Palestine Polytechnic University

College of Engineering & Technology
Mechanical Engineering Department

Graduation Project

Dead Red Sea Water Conveyer

Project Team
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Hebron-Palestine

June, 2008

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According to the project supervisor and according to the agreement of the testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements of the bachelor's degree.

Department chairman Signature

Name: ....

Supervisor Signature

Name: ....

Signatures of reviewing examination committee members:

Name: ....

Name: ....

In this report text we use the term (occupation state-OS-) to refer to Palestinians land occupied in 1948 by "Israeli" forces.

And we are very sorry if the word "Israeli" appear in this report text, figures, graphs and tables.

إهداء :

- إلى التي رحلت إلى بارئها بعد عناء الأيام وكانت ذات قلب حاني وأيادي بيضاء علينا وذات صبرٍ وتلهف لرؤية لحظات التخرج . . . عليك رحمة الله .
- إلى الأب الحاني ذو الفضل الكبير أدام الله عمره وفضله .
- إلى الأكرم منا جميعاً . . . شهداء الأمة .
- إلى أخواننا أسرى السجون . . . سلام الله .
- إلى صرح علمي شامخ بإذن الله . . . جامعة بوليتكنك فلسطين .
- إلى الأفاضل مدرسينا الكرام . . . جزاكم الله كل الخير .
- إلى زملائنا الكرام . . . والطلبة الأحبة . . . وفقكم الله .

<u>علي ثمينات</u>

إهداء:

إلى من غرسوا في غصن الحنان

إلى من علموني معناً للحياة

إلى من علموني معنى الفداء

إلى من لقنوني معنى التضحية والوفاء

إلى من سهروا الليالي الطوال . . . . .

إلى أمي رمز الحنان

إلى أبي رمز العطاء

إلى من رووا بدمائهم ارض الأمة الإسلامية

إلى الشهداء : شهداء الأمة الإسلامية

إلى الأسرى: أسرى الأمة الإسلامية

إلى أحبائي . . .

إلى أصدقائي . . .

إلى جامعتي: جامعة بوليتكنك فلسطين

إلى طاقم دائرة الهندسة الميكانيكية

إلى زملائي

إلى من قدم النفيس والغالي . . . لإعلاء كلمة الله في الأرض

حسام غيث

Acknowledgments:

To our great supervisor, Eng. Zuheir Wazwaz who gives us all information and support idea that give our project good look.

We want to thank our university and it's teaching staff, for their guidance of us in order to get the wide, and the most important information and knowledge in different fields.

To lecturers of surveying major:

- Dr. Maher Iwawieh.
- Eng. Ghadi Zakarneh.
- Eng. Ashraf Zabin.

To our department teachers who guide us to good work:

- Dr.Yousef Alsweiti .
- Eng. Mohamed Awad .

To our report reviewing examination committee members:

- Dr.Imad Alkhateeb.
- Dr. Maher Aljabari.

Abstract (English):

This project discusses the historical problem of Dead Sea surface level sharp declining, and the suggested solutions to save the sea level.

Our project will focus on one of the suggested solution that is Red-Dead Sea pipe which was agreed by representatives of Jordan, occupation state and Palestine Authority on 9/5/2005 to begin a feasibility study, environmental and social Assessment.

In our project we detailed the Dead Sea level problem and the amount of water required need to refill Dead Sea and keep its level in a steady state.

Then we describe and design the required parts to achieve the purpose of conveying water to Dead Sea region.

The major parts of the design project include:

1. Inlet suction well: which enters the water from bottom of Gulf of Aqaba to the pump process.
2. Pump process: which pumps the water to lake 1 on the shore of red sea to lake 2 by open canal to pump station that will pump the water to one of Aqaba mountains at level 125masl to flow the water by gravity through pips, tunnel and canal.
3. Water conveyers: pipe, tunnel and canal that is used to transfer the water to Dead Sea region
4. Turbine: that extracts the fluid energy from water flowing under astatic head of about 500 m.
5. Finally we preview desalination plant types and volume requirement of water to be used by regional countries that's agreed at water cooperation aggrement.

Abstract (Arabic):

يتناول هذا المشروع عرض لمشكلة انخفاض مستوى سطح البحر الميت عبر السنين بسبب استغلال الموارد المائية التي تغذيه من قبل الدول المجاورة لتلك الموارد – الأردن ودولة الاحتلال –.

كما يتناول عرض لبعض الحلول المقترحة لحفظ مستواه للمستوى التاريخيّ.

كما يركز مشروعنا على أحد الحلول المقترحة وهو أنبوب قناة البحر الأحمر – الميت والموقع على هذا الخيار من قبل ممثلي كل من الأردن وإسرائيل والسلطة الفلسطينية بتاريخ ٩\٥\٢٠٠٥ والمتفقون على بدء عمل دراسة جدوى اقتصادية وبيئية وتقنية لهذه القناة.

في هذا المشروع قمنا بتفصيل مشكلة البحر الميت وكمية المياه المطلوبة لإعادة ملئه والحفاظ على مستواه ليبقى في حالة الثبات.

بعد ذلك قمنا بوصف وتصميم الأجزاء المطلوبة لتحقيق هذا الهدف وهذه الأجزاء هي:

١. بئر الإدخال : الذي يدخل الماء من خليج العقبة إلى بحيرة ١.
٢. عملية الضخ : والتي تتضمن عملية ضخ المياه من محطة الضخ ١ إلى بحيرة ١ ومن ثم يتم نقلها عبر قناة مفتوحة إلى بحيرة ٢ ومن ثم ضخها إلى إحدى جبال العقبة على ارتفاع ١٢٥ م فوق مستوى سطح البحر لتتدفق المياه تحت الجاذبية عبر المواسير والأنفاق والقنوات إلى البحر الميت.
٣. نواقل المياه : من أنفاق ومواسير وقنوات والتي ستنقل المياه المطلوبة إلى منطقة البحر الميت.
٤. التوربين : الذي يقوم باستخراج طاقة المياه المتدفقة تحت تأثير الفرق بين مستوى البحرين وعلو الجبل وهذا الفرق يصل إلى ٥٠٠متر.
٥. أخيرا استعرضنا أنواع محطات تحليه المياه واحتياجاتها من الماء وتوزيع هذه المياه المحلاة على دول المنطقة المتفقة على التعاون بينهما في مجال المياه.

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Chapter One

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- **Project idea.**
- **Important of project**
- **Scope of the project.**
- **Literature review.**
- **Report schedule.**
- **Estimate cost.**

Chapter one

Introduction

1.1 General perspective.

This general perspective will show Palestine such that:

- Palestine location and geographic
- Palestine seas.

1.1.1 Palestine location and geography.

Palestine is located into asia contient at the east shore of the Mediterranean between:

- Two longitudinal line (34°-15') and (35°- 40') at east,
- Two latitudinal line (29°-30') and (33°-15') at north.

So the geographic location Palestine is strategically important because it is the connection point of the three continents (Asia, Africa and Europe).

Border of historical Palestine:

- From the north Lebanon and Syria.
- From the south Egypt and gulf of Al-Aqaba.
- From the west Mediterranean Sea.
- And Jordan from the east.

1.1.2 Palestinian seas.

Palestinian seas are listed below as shown into figure (1.1).

Figure (1.1) seas of Palestine

- In the west Mediterranean Sea.
- In the south Red Sea.
- In the east Dead Sea
- In the north Lake Hula and Sea of Galilee.

1.1.2.1 The Mediterranean Sea.

The Mediterranean is a sea of the Atlantic Ocean almost completely enclosed by land:

- From the north by Europe,
- From the south by Africa,
- And from the east by Asia

It covers an approximate area of 2.5 million km^2, and it's width is approximately 14 km. [1]

1.1.2.2 Red Sea.

The Red Sea is an inlet of the Indian Ocean between Africa and Asia and it has:

- Surface area of about 450,000 km^2
- 1,900 km long
- Its widest point, over300 km wide
- Average depth of 500 m. [2]

1.1.2.3 The Dead Sea.

The Dead Sea is the terminal lake of the Jordan Rift Valley. It is the lowest point on earth surface, and the waters have the highest density and salinity of any sea in the world.

Dead sea is composed from two basins, the northern and southern basin and “lisan”into mid region.

1.1.2.4 Lake Hula (its converted to valley since it dried).

The Hula Valley lies within the northern part of the Syrian-African Rift Valley and it has:

- An elevation of about 70 meters above sea level
- An area of 177 square kilometers [3]

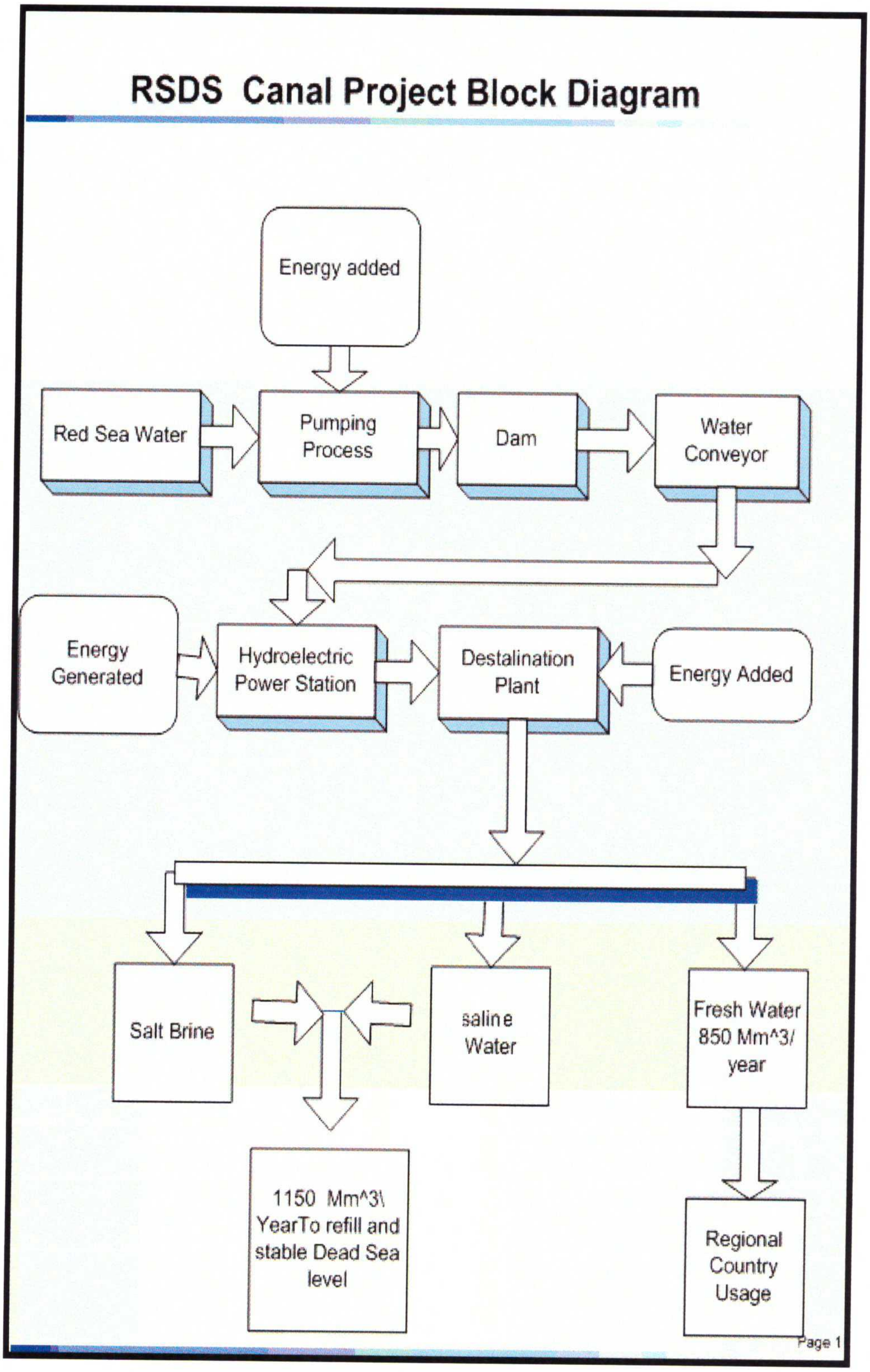
But now its dried and converted agricultural land.

1.1.2.5 Sea of Galilee(tabaries).

- It is 96 km north of Jerusalem
- It is 21 km long
- It 13 km wide at its greatest extent
- Its surface is about 213 m below sea level
- It is about 46 m deep at its lowest point. [4]

1.2 Project idea.

The main idea of the project is to carry the water from the Red Sea to the Dead Sea by hydraulic piping to prevent the sharp declining in the Dead Sea level and employ the difference between the Dead and Red Sea level to generat electricity. and use some of these generating electricity to feed the desalination station which will deslinate water to use it into agricultural and daily usage in the regional countries so, the idea of the project can be described by figure(1.2).



Figure(1.2):RSDSC project diagram

1.3 Important of the project.

The objectives of the dead- red sea canal are to achieve the following:

1. Prevent sharp declining of the Dead Sea level by carrying water from Red Sea to Dead Sea.
2. Employ elevation difference between Red-Dead Sea levels to produe hydro electric power
3. Feeding desalination station with water and part of electric energy generated to run these stations.
4. To provide fresh water to regional countries Palestinian, Jordan and OS as aggreed in feasebility aggrement.

1.4 Scope of the project.

The field of this project is energy conversion, so we will convert hydraulic energy of the flowing water to electricity by hydro-electric power plant.

1.5 Literature review.

1.5.1 Possible Alignments for Water Conveyance

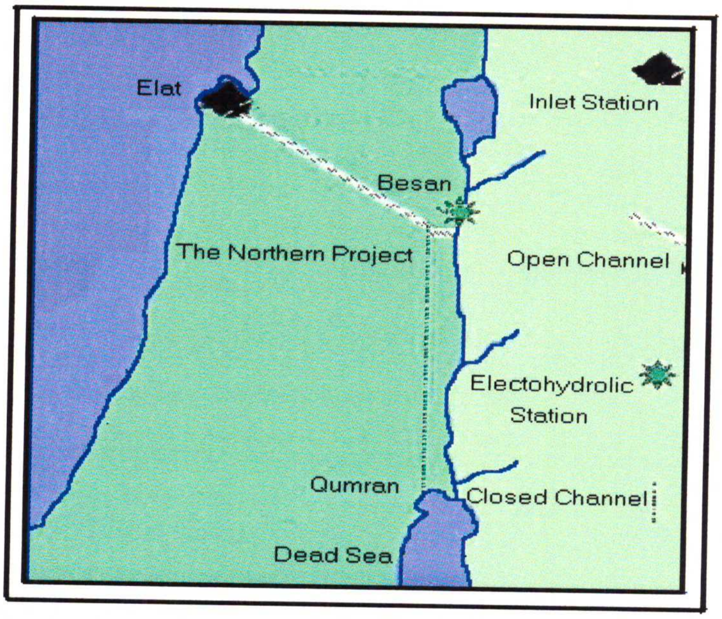
This studying of the Dead Sea problem related with possible alignments suggested conveying Red Sea water to Dead Sea. The most suitable path to deliver Red Sea water to Dead Sea depends on technical, geological, environmental and economic aspects.

According to the Israel Ministry of Foreign Affairs 2002 report, they have suggested three possible alternative paths namely Red Sea – Dead Sea canal (RSDSC) ,Qatif alignment and Northern project alignment (belongs to Mediterranean Sea – Dead Sea project).so all of the three alignment will be describe in the following notes.

1.5.1.1 Northern project alignment

It is path shown into figure(1.3) and have the following:

- It is the shortest possible path.
- It is the most technically feasible alternative due to the fact that of low cost this was planned to join with national water carrier near the Sea of Galilee.
- It will be driven through the Carmel Mountain with 80 Km pipelines plus short tunnel.

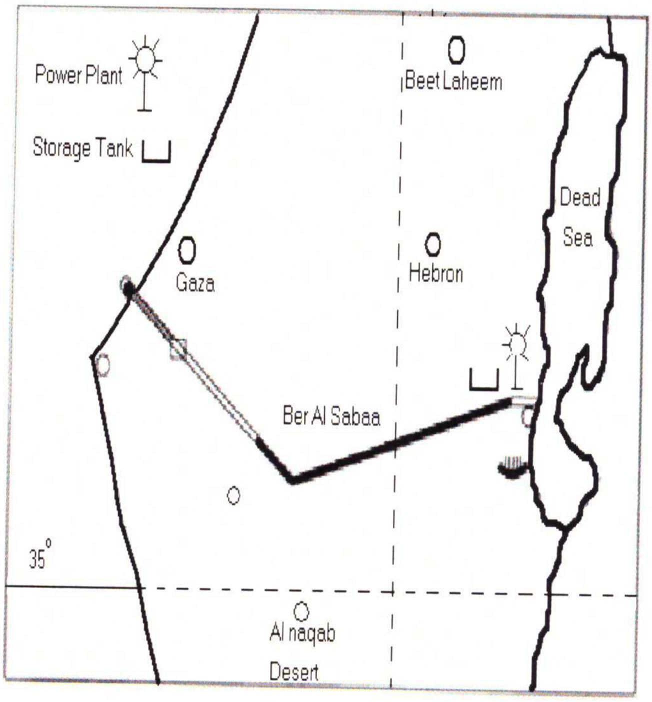


Figure(1.3)The northern alignment

1.5.1.2 Qatif alignment

It is path shown into figure(1.4) and have the following:

- It is a part of Mediterranean Sea – Dead Sea project
- Mediterranean Sea water will be diverted to the Dead Sea via 80 Km tunnel and 20 Km canal.
- It is more expensive.
- it is contain tunnel from intake from the sea to Dead sea whole along

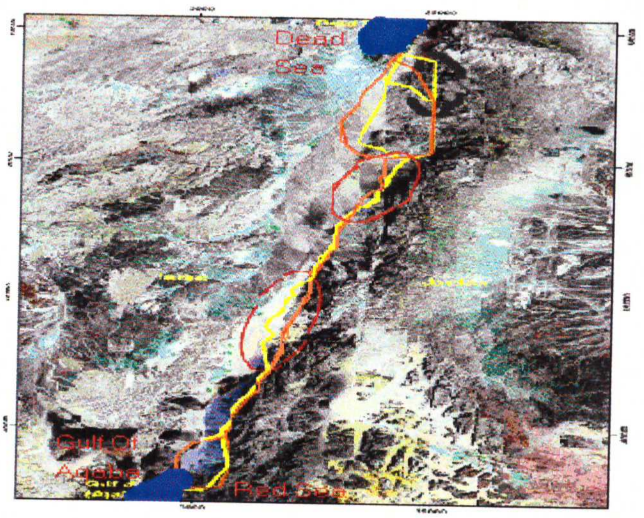


Figure(1.4) Qatif alignment

1.5.1.3 Dead Read Sea Canal.

- It is agreed between Jordan, Palestinian Authorities and OS jointly signed letter with the World Bank dated May 9 /2005 agreed to work on Red Sea – Dead Sea peace canal .
- It has the capacity to gain hydropower using nearly 400 m elevation difference between Red Sea and Dead Sea.
- This power can be used to desalination and rest will be distributed via electricity network .
- There are several proposed alignments based on geotechnical and economical factors and these alignment shown into figure (1.5) .

Actually American company Harza group proposed five alternative routes and among them eastern alignment with three open or near surface canals is the most suitable alternative. This alignment is driven entirely through the Jordanian territories.



Figure(1.5) Red Dead Sea alignment

1.6 First Semester schedule.

Table (1.1) schedule table explain how we manage our report time period

process	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting Data	1	2	3	4	5	6	7	8	9							
Analyzing of data				4	5	6	7	8	9	10	11	12	13			
Beginning with parts design				4	5	6	7	8	9	10	11	12	13			
Calling some ministers and researcher institute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Visiting our university department and ask about data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Writing The documentation												12	13	14	15	16

1.7 Second Semester Schedule.

Table (1.2) schedule table explain how we manage our report time period

process	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting data	1	2	3													
Used avarious method to calculate the volume				4	5	6	7									
Canal and tunal calculation				4	5	6	7									
Turbine selector and design								8	9	10	11					
Design the pump station												12	13	14	15	
Writing The documentation								8	9	10	11	12	13	14	15	16

1.8 Estimated cost.

Mission	Cost
Printing our report	60(NIS)
Calling to Jordan ,OS ,Palestinian centeres(geology centeres)	200(NIS)
Other cost	200(NIS)

Chapter Two

Source of Renewable Energy

- **Main renewable energy technologies.**
- **Electricity energy situation into Jordan, Israel OS, and Palestine territory.**

Chapter 2

Source of Renewable Energy

2.1 Main renewable energy technologies

There are main renewable energy technologies as it classifying here: [5]

- Wind power.
- Geothermal energy.
- Solar energy use.
- Biofuel.
  - Liquid biofuel.
  - Solid biomass.
  - Biogas.
- Water power.

And we go to explain the water power because it is most important in our project.

2.1.1 Water power

Energy in water (in the form of motive energy or temperature differences) can used. Since water is about 800 times denser than air, even a slow flowing stream of water, or moderate sea swell, can yield considerable amounts of energy.

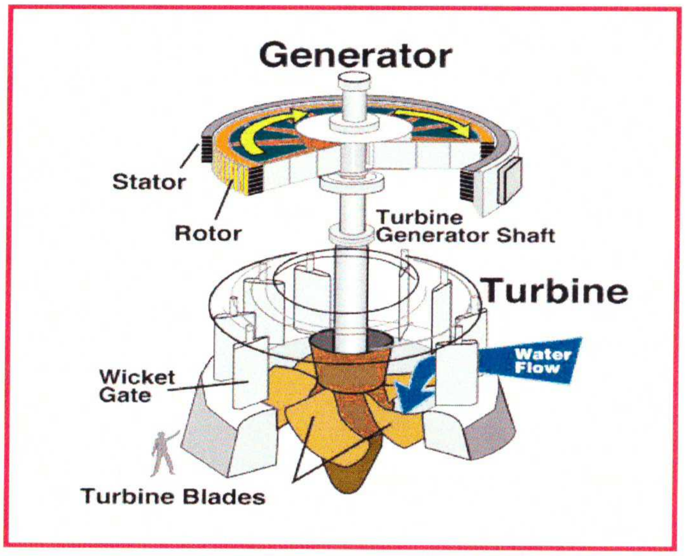


Figure (2.1) Water turbine & electrical generator

And the major type of water powers are hydroelectric powers which have the large value part into electrical generating by using many tools like water turbines that shown into figure(2.1),so we go to explain hydroelectricity into following.

2.1.1.1 What is Hydroelectricity? [6]

Hydroelectricity is electricity produced by hydropower. Hydroelectricity now supplies about 715,000 MWe or 19% of world electricity (16% in 2003), accounting for over 63% of the total electricity from renewable in 2005.

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. In this case the energy extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is proportional to the head. To obtain very high head, water for a hydraulic turbine may be run through a large pipe called a penstock.

Pumped storage hydroelectricity produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine. Pumped storage schemes currently provide the only commercially important means of large-scale grid energy storage and improve the daily load factor of the generation system. Hydroelectric plants with no reservoir capacity are called run-of-the-river plants, since it is not then possible to store water.

A tidal power plant makes use of the daily rise and fall of water due to tides; such sources are highly predictable, and if conditions permit construction of barrages and reservoirs, can also be dispatch able to generate power during high demand periods.

Less common types of hydro schemes use water's kinetic energy or undimmed sources such as undershot waterwheels, the relatively recent field of hydrokinetics.

2.2 Electricity energy situation into Jordan, OS , and Palestine territory.[7]

Table (2.1), show the total electrical energy of Palestine, Jordan , OS and other countries which shown the production and consumption value for several year and show the consumption and production value for every person and the price of the electric for each countries .

Table (2.1) Energy of Palestine, Jordan , OS

Indicator	Palestinian	OS	Jordan
Population (thousands) 2000	3.150*10^6	6.639*10^6	4.886*10^6
GDP(Million current $) 2000	4.619*10^6	116.409*10^6	8.465*10^6
Electricity consumption(GWh) 2000	2.263*10^6	34.739*10^6	6.392*10^6
Total electricity production capacity billion of KWh 2002	0.112	45.4	7.1
Total electricity production capacity GWh 2002	0.14	9.1	1.7
electricity production supply KWh/person/year	690	6.906*10^6	1.299*10^6
Electricity consumption KWh/person/year 1999	583	6.429*10^6	1.185*10^6
Electricity exportation(million KWh) 2001	0	1.457*10^6	2
Electricity import(million KWh) 2001	1.965*10^6	0	267
Average electricity price (cent of $)2000	11-50	8.5	4-11
Transmission losses of total generated capacity 2002	1-25 % (1994)	3 %(1.396 *10^6 GWh)	14 %(989 GWh)
Market share (portion of local electricity consumed)	0.05 %	100 %	100 %

2.2.1 Palestinian territories

As shown in the table (2.1),

- The electrical import was 1'965 million KWh into the year 2001.
- The value of the electric consumption was 2'263 GWh into the year 2000.
- The total electricity production value reaches 0.112 billion of KWh into the 2002.
- The average electricity price reaches (11-50) cents of dollar into the year 2000.

2.2.2 Jordan state

- The electrical import was 267 million KWh in the year 2001.
- The value of the electric consumption was 6'392 GWh in the year 2000.
- The total electricity production is 1.7 billion of KWh in the year 2002.
- The average electricity price reaches (4-11) cents of dollar in the year 2000.

2.2.3 Occupational (OS)

- The value of the electric consumption was 34'739 GWh in year 2000.
- The total electricity production value reaches 45.4 billion of KWh in the year 2002.
- The average electricity price reaches 8.5 cents of dollar in the year 2000.

As shown in figure (2.2), the graph show the relation between the tonne of equivalent petroleum and the moths in year for several petroleum derivative used in west bank and Gaza strip for a year 2002.

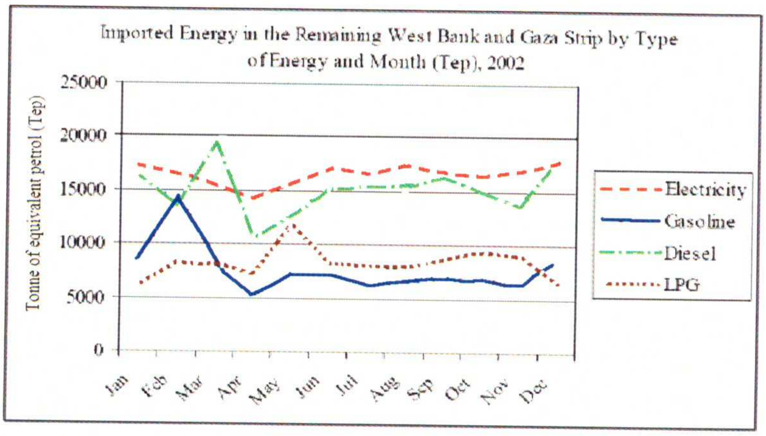


Figure (2.2): Imported energy in the remaining west bank and Gaza strip by type of energy and month (Tep), 2002

Figure (2.3), below show the relationship between the electric consumption in gega watt hour and gross domestic product in million dollars at several years.

We conclude from the diagram that the electric consumption increases when the year increase and this related to the development and the economic growth.

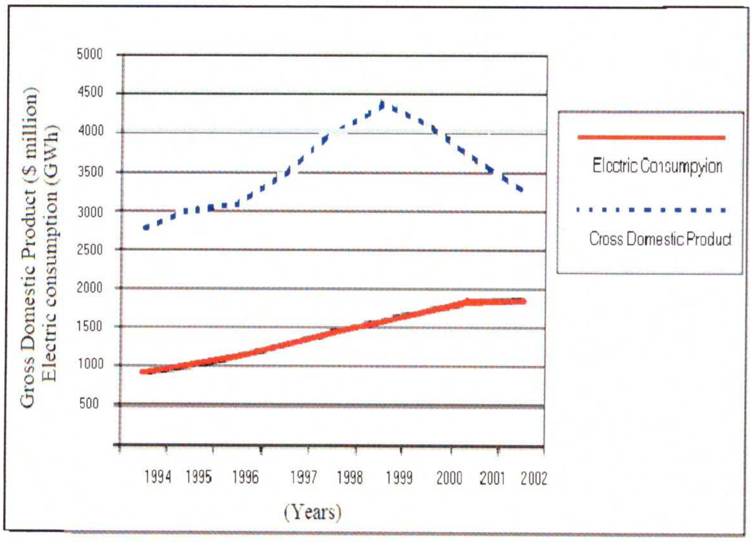


Figure (2.3): Electric consumption (GWh) and Gross Domestic Product ($million) For Palestinian territories (1994-2002)

The demand for electricity in OS could be estimated at 7,650 MW in 2000. Given that this demand increases rapidly, it is estimated that it will reach 9,497 MW in 2005 as shown in figure (2.4).

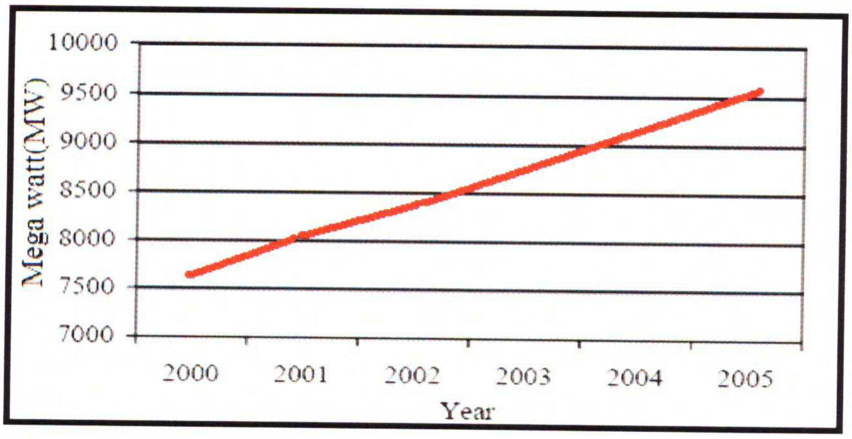


Figure (2.4): Demand for electricity in Israel (MW) (2000-2005)

Most of the electricity demand in OS comes from the domestic sector, followed by the commercial sector, while the industrial sector comes in third place as shown in figure (2.5).

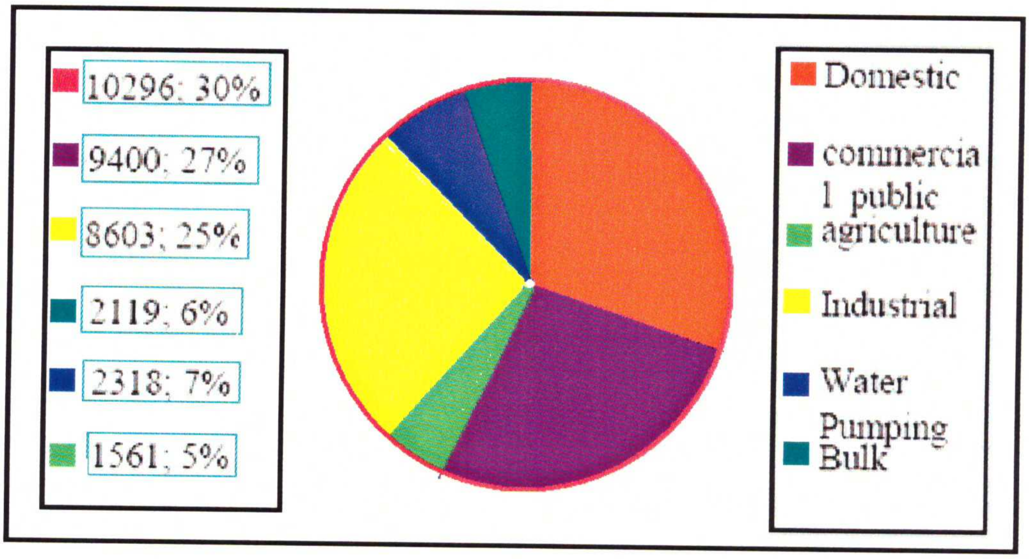


Figure (2.5): Electricity Consumption in OS by sector (million KWh),1999

One of the main problems, is the high price for electricity in the Palestinian territories.

With an average price of nearly US 30 cents per kWh, the electricity price reached a very high level in 2000; this was 3 times higher than the average price in OS or Jordan; twice as high as that in Lebanon and 5 times higher than the average price in the USA figure (2.6).

