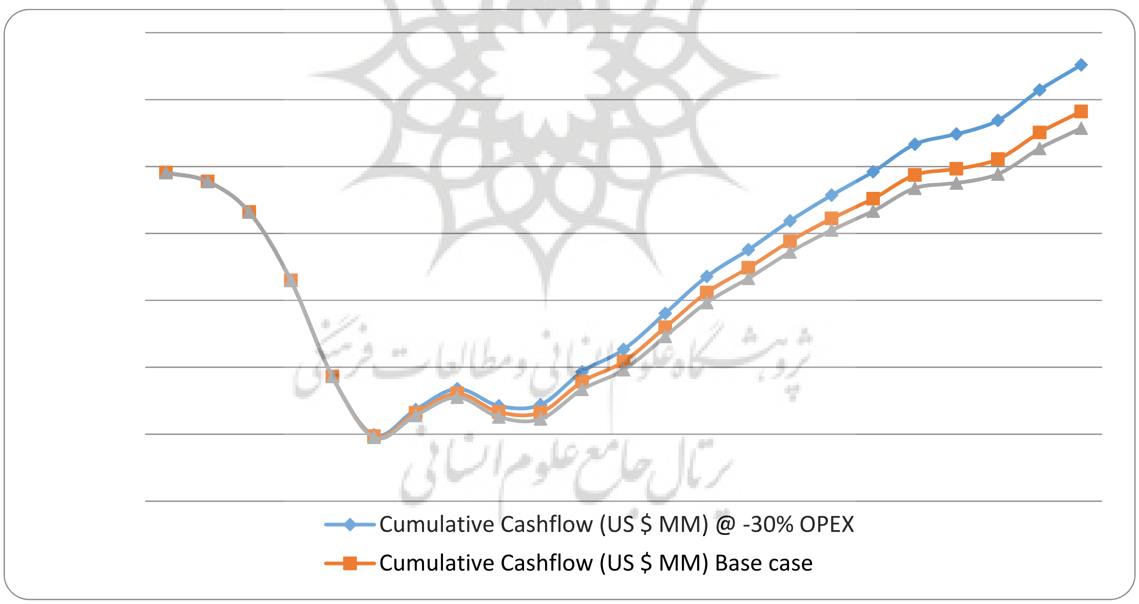

Figure 15: The cumulative cash flow for OPEX showing the different breakeven points

4.2. Discussion

The results obtained from the economic analysis that was carried out for the case study permit a significant look at the objectives and questions that were set out to be investigated and identified in this study, including the following.

4.2.1. The economic feasibility and viability of oil rim development

Based on the results from the economic analysis that was carried out, oil rim development is profitable, but it is marginally economical. According to Ike and Mbee (2011), it is the marginal position between economic fortune and failure. This is because it requires enormous capital investment to develop the reservoir and extract the oil to the surface. Since the development started in Troll Oilfield, there has been constant investment yearly to improve, expand, and extract the oil more economically. The oil rim differs from other reservoirs because its thin column requires a multidisciplinary team and technology to extract the oil economically. Figure 16 shows the capital investment since the development of the Troll oilfield. Developing oil rims is capital-intensive.

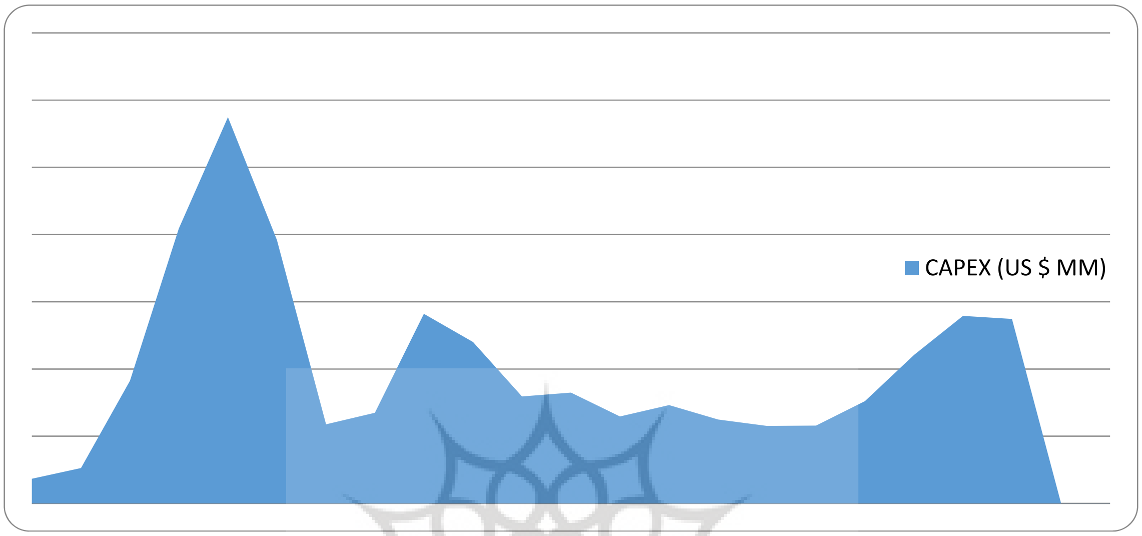

Figure 16: The capital investment of the Troll oilfield

According to Figure 16, not until 2010 was constant capital investment yearly in the field. In the base case scenario, the breakeven point from the cumulative cash flow was 14 years after production. The reasons include drilling more multilateral and horizontal wells in the field (field expansion). The feasibility and viability of oil rim development depend on factors such as CAPEX, OPEX, oil price, and fiscal structure (tax).

