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Sudan University of Science & Technology

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A Project Submitted in Partial Fulfillment of The Requirements of The Degree B.Sc. In transportation and refining Engineering

Design of A new Field Pipeline From Rawat field to Al-Jabalain

تصميم لخط انابيب من حقل الراوات الي الجبلين

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قال تعالى:

﴿ وَأَنْزَلَ اللَّهُ عَلَيْكَ الْكِتَابَ وَالْحِكْمَةَ وَعَلَّمَكَ مَا لَمْ تَكُنْ تَعْلَمُ ۚ وَكَانَ فَضْلُ اللَّهِ عَلَيْكَ عَظِيمًا ﴾

صدق الله العظيم

سورة النساء

﴿١١٣﴾

Dedication

إلى من أرضعتنا الحب والحنان

إلى من عاشت اصعب اللحظات كي نعيش اجمل اللحظات

إلى رمز الحب وبلسم الشفاء,,إلى الحب الباقي الذي لا يزول

إلى من تسعد بسعادتنا وتحزن بحزننا

إلى القلب الناصع بالبياض

نعم إلى الغالية

أمي

***

إلي من جرع ألكاس فارغا ليسقينا قطرة حب ... إلي من كلت انامله ليقدم لنا لحظة سعادة

إلي من حصد الأشواك عن دربنا ليمهد لنا طريق العلم

إلي القلب الأكبر

إلي الأب

***

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Abstract

Piping systems are the most important transmission method in oil industry that help distribution of the natural resources over different regions. This thesis was prepared in order to give detailed characterization of pipeline design process from the new Rawat field to Al-Jabalain CPF.

This study focus on determining the optimum route and diameter by using PIPESIM simulation and GIS technique. The design process is significantly impacted by the fluid properties , geological factors ,pumping system , pressure drop in the pipeline , selected material , environment and regulation , and took into account the expected problems that may face the design and construction phase.

The design results conclude two routes scenarios. The first scenario is an ideal straight line that does not consider any design factors. The second scenario (real situation) took into account all the factors affecting the route establishing and the obstacles faced, an estimation of the cost for the real scenario pipeline was done.

Keywords: Pipeline, Design ,Simulation, Pump requirements, Route selection

التجريد

أنظمة خطوط الأنابيب تعتبر من أهم طرق النقل في الصناعة البترولية لمساهمتها في توزيع المصادر الطبيعية خلال مناطق مختلفة ، هذه الدراسة أعدت لعرض وصف مفصل لعملية تصميم خط أنابيب يربط بين حقول الراوات الجديدة و منطقة الجبلين.

ركزت الدراسة على إيجاد المسار و القطر الأمثل لخط الأنابيب عن طريق برنامج (PIPESIM)و تقنية ال(GIS) ، عملية التصميم تتأثر بعدة عوامل مهمة وهي خواص المائع ، العوامل الجيولوجية ، المضخات، انخفاض الضغط في الأنبوب ،المادة المستخدمة لتصنيع الأنبوب ،العوامل البيئية ، والضوابط القانونية . ويتم الأخذ في الاعتبار المشاكل المتوقعة خلال عملة التصميم والتركيب.

مخرجات عملية التصميم تتمثل في مسارين. المسار الأول يعتبر مسارا مثاليا ولا يأخذ في الاعتبار أيا من العوامل التصميمية، أما المسار الثاني هو المسار (الوضع الحقيقي)الذي يأخذ في الاعتبار كل عوامل التصميم والعوائق المتوقعة. تم تقدير التكلفة المتعلقة بالمسار الحقيقي.

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Chapter 1

Introduction

1.1 Introduction:

After the industrial revolution and as a main source of fuel, especially in transportation. Oil and gas have become a necessity in the past decades and their need increases with the increasing demand and the lack of other sources of sufficient fuel. Modern people's lives are based on an environment in which energy plays a (predominant) role. Oil and gas are major participants in the supply of energy.

The problem of transportation specially arises in the area of production fields after the produced oil is in the surface and must be moved from the production area to the desired area to be further more processed wither to be exported or to refineries. There are many solution of transportation but pipelines arise as one of the most economical, common and feasible means for the transportation of large quantities of crude oil. For efficient operation of a pipeline system, it is desirable to maintain a steady and continuous flow rate without any interruption such as shutdown of a pipeline (E. Shashi Menon, 2014).

Oil and Gas affect daily lives in most common parts of the worlds, and pipelines are the primary means by which the oil and gas are transported. Oil field surface pipeline systems are designed to gather and transport oil and gas from wells. This is an important production network in oilfields after reservoir exploration and oil recovery. It aims at gathering oil and gas from hundreds even thousands of individual wells and then transporting` them to a central plant in the oilfield. With a gathering pipeline network, oil and gas from wellheads are progressively transported through some intermediate stations , namely, from wellheads to flow stations, then to boosting stations and, finally, to the central gathering plant. During the transportation, heating and boosting are necessary (P. Hopkins, 2007).

It is no coincidence that an extensive pipeline network goes hand-in-hand with high standard of living. pipelines are utilized to transport the supply from their source a desired area.

1.2 The Problem Statement:

Establishing the optimum route and diameter for a Pipeline system connecting the new Rawat oil field with al-Jabalain CPF.

In order to obtain optimum results for a pipeline transmission system and decide on the pipeline diameter, material, compression/pumping power requirements ,and optimum location of the pipeline route, some considerations must be taken into account such as the type of crude ,properties of crude (API, wax content…etc), distance ,geological factors, the capacity, start and end point, pumping power requirements for hydraulic balance, and performance ability, safety and environmental factors, corrosion effects in the pipeline, with the design code implications for gas and liquid pipelines, and economic feasibility.

1.3 Objectives:

- To investigate the field situation.
- Evaluate crude oil Properties and the expected quantity.
- Survey the area between Al-Rawat and Al-Jabalain to find the optimum location for the pipeline route.
- Design the new Pipeline system to simulate the physical situation.
- Obtain the optimum diameter, operating conditions, and minimum power requirements.
- Economic feasibility study to evaluate the Design.

Chapter 2
LITERATURE REVIEW

2.1 Introduction:

This chapter discussed the basic parameters, major factors in transmission pipeline hydraulic and properties of fluids. Pipe route selection, as well as the GIS concept, pumping system, losses due to friction, pipeline coating and PIPESIM application aspect are all well specified. The various components that contribute to the economics are introduced.

2.2 The Theoretical Background:

Pipeline is the most economical and only feasible means for the transportation of large quantities of crude oil. For efficient operation of a pipeline system, it is desirable to maintain a steady and continuous flow rate without any interruption such as shutdown of a pipeline. And the best way to maintain such operation conditions is through precise and accurate design of the pipeline system.

Pipelines may be small or large, nearly all of the mainline pipe is buried , but pipeline components such as pump stations are above ground with many different designs. The best piping configurations is the least expensive over long term basis.

