بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Petroleum Engineering and Technology

Department of Transportation and Refining Engineering

Design Of Petroleum Products Pipeline From Haya Station To Algadaref Storage Facilities

تصميم خط انابيب ينقل منتجات بترولية من محطة هيا إلى مستودعات القضارف

A Thesis Submitted To The College Of Petroleum Engineering And Technology – Sudan University Of Science And Technology In Partial Fulfillment Of The Requirements For Degree Of B.Sc In Petroleum Refining And Transportation Engineering

Prepared By:

1. Awad Hassan Ahmed
2. Mohammed Ibrahim Khalafalla
3. Omer Mahdi Mohammed

Supervised By:

Dr. SumiaAbdoalmoneim.

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الإستهلال

قال تعالى :

بسم الله الرحمن الرحيم

(وَلَوْ أَنَّ أَهْلَ الْقُرَى آمَنُوا وَاتَّقَوْا لَفَتَحْنَا عَلَيْهِمْ بَرَكَاتٍ مِنْ السَّمَاءِ وَالأَرْضِ
وَلَكِنْ كَذَّبُوا فَأَخَذْنَاهُمْ بِمَا كَانُوا يَكْسِبُونَ (٩٦))

سورة الأعراف – الآية (٩٦)

DEDICATION

This work is dedicated

To the people who helped and supported us in all aspects of life;

Our parents

To those who stand by our side during the whole journey;

Our brother & sisters

To those who gave us a lot of lessons to learn, and inspired us to get involved in a beautiful world of science;

Our teachers

To those who have a hand in this success;

Our friends

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Before anything; we would like to thank Allah for his blessing on us to achieve this work.

Secondly; we would like to give many thanks to the castle of science Sudan University of Science & Technology; as well as College of Petroleum Engineering & Technology, and Department of Refinery & Transportation.

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ABSTRACT

Three pipelines with different diameters were studied in this thesis to transport gasoline and gasoil products from Haya station –which lies on Al-bahar Al-ahmer state – to meet needs for Gadaref and Kassala states in addition to Ethioupia .this study is done by using Google Earth software program to identify the alternatives for these line and identify the best route. Also pipesim software program is used to determine required line pressure and required number of pump stations for each line , and cost estimation was established for each line to select appropriate diameter for this line to transport the products with high quality and minimum cost. The results show the best alternative is 10 inch with two pump stations.

Key words :

-HAYA

-GADAREF

-Pipesem Soft Ware

-Pump Station

-Cost Estimation

مستخلص البحث

في هذا البحث تمت دراسة ثلاثة خطوط أنابيب بأقطار مختلفة لنقل منتجات الجازولين والبنزين من محطة هيا الواقعة في ولاية البحر الأحمر إلى مستودعات القضارف لتغطية احتياجات ولايتي كسلا والقضارف بالإضافة الى احتياجات دولة اثيوبيا . تمت الدراسة باستخدام برنامج (القوقل ايرث) حيث تم من خلاله تحديد خيارات مسار الخطوط وبالتالي اختيار المسار الأمثل ،أيضاً تم استخدام برنامج (البايب سيم) وذلك لحساب الضغط المطلوب في الخط وعدد محطات الضخ المطلوبة ،وأيضاً حساب تقدير التكاليف لكل خط على حده وذلك لاختيار القطر المناسب للخط الذي ينقل المنتج بأقل تكلفة وأعلى جودة. فأظهرت النتائج أن الخط الذي قطره عشر بوصات والذي يحتاج الى محطتي ضخ هو الخط الأمثل.

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CHAPTER ONE

Introduction

1.1 Definition And Scope

The term pipe is defined here in as a closed conduit, usually of circular cross section.

It can be made of any appropriate material such as steel or plastic. The term pipeline refers to a long line of connected segments of pipe, with pumps, valves, control devices, and other equipment/facilities needed for operating the system. It is intended for transporting a fluid (liquid or gas), mixture of fluids, solids, fluid solid mixture, or capsules (freight-laden vessels or vehicles moved by fluids through a pipe). The term pipeline also implies a relatively large pipe spanning a long distance. Unless otherwise specified. (NOVA international consulting Inc, (1991), pipeline design and construction, university of calagry.)

1.2 Brief History Of Pipelines

The use of pipelines has a long history. For instance, more than 1,000 years ago, the Romans used lead pipes in their aqueduct system to supply water to Rome. As early as 400 B.C., the Chinese used bamboo pipes wrapped with waxed cloth to transport natural gas to their capital Beijing for lighting. Clay pipes were used as Early as 4000 B.C. for drainage purposes in Egypt and certain other countries.

An important improvement of pipeline technology occurred in the 18th century when cast-iron pipes were manufactured for use as water lines, sewers, and gas pipelines. A subsequent major event was the introduction of steel pipe in the 19th century, which greatly increased the strength of pipes of all sizes. In 1879, following the discovery of oil in Pennsylvania, the first long-distance oil pipeline was built in this state. It was a 6-inch-diameter, 109-mi-long steel pipeline. Nine years later, an87-mi-long, 8-inch-diameter pipeline was built to transport natural gas from Kane, Pennsylvania to Buffalo, New York. The development of high-strength steel pipe made it possible to transport fluids such as natural gas, crude oil, and petroleum products over long distances. Initially, all steel pipes had to be threaded together, which was difficult to do for large pipes, and they often leaked under high pressure.

The development of electric arc welding to join pipes in the late 1920s made it possible to construct leak proof, high-pressure, large-diameter pipelines. Today virtually all high-pressure piping consists of steel pipe with welded joints. Large seamless steel pipe was another major milestone achieved in the 1920s.

Major innovations in pipeline technology made since 1950 include:

- Introduction of new pipeline materials such as ductile iron and large diameter concrete pressure pipes for water, and PVC (polyvinyl chloride)pipe for sewers
- Use of *pigs* to clean the interior of pipelines and to perform other functions
- *Batching* of different petroleum products in a common pipeline
- Application of cathode protection to reduce corrosion and extend pipeline life
    - Use of large side booms to lay pipes, machines to drill or bore under rivers and roads for crossing, machines to bend large pipes in the field, x rays to detect welding flaws, and so forth. Since 1970, major strides have been made in new pipeline technologies including trenchless construction (e.g., directional drillings, which allow pipelines to be laid easily under rivers, lakes, and other obstacles, without having to dig long trenches),pipeline integrity monitoring (e.g., sending intelligent *pigs* through pipes to detect pipe wall corrosion, cracks, and other pipe flaws), computers to control and operate pipelines, microwave stations and satellites to communicate between head quarters and remote stations, and new pipeline technologies to transport solids over long distances (e.g., slurry pipelines for transporting coal and other minerals, and capsule pipelines for bulk materials transport).(NOVA international consulting Inc, (1991), pipeline design and construction, university of calagry.)

1.3 Importance Of Pipelines

Pipelines are the least understood and least appreciated mode of transport. Pipelines are poorly understood by the general public because they are most often underground and invisible—out of sight, out of mind! Despite the low degree of recognition by the public, pipelines are vitally important to the economic wellbeing and security of most nations. All modern nations rely almost exclusively on pipelines to transport the following commodities:

- Water from treatment plants to individual homes and other buildings.
- Sewage from homes to treatment plants.
- Natural gas all the way from wells to the consumers who may be located more than a thousand miles away—be it a home, a factory, a school, or a power plant.
- Crude oil from oil fields to refineries.
  - Refined petroleum products (gasoline, diesel, jet fuel, heating oil, etc.) From refineries to various cities over hundreds of miles In addition, hundreds of other liquid, gas, and solid commodities (freight) are transported via pipeline over long and short distances.(NOVA international consulting Inc, (1991), pipeline design and construction, university of calagry.)

1.4 Types of Pipelines

Pipelines can be categorized in many different ways. Depending on the commodity transported, there are water pipelines, sewer, natural-gas pipelines, oil pipelines (for crude oil), product pipelines (for refined petroleum products such as gasoline, diesel, or jet fuel), solid pipelines (freight pipelines) for various solids, etc. According to fluid mechanics or the types of flow encountered, pipelines can be classified as single-phase incompressible flow (such as water pipelines, oil pipelines, and sewers), single-phase compressible flow (natural gas pipelines, air pipelines, etc.), two-phase flow of solid-liquid mixture (hydro transport), two-phase flow of solid-gas mixture (pneumonia transport), two-phase flow of liquid-gas mixture (oil-gas pipelines), non-Newtonian fluids, and finally, the flow of capsules. This type of classification is the best one from a scientific (analytical) standpoint since different pipelines of the same flow type are covered by the same fluid mechanic equations.

The basic types of pipe line in petroleum field terms are:

Flow lines, gathering lines, transmission lines, crude truck pipe lines and product trunk pipe lines.

Flow lines: move crude oil or natural gas from the producing wells to producing field storage tanks and reservoir. It Sizes vary 5 cm in diameter in older ,lower pressure fields with only a few wells to much larger lines in multi-well high pressure field.

Gathering line: it collects oil from several locations for delivery to central accumulating point, such as from field oil tanks to marine docks

Crude tank pipe lines: natural gas and crude oil are moved long distances from producing areas or marine docks to refinery and from refineries to storage and distribution facilities by 1-3m or larger-diameter trunk pipe lines. Petroleum product Trunk pipe lines: these pipe lines move liquid products such as gasoline and fuel oil from refinery to terminals.

1.5 Advantages Of Pipelines

For the transport of large quantities of fluid (liquid or gas), pipeline is undisputedly the most favored mode of transportation. Even for solids, there are many instances that favor the pipeline over other modes of transportation. The advantages of pipelines are:

- Economical in many circumstance
- Low energy consumption
- Friendly to environment
- Safe for humans
- Unaffected by weather
- High degree of automation
- High reliability
- Less sensitive to inflation
- Convenience
- Less susceptible to theft
- Efficient land use
- High degree of security

1.6 Proplem Statement

To design petroleum products pipeline from Haya station –which lies on main line (Al-jail-portsudan pipeline)- to Sudan eastern states (Kassla ,Al-gadarif) and Ethiopia ,this line transports two products (gasoline & gasoil) with enough quantities to meet the needs of this states ,also to improve the transportation method .

1.7 Objectives

-Design of petroleum products pipeline from HAYA STATION to GADAREF

-Pipesim simulation and cost estimation to select the best optimum line

CHAPTER TWO

Literature Review

The historical devolepment of three pipelines was discussed as following:

2.1 Elgaily- Rabak Products PipeLine

Conceptual pipeline the runs from ELGAILY through MADANY& SENNAR to RABAK strategic Storage depots resulting in about 450 kilometers long. The route of which follows the eastern bank of the Blue Nile to MADANY after crossing the Blue Nile; afterwards parallels MADANY – SENNAR – RABAK high way all the way to RABAK strategic storage depots.

The targeted areas are (GEZIRA, SENNAR, BLUE NILE, GEDARIF, KASSALA & WHITE NILE, (NORTH, SOUTH, WEST KORDOFAN) & (NORTH, SOUTH, WEST DARFOR), In addition to the neighboring countries of SOUTH SUDAN & EITHIOPIA.

The Total demand of the targeted states during 2011-the base year - is approximately: 780,000 tons of Gasoil, 360,000 tons of MOGAS, and 180,000 tons of Kerosene.

Due to the relatively significant quantities to be withdrawn in MADANY; the study was based on dividing the pipeline into two portions; one is ELGAILY-MADANY while the other one is MADANY-RABAK

The hydraulic study revealed that three sizes were technically viable; 12, 14 and 16 inch. Evidently, and for all size options the conceptual pipeline shall mainly be composed of the following: a mother station, and a terminal station plus booster stations in between also off-take points at MADANY and SENNAR were considered.

The estimated capital to be invested in both phases (I & II):

ELGAILY to MADANY portion is approximately:

- $124.00 million for the 12-inch pipeline,
- $113.00 million for the 14-inch pipeline
- $121.00 million for the 16-inch pipeline.

MADANY – RABAK portion is approximately:

- $122.00 million for the 12-inch pipeline,
- $119.00 million for the 14-inch pipeline.

The pipeline EPCC works would take about 24 months, following conceptual approval and financial backing.

The financial analysis for the chosen options was performed and the results were compared based on the emerged "Internal rate of return "IRR" and Payback Period "PBP".

The financial analysis results shows that the second option (14") for ELGAILI – MADANI & MADANI –RABAK pipeline gives the best results compared to the other options as reflected by the IRR & PBP.

Option 3 – the 16 inch size pipeline (For ELGAILI – MADANI portion) – is the second best. The values of the IRR and the PBP are almost very close of that of the second option – the 14 inch size pipeline - . However; option 3 is favored over option 2 for being potentially capable of absorbing any possible increase in throughput.

A strategic storage facility in MADANI is deemed necessary to avoid the problems associated with the refinery down time and/or fuel shortages. As the aforementioned storage facilities shall ensure the supply of petroleum products to eastern and middle states of SUDAN even in the above mentioned circumstances.

The Project of ELGAILY-MEDANI-SENNAR-RABAK pipeline has been found technically viable & financially worthy of implementation

2.2 The pipeline crossing a cotton field near the Arkansas

Pipeline operated by a different company—the Texas Eastern Products Pipeline Company (TEPPCO). Now it carries about 20 types of gasoline and 4 types of fuel oil, in addition to kerosene, jet fuel, butane, propane, and alkylate. At present (2003), both TETCO and TEPPCO are under Duke Energy, which has published an interesting booklet on the history of the Big Inch and Little Big Inch pipeline.

The Colonial Pipeline is telescoping from 36 inches (91 cm) to 30 inches (76cm). It transports approximately 1.2 million barrels of petroleum products per day .The pipeline was constructed between 1962 and 1964 by the Colonial Pipeline Company, which had been incorporated by a consortium of nine oil companies.

The name Colonial was chosen because this pipeline from Texas to New York crosses most of the original 13 colonies. From 1967 to 1987, the company has greatly expanded the Colonial Pipeline System—adding main pipelines along the existing main line, and adding lateral lines and pump stations. Currently, it is the largest pipeline system for transporting petroleum products—approximately 1.8 million bpd, which is equivalent to about 10% of the petroleum used daily in the U.S.A(NOVA international consulting Inc, (1991), pipeline design and construction, university of calagry.)