The sensitivity analysis shows that oil price is the main factor determining the viability of oil rim development. Oil rim development is very economical at high oil prices, as shown in Figure 10. At the nominal value, the base case scenario, it is marginally economical, but producing an oil rim at a low price is not viable.

The influence of CAPEX is indisputable because oil rim development is capital-intensive, as shown in Figure 16. The sensitivity analysis of the CAPEX shows a lower impact than that of oil prices. Oil rim development is viable at a low capital cost. Technology advancement has to be more efficient and economical to develop and produce oil from rim reservoirs. If the cost of developing an oil rim increases, just as it is in the sensitivity analysis, it is not viable to develop an oil rim. At this point, it is economically not viable.

Operating cost has a minor impact on the viability of developing the oil rim. The cumulative cash flow was lower than that of high oil prices and capital costs. Further, the breakeven point was almost the same as the base case.

The tax also has a role to play in developing the oil rim, but this depends on the country in which the reservoir has been developed. In the case of the Troll oilfield, the petroleum tax regime has experienced an increase in recent years, which also impacts the cash flow analysis; however, since the tax rate does not undergo sensitivity analysis, its impact is not felt on the results.

Based on the results of this analysis, oil rim development is viable but on certain conditions (low CAPEX and high oil price). Oil price is the primary determinant of the viability of oil rim development.

4.2.2. Economic comparison

Based on the economic analysis, the estimated production cost of oil rim ranges from $50 to $60 per barrel in the Troll Field. The production cost includes both the lifting cost and the development cost. The lifting cost is the operational cost to extract the oil to the surface, while the development cost is the equipment to develop wells. Table 1 presents the conventional crude oil and natural gas cost between 2007 and 2009. Comparing oil rim development cost with the EIA estimate, it is expensive to develop rim reservoirs.

Table 1: The cost of producing conventional crude oil and natural gas (EIA 2012)

	Lifting cost	Finding cost	Total upstream cost
Average of the United States	$12.18	$21.58	$33.76
On-shore	$12.73	$18.65	$31.38
Offshore	$10.09	$41.51	$51.60
Average of all other countries	$9.95	$15.13	$25.08
Canada	$12.69	$12.07	$24.76
Africa	$10.31	$35.01	$45.32
Middle East	$9.89	$6.99	$16.88
Central and South America	$6.21	$20.43	$26.64

According to Greenbang (2012) estimate, US Gulf of Mexico deepwater oil is around $65 per barrel, Nigerian deepwater oil is around $78 per barrel, Canada oil sands is around $85 per barrel, gas to liquid is more than $90 per barrel, and other unconventional sources in North and South America is around $95 per barrel. Further, Reuters (2009) reported the estimated production costs per barrel of heavy oil/bitumen between $32 and $68, oil shales between $52 and $113, gas to liquid between $38 and $113, and coal to liquid between $60 and $113. Comparing oil rim development cost with other liquid fuel sources shows that it is economical to produce oil rim rather than other liquid fuel sources. Figure 17 shows the global marginal cost of the production of liquid fuels in 2008.

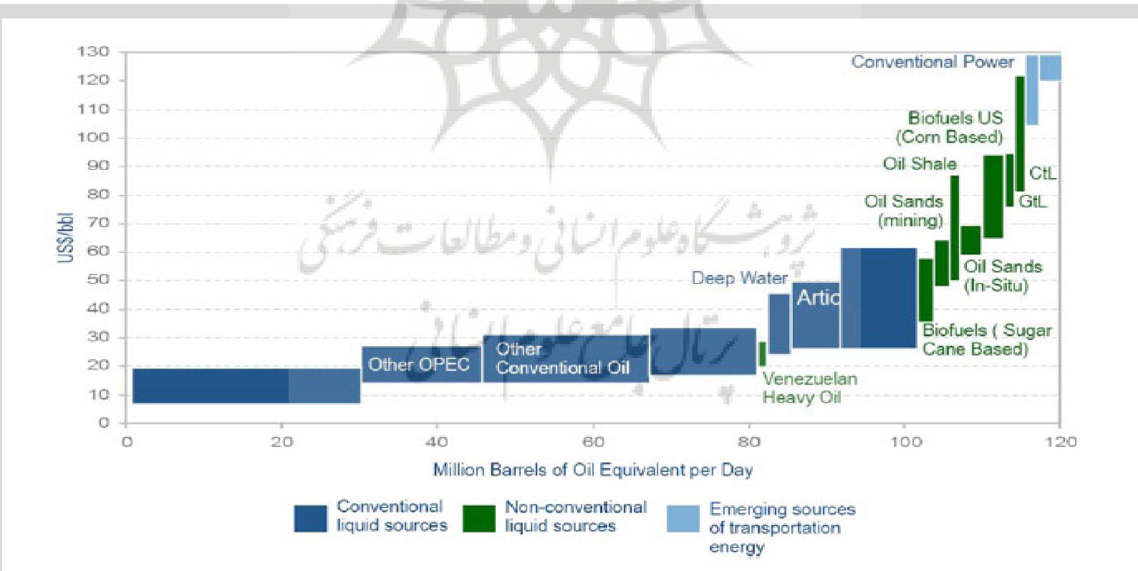

Figure 17: The global marginal cost of liquid fuel production (Fantazzini et al., 2011)