2.2.1 Pipeline basic considerations:

There are critical pipeline design consideration parameters such as:

- Origin and destination points
- The characteristics and physical properties of the fluid.
- The desired mass-flow rate (or volume) of the fluid to be transported
- The pressure, temperature, and elevation at origin point A.
- The pressure, temperature, and elevation at destination point B.
- The distance between point A and point B (or length the fluid must travel) and the equivalent length (pressure losses) introduced by valves and fittings.

- Topography of pipeline route
- Maximum allowable operating pressure
- Hydraulic calculations
- Pipeline diameter wall thickness and required yield strength
- Pump station horse power requirements
- Distance between pump stations and there number.

Many factors have to be considered in the engineering and design of long distance pipeline, including the nature and volume of fluid to be transported, the length of the pipeline, the type of terrain traversed, and the environmental constraints.

To obtain optimum results for a pipeline transmission system, complex economic and engineering studies are necessary to decide on the pipeline diameter, material, compression/pumping power requirements, and location of the pipeline route.

2.2.2 Major Design factors

The major factors influencing pipeline system design are:

1. **Fluid properties**
2. **Regulation codes and standards**
3. **Environmental impacts**
4. **Design conditions**

1.Fluid properties:

The pipeline system design is significantly impacted by the properties of the fluid to be transported. The following properties are to be calculated for liquid :

- Temperature
- Pressure
- Viscosity
- Density
- Specific heat

- Pour point

2. Regulations codes and standards:

National and international regulations have been developed to limit the risk to reasonable minimum for the pipeline construction and operation to meet safety and environmental standards.

International codes such as the ASME B31 (American Society of Mechanical Engineers) code for pipeline transportation systems for liquid hydrocarbons and other liquids for the construction.

3. Environmental Impacts:

During construction of pipeline, environmental inspection is ongoing to ensure compliance with environmental design and protection procedures, and to maintain consistence with various regulatory approvals. Problems that are identified during the design and construction phase of the project are reviewed internally and may initiate environmental research, which in turn may modify future design criteria.

4. Design conditions:

1) Material And construction:

For long distance pipeline systems, the significant cost in term of capital investment is the cost of the pipe material and installation .Pipe line pressure, grade , installation location, and technique effect the cost and design (Mohitpour M et al 2000).

Pipe material/grade affect the wall thickness and determine the choice of or limit on the wielding/installation technique. For a given design pressure and pipe diameter , the wall thickness decrease with a higher grade material. However higher grade of steam are usually combined by cost premiums and more stringent construction techniques, which translate into higher costs.

The location of the pipeline or surrounding environment determines allowable material and labor/equipment, including construction materials requirements.

2) Operation

The conditions under which a pipeline operates are set at the design stage. The design stage should also determine the most stringent conditions the pipeline would operate under and provide for facilities to prevent failure, including line rupture.

3) Protection

Protection system of pipeline is required in the design stage for both Internal and external parts of the pipe.

External protection is usually applied to the pipeline through coating is usually a plastic material that wrapped or extruded into the pipe, or fusion-bonded to the surface.

Internal protection is applied to pipelines with fluids containing corrosive components such as salt water, hydrogen sulphide, or carbon dioxide/monoxide can cause internal corrosion. An example is the pipeline transportation of sour gas.

2.2.3 Key factors for route selection:

A pipeline system survey is sanctioned prior to construction to obtain complete and comprehensive record of all physical aspect associated with the system to design and construct a pipeline project the following survey activities are required:

- Preliminary route selection
- Engineering survey
- Legal survey
- Construction/As-built survey.

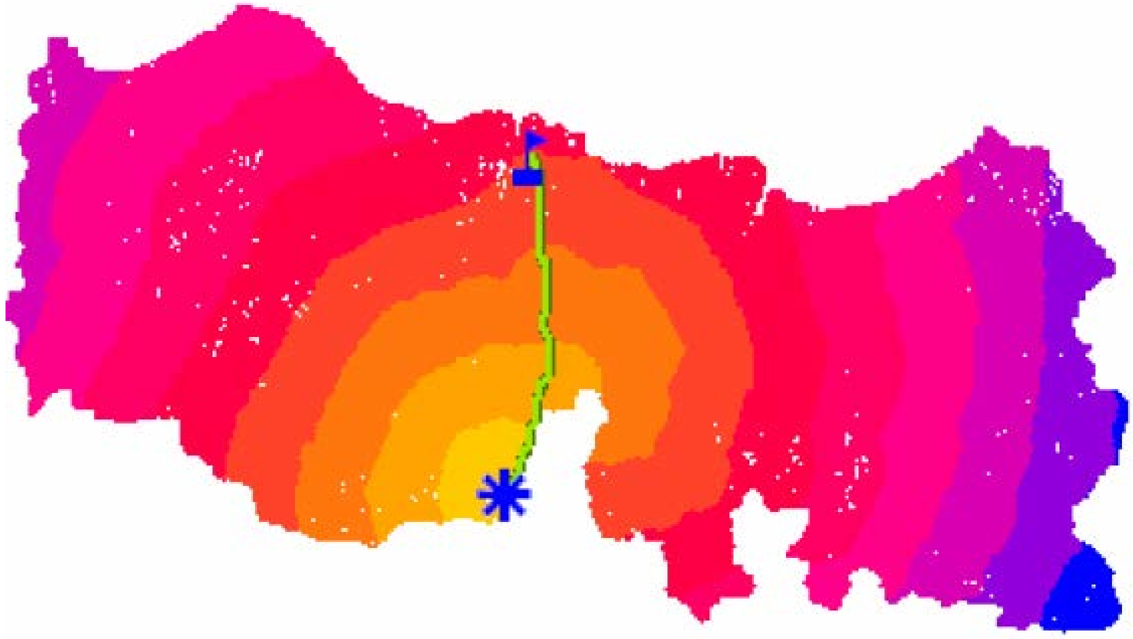
Route selection is a process of identifying constrains , avoiding undesirable areas and maintaining the economic feasibility of the pipeline. Having to divert a pipeline around obstacles can be very costly. The ideal route, of course would be a straight line from the origin to the terminal point. However, physiographic, environmental , design and construction constraints usually alter the route. Factors to be considered prior to optimal route selection for the pipeline are its cost efficiency, pipeline integrity, environmental impacts, public safety, land used constraints and restricted proximity to existing facilities (Mohitpour M. et al. 2000).

2.2.4 GIS Concept:

The overall objective in selecting a petroleum pipeline route is the connection of the crude/natural gas source to the refinery or utility company. Obviously, choosing the shortest, most direct route is always a goal for capital expenditure reasons. So, effective route selection process is very important for minimizing economic cost and determining the best route (Sandra C. Feldman et al,1995).

Till recently, route determination was created on the topographic maps manually. But nowadays, GIS technologies are used effectively in route determination process.