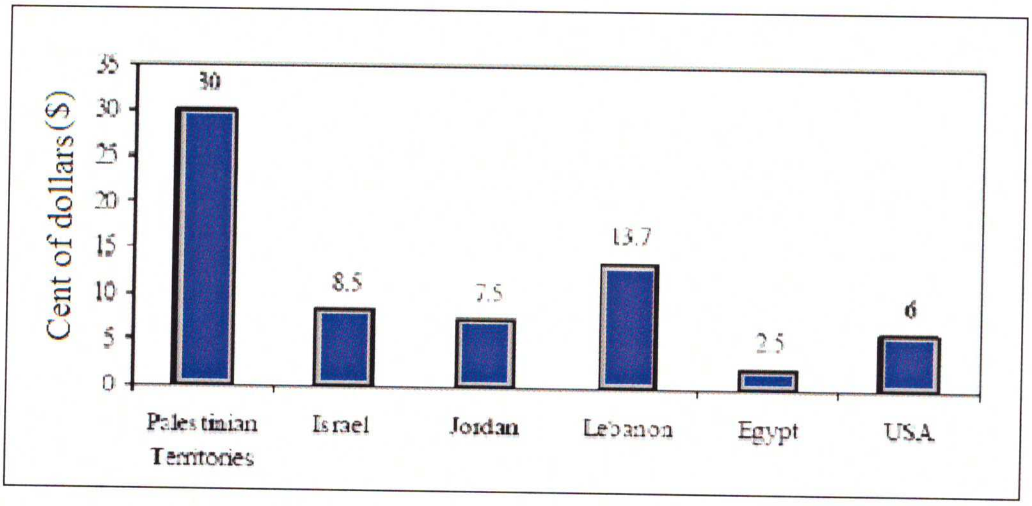


Figure (2.6): Average electricity prices (cent of dollars), 2000

Chapter Three

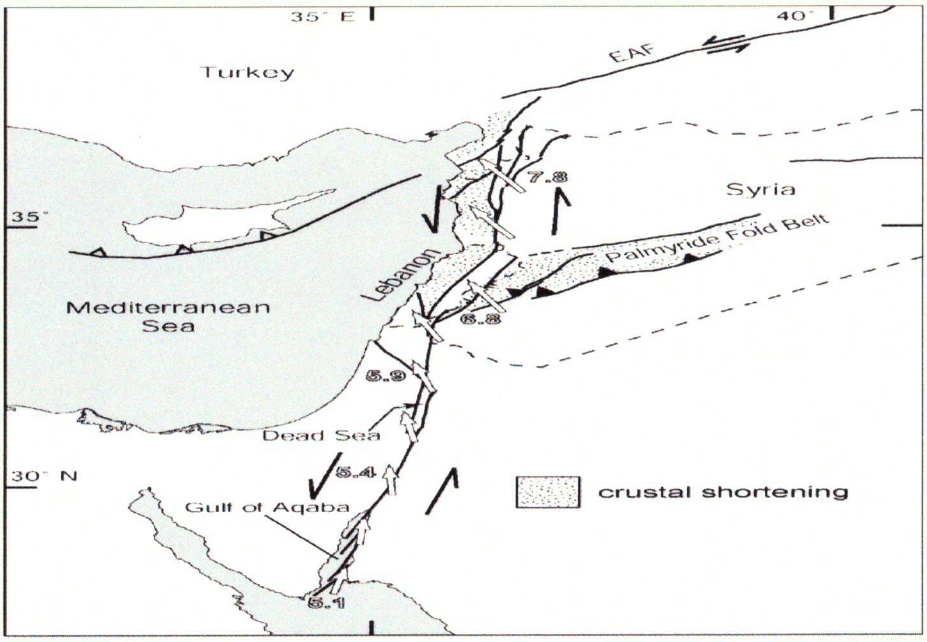
Overview on Dead Sea

- **Dead Sea and its geological.**
- **View the Dead Sea problem.**
- **Dead Sea water sources.**
- **Reason of Dead Sea problem.**

3.1 Dead Sea and its geological.

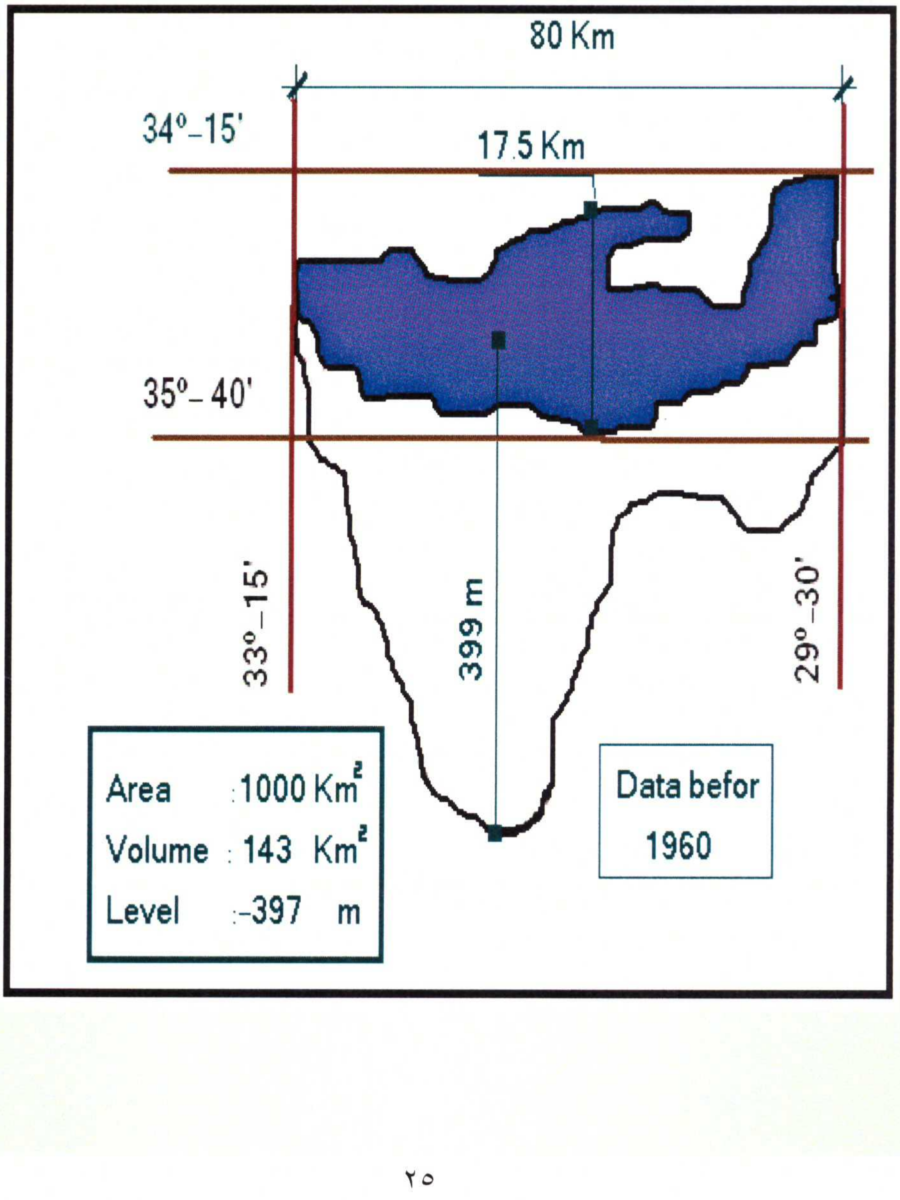
Dead Sea and its Geological

Unique geological phenomena → Dead Sea consider a unique natural geological phenomena since it layout at longest rift valley into world which extend to 1000 km within sided displacement equal 105 km as shown in figure so, its isolation sea



Terminology Dimention

As figure show :Dead Sea location ,surface ,area ,level, volume, long, width ,depth point of north basin ,for a period before 1960



Dead Sea climate

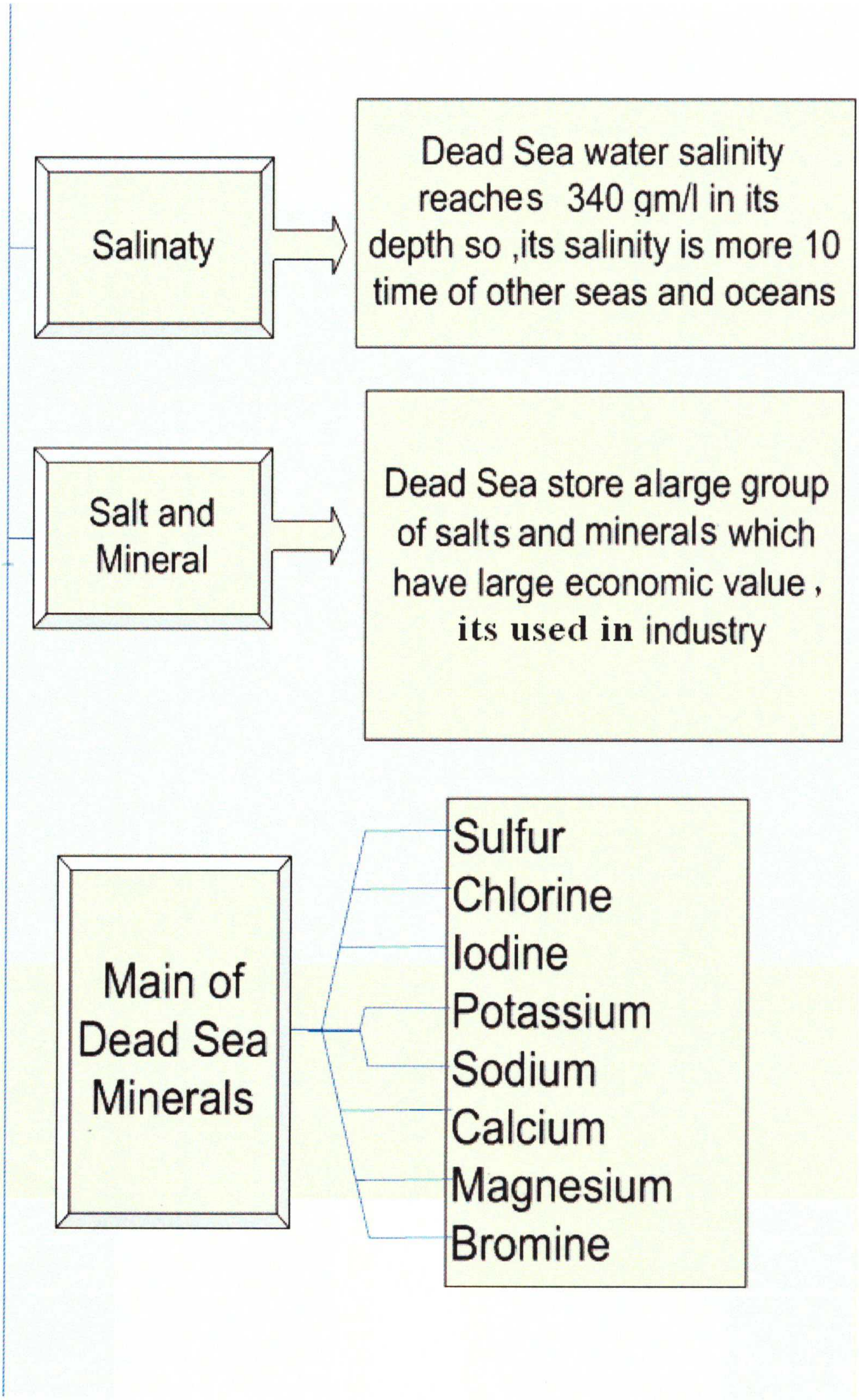
The average temperature in winter is 19.2 c° and 37.3 c° in summer but the Max temperature recorded was 51 c° ,and its shore temperature is 24 c° in winter day and 15.5 c° in night

Depth water temperature

Deep water temperature vary from depth to other ,large temperature record is 45c° at 36 cm depth from surface .but minimum temperature record is 10c°

Humidity range

Average humidity inDead Sea region is 57% with a Max value record in December, January ,that is 75% ,and the minimum of 45% recorded into June ,July

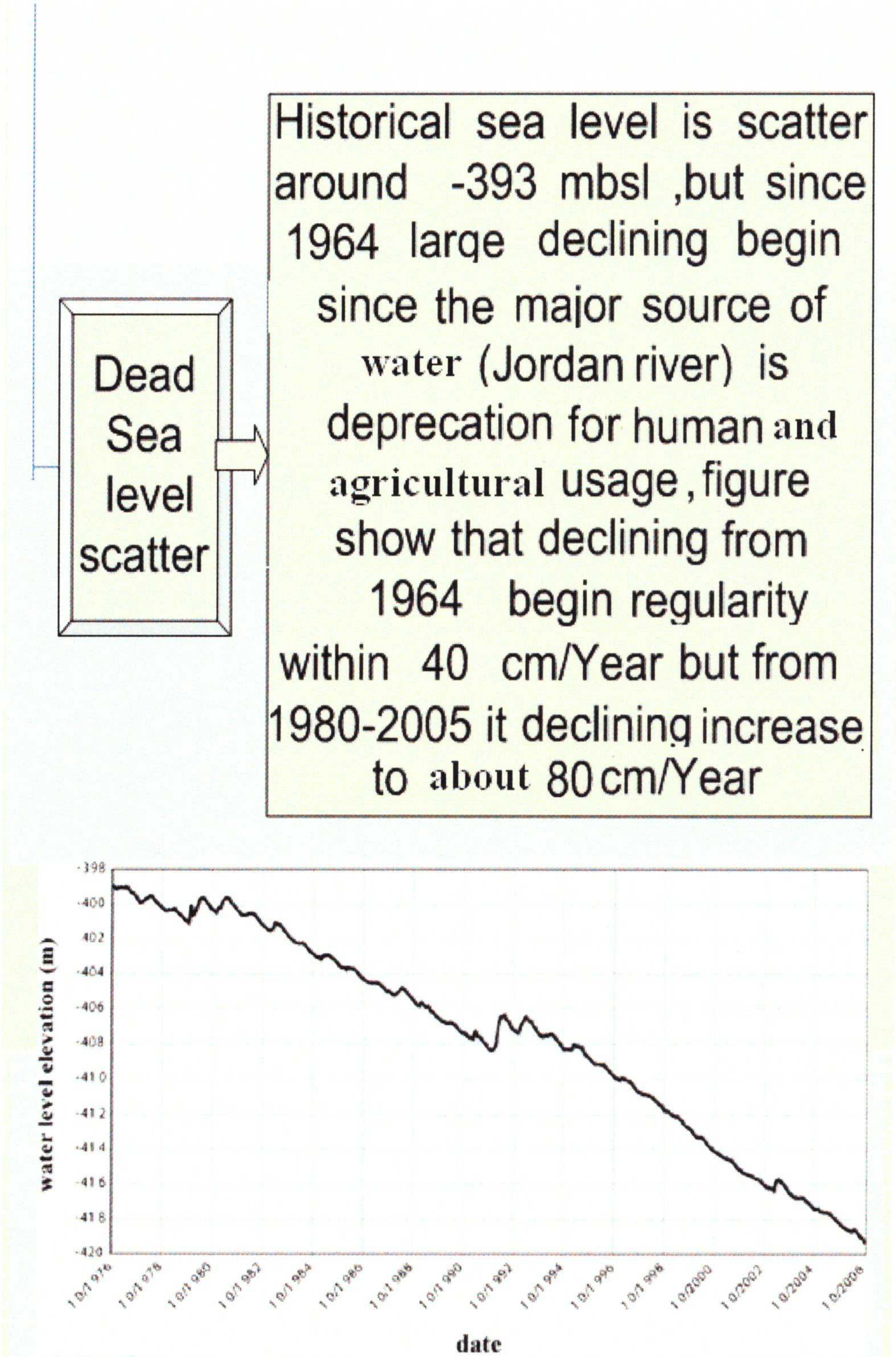

Salinaty
Dead Sea water salinity reaches 340 gm/l in its depth so ,its salinity is more 10 time of other seas and oceans
Salt and Mineral
Dead Sea store alarge group of salts and minerals which have large economic value , its used in industry
Main of Dead Sea Minerals
Sulfur
Chlorine
Iodine
Potassium
Sodium
Calcium
Magnesium
Bromine

Rainfall

The Max amount of rainfall recorded was 300 mm/Year into 1990-1991 and this value is vary, but the average is 80 mm/Year

Evaporation range

Its evaporation range depend on surface area ,but the average recorded is 2200 mm/ Year



Figure(3.1): Dead Sea and its geological.

3.2 View the Dead Sea problem ?

- Geographical view
- Terminology view
- Chemical composition view

3.2.1 what is the Dead Sea problem?

If we look to Dead Sea location we will see the different between this sea and another seas into world that is Dead Sea geographical isolation from another seas and the alone inflow source is Jordan river as seen into figure (3.2).

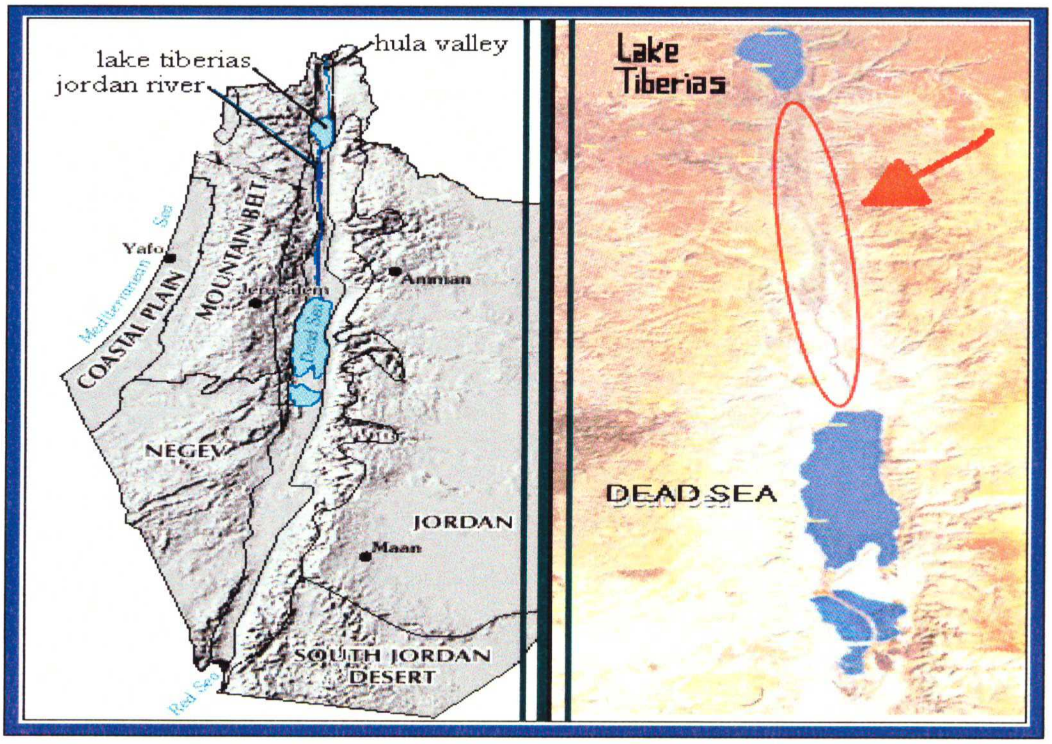
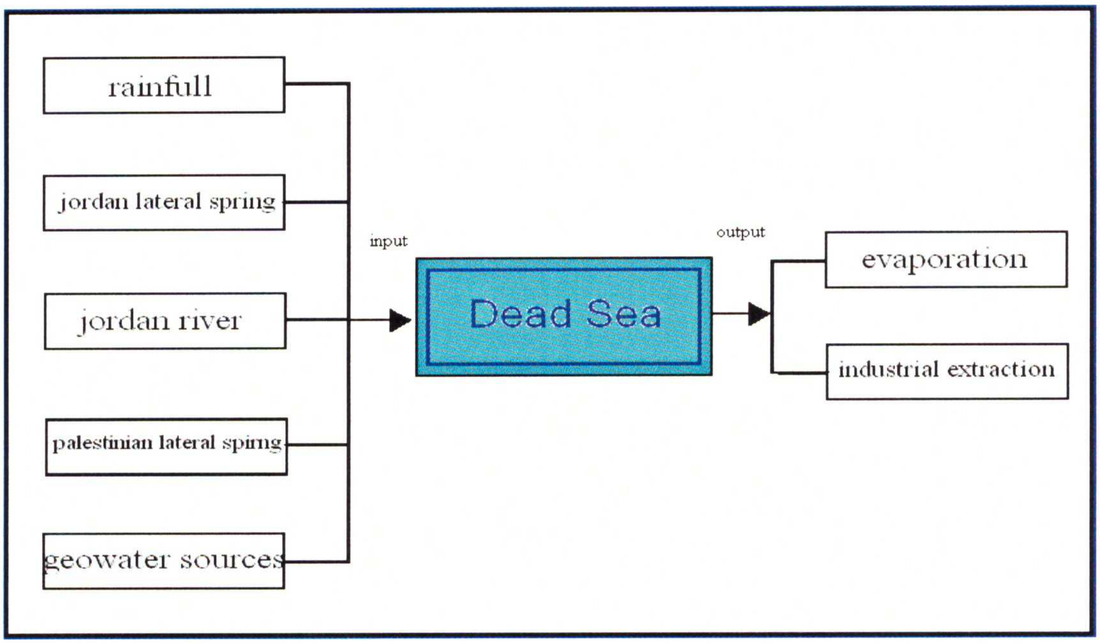


Figure (3.2): Dead Sea geographical isolation(except Jordan river)

And by represent the Dead Sea as a system we will show its input and its out put as seen into figure (3.3) .



Figure(3.3): Representation dead sea as system

Then when we go to write the water balance equation we will write as figure (3.4)

Dead Sea leve rulled by the equation:

$$\dot{V}inflow - \dot{V}outflow = Value\ A$$

if	A = +	Dead Sea level will increase ↑↑↑
if	A = 0	Dead Sea level will be stable [no increase . no decrease] ≡
if	A = −	Dead Sea will decrease ↓↓↓

Figure (3.4):Dead Sea water balance

But the main water source of Dead Sea –except lateral spring- is Jordan river so historically when Jordan river and the other sources be wake then dead sea is decrease and when these sources is strong then dead sea level is increase so let us view dead sea level historically by figure (3.5)

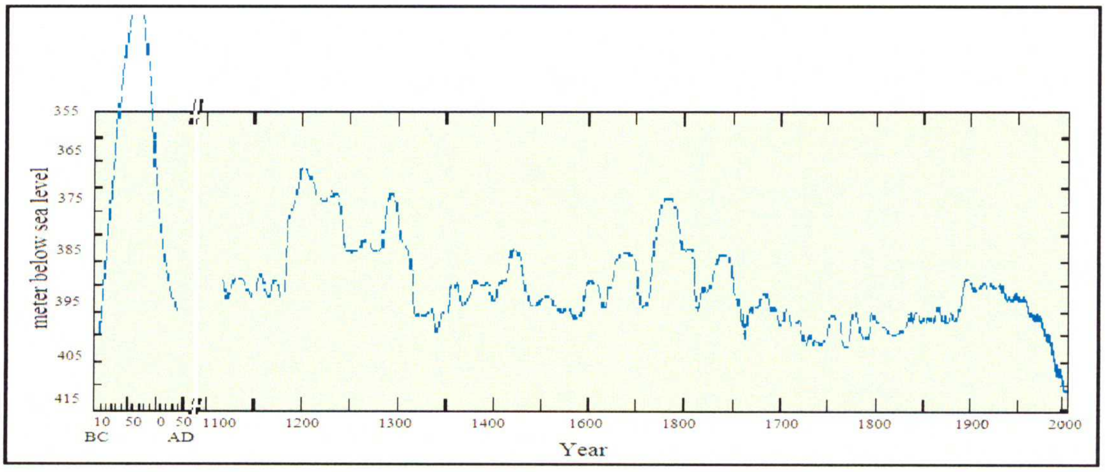
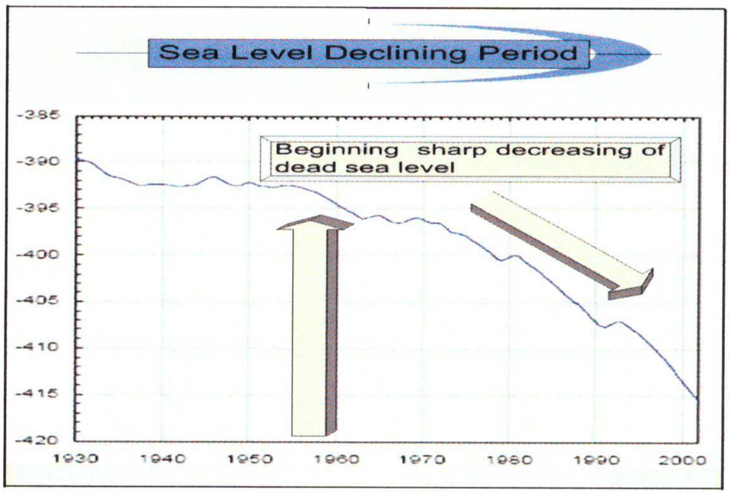


Figure (3.5): Historical Dead Sea level graph.

And when we look to this curve from width band to a period (up to 1960) we will see the sea level damage period which is nearly beginning into 1960 to current year (2008) ,so figure (3.6) show these period clearly for (1960-2002) .



Figure(3.6):Beginning of sea level period

So , table(3.1) show the declining occurs to sea level and shortage into sea area.

Table (3.1) level declining and surface area shortage

Year	Level (m)	Surface Area(km ^{2})
1930	-391	1040
1940	-392.5	1000
1950	-392.7	980
1960	-395	960
1970	-396	930
1980	-400	760
1990	-407	660
2000	-413.5	600
.	.	.
.	.	.

And the surface area shortage mean shore shrinking and figure(3.7) below show the shore shrinking

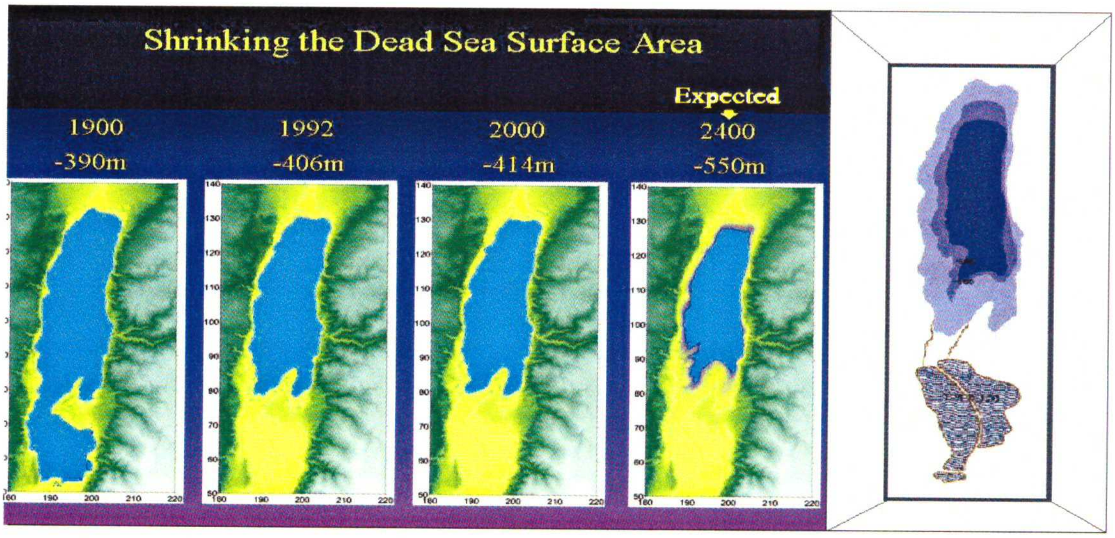


Figure (3.7): Dead Sea surface shrinking

The input and output of dead sea is a parameter which control the Dead Sea level so we will discuss these parameter and its influence at the Dead Sea in the next section.

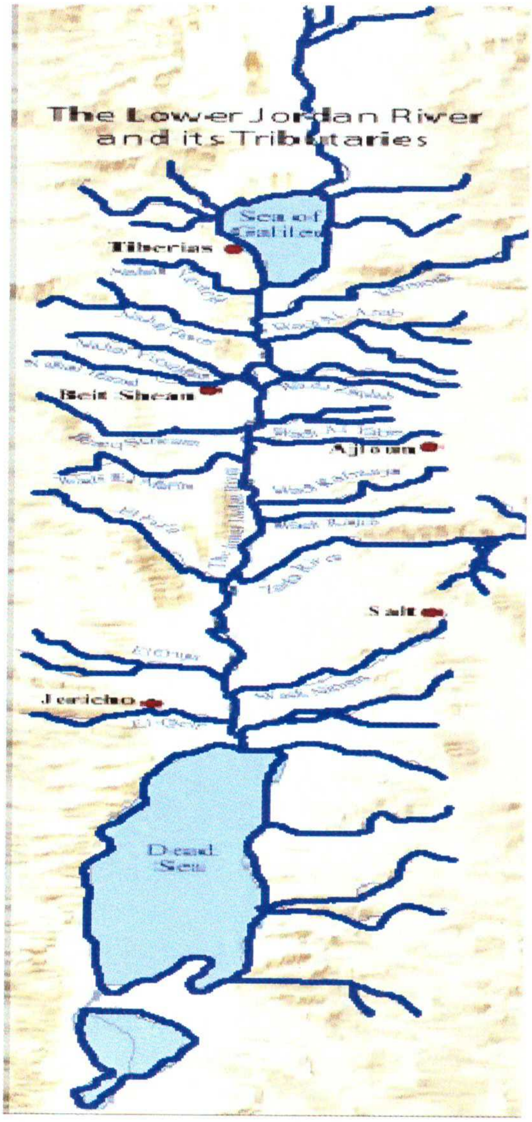
3.3 The Dead Sea water sources

Water Sources of Dead Sea

The sources of dead sea water is divided into four sources as follows:

1) Jordan River and its income branches

As shown in Figure : Jordan river and its branches that feed Jordan river and the amount of its feeding water equal 1300 M m³/Year

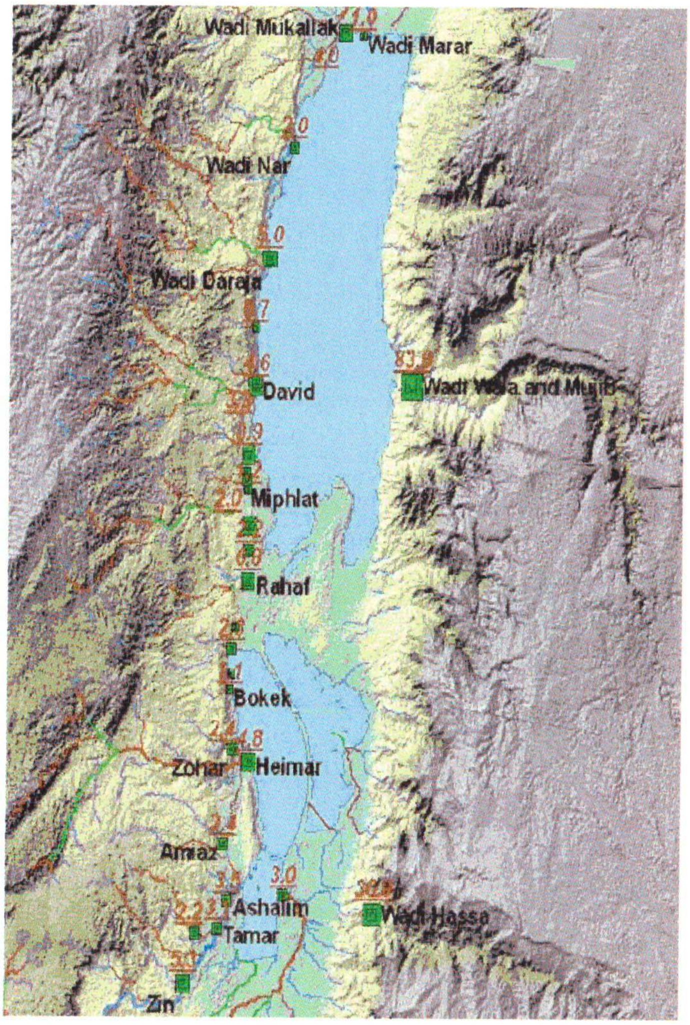


2) Valley and lateral spring

As shown in the figure : lateral spring of basin which is divided into:

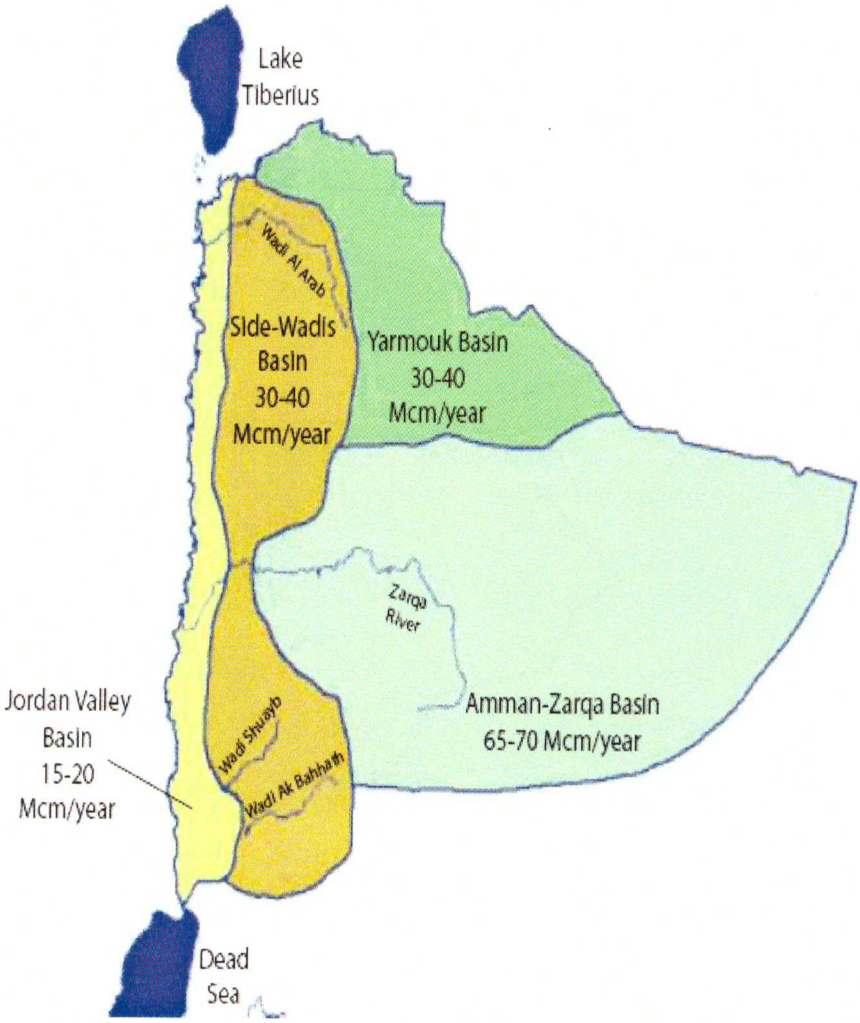
Jordan spring which Gives 150-200 M m³/Year

Palestinian spring which gives 100-150 M m³/Year



3) Geo water of Dead Sea Basin

As shown in the figure: Geo water that deposits to dead sea is estimated to 70 M m^3/Year



3.4 Reasons of Dead Sea drying problem

The reason of Dead Sea problem is divided into two reason as figure (3.9) show.

Figure (3.9): Reason of Dead Sea dying

Now we will go to explain the two major reason of dead sea dying as shown in the figure(3.10) .

3.4.1 A: Natural reasons

Natural reason represented by the region climate specially dead sea climate that is dry and low rainfall rate so, high temperature will cause to increase the evaporation rate into Dead Sea zone which reach to 2200 mm/year and this value is large and average amount of dead sea evaporation estimated to be 1755 Mm^3/Year.

3.4.2 B: Human reasons

Which it divided into two reasons

3.4.2.1 B.1: Regional countries politics of water

Countries (Jordan , OS , West bank ,Syria , Lebanon)that layout at two side of dead sea contributes in drying dead sea by make depreciation for the sources of dead sea (Jordan river , tabariea) and its springs, so table(3.2) show Jordan river basins countries and the percent of consumption for each country.

Table (3.2) below show the amount of water that consumed by each basin country.

<table>
<tr><th>Water Source</th><th>Lebanon (Mm^3)</th><th>Syria (Mm^3)</th><th>Jordan (Mm^3)</th><th>OS (Mm^3)</th><th>West Bank(Mm^3)</th></tr>
<tr><td>Hasbani river spring</td><td>20</td><td>----</td><td>----</td><td>----</td><td>----</td></tr>
<tr><td>Yarmok river spring</td><td>----</td><td>>200</td><td>----</td><td>----</td><td>----</td></tr>
<tr><td>Eastern ghore canal</td><td>----</td><td>----</td><td>120</td><td>----</td><td>----</td></tr>
<tr><td>Dams into Jordan</td><td>----</td><td>----</td><td>120</td><td>----</td><td>----</td></tr>
<tr><td>Jordan river northern</td><td>----</td><td>----</td><td>----</td><td rowspan="3">670</td><td>----</td></tr>
<tr><td>From tabariea lake</td><td>----</td><td>----</td><td>----</td><td>----</td></tr>
<tr><td>From tabariea to OS</td><td>----</td><td>----</td><td>----</td><td>----</td></tr>
<tr><td>From down yarmok basin</td><td>----</td><td>----</td><td>----</td><td>25-70</td><td>----</td></tr>
<tr><td>Total</td><td>20</td><td>>200</td><td>240</td><td>740</td><td>----</td></tr>
</table>

But the Jordan River basin discharge amount of water equal to 1300 Mm^3/Year and the usage of Jordan river is equal to 1200 Mm^3/Year so, the net water that inflow to dead sea is 100 – 120 Mm^3/Year which mean that 90% of Jordan river basin spring and branches are prevented from reaching to Dead Sea so, large declining has occurred and still decline to its flow rate.

3.4.2.2 B.2: Extracting industry from Dead Sea

Extracting industry from salt and mineral is the second major human reason for Dead Sea dying and extracting industry usage amount of water estimated to be 250 \-300 Mm^3/Year and the average amount is 270 Mm^3/Year ,so, it depend on the method that drying the brine water in large basin to obtain the salt and mineral.

So, at the last we summarize the human reason of Dead Sea drying into the table (3.2) which show the total present for each country into Dead sea drying problem.

Table (3.3) present of each country contribution into Dead Sea drying problem So, the total Dead Sea weakness in its judgment is 1600 Mm^3/Year.in other meaning there are 1600 Mm^3/Year is prevent to reach dead sea which create the dead sea level declining problem.

Table (3.3): Contribution countries caused drying of Dead Sea in value of Mm^3

Country	Jordan River	Valley and Spring	Extracting Spring	Sum
OS	740	50	135	930
Jordan	240	80	135	460
Syria	200	----	----	200
Lebanon	20	----	----	20
Total	1200	130	270	1600

Chapter Four

A Mount of water required
And description of conveyor system

- **Water requirement parts block diagram**
- **Water requirement parts description.**
    - **Filling process requirement.**
    - **Steady state requirement**
    - **Desalination requirement**
- **Jordan-OS agreement strategy**
- **Description of project parts**

4.1 Water requirement parts block diagram

RSDS canal project aims to transfer amount of water from Red Sea to Dead Sea so, in this chapter we go to explain how much this amount.