4.2.3. The role of technology in oil rim development

The type of technology used in developing oil rims determines the efficiency and economic feasibility of the development. Technology has made it possible to develop oil rims, once seen as uncommercial. The Troll oilfield is a critical success story of this advancement in technology. Oil rim development involves complicated production, driving mechanisms, and well type/design/

drilling/completion techniques. An essential factor in exploiting thin oil columns in the Troll field is the ability to drill and steer the horizontal wells. The advanced drilling technology comes with real-time data processing of geological measurements and well placement. The development of the Troll Field oil rim has been incorporated with high-quality seismic and detailed geological models, which are the fundamentals of any reservoir development in the oil and gas industry. The increasing drilling of more extended horizontal sections, implementation of multilateral well technology, and inflow control device (ICD) applications have made the Troll oilfield development successful.

4.2.5. The development potentials of oil rim

The development of the oil rim has opportunities, but for its potential to become a reality, there must be an integration of geological uncertainty, technology, and economics. The two key opportunities that were identified in this study include the following.

4.2.6. Concurrent oil and gas development

Oil rim development presents a chance to produce both oil and gas simultaneously. This is called concurrent oil and gas production. The Troll field was once a gas field with an oil rim seen as uncommercial, but after integrating multidisciplinary action, it started producing oil. It is one of the largest oilfields in the world, and it is still expanding. The gas produced is exported to other neighboring countries in Europe (NPD, 2011).

Moreover, some of the gas produced is used for gas injection to support the reservoir drive mechanism and to generate electricity. Combining these potentials may make the government interested in investing in gas and starting to think about producing oil rims. Oil recovery from oil rims may appear in general as nonprofitable just looking only at the oil production; however, producing gas from it can make it more profitable because, with the increased focus on environmentally clean fuel due to climate change in the global scenario, it is crucial now to produce gas.

4.2.4. Field depletion strategy and production optimization

From the literature review and the field development overview of the Troll field critically analyzed, it could be concluded that oil rim development can be a depletion strategy for the matured oilfields. The reason is the capital investment for developing oil rims in a new field. A matured field experiencing a decline in production and with existing facilities could produce oil rim more profitably. These present a chance to utilize the rim reserve more economically and optimize production by drilling a sidetrack well to produce the oil rim. In this context, the oil price would play an essential role in economic analysis because management would be keen to know how much it costs to produce this rim reservoir. This is a crucial issue before any final investment decision is made. Developing oil rims because of field depletion and production optimization may give the operator a chance to make the best use of infrastructure and extend the economic life of the field. The Troll field was upgraded from a gas field into an oil and gas field. Currently, it is producing both oil and gas.

4.2.7. The economical and the technical factor of oil rim development

Oil rim development comes with both economic and technical challenges. Carrying this study, the critical business and technical factors identified include the following.

4.2.8. High cost of field development

This is an economic factor that affects oil rim development. Economic analysis is necessary for any business scenario. Oil rim development is more financially intensive than other types of reservoir development. The capital investment is high because of the technologies and multidisciplinary team involved. Many operators still regard oil rims as a nuisance because of the capital cost involved (Figure 16). This discourages oil and gas investors from developing oil rims. The development is quite different because it comes with improved oil recovery (IOR) and enhanced oil recovery (EOR). These factors contribute to the high CAPEX of oil rim development. Even at low capital costs, the conning phenomenon brings additional costs during operation. As coning starts, it reduces oil and gas production, thereby increasing the operating cost and reducing revenue (Onwukwe et al., 2012). Figure 18 shows the operational cost of the Troll field. According to Figure 18, immediately after the field started producing water, the operational cost increased as well.

Figure 18: The operational cost of the Troll oilfield

4.2.9. Coning phenomenon

This phenomenon is a technical challenge that affects oil rim production. Oil production from the oil rim is typical of the double coning phenomenon, which could be either early propensity of gas or water production. In this case study, the water cut in Troll has steadily been increasing, as well as the gas-to-oil ratio. The oil production from the Troll field has fallen due to water coming in recent years. This started after the field reached its peaked production in 2001, as shown in Figure 18.

According to NPD (2011), water production came too soon. This challenges production facilities and has environmental concerns for the field. Research has shown that horizontal wells are better than vertical wells in developing oil rims because they reduce the early conning phenomenon. It is not easy in long-term practice because of the water aquifer in the reservoir. This partially annulled the benefit of the horizontal well in the field. According to Silva and Dawe (2010), coning is unavoidable when there is a thin oil-bearing layer. This shows that conning is unavoidable in oil rim production, even with horizontal wells. Figure 19 demonstrates the coning issue in the Troll field and how production has dropped since the field started producing water. Coning has a significant impact on operations, oil recovery, and economics. It is a crucial technical concern when extracting oil from the oil rim.