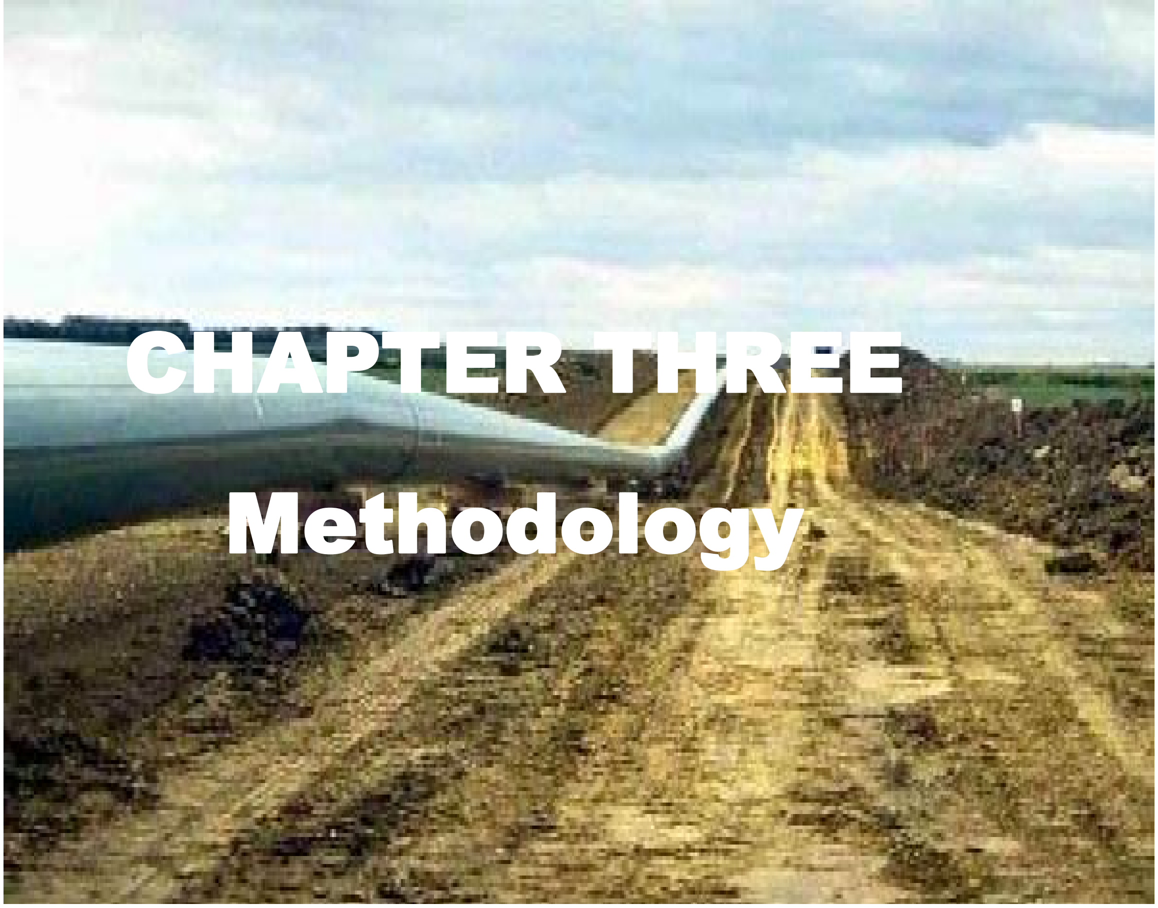
2.3 The Trans-Alaska pipeline

The Trans-Alaska pipeline is a crude oil pipeline completed in 1977. It is 48inches (1.22 m) in diameter and 798 mi (1284 km) long, transporting approximately1.7 million barrels of oil a day, which is equivalent to about 9% of the oil consumed in the entire U.S. Due to the extreme arctic climate, rugged mountain terrain, Earth quake regions (geological faults), stringent standards to preserve the Arcti environment, and lengthy delays during construction caused by law suits filed by opponents of the pipeline, the construction cost of the Trans-Alaska pipeline approached $9 billion, making it by far the most costly pipeline project in the world. Despite the cost, the pipeline has been profitable, and it serves vital national interests.

The U.S. has far more oil and natural gas pipelines than any other nation in the world: approximately 1.3 million mi (2.1 million km) of gas pipeline and 0.2million mi (0.4 million km) of oil pipeline. The amount of oil transported by pipeline in the U.S. in 2000 was approximately 500 billion tons, which constitutes about half of the oil transported in the nation. The largest natural gas producing state I the U.S. is Texas. A network of pipelines totaling 4300 mi (6920 km) transports natural gas from Texas to the Central and Eastern U.S., and California.(NOVA international consulting Inc, (1991), pipeline design and construction, university of calagry.)

CHAPTER THREE

Methodology

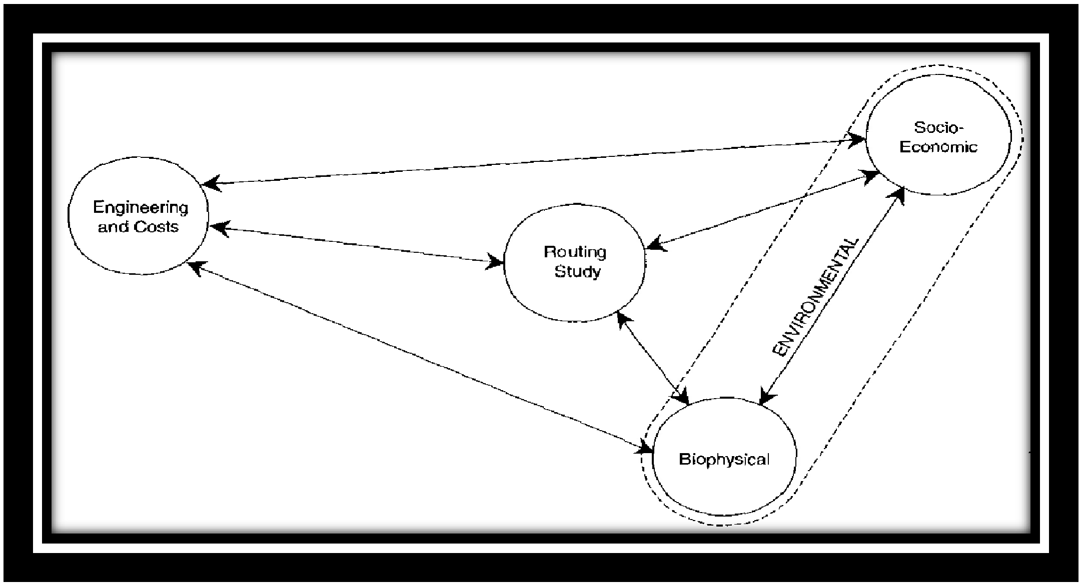


3.1 Pipeline route selection

3.1.1 Introduction

It is the process of identifying the constraints and avoiding undesirable locations; while maintaining economic feasibility of the pipeline.

- There are many constraints for identifying the shortest straight path to be the pipeline route. These constraints include physiographic, construction costs, environmental, and design constraints.
- The optimal route is affected by the following factors: cost efficiency, pipeline integrity, environmental impacts, public safety, land-use constraints, and restricted nearness to existing facilities



Figure(3.1):factors affected in pipe line route selection

3.1.2 Method of pipeline route selection

- Step 1: identify supply/demand points
- Step 2: prepare a preliminary route as follows:

❖ Prepare 1:50000 map including the supply/delivery points

- identify the control points on the map
- Plot of shortest route considering areas of concern (peak points, waterlogged terrains, lakes, etc)
- Plot of the selected route on an aerial photograph and analyze it carefully.
- Refine the selected route to accommodate better terrain, easier crossings, etc

3.1.3 General consideration of pipelines route selection

The optimum route selection process involves careful review and consideration for the following criteria:

Criteria	Considerations
Health and safety	• limiting the number of infrastructure crossings • limiting the potential for line assaults
Environment	• limiting pipeline and tie-in length • using existing corridors where possible • limiting the number of watercourse and wetland crossings • crossing water bodies at appropriate locations and during appropriate timing windows, where feasible
Regulatory and landowner access requirements	• responding to public and landowner input on route •coordinating with existing and planned land use along the proposed route •avoiding potential future development possibilities
Cost	• limiting pipeline and tie-in length • limiting construction costs by avoiding identified obstacles and locations with additional construction challenges

In this case the supply and demand points are Haya and Gadaref respectively, three routes were studied.

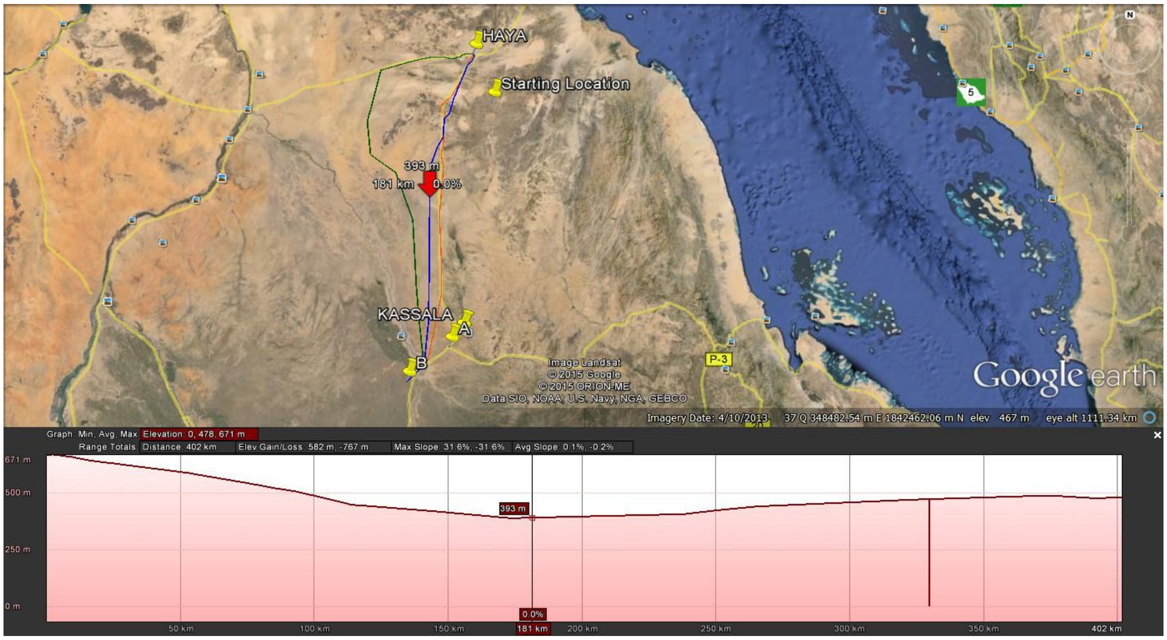


Figure (3.2):availablealternativestoselectedoptimal route

As figure (3.1) indicates; blue, red and green lines are available alternatives, then, in order to above steps and considerations the selected optimal route is a blue line, this line is a shortest straight path-most safe line.

The identification of these alternatives is done by Google earth software program, which shows all details of specific region; so rivers, creeks and mountains was averted

3.2The Hydraulic Study

3.2.1 Line Sizing

In order to properly size the conceptual line, the following facts & assumptions have been considered:

(a) The product velocity is in the range (0.9 – 3 m/s).

(b) The product properties are as shown in the table below table No.(1)Appendix (B).

(c) The line topography is as illustrated by Fig (3.1)

(d) The landing pressure is 5 barg of liquid column.

(e) The sizing/simulation tool used for the development of this study will be PIPESIM software.

(f) The pipeline load factor assumed to be 90%.

(g) Required annual throughput & the design flow rate ton/year Table No. (1)Appendix (A).

(h) The pipeline wall thickness was assumed to be 0.25 inches.

(i) Pumping stations operating Pressure was assumed to be around 80 bar.

Table (3.1):Viscosity vs temperature Product Properties

Temperature (ºC)	Dynamic Viscosity (cP)
5	5.686
15	4.742
20	4.241
30	3.299
37	2.807
40	2.627
Gasoil Density	870 Kg/m³

3.2.2 Simulation Assumptions

The main assumptions to be considered in this study are as presented below:

- Ground temperature: 29°C.
- The landing pressure: 5 barg.
- The source temperature: 37.5 °C

For pipeline sizing, these assumptions are considered:

- Absolute roughness: 0.04572 mm
- Pipe thermal conductivity: 50 W/m K;
- Soil conductivity: 0.865W/m K *;
- Mean pipe burial depth: 1.8 m to the top of pipeline;
- Thermal conductivity of pipe coating is of 0.4 W/m.K

- Coating thickness is taken equal to 3.2 mm.

3.3 Pipe Simulation Process

The pipesim software program is used to make a trade-off (differentiations and comparison) between many alternatives line sizes. and the pipesim input data are:

- Profile information (elevation vs. distance) as illustrated in Table (1) Appendix (B)
- Gasoil viscosities at different temperatures.
- PVT properties of specific product (gasoil) as illustrated in Table (1) Appendix (C)
- Line specifications (length, roughness, inner diameter, wall thickness)

The main job of pipesim is a determination of inlet pressure or outlet pressure or flow rate; two of these three specifications should be known to output the third property, in this case the desired unknown property is an inlet pressure, so the other two properties must be input data.

if the inlet pressure determined, the number of pump stations and their capabilities-along the line- can be calculated.

3.4 Determination Of Diameter

Table (1) Appendix(A) illustrate the quantities of gasoil and gasoline which eastern states (kassala, Gadaref) and Ethiopia needs from 2005 to 2040.

To make a design of pipeline which transports these products, usually selected the biggest quantity of these products

In this case the biggest quantity is a gasoil quantity in 2040 –which Kassala needs (25277827 metric ton) and Gadaref needs (48059194 metric ton), the summation of them is(73335021.3 metric ton)

So the determination of diameter of this line depends on the flow rate of (73335021 metric ton/year).

Converting this quantity to standard (Ibb/year) term by following correlation:

Barrels of crude oil per metric ton =

$$\frac{1}{SG * .159}$$

The main formula used to calculate line diameter in fluid flow is a continuity equation:

$$Q = A \times V \tag{3.1}$$

Pipe diameter can be calculated when volumetric flow rate and velocity is known as:

$$D=\sqrt{\frac{4*Q}{\pi*V}}$$

Where is:

D ≡ internal pipe diameter
Q≡volumetric flow rate
V≡velocity
A≡ pipe cross section area.

3.5 Friction losses calculations

Friction loss is a loss of energy or head that occurs in pipe flow due to viscous effects generated by the surface of the pipe. Friction loss is considered as a major loss and it is not to be confused with minor loss

CAUSES:

Friction loss has several causes including:

- Frictional losses depend on the conditions of flow and the physical properties of the system.
- Movement of fluid molecules against each other

- Movement of fluid molecules against the inside surface of a pipe , particularly if the inside surface is rough
- Bends, kinks, and other sharp turns in pipes.

3.5.1 Equations used in pipeline losses calculations

- In long distance pipeline, we more concern about the main (viscous) losses.
- Secondary (minor) losses can be neglected or arbitrary considered as a percentage from the main losses.
- Two equation forms are used to calculate the main losses. The first equation is Darcy-Weisbatch equation and the second equation is the exponential equation.

3.5.1.1 Darcy-Weisbatch equation

- Darcy weisbatch equation relates the pressure head loss (friction pressure head) to flow parameters as follows

$$h_f = f\frac{L}{D}\frac{V^2}{2g} \tag{3.2}$$

- Where hf is the pressure head loss (m), L is the pipeline length (m), D is the diameter (m), and V is the velocity (m/s)

The key factor of calculating pressure loss using Darcy-Weisbatch equation is friction factor which is dependent on Reynolds number and pipe roughness and identified according to the flow regime.