Amount of required water is divided into three parts as shown into figure (4.1)

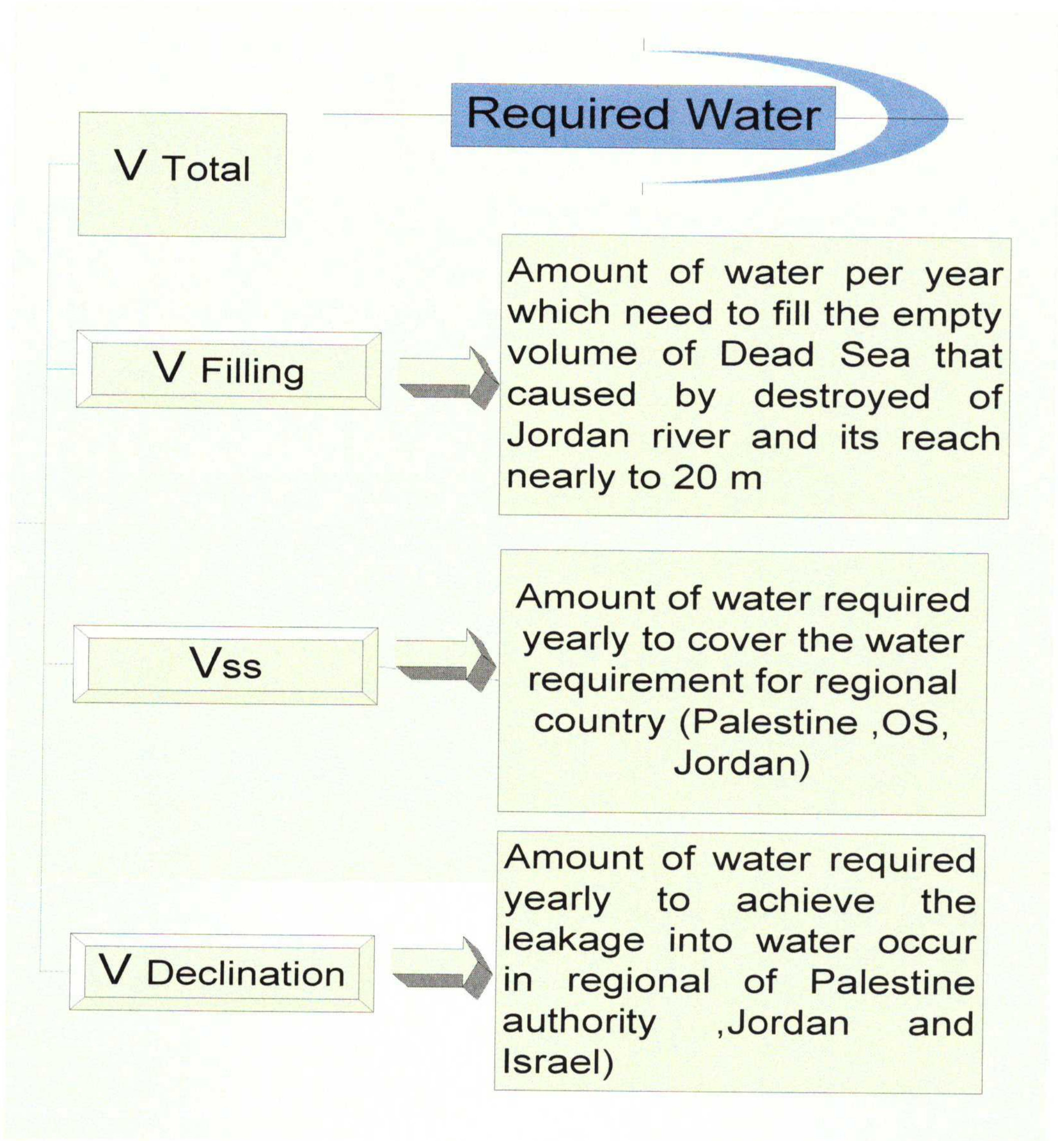


Figure (4.1):The part of water requirement

As seen the total amount of water required are divided to three parts so ,we will describe each of these parts.

4.2 Water requirement parts description

4.2.1 Filling process requirements

Since the historical level of the dead sea (-395 m) has fallen down so., the losses water create empty volume of Dead Sea which cause declining into sea level so if we can calculate the empty volume then can calculate the amount of water that will refill this empty volume .

so ,we will suggest two method to calculate the empty volume of Dead Sea .

4.2.1.1 GIS soft ware program technique.

Any geographical region on the earth can be captured within the space satellites as image and this image can be converting to point which each of these point represented into three coordinate (latitude ,longitude ,altitude)and this space representation appear as DEM(Digital Elevation Model) image ,then DEM image can process into software program called Arc GIS.

Arc GIS are a program have technique called spatial analyses and this technique can be convert DEM to 3D modes as appear into figure (4.2) which take to some side mountain of Dead Sea as example.

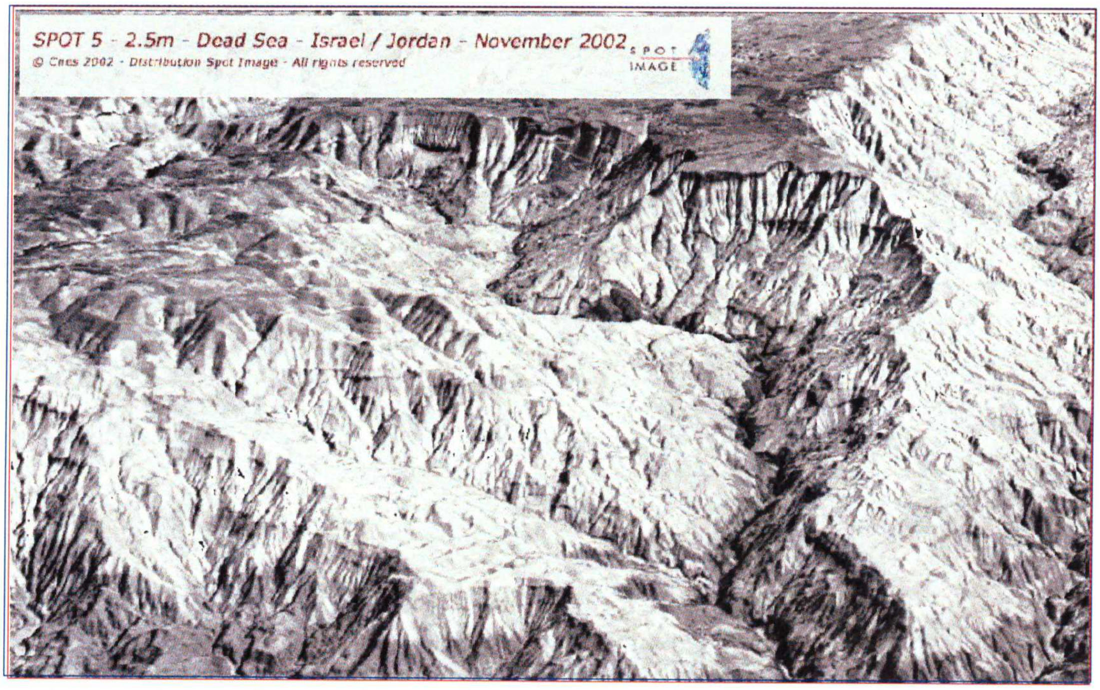


Figure (4.2):3D model for sided mountain of Dead Sea.

Spatial analyses technique can calculated the empty volume of Dead Sea after bounded the empty volume between two surface levels (2-altitude) point as the following:

First level :current level 2008 which is nearly (-416 m).
Second level: the best level (-395 m).

Then the empty volume founded between these two level can be computes. Now the amount of water that required to refill the empty volume can be achieved as flow rate as:

$$\text{Amount of flow rate} = \frac{\text{empty volume calculated}}{\text{Period of refill}}$$

If we look to flow rate required to refill we see that its depend on the period that required to refill so , the time required must satisfy many consideration like

- If the period of refill is long then the conveyor which will transfer the water from Red Sea to Dead Sea will have small diameter which mean its easy to construct and manufacturing so, the time of filling is a function of diameter of water conveyor as show.

The flow rate required is:

$$\dot{V}total = \dot{V}fill + \dot{V}ss + \dot{V}dis$$

Where:

$\dot{V}$ fill: filling volume

$\dot{V}ss$: Steady state volume

$\dot{V}dis$: Desalination volume

$$\dot{V}total = \dot{V}fill + const(1)$$

Where:

$$const(1) = \dot{V}ss + \dot{V}dis$$

$$\dot{V}total = \frac{CalculatedVolume}{Time} + const(1)$$

$$\dot{V}total = \frac{const(2)}{Time} + const(1)$$

So,

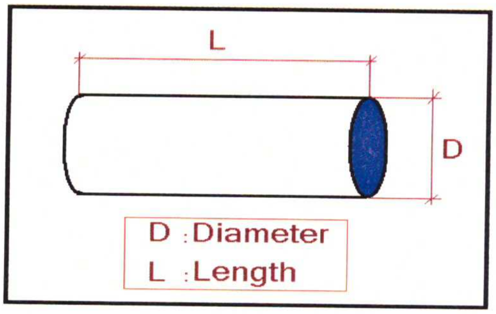
$\dot{V}total$ =function (time).

$$\dot{V}total = V * A$$

$where:$

$V : Velocity$

$A : Area$



$$\text{function(time)} = V * A = V * \left(\frac{\pi * D^2}{4}\right)$$

So ,the water conveyor is a function of the time of refilling as shown in previous equation if we go to fill the Dead Sea in large time we need to small pipe diameter, the Arc GIS technique not used since we cant obtain the DEM file of the dead sea region.

- Normal pump station need to pump water since $\dot{V}total..required = \sum \dot{V}$ of pump station so the $\sum \dot{V}$ must be acceptable which can be achieved from pump station .

- Mixing process which will occur between red and Dead Sea water need more time to prevent the increase of Dead Sea salinity sharply and float it at the water surface.

4.2.1.2 Approximation technique (surface area of Dead Sea level)

- Another method which we used (not accurate), depend on the surface area of dead sea level obtained from figure(4.3) by calculate multi surface area within its year level which shown in table (4.1)

Table (4.1): Dead Sea surface area, level and volume

Area	Level	volume
(m^2)	(m)	(Mm^3)
1034	-390	--
1010	-391	1022
1000	-392	1005
980	-393	990
1000	-392	990
970	-394	1970
950	-395	**960**
940	-395.5	**472.5**
940	-395.7	**188**
930	-396	**280.5**
930	-396.3	**279**
885	-396.5	**181.5**
930	-396	**453.75**
930	-396.3	**279**
885	-396.5	**181.5**
930	-396	**453.75**
882	-397	**906**
882	-397.5	**441**
830	-398	**428**
830	-398.5	**415**
720	-400	**1162.5**
715	-400.5	**358.75**
710	-401	**356.25**
685	-402	**697.5**
675	-403	**680**
674	-404	**674.5**
673	-405	**673.5**
672	-406	**672.5**
671	-407	**671.5**
670	-408	**670.5**

669	-409	**669.5**
665	-410	**667**
660	-411	**662.5**
650	-412	**655**
640	-414	**1290**
625	-416	**1265**
610.3	-418	**1235.3**
605	-419	**607.65**
600	-420	**602.5**
595	-421	**597.5**
590	-422	**592.5**
	Total Volume	**27358.45 Mm³**

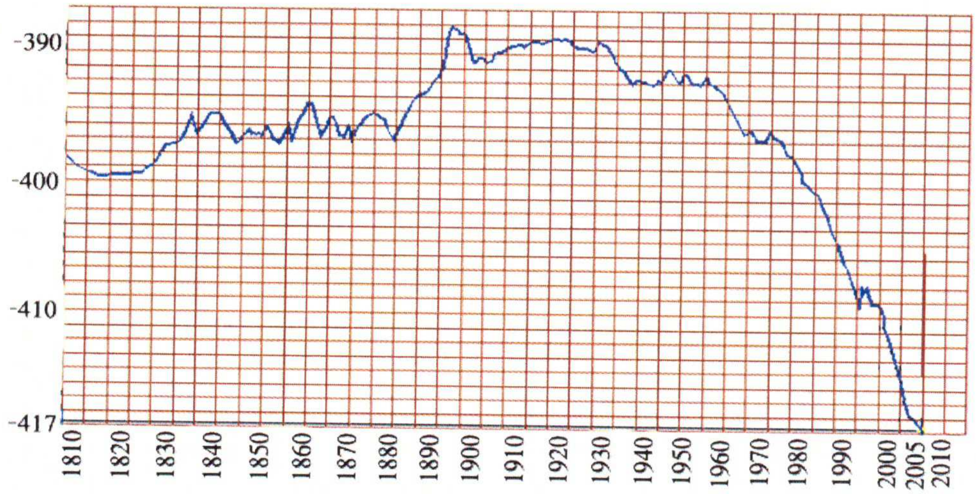


Figure (4.3): Dead Sea level versus year

When we look to figure (4.4) to see how arrange this surface area to give imagination how surface area used (drawing just for imagination)

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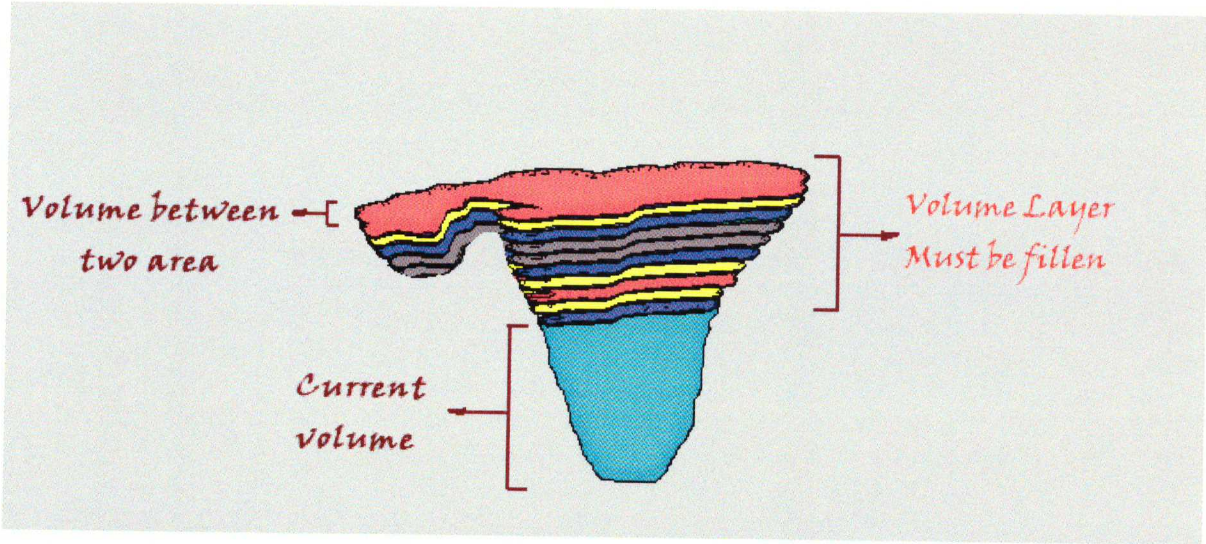


Figure (4.4): Imagination drawing

Then we go to determine the two levels that surface area will use to calculation so, figure (4.5) show the level required:

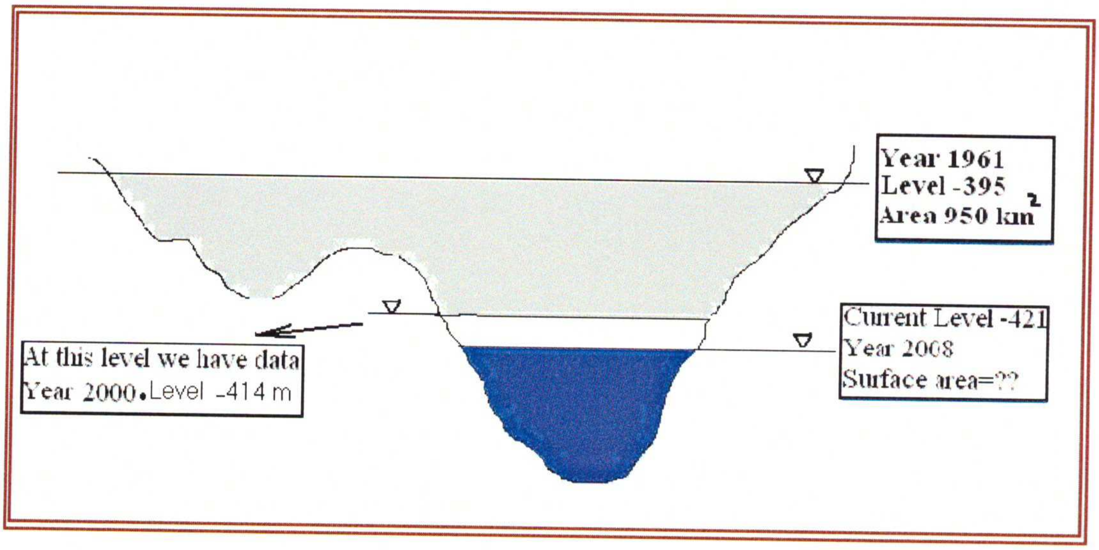


Figure (4.5):Two surface levels used to make our calculation.

So, we rearrange the excel table to bounded between two level :(-395and -414),

- -395 at year 1961
- -414 at year 2000 since we have data only to year 2000.

Table (4.2): Dead Sea level, area and volume

Area	Level	volume
m^2	m	Mm^3
950	-395	**960**
940	-395.5	**472.5**
940	-395.7	**188**
930	-396	**280.5**
930	-396.3	**279**
885	-396.5	**181.5**
930	-396	**453.75**
930	-396.3	**279**
885	-396.5	**181.5**
930	-396	**453.75**
882	-397	**906**
882	-397.5	**441**
830	-398	**428**
830	-398.5	**415**
720	-400	**1162.5**
715	-400.5	**358.75**
710	-401	**356.25**
685	-402	**697.5**
675	-403	**680**
674	-404	**674.5**
673	-405	**673.5**
672	-406	**672.5**
671	-407	**671.5**
670	-408	**670.5**
669	-409	**669.5**
665	-410	**667**
660	-411	**662.5**
650	-412	**655**
640	-414	**1290**
625	-416	**1265**
610.3	-418	**1235.3**

605	-419	**607.65**
600	-420	**602.5**
595	-421	**597.5**
590	-422	**592.5**
	Total Volume	**21381.45**

Then by using trapezoidal method which give.

$$-V1 = \frac{A1 + A2}{2}(\Delta L_{12})$$

$$-V2 = \frac{A2 + A3}{2}(\Delta L_{23})$$

$$-Vi = \frac{Ai + A_{i+1}}{2}\left(\Delta L_{(i)(i+1)}\right)$$

$$Vtotal = \sum_{i=1}^{n} V_i$$

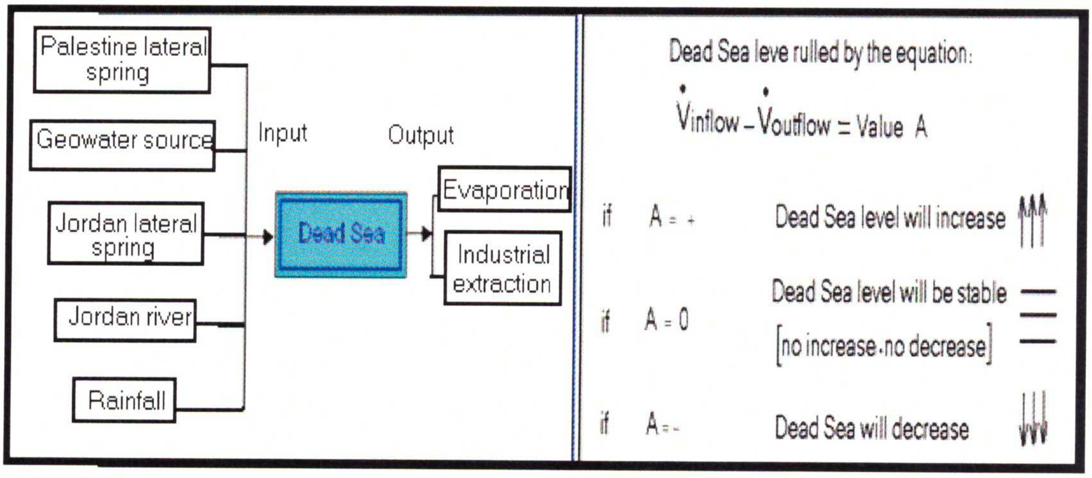
And by solving into excel program for these levels we obtain Vtotal of empty volume.

The calculated volume is divided by filling time to obtain flow rate for each year of filling period.

We did not adopt any time strategy to refilling but we will depend on the Jordan strategy to refilling as will be mention later under Jordan strategy.

4.2.2 Steady state requirement

If we return to chapter three under the section Dead Sea drying problem we see that we represent the Dead Sea as a system and see there are multi input and multi output and we write the equation of the Dead Sea level balance which is shown in figure (4.6).



Figure(4.6):Dead Sea level balance Equation

We see that the main water source of Dead Sea begin sharply after 1967 ,in this period and previous period the regional country contributed in destroying Jordan river depreciating it table (4.3) show the regional country and the contribution for each one of them in depreciation Jordan river.

Table (4.3): Contribution countries caused drying of Dead Sea in value of Mm^3

Country	Jordan River	Valley and Spring	Extracting Spring	Sum
Israel	740	50	135	930
Jordan	240	80	135	460
Syria	200	----	----	200
Lebanon	20	----	----	20
Total	1200	130	270	1600

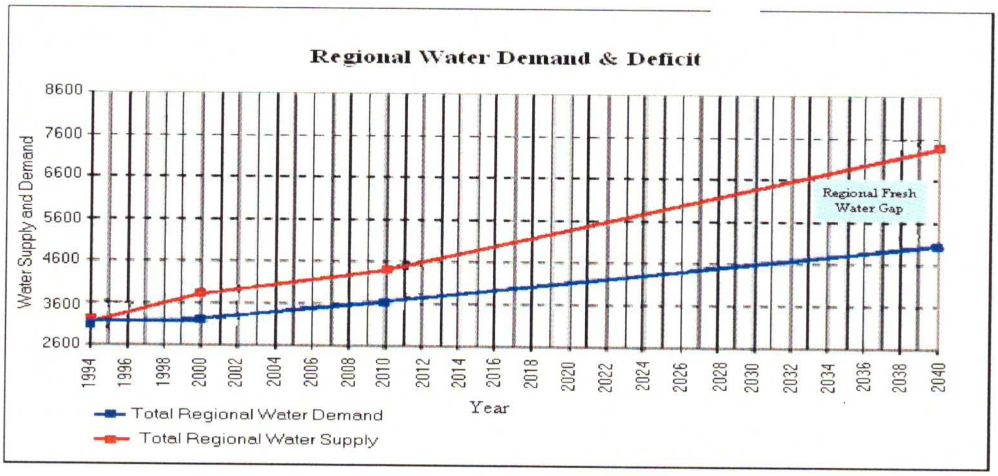
We find the total water amount depreciate from basin countries is equal to 1600 Mm^3/Year and this number is act $\dot{V}$ steady state which will keep dead level stable (no increase, no decrease).

The total amount of water that consumed yearly from regional country is 1600 Mm^3 and if we brine this amount the sea level will be stable.

So, this amount represents $\dot{V}$ steady state.

4.2.3 Desalination requirement

Dead Sea basin country (Palestine ,Jordan ,OS) are suffer from water problem and this problem is increase sharply specially into Jordan and the figure(4.7) show the relation between water supply which is offer into countries and the water demand which is required from regional countries usage.



Figure(4.7):Water supply and demand into regional country

When we look to the graph we see the regional fresh water gap between water supply and demand water and how this gap increase sharply so, they go to beneficent from RSDSC project and agreed to use the water conveyor that will transfer water to Dead Sea and bring water through it to desalination it into desalination plant which will be constructed later near Dead Sea and the desalination water will distributing for regional country as they agreed within a percent as:

Palestinians :140 Mm^3/year

Jordan :750 Mm^3/year

OS :140 Mm^3/year

4.3 Jordan – OS agreement strategy

In this chapter we give short description for filling ,steady state ,desalination requirement of water that will bring from Red Sea to Dead Sea through water conveyor.

But RSDSC project feasibility study agreement signed by Palestinians ,OS ,Jordan sketch primary strategy of filling the and we obtain this strategy from the Jordanian ministry of water and energy and this strategy state:

2 billion m^3/year will be brought from Red Sea through water conveyor and used for filling and steady state and desalination usage with an average flow rate equal 60 m^3/sec for 15 years and after this water conveyor will be used for steady state flow and desalination only so figure (4.8)show block diagram for this strategy .

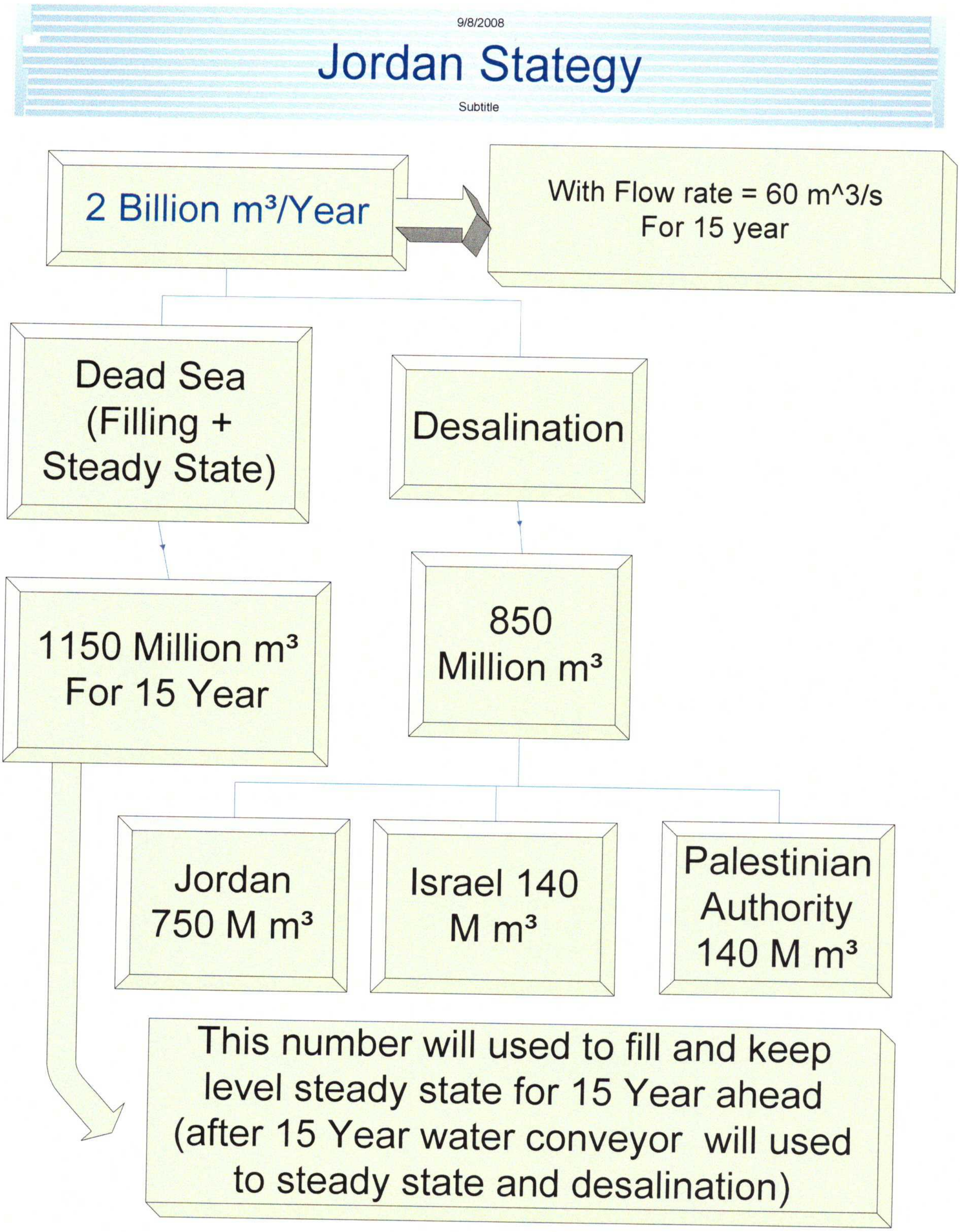
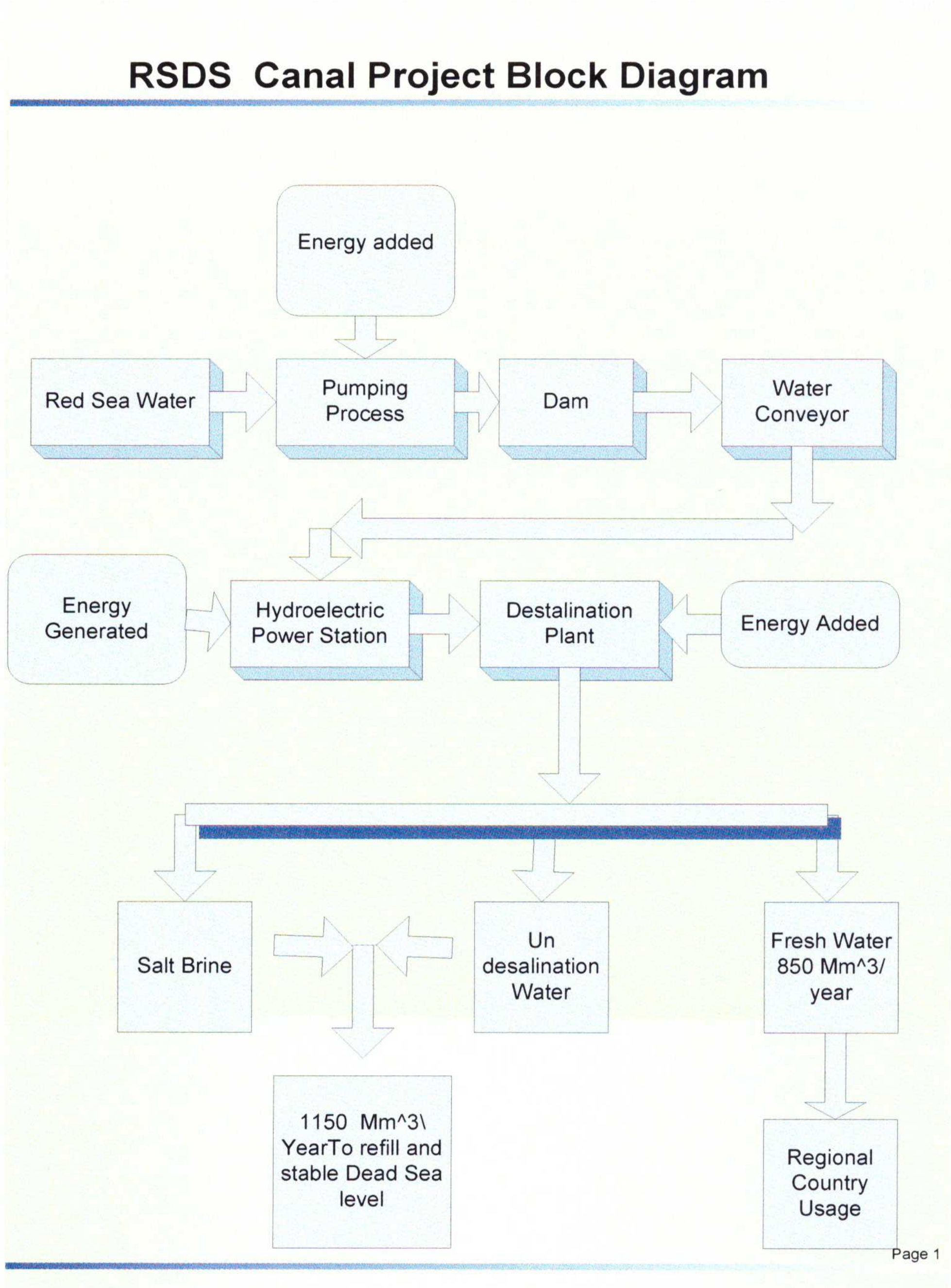


Figure (4.8) Jordan strategy for filling ,Steady state ,Desalination

The project of RSDSC can be explain as a diagram which is represent how we can transfer of the Red Sea water to the Dead Sea and all its processing that will use so, figure (4.9) show these process.



Figure(4.9):RSDSC project block diagram.

4.4 Description of project parts

- Into dead red sea project we need to transfer amount of water equal 60 m^3/s from red sea to Dead Sea, this amount of water will transfer through pipe, tunnels, and open canal. so we go to draw the project parts diagram with respect to wade araba topography ,we see that at the eastern side of wade araba there are a chain of mountain through Jordan state as shown in the figure(4.9).

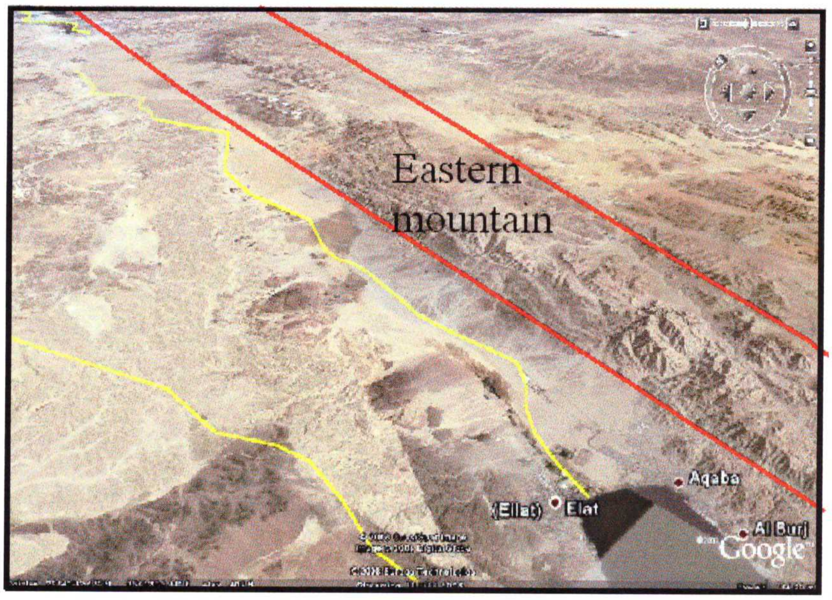


Figure (4.9): Eastern mountain chain of wade araba

- Then we benefit from the mountain profile of the chain of mountain which shown into figure (4.10)

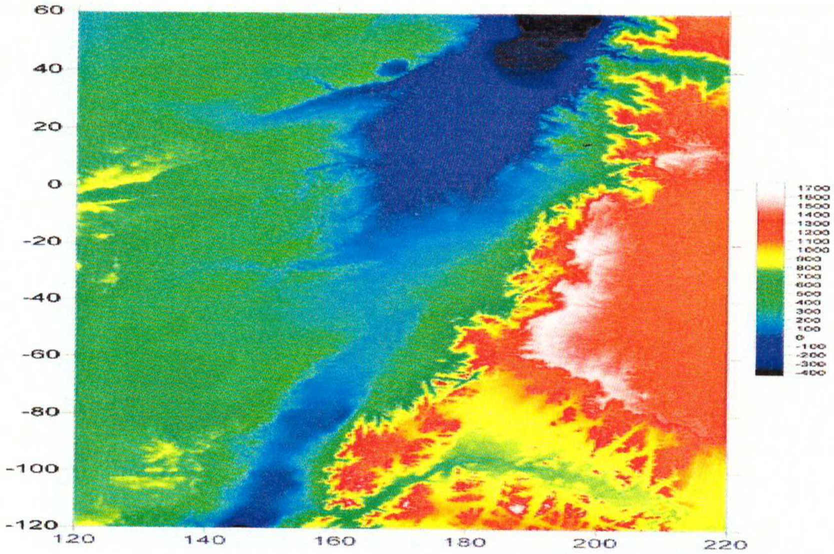


Figure (4.10): Chain of mountain profile

These chains of mountain have a large elevation so, if we go to transfer the amount of water through the chain by gravity which will consume flow pump energy, so we take in account.