Geographic Information System (GIS) technology is integrated into the decision-support system and utilized to provide the alternative routes. The intermediate level is composed of the broad goal categories of pipeline length, operability, maintainability, approachability, feasibility of construction, and environmental friendliness. Each of these factors has sub factors, which are included in the analysis. Examples of the sub factors include minimizing environmental damage, ensuring accessibility, avoiding obstacles, avoiding routes parallel to high voltage transmission lines, using existing right-of ways if possible, avoiding densely populated areas, and keeping water and rail crossings to a minimum (Volkan Y.2007).



Fig(2.1): Optimum route using GIS

2.2.5 Pumping System:

The role of a pump is to provide sufficient pressure to move fluid through the system at the required flow rate. This energy compensates for the energy losses due to friction, elevation, velocity and pressure differences between the inlet and outlet of the system (J. Paul Tulli,1989).

Pumps may be classified in two general types, dynamic and positive displacement. Positive displacement pumps are those in which energy is imparted to the liquid in a fixed displacement volume, such as a casing or a cylinder, by the rotary motion of gears, screws, or vanes, or by reciprocating pistons or plungers.

2.2.6 Friction loss in Pipes:

Pipe Friction also named as major losses is the loss of pressure or head that occurs in pipes due to the various effect of the fluid properties and is mainly effected by viscosity. Pipe friction happens near the internal surface of the pipe wall(J. Paul Tulli 1989).

2.2.7 Pipeline Coating:

Pipeline design engineers have traditionally considered external anti-corrosion coatings for the protection of gas transmission pipelines, with less consideration given to the benefits of internal flow efficiency coatings.

The benefits of using Pipeline coating:

1. A reduction in the pressure drop in the pipeline and thus an increase in the flow rate of natural gas through the pipeline with the use of internal coating.

2. Mitigate the corrosion of the internal surface of the pipe during storage and transportation with the use of internal coating.

3. Provide a clean smooth surface for ease of pipe inspection.

4. Reduce the effort and cost of cleaning the pipeline after hydrostatic testing, and subsequent ease of disposal of water used in hydrostatic testing.

5.Decreased line maintenance through minimizing fouling and damage to valves.

2.2.8 Economics:

The economic analysis for any pipeline transport system and the estimation of the financial costs is based on the whole pipeline network, which includes the gathering, transportation and distribution network systems.

The computation of the financial costs for the pipeline industry includes two elements.

1. Capital Cost
2. Operating Cost

1- Capital Cost:

In general are costs that are fixed one time expenses incurred on the purchasing of land, buildings, construction, and equipment used in the production of goods. In pipeline industry capital cost are mainly the cost of the machines for the field exploration, trenching, development, pumps and pipe construction.

2- Operation Cost:

In general are the expenses which are related to the operation of business, component, piece of equipment or facility. In the pipeline industry these cost appear mainly from the cost of labor , fuels for the daily operation of machines, pumps, power and the costs of repair and maintenance.

2.3 Literature Review:

The relevant and important studies related to this thesis were studied and written to get a better understanding of the concepts of the thesis:

In 1979 P.P Borodavkin V.L Berezin ensured confidence in getting the best design based on optimum variant (pipeline route and parameters) and the detailed analysis of all factors and conditions influencing final optimum pipeline design by special calculating chart plotted on maps of possible pipeline layout region.

In 1983, works by Dr.lng. Lund discussed the challenges faced with design and construction of a high pressure pipeline close to other high pressure pipelines and electrical power transmission lines, the construction of three major fjord crossings, and the challenges in construction of large diameter high pressure pipelines.

In 2000, Yong Pai described practical considerations on material properties, the development of new steel and improve pipe manufacturing capabilities, enable high strength linepipe with appropriate toughness to be supplied , design loads, code requirements and the developments in design criteria for strength design of high strength pipes with yield anisotropy.

In 2000, Nelson et al reported that flow efficiency coatings may reduce the friction coefficient across a carbon steel surface by up to 50%, allowing transmission increases of 15 to 25%. A number of companies have conducted more in depth studies and reported the economic analysis of using internal flow efficiency coatings.

In 2001, Arne Ingvar et all discussed the challenges faced with design and construction of high pressure pipeline, and studied the possibility of construction of onshore pipeline with high design pressure by using a higher grade of steel, and finally discuss the challenges in construction of large diameter and high pressure pipeline.

In 2010 R.N. Burke and T. Ody offered a new method of low cost pipeline construction suitable for onshore gas and oil pipelines. The pipe is based on a thin wall liner that provide the fluid containment by using X200™ Steel. Steel X200™is a steel strip laminate technology which use high-performance adhesive to manufacture a metallic pipe , X200™.

In 2011 works by Mohamed Benaicha and Mansour Belhadri investigated the rheological properties of the light crude oil and its emulsions in order to obtain more knowledge about the rheological behavior of oil flow in pipelines. The results indicated that the rheological properties and the physical stability of emulsions were significantly influenced by the water contents and the nature of crude oils.

In 2016, Nawinsingh and Sajith Nair, 2016 presented a comparative study to optimize the material cost of line pipe, through a rational selection of the governing design code and material grade which lead to optimum capital expenditure (CAPEX), and result in a case study that indicate the opportunities exist to optimize the material cost up to 15%.

Chapter 3
METHODOLOGY

3.1 Introduction:

This chapter showed the selected software program and the company that owned the field for which the pipe is designed, and discussed the methodology of route selection, the expected problems to be faced and Pumping power. The components of the pipeline Economics are described in details.

3.1.1 PIPESIM:

Schlumberger's PIPESIM is a base system analysis software for well modeling , nodal analysis, artificial lift design, pipeline simulation, and process facilities simulation. It is a new generation in multiphase flow simulation to overcome fluid flow challenges and optimize production.

The PIPESIM simulator includes a calibration feature for flow correlation ,which can automatically adjust the holdup factor and friction factor, to the match measured pressures and temperature, additionally , the flow comparison operation can quickly sensitize to flow correlation and help selecting the most appropriate model. High resolution flow map can also be produced for any point in the system.

Advantages of PIPESIM:

Some of the main and most important advantages that PIPESIM simulator offers are listed below:

1) GIS :

PIPESIM contains a GIS model simulator which was suitable to be used in route selection to fulfill the objective of the thesis

2) Safe and effective fluid transport:

Simulation offers the ability to simulate real life situations and experiment different scenarios on them without any safety hazards or loss in cost.

3) Steady-state flow assurance:

The state of the system from start to operations is set constant as steady state.

In this thesis PIPESIM 2015 will be used in the simulation together with GIS maps to achieve the objectives of the thesis.

3.1.2 Rawat Petroleum Operating company (RPOC):

The RPOC was establish in 2015. The RPO company is a consortium of the government- owned SUDAPET (70 percent), Express petroleum and Gas Ltd Nigeria (15 percent) and another Nigerian Company MISANA (15 percent).