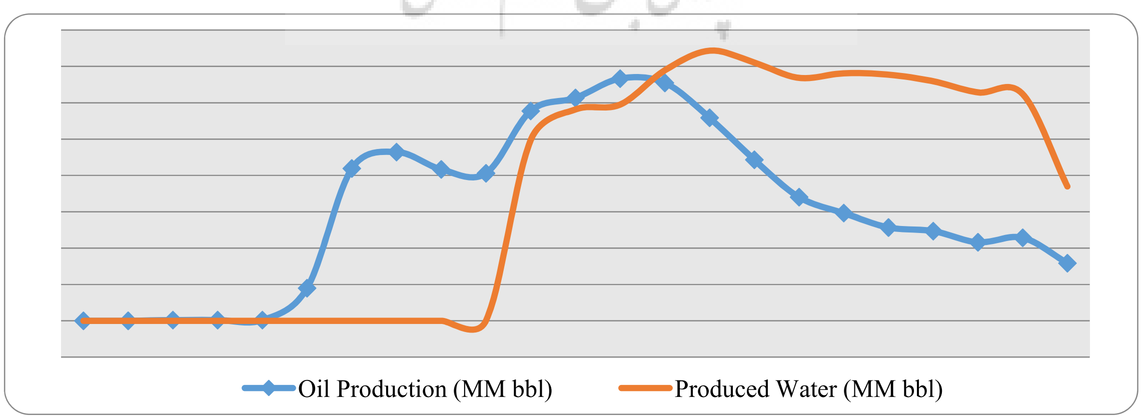

Figure 19: The coning phenomenon in the Troll oilfield

5. Conclusions and recommendations

In the oil and gas industry, the main goal for management is not only to maintain assets and deliver oil and gas but also to look out for opportunities and break frontiers to optimize production. Oil rim presents an opportunity for this scenario but is quite challenging due to the financial commitment and technology involved in extracting the oil. With the continuous increase in the energy demand, many oil investors are compelled to take a second look at oil rims that were formerly considered uncommercial due to technological advancement. Oil rim has a significant role to play in meeting this demand. Based on the findings of this study, it brings an opportunity and a challenge.

Based on the result of the economic analysis that was carried out and the findings of this study, the following conclusions are drawn:

Firstly, oil rim development is feasible and viable under certain conditions. These conditions include oil price, OPEX, and CAPEX. Nevertheless, the primary determinant is the oil price. This is based on the sensitivity analysis carried out on oil prices. With the increasing oil price, oil rim development is vital in sustaining world oil production. As shown in the result of the sensitivity analysis carried out on CAPEX, this also has a significant impact on developing oil rims. CAPEX has discouraged investors from developing oil rims. At high CAPEX, oil rim development is not feasible and viable. Oil price shows more impact than CAPEX, and OPEX effects are seen during production activities. Its impact is seen when there are production challenges in the reservoir. Based on the sensitivity analysis, its impact is minor compared to oil price or CAPEX.

Secondly, the base-case scenario clearly shows that oil rim development is marginally economical. This is mainly due to the high capital development cost and technologies involved in extracting the oil to the surface.

Thirdly, oil rim development presents opportunities and challenges to the oil and gas industry. It not only presents the opportunity to simultaneously optimize production through oil and gas production but also offers a production challenge, which could be gas or water coning. Reducing this uncertainty could make it a more successful development.

Fourthly, technology has made oil rim development possible which was once seen as uncommercial in the past. It is a good business opportunity in the oil and gas industry.

Fifthly, comparing oil rim development with other sources of liquid fuels, it is economical to produce oil rim rather than other liquid fuel sources.

Many development projects in the oil and gas industry come with challenges, and investors interested in developing oil rim must be conscious of the following recommendations based on the reviewed literature and the data analyzed.

1. There must be a proper evaluation of the geological setting and technology involved in developing and producing oil rims to ensure the oil is cost-efficient.
2. Prediction in producing oil rims is crucial. This means regular active monitoring of the oil rim reservoir behavior is essential to predict failure and maximize recovery.
3. A real-time feasibility study should be carried out to analyze the technology involved to ensure successful management and application of the technology to reduce operational costs. Failure to understand this issue may increase operational costs and eventually affect the NPV of the field.
4. The economic analysis for investment decisions in oil rim development should be based on a deterministic approach and probabilistic methods, which involve uncertainty in multiple scenarios.
5. A holistic integration of reservoir management, field development strategy, and reservoir energy balance could make oil rim development a more profitable business while optimizing production to meet the ever-growing demand for energy with a favorable oil price.

Based on this recommendation, further studies should be carried out on the economic challenges of oil rim development to identify its uncertainty. Future studies should involve both the historical and forecast data of the field.