3.5.1.2 The exponential equation

- The exponential equation is derived from Darcy Wesbach equation as follows:

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

- Assuming that friction factor is related to Reynolds number as follows:

$$\text{f} = \frac{A}{Re^m} \qquad (3.3)$$

- Reynolds number can be written in term of flow rate as follows:

$$\text{Re} = \frac{4\,Q}{\pi D V} \qquad (3.4)$$

- And hence, the friction pressure head can be written follows:

$$H = \beta \frac{Q^{2-m} v^m}{D^{5-m}} L \quad \text{With} \quad \beta = \frac{8A}{4^m \pi^{2-m} g} \qquad (3.5)$$

Table(3.2);The values of β and m for different flow regimes are listed in the following table:

Flow regime		A	m	β	H
Laminar		64	1	4.15	$H_f = 4.15\frac{Qv}{D^4}L$
Turbulent	Smooth	0.3164	0.25	$\frac{8A}{4^m\pi^{2-m}g} = 0.0246$	$H_f = 0.0246\frac{Q^{1.75}v^{0.25}}{D^{4.75}}L$
	Mixed	$10^{0.127log\frac{e}{D}-0.627}$	0.123	$\frac{8A}{4^m\pi^{2-m}g} = 0.0802A$	$H_f = 0.0802A\frac{Q^{1.877}v^{0.123}}{D^{4.877}}L$
	Rough	$\gamma = 0.11\left(\frac{e}{D}\right)^{0.25}$	0	$\frac{8\gamma}{\pi^2 g} = 0.0826\gamma$	$H_f = 0.0826\gamma\frac{Q^2}{D^5}L$

3.6 Cost Estimation

The economics of transporting fluids by pipelines affect almost all design andConstruction parameters. Alternative technical solutions are possible. For any pipelineproject, the objective of economic analysis is to determine which of the alternative designand construction solutions offers the best economic advantage. Economic analysis iscarried out to determine optimum choice between size of pipelines (diameter, wallthickness and material) and compression and/or pumping power requirements. It is alsoused for utility purposes to define tariffs that have to be charged for the transmission ofthe fluid to achieve a stipulated economic performance of a pipeline system investment.

From an initial economic analysis to determine the optimum size of facilities andsubsequent design, an estimate is made of the overall investment required and associatedoperating costs to provide two principal components of owning and operating a pipelinesystem. These are then used to establish the tariff or cost of service. Elements whichinfluence the economic analysis are outlined in the following subsections.

3.6.1 Direct Costs

These costs cover expenditure directly related to the design and construction? Of a pipeline system and include:

- Pipeline
- Compression/pumping facilities
- Meter stations
- Valve and fittings
- Protection facilities (coating plus cathode protection)
- Scraping/cleaning facilities if any
- Pressure reduction facilities
- Power generation (if applicable)
- Construction costs
- Engineering costs
- Cost of ancillary facilities
- Stock pile site
- Docks, wharfs
- Leak detection system
- Logistic cost, e.g. cost associated with material and equipment transportation.
- Operating and maintenance cost, e.g. cost associated with local taxes, fuel,, material and labor costs
- Other costs, e.g. line fill, working capital required to operate the pipelineetc.

3.6.2 Indirect Costs

These are costs that affect the financing of a pipeline project. These include costs associated with acquisition of necessary funds to cover the cost of material and construction. This cost also covers the interest on money borrowed to finance the pipeline project.

We have many alternatives lines (8 inch, 10 inch and 12 inch diameters) with owned pump stations, pump stations are decreasing with increasing diameter. And to choice the best line, we should be calculate the costs of each pipeline alone , and take the line which has low costs.(w.kent Mahlbauer, (2004), pipeline risk management manual ideas,techniques and resources.third edition, Elsvior, USA.)

3.7 material selections

The basic question is how do we go about selecting a material for a given part? This may seem like a very complicated process until we realize than we are often restrained by choices we have already made. For example, if different parts have to interact then material choice becomes limited.

When we talk about choosing materials for a component, we take into account many different factors. These factors can be broken down into the following areas.

3.7.1 Material Properties

The expected level of performance from the material

- Material Cost and Availability:
    - Material must be priced appropriately (not cheap but right)
    - Material must be available (better to have multiple sources)
- Processing:

Must consider how to make the part, for example:

- Casting
- Machining
- Welding

- Environment:
    - The effect that the service environment has on the part
    - The effect the part has on the environment
    - The effect that processing has on the environment

Now clearly these issues are inter-linked in some fashion. For example, cost is a direct result of how difficult a material is to obtain and to machine. And the effect of the environment on the material is clearly related to the material properties.

So if we really want to use a novel or unusual material, the choice must be made early in the design process. Then we can do the detailed design work using the correct material properties.

3.7.2 Mechanical Properties

As mechanical engineers we are most concerned with characteristics such as:

Mechanical Properties

- Strength
- Yield Strength
- Ultimate Tensile Strength
- Shear Strength
- Ductility
- Young's Modulus
- Poisson's ratio
- Hardness
- Creep
- High or low temperature behavior
- Density
- Anisotropy
- Fatigue strength
- Fracture Toughness

3.7.3Thermal Properties

- Thermal expansion coefficient
- Thermal conductivity
- Specific heat capacity

3.7.4Fabrication Properties

- Ease of machining
- Ease of welding, casting, etc
- Hardening ability

However, numerical properties to represent these properties are not easy to find. We would like all this information at our fingers, but it takes some digging. In some cases, objective data does not exist. There is no single, standard place to go and look for all this information. We can however make some recommendations.

(w.kent Mahlbauer, (2004), pipeline risk management manual ideas,techniques and resources.third edition, Elsvior, USA.)

The selection of material depend mainly on the testing pressure of materials, each material has minimum testing pressure as illustrated in standard (specification for line pipe API 5L.)

The design pressure can be obtained from pipesimsoft ware which multiplies it in (1.25) to give the minimum testing pressure; then select the material according to it.

3.8 THICKNESS CALCULATION

$$P_{\text{design}} = \frac{2St}{D_o}$$

in this equation:

P_{design} = pipeline design pressure, psia
S = specified minimum yield strength of the pipe, psia
t = pipeline thickness, inches
D_o = pipeline outside diameter, inches.

The design pressure for a given wall thickness, considering all these safety factors, will then be determined by

$$P_{\text{design}} = \frac{2St}{D_o} \cdot F \cdot L \cdot J \cdot T$$

where F = design factor
L = location factor
J = joint factor
T = temperature correction factor or temperature derating factor.

The Canadian Standards Association (CSA) recommends the following values:

- The design factor (*F*) = 0.80:
- The location factor (L) depends on both population and other factors, such as roads, railways, and stations:

Class 1	Deserted	$L = 1.00$
Class 2	Village	$L = 0.90$
Class 3	City	$L = 0.70$
Class 4	City (densely populated)	$L = 0.55$

The values of location factors (*L*) between ASME and CSA Codes are compared Below:

	CSA Recommended Values	ASME Recommended Values
Class 1	0.80	0.72
Class 2	0.72	0.60
Class 3	0.56	0.50
Class 4	0.44	0.40

- The joint or welding factor is given as follows:

Pipe Type	Joint Factor
Seamless	1.00
Electric welded	1.00
Submerged arc welded	1.00
Furnace butt welded	0.60

Temperature correction factor for gas transmission lines [ASME, B31.8]

Temperature (°F)	**Temperature Correction Factor**
Up to 250	1.00
300	0.97
350	0.93
400	0.91
450	0.87

CHAPTER FOUR

Result & Discussion

4.1 Identification of Length

By using Google earth soft ware; and after avoiding obstacles such as rivers, creeks and mountains, the true length of shortest-most safe path route (from Haya station to Gadaref) is 402 kilometers.

4.2alternatives diameters calculations

From table (1)Appendix (A) the total quantity of gasoil in 2040 is 73335021 metric ton; then the design flow rate is 73335021metric ton/year.

- Converting this flow rate to SI units:

  Barrels of crude oil per metric ton= $\frac{1}{\text{SG}*.159}$

SG ≡ Specific Gravity From table (2) appendix (B)

$\frac{1}{0.87*0.159}= 7.23$

$73335021 \, \frac{\text{metric ton}}{\text{year}} * \frac{1}{7.23} = 10143156.4$ bbl/year

1014315.4bbl	m^3	Year	Day	Hr
Year	6.3bbl	300day	24hr	3600s

$= 0.062 m^3/s$

Usually in pipeline design, year is taken as 300 days, the remain days (60 days) indicates load factor which equals 60/360=17%.becuase the line is not operates daily along year.

$$Q = A \times V$$

Where:

Q ≡Flow rate ($\frac{m^3}{s}$)

A ≡Area (m^2)

V ≡ Volume (m^3)

$$A=\frac{Q}{V}$$

$$D=\sqrt{\frac{4*Q}{\pi*V}}$$

D≡inlet line pipe diameter (m)

In pipeline industry, common and available pipe diameters are 8, 10, 12, 14, 16, 24, 32 inch, in this case the study concern on 8, 10, 12 inch, because our transported quantity is relatively small.

Comparing between these alternatives (8, 10, 12 inch) by using pipesim software program which give us number of required pumps for each case, the selection of optimum diameter depends on this comparing also on cost estimation.

4.2.1Calculation of appropriate velocity for each diameter case

4.2.1.1 8 inch:

$$8\text{inch}=0.2032\ \text{m}=\sqrt{\frac{4*.062}{\pi*V}} \qquad V=1.9\ \text{m/s}$$

4.2.1.2 10 inch:

$$10\ \text{inch}=0.254\ \text{m}=\sqrt{\frac{4*.062}{\pi*V}} \qquad V=1.1\ \text{m/s}$$

4.2.1.3 12inch:

$$12\text{inch}=0.3048\ \text{m}=\sqrt{\frac{4*.062}{\pi*V}} \qquad V=0.922\ \text{m/s}$$

4.3 Simulation process

The simulation of this line is done by apipesim software; to give us number of pump stations and its distribution along line.

4.3.1 pipesim input data

- Pressure and temperature inside the tank which transported product stored in HAYA storage facilities
    - Temperature inside these tanks is range between 30c at winter and 37c at summer(take mean temperature equals 33.5 c)
    - Pressure inside these tank equals always 5 bar
- Elevation vs. distance profile data (which obtained by Google earth and illustrated in table (1)Appendix (B)
- Inner diameter for each case(8, 10, 12 inch)
- Wall thickness; read directly from standard API 5l according to inner diameter as following:
    - in case ID=8in, wall thickness=0.312 inch
    - in case ID=10in, wall thickness=0.365 inch
    - in case ID=12in, wall thickness=0.374 inch
        - table(1) Appendix (d) illustrated 8in line material, nominal and true diameter and wall thickness
        - table(2) Appendix (d) illustrated 10in line material, nominal and true diameter and wall thickness
        - table(3) Appendix (d) illustrated 12in line material, nominal and true diameter and wall thickness

NOTE: according to API 5L (line pipe specification),the(8, 10, 12) inch are nominal sizes, true diameters are(8.628, 10.75, 12.75) inch respectively

- design absolute roughness ;taken as stainless steel absolute roughness equals 0.0018 inch
- Total pipe line length equals 402 km.
- Ambient temperature taken as 33.5 c.

- U value (for stain less steel pipe equals 0.2 w/m^2/k.
- Water cut equals 0 (assume no water with in product).
- Gas oil ratio equals 0 (assume all liquid)
- API for Transported product (SG=0.87; from table (2) then, API=31).
- Viscosity vs. temperature data .from table (3).

4.3.2 Pipesim output data

Pipesim give us three results; inlet pressure, out let pressure, liquid flow rate for each diameter case.

Two of these three specifications should be known to output the third property, in this case the desired unknown property is an inlet pressure, so out let pressure and liquid flow rate became input data.

- Design liquid flow rate equals 0.062 (m^3/s)=33747.84 Ibb/day
- Out let pressure is a pressure inside tanks in terminal station (Gadaref storage facilities) equals 5 bar

4.3.3 Simulation results

4.3.3.1 8inch results

Figure (2) appendix (e1) shows pipesim-8 in line test to give us required inlet pressure.

Inlet pressure =8332.335 psi = 566.8 bar (figure (3) Appendix (e2)

So according to this inlet pressure we need to four pump stations along line.

Table (4.1): Distribution of 8in line pump stations and their capabilities

No. pump station	Distance(km)	Capability(bar)
HAYA pump station	0	87
P S (2)	75	86
P S(3)	150	96
P S(4)	225	103
PS(5)	300	99
PS(6)	375	36

- Figure (4) appendix (e3) shows the 8in line with it no. of pump stations.
- Figure (5) appendix (e4) shows required liquid flow rate for 8in line.

4.3.3.2 10Inch Results:

Figure (6) appendix (f1) shows pipesim-10 in line test to give us required inlet pressure.

Inlet pressure =2062.06 psi = 140.3 bar (figure (7) Appendix (f2)

So according to this inlet pressure we need to two pump stations along line.

Table (4.2). Distribution of 10in line pump stations and their capabilities

No. pump station	Distance(km)	Capability(bar)
HAYA pump station	0	77
P S (2)	250	65

- Figure (8) appendix (f3) shows the 10in line with it no. of pump stations.
- Figure (9) appendix (f4) shows required liquid flow rate for 10in line.

4.3.3.3 12inch results:

Figure (10) appendix (g1) shows pipesim-12 in line test to give us required inlet pressure.

Inlet pressure =764.732 psi = 52 bar (figure (11) Appendix (g2)

So according to this inlet pressure we need to only one pump station along line.

Table (4.3): Distribution of 12in line pump station and its capability

No. pump station	Distance(km)	Capability(bar)
HAYA pump station	0	51.9

- Figure (12) appendix (g3) shows the 12in line with its pump station.
- Figure (13) appendix (g4) shows required liquid flow rate for 12in line.

4.4 friction losses determination

NOTE:Equations used here are shown in table (4).