3.2 Pipeline Route selection:

The initially selected routes should address the intrinsic and extrinsic constraints inherent to pipeline construction and operation by avoiding or minimizing the various geographic and regulatory restrictions. The following elements headline restrictions, construction challenges, factors that affect routes that can actually help routing.

A) Physiographic:

Excessively steep slopes, Side slopes rocky slopes, Erosive soils, Rocky soil, Sandy soils, and Locations subjected to land movements(earthquakes, fault movements) are examples of important physiographic factors

B) Environment:

Environment and environmental conditions which are becoming highly supervised with the years due to their mass effect. Lakes fish spawning areas, Endangered species habitat ,Historical and archaeological sites, Forests and merchantable timberlands, Other factors considered during the selection process: Roads and railways corrosions, Areas of population concentration, Restricted areas such as, natural parks, Native reservations, Camp location, Forest regeneration sites.

Route selection in old times and before satellite imaging was available, was a long and expensive process that consumed a lot of human resources and effort especially in map selection and route selection because maps containing all the different required data and obstacles were not as easily available as they are today.

3.2.1 Method of route selection

1-Maps selection:

Establishing the route:

1- Identify areas to avoid, and select areas that are advantageous between the two points A and B , the start and end point of the line.

2- Draw a line from point A to B, while adhering to the previously identified restrictions.

3- Draw alternate routes.

4- Draft a preliminary route sketch.

2- **Primary evaluating of route:**

1- check route for restrictions

2-complete a rule of thumb cost estimation.

3- establishing the primary length of the route

3.2.2 Expected problems in route selection:

Are the problems that are expected to face the pipeline through its entire life period such as the phases of design, construction and operation. The expected problems are commonly one of the following:

1- Right-of-way Issues:

Another major issues is the shear amount of area a pipeline covers which can be a problem in securing the right of way, this can be an extremely costly and time consuming process.

2- Difficult terrain:

This include elements like mountain terrain, hills, change in elevation of the land and weather.

3- Infrastructure Shortfall:

New pipelines are built in areas that already have existing pipeline, in most cases the old pipeline are already too old or too small to support the new capacity.

4- Geopolitical issues:

Results mainly from the pipeline crossing political borders and political jurisdiction that may have their own codes and regulations which can cause serious delay.

3.3 Pumping Power Requirement:

A pump's power demand is directly proportional to the difference between the inlet and outlet pressure and the flow rate.

$$P = \Delta P_P q \tag{3.1}$$

Where:

ΔP_P: Is the difference in pressure at the inlet and the outlet of the pump,

Q: The flow rate.

The above equation expressed in imperial units is:

$$P_{hp} = \frac{\Delta P_P (psi)\ q(USgal/min)}{1714.2} \tag{3.2}$$

To obtain the pumping power in kilowatts:

$$P_{Kw = 0.746 * P_{hp}} \tag{3.3}$$

For a pump with efficiency less than 100% use:

$$P_{KW = \frac{Ideal\ Power}{efficency}} \tag{3.4}$$

3.4 Economic analysis:

In any pipeline investment project, we must perform an economic analysis of the pipeline system to ensure that we have the right equipments and material at the right cost to perform the necessary service and provide the profitable income for the venture(Shashi M.,2014) .

The major capital component of pipeline system consist of the pipe itself, pump station , storage tank, valves, fittings and meter stations. Annual cost will also include general and administrative cost including payroll cost, rental and lease cost and other recurring costs necessary for the safe and efficient operation of the pipeline system.

1- Capital cost:

The capital cost of pipeline project consist of the following major components:

Pipeline, pump station, tanks and manifold piping valve fittings and meter station, engineering and construction management , environmental and permitting, right-of-way acquisition cost and other cost paid in the initial phase for an asset.

2- Operating Cost:

The annual operating cost of a pipeline system consist mainly of the following:

Fuel cost, Operating staff cost, Land lease cost, if applicable, Insurance and taxes, maintenance, pipeline maintenance cost, SCADA and telecommunication cost, utility cost, Other utility cost (water and natural gas….etc), ongoing environmental and permitting cost, rental and lease cost.

3- Total Cost:

Total cost are the summation of the Capital cost and the operation cost and they represent all the calculated cost of the pipeline:

$$\text{Total Cost} = \text{CAPEX} + \text{OPEX} \qquad (3.5)$$

4- Feasibility study and economic pipe size:

Investigating the technical and economic feasibility of building a new pipeline system to provide transportation service for liquids from storage facility to refinery or from refinery to storage tanks. Other types of studies may include technical and economic feasibility studies for expanding the capacity of the existing pipeline system to handle additional through put volume because of increased marked demand or refinery expansion**.**

CHAPTER 4
RESULT AND DISSCUSION

4.1 Introduction:

This chapter showed the results of the simulation for two case scenarios, the pump requirements and the cost calculation for the pipeline.

4.2 Case Study Background:

The Rawat company has made progress in project wells in Sudan. This particular study is concerned with the Rawat field containing well (Rawat C2, Rawat C3, Wateesh 1 and Wateesh 2) and any well that the RPOC may develop in the future in this field. The Rawat company has made progress in these wells in the past years and it is assumed that development and production are to follow in the following years.

The wells (Rawat C1, Rawat C2, Wateesh 1, Wateesh2) are all located within a 3 KM radius of each other. In the case of development and production of these wells, there must be a pipeline to transport this production. The design of this pipeline is discussed here. The pipeline must transport the fluid to the nearest facility where the oil can be further treated. The nearest existing facility to the field is the Al Jabalain CPF which is located about 70 km to the north-east.

4.2.1 Oil Specifications:

Data of the oil from RPOC field report:

API	24
GOR	zero
Water cut	Zero%
Viscosity@35C	200 cp
Type of oil	Medium
Minimum production	3000 (STB/D)
Average production	4000 (STB/D)

Maximum Production	6000 (STB/D)

Table(4.1): Oil Properties

Table (4.1) show the average properties of the oil as provided by the data from the RPOC field report.

4.2.2Field:

The study focuses on the wells Rawat C2 ,Rawat C3, Wateesh 1 and Wateesh 2 and the way their products are transported. Rawat company has the right of exploitation of these wells. It also include nearby wells in that area, wither they are wells to be drilled in the future or wells already drilled and are to be developed to start production.

Fig(4.1) location of wells

Figure above showed the location of two wells in the RPOC area of work. The wells are all located within a 3 Km radius of each other

4.2.3 FPF:

It is assumed that the RPOC must provide a Field Processing Facility (FPF) for the wells to gather the production of the different wells in one location in order for the all the oil to be transported to the CPF.

The location latitude (12.074) and longitude (32.38) represents a center location for the field. All wells are within 3KM radius of this location. Therefore it is assumed that the location latitude (12.074) and longitude (32.38) will be the companies new Field Processing Facility (FPF).