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APPENDIX 1

Table A1: The cash flow model for the base case scenario

Field Name	Year	Oil Production (MM bbl)	Oil Price ($)	Revenue (US $ MM)	CAPEX (US $ MM)	OPEX (US $ MM)	Tax (US $ mm)	Total Cash flow (US $ MM)	Cumulative Cash flow (US $ MM)
TROLL	1990	0.0	23.19		184.1		0.0	–184.1	–184.1
TROLL	1991	0.0	20.19		263.9		0.0	–263.9	–448.0
TROLL	1992	0.0	19.25		912.1		0.0	–912.1	–1360.1
TROLL	1993	0.0	16.74		2044.4		0.0	–2044.4	–3404.5
TROLL	1994	0.0	15.66		2873.5		0.0	–2873.5	–6278.0
TROLL	1995	18.0	16.75	300.9	1959.7	123.5	0.0	–1782.2	–8060.3
TROLL	1996	83.8	20.46	1714.7	588.3	192.2	235.4	698.7	–7361.5
TROLL	1997	92.9	18.97	1762.0	674.5	158.8	352.9	575.9	–6785.7
TROLL	1998	83.4	11.91	992.9	1410.5	133.6	0.0	–551.1	–7336.8
TROLL	1999	81.2	16.55	1343.8	1200.8	155.9	0.0	–12.9	–7349.7
TROLL	2000	115.5	27.4	3164.5	795.8	234.2	1221.0	913.6	–6436.1
TROLL	2001	122.7	23	2821.5	824.9	205.6	1183.8	607.1	–5828.9
TROLL	2002	133.3	22.81	3040.8	646.2	184.0	1189.3	1021.3	–4807.6
TROLL	2003	131.0	27.69	3626.4	732.1	213.3	1640.8	1040.2	–3767.4
TROLL	2004	111.7	37.41	4180.0	624.8	201.2	2616.1	737.9	–3029.5
TROLL	2005	88.6	49.81	4415.3	576.4	225.5	2818.5	794.9	–2234.6
TROLL	2006	68.1	58.3	3967.7	579.1	297.5	2411.1	680.1	–1554.5
TROLL	2007	59.3	64.2	3806.2	760.5	353.2	2100.2	592.4	–962.1
TROLL	2008	51.4	91.48	4700.1	1103.4	378.2	2510.5	708.1	–254.1
TROLL	2009	49.4	53.48	2640.4	1395.4	409.1	652.0	183.9	–70.2
TROLL	2010	43.2	71.21	3076.9	1373.0	391.0	1024.1	288.8	218.7
TROLL	2011	45.7	87.48	3997.0	0.0	391.0	2812.7	793.3	1012.0
TROLL	2012	31.7	102.8	3262.1	0.0	391.0	2239.5	631.7	1643.7
Total		1410.76495		52813.38	21523.2	4638.6	25007.9	1643.66879	

APPENDIX 2

Table A2: The sensitivity analysis for oil price at –30%

Field Name	Year	Oil Production (mm bbl)	Oil Price ($)	Sensitivity at –30%	0il Price at –30%	Revenue (US $ mm)	CAPEX (US $ mm)	OPEX (US $ mm)	Tax (US $ mm)	Total Cash flow (US $ mm)	Cumulative Cash flow (US $ mm)
TROLL	1990	0.0	23.2	7.0	16.2		184.1			–184.1	–184.1
TROLL	1991	0.0	20.2	6.1	14.1		283.9			–283.9	–468.0
TROLL	1992	0.0	19.3	5.8	13.5		912.1			–912.1	–1380.0
TROLL	1993	0.0	16.7	5.0	11.7		2044.4			–2044.4	–3424.5
TROLL	1994	0.0	15.7	4.7	11.0		2873.5			–2873.5	–6298.0
TROLL	1995	18.0	16.8	5.0	11.7	210.6	1959.7	123.5	0.0	–1872.5	–8170.5
TROLL	1996	83.8	20.5	6.1	14.3	1200.3	588.3	192.2	105.8	314.0	–7856.5
TROLL	1997	92.9	19.0	5.7	13.3	1233.4	674.5	158.8	152.1	248.1	–7608.4
TROLL	1998	83.4	11.9	3.6	8.3	695.0	1410.5	133.6	0.0	–849.0	–8457.4
TROLL	1999	81.2	16.6	5.0	11.6	940.7	1200.8	155.9	0.0	–416.0	–8873.4
TROLL	2000	115.5	27.4	8.2	19.2	2215.2	795.8	234.2	677.9	507.3	–8366.2
TROLL	2001	122.7	23.0	6.9	16.1	1975.0	824.9	205.6	624.3	320.2	–8046.0
TROLL	2002	133.3	22.8	6.8	16.0	2128.6	646.2	184.0	698.6	599.9	–7446.1
TROLL	2003	131.0	27.7	8.3	19.4	2538.5	732.1	213.3	975.0	618.1	–6828.0
TROLL	2004	111.7	37.4	11.2	26.2	2926.0	624.8	201.2	1638.0	462.0	–6366.0
TROLL	2005	88.6	49.8	14.9	34.9	3090.7	576.4	225.5	1785.3	503.5	–5862.4
TROLL	2006	68.1	58.3	17.5	40.8	2777.4	579.1	297.5	1482.6	418.2	–5444.3
TROLL	2007	59.3	64.2	19.3	44.9	2664.3	760.5	353.2	1209.5	341.1	–5103.1
TROLL	2008	51.4	91.5	27.4	64.0	3290.1	1103.4	378.2	1410.6	397.9	–4705.2
TROLL	2009	49.4	53.5	16.0	37.4	1848.3	1395.4	409.1	34.1	9.6	–4695.6
TROLL	2010	43.2	71.2	21.4	49.8	2153.8	1373.0	391.0	304.1	85.8	–4609.8
TROLL	2011	45.7	87.5	26.2	61.2	2797.9	0.0	391.0	1877.4	529.5	–4080.3
TROLL	2012	31.7	108.8	32.6	76.2	2416.8	0.0	391.0	1580.1	445.7	–3634.6
Total		1410.8				37102.6	21543.2	4638.6		–3634.6	