- Chain of mountain" Google earth" picture.
- Elevation of the chain of mountain picture.
- Mountain profile picture from previous study.

Then we go to draw estimated schematic diagram to dead red sea project as figure (4.11) describe the picture that we used to estimate the schematic drawing of the project.

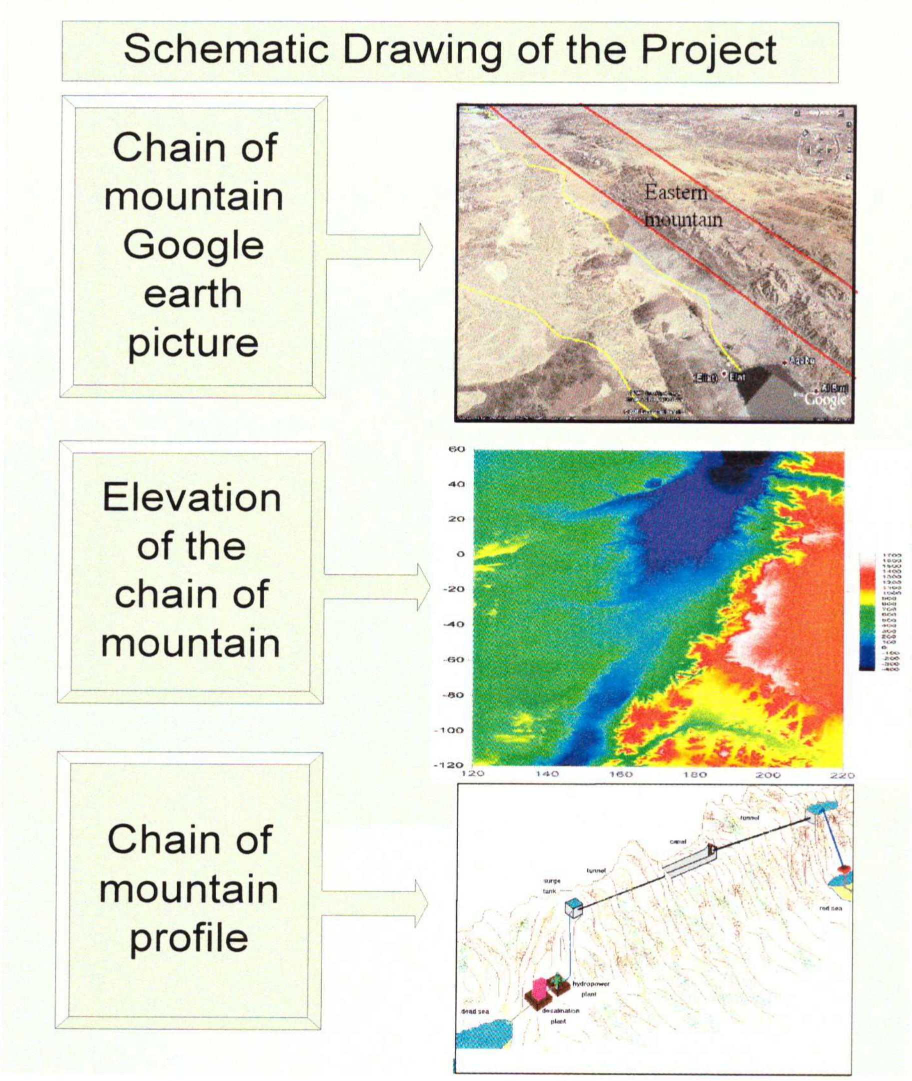


Figure (4.11): Picture used to estimate the schematic drawing of the project

Then we estimated and sketch the schematic draw for the project as shown into figure (4.12) which show the principle of carrying water from the Red Sea such as the water is pumping from the Red Sea to the lake 1 by pumping station building on the well and transfer the water to the lake 2 by open canal and then pumping it into the dam on the al aqaba mountain by pump station which shown on the figure.

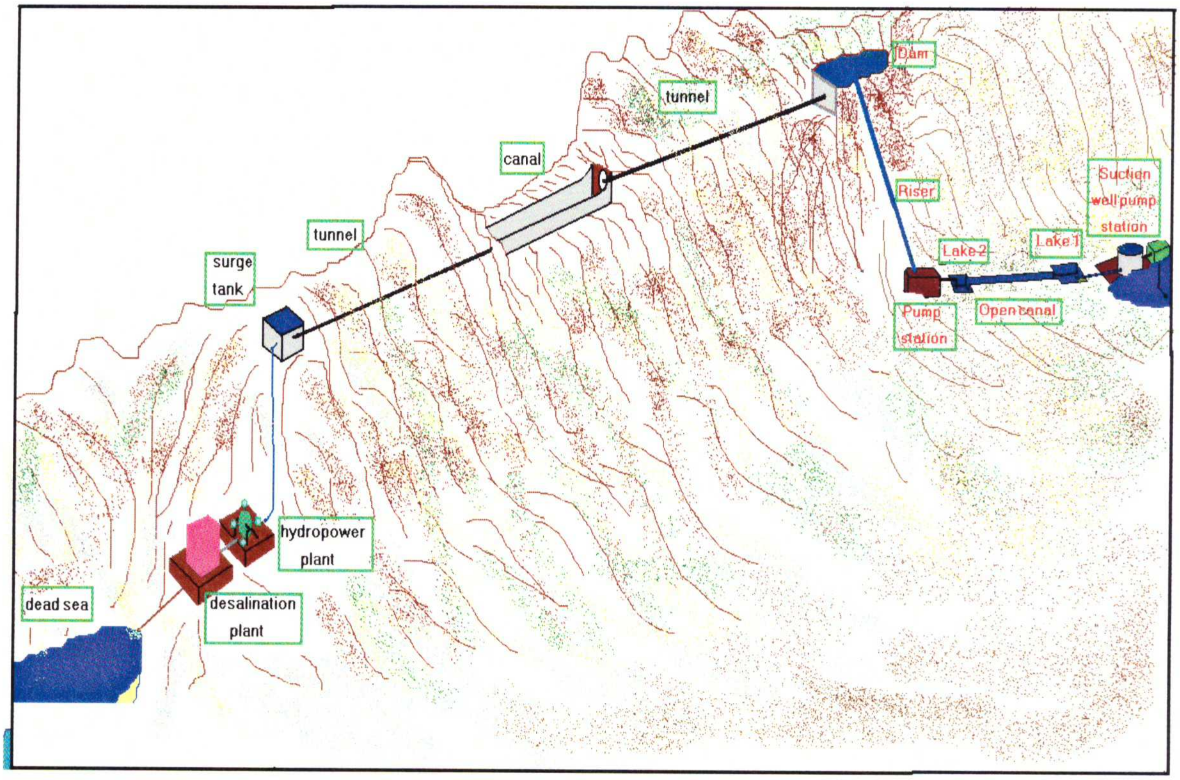


Figure (4.12): Estimated sketch of dead red sea project

❖ Quick describe of the dead red sea project parts as shown into figure (4.13)which repeated below.

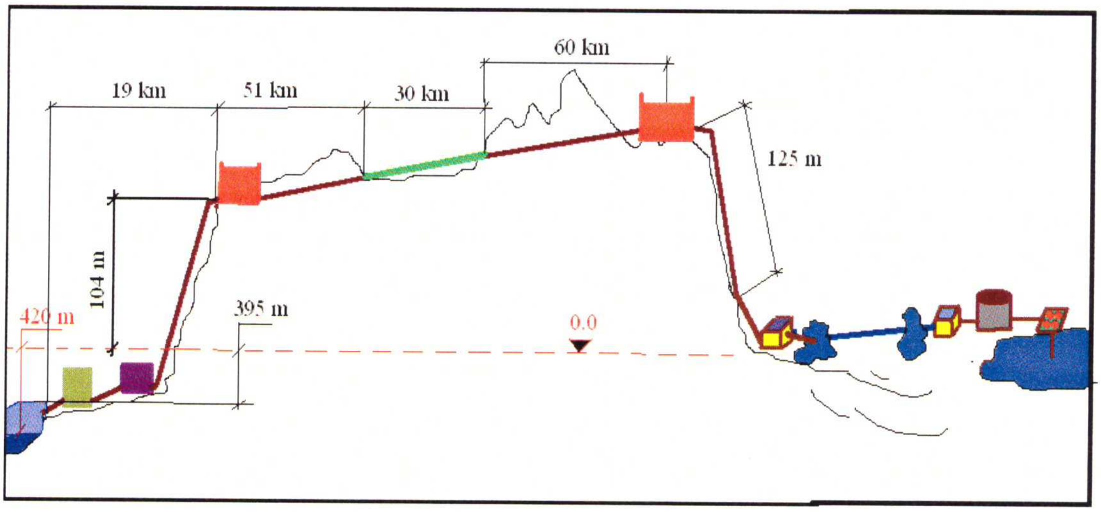


Figure (4.13): Estimated sketch of dead red sea project

We will describe the parts of the project:

- Suction well: which construction at the shore of Red Sea to inlet the water to pump station as figure (4.16) show.
- Pump station: it is a station which contains open canal that connect the two lakes (lake1, lake2) and use a pump station to feed lake1 and other pump to feed the dam on alaqaba mountain which it elevation head equal to 125 m as figure (4.14) show.

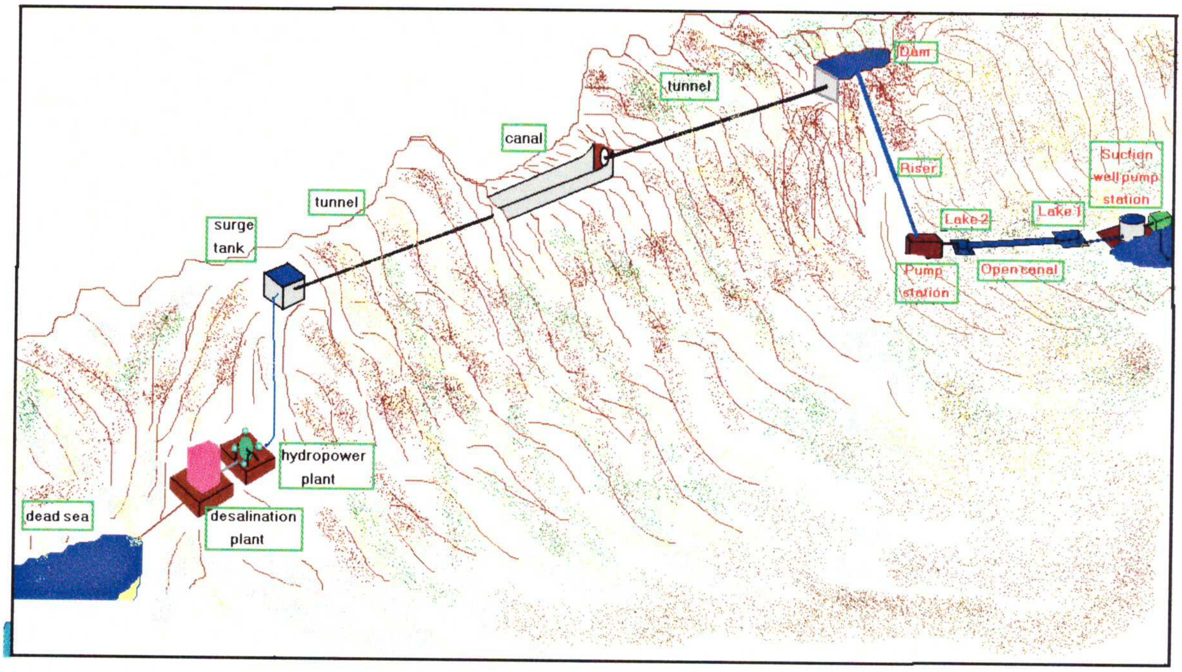


Figure (4.14): Pumping process

- Dam that locate above the mountain near red sea, the purpose of dam is collect the pumping water and discharge it through water conveyor to reach hydropower plant then to dead sea as figure (4.15)show.

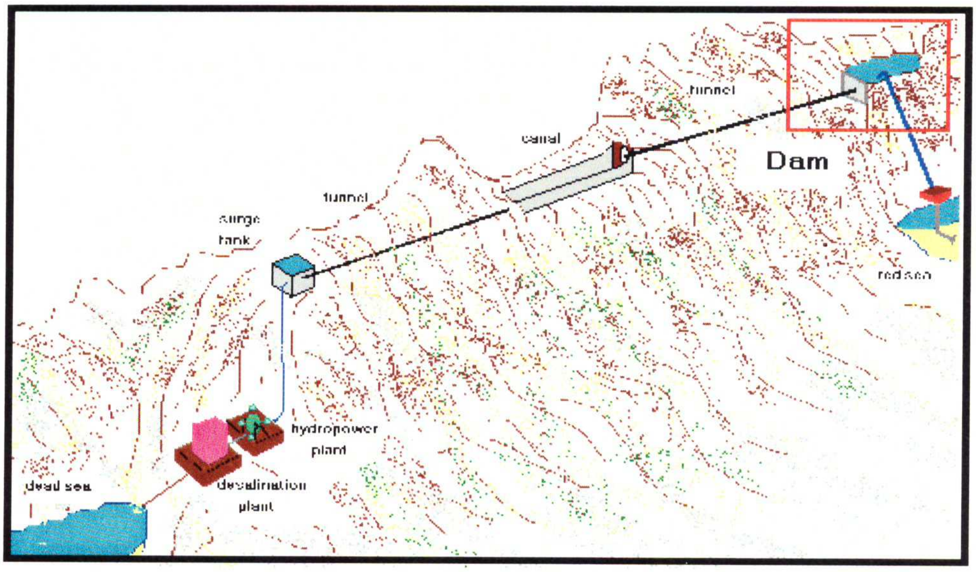


Figure (4.15): Dam location

- Water conveyer :it is the rout of following water which consist from
  - Tunnel 1 with a length of 60 km
  - Open canal with length 30 km
  - Tunnel 2 with a length of 50 km
  - Tthis conveyor will sloped to flow the water under gravity as figure (4.16)show

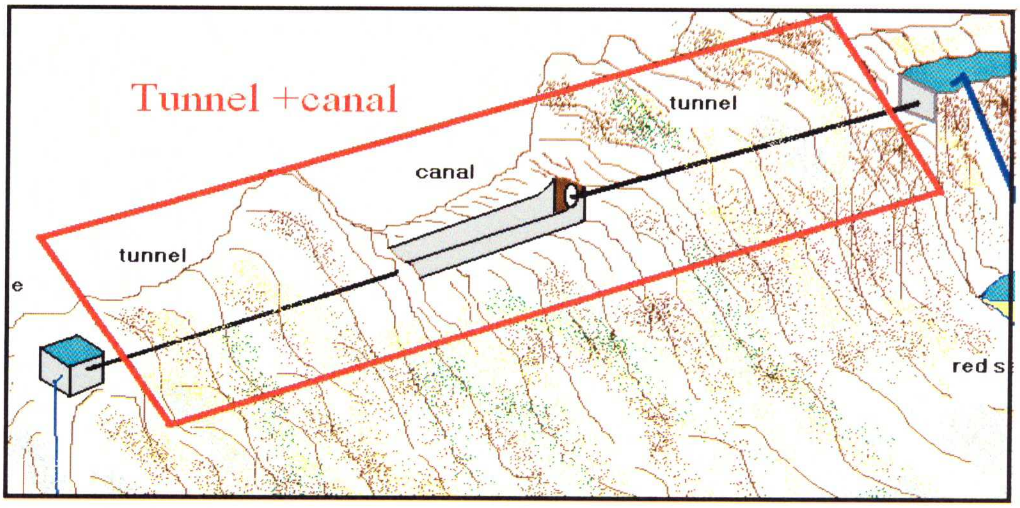


Figure (4.16): Water conveyer

- Hydropower plant and surge tank ,which extract the fluid energy into generator as figure (4.17)show

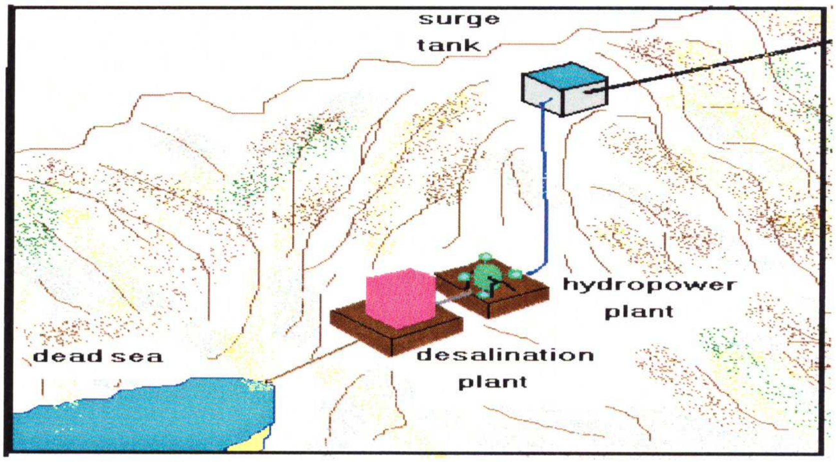


Figure (4.17): Hydropower plant and surge tank

- Desalination plant: which will use to desalinate 850 Mm³ of the transferring water from red sea to distribute it to Jordan, Israel, and Palestinian authority as figure (4.18) show

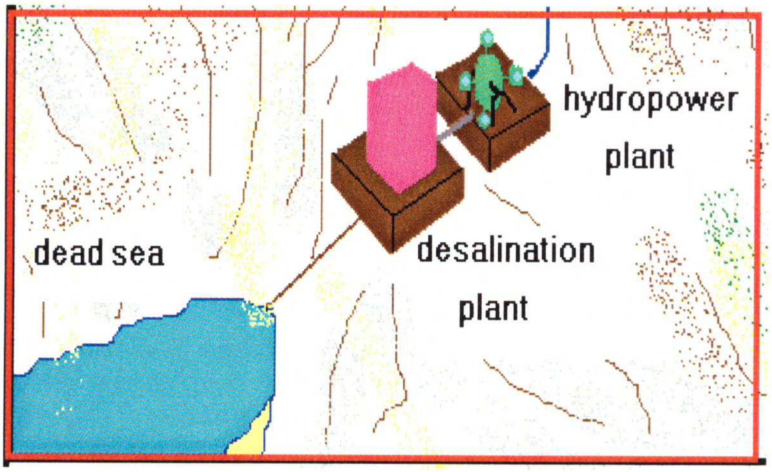


Figure (4.18): Desalination plant

So, we go to detail each parts of Dead Sea project.

Chapter Five

Suction well

- **What is suction well**
- **Important of suction well**
- **Suction well parts design**

5.1 What is suction well?

Suction well can be defined as drilled tunnel down word near the shore of alaqaba gulf, this well will act as water raiser from the bottom of Red Sea (at a fixed depth under Red Sea level) to the Red Sea shore level region, so the following figure (5.1) show this well installation.

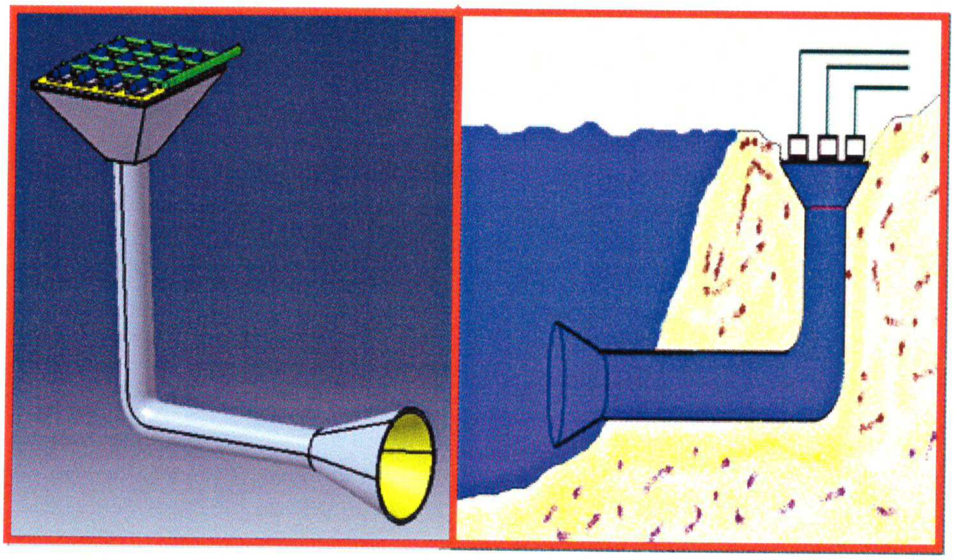


Figure (5.1): suction well location

5.2 Important of the suction well

We need to pump 60 $m^3/s$from Red Sea to carrying it to Dead Sea rejoin for filling, desalination, and other usage so our design must take the nature of Red Sea basins and its tourism situation.

From the previous study at aqaba gulf they found that there are many type of marine animal lives under water at a different depth like coral as shown in figure (5.2) and these type of animals represent a tourism sources for alaqaba gulf region .

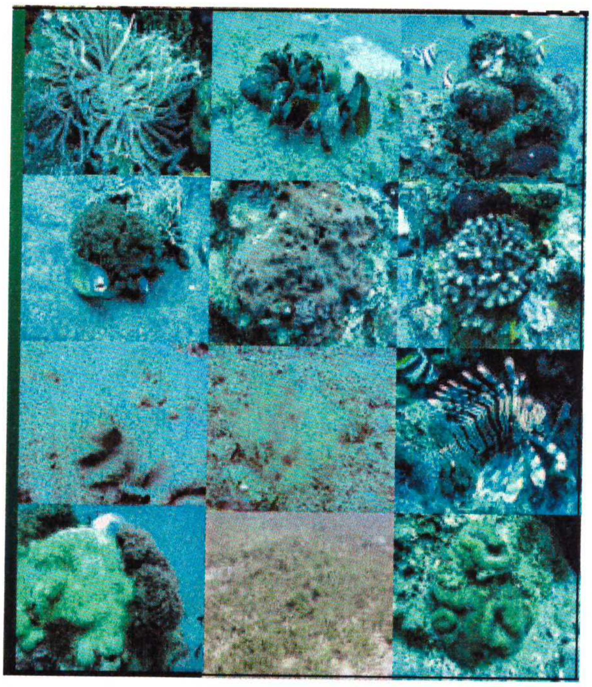


Figure (5.2) coral under red sea

In our project if we go to pumping water from ashore rejoin it will create turbulent vortex at the surface and depth layer of water so; we must solve this problem.

We suggest to drill well near the shore of red sea (shore detect later) to pump water from the bottom of red sea as figure (5.1) show.

5.3 Suction well parts design

We suggest the shape for suction well tunnel as shown into figure (5.1) so, we go to explain each part of this well.

5. 3.1 Region (3): horizontal tunnel

This horizontal tunnel is apart from suction well which drilled into the land at detect depth and the tunnel interior surface will cover within nearly smooth concrete to reduce friction between water and tunnel surface and figure (5.3) show horizontal tunnel.

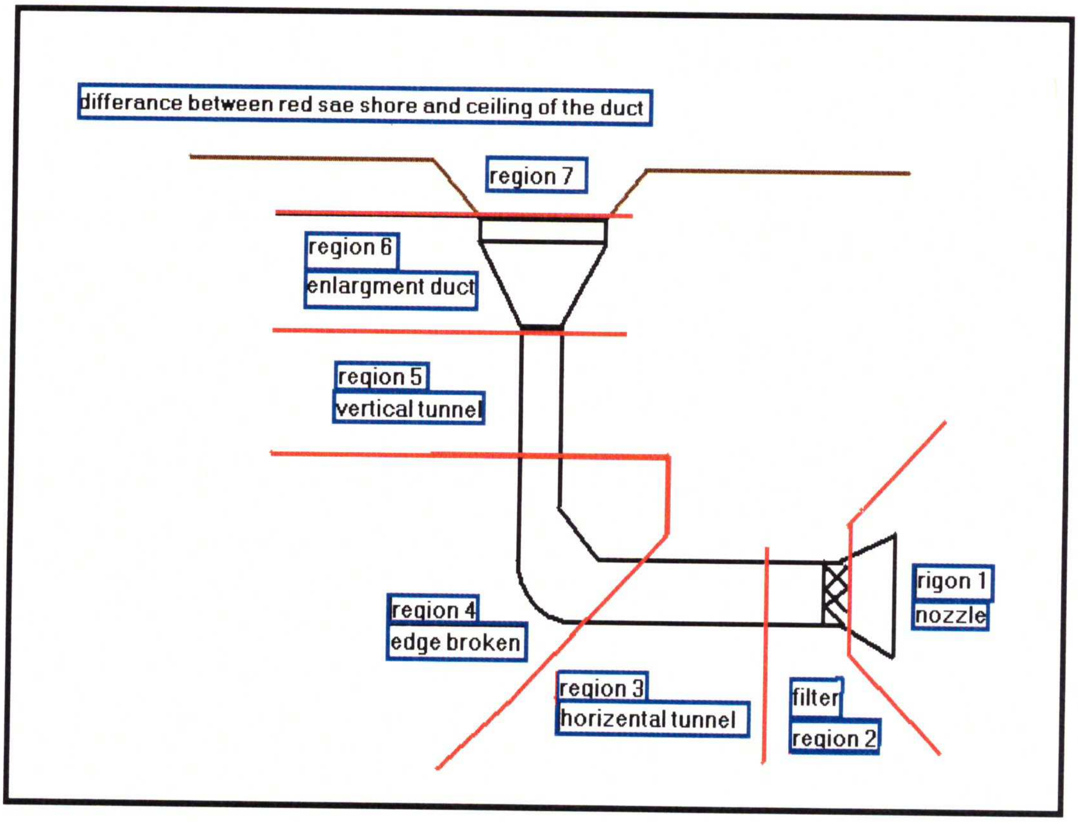


Figure (5.3): suction well region design

This tunnel will pass required flow rate which is $60 m^3/sec$ and the recommended velocity for the flowing water in the intake line is 1 m/s so, we can calculate tunnel diameter by using continuity equation as:

Continuity equation

$$\dot{V} = VA$$

Where :

$\dot{V}$: Flow rate (m^3/s)

V: velocity (m/s)

A: Cross sectional area (m^2)

So after apply equation:

$$A = \frac{\dot{V}}{V} = \frac{60}{1} = 60\ m^2$$

But,

$$A = \frac{\pi D^2}{4}$$

$$D = \sqrt{\frac{4*(A)}{\pi}}$$

$$D = \sqrt{\frac{4*(60)}{3.14}}$$

$$D = 8.74\ m$$

5.3.2 Region (2): Filter

Here filter is fixed to prevent body to enter tunnel like panthers, fishes and coral and the location shown into figure (5.2).

5.3.3 Region (1): Nozzle

The flow velocity (1m/s) into horizontal tunnel is really large which will cause turbulence flow at the gate of tunnel so, we go to reduce velocity of water at the gate of tunnel so, we will go to put nozzle at the gate of horizontal tunnel ahead the filter as shown in figure (5.4).

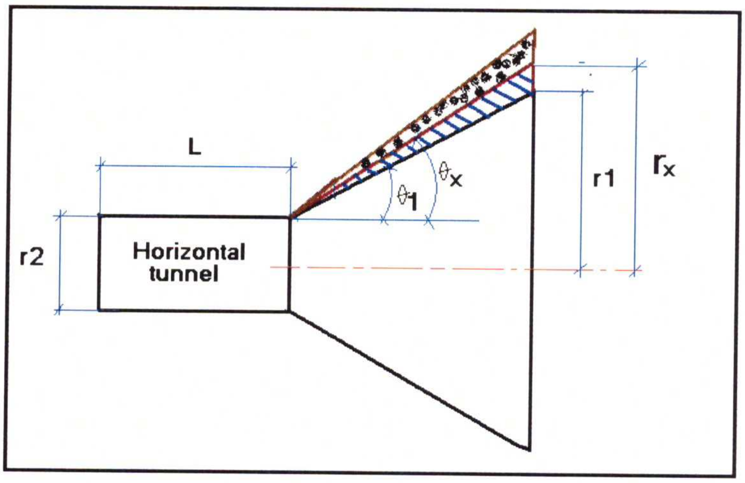


Figure (5.4): Terminology of nozzle

Nozzle terminology rules by multi parameter that is (r1, r2, Θ, L).

If we look to figure (5.5) that represent cross section of nozzle it show that enlargement of nozzle must have slope angel to achieve the self rolling of waste mass that deposits from the filter so, we must calculate this angel as:

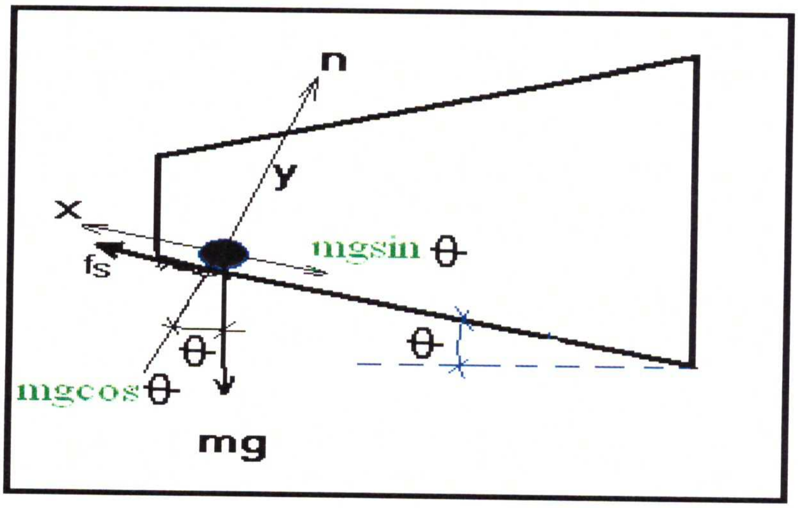


Figure (5.5): Nozzle incline angel

- Suppose the mass deposits =m kg
- Suppose coefficient of friction between the waste and concrete is (μs=1)(here we take approximately surface that is rubber on concrete)
- Mass can be rolling (sliding) when the incline angel have larger than critical angel so, we will write by depend on free body diagram.

$$\sum f_x = 0.0$$
$$m * g * \sin\theta - f_s = 0.0 \rightarrow \underline{1}$$
$$\sum f_y = 0.0$$
$$n - m * g * \cos\theta = 0.0 \rightarrow \underline{2}$$

From equation $\underline{2}$

$$mg = \frac{n}{\cos\theta}$$

Equation 2 in 1 to get:

$$f_s = m * g \sin\theta \rightarrow \underline{3}$$

$$f_s = \left(\frac{n}{\cos\theta}\right)\sin\theta$$

$$f_s = n\tan\theta$$

When the inclined plane is at critical angel :

$$\theta_c = f_s = f_{s\max} = \mu_s * n$$

so, at this angel equation 3 become :

$$\mu_s * n = n * \tan\theta_s$$

$$\mu_s = \tan\theta_c$$

Now our :

$$\mu_s = 1 \rightarrow \tan\theta_c = 1$$

$$\theta_s = 50^0$$

But rolling occurs at $\theta \rangle \theta_c$. So, we will take $\theta = 55^0$

Now we have nozzle incline angel =55° and we have to decrease velocity at the nozzle gate to be 1/4 (V2) as figure (5.6) shown

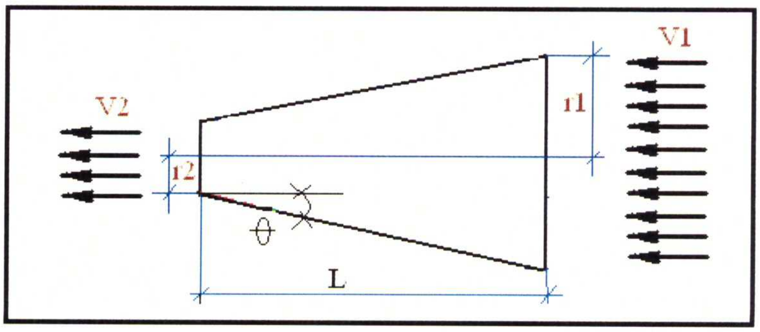


Figure (5.6): Nozzle L versus incline angel (θ)

We will write:

$$V_1 = \frac{1}{4} V_2 = 0.25\,(1\ m/s) = 0.25\ m/s$$

$$\theta = 55^\circ$$

$$r_2 = 8.74/2 = 4.37\ \ m$$

$$\dot{V} = 60\ \ m^3/s$$

r_2 : (From horizontal tunnel diameter) So,

$$V_1 = \frac{\dot{V}}{A_1} = \frac{\dot{V}}{\pi * r_1^{\ 2}} \rightarrow \underline{1}$$

$$\tan\theta = \frac{r_1 - r_2}{L}$$

$$L\tan\theta = r_1 - r_2$$

$$r_1 = L\tan\theta + r_2 \rightarrow \underline{2}$$

Substitution 2 in 1 it will give

$$V_1 = \frac{\dot{V}}{A_1} = \frac{\dot{V}}{\pi\ (L\tan\theta + r_2)^2}$$

$$V_1 = \frac{\dot{V}}{\pi\ (L^2\ \tan\theta^2\ + 2L\tan\theta * r_2^{\ 2})}$$

$$\dot{V} = V_1\pi\ (L^2\ \tan\theta^2\ + 2L\tan\theta * r_2 + r_2^{\ 2})$$

$$\frac{\dot{V}}{V_1\ \pi} - r_2^{\ 2} = (L^2\ \tan\theta^2\ + 2L\tan\theta * r_2)$$

$$\frac{60}{0.25 * \pi} - (4.37)^2 = L^2(\tan 55)^2 + 2L\tan 55 * (4.37))$$

$$57.297 = 1.37L^2 + 10.233L$$

$$1.37L^2 + 10.233L - 57.297 = 0.0 \rightarrow \underline{3}$$

We go to solve equation 3 by:

$$L_{1,2} = \frac{-b \pm \sqrt{b^2 - 4\,a\,c}}{2 * a}$$

$$L_{1,2} = \frac{-10.233 \pm \sqrt{(10.233)^2 - 4(1.37) * (-57.297)}}{(1.37) * 2}$$

$$L_1 = \frac{-10.233 + \sqrt{(10.233)^2 + 20.462}}{2.74} = +3.733m$$

$$L_1 = \frac{-10.233 + \sqrt{(10.233)^2 - 20.462}}{2.74} = -11.20m$$

So, length L = 3.733 m

$$r_1 = L \tan\theta + r_2$$

$$r_1 = 3.733 \tan 55 + 4.37$$

$$r_1 = 8.74 \;\; m$$

$$d_1 = 2r_1 = 17.48 \;\; m$$

$check:$

$$V_1 * \pi * r_1^{\,2} = V_2 * \pi * r_2^{\,2}$$

$$V_1 = V_2 * \frac{r_2^{\,2}}{r_1^{\,2}}$$

$$V_1 = 1 * \frac{r_2^{\,2}}{r_1^{\,2}}$$

$$V_1 = \frac{(4.37)^2}{(8.74)^2} = 0.25 \;\; m/s$$

So, at last our nozzle dimension is as figure (5.7)

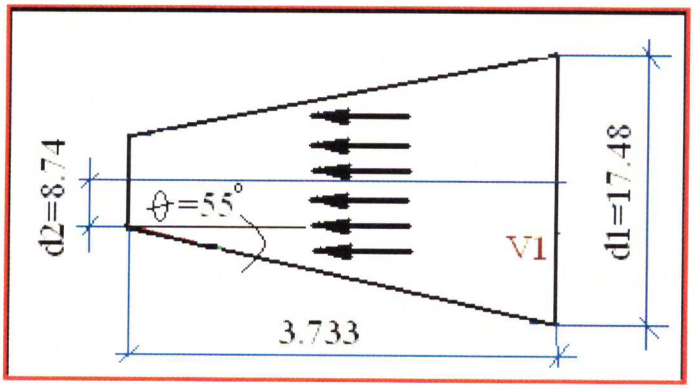


Figure (5.7): Nozzle dimensions

5.3.4 Region: (4)

Edge broken must occur to prevent turbulence flow which will increase friction losses inside tunnel so, when drilling tunnel we must broke edge as shown in the figure (5.3).