4.4.1 total losses through 8 in line:

Re= $\frac{V\,D}{v}$= $\frac{1.9*0.2032}{5.5*10^{-6}}$= 70196.4

Flow is turbulent rough

$\gamma = 0.11(\frac{\epsilon}{D})^{0.25}$ = $0.11((\frac{4.572*10^{-5}}{0.2032})^{0.25}$ = 0.0135

m= 0

$\beta = 0.0826 * \gamma$ = 0.0826*0.0135 =$1.113* 10^{-3}$

Hf= $\beta * \frac{Q^{2-m}}{D^{5-m}}$*L =$1.113 * 10^{-3} * \frac{0.062^{2-0}}{0.2032^{5-0}}$*402000 = 4963.7 m

The total loss for 8in line is = 4963.7 m

4.4.2 total losses through 10 in line

Re= $\frac{V\,D}{v}$= $\frac{1.9*0.0.254}{5.5*10^{-6}}$= 56800

Flow is turbulent rough

$\gamma = 0.11(\frac{\epsilon}{D})^{0.25}$ = 0.11(($\frac{4.572*10^{-5}}{0.254}$)$^{0.25}$ = 0.0127

m= 0

$\beta = 0.0826 * \ \gamma$ = 0.0826*0.0127 =1.05$*\ 10^{-3}$

Hf=$\beta * \frac{Q^{2-m}}{D^{5-m}}$*L =$1.05 * 10^{-3} * \frac{0.062^{2-0}}{0.254^{5-0}}$*402000 = 1538.3 m

The total loss for 10in line is = 1538.3 m

4.4.3total losses through 12 in line

Re= $\frac{V\,D}{v}$= $\frac{1.9*0.3048}{5.5*10^{-6}}$= 51095.5

Flow is turbulent rough

$\gamma = 0.11(\frac{\epsilon}{D})^{0.25}$ = 0.11(($\frac{4.572*10^{-5}}{0.3048}$)$^{0.25}$= 0.0121

m= 0

$\beta = 0.0826 * \ \gamma$ = 0.0826*0.0121 =1$*\ 10^{-3}$

Hf=$\beta * \frac{Q^{2-m}}{D^{5-m}}$*L =$1 * 10^{-3} * \frac{0.062^{2-0}}{0.3048^{5-0}}$*402000 = 589.4m

The total loss for 12in line is = 589.4m

4.5Cost Estimation

4.5.1 Manufacturing cost

Table (4.4):the available Manufacturing data (from GIAD PIPELINE FACTORY):

D(in)	Long(m)	Wight of CS(kg)	Price($)
8	1	33.34	80.88

4.5.1.1 8in line Manufacturing cost estimation

Diameter=8in=0.2032m,

Thickness=0.0064m

Ain=$\frac{\pi * D^2}{4}$=$\frac{\pi * 0.2032^2}{4}$=0.03243m^2

Aout=$\frac{\pi *(D+T)^2}{4}$=$\frac{\pi *(0.2032+0.0064)^2}{4}$=0.03450$m^2$

Ac= Aout–Ain=0.03243-0.3450=0.002075m^4

At=Ac*πDL=0.002075*π*0.2032*1=0.001325m^4

0.001325m^4 →80.88$*

This relation help us to estimate cost for 10,12in lines

8in line Manufacturing cost estimation=80.88$/m *402000m=32.5 MM $

4.5.1.2 10in line Manufacturing cost estimation

Diameter=10in=0.254m,

Thickness=0.0093m

Ain=$\frac{\pi * D^2}{4}$=$\frac{\pi * 0.254^2}{4}$=0.05067m^2

Aout=$\frac{\pi*(D+T)^2}{4}$=$\frac{\pi*(0.254+0.0093)^2}{4}$=$0.05445m^2$

Ac= Aout–Ain=0.05445-0.0.05067=$0.003779m^2$

AT =Ac*πDL=$0.003779m^2$*π*0.254*1=0.003016m^4

Relation* $0.001325m^4$ → 80.88$

$0.003016m^4$ → X

X=$\frac{0.003016m^4*80.88\$}{0.001325m^4}$ = 184 $

10in line Manufacturing cost estimation=184 $/m * 402000m=74 MM$

4.5.1.3 12In Line Manufacturing Cost Estimation

Diameter=12in=0.3048m,

Thickness=0.0095m

Ain=$\frac{\pi*D^2}{4}$=$\frac{\pi*0.3048^2}{4}$=0.07297m^2

Aout=$\frac{\pi*(D+T)^2}{4}$=$\frac{\pi*(0.3048+0.0095)^2}{4}$=0.$077585m^2$

Ac= Aout–Ain=0.077585-0.0.07297= $0.004615m^2$

AT=Ac*πDL=$0.004615m^2$*π*0.3048*1=0.004419m^4

Relation* 0.001325m^4 → 80.88$

$0.004419m^4$ → X

X=$\frac{0.004419m^4*80.88\$}{0.001325m^4}$ = 269 $

10in line Manufacturing cost estimation=269$/m *402000m=108MM$

4.5.2 Construction Cost

Table (4.5) The available data of line pipe construction

D(in)	Long(m)	Cost ofonstruction($/m)	Total cost for 402 km($MM)
8	1	78	78$/m*402000m=31.356
10	1	83	83$/m*402000m=33.366
12	1	88	88$/m*402000m=35.376

4.5.3The average price for pump and electrical power

The average price for pump and electrical power available in market today is 500000$, 400000$ respectively:

Table (4.6) the average price for pump

D(in)	NO. of pumps	Pump cost($MM)	Electrical power cost ($MM)
8	6	6*0.5 = 3	6*0.4 = 2.4
10	2	2*0.5 = 1	2*0.4 = 0.8
12	1	1*0.5 = 0.5	1*0.4 = 0.4

4.5.4 Operational expenditure (OPEX) & maintenance cost

OPEX:

- Fuel cost
- Other utility cost
- Operating staff cost
- Land lease cost, if applicable
- Insurance and taxes

Maintenance cost:

- Inspection cost

- Labor cost
- Repair cost

Table (4.7) illustrates approximate values of OPEX and maintenance cost for three lines for 25year

D(in)	OPEX and maintenance cost($MM)
8	81.7
10	27.43
12	13.6

Table (4.8) illustrated summary and final results of cost estimation:

D(in)	OPEX+CAPE X cost ($MM)				Summation cost ($MM)
	OPEX	CAPEX			
		Manufacturing	Construction	purchasing	
8	81.7	32.5	31.356	5.4	150.956
10	27.43	74	33.366	1.8	136.596
12	13.6	108	35.376	0.9	157.876

- Basd on above cost estimation ,we can say that the 10 in-two pump stations line is abest line to transport these product

CHAPTER FIVE

Conclusion

&Recommendations

5.1 Conclusion

Three lines with different diameters(8, 10, 12 in) but same long(402km)to transport petroleum products were studied in this research to cmpare between them, then to select minimum cost-most usful line to meet this job.

And after compelition of study,results indicate that the 10in line is the best line to do this job .

The following table show the summary of this case study.

Table(5.1): shows final results :

D(in)	Q(m^3/s)	V(m/s)	Total losses(m)	NO. of pump stations	Required pressure(bara)	Total cost($MM)
8	0.062	1.9	4963.7	6	566.8	150.956
10	0.062	1.1	1538.3	2	140.3	136.596
12	0.062	0.922	589.4	1	52	157.876

5.2 Recommendations

- This line can be study by more than one method;either:
    - Consider it independent line-which mean not depend on mian line (ELJAILE PORTSUDAN LINE)–and pumping product from HAYA storage as in this case
    - Other case,consider line is adirect connected part of main line,and each case have achrastristic result.here we recommend to establish this case study and compare results with this case study to select the optimum line
- The pipesim software program is viald only for steady state study , transient study is done by other more complex soft ware.here recommend to establishing transient study for this line to give us more accurate result

- Cost estimation in this research is not accurate , because it is very complex calculations and need long period of time to achive, so we suggest stablishing full detail cost estimationfor this project.

References

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Appendixes

Appendixes

Appendix (A)

Table (1) illustrate the quantities of gasoil and gasoline which eastern states (kassala, Gadaref) and Ethiopia needs from 2005 to 2040

Column1	Column2	Column3	Column4	Column5	Column6
	Kassala		Gadarif		athuiopia
Year	Gasoil	gasoline	Gasoil	Gasoline	gasoline
	(metric ton)	(metric ton)	(metric ton)	(metric ton)	(metric ton)
2005	23515	7111	24326	16742	150000
2006	36680	12146	33970	16227	150000
2007	47067	15436	32168	15819	150000
2008	50053	14893	40518	13903	150000
2009	65714	22951	53288	18094	150000
2010	61041	18771	55541	23663	150000
2011	55253	15075	55996	22392	150000
2012	57041	19667	67249	25813	150000
2013	111263	26421	139406	37068	150000
2014	116191	27591	145250	38641	150000
2015	142914.93	33109.2	181562.5	42891.51	150000
2016	175785.3639	39731.04	226953.125	47609.5761	150000
2017	216215.9976	47677.248	283691.4063	52846.62947	150000
2018	265945.677	57212.6976	354614.2578	58659.75871	150000
2019	327113.1828	68655.23712	443267.8223	65112.33217	150000
2020	402349.2148	82386.28454	554084.7778	72274.68871	150000
2021	494889.5342	98863.54145	692605.9723	80224.90447	150000
2022	608714.1271	118636.2497	865757.4654	89049.64396	150000
2023	748718.3763	142363.4997	1082196.832	98845.1048	150000
2024	920923.6028	170836.1996	1352746.04	109718.0663	150000
2025	1132736.032	205003.4396	1690932.55	121787.0536	150000
2026	1393265.319	246004.1275	2113665.687	135183.6295	150000
2027	1713716.342	295204.953	2642082.109	150053.8288	150000
2028	2107871.101	354245.9436	3302602.636	166559.7499	150000

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2029	2592681.454	425095.1323	4128253.295	184881.3224	150000
2030	3188998.188	510114.1587	5160316.618	205218.2679	150000
2031	3922467.772	612136.9905	6450395.773	227792.2774	150000
2032	4824635.359	734564.3886	8062994.716	252849.4279	150000
2033	5934301.492	881477.2663	10078743.4	280662.8649	150000
2034	7299190.835	1057772.72	12598429.24	311535.7801	150000
2035	8978004.727	1269327.263	15748036.56	345804.7159	150000
2036	11042945.81	1523192.716	19685045.69	383843.2346	150000
2037	13582823.35	1827831.259	24606307.12	426065.9904	150000
2038	16706872.72	2193397.511	30757883.9	472933.2494	150000
2039	20549453.45	2632077.013	38447354.87	524955.9068	150000
2040	25275827.74	3158492.416	48059193.59	582701.0566	150000
Total					**39**
		gasoil(2040)		**gasoline(2040)**	
		73335021.33		3891193.473	

Appendixes

Appendix (B)

Table (1) illustrated (elevation vs. distance) information:

DESTANCE (Km)	*ELEVATION(m)*
0	*671*
25	*632*
50	*594*
75	*544*
100	*490*
125	*439*
150	*415*
175	*391*
200	*398*
225	*405*
250	*425*
275	*448*
300	*460*
325	*473*
350	*482*
375	*490*
400	*482*
402	*479*

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Appendix (C)

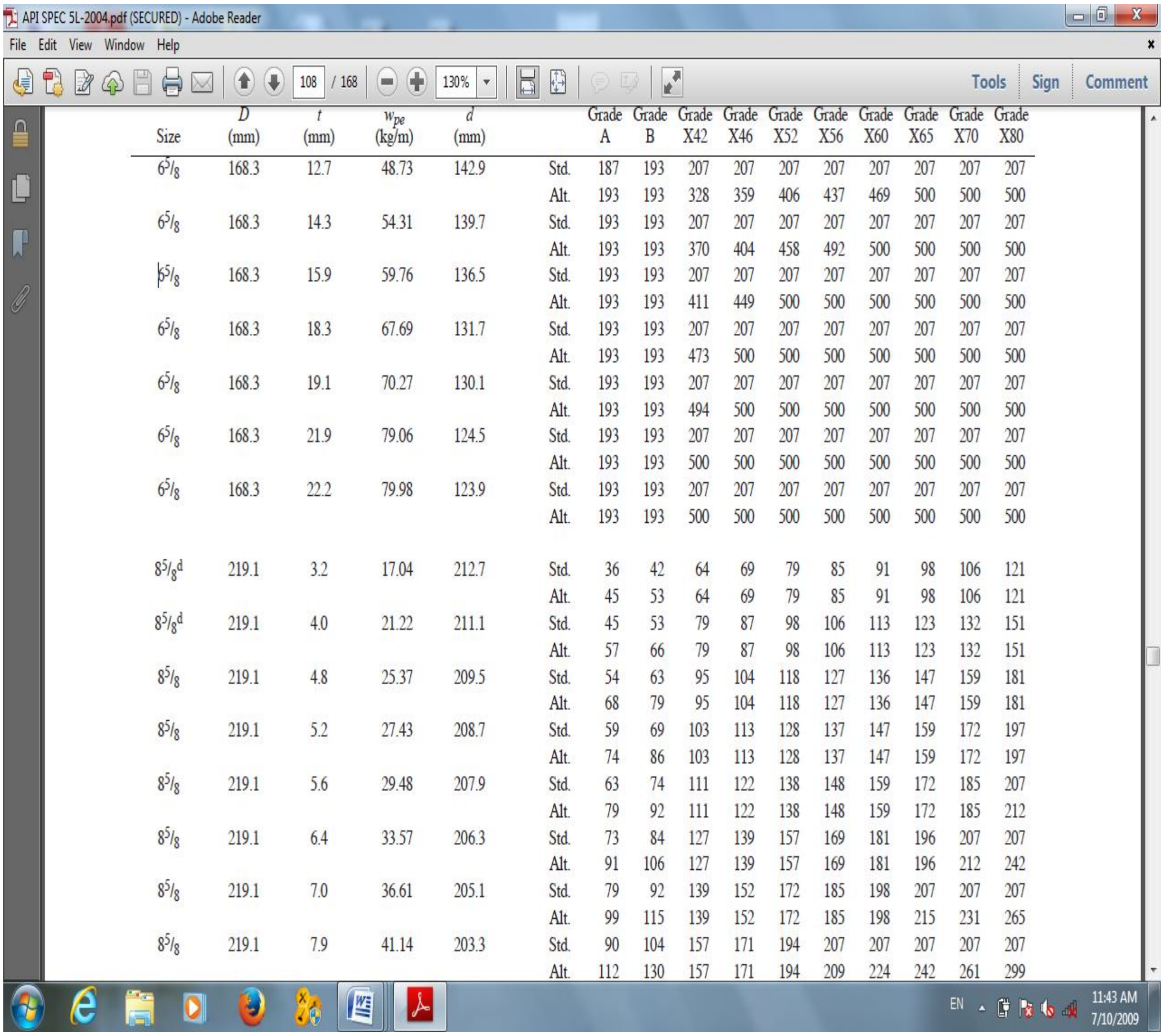
Table (1) illustrated PVT properties of specific product (gasoil):

Properties	*Specification*	*Test methods*
Flash point ,℃	*Min 57*	*ASTM D93*
Kinematic viscosity at (20℃),mm^2/s	*2.2-8.8*	*ASTM D445 ASTM D7042*
Ash,%mass	*Max 0.01*	*ASTM D482*
Sulfur content,% mass	*Max 0.05*	*ASTM D5453*
Copper strip corrosion	*Max NO.1*	*ASTM D130*
Cetane index, (calculate)	*Min 45*	*ASTM D976* *ASTM D4737*
Cloud point,℃	*Max 12*	*ASTM D2500* *ASTM D5773*
Carbon residue on10% Distillation residue %mass	*Max 0.3*	*ASTM D189* *ASTM D4530*
Color	*Max 3.0*	*ASTM D1500*
Water,%mass	*Max 0.05*	*ASTM D95*
Density	*Report*	*ASTM D1298* *ASTM D4052*
Specific gravity	*.087*	