Table A3: The sensitivity analysis for oil price at +30%

Field Name	Year	Oil Production (mm bbl)	Oil Price ($)	Sensitivity at 30%	Oil Price at 30%	Revenue (US $ mm)	CAPEX (US $ mm)	OPEX (US $ mm)	Tax (US $ mm)	Total Cash flow (US $ mm)	Cumulative Cash flow (US $ mm)
TROLL	1990	0.0	23.2	7.0	30.1		184.1		0.0	–184.1	–184.1
TROLL	1991	0.0	20.2	6.1	26.2		283.9		0.0	–283.9	–468.0
TROLL	1992	0.0	19.3	5.8	25.0		912.1		0.0	–912.1	–1380.0
TROLL	1993	0.0	16.7	5.0	21.8		2044.4		0.0	–2044.4	–3424.5
TROLL	1994	0.0	15.7	4.7	20.4		2873.5		0.0	–2873.5	–6298.0
TROLL	1995	18.0	16.8	5.0	21.8	391.2	1959.7	123.5	0.0	–1692.0	–7990.0
TROLL	1996	83.8	20.5	6.1	26.6	2229.1	588.3	192.2	365.0	1083.5	–6906.5
TROLL	1997	92.9	19.0	5.7	24.7	2290.6	674.5	158.8	553.8	903.6	–6002.9
TROLL	1998	83.4	11.9	3.6	15.5	1290.8	1410.5	133.6	0.0	–253.3	–6256.1
TROLL	1999	81.2	16.6	5.0	21.5	1746.9	1200.8	155.9	48.4	341.9	–5914.2
TROLL	2000	115.5	27.4	8.2	35.6	4113.9	795.8	234.2	1764.0	1319.9	–4594.3
TROLL	2001	122.7	23.0	6.9	29.9	3667.9	824.9	205.6	1743.3	894.1	–3700.2
TROLL	2002	133.3	22.8	6.8	29.7	3953.1	646.2	184.0	1680.1	1442.8	–2257.4
TROLL	2003	131.0	27.7	8.3	36.0	4714.3	732.1	213.3	2306.6	1462.3	–795.1
TROLL	2004	111.7	37.4	11.2	48.6	5434.0	624.8	201.2	3594.2	1013.8	218.6
TROLL	2005	88.6	49.8	14.9	64.8	5739.9	576.4	225.5	3851.6	1086.4	1305.0
TROLL	2006	68.1	58.3	17.5	75.8	5158.1	579.1	297.5	3339.5	941.9	2246.9
TROLL	2007	59.3	64.2	19.3	83.5	4948.1	760.5	353.2	2990.8	843.6	3090.5
TROLL	2008	51.4	91.5	27.4	118.9	6110.1	1103.4	378.2	3610.3	1018.3	4108.8
TROLL	2009	49.4	53.5	16.0	69.5	3432.5	1395.4	409.1	1269.9	358.2	4466.9
TROLL	2010	43.2	71.2	21.4	92.6	4000.0	1373.0	391.0	1744.1	491.9	4958.9
TROLL	2011	45.7	87.5	26.2	113.7	5196.2	0.0	391.0	3748.1	1057.1	6016.0
TROLL	2012	31.7	102.8	30.8	133.6	4240.8	0.0	391.0	3002.9	847.0	6863.0
Total		1410.8				68657.4	21543.2	4638.6	35612.7	6863.0	