5.3.5 Region: (5)

Vertical tunnel: it will passes water vertically within flow rate 60m³/sec and recommended velocity 1m/s so,

$$A = \frac{\dot{V}}{V_1} = \frac{60}{1} 60 \quad m^2$$

$$d = \sqrt{\frac{4\,A}{\pi}} = \sqrt{\frac{4\,(60)}{\pi}} = 8.74 \quad m$$

As horizontal tunnel

5.3.5 Region (6):

- **Enlargement duct:**

Enlargement duct will achieve:

1. To convert circular cross section of vertical tunnel to square shape
2. Increase the area of the square shape of duct ceiling where the pump will layout.

So, its enlargement ratio calculates depend on (A1, A2.L) as shown in the figure (5.8).

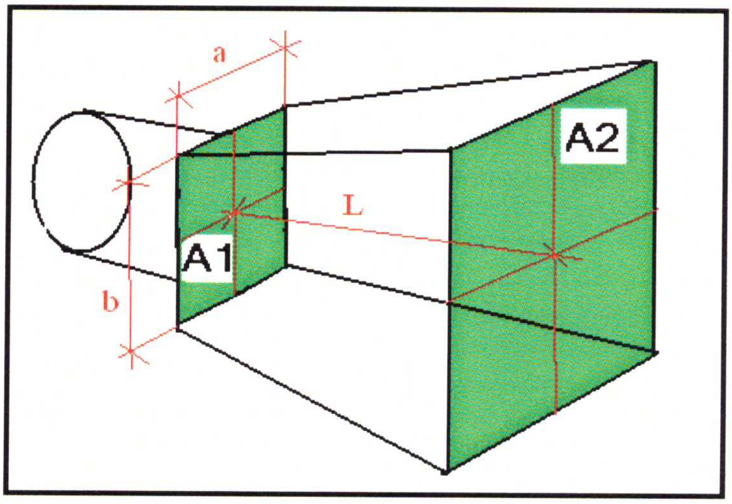


Figure (5.8): Enlargement ratio of duct

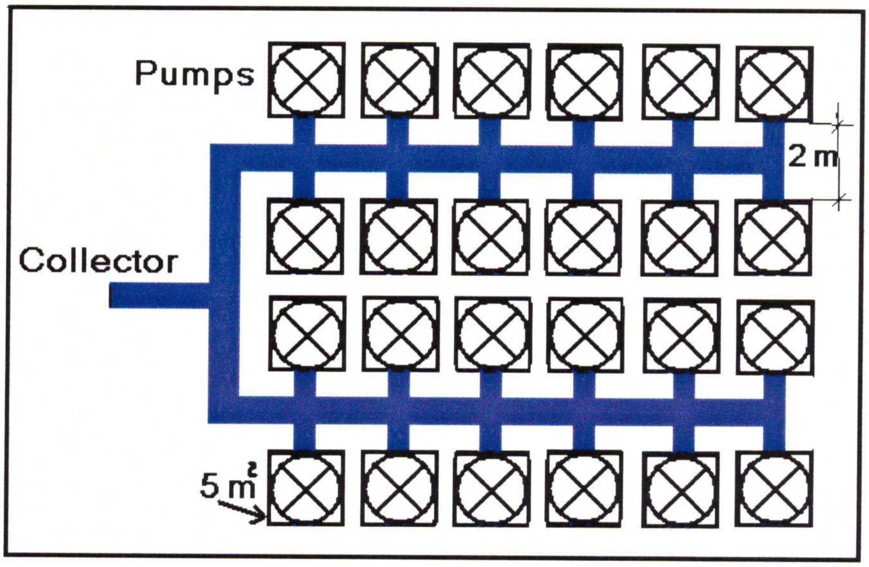
Now we go to know how much (A1,A2 ,L) so, we go to estimating each one.

- **Estimate A2:**

To estimate A2 we must take many consideration:

1. We need to pump 60m^3/sec by pump station which layout up this A2.
Suppose that we will use pumps each of them flow rate =0.5 m^3/sec.
So, we need to 120 pumps for pump station to give the required flow rate.
2. in addition to 120 pumps we need another 60 pump to make the period of pumping divided into three intervals to increase the life of pump.
3. We need 60 pumps for emergency or maintenance of any set of pump .
4. The overall pump required is 240 pumps .
5.suppose every pump with its accessories required area equal 5 m^2 so, the total area required equal (5*240)=1200 m^2.

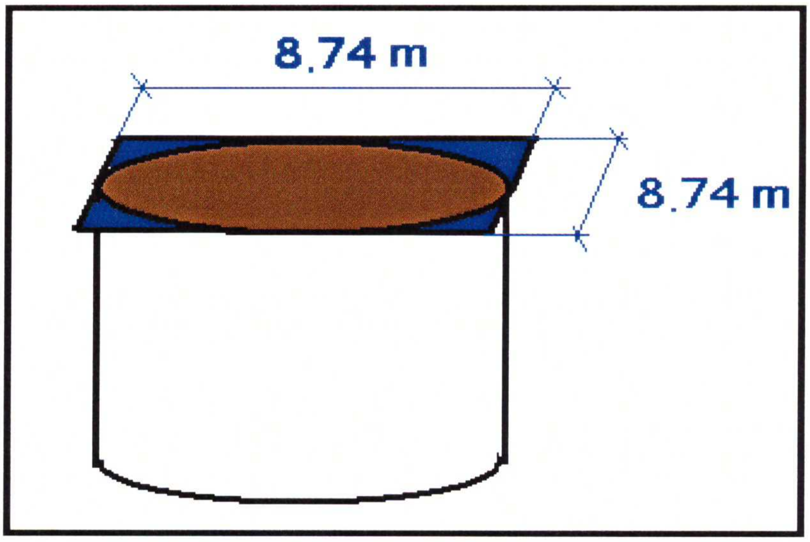
So, we need A2 to be 1200 m^2 and if we added a 300 m^2 to collector line so, the total area equal to 1500 m^2 and the pumps layout at the duct ceiling A2 can be design as shown in figure(5.9)



Figure(5.9):Layout of pumps

Estimate A1:

As we see vertical tunnel diameter equal 4.37 m and for approximation ,we will convert cross sectional shape from circular to square as shown in figure (5.10).



Figure(5.10):Convert cross sectional shape

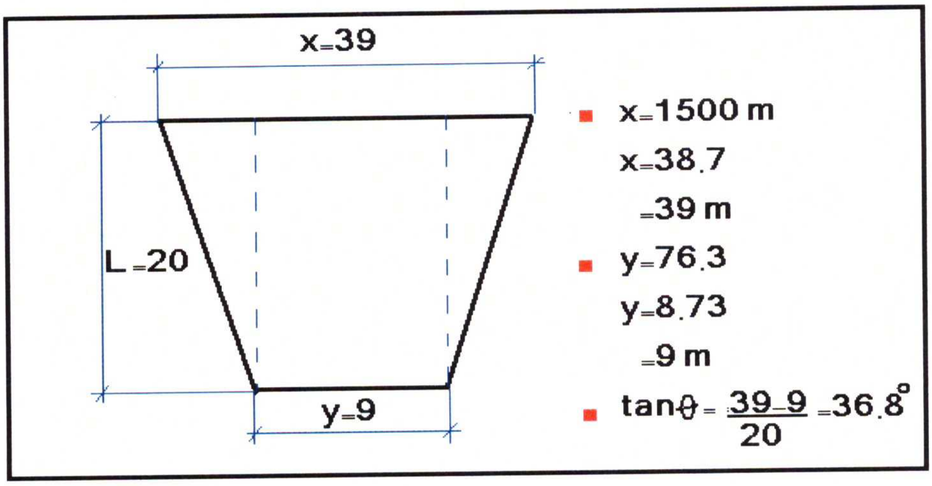
So , area A_1=8.74*8.74=76.387 m^2

Estimate L:

Depth of duct (L) not rolled within A_1 ,or A_2 so, for easy drilling and construction we will approximate (L) as a percent of A_2 to A_1 as:

$$\frac{A2}{A1} = \frac{1500}{76.387} = 19.6 \approx 20 \ m$$

And the dimension of the duct shown in figure(5.11)



Figure(5.11):Duct dimension

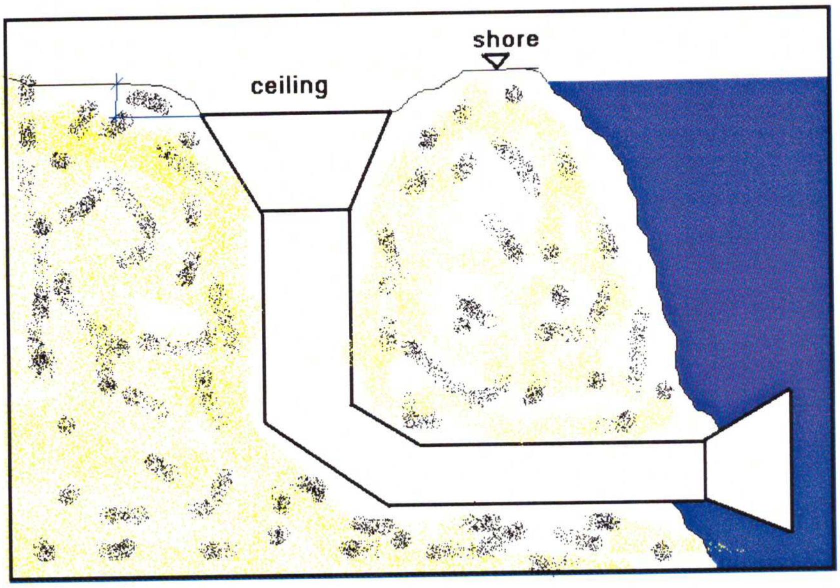
Now the total depth of the nozzle =duct depth + vertical tunnel depth

- But the depth of nozzle must equal at least 80 m (to avoid coral which active at 40 m and large)
- Duct depth =20 m

So , vertical tunnel length = 80 -20 =60 m

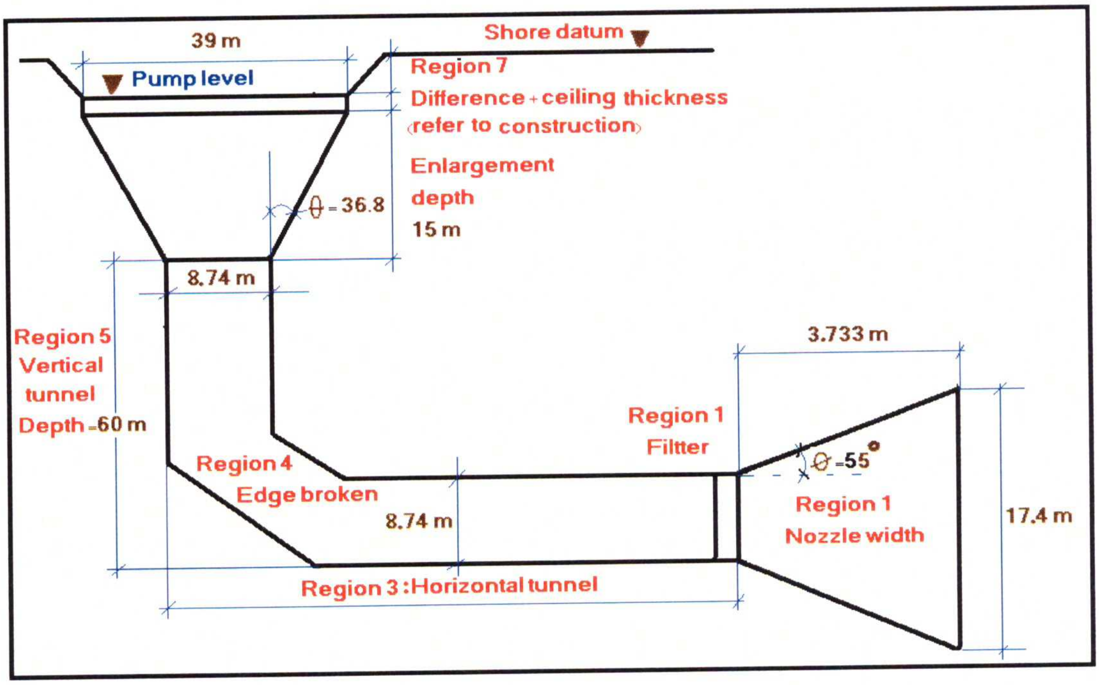
5.3.6 Region (7).

Difference between shore level and duct ceiling level shown into figure(5.12) that show shore level and duct ceiling level and this difference required for:
To achieve that at every time duct ceiling level is lower than Red Sea water level which give that at every time duct will be keep fallen which give no vacuum creation into duct which give good positive suction head for pump station ,And this difference value estimated from construction engineering .



Figure(5.12):Difference between shore level and duct ceiling level

At least figure (5.13) show the suction well dimensions



Figure(5.13):Suction well dimension

Chapter six

Pumping Process

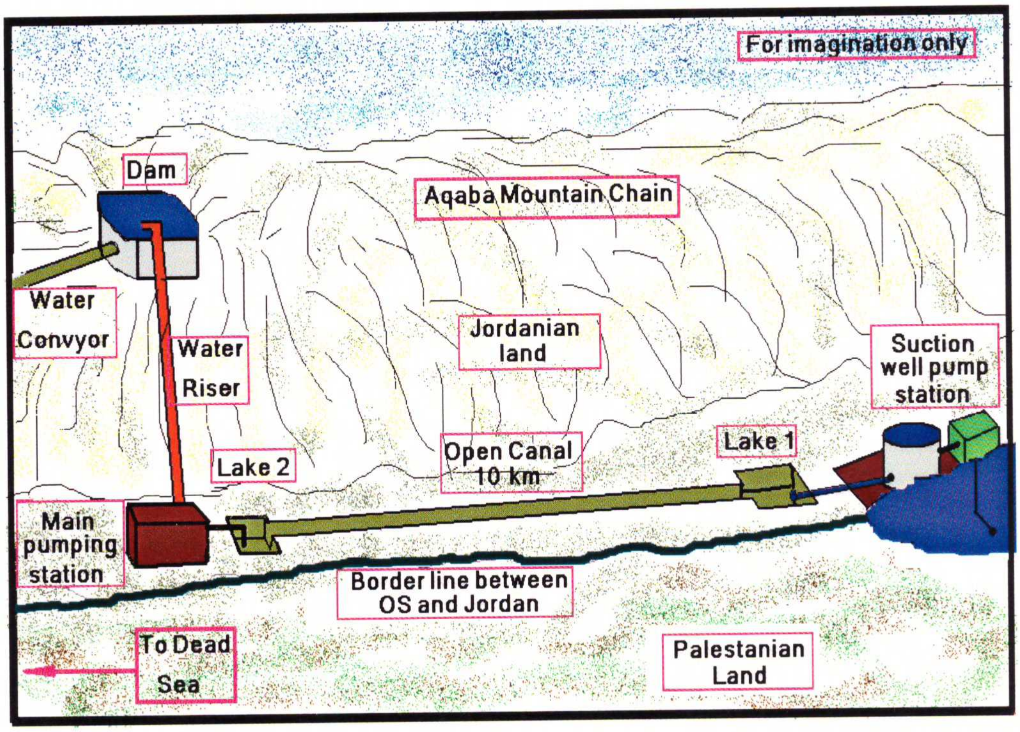
- **General description to the pumping process.**
- **Explaining the parts of pumping process.**

6.1 General description to the pumping process.

Pumping process means that we use a machine to supply energy to a liquid in order to move it from place to another so, pumps enable a liquid to :

- Flow from a region of low pressure to one of high pressure.
- Flow from a low level to a higher level.
- Flow at a faster rate.

In our RSDSC project we suggested that pumping process will happen into a category that shown into figure (6.1).



Figure(6.1):Pumping process category

Now, as seen into figure (6.1) we will go to explain each parts of pumping process.

- Part1: Intake pump station

Its layout at suction well ceiling and its purpose to pumping the water from suction well to lake 1.

- Part2: Collecting lake

Its industrial lake used to receive water from intake pumps station and flow it to open canal.

- Part3: Open canal:

Its length is approximately 10 Km and it will connect lake 1 to lake 2.

- Part4: Lake 2:

I Its create as a preparing water source to main pump station.

- Part5: Main pump station:

Its option is to pumping the water from lake 2 to the dam that placed at the top of mountain.

- Part6: Water riser:

Its asset of pipe that will hold the water to the dam from main pump station.

So ,we will to explain each part of pumping process into the following section.

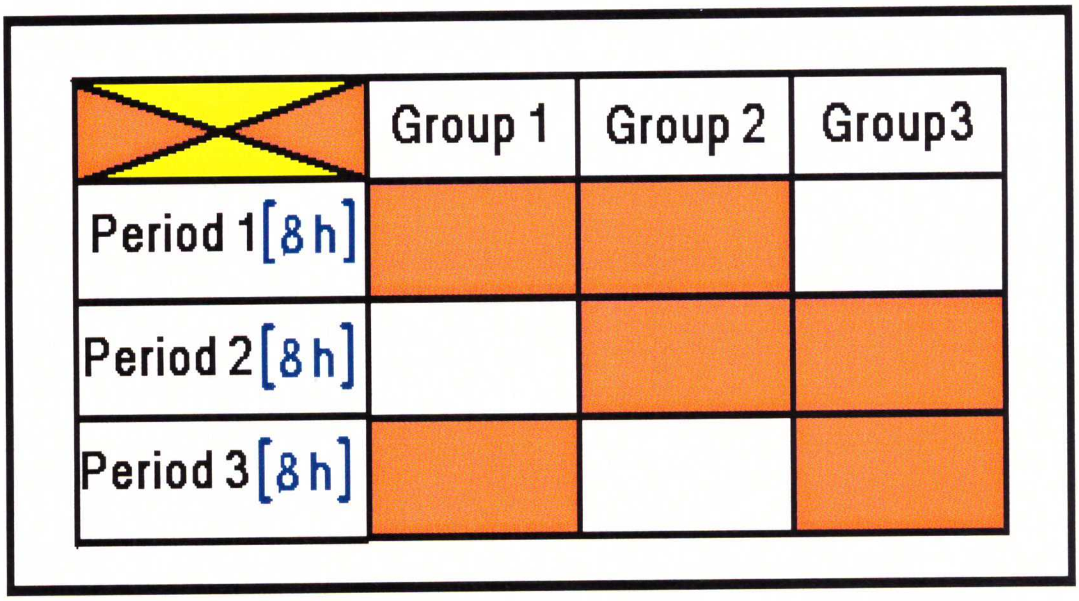
6.2 Explaining the parts of pumping process.

In each part of pumping process we will give general description , dimension, and any other design details.

6.2.1 Intake pump station.

- The aim of this pump station is to pumping water from the tunnel that drilling under Red Sea to prevent vortex water at the surface of Red Sea since its tourism and industrial region ,so we suggest suction well as solution.
- The required flow rate from intake pumps station is **60** m^3/s and this flow rate can not obtain from one pump so , it will come from a group of pumps and each one will contribute at a percent to collect the total flow rate **60** m^3/s.
- Each pump rolled within a performance curve and a product catalogue describe the performance of the pump and since we can not reach to large flow rate pump catalogue so, we will suppose a flow rate to make our calculation and design.
- Suppose we have to use a group of pump each pump flow rate is **0.5** m^3/s
- We need to **120** pumps to save the pumps and increase its surface life we will use 3 group of pump each group is **60** pumps and the period of working will divided to **3** period each period is 8 hours.

So , the total pumps required is 180 pumps and the period of working shown into figure (6.2).



Figure(6.2):Method of running pumps

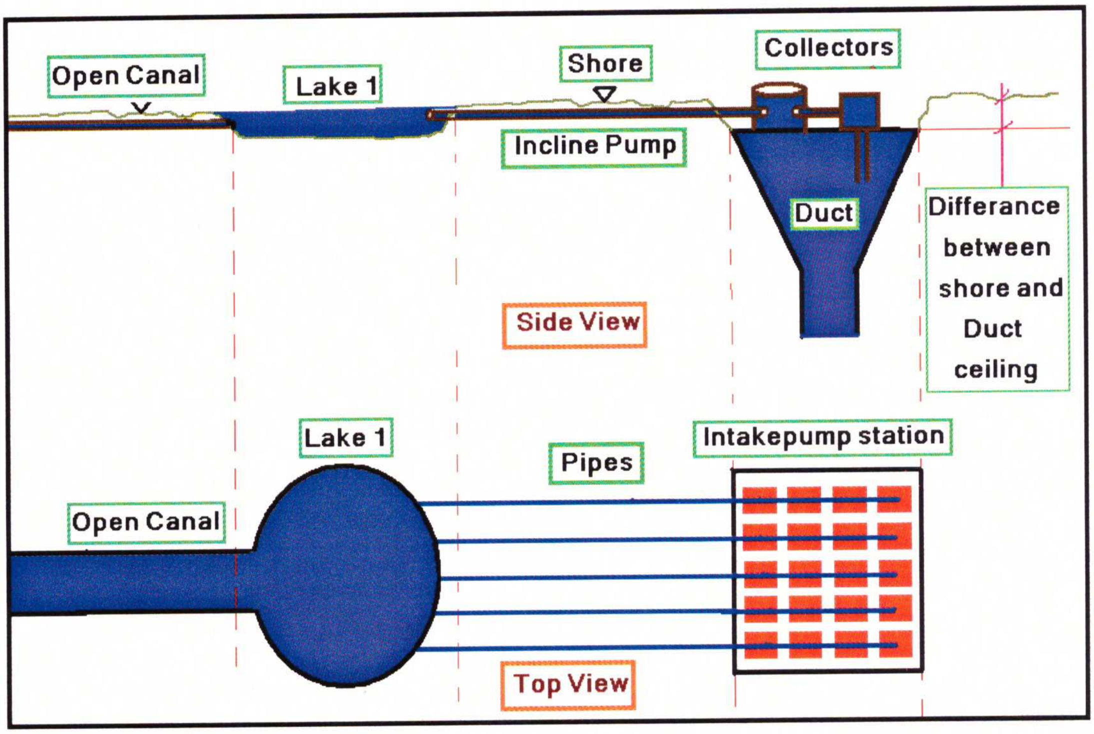
- But to make maintenance to any pumps group we need a group of pumps(60) to replaced within the group that will repair .
- The total pumps required is:

☒ 3 group each group 60 pumps required so the total number of pump is equal to 180 pumps.

☒ Maintenance group =60 pumps.

The total pump required =240 pumps .

- The category of pumps connection is shown into figure (6.3)



Figure(6.3):Category of pumps connection

- As figure (6.3) we connect every 10 pumps to one collectors so , we need

$$Number\ of\ collector = \frac{240\ \ Pumps}{10\ \ Pumps} = 24\quad collector$$

- The flow rate of 10 pumps to collectors equal

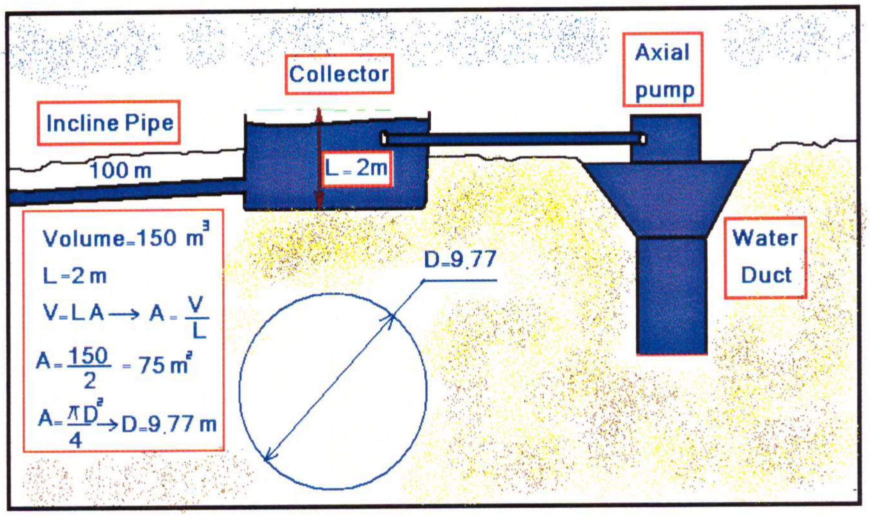
$$0.5\ \ m^3/s*10\ \ pump = 5\ \ m^3/s$$

- Each collectors will works for 5 min without water flood so,

$$Size\ of\ collector = 5\ \text{min}*60\ s = 30\ s$$

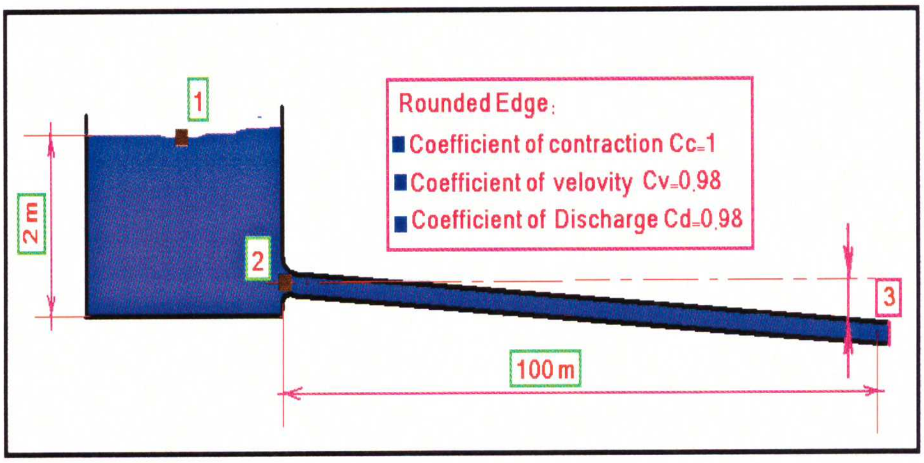
$$Size\ of\ collector = 30\ s*5\ m^3/s = 150\ m^3$$

Dimension of collector and category shown into figure (6.4)



Figure(6.4):Category of collectors

- The water that collecting into collector will discharge continuously to lake 1 through incline pipe so , the slope and diameter of incline pipe will be calculating and figure (6.5) show one collector and its incline pipe.



Figure(6.5):Collector and incline pipe.

❖ Apply Bernoulli equation between point 1 and point 2 ,point 2 and point 3

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+Z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+Z_2+h_f$$

$$but\ \frac{P_1}{\rho g}\approx\frac{P_2}{\rho g}=0.0$$

* $\frac{V_1^2}{2g}\cong 0.0\ldots(\textit{inlet water keep water level stable})$

* $\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+Z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+Z_2+h_f$

$Z_2=0.0\ ,\ Z_1=2\ m$

* $h_f\cong 0.0\ldots(\textit{Collector diameter relatively large and friction less})$

$$So\ ,\ Z_1=\frac{V_2^2}{2g}\rightarrow V_2=\sqrt{2gZ_1}=\sqrt{2*9.81*2}=6.2\ m/s$$

❖ V_2 is ideal and rounded edge have coefficient velocity as a correction factor

so:

Actual velovity$(V_x)=C_v*V_2$

$V_x=0.98*6.2$

$V_x=6.1\ \ m/s$

V_x will pass through incline pipe and we need incline pipe to discharge $5\ \ m^3/s$.

$$Q=V*A\rightarrow A=\frac{Q}{V}=\frac{5}{6.1}=0.819\ \ m^2$$

$$A=\frac{\pi D^2}{4}\rightarrow D=\sqrt{\frac{4A}{\pi}}=\sqrt{\frac{40.819}{3.14}}=1.02\ \ m$$

❖ Apply Bernoulli equation between point 2 and point 3

$$\frac{P_2}{\rho g}+\frac{V_2^{\ 2}}{2g}+Z_2=\frac{P_3}{\rho g}+\frac{V_3^{\ 2}}{2g}+Z_3+h_f.$$

* $\dfrac{P_2}{\rho g}=2\ m(\ atmospheric\ \ pressure\ \ head\ \ from\ water\ level\ ).$
* $V_2=V_x=6.1\ m/s\approx V_3.$
* $Z_2=0.0.$
* $\dfrac{P_3}{\rho g}=(\ atmospheric\ \ pressure\ ).$

but :

$$h_f=f\frac{V_2^{\ 2}}{2g}\frac{L}{D}$$

* $L=100\ m$
* $D=1.02\ m$
* $f=0.01(\ steel\ \ pipe\ )$
* $V_2=6.1\ m/s$

$$h_f=0.01\frac{(6.1)^2}{2*9.81}\frac{100}{1.02}$$

$$h_f=1.859\ m$$

Now :

$$\frac{P_2}{\rho g}+\frac{V_2^{\ 2}}{2g}+Z_2=\frac{P_3}{\rho g}+\frac{V_3^{\ 2}}{2g}+Z_3+h_f.$$

$$2+0.0+0.0=0.0+0.0+Z_3+1.859.$$

$$Z_3=2-1.859$$

$$Z_3=14.1\ cm(\ slope\ \ of\ \ incline\ \ pipe\ )$$

As figure(6.4):each pump will

- Rise the water 1 m vertical
- Since pump near collector so,the dynamic friction losses is approximately 1m
- Flow rate of each pump =0.5 m³/s
- The power required to run each pump:

$$P = \rho gQH$$

$$P = 1000\frac{kg}{m^3} * 9.81\frac{m}{s^2} * 0.5\frac{m^3}{s} * 2\ m$$

$$P = 9810\ \ watt$$

But at each period of working we have 120 pumps is running so,

$$Total\ \ power\ \ required = 120\ \ pump * 9810\ watt$$

$$Total\ \ power\ \ required = 1.117\ \ \ MW$$

It's the power required to run the intake pumps station=1.177 MW.

6.2.2 Industrial lakes and open canals.

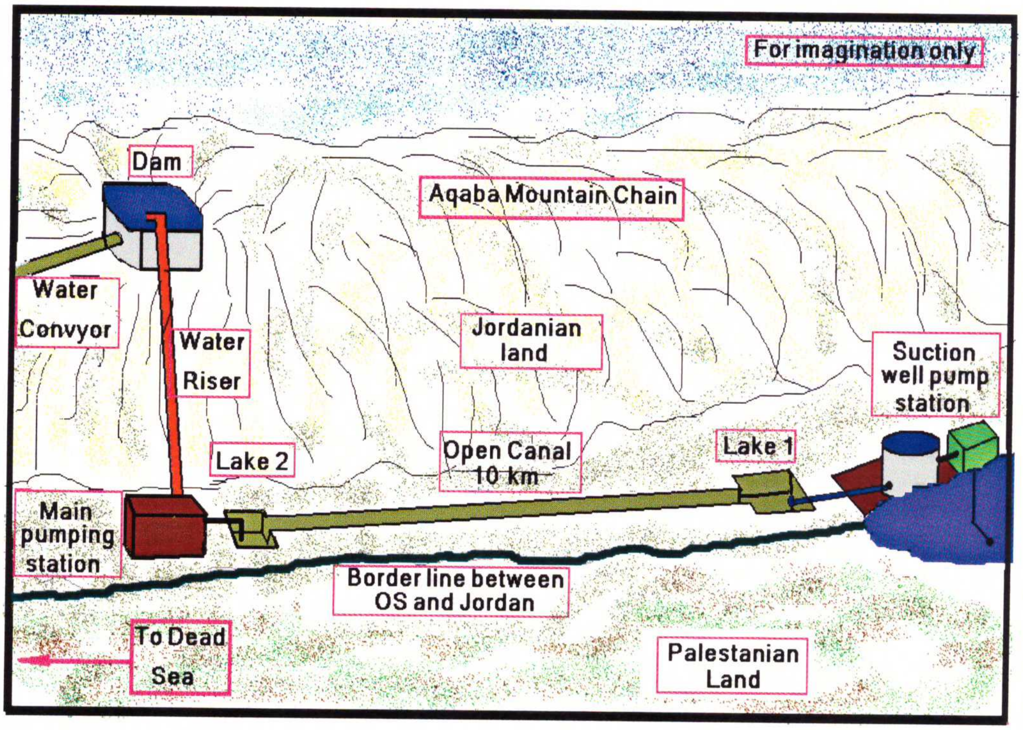
- Another parts of pumping process is lake (1&2) which will construct to collecting the pumping water so.

❖ Lake 1 : will collect the water from intake pumps station which then will feed this water to open canal.

❖ Lake 2:will receive water from open canal and act as water source to feed the main pumps station.

❖ Open canal: will transport water from lake 1 to lake 2 with a length equal 10 Km.

- The location of two lakes and open canal shown in figure(6.6).



Figure(6.6):Two lakes and open canal location

- The main problem of two lakes and open canal are evaporation of water which acts losses of energy that pumping this evaporative water , but this problem can be solve by increase the number of pumps into intake pumps station to compensate the amount of evaporation.
- The benefit of two lakes and open canal are a tourism canal since it will act a good sight to visitors.
- Capacity of each lakes:

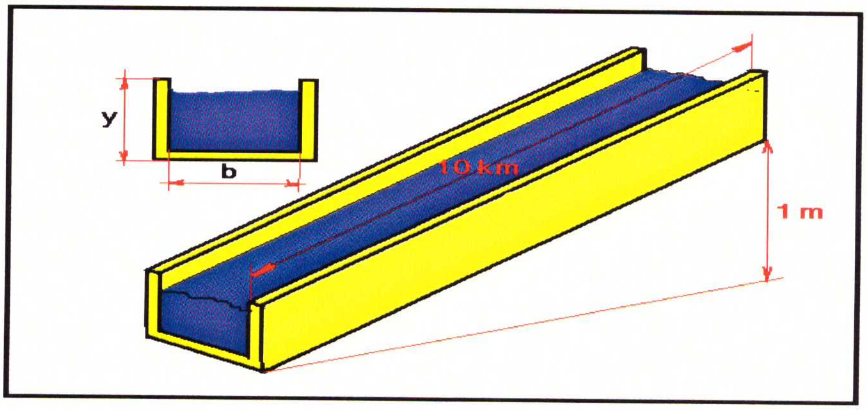
To calculate the capacity suppose that lakes will collect water without discharge for a period equal (1 hour) so ,

$$\text{Lake capacity (1 hour)} = 60\ \text{min} * 60\ \text{sec} * 60\ m^3/s$$
$$\text{Lake capacity (1 hour)} = 216.000\ m^3$$

- Open canal dimension:

Open canal which will discharge $60\ m^3/s$.

For construction dimension suppose that the incline difference between beginning and the end of the open canal is 1 m as shown in figure (6.7).



Figure(6.7):Slope of open canal

- The best hydraulics section for a rectangular canal occurred at b = 2y .
- By using equation: $V = \frac{1}{n} R^{2/3} S^{1/2}$ *and* $Q = A * \frac{1}{n} R^{2/3} S^{1/2}$

Where :

Q: Flow rate , [m^3 / sec].

A: Cross sectional area , [m^2]

n: Manning roughness factor.

R: hydraulics radius .

S: Slope of canal.

V: Velocity of flow, [m/sec].

So , we will find all parameter to find area of the canal as:

Q=60 m^3 / sec .

n=0.014 (for average concrete) that will cover internal surface of the canal.