Fig(4.2) Field location

Figure above shows the locations of Rawat C2 and Rawat C3 wells and the suggested location for the FPF.

4.2.4 CPF :

The CPF is where the oil is transported in order to be treated from where it can be exported or sent to the refinery for further treatment. The CPF is located at al Jabalain, about 70 KM from the field location. CPF location is (latitude 12.45, longitude 32.78).

Fig(4.3) CPF location.

4.3 Route selection:

According to the field data and location it was considered that that the most suitable (economically and location wise) way to transport the oil is to connect the field with a pipeline to the CPF(Central Processing Facility) at al Jabalain.

The design phase concluded two routes as main scenarios based on the main parameters of design consideration.

4.3.1 Pipe Assumption:

A 12 inch buried carbon steel pipelines have according to previous studies, real life application, commercial availability, durability, maintainability and cost proved to be the best choice for the pipeline. A carbon steel pipeline of 12 inch diameter is assumed in this thesis.

4.3.2 Ideal Scenario:

This scenario represented the ideal situation for a pipeline route which would be a straight line pipeline that connects the field and the CPF. This straight route pipeline did not avoid or deviate from any obstacles and did not consider any of the factors that affected the pipeline. This meant that the straight line scenario had to go through the villages farms and other obstacles without going via the proper codes, regulations and environmental aspects. This scenario only relayed on the factor of distance depending on the fact that the shortest distance between two points is a straight line. The shortest distance also meant the least construction cost which is the main component in the overall cost of the pipeline implying a great decreased in the overall cost. The line had a length of 68 KM (224000 ft) which can be considered as the shortest distance between the FPF in the field and the CPF in al Jabalain.

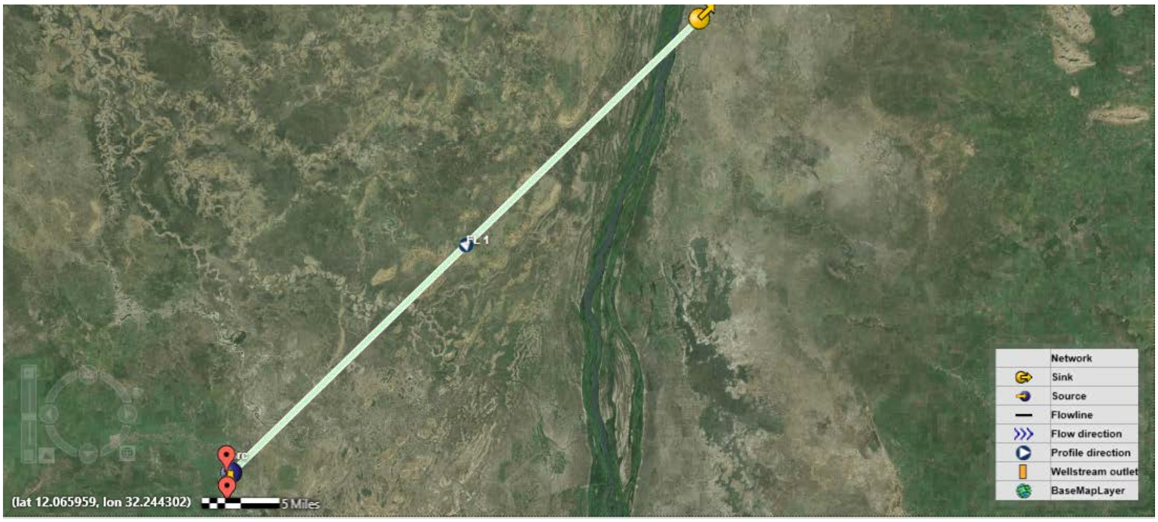


Fig (4.4) Straight Pipeline

Figure above shows the first scenario of the design. the pipe is designed as a straight line from the FPF in the field to the nearest facility which is al Jabalain CPF

4.3.3 Real scenario:

This scenario represented the real situation that considered all the factors and the parameters of pipeline design including the obstacles faced, the elevation changes, the pressure drop and the pumping requirements of the pipeline. The pipeline design of the real situation had a length of 78.2 KM (256686 ft).

4.3.3.1 Obstacles:

1-Khour (Creek \Seasonal river)

A long seasonal Khour spanned from the north east to the south west about 25,000 ft from the field location. It covered a large area between the field location and the CPF. The Khour was unavoidable without greatly increasing the distance but there where points with less curves and thinner gap between the sides of the Khour which represented the best and safest places for the pipeline to be constructed over to the other side .

No change in the pipeline route was made since the pipeline crossed in one of the best points by default while moving in a straight line.

Fig(4.5) Seasonal rivers (Khour)

2- Hafeer:

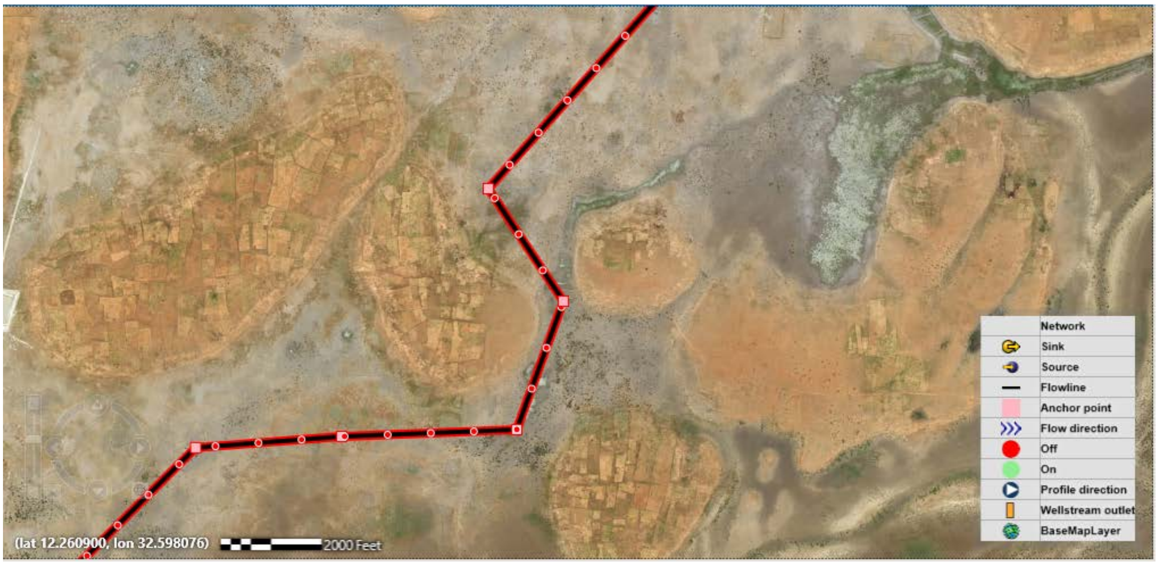
A small Hafeer after 75,000 ft appeared. The Hafeer was avoided by a small deviation in the pipeline route through the use of two nodes (one node to change the direction of the pipe and move it away from the Hafeer and the other node to redirect the pipeline to the direction of the CPF again).