Table A4: The sensitivity analysis for CAPEX at +30%

Field Name	Year	Oil Production (mm bbl)	Oil Price ($)	Revenue (US $ MM)	CAPEX (US $ MM)	OPEX (US $ MM)	Tax (US $ mm)	Total Cash flow (US $ MM)	Cumulative Cash flow (US $ MM)
TROLL	1990	0.0	23.2	0.0	239.4		0.0	–239.4	–239.4
TROLL	1991	0.0	20.2	0.0	343.0		0.0	–343.0	–582.4
TROLL	1992	0.0	19.3	0.0	1185.7		0.0	–1185.7	–1768.1
TROLL	1993	0.0	16.7	0.0	2657.8		0.0	–2657.8	–4425.9
TROLL	1994	0.0	15.7	0.0	3735.6		0.0	–3735.6	–8161.5
TROLL	1995	18.0	16.8	300.9	2547.6	123.5	0.0	–2370.1	–10531.6
TROLL	1996	83.8	20.5	1714.7	764.8	192.2	190.9	566.7	–9964.9
TROLL	1997	92.9	19.0	1762.0	876.8	158.8	276.1	450.4	–9514.5
TROLL	1998	83.4	11.9	992.9	1833.6	133.6	0.0	–974.3	–10488.7
TROLL	1999	81.2	16.6	1343.8	1561.0	155.9	0.0	–373.1	–10861.8
TROLL	2000	115.5	27.4	3164.5	1034.5	234.2	1084.4	811.4	–10050.4
TROLL	2001	122.7	23.0	2821.5	1072.4	205.6	1020.3	523.2	–9527.2
TROLL	2002	133.3	22.8	3040.8	840.1	184.0	1085.1	931.8	–8595.4
TROLL	2003	131.0	27.7	3626.4	951.7	213.3	1506.4	955.0	–7640.4
TROLL	2004	111.7	37.4	4180.0	812.2	201.2	2469.9	696.6	–6943.7
TROLL	2005	88.6	49.8	4415.3	749.3	225.5	2683.6	756.9	–6186.8
TROLL	2006	68.1	58.3	3967.7	752.8	297.5	2275.6	641.8	–5545.0
TROLL	2007	59.3	64.2	3806.2	988.7	353.2	1922.2	542.2	–5002.8
TROLL	2008	51.4	91.5	4700.1	1434.4	378.2	2252.3	635.3	–4367.6
TROLL	2009	49.4	53.5	2640.4	1814.0	409.1	325.5	91.8	–4275.8
TROLL	2010	43.2	71.2	3076.9	1785.0	391.0	702.8	198.2	–4077.6
TROLL	2011	45.7	87.5	3997.0	0.0	391.0	2812.7	793.3	–3284.2
TROLL	2012	31.7	102.8	3262.1	0.0	391.0	2239.5	631.7	–2652.6
Total				52813.4	27980.2			–2652.6	

Table A5: The sensitivity analysis for CAPEX at –30%

Field Name	Year	Oil Production (MM bbl)	Oil Price ($)	Revenue (US $ MM)	CAPEX (US $ MM)	OPEX (US $ MM)	Tax (US $ mm)	Total Cash flow (US $ MM)	Cumulative Cash flow (US $ MM)
TROLL	1990	0.0	23.19	0.0	128.9		0.0	–128.9	–128.9
TROLL	1991	0.0	20.19	0.0	184.7		0.0	–184.7	–313.6
TROLL	1992	0.0	19.25	0.0	638.4		0.0	–638.4	–952.1
TROLL	1993	0.0	16.74	0.0	1431.1		0.0	–1431.1	–2383.2
TROLL	1994	0.0	15.66	0.0	2011.5		0.0	–2011.5	–4394.6
TROLL	1995	18.0	16.75	300.9	1371.8	123.5	0.0	–1194.3	–5589.0
TROLL	1996	83.8	20.46	1714.7	411.8	192.2	190.9	279.9	–5309.1
TROLL	1997	92.9	18.97	1762.0	472.1	158.8	276.1	429.8	–4879.3
TROLL	1998	83.4	11.91	992.9	987.3	133.6	0.0	–128.0	–5007.2
TROLL	1999	81.2	16.55	1343.8	840.5	155.9	43.1	304.3	–4702.9
TROLL	2000	115.5	27.4	3164.5	557.0	234.2	1357.5	1015.8	–3687.2
TROLL	2001	122.7	23	2821.5	577.5	205.6	1347.4	691.0	–2996.1
TROLL	2002	133.3	22.81	3040.8	452.3	184.0	1293.6	1110.9	–1885.2
TROLL	2003	131.0	27.69	3626.4	512.4	213.3	1775.2	1125.4	–759.8
TROLL	2004	111.7	37.41	4180.0	437.3	201.2	2762.3	779.1	19.3
TROLL	2005	88.6	49.81	4415.3	403.5	225.5	2953.3	833.0	852.3
TROLL	2006	68.1	58.3	3967.7	405.3	297.5	2546.6	718.3	1570.6
TROLL	2007	59.3	64.2	3806.2	532.4	353.2	2278.1	642.6	2213.1
TROLL	2008	51.4	91.48	4700.1	772.4	378.2	2768.7	780.9	2994.0
TROLL	2009	49.4	53.48	2640.4	976.8	409.1	978.5	276.0	3270.0
TROLL	2010	43.2	71.21	3076.9	961.1	391.0	1345.4	379.5	3649.5
TROLL	2011	45.7	87.48	3997.0	0.0	391.0	2812.7	793.3	4442.8
TROLL	2012	31.7	102.8	3262.1	0.0	391.0	2239.5	631.7	5074.5
Total				52813.4	15066.2			5074.5	