S=0.0001 [$\frac{m\ length}{m\ width}$].

$$R = \frac{Area}{wetted\ perimeter} = \frac{A}{P} = \frac{by}{b+2y} = \frac{b}{4} = \frac{2y}{4} = \frac{y}{2}$$

$$A = by = (2y)y = 2(y)^2$$

So , apply into equation:

$$Q = V * \frac{1}{n} R^{2/3} S^{1/2}$$

$$60 = (2(y)^2)(\frac{1}{0.014})(\frac{y}{2})^{2/3}(0.0001)^{1/2}$$

$$60 = (2(y)^2)(71.428)(\frac{y}{2})^{2/3}(0.01)$$

$$y^{8/3} = \frac{60 * (2)^{2/3}}{2(71.428)(0.01)}$$

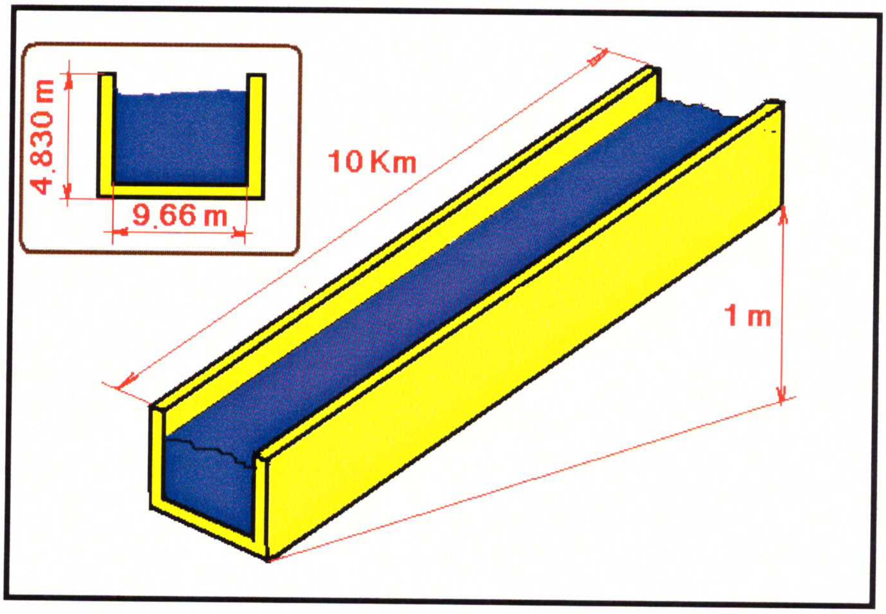
$$y^{8/3} = 4.830\ m$$

But:

$b = 2y$

$\rightarrow b = 9.66$

So , canal dimension shown into figure(6.8).

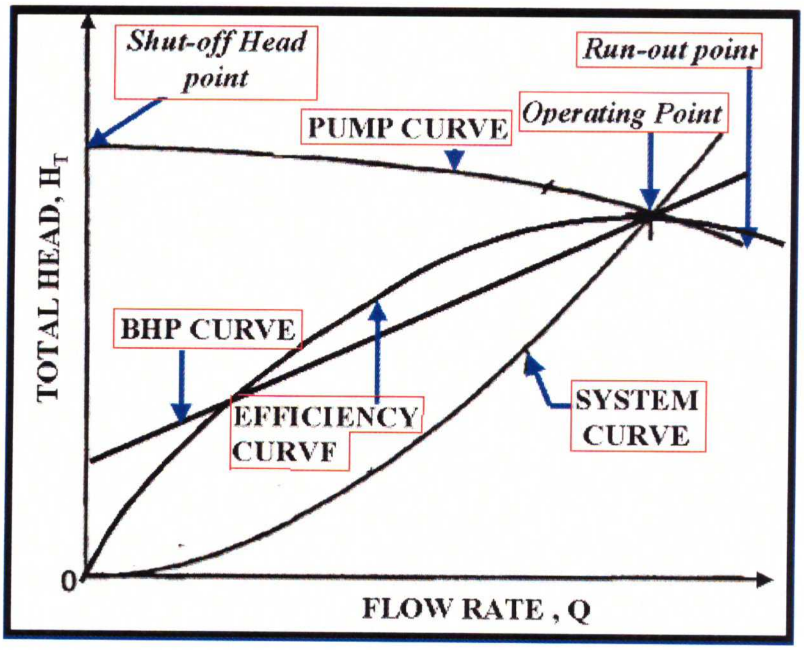


Figure(6.8):Canal dimension

6.2.3 Main pump station.

- The purpose of main pump station is to completing pumping process by pumping water from lake 2 to the dam that placed at the top of a mountain at 125 m elevation and figure (6.1) show the location of pumps station.
- Water will pumping by using pumps within detect type and this type of pumps must be able offer power required to recover
  - ❖ Power losses due to static elevation
  - ❖ Power losses due to dynamic head friction into pipes(risers)

- Since any pump ruled within a performance curve that shown into figure (6.9).



Figure(6.9):Pump performance curve

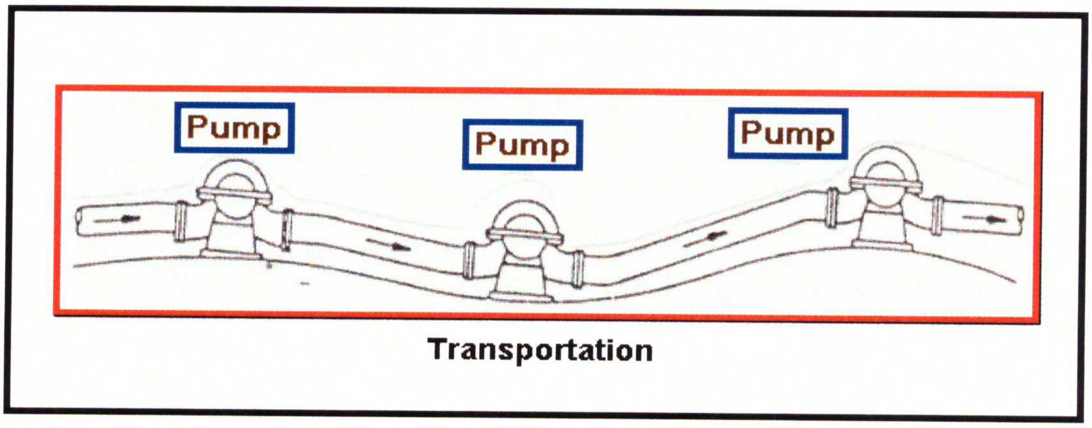
- As shown into figure(6.9) if the flow demand increase then the system dead losses will increase .
- Pumps can pumping water if system head losses less than head obtain from pump.
- Since there are no pump can give flow rate required ($60\,m^3/\sec$) and high total head so , this can be obtain by:

Using multi pumps and risers to recover large flow rate.

Using transportation method to connect pumps together to recover large head as Figure (6.10) showing since in transportation method

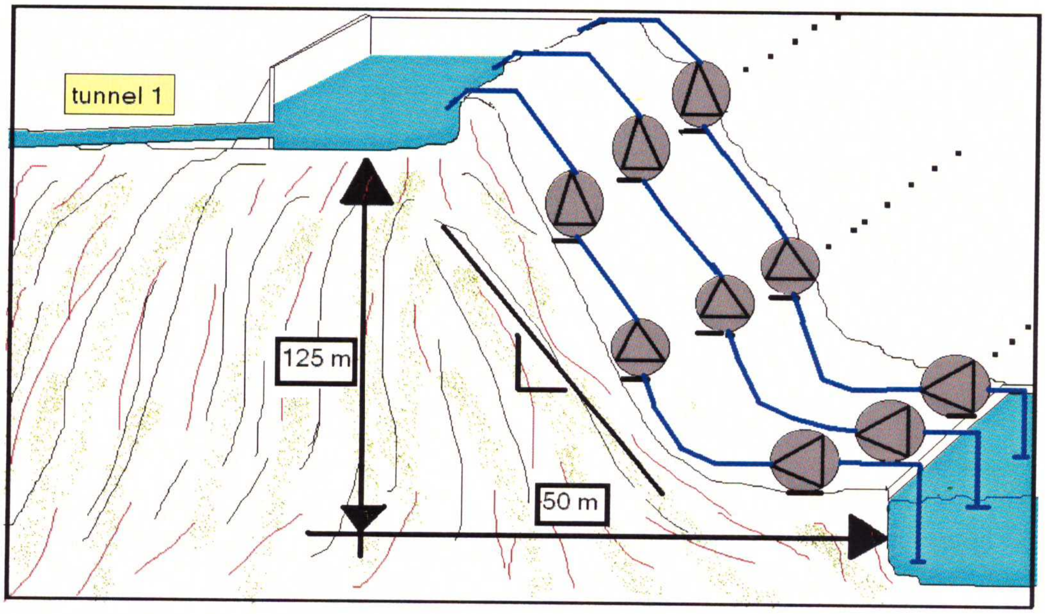
Pumps are connected as series and into series connection we have.

- Flow rate will be the same.
- Head will be increase and the total head $= \sum$ of each pump head.



Figure(6.10):Transportation method for pumps connection

- We suggest strategy to rise the water to mountain as shown into figure (6.11).



Figure(6.11): Strategy of pumping water to mountain.

- Since we did not find catalog describe performance (large flow ,large head) pump so , we will suppose that :

❖ We will use a pumps with each pump have a flow rate equal to $0.5\, m^3/\sec$.

❖ Number of riser required $= \dfrac{Flow\ rate\ requied}{Pump\ flow\ rate} = \dfrac{60}{0.5} = 120\ riser$

❖ Each riser required numbers of pumps to recover the head due to static and dynamic and this number depend on the catalog since total head required $= \sum head\ of\ each\ pump$

- Dynamic head losses due to riser can be calculated as:

❖ If we look to figure (6.11) we can calculate the length of riser as:

$$L = \sqrt{(50)^2 + (125)^2}$$
$$L = 134.6 \cong 135\ m$$

And we will add $5\ m$ to intake and discharge lines for technical usage so , the total length of riser is $140\ m$.

❖ The recommended velocity into discharge line is $3\ m/s$.

❖ Each riser will used to transport $Flow\ rate = 0.5\ m^3/s$.

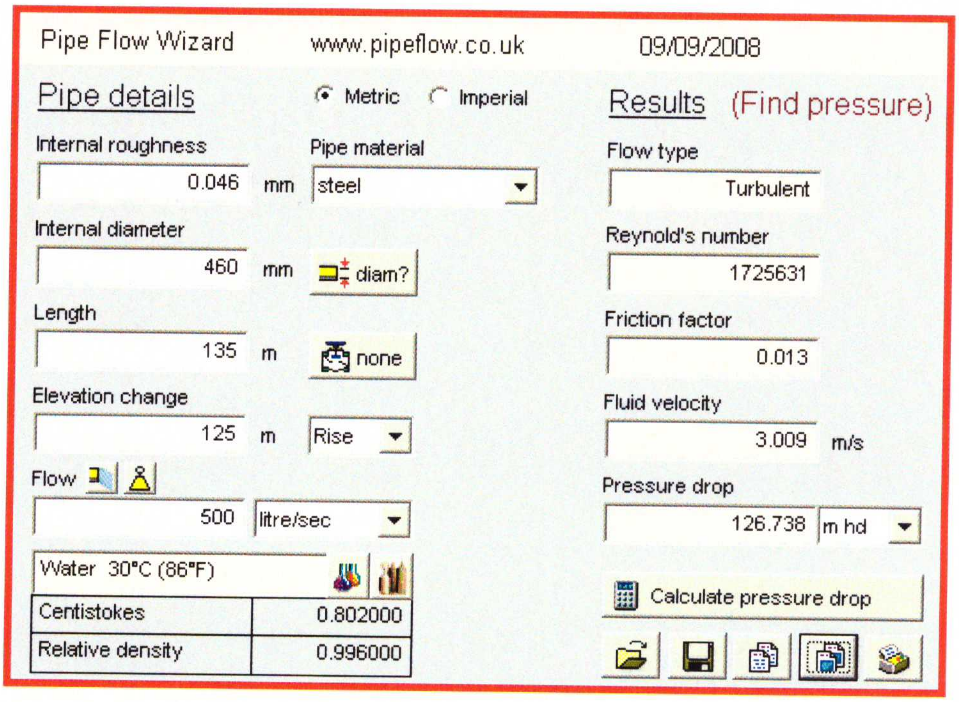
❖ So , cross sectional area of each riser is:

$$Q = VA \rightarrow A = \frac{Q}{V} = \frac{0.5}{3} = 0.16\ m^2$$
$$A = \frac{\pi D^2}{4} \rightarrow D = \sqrt{\frac{4A}{\pi}} = 0.46\ m$$

- For each riser: dynamic and static pressure drop (head losses) can be computing as:

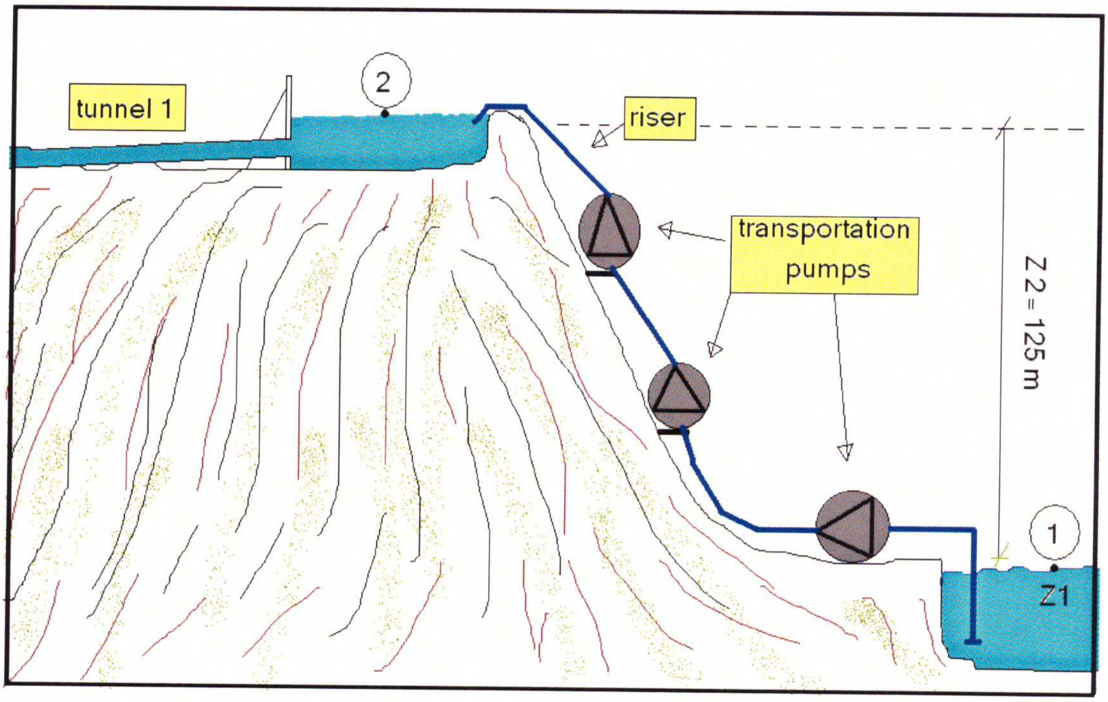
- ❖ Pipe material used for riser is steel.
- ❖ Riser diameter=0.46 m.
- ❖ Flow rate=0.5 m^3/s $(500\frac{liter}{\sec})$.
- ❖ Riser length=135 m.
- ❖ Static elevation due to mountain =125 m.
- ❖ Water flow at $30C^0$.

So , when we use this data into pipe flow wizard software then pressure drop due to static and dynamic as shown into figure(6.12).



Figure(6.12):Riser pressure drop calculation

- Power required to pumping water can be calculated as;
- ❖ If write energy equation for steady incompressible flow for a control volume between 1 & 2 as shown in figure (6.13).



Figure(6.13):Control volume of pump.

$$\dot{m}\,(\frac{P_1}{\rho}+\frac{V_1^{\,2}}{2}+gZ_1)+\dot{W}_{Pump}=\dot{m}\,(\frac{P_2}{\rho}+\frac{V_2^{\,2}}{2}+gZ_2)+\dot{W}_{turbine}+\dot{E}_{mechanical\ losses}$$

But:

$$\dot{m}=\rho\dot{V}$$

$$\frac{P_1}{\rho}=\frac{P_2}{\rho}=0.0$$

$$Z_1=0.0$$

$$\dot{W}_{turbine}=0.0$$

So ,

$$\dot{W}_{Pump} = \dot{m}gZ_2 + \dot{E}_{mechanical\ losses\ in\ pipe}$$

$$\dot{W}_{Pump} = \rho\, g\, Q\, Z_2 + \rho\, g\, Q\, h_{f(pipe)}$$

$$\dot{W}_{Pump} = \rho * g * Q * (Z_2 - h_f)$$

$$\dot{W}_{Pump} = (1000) * (9.81) * (0.5) * (125 + 1.738)$$

$$\dot{W}_{Pump} = 4905 + 126.738$$

$$\dot{W}_{Pump} = \rho gQZ_2 + \rho gQh_{f(pipe)} 621649.89\ \ Watt$$

$$\dot{W}_{Pump} = 0.62164989\ \ MW \quad for\ each\ riser$$

- We have 120 riser so , the total power required to main pumps station compute as:

$$\text{Total power required} = 120\ riser * each\ riser\ \ power$$

$$\text{Total power required} = 120 * 0.62164989$$

$$\text{Total power required} = 74.5979868\ MW.$$

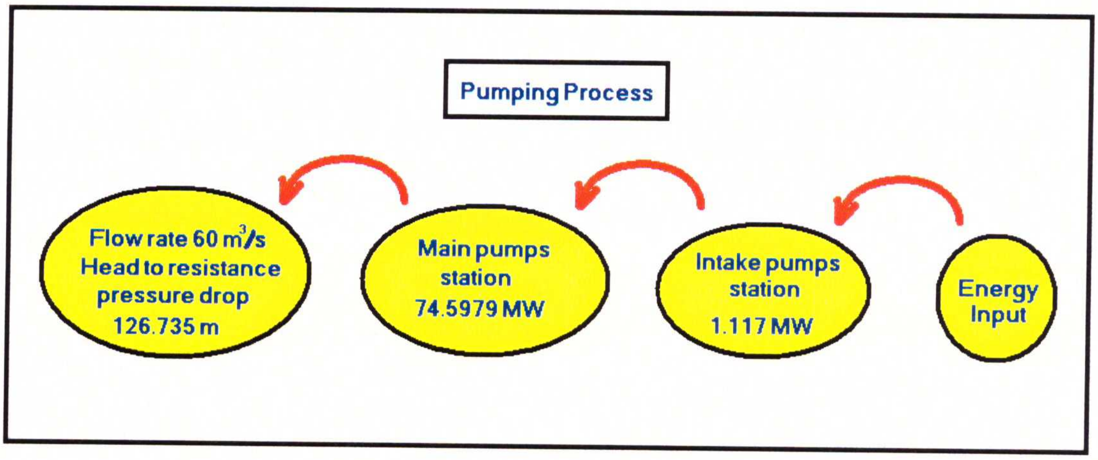
- Intake pumps station need 1.177 MW so , the total power required to pumping process is:

$$\text{Total pumping process power} = \text{intake pumps station} + \text{main pumps station}$$

$$\text{Total pumping process power} = 1.177\ MW + 74.5979\ MW$$

$$\text{Total pumping process power} = 75.7749\ MW$$

And figure(6.14) show energy block diagram for pumping process.



Figure(6.14):Pumping process energy block diagram.

Chapter Seven

Water Conveyer System

- **What is the conveyor.**
- **What is Dam.**
- **Tunnel and open canal .**

Chapter Seven

Water conveyors system

7.1 What is the conveyor?

We go to transfer amount of water equal $60m^3/s$ from red sea to dam then from dam to hydro power plant then to Dead Sea.

Water conveyor consists from:

- Tunnel 1
- Open canal
- Tunnel 2

And figure (7.1) show the category of water conveyor.

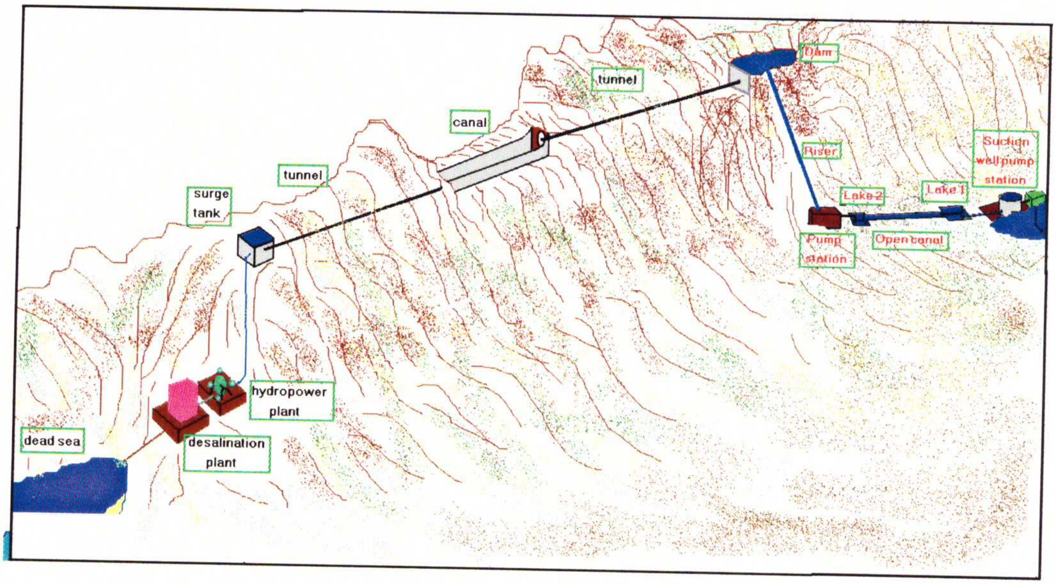


Figure (7.1): Water conveyor category.

7.2 What is dam?

Simply, it is strong wall built from forced concrete and has high thickness at its base, used to collect the water behind him to create as a storage tank which then allow to discharge it from gates or pipe which connected within its wall.

dam will built at the top of the mountain near red sea shore at elevation (125 m) ;so dam will placed at a region have valley nature then dam will acting as closed region with the rock wall and the total shape will act as storage tank.

7.2.1 Shapes of the dam

Dam has multi shape which depends on its aim so the following shape show three general main type of dams.

Figure (7.2), show the gravity dam and how pressure forces act on the wall as the weight of concrete and center of water pressure.

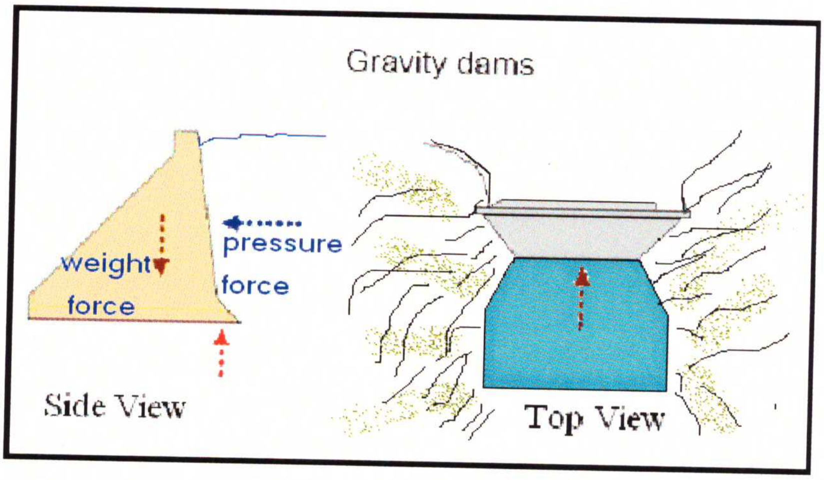


Figure (7.2): Gravity Dam

Figure (7.3) show the arc dam its free body diagram of forces that act on its wall.

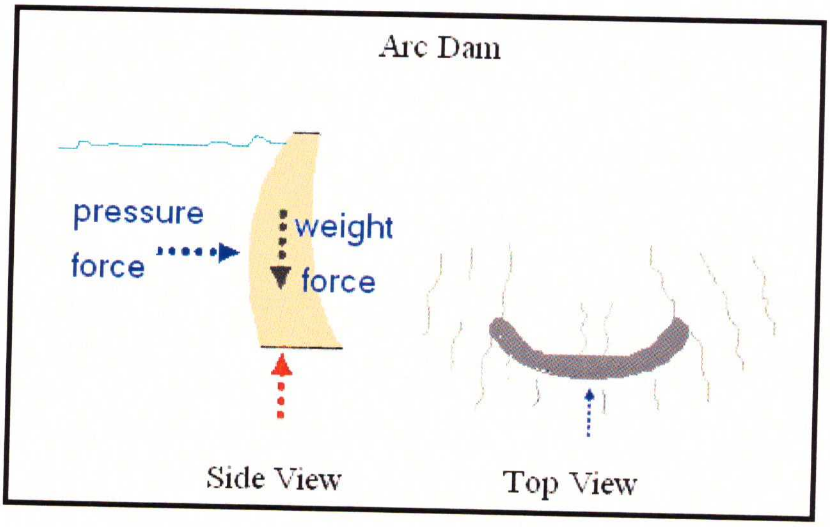


Figure (7.3): Arc Dam

Also the third type of dam can be seen as figure (7.4).

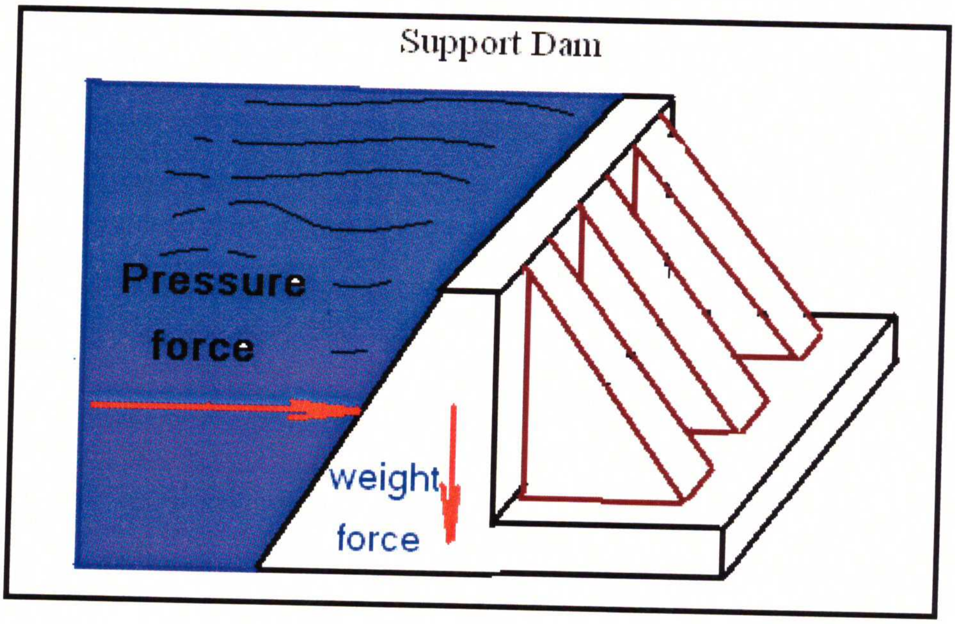


Figure (7.4): Support Dam

7.2.2 Dam location

In dead red sea project dam will collecting water that pumped from red sea above the mountain near red sea shore which pumped from station, then this collected water will transfer within conveyer to reach hydropower plant at the southern shore of Dead Sea and figure (7.5) show the dam location

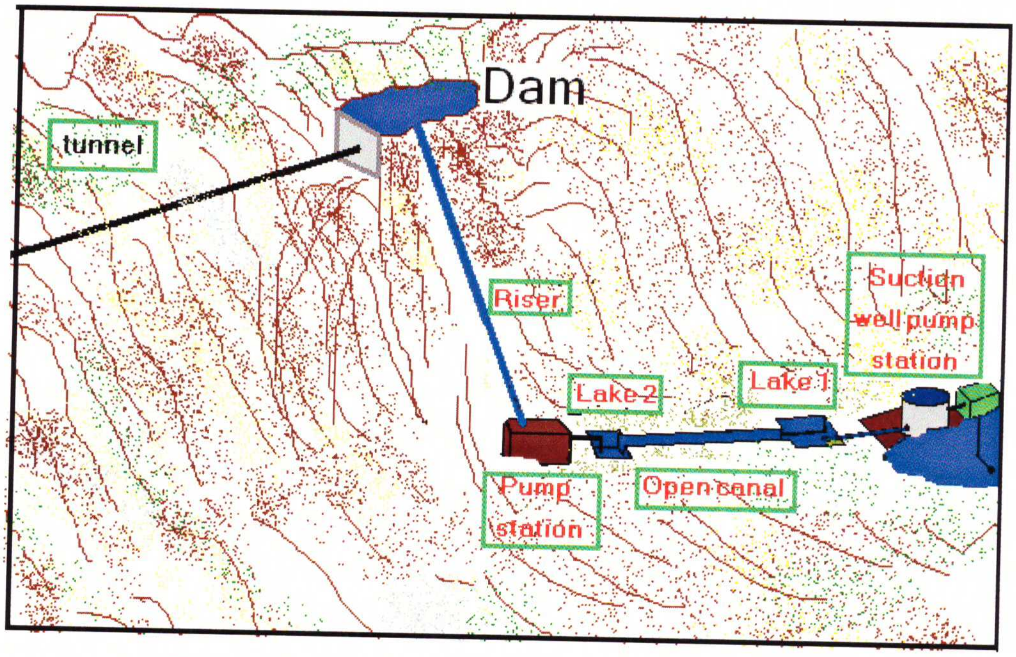


Figure (7.5): Location of Dam above the mountain.

7.2.3 Construction consideration of the dam

The construction design refer to layout at the construction engineer's responsibility so, the procedure of construction design is:

- Depending on mountain topography ,engineer must choose a region where a lake can be create by drilling from cavitations into mountain to create as three natural wall to dam and the fourth wall will be from forced concrete and finally fourth wall with other wall will create as a storage lake as figure(7.6) show

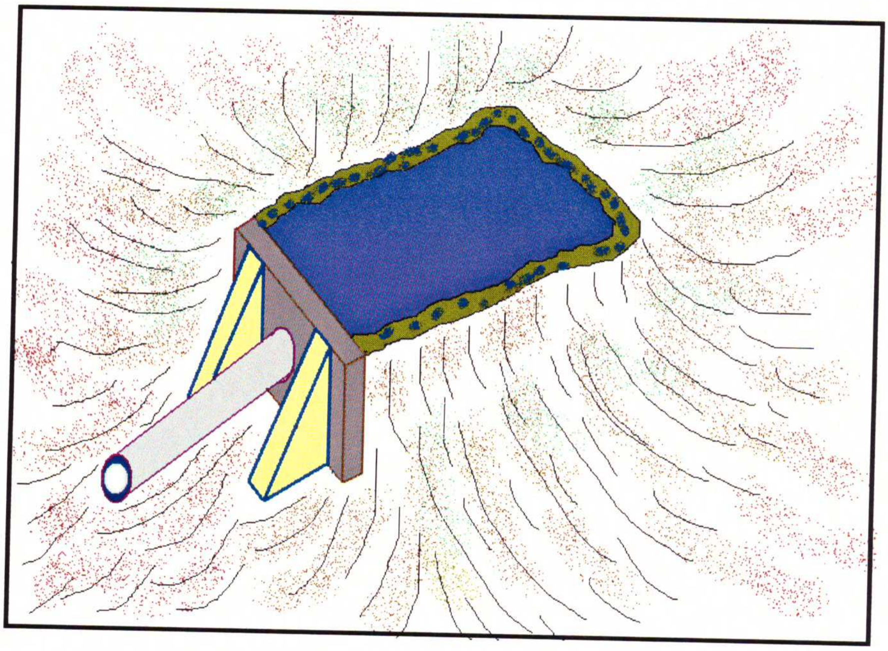


Figure (7.6) Region of Dam

- Then with respect to dam terminology the hydro static pressure will compute due to the following relation.

$P = \rho g h$

Where:

P : Hydrostatic pressure (Pascal)

ρ : Water density (kg/m^3)

h : Depth of water

This pressure will act as a distributing force at the dam wall surface and the maximum force will be at the deepest point of the wall due to pressure relation, the result of distributing force will act at the point below the center of dam wall area and this point called center of pressure so figure (7.7) show dam free body diagram.

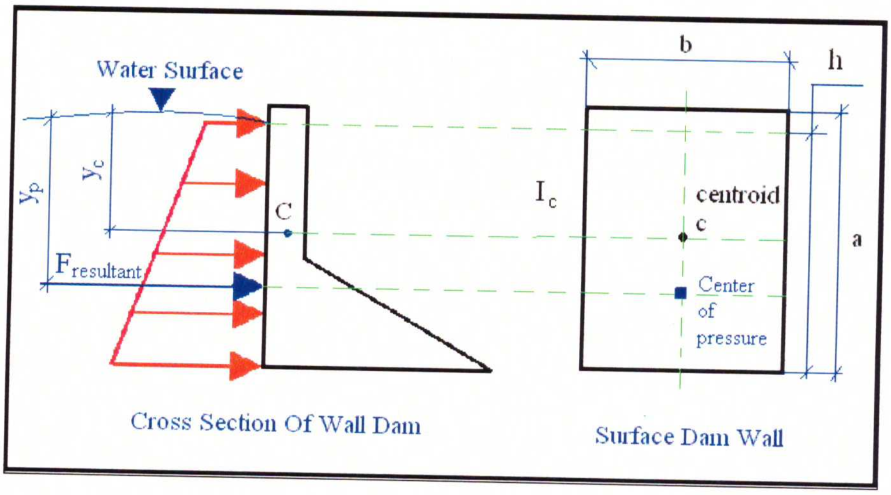


Figure (7.7): Free body diagram of dam wall

Then pressure force that act at the center of pressure will compute due to relation

$$F = P * A = \rho g h * (b * h)$$

Then the result of distributing force will act at the centre of pressure y_p that can be computing from relation

$$y_p = y_c + \frac{I_c}{y_c * A} \rightarrow (3)$$

Where:

y_p: Depth center of pressure (m)

y_c: Depth of center of dam wall area (m)

A: Area of wall surface (m^2)

I_c: First moment of area of dam wall (m^4)

And due to rectangular shape of dam wall then

$$y_c = a/2$$
$$A = b * a$$
$$I_c = \frac{b * a^3}{12}$$

So due to equation (3) y_p will be computed by:

- Due to y_p and amount of force distribution and maximum force so, the cross section shape will be selected
- Then the thickness of the dam can be calculated due to forced concrete .
- With related to other consideration and procedure mentioned above construction will be occur.

7.2.4 Dam capacity

- Dam will design to become interface chain between main pumps station and surge tank.
- Dam will receive water from main pumps station with amount of 60 m^3/s and discharge it to surge tank continuously.
- The capacity of dam must take in account that if pumped water is stopped due to maintenance into pumps station ,then surge tank must be continue into discharge to hydro power plant for time equal $= \frac{Dam\ capacity}{Flow\ rate} = \text{Re}quired\ (m^3/s)$.

- So , Dam will work for one day after pump station is stopped so,

Storage capacity =one day*flow rate

$$= (1day * 24hour * 60\min * 60\sec) * 60$$
$$= 259200 * 60$$
$$= 5184000m^3$$

Total dam capacity = run capacity + storage capacity

$$= 60 + 5184000$$
$$= 5184060m^3$$

- And this volume is large comparatively so, we can benefit from this storage water to generate energy to feed pumps station and the best method is to use law head turbine like Kaplan turbine and this turbine will placed at the dam so, the water will discharge from dam to Kaplan turbine then to tunnel 1 so, this is stay as suggestion.

7.3 Tunnel and open canal

When we look to the schematic descriptions of project into figure(7.1) we see the location of water conveyor which consist from:

- Tunnel 1
- Open canal
- Tunnel 2

And tunnels will drilling into maintain.

Tunnel 1 and 2 and open canal will passing amount of water equal 60 m^3/s and we will suppose that the water velocity inside the tunnel is equal to 1.5 m/s due to.

1. To avoid large pressure drop into tunnel since pressure drop into tunnel since pressure drop is a function of flow rate (Q) .
2. To reduce the radius of the tunnel since $Q = VA$.
3. To reduce the slope between the dam and surge tank since the slope will resist the pressure drop since the flow occurred under the gravity.