Fig(4.6) Artificial lakes (Hafeer)

3-Villages:

A group of small villages where found after 90,000ft from the field. The villages each contained a number of houses and a group of farms that surrounded them, making it difficult to cross one of them directly. Although the villages were on the shortest route to the CPF destination point, the possibility of crossing through the village may represent a problem due to settlements that will be paid to the villagers for compensation as a result of the pipe.

The villages where avoided by moving the pipeline to the east and moving the pipe away from the villages until there was a point for the pipeline to cross between the villages without affecting any of them.



Fig(4.6) Villages

Figure above shows the pipe moving around and away from the villages and returning to its original path after passing the villages

4- Nile:

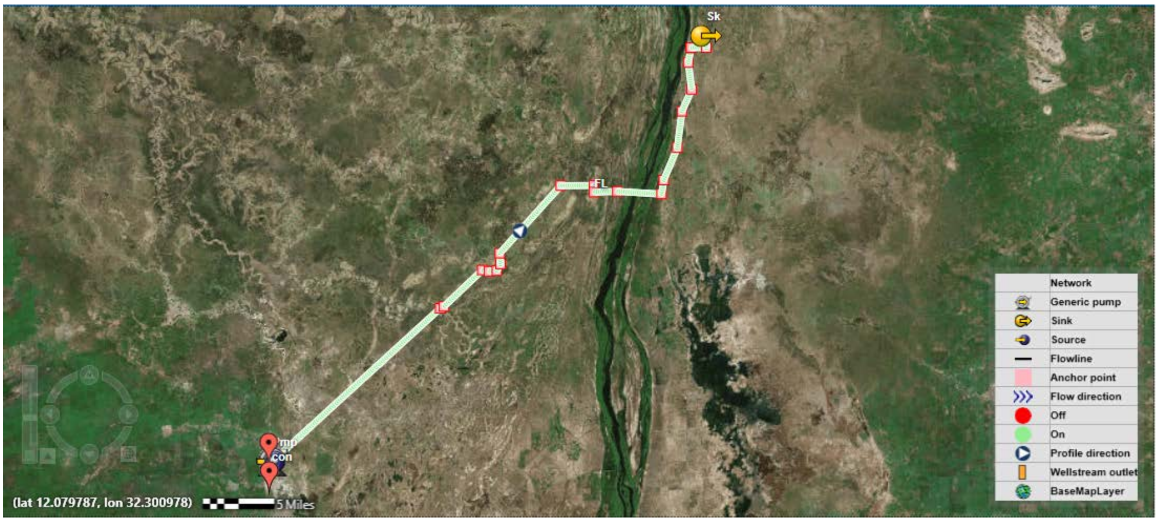
The White Nile river which was the last obstacle before the Central Processing facility (CPF). The white Nile river flow from the south all the way to the north until Khartoum city, meaning the only way to overcome this river was to cross it directly.

Fig(4.7) White Nile

Figure above show the pipe crossing directly the White Nile from the west to the east river bank. From there the pipeline heads straight to the north flowing the white Nile river until the pipeline reaches the Central Processing Facility (CPF) .

4.3.3.2 Final Route:

The result of consideration of the obstacles discussed above changed the pipeline route, the resulting route from the FPF to the CPF was found to be 78.25 KM in length and had a non-fluctuating elevation gradient.



Fig(4.8) real scenario final route

Figure (4.8) show the real scenario including the changes made in the route to avoid all the obstacles leading to the final route .

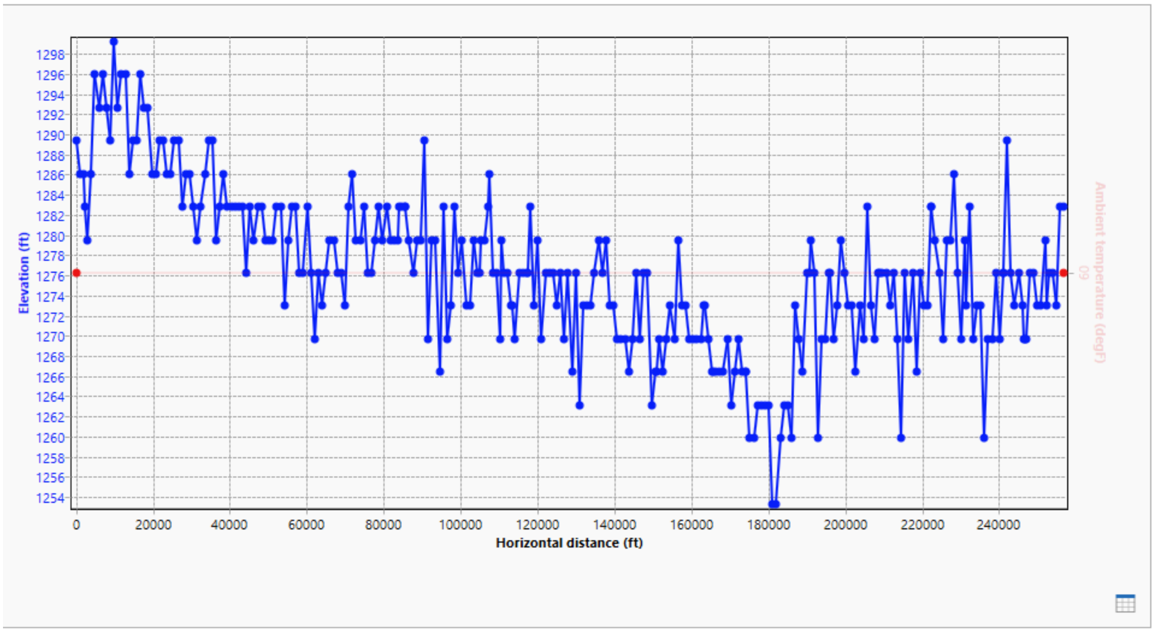


Figure (4.9) Real scenario elevation gradient

Figure (4.9) shows the elevation gradient of the pipeline , taken every 300M(985ft). The elevation constantly decreases from the field location to the Central processing Facility. The elevation drop between 17,000 ft and 19,000 ft is due to the low land formed by the Nile river.

4.3.4 Field Production:

The production data of the field obtained from the RPOC field report:

Production	**Rate** $(^{STB}/_{D})$
Minimum production	3000
Average production	4000
Maximum production	6000

Table(4.2): Expected Production Data

Table (4.2) show the production flow rate (Minimum, Average production and Maximum) expected to be produced by the field.