Table A6: The sensitivity analysis for OPEX at –30%

Field Name	Year	Oil Production (mm bbl)	Oil Price ($)	Revenue (US $ mm)	CAPEX (US $ mm)	OPEX (US $ mm)	Tax (US $ mm)	Total Cash flow (US $ mm)	Cumulative Cash flow (US $ mm)
TROLL	1990	0.0	23.2		184.1	0.0	0.0	–184.1	–184.1
TROLL	1991	0.0	20.2		263.9	0.0	0.0	–263.9	–448.0
TROLL	1992	0.0	19.3		912.1	0.0	0.0	–912.1	–1360.1
TROLL	1993	0.0	16.7		2044.4	0.0	0.0	–2044.4	–3404.5
TROLL	1994	0.0	15.7		2873.5	0.0	0.0	–2873.5	–6278.0
TROLL	1995	18.0	16.8	300.9	1959.7	86.4	0.0	–1745.2	–8023.2
TROLL	1996	83.8	20.5	1714.7	588.3	134.6	235.4	756.4	–7266.8
TROLL	1997	92.9	19.0	1762.0	674.5	111.1	352.9	623.5	–6643.3
TROLL	1998	83.4	11.9	992.9	1410.5	93.5	0.0	–511.1	–7154.4
TROLL	1999	81.2	16.6	1343.8	1200.8	109.1	0.0	33.9	–7120.5
TROLL	2000	115.5	27.4	3164.5	795.8	163.9	1221.0	983.9	–6136.7
TROLL	2001	122.7	23.0	2821.5	824.9	143.9	1183.8	668.8	–5467.8
TROLL	2002	133.3	22.8	3040.8	646.2	128.8	1189.3	1076.5	–4391.3
TROLL	2003	131.0	27.7	3626.4	732.1	149.3	1640.8	1104.2	–3287.1
TROLL	2004	111.7	37.4	4180.0	624.8	140.9	2616.1	798.2	–2488.9
TROLL	2005	88.6	49.8	4415.3	576.4	157.9	2818.5	862.6	–1626.2
TROLL	2006	68.1	58.3	3967.7	579.1	208.3	2411.1	769.3	–856.9
TROLL	2007	59.3	64.2	3806.2	760.5	247.2	2100.2	698.3	–158.6
TROLL	2008	51.4	91.5	4700.1	1103.4	264.7	2510.5	821.5	662.9
TROLL	2009	49.4	53.5	2640.4	1395.4	286.4	652.0	306.6	969.5
TROLL	2010	43.2	71.2	3076.9	1373.0	273.7	1024.1	406.1	1375.7
TROLL	2011	45.7	87.5	3997.0	0.0	273.7	2812.7	910.6	2286.3
TROLL	2012	31.7	102.8	3262.1	0.0	273.7	2239.5	748.9	3035.2
Total				52813.4	21523.2	3247.0		3035.2	

Table A7: The sensitivity analysis for OPEX at +30%

Field Name	Year	Oil Production (mm bbl)	Oil Price ($)	Revenue (US $ mm)	CAPEX (US $ mm)	OPEX (US $ mm)	Tax (US $ mm)	Total Cash flow (US $ mm)	Cumulative Cash flow (US $ mm)
TROLL	1990	0.0	23.2		184.1	0.0	0.0	–184.1	–184.1
TROLL	1991	0.0	20.2		263.9	0.0	0.0	–263.9	–448.0
TROLL	1992	0.0	19.3		912.1	0.0	0.0	–912.1	–1360.1
TROLL	1993	0.0	16.7		2044.4	0.0	0.0	–2044.4	–3404.5
TROLL	1994	0.0	15.7		2873.5	0.0	0.0	–2873.5	–6278.0
TROLL	1995	18.0	16.8	300.9	1959.7	160.5	0.0	–1819.3	–8097.3
TROLL	1996	83.8	20.5	1714.7	588.3	249.9	220.9	655.6	–7441.7
TROLL	1997	92.9	19.0	1762.0	674.5	206.4	334.8	546.3	–6895.4
TROLL	1998	83.4	11.9	992.9	1410.5	173.6	0.0	–591.2	–7486.6
TROLL	1999	81.2	16.6	1343.8	1200.8	202.6	0.0	–59.6	–7546.2
TROLL	2000	115.5	27.4	3164.5	795.8	304.4	1180.8	883.5	–6662.7
TROLL	2001	122.7	23.0	2821.5	824.9	267.2	1143.1	586.2	–6076.5
TROLL	2002	133.3	22.8	3040.8	646.2	239.1	1159.7	995.8	–5080.6
TROLL	2003	131.0	27.7	3626.4	732.1	277.3	1601.6	1015.4	–4065.2
TROLL	2004	111.7	37.4	4180.0	624.8	261.6	2569.0	724.6	–3340.6
TROLL	2005	88.6	49.8	4415.3	576.4	293.2	2765.7	780.1	–2560.6
TROLL	2006	68.1	58.3	3967.7	579.1	386.8	2341.5	660.4	–1900.2
TROLL	2007	59.3	64.2	3806.2	760.5	459.1	2017.5	569.0	–1331.1
TROLL	2008	51.4	91.5	4700.1	1103.4	491.6	2422.0	683.1	–648.0
TROLL	2009	49.4	53.5	2640.4	1395.4	531.9	556.3	156.9	–491.1
TROLL	2010	43.2	71.2	3076.9	1373.0	508.2	932.6	263.0	–228.1
TROLL	2011	45.7	87.5	3997.0	0.0	508.2	2721.3	767.5	539.5
TROLL	2012	31.7	102.8	3262.1	0.0	508.2	2148.0	605.9	1145.3
Total				52813.4	21523.2			1145.3	