- The flow rate required to flow from tunnel $= 60\ m^3/s$ with recommended velocity $= 1.5\ m/s$ so,

$$Q = VA \rightarrow A = \frac{Q}{V} = \frac{60}{1.5} \rightarrow A = 40\ m^2$$

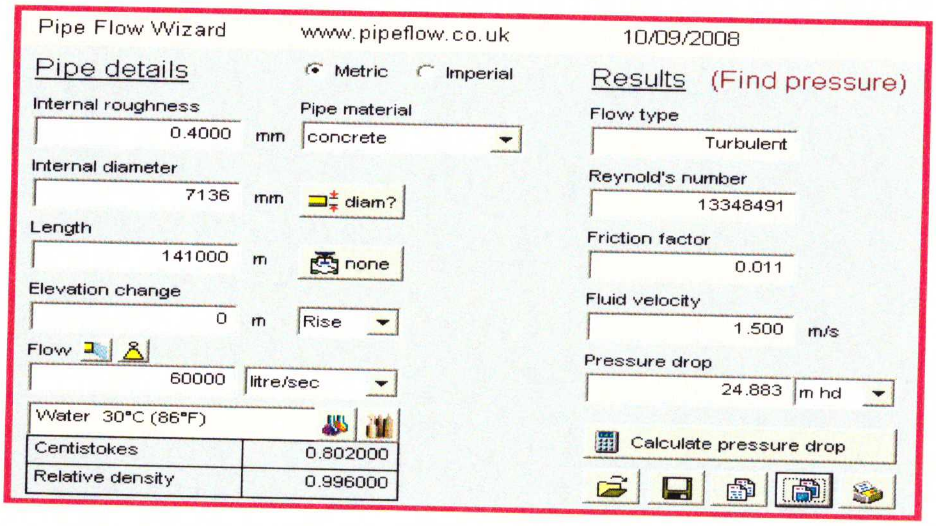
$$A = \frac{\pi D^2}{4} \rightarrow D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4*40}{\pi}} = 7.136\ m$$

So, the tunnel 1 and tunnel 2 diameter is 7.136 m

- To calculate the slope of tunnel and canal:
- ❖ We will consider 2 tunnel and open canal as a combined into one tunnel with a length equal to all length of them.

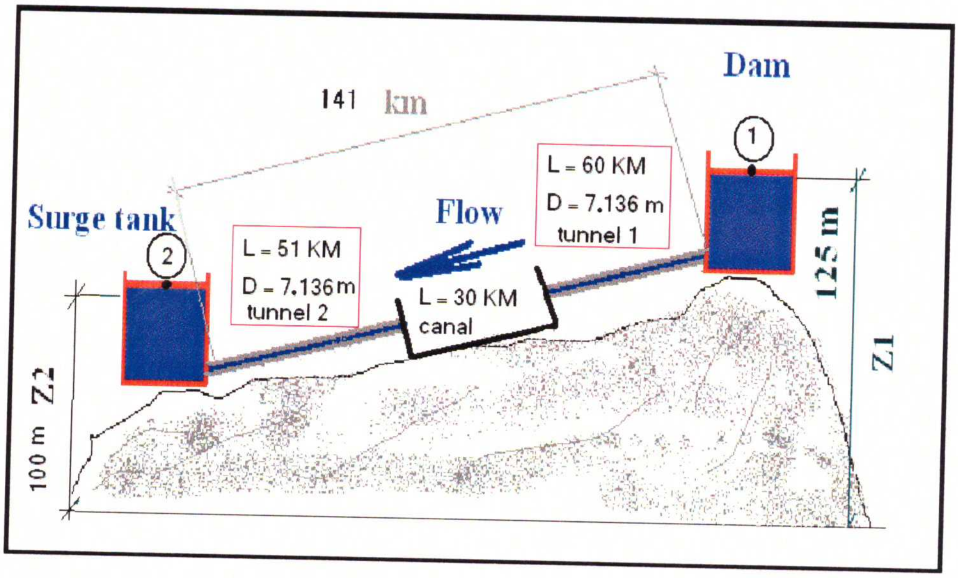
- With :
- ❖ Tunnel diameter= 7.136 m.
- ❖ Combined length of tunnel and open canal = 141 Km.
- ❖ Material that cover the internal surface of tunnel is concrete.

We can calculate the pressure drop into combined tunnel within pipe flow software shown into figure (7.8)



Figure(7.8):Pressure drop into combined tunnel calculation.

Then due to dimension shown into figure(7.9) we will apply Bernoulli equation between points 1 and 2 .



Figure(7.9):Combine tunnel dimension.

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+Z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+Z_2+h_f$$

$but:$

$$\frac{P_1}{\rho g}=\frac{P_2}{\rho g}=0.0$$

$$\frac{V_1^2}{2g}=\frac{V_2^2}{2g}=0.0$$

$so,$

$$Z_1=Z_2+h_f$$

$$h_f=Z_1-Z_2$$

But dam mountain elevation = 125 m which act Z_1 and h_f so,

$$Z_2=Z_1-h_f$$

$$Z_2=125-(24.88)$$

$$Z_2=100.22\ m$$

So, combined tunnel slope = 24.88 m difference between points 1 and 2.

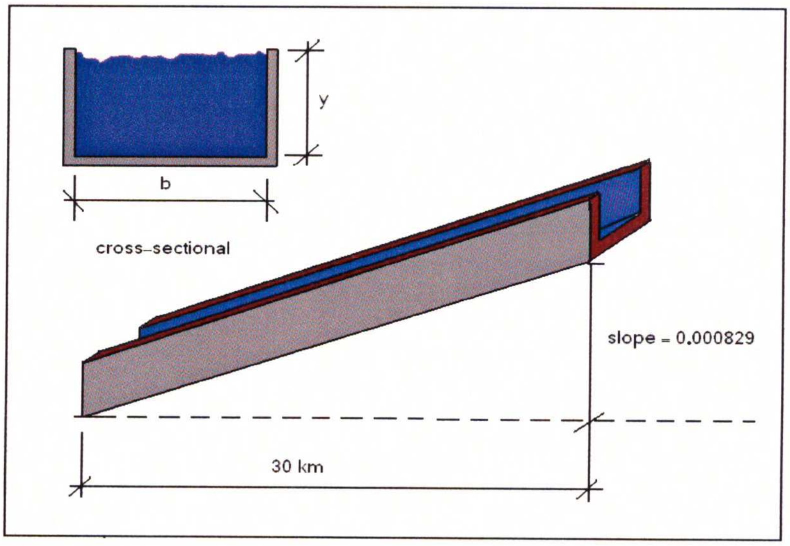
- Open canal dimension.

❖ To estimate the dimension of open canal we suppose that it have the incline difference as a combined tunnel=24.88 m and due to figure (7.9) the open canal length 30 Km.

❖
$$slope\ of\ canal=\frac{incline\ differance}{length\ of\ canal}$$

$$slope\ of\ canal=\frac{24.88}{30000}=0.000829\ {}^{m}/_{m}$$

With respect to figure(7.10)that show open canal we will compute canal dimension.



Figure(7.10):Open canal category.

- $b = 2y$ (best cross sectional of rectangular canal).

$$Q = A * \frac{1}{n} R^{2/3} S^{1/2} (Velocity\ of\ water\ flow\ into\ canal)$$

Where :

Q: Flow rate , $[m^3/\sec]$.

A: Cross sectional area , $[m^2]$

n: Manning roughness factor.

R: hydraulics radius, [m] .

S: Slope of canal.

V: Velocity of flow, $[m/\sec]$.

Q=60 $m^3/\sec$.

n = 0.014 (for concrete)

s=0.000829

$$R = \frac{Area}{wetted\ perimeter} = \frac{A}{P} = \frac{by}{b+2y} = \frac{b}{4} = \frac{2y}{4} = \frac{y}{2}$$

$$A = by = (2y)y = 2(y)^2$$

So ,

$$Q = V * \frac{1}{n} R^{2/3} S^{1/2}$$

$$60 = (2(y)^2)(\frac{1}{0.014})(\frac{y}{2})^{2/3}(0.000829)^{1/2}$$

$$y^{8/3} = \frac{60 * (2)^{2/3}}{2(0.02879)(71.428)}$$

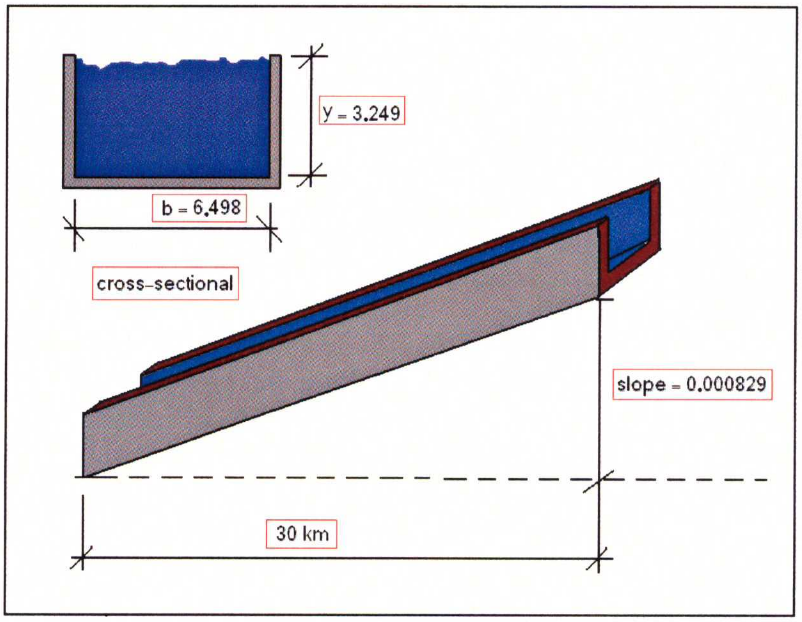
$$y = 3.249\ m$$

But:

b = 2y

→ b = 6.498

So, canal dimensions as sho2wn into figure (7.11).



Figure(7.11):Open canal dimensions.

Chapter Eight

Hydropower plant (Turbine)

- **What is a Turbine**
- **Types of Turbine**
- **Dead Red Sea project elevation distribution.**
- **Power ,desalination plant and surge tank location.**
- **Surge tank**
- **selecting of Pelton turbine .**
- **Penstock design.**
- **Turbine hydraulics calculation.**

Chapter Eight

Hydropower plant (Turbine)

8.1 What is a Turbine .

Hydraulic turbine is a machine rotary engine that converts the energy of a stream of water into mechanical energy, which is often used to generate electricity.

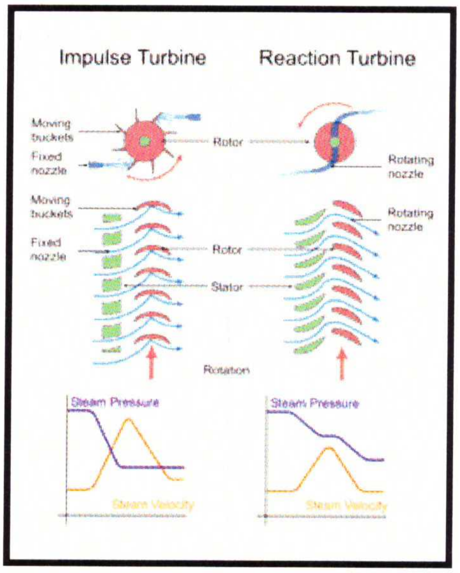
The basic element in a turbine is a wheel or rotor with paddles, propellers, blades, or buckets arranged on its circumference in such a fashion that the moving fluid exerts a tangential force that turns the wheel and imparts energy to it. This mechanical energy is then transferred through a drive shaft to operate a machine ، compressor, electric generator, or propeller. Turbines are classified as water turbines, steam turbines, or gas turbines. Today turbine-powered generators produce most of the world's electrical energy .[9]

8.2 Types of Turbines .

The potential energy in the water is converted into mechanical energy in the turbine, by one of two fundamental and basically different mechanisms:

1. The water pressure can apply a force on the face of the runner blades, which decreases as it proceeds through the turbine. Turbines that operate in this way are called reaction turbines.

2. In the second case, the water pressure is converted into kinetic energy before entering the runner. The kinetic energy is in the form of a high-speed jet that strikes the buckets, mounted on the periphery of the runner. Turbines that operate in this way are called impulse turbines ,so figure(8.1)show the two type. **[10]**



Figure(8.1):Two turbine mechanisms

8.2.1 Impulse Turbines

Impulse turbines have three major types which is describe below.

8.2.1.1 Pelton turbines

Pelton turbines are impulse turbines where one or more jets impinge on a wheel as show in figure (8.2) which carrying on its periphery a large number of buckets. Each jet issues through a nozzle with a needle (or spear) valve to control the flow. They are only used for relatively high heads.

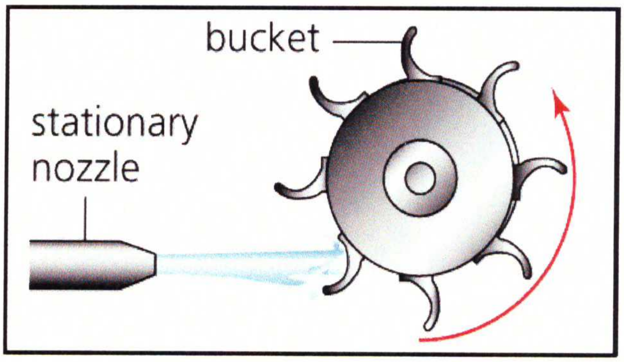


Figure :(8.2) Pelton Turbine

8.2.1.2 Turgo turbines

The Turgo turbine can operate under a head in the range of 30-300 meters. But its buckets are shaped differently and the jet of water strikes the plane of its runner at an angle of 20°. Water enters the runner through one side of the runner disk and emerges from the other as shown in the figure (8.3).

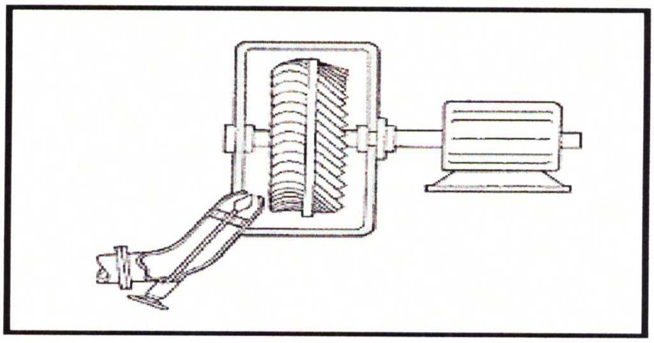


Figure (8.3): Turgo Turbine

8.2.1.3 Cross-flow turbines

A cross-flow turbine is drum-shaped and uses an elongated, rectangular-section nozzle directed against curved vanes on a cylindrically shaped runner. The cross-flow turbine allows the water to flow through the blades twice. The first pass is when the water flows from the outside of the blades to the inside; the second pass is from the inside back out. A guide vane at the entrance to the turbine directs the flow to a limited portion of the runner as shown in the figure (8.4).

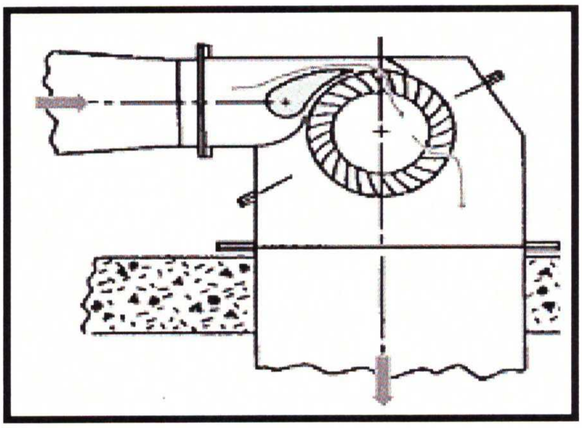


Figure (8.4): Cross Flow Turbine

8.2.2 Reaction turbines

Reaction turbines have two major type which is describe below.

8.2.2.1 Francis turbines

Francis turbines are radial flow reaction turbines as figure (8.5) show, with fixed runner blades and adjustable guide vanes, used for medium heads. In the high speed Francis the admission is always radial but the outlet is axial.

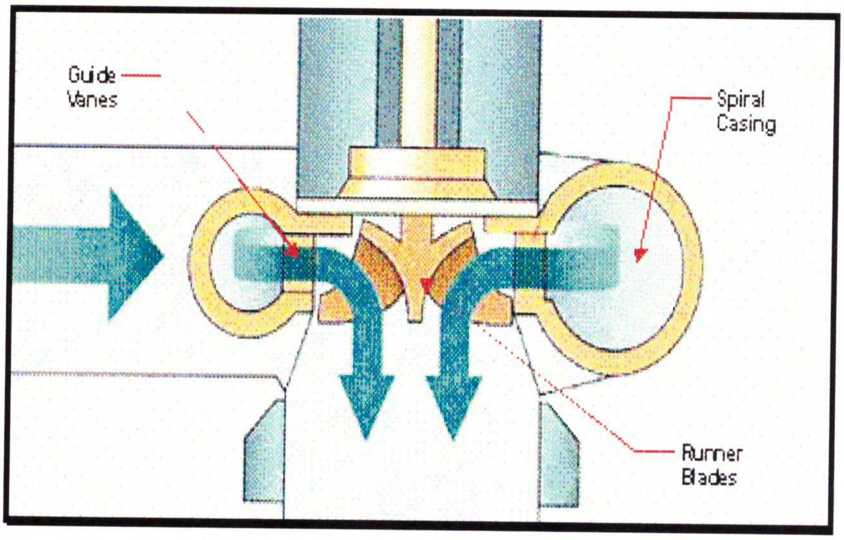


Figure (8.5): Frances Turbine

8.2.2.2 Kaplan and propeller turbines

Kaplan and propeller turbines are axial-flow reaction turbines, generally used for low heads; if both blades and guide-vanes are adjustable it is described as "double-regulated". If the guide-vanes are fixed it is "single-regulated" as show in figure (8.6).

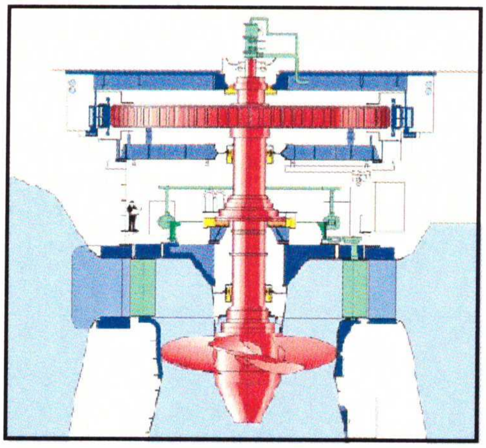
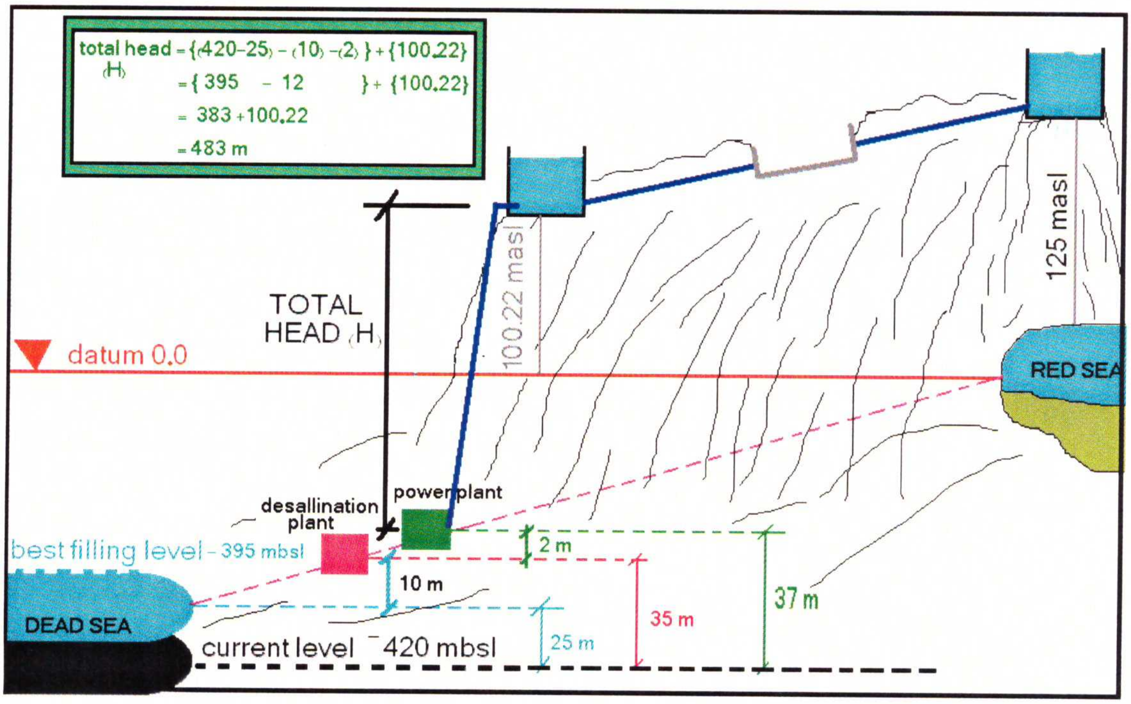


Figure (8.6): Kaplan Turbine

8.3 Dead Red Sea project elevation distribution.

If we look to figure (8.7) we show the elevation difference between RSDS project content.



Figure(8.7):RSDS project elevation.

And these elevations computed as:

- Dam elevation(125):It is assumed elevation due to Jordanians strategy.
- Surge tank (100.22):due to pressure drop into combined tunnel .
- Dead Sea :
  - ❖ current level (2008)is -420 mbsl.
  - ❖ The best new level after refilling is -395 mbsl.

So, we need to refill 25 m

- Desalination plant:
  - ❖ we required 10 m as assumed elevation to make good discharge for rejected brine .
  - ❖ so , new level above dead sea level refilling level is:

    -395 + 10 = -385 mbsl.
- Power plant:
  - ❖ Since power plant location near desalination plant so, we assume 2 m as slope for make water discharge from power plant to desalination plant.
  - ❖ Power plant level is:

    -385+2 = 383 mbsl

- Total elevation:

❖ Power plant elevation is -383 mbsl. To reach datum 0.0 (red sea level).

❖ We have 100.22 m above datum (surge tank elevation).

The total elevation between surge tank and power plant is

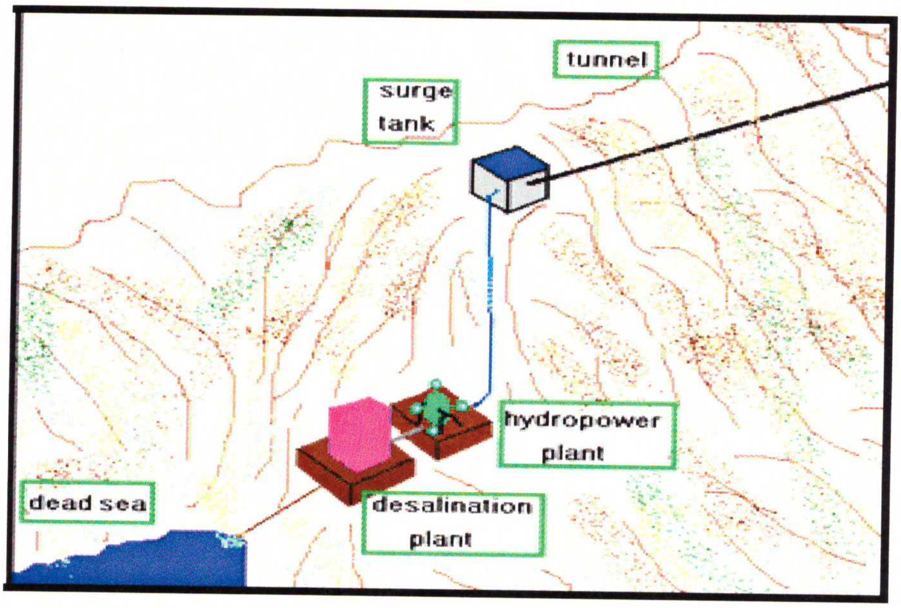
= 383 + 100.22

= 483 m

The distance 483 is the head that will run the turbine.

8.4 Power ,desalination plant and surge tank location.

Figure(8.8) show the location of power plant (turbine) which supplied water from surge tank to generate the energy from flowing water and the discharge water will flow within incline canal to desalination plant which will desalinate required amount of fresh water.



Figure(8.8): Power and desalination plant location.

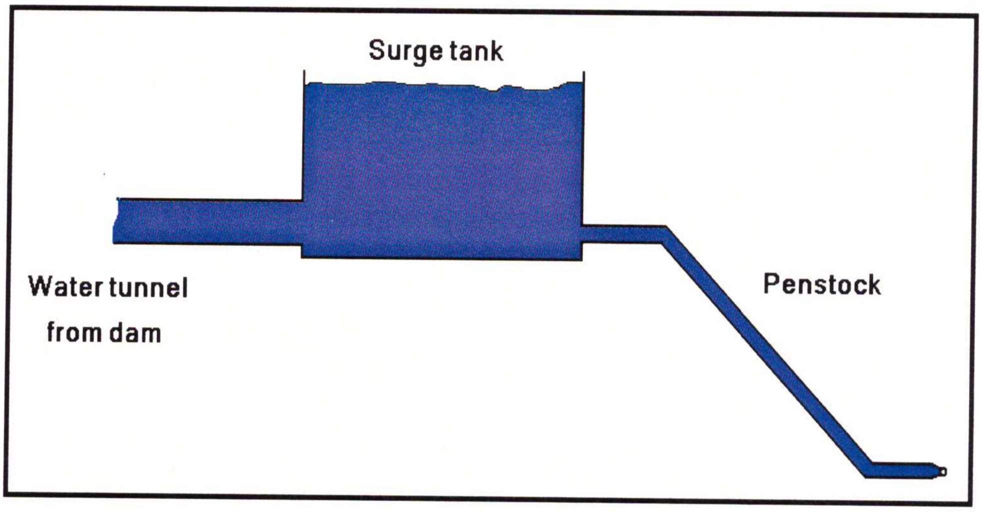
8.5 Surge tank

- Figure(8.8) show the position of surge tank at the top of mountain that have elevation 100.22 masl.
- The major purpose of surge tank is :

❖ Act as receiver tank for a water that come from dam through water conveyor system.

- ❖ At every time surge tank offer constant head for power plant which prevent mechanical stresses at a turbine mechanical parts when head or flow rate varying.
- ❖ Act as a damper for water fluctuation if water conveyor system flowing varying.

So, the figure (8.9) show the drawing of surge tank to achieve constant head.



Figure(8.9):Surge tank shape.

- To estimate surge tank capacity :

- ❖ The running flow rate required for power plant at every time is 60 m^3/s
- ❖ Suppose that the water that cover from dam is cutting for any reason for a small period so , turbine must be continue in working from surge tank only so suppose we need from surge tank to stay filling for 10 minute so,

$$\text{Emergency Capacity} = 10\ \text{min} * 60\ \frac{\text{s}}{\text{min}} * 60\ \frac{\text{m}^3}{\text{s}}$$

$$\text{Emergency Capacity} = 36000\ m^3$$

- So ,the total capacity of surge tank is:

  $\text{Total capacity} = \text{running capacity} + \text{emergency capacity}$

  $\text{Total capacity} = 36000 + 60$

  $\text{Total capacity} = 36060 \;\; m^3$

- **Surge tank terminology is:**

$$V \quad = A * L$$
$$36060 = A * L$$

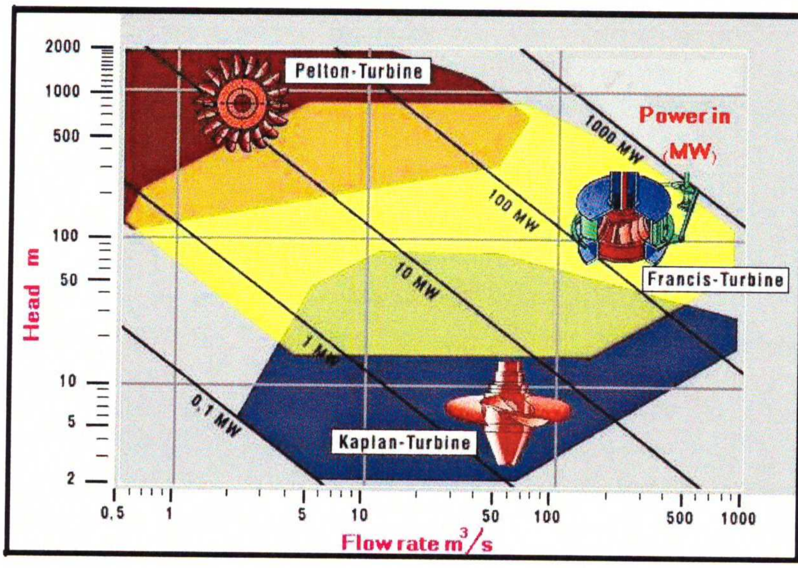
But for easy construction we assumed L = 5 m .

$$A = \frac{V}{L} = \frac{36060}{5} = 7212 \, m^2$$

It's the area of surge tank base.

8.6 selecting of Pelton turbine .

- The aim of Pelton turbine is to extract the water energy and convert it to mechanical energy
- Due to figure (8.7) the total head elevation between surge tank and power plant (turbine) and this head is 483 m and this static head act the core of RSDS project to be useful for power generation.
- Each turbine work into hydraulic region depend on head and flow rate available as show into turbine application chart as figure(8.10).



Turbine types	
(H: head in m)	
Kaplan	2 < H < 40
Francis	10 < H < 350
Pelton	50 < H < 1300
Turgo	50 < H < 250

Figure(8.10):Turbine application chart.

- We will benefit from turbine dimension that built into Big creek-2A plant of southern California Edison Co. 1948 and this turbine wheel have the characteristics as table (8.1)

Table(8.1):Previous turbine characteristics.

Plant name : Big creek -2A plant Company name: Edison Co.
Static head 737 m , net head 670 m
Angular speed (ω)=300 rpm
Frequency generated f = 60 cycle/s
Wheel pitch diameter = 4.11 m
Power generated = 41750 KW
Flow rate = 6 m^3/s
Jet impulse diameter = 216 mm

- Now , due to :

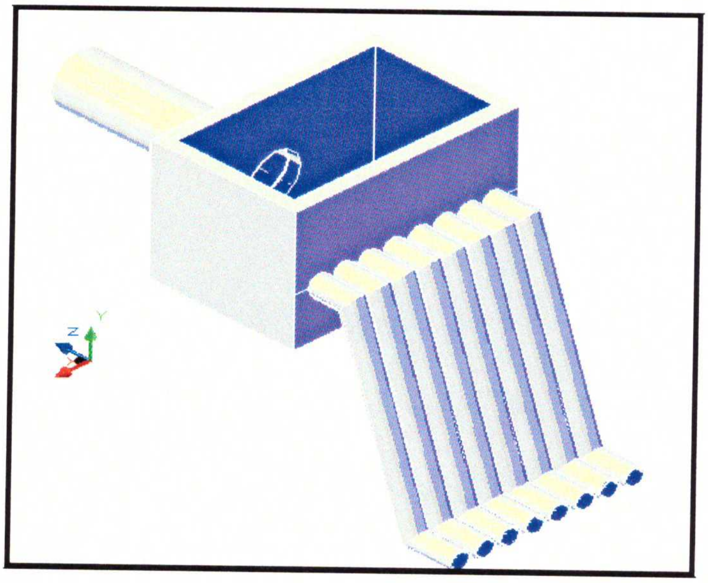
  - ❖ Our available static head = 483 m.
  - ❖ Pelton region is $50<H<1300$
  - ❖ Table (8.1) and figure (8.10)

Our static head layout at the Pelton turbine region so it is selected.

8.7 Penstock design.

- Since we have large flow rate 60^3 m/s come from dam so, we canot run one turbine at this flow rate so, with depend on table (8.1) we find that large creel turbine work at 6 m^3/s so, we can use this flow rate by using 10 turbine.
- We go to use 10 turbine ,each one have flow rate 6 m^3/s .
- The penstock is a hollow pipe that will carry the flow rate to turbine from surge tank so we have 10 penstock.

And figure(8.11) show these penstock with surge tank.



Figure(8.11):Turbines penstocks.

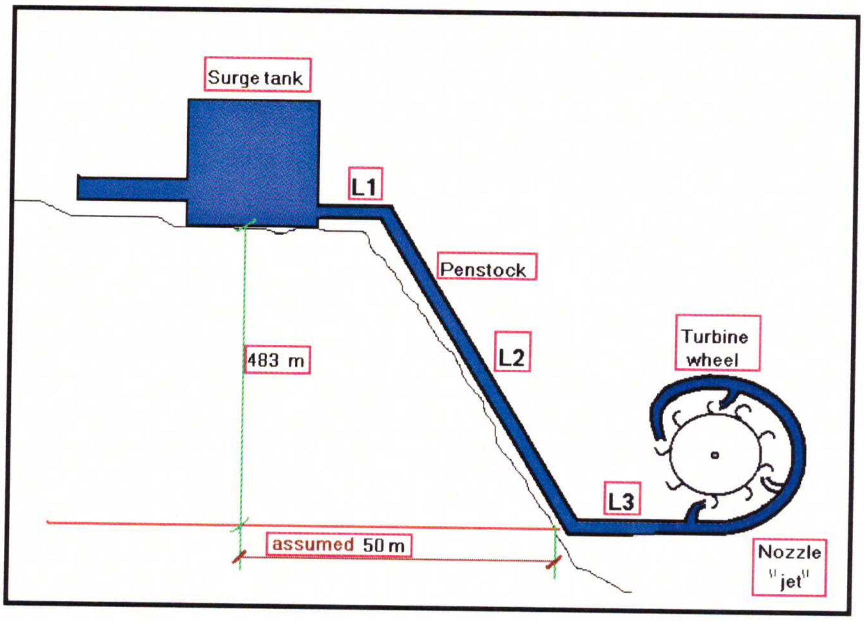
- Diameter of penstock:

❖ Penstock will pass 6 m³/s with a recommended initially velocity =3m/s So,

$$Q = VA \rightarrow A = \frac{Q}{V} = \frac{6}{3} = 2 \ \ m^2$$

$$A = \frac{\pi D^2}{4} \rightarrow D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4(2)}{\pi}} = 1.595 \ \ m$$

- Penstock length computed due to figure(8.12).



Figure(8.12):Penstock length.

$$L_2 = \sqrt{(483)^2 + (50)^2} \rightarrow L_2 = 485.5 \ \ m$$
$$L_1 \approx 5 \ \ m$$
$$L_3 \approx 5 \ \ m$$

Total length = 485 m.

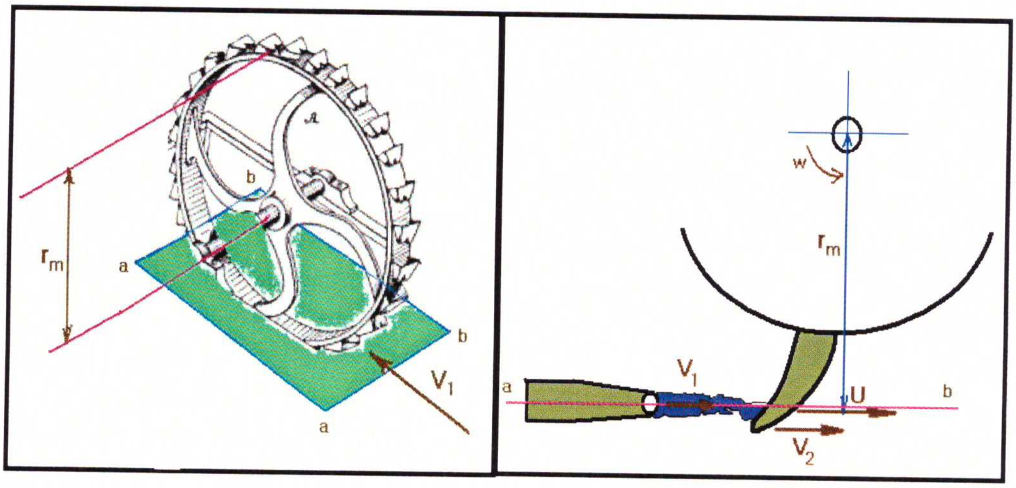
8.8 Turbine hydraulics calculation.