Appendixes

Appendix (d)

table(1) illustrated 8in line material, nominal and true diameter and wall thickness:



Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$6^{5}/_{8}$	168.3	12.7	48.73	142.9	Std.	187	193	207	207	207	207	207	207	207	207
					Alt.	193	193	328	359	406	437	469	500	500	500
$6^{5}/_{8}$	168.3	14.3	54.31	139.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	370	404	458	492	500	500	500	500
$6^{5}/_{8}$	168.3	15.9	59.76	136.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	411	449	500	500	500	500	500	500
$6^{5}/_{8}$	168.3	18.3	67.69	131.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	473	500	500	500	500	500	500	500
$6^{5}/_{8}$	168.3	19.1	70.27	130.1	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	494	500	500	500	500	500	500	500
$6^{5}/_{8}$	168.3	21.9	79.06	124.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$6^{5}/_{8}$	168.3	22.2	79.98	123.9	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$8^{5}/_{8}{}^{d}$	219.1	3.2	17.04	212.7	Std.	36	42	64	69	79	85	91	98	106	121
					Alt.	45	53	64	69	79	85	91	98	106	121
$8^{5}/_{8}{}^{d}$	219.1	4.0	21.22	211.1	Std.	45	53	79	87	98	106	113	123	132	151
					Alt.	57	66	79	87	98	106	113	123	132	151
$8^{5}/_{8}$	219.1	4.8	25.37	209.5	Std.	54	63	95	104	118	127	136	147	159	181
					Alt.	68	79	95	104	118	127	136	147	159	181
$8^{5}/_{8}$	219.1	5.2	27.43	208.7	Std.	59	69	103	113	128	137	147	159	172	197
					Alt.	74	86	103	113	128	137	147	159	172	197
$8^{5}/_{8}$	219.1	5.6	29.48	207.9	Std.	63	74	111	122	138	148	159	172	185	207
					Alt.	79	92	111	122	138	148	159	172	185	212
$8^{5}/_{8}$	219.1	6.4	33.57	206.3	Std.	73	84	127	139	157	169	181	196	207	207
					Alt.	91	106	127	139	157	169	181	196	212	242
$8^{5}/_{8}$	219.1	7.0	36.61	205.1	Std.	79	92	139	152	172	185	198	207	207	207
					Alt.	99	115	139	152	172	185	198	215	231	265
$8^{5}/_{8}$	219.1	7.9	41.14	203.3	Std.	90	104	157	171	194	207	207	207	207	207
					Alt.	112	130	157	171	194	209	224	242	261	299

Appendixes

Appendix (d)

table(2) illustrated 10in line material, nominal and true diameter and wall thickness:

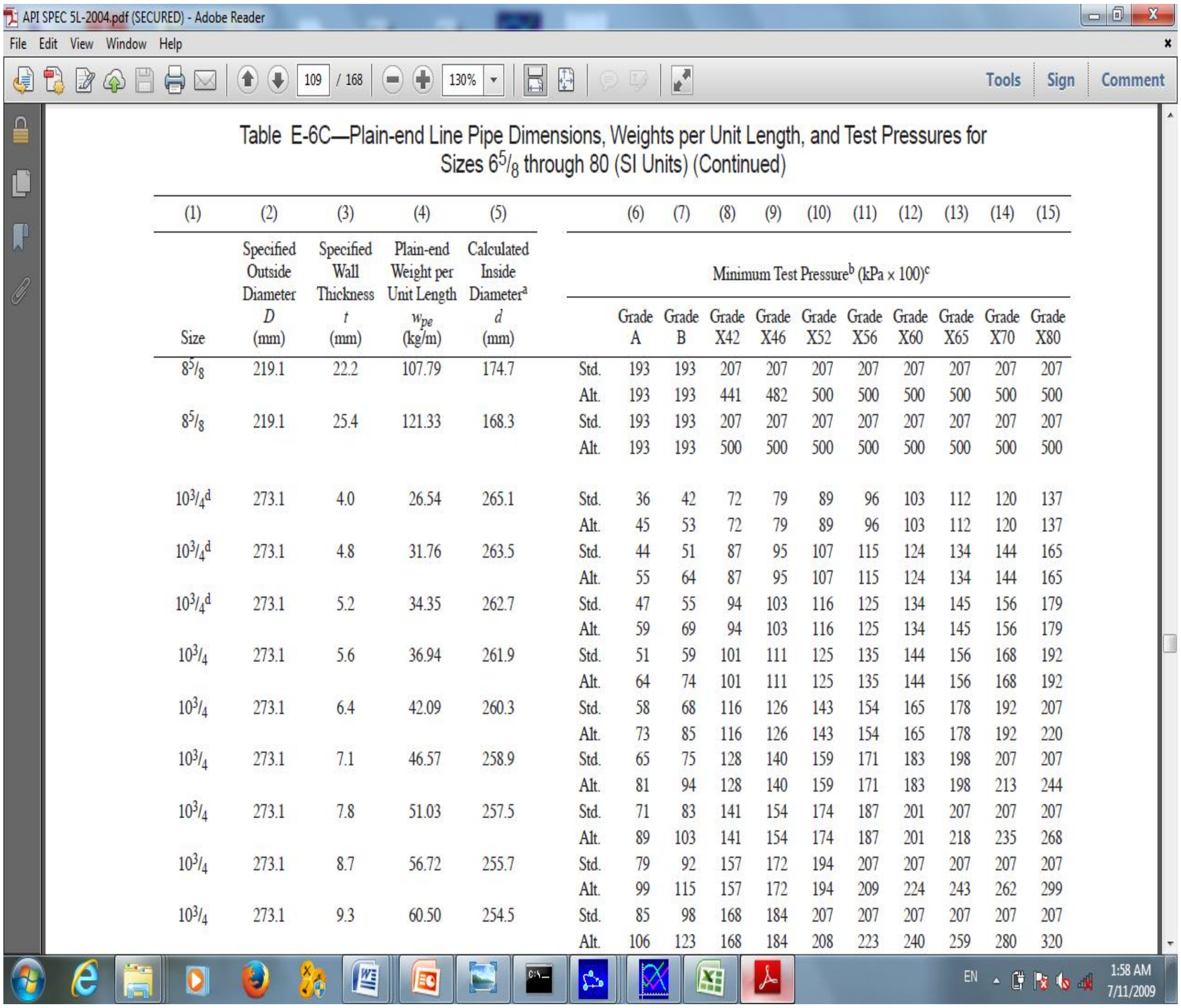


Table E-6C—Plain-end Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^{5}/_{8}$ through 80 (SI Units) (Continued)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-end Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$8^{5}/_{8}$	219.1	22.2	107.79	174.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	441	482	500	500	500	500	500	500
$8^{5}/_{8}$	219.1	25.4	121.33	168.3	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$10^{3}/_{4}$[d]	273.1	4.0	26.54	265.1	Std.	36	42	72	79	89	96	103	112	120	137
					Alt.	45	53	72	79	89	96	103	112	120	137
$10^{3}/_{4}$[d]	273.1	4.8	31.76	263.5	Std.	44	51	87	95	107	115	124	134	144	165
					Alt.	55	64	87	95	107	115	124	134	144	165
$10^{3}/_{4}$[d]	273.1	5.2	34.35	262.7	Std.	47	55	94	103	116	125	134	145	156	179
					Alt.	59	69	94	103	116	125	134	145	156	179
$10^{3}/_{4}$	273.1	5.6	36.94	261.9	Std.	51	59	101	111	125	135	144	156	168	192
					Alt.	64	74	101	111	125	135	144	156	168	192
$10^{3}/_{4}$	273.1	6.4	42.09	260.3	Std.	58	68	116	126	143	154	165	178	192	207
					Alt.	73	85	116	126	143	154	165	178	192	220
$10^{3}/_{4}$	273.1	7.1	46.57	258.9	Std.	65	75	128	140	159	171	183	198	207	207
					Alt.	81	94	128	140	159	171	183	198	213	244
$10^{3}/_{4}$	273.1	7.8	51.03	257.5	Std.	71	83	141	154	174	187	201	207	207	207
					Alt.	89	103	141	154	174	187	201	218	235	268
$10^{3}/_{4}$	273.1	8.7	56.72	255.7	Std.	79	92	157	172	194	207	207	207	207	207
					Alt.	99	115	157	172	194	209	224	243	262	299
$10^{3}/_{4}$	273.1	9.3	60.50	254.5	Std.	85	98	168	184	207	207	207	207	207	207
					Alt.	106	123	168	184	208	223	240	259	280	320

Appendixes

Appendix (d)

table(3) illustrated 12in line material, nominal and true diameter and wall thickness:

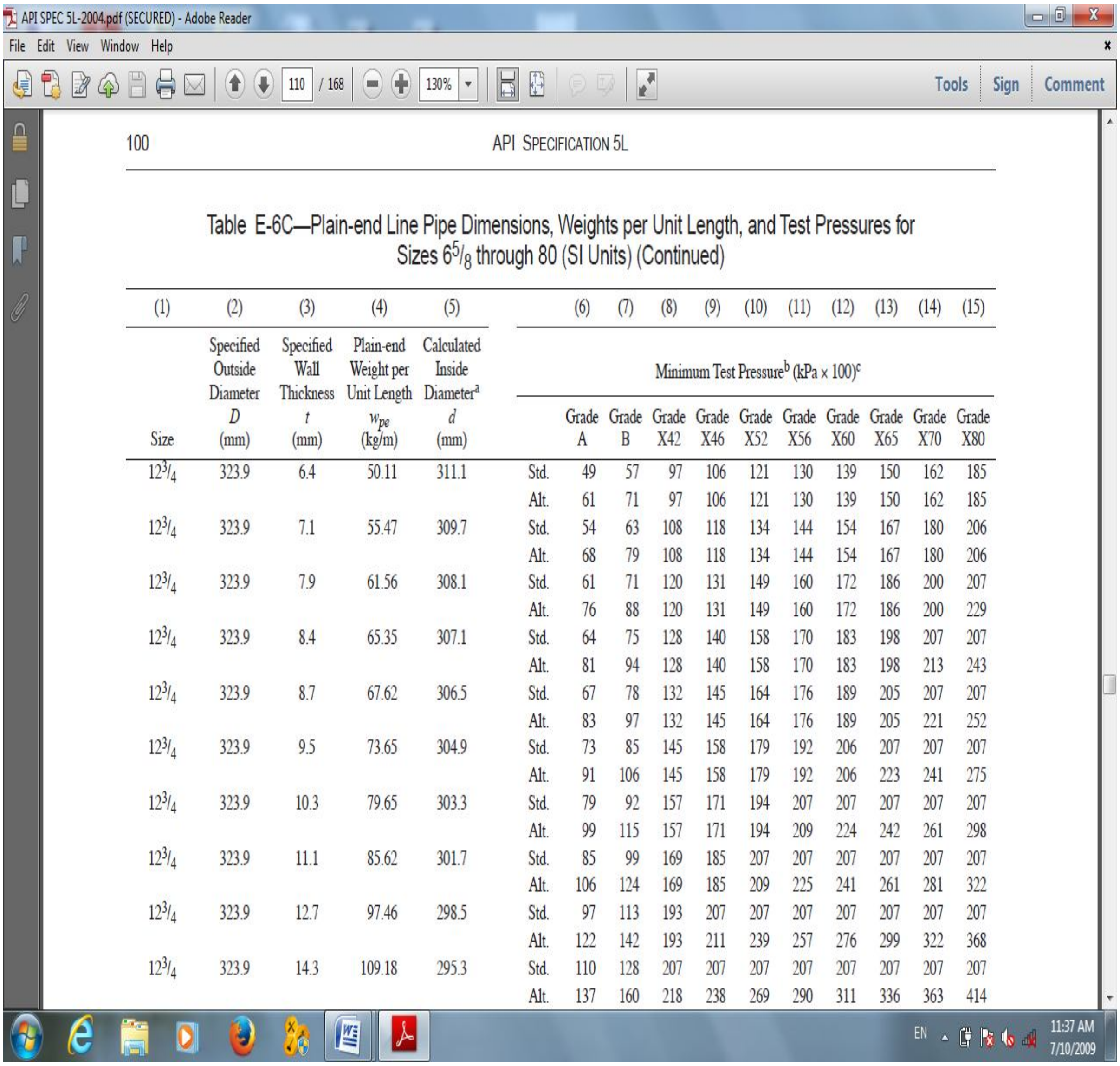


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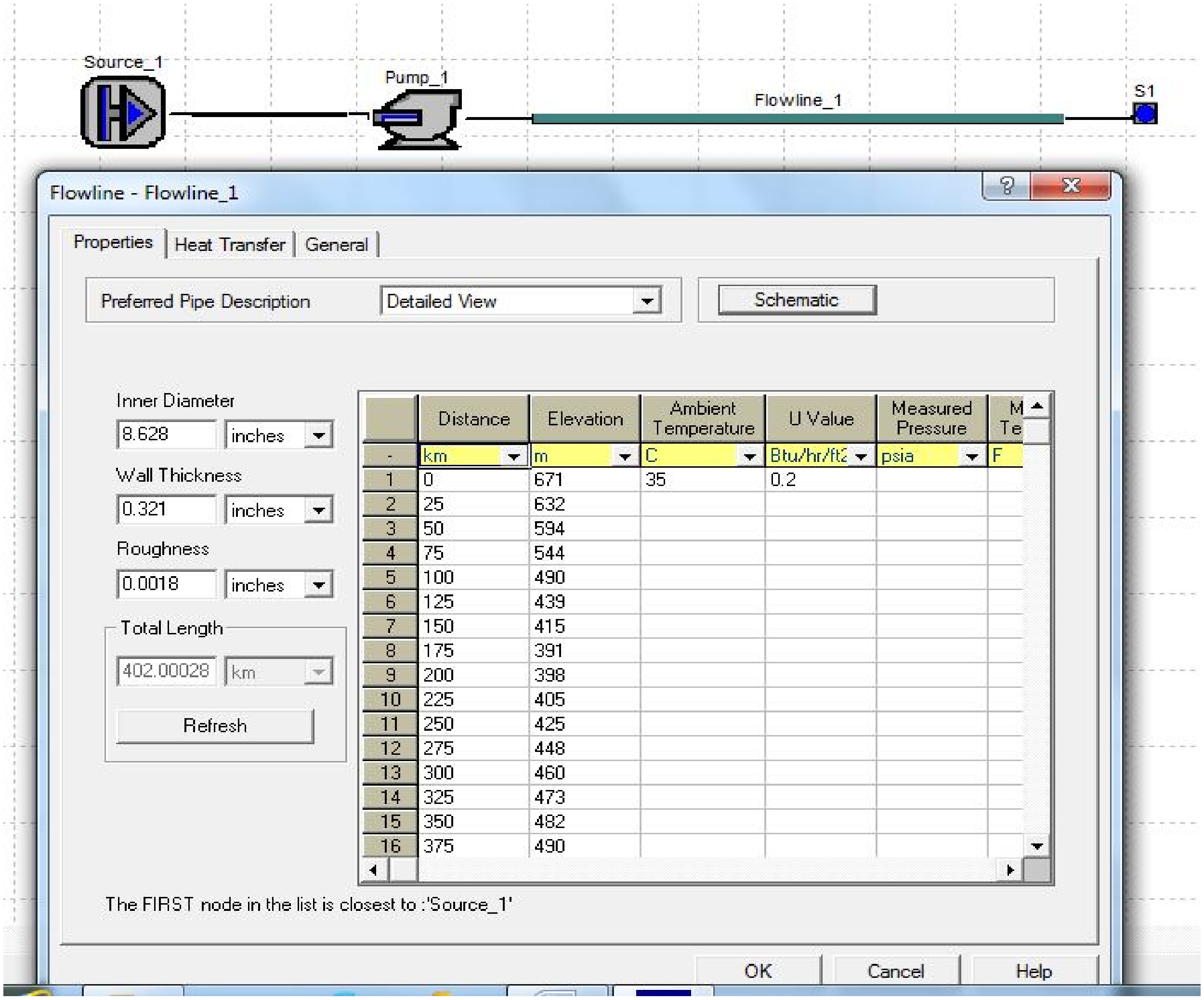
Table E-6C—Plain-end Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units) (Continued)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-end Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Minimum Test Pressure[b] (kPa x 100)[c]									
Size						Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$12^3/_4$	323.9	6.4	50.11	311.1	Std.	49	57	97	106	121	130	139	150	162	185
					Alt.	61	71	97	106	121	130	139	150	162	185
$12^3/_4$	323.9	7.1	55.47	309.7	Std.	54	63	108	118	134	144	154	167	180	206
					Alt.	68	79	108	118	134	144	154	167	180	206
$12^3/_4$	323.9	7.9	61.56	308.1	Std.	61	71	120	131	149	160	172	186	200	207
					Alt.	76	88	120	131	149	160	172	186	200	229
$12^3/_4$	323.9	8.4	65.35	307.1	Std.	64	75	128	140	158	170	183	198	207	207
					Alt.	81	94	128	140	158	170	183	198	213	243
$12^3/_4$	323.9	8.7	67.62	306.5	Std.	67	78	132	145	164	176	189	205	207	207
					Alt.	83	97	132	145	164	176	189	205	221	252
$12^3/_4$	323.9	9.5	73.65	304.9	Std.	73	85	145	158	179	192	206	207	207	207
					Alt.	91	106	145	158	179	192	206	223	241	275
$12^3/_4$	323.9	10.3	79.65	303.3	Std.	79	92	157	171	194	207	207	207	207	207
					Alt.	99	115	157	171	194	209	224	242	261	298
$12^3/_4$	323.9	11.1	85.62	301.7	Std.	85	99	169	185	207	207	207	207	207	207
					Alt.	106	124	169	185	209	225	241	261	281	322
$12^3/_4$	323.9	12.7	97.46	298.5	Std.	97	113	193	207	207	207	207	207	207	207
					Alt.	122	142	193	211	239	257	276	299	322	368
$12^3/_4$	323.9	14.3	109.18	295.3	Std.	110	128	207	207	207	207	207	207	207	207
					Alt.	137	160	218	238	269	290	311	336	363	414

Appendixes

Appendix (e)

Figure (1) shows pipesim-8 in line test to give us required inlet pressure.:



Preferred Pipe Description: Detailed View

Inner Diameter: 8.628 inches

Wall Thickness: 0.321 inches

Roughness: 0.0018 inches

Total Length: 402.00028 km

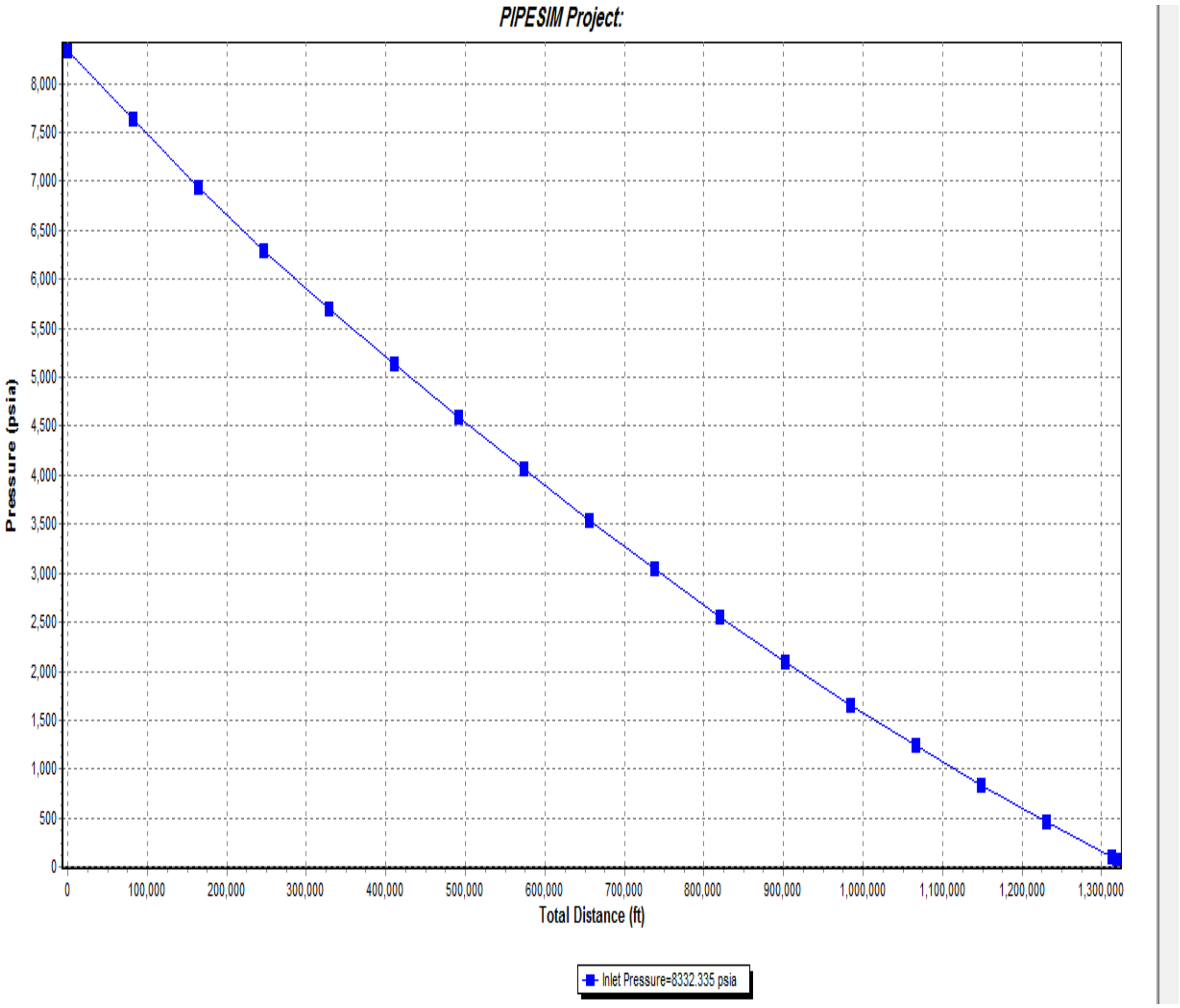
	Distance	Elevation	Ambient Temperature	U Value	Measured Pressure	M Te
-	km	m	C	Btu/hr/ft2	psia	F
1	0	671	35	0.2		
2	25	632				
3	50	594				
4	75	544				
5	100	490				
6	125	439				
7	150	415				
8	175	391				
9	200	398				
10	225	405				
11	250	425				
12	275	448				
13	300	460				
14	325	473				
15	350	482				
16	375	490				

The FIRST node in the list is closest to :'Source_1'

Appendixes

Appendix (e)

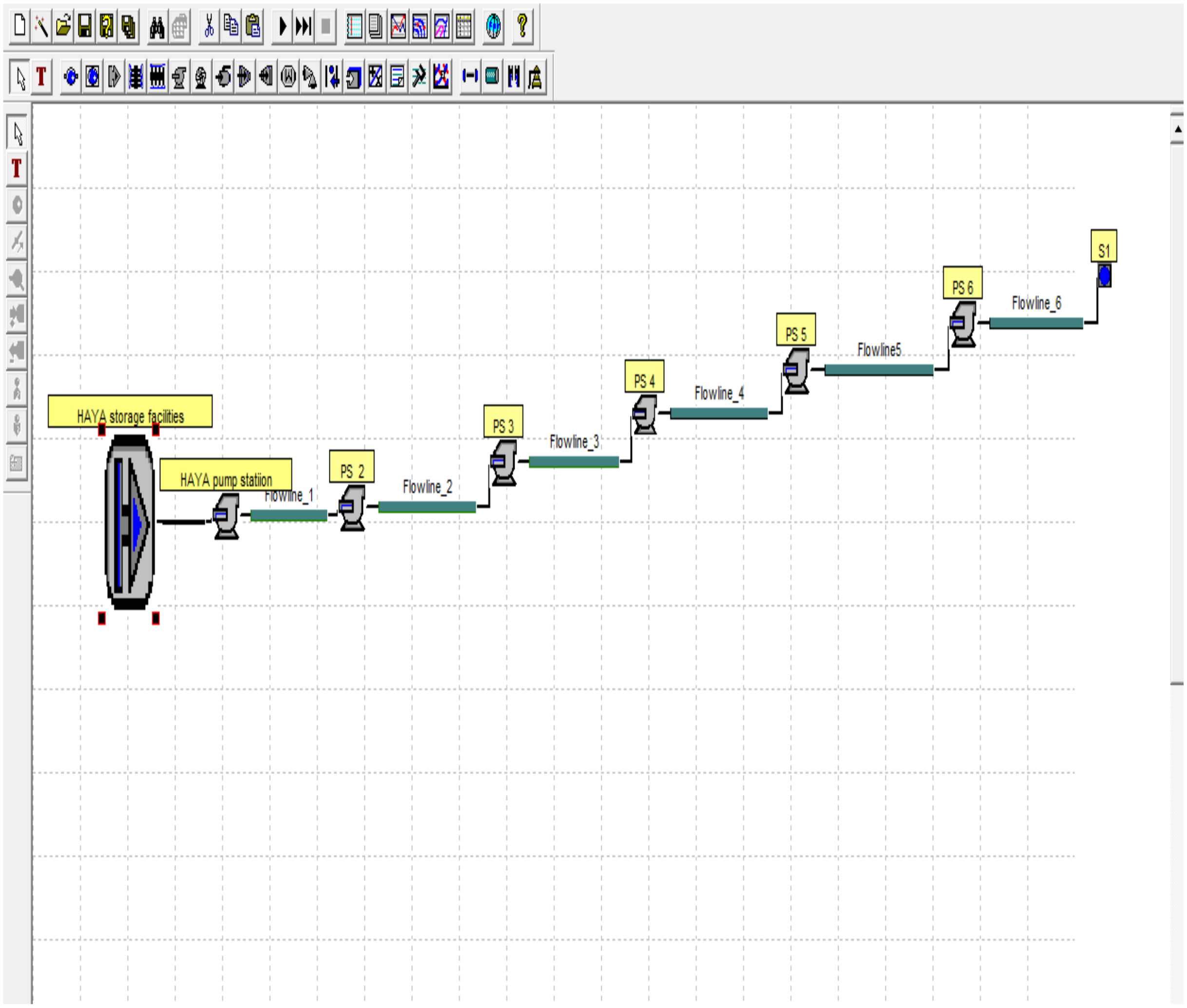
figure (2) shows 8in line inlet pressure:



Appendixes

Appendix (e3)

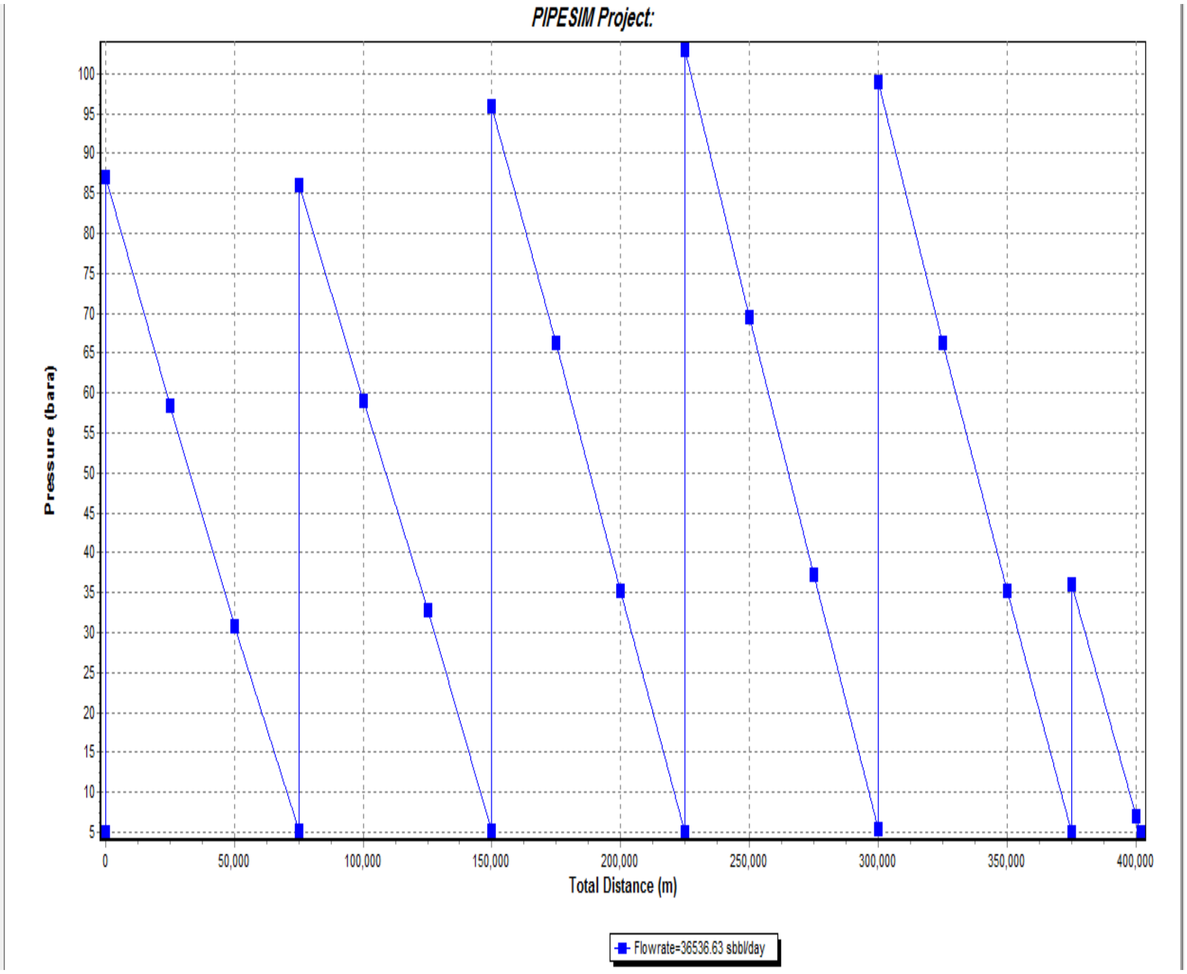
Figure (3) shows the 8in line with it no. of pump stations:



Appendixes

Appendix (e)

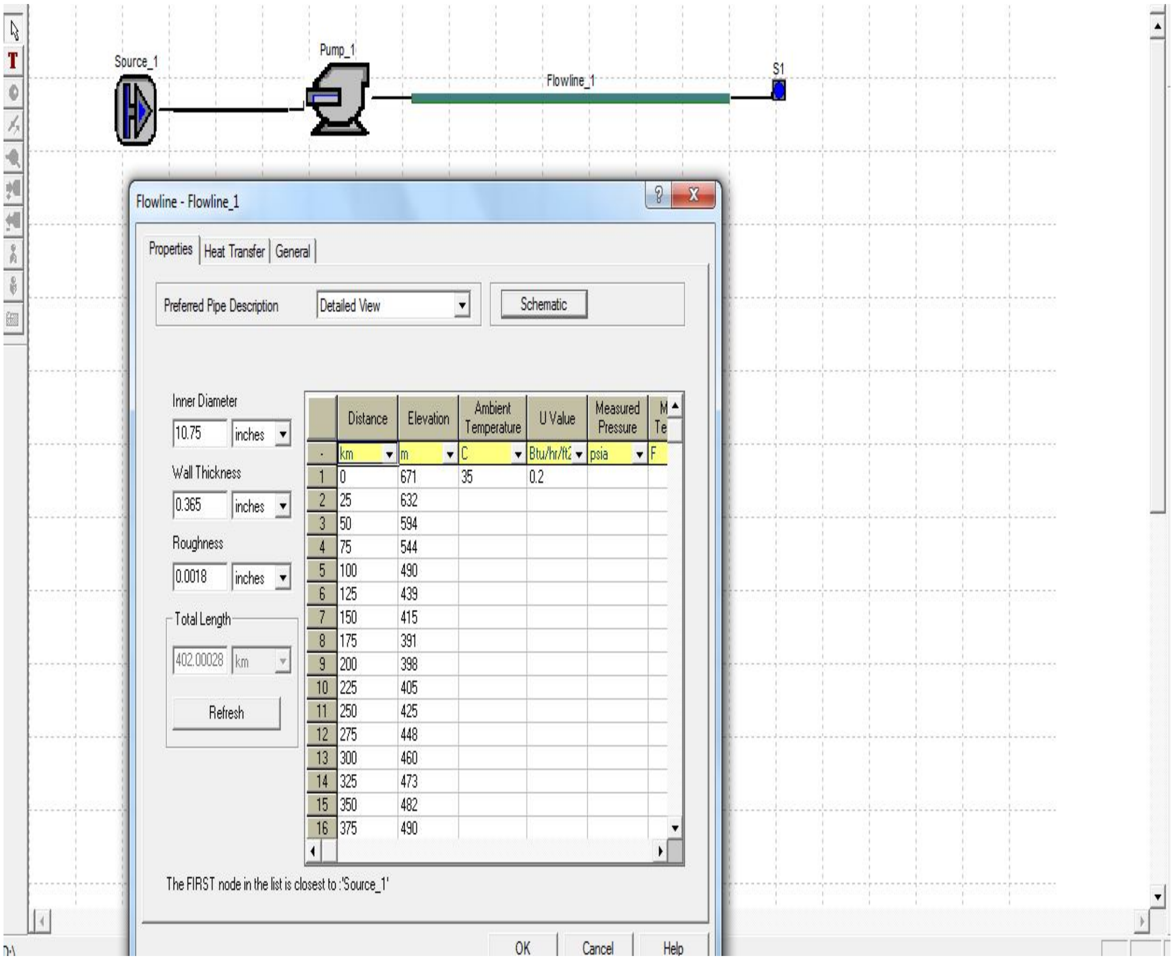
Figure (4) shows required liquid flow rate for 8in line:



Appendixes

Appendix (f)

Figure (1) pipesim-10 in line test to give us required inlet pressure:



Preferred Pipe Description: Detailed View

Inner Diameter: 10.75 inches

Wall Thickness: 0.365 inches

Roughness: 0.0018 inches

Total Length: 402.00028 km

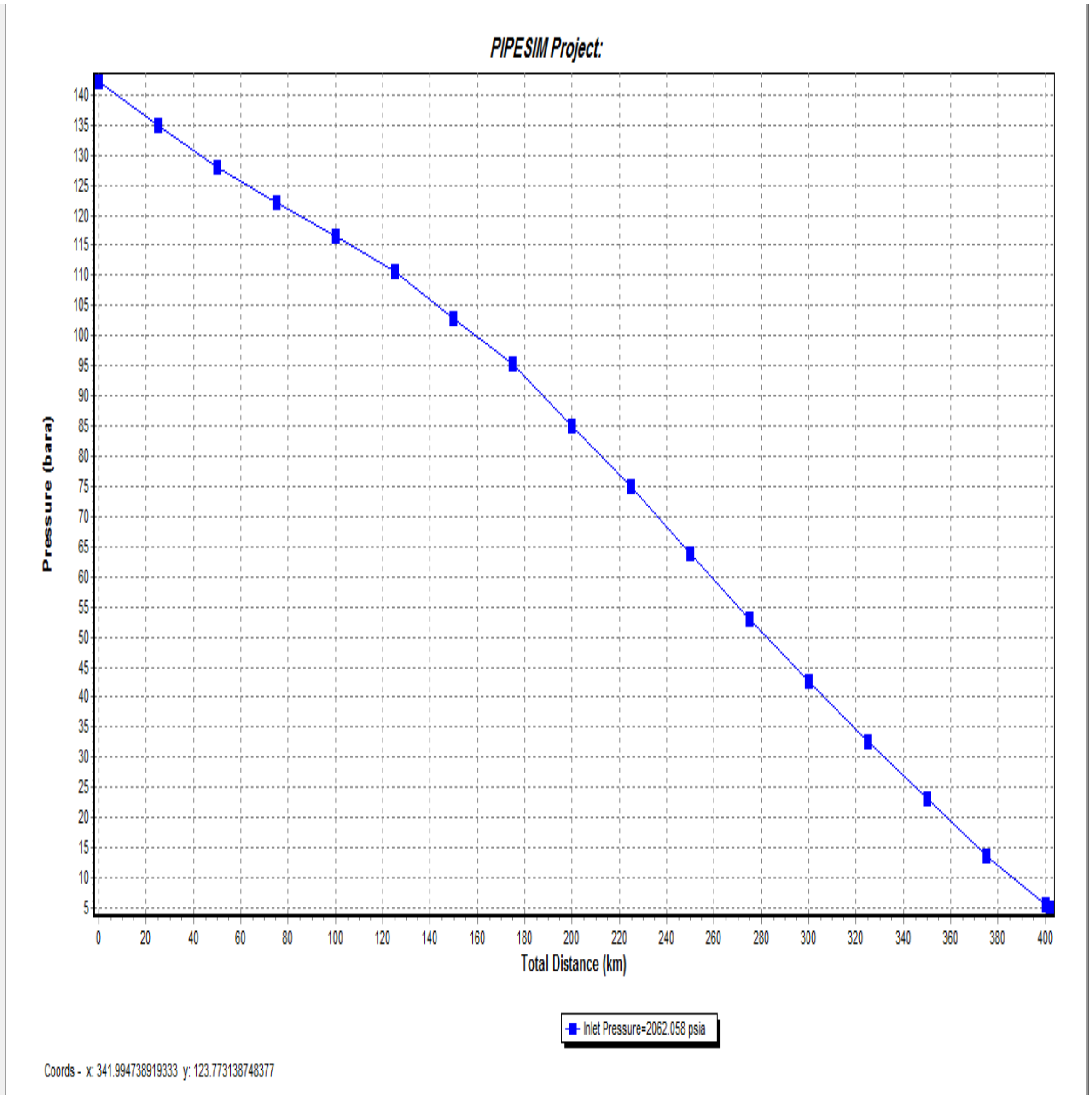
	Distance	Elevation	Ambient Temperature	U Value	Measured Pressure	M Te
.	km	m	C	Btu/hr/ft2	psia	F
1	0	671	35	0.2		
2	25	632				
3	50	594				
4	75	544				
5	100	490				
6	125	439				
7	150	415				
8	175	391				
9	200	398				
10	225	405				
11	250	425				
12	275	448				
13	300	460				
14	325	473				
15	350	482				
16	375	490				

The FIRST node in the list is closest to :'Source_1'

Appendixes

Appendix (f)

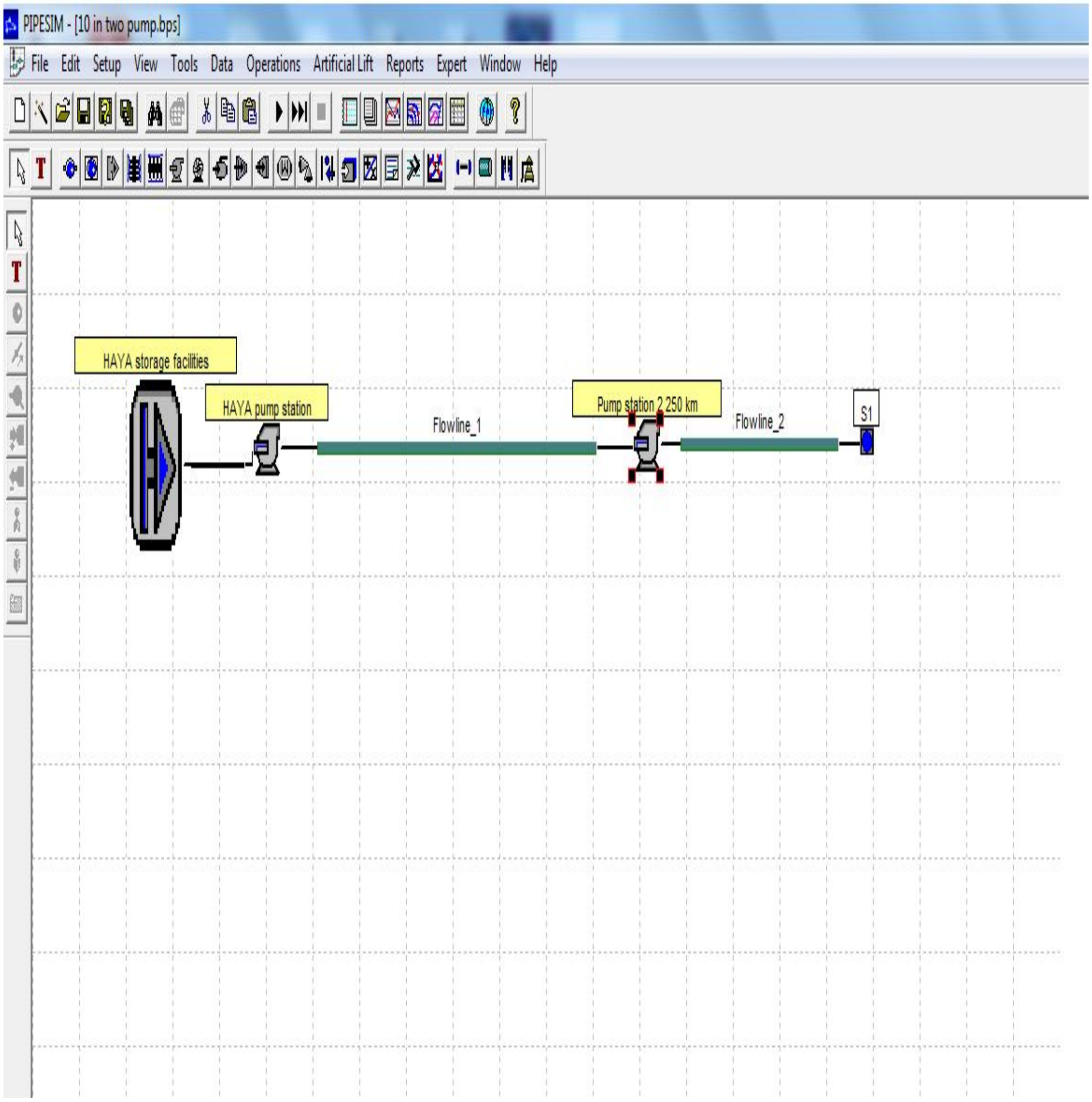
figure (2) 10 in line required Inlet pressure:



Appendixes

Appendix (f)