The production rates and the pressure required to move the oil from the FPF and deliver the product to the CPF at a terminal pressure of 50 (psia) :

A) Minimum Production 3000 (STB/D):

The pressure required to deliver 3000 (STB/D) from the FPF to the CPF is 253.4 (psia) and is shown in figure (4.10).

Network simulation | Engine console | Node/Branch results | Profile results

Display mode: Node Branch

Type filter: All

Select columns... Expand all

	Name	Type	Pressure (out)	Temperatur...	ST liquid rate	ST Oil rate	ST Water rate	ST Gas rate	ST GOR	ST WCUT	FL Gas rate (...	FL WCUT
			psia	degF	STB/d	STB/d	STB/d	mmscf/d	SCF/STB	%	mmcf/d	%
1	Sk	Sink	50	60.18915	3000	3000	0	0	0	0	0	0
2	Src	Source	253.4137	95	3000	3000	0	0	0	0	0	0

Figure (4.10):production of 3000 (STB/D).

B) Average Production 4000 (STB/D):

The pressure required to deliver 4000 (STB/D) from the FPF to the CPF is 302.3 (psia) and is shown in figure (4.11).

Select columns... Expand all

	Name	Type	Pressure (out)	Temperatur...	ST liquid rate	ST Oil rate	ST Water rate	ST Gas rate	ST GOR	ST WCUT	FL Gas rate (...	FL WCUT
			psia	degF	STB/d	STB/d	STB/d	mmscf/d	SCF/STB	%	mmcf/d	%
1	Sk	Sink	50	60.34724	4000	4000	0	0	0	0	0	0
2	Src	Source	302.2227	95	4000	4000	0	0	0	0	0	0

Fig(4.11): Production of 4000(STB/D).

C) Maximum Production 6000 (STB/D):

The pressure required to deliver 6000 (STB/D)from the FPF to the CPF is 368.7 (psia) and is shown in figure (4.12).

Network simulation | Engine console | Node/Branch results | Profile results

Display mode: Node Branch

Type filter: All

Select columns... Expand all

	Name	Type	Pressure (out)	Temperatur...	ST liquid rate	ST Oil rate	ST Water rate	ST Gas rate	ST GOR	ST WCUT	FL Gas rate (...	FL WCUT
			psia	degF	STB/d	STB/d	STB/d	mmscf/d	SCF/STB	%	mmcf/d	%
1	Sk	Sink	50	60.90837	6000	6000	0	0	0	0	0	0
2	Src	Source	368.6585	95	6000	6000	0	0	0	0	0	0

Fig(4.12):Production of 6000 (STB/D).

4.3.5 Pumping requirements:

A pump is required in the field FPF(Field Processing Facility) to create pressure at the start of the pipe enough to allow the fluid to flow from the field to the CPF in Al Jabalain.

It is safe to assume that the best pump for the designed pipeline will be the pump that delivers the fluid to the CPF and create enough pressure for all flow rates expected from the field. It is expected that the area is promising for production and more wells are to be drilled in the upcoming future. A safe assumption will be to take the maximum expected production (6000 STB/D) to be used in the design of the pumping pressure requirements.

From figure (4.12) FPF it was found that at a production rate of 6000 (STB/D), if the field produce 6000(STB/D) it requires a minimum pressure of 368.7 (psia) to get the fluid to flow from the well across the 78 KM pipe and reach at AL Jabalain CPF at a terminal pressure of 50 (psia).

A) Simulation result:

PIPESIM simulation made for the pump that will be required in the field and that the pressure produced from this pump should not be less than 368.7 (psia). Simulation of these results and adding a pump to the designed pipeline predicted that the pump must produce a pressure of 376.7 (psia).

Display mode: Node Branch

Type filter: All

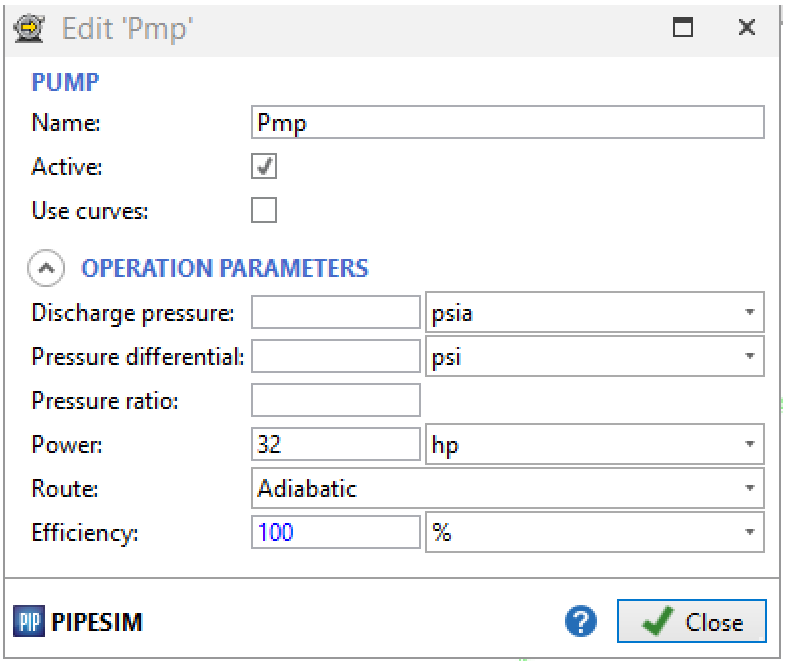
Select columns... Expand all

	Name	Type	Pressure (out)	Temperatur...	ST liquid rate	ST Oil rate	ST Water rate	ST Gas rate	ST GOR	ST WCUT	FL Gas rate (...	FL WCUT
			psia	degF	STB/d	STB/d	STB/d	mmscf/d	SCF/STB	%	mmcf/d	%
1	Pmp	Generic pump	376.6273	92.49667	6000	6000	0	0	0	0	0	0
2	Sk	Sink	50	60.89481	6000	6000	0	0	0	0	0	0
3	Src	Source	67.07922	95	6000	6000	0	0	0	0	0	0

Fig(4.13) Pump pressure

Figure above show the pump with a pressure of 376.7 (psia) enough to make the fluid flow to the CPF.