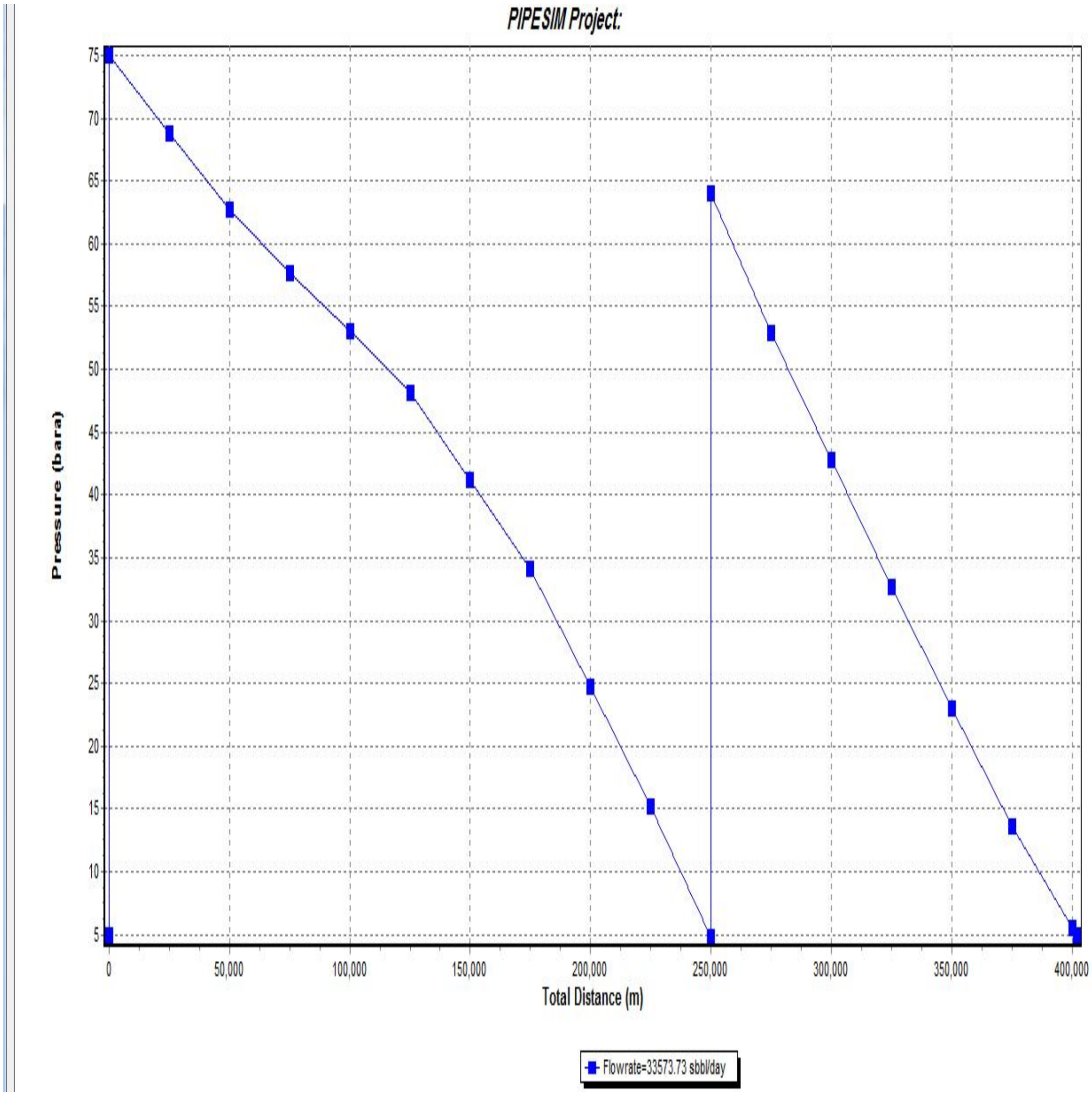
Figure (3) shows the 10in line with it no. of pump stations.



Appendixes

Appendix (f)

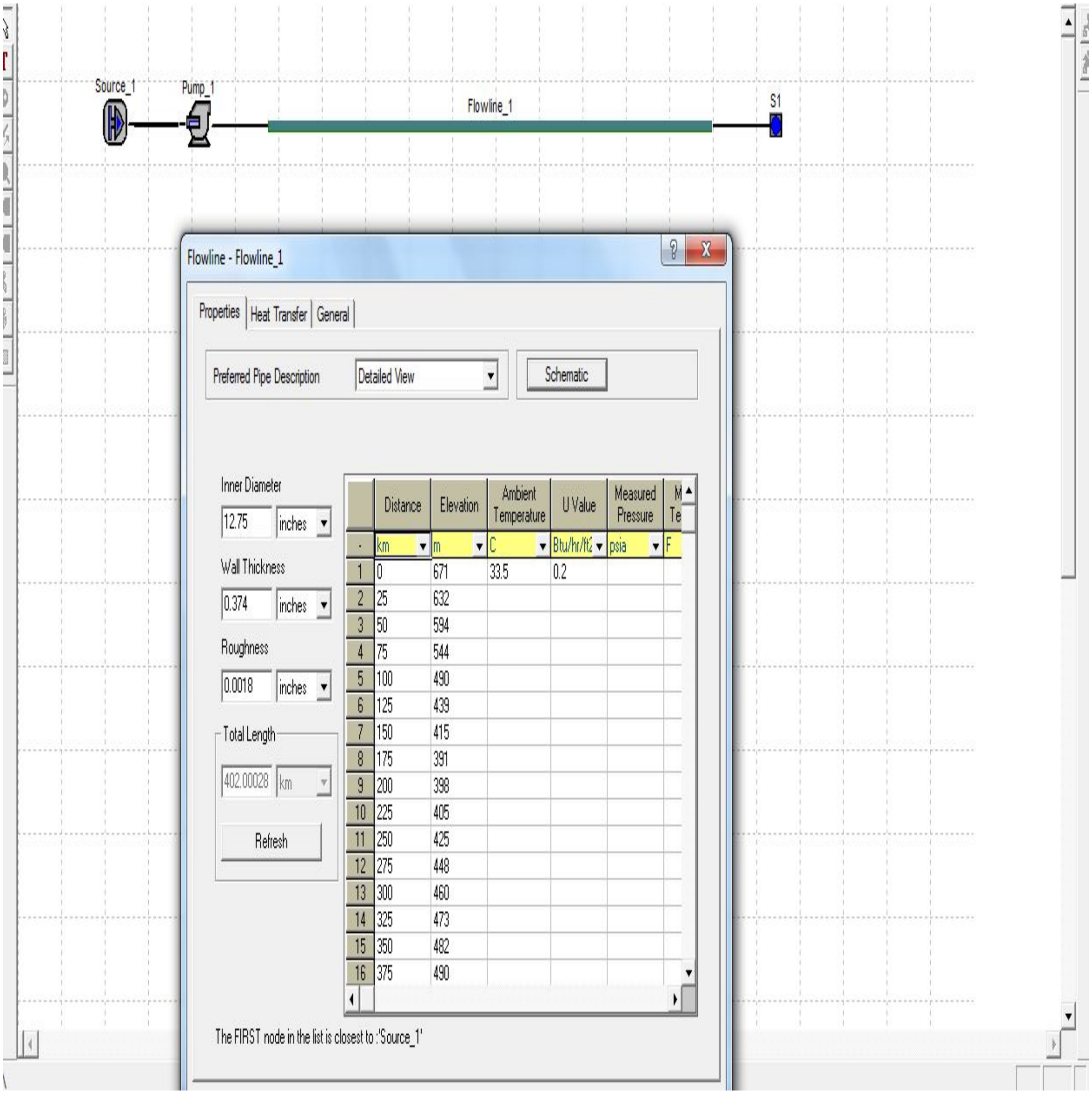
Figure (4) shows required liquid flow rate for 10in line



Appendixes

Appendix (g)

Figure (1) pipesim-12 in line test to give us required inlet pressure.



Preferred Pipe Description: Detailed View

Inner Diameter: 12.75 inches

Wall Thickness: 0.374 inches

Roughness: 0.0018 inches

Total Length: 402.00028 km

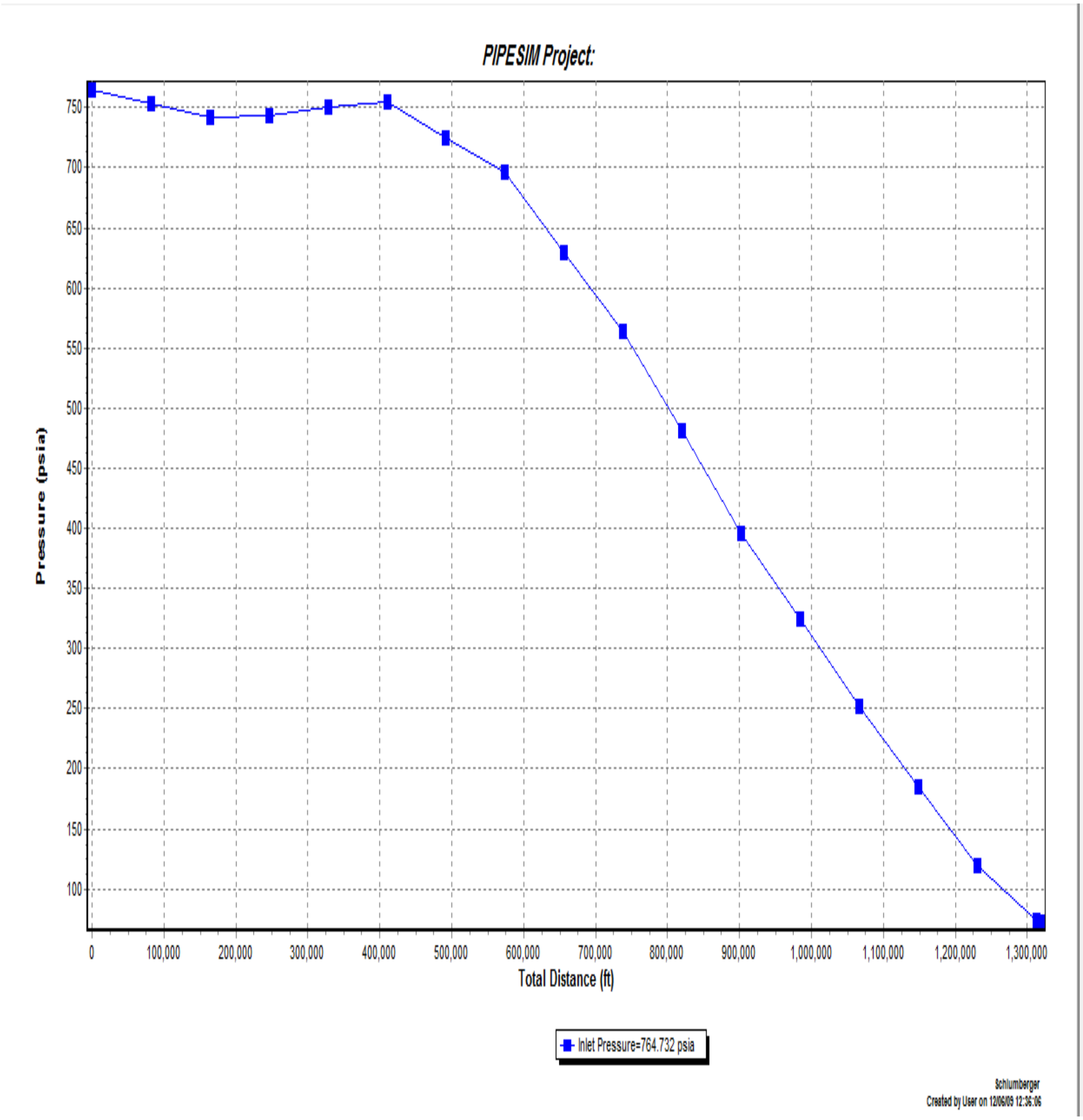
	Distance	Elevation	Ambient Temperature	U Value	Measured Pressure	M Te
·	km	m	C	Btu/hr/ft2	psia	F
1	0	671	33.5	0.2		
2	25	632				
3	50	594				
4	75	544				
5	100	490				
6	125	439				
7	150	415				
8	175	391				
9	200	398				
10	225	405				
11	250	425				
12	275	448				
13	300	460				
14	325	473				
15	350	482				
16	375	490				

The FIRST node in the list is closest to :'Source_1'

Appendixes

Appendix (g)

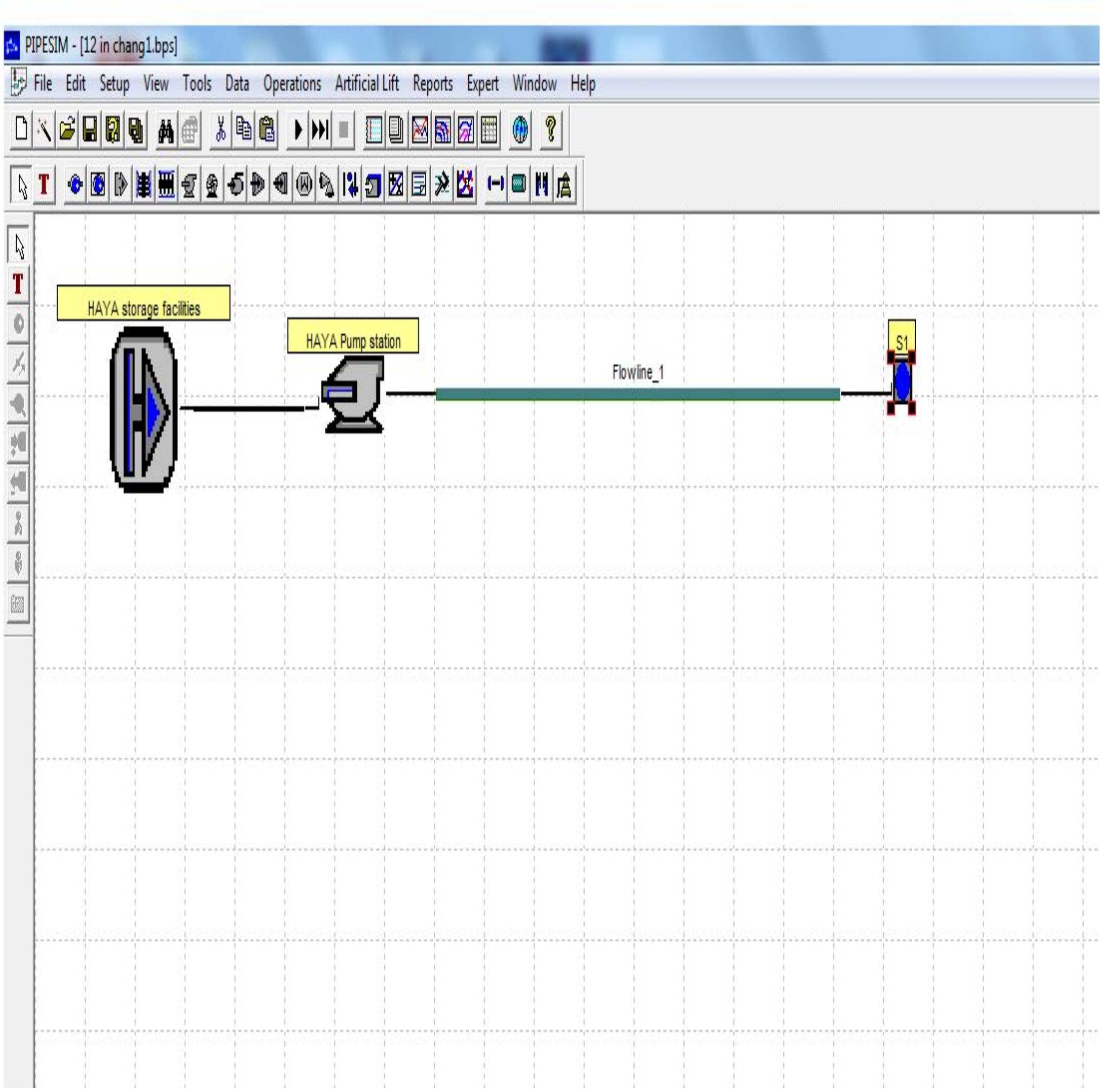
figure (2) 12 in line required Inlet pressure



Appendixes

Appendix (g)

Figure (3) the 12in line with its pump station.



Appendixes

Appendix (g)

Figure (4) required liquid flow rate for 12in line