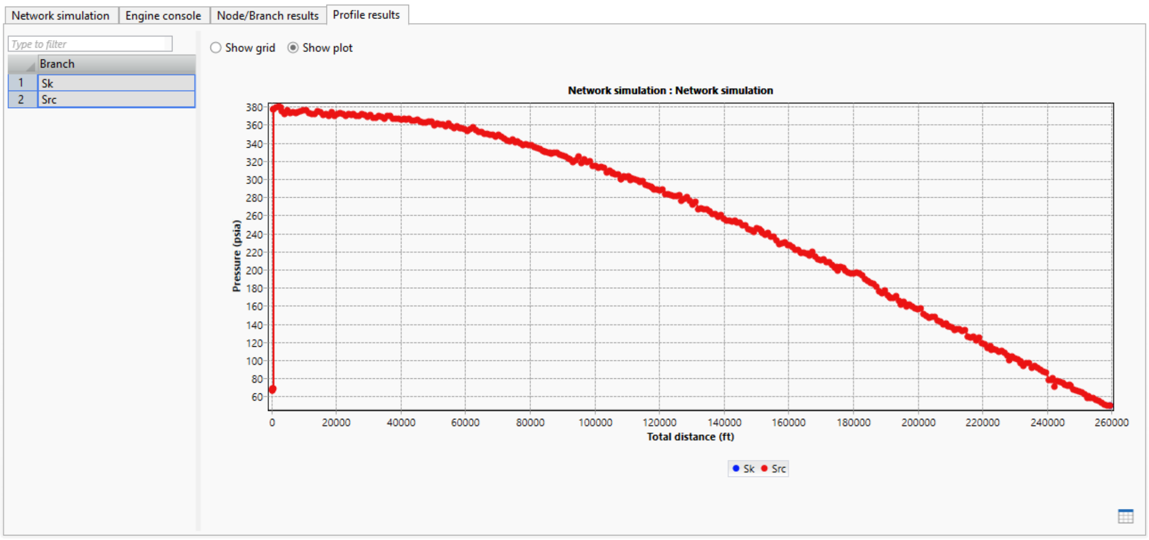
The PIPESIM simulated pump with pressure 376.7 (psia) had a predicted horsepower simulation of 32 (hp).



Fig(4.14) Pump horsepower

Figure above show the pump simulated in the PIPESIM had a 32 (hp) required to produce 376.6 (psia) of pressure.

The result of addition of the pump to the Design ensured the fluid flow to the CPF and required no addition of secondary pumps or pump stations to the line.



Fig(4.15): Pressure Gradient with pump.

Figure (4.15) above show the pressure gradient of the line with pump added to it to insure that the fluid reach the CPF at al Jabalain at a terminal pressure of 50 (psia), and the line will require no more pump stations.

B) Manual calculations:

Manual calculation is made to confirm the previous results:

1- Calculate horse power required with the use of equation (3.2):

$$P_{hp}=\frac{\Delta P_P(\text{psi})*q(\text{USgal /min})}{1714.2}$$

ΔP_P:Difference pressure at the inlet and outlet of the pump, i.e. the difference in between pressure required by the pump and the pressure of the source entering the pump.

$$\Delta P_P = 376.7\ (\text{psia}) - 67\ (\text{psia}) = 309.6\ (\text{Pisa})$$

Q: The flow rate in $(\frac{USgal}{\text{min}})$.

$$Q=\frac{6000\left(\frac{STB}{D}\right)*42\left(\frac{USgal}{\text{min}}\right)}{24\left(\frac{hr}{D}\right)*60\left(\frac{min}{hr}\right)}=175\ \left(\frac{USgal}{min}\right)$$

$$P_{hp} = \frac{(376.7-67)(\text{psi})*(175)(\frac{USgal}{\min})}{1714.2} = 31.606 \text{ (hp)}$$

2- Calculate Kilowatts required with the use of equation (3.3):

$$P_{Kw=0.746*P_{hp}}$$

$$P_{kw}=0.746*31.606=23.5 \text{ (KW)}$$

Comparison of the pump simulation results with the calculated results:

	Simulation	Calculation
Pressure required(psia)	376.7	309.6
Horsepower (hp)	32	31.606
Kilowatts (KW)	23.9	23.5

Table(4.3) Comparison between PIPESIM and calculated results

4.4 Cost Calculation:

Calculation of the economic analysis for this primary phase of design focuses on the CAPEX (Manufacturing, Construction, and Pump) cost and OPEX (Operation and maintenance) cost of the pipeline by the use of data from GIAD Industrial complex for the next 25 years.

The calculation is based on a 78.25 KM Carbon steel pipe of 12 (in) diameter

1- CAPEX:

A) Manufacturing Cost:

The available Manufacturing data from GIAD for a 12 (in) carbon steel pipe:

Material	Diameter (in)	Length (m)	Price $\$/_{m}$
Carbon Steel	12	1	269

Table (4.4) GIAD Manufacturing data

For 78.25 KM Manufacturing Cost = 269 $\$/_{m}$*78250 m

Manufacturing Cost = 21.05 MM$

B) Construction Cost:

The available Construction data from GIAD for a 12 (in) carbon steel pipe:

Material	Diameter (in)	Length m	Construction $\$/_{m}$
Carbon Steel	12	1	88

Table (4.5) GIAD Construction data

For 78.25 KM Construction Cost = 88$\$/_{m}$*78250 m

Construction cost = 6.88 MM$

C) Pump Cost:

The pumping power needed for the pump is 23.9 (KW) .this result is was obtained assuming the efficiency of the pump is 100%. For the cost it is assumed that the pumps efficiency is 75%. To obtain the power of the pump with a 75% efficiency use equation (3.4):

$$P_{KW}=\frac{24}{0.75}$$

$$P_{KW}=32 \text{ (KW)}$$

The approximate cost of the pump that met the requirements from the Sudanese Petroleum Pipelines Company (SPPC) is 60,000$ for a 55 (KW) pump

Pump Cost = 60,000 $

2- OPEX and Maintenance:

The approximate values of OPEX and Maintenance cost for the pipeline for 25year from was obtained from previous pipeline studies to the same type of pipeline:

OPEX and Maintenance = 2.64 MM$

3- Total Cost:

The total cost of the design is calculated from equation (3.5)

Total Cost = Cost of (Manufacturing +Construction +Pump) + OPEX

Total cost = (21.05+6.88+0.06)+2.64 = 30.63 MM$

The total Cost calculated is the cost of the pipe line material, manufacturing, construction, operation, maintenance and pump cost for the next 25 years is 30.63 MM$.

Chapter 5

Conclusion and Recommendation

5.1 Conclusion:

This study provides an initial attempt to design a suitable route, calculate the pressure for each production rate, the maximum pump requirements of a pipeline:

- The routes selected for two scenarios was done, case one the (ideal) 68 KM and case two (real situation) has a 78.25 KM.
- Considering route obstacles it is best to use case two (real) as the selected route.
- Different production data was simulated to give the pressure required to deliver them to the CPF. 3000 (STB/D)required 253.4 (psia), 4000 (STB/D) required 302.3 (psia), and 6000 (STB/D) required 368 (psia).
- Pumping requirements was done using simulation 32 HP ,23.9 KW, and manual calculation 31.6 HP, 23.5 KW.
- Economic analysis was estimated for the next 25 years. Capital cost =27.99 MM$, Operating cost = 2.64 MM$, and the total cost =30.63 MM$

5.2 Recommendation:

- To use scenario two design.
- To make a more detailed cost estimation.
- To make a detailed economic feasibility study of the design.

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