We go to make the hydraulics calculation due to turbine like:

- V_{jet}, D_{jet}
- Wheel diameter
- Turbine power.
- Bucket design.
- Shaft diameter

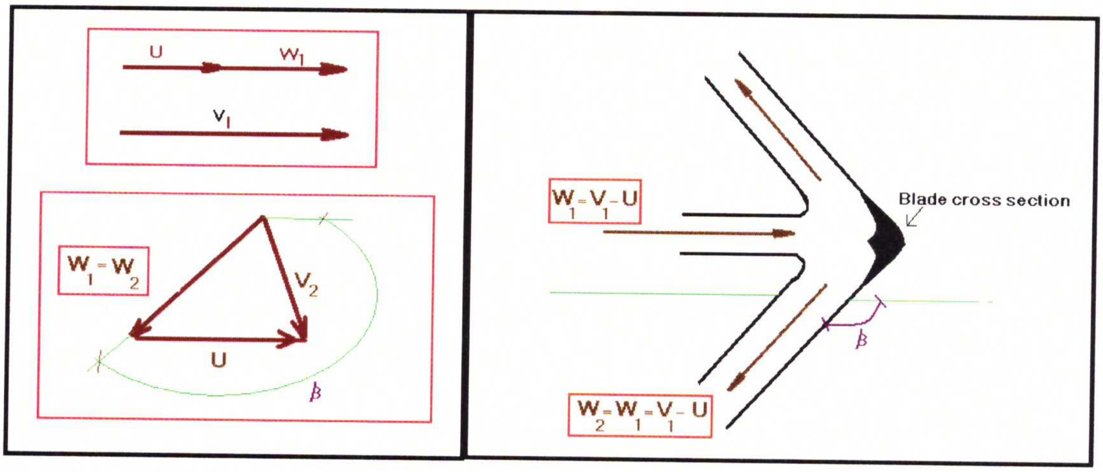
8.8.1 impulse turbine(Pelton) mathematical equation.

- We go to derive equation to describe the performance of Pelton turbine.
- Due to figure(8.13)that show details of Pelton wheel turbine bucket.



Figure(8.13): Details of pelton wheel bucket.

We will take a section (abab) into bucket flow ,and write relative velocities as shown into figure(8.14)



Figure(4.14): Flow on bucket and relative velocities.

- Due to figure(8.14),we can write

$$V_{\theta 1} = V_1 = W_1 + U$$
$$V_{\theta 2} = W_2 * \cos\beta + U$$

- By assumption that $W_1 = W_2$ so,

$$V_{\theta 2} - V_{\theta 1} = (U - V_1)(1 - \cos\beta)$$

- This change into tangential component of velocity combined with the torque and power equations into:

$$T_{shaft} = F * r_m$$

$$F = \dot{m} * \Delta V$$
$$T_{shaft} = F * r_m (U - V_1)(1 - \cos\beta) \text{-------------------------} 8.1$$

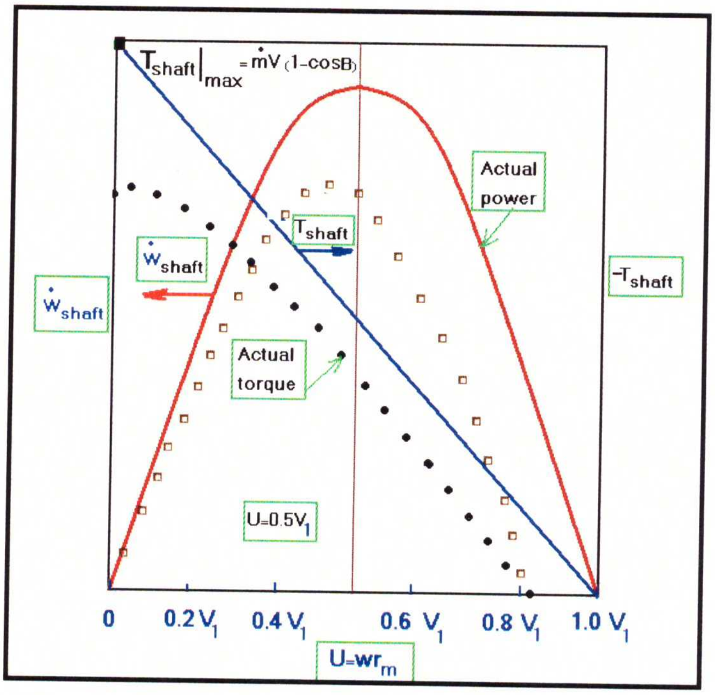
With

$$\dot{m} = \rho * Q \ \ (flowrate)$$

$$U = \omega * R_m$$

$$\dot{W}_{shaft} = T_{shaft}\omega = \dot{m}U(U - V_1)(1 - \cos\beta) \text{-------------------- 8.2}$$

Equation (8.1) and (8.2) is plotted into figure (8.15) as theoretical and experimental torque and power for Pelton wheel turbine as function of bucket speed



Figure(8.15):Theoretical and experimental power and torque

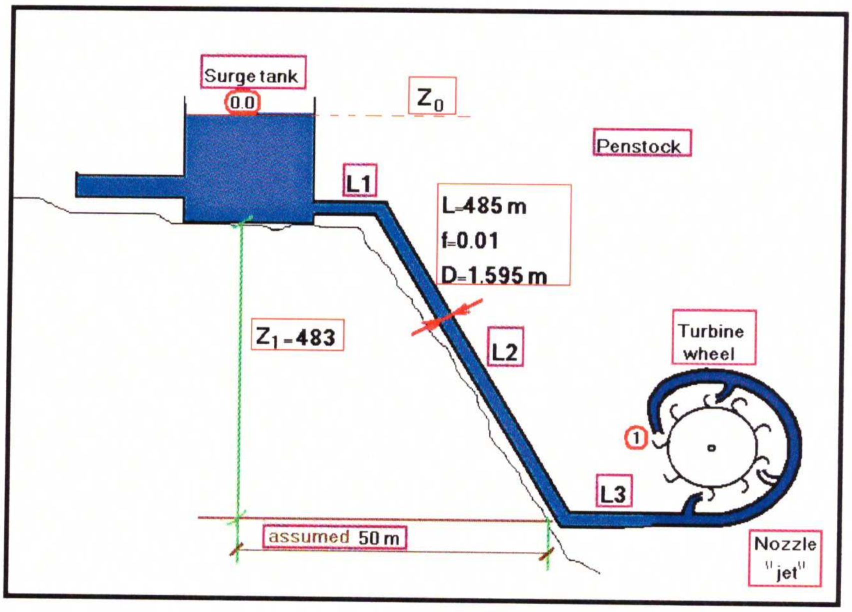
Due to figure(8.15),we see that maximum power output occur at :

$$U_{max.power} = \frac{V_1}{2}$$

- From optimum result they found that maximum power occure at bucket angel $\beta = 165^0$.

8.2.2 Pelton turbine calculation procedure

- We go to draw details of turbine as in figure(8.16).



Figure(8.16):Details of Pelton turbine

- (f) computed due to:
  - ❖ Penstock material is steel with internal roughness e= 0.046 mm ,D=1.595 m.
  - ❖ Due to moody chart friction factor is 0.010 .

- With respect to figure(8.16)we can write energy equation between two points (0) and (1) we see.

$$\frac{P_0}{\rho g}+\frac{V_0^{\,2}}{2g}+Z_0=\frac{P_1}{\rho g}+\frac{V_1^{\,2}}{2g}+Z_1+h_f .$$

With:

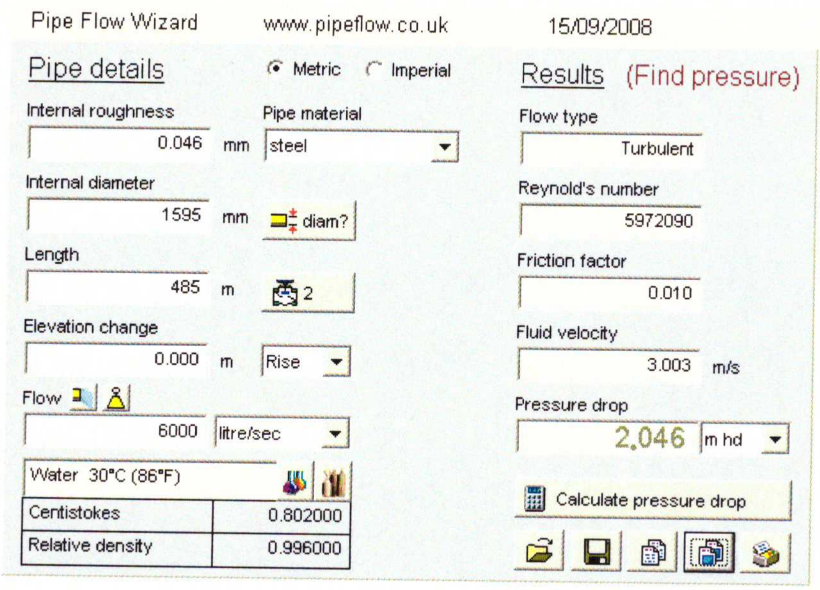
$$V_0 = P_0 = 0.0$$

$* \quad Z_1 = P_1 = 0.0.$

$so,$

$$Z_0 = \frac{V_1}{2g} + h_{l8.3} \text{ ---------------------------------- } (8.3)$$

- for penstock installation we have two elbow (45°) so, dynamic head losses into penstock and minor head losses will compute into pipe flow wizard software and the result shown into figure(8.17).



Figure(8.17):Head losses into penstock and elbows .

- We have elevation between surge tank and nozzle= $483 = Z_0$. so, the total working head is equal

$$\text{working head} = 483 - 2.046$$
$$\text{working head} = Z_0 - h_l$$
$$\text{working head} = 480.954 \ m$$

- With refer to equation (8.3) we see:

$$V_1 = \sqrt{2g(Z_0 - h_l)}$$
$$V_1 = V_{jet} = \sqrt{2*(9.81)(480.954)} = 97.14 \ \ m/s$$

❖ But the head losses due to nozzle compute as:

$$V_{jet}(actual) = C_v(V_{jet} ideal)$$

C_v take to be 0.97 (from experimental).

So,

$$V_{jet}(actual) = 0.97(97.14)$$
$$V_{jet}(actual) = 94.228 m/s.$$

$$Q_{penstock} = 6 \ m^3/s$$
$$Q_{jet} = \frac{Q_{penstock}}{4} = 1.5 \ m^3/s$$
$$4(V_j A_j) = V_{penstock} A_{penstock}$$
$$A_j = \frac{Q_{jet}}{V_j} = \frac{1.5}{97.14} = 0.0154 \ \ m^2$$
$$D_j = \sqrt{\frac{4A_j}{\pi}} = \sqrt{\frac{4(0.0154)}{\pi}} \rightarrow D_j = 0.14 \ \ m = 14 \ \ cm$$

- For a purpose to generate energy within 60 Hz frequency we assumed that angular speed of turbine shaft=300 rpm
- And this value show into table (8.1) in a previous design, so our generator will have a number of poles as:

$$\omega = \frac{120 * f}{P}$$

Where:

ω : angular speed(rpm).

f :frequency.

P :Poles number.

$$\omega = \frac{120 * f}{P}$$

$$\omega = \frac{120 * 60}{300} = 24 \quad poles$$

So, we will assume our turbine angular speed is 300 rpm

- Maximum power generate occurred at :

$$U_{\max} = \frac{V_j}{2}$$

$$U_{\max} = \frac{94.228}{2} = 47.114 \quad m/s$$

$$U = \frac{\pi D \omega}{60}$$

Diameter of the wheel is equal to :

$$D = \frac{60U}{\pi\omega} = \frac{60(47.114)}{\pi(300)} = 2.999 \quad m.$$

$$R = \frac{D}{2} = 1.499 \quad m.$$

- Power generated from turbine for one jet can computed from equation (8.2) as:

$$W_{shaft} = \dot{m}U(U - V_1) * (1 - \cos\beta)$$
$$W_{shaft} = \rho * V * U * (U - V_1) * (1 - \cos\beta)$$
$$W_{shaft} = \rho * Q * U * (U - V_1) * (1 - \cos\beta)$$

$$W_{shaft} = 1000 * 1.5 * 47.114 * (47.114 - 94.228) * (1 - \cos 165)$$
$$W_{shaft} = 6168538.6 \ \text{W.}$$
$$W_{shaft} = 6.1685386 \ \text{MW.}$$

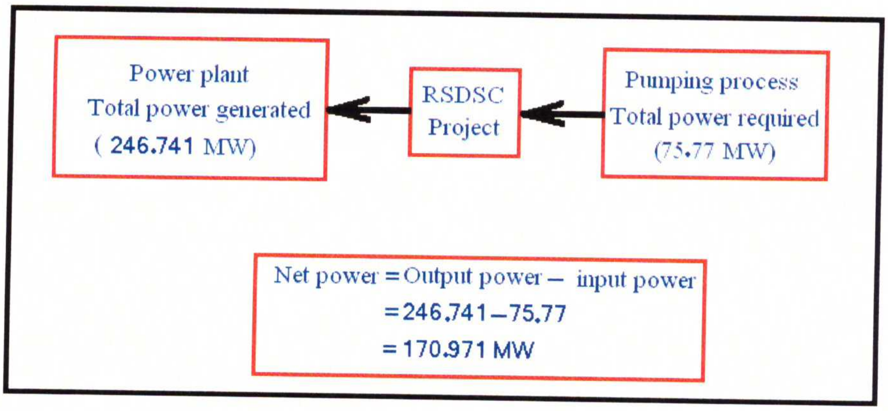
So, the total power of the turbine is calculated by multiply the power by four jet as the follow:

$$W_{turbine} = W_{shaft} * 4$$
$$W_{turbine} = 24.674 \text{ MW.}$$

- Each turbine generate power equal =24.674 MW and we have (10) turbine so, the total power generated from power plant are equal

  $$Total\ power\ generated = 10 * 24.674$$
  $$Total\ power\ generated = 246.741 \ MW$$

- Figure(8.18) show the input and the output power for our project (RSDSC) and its net generated power that can be extracted from water energy .



Figure(8.18):RSDSC project net power.

- When we apply energy equation at the head and flow rate available as:

$$Flow\ rate = 60\ \ m^3/s$$
$$Head = 483\ \ m$$

$$Power = \rho * g * Q * H$$
$$Power = 1000 * 9.81 * 60 * 483$$
$$Power = 284.293\ MW$$

But this power generated without losses occure into penstock and minor losses into elbow and nozzle and mechanical friction.

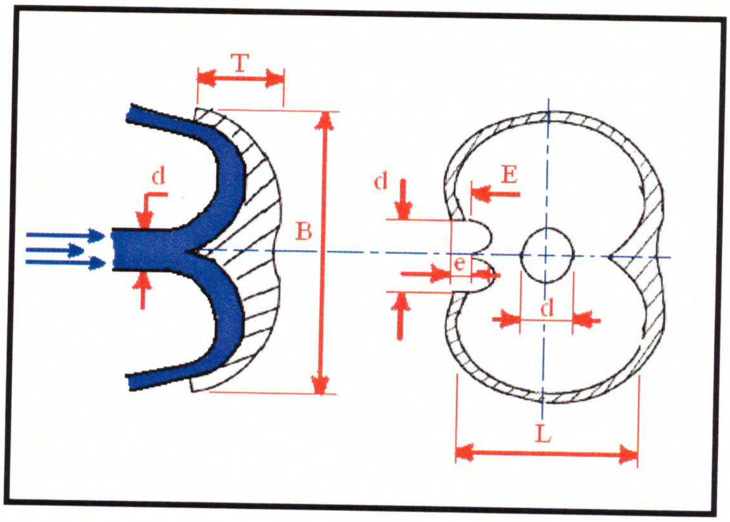
So, not all power available in our project that potential head must be convert into kinetic energy since part of them will convert to losses into pipe.

8.3.3 Turbine parts design.

In this section of this chapter we go to estimate and calculate the parts of a pelton turbine.

8.3.3.1 Bucket design

Here we go to make approximation to bucket shape from standard parameters for a turbine bucket and then make distribution for these buckets at the turbine wheel circumferences, We go to approximate the shape of turbines bucket due to standard dimension that recommended shown into figure (8.19).



Figure(8.19): Turbine bucket standard.

- The dimensions shown into figure(8.19) is combined together as follow:

$$B/d = 3$$
$$e/d = 0.35$$
$$T/d = (0.8 - 0.95)$$
$$L/d = (2.5 - 2.8)$$
$$E/d = 0.85$$

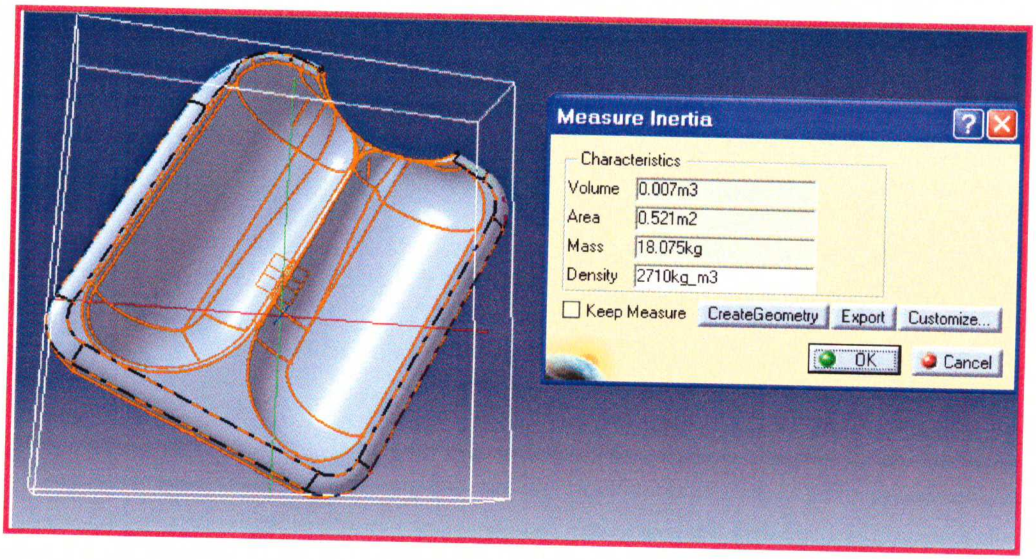
- d: represent the diameter of striking stream line of jet water and for approximately it's the diameter of jet so,

$$d = diameter\ of\ \ jet$$
$$d = 14\ \ cm$$

- Now by solving the previous relation ship we extract all parameter:

$$B/d = 3 \quad \rightarrow B = 42\ \ cm$$
$$e/d = 0.35 \rightarrow e = 4.9\ \ cm$$
$$T/d = 0.9 \quad \rightarrow T = 12.6\ \ cm$$
$$L/d = 2.6 \quad \rightarrow L = 36.4\ \ cm$$
$$E/d = 0.85 \rightarrow E = 11.9\ \ cm$$

- Then we draw this dimension into catia software program to estimate the weight of the bucket as figure (8.20).



Figure(8.20): Bucket catia drawing.

- From catia we estimate the weight of this bucket to be:

W=18.075 Kg

8.3.3.2 Design the arms cross section

- Each bucket must attach to turbine wheel within two arm so, we will go to give cross sectional area of each arm after calculate the forces on each of them.
- The forces that act on the bucket can be estimated as follows:

☒ **Centrifugal force**

Wheel will rotate with 300 rpm which will convert cup weight to centrifugal force that will act as a tensile stress on the arm cross sectional area as.

❖ **Centrifugal force:**

$$F_c = \frac{mV^2}{R_m}$$

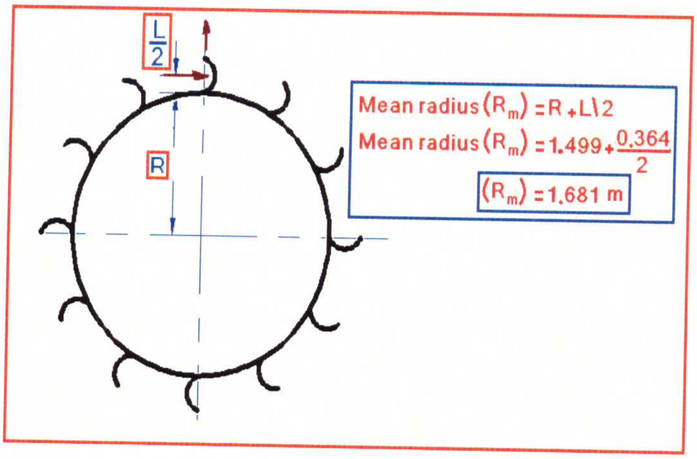
Where:

m : mass of the bucket that estimated from catia.

V : Tangential velocity.

R_m :Mean radius.

- Mean radius can be calculated as show in figure(8.21)



Figure(2.1):Mean radius of the wheel

$$\text{Mean radius} = \text{Wheel radius} + \frac{\text{cub length}}{2}$$

$$\text{Mean radius} = 1.499 + \frac{0.364}{2}$$

Mean radius =1.681 m.

- Tangential velocity is obtain by using.

$$\omega = \frac{2\pi\ n}{60}$$

$$\omega = \frac{2\pi\ (300)}{60}$$

$$\omega = 31.4\ rad/s.$$

$$V = \omega * R_m$$

$$V = 31.4 * 1.681$$

$$V = 52.810\ m/s$$

$$F_c = \frac{mV^2}{R_m}$$

$$F_c = \frac{18.075 * (52.810)^2}{1.681}$$

$$F_c = 29.987\ KN$$

❖ Jet force

Its formed by the water that impact the cub ,and its cause the rotation of the wheel turbine so , we will calculated by using the following equation.

$$F_j = 2mV$$

$$F_j = 2(\rho * Q)V$$

$$F_j = 2(1000*1.5)97.14$$

$$F_j = 291.420\ N$$

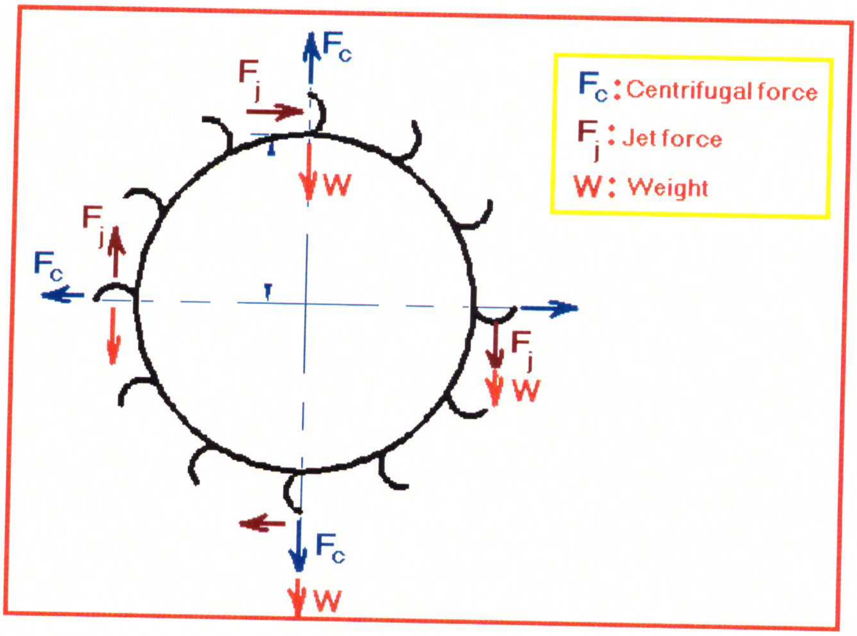
❖ Weight

$$W = m g$$

$$W = 18.075*9.81$$

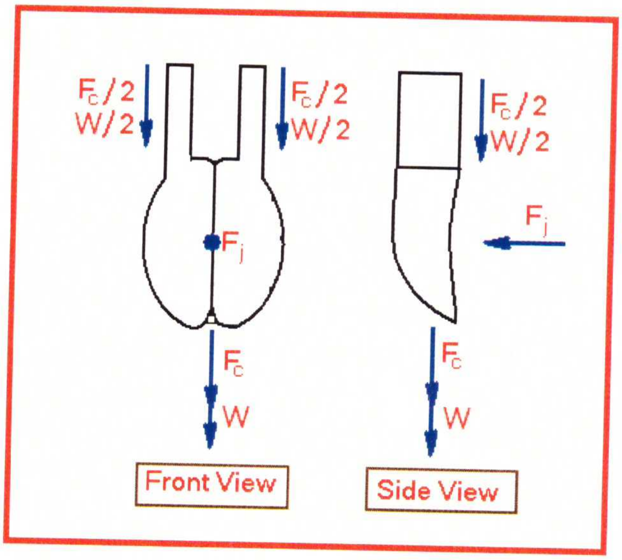
$$W = 177.315\ N$$

The centrifugal force , jet forces and weight of the cub act to cut the arm , so we will take all of these forces to determine the cross sectional area of arm so, figure(8.22) show these forces.



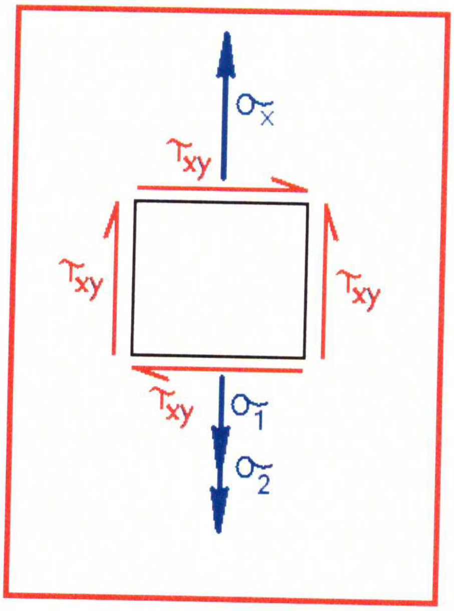
Figure(8.22):Forces on the cub.

To design the dimension of the arm , we will assume the forces that exerted on the cub so, the dimension of the arm depend on these forces and its can be estimated as figure(8.23) show.



Figure(8.23):Forces on the cub

- As shown in figure (8.23),it show the forces on the lower cub and our analyses will built with respect to it , because it more danger to fail .
- By using principle stresses we can estimate the stresses and shear stress that act on the cross sectional area of the arm as shown in the figure(8.24).



Figure(8.24):Stresses and shear forces on the arm.

As shown in figure(8.24) ,the stresses and shear stress can be determine as the following:

$$\sigma_x = \sigma_1 + \sigma_2$$

$$\tau_{xy} = \frac{F}{A_T}$$

$$\sigma_1 = \frac{W + F_c}{A_T}$$

$$\sigma_1 = \frac{177.315 + 29.987 * 10^3}{A_T}$$

$$\sigma_2 = \frac{Mc}{I}$$

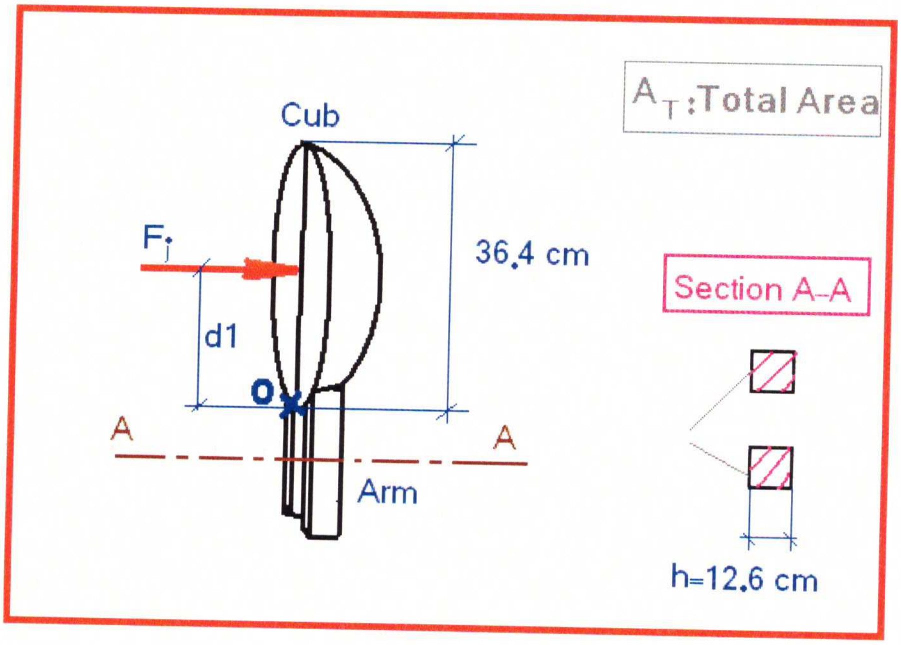
Where:

M : Moment about point O of the arm as shown in the figure(8.25)

c : Distance between jet force and point O.

I : Second moment of area

The water exert forces in the cub and cause a moment on the arm and these moment can be estimated as figure(8.25)show.



Figure(8.25):Free body diagram of the cub

Moment can be determine by multiply the jet forces by the distance d_1 as the follow.

$$M = F_j * d_1$$

$$M = 291.420 * 10^3 * (0.63/2)$$

$$M = 53038.44 \quad N.m$$

$$M = 53.038 \quad KN.m$$

$$c = d_1 / 2$$
$$c = 0.364 / 2$$
$$c = 0.15$$

$$I = \frac{1}{12} b * (h^3)$$
$$I = \frac{1}{12} b * h * (h^2)$$
$$I = \frac{1}{12} (A_T) * (h^2)$$
$$I = \frac{1}{12} (A_T) * (0.126^2)$$
$$I = 1.323 * 10^{-3} * A_T \quad m^4$$

$$\sigma_2 = \frac{Mc}{I}$$
$$\sigma_2 = \frac{53038.44 * 0.15}{1.323 * 10^{-3} * A_T}$$
$$\sigma_2 = \frac{2525640}{A_T}$$

$$\sigma_x = \sigma_1 + \sigma_2$$
$$\sigma_x = \frac{177.315 + 29.987 * 10^3}{A_T} + \frac{2525640}{A_T}$$
$$\sigma_x = \frac{2555804.315}{A_T}$$
$$\tau_{xy} = \frac{F_j}{A_T} = \frac{291.420 * 10^3}{A_T}$$

And these stresses $\sigma x, \tau_{xy}$ can be combined by applying von misses equation for plane stresses as.

$$\sigma' = \sqrt{(\sigma_x)^2 + 3(\tau_{xy})^2}$$

$$\sigma' = \sqrt{(\frac{2555804.315}{A_T})^2 + 3(\frac{291.420*10^3}{A_T})^2}$$

$$\sigma' = \sqrt{\frac{6.78687*10^{12}}{A_T}}$$

So the von Mises equation can be express as a design equation by

$$\sigma' = \frac{S_y}{n}$$

Where:

S_y :yield strength of material.

n : Factor of safety.

A_T : Total area.

In our design of cub material we apply an aluminum metal for cub and arm so by using yield strength of the aluminum and factor of safety 3 we can obtain the dimension of the cub as:

S_y = 169 Mpa (from appendix A).

n=3 .

by substitution in design equation:

$$\sigma' = \frac{S_y}{n}$$

$$\sigma' = \frac{169*10^6}{3}$$

$$\sqrt{\frac{6.78687*10^{12}}{A_T}} = \frac{169*10^6}{3}$$

$$\sqrt{\frac{6.78687*10^{12}}{A_T}} = \frac{169*10^6}{3}$$

$$A_T = \sqrt{\frac{2.036*10^{13}}{2.8561*10^{16}}}$$

$$A_T = \sqrt{7.128*10^{-4}}$$

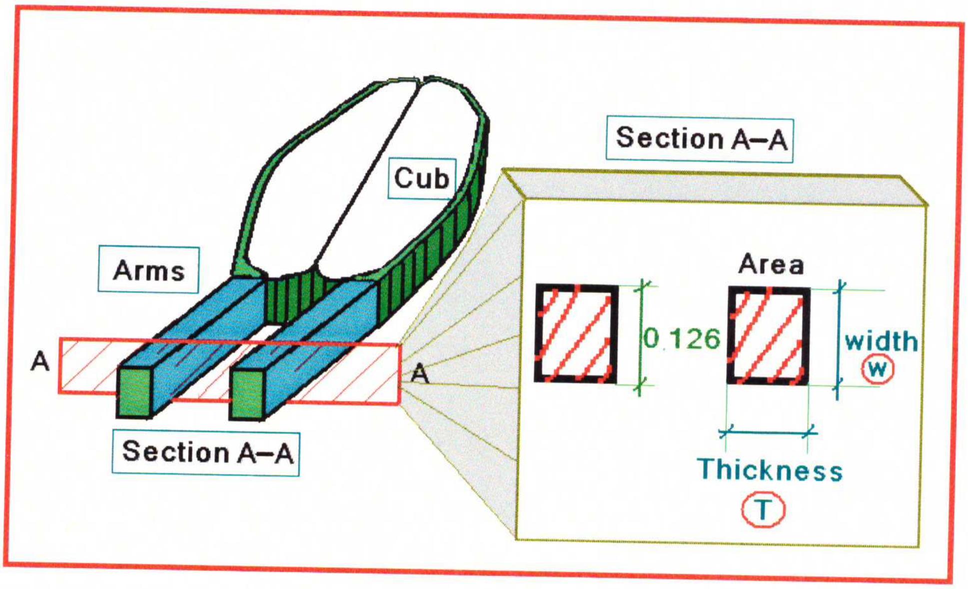
$$A_T = 0.02669 \quad m^2$$

The area that will prevent the arm to failure is equal to $A_T = 0.02669 \quad m^2$ so, we have two arm to match the arm so , we will divide the area by 2 to find the dimension for each arm as .

Area of the arm = $\frac{A_T}{2}$

Area of the arm (A)= $\frac{0.02669}{2} = 0.01334 \quad m^2$

As we see in the figure(8.26),the width of the arm is known so , we can evaluate the thickness of the arm by substitute the area as the following.



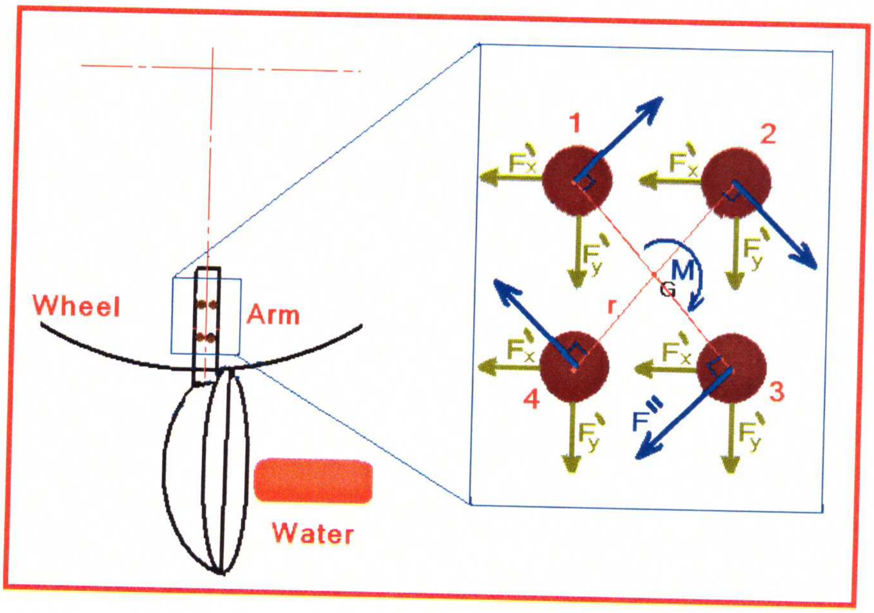
Figure(8.26):Dimension of the arm

Now we can calculate the thickness of the arm by :

$$Area\ of\ the\ arm = Thickness * Width$$
$$Area\ of\ the\ arm = T * W$$
$$0.01334 \quad = T * 0.126$$
$$T = \frac{0.01334}{0.126} = 0.105 \ \ m$$
$$T = 10.5 \ \ cm.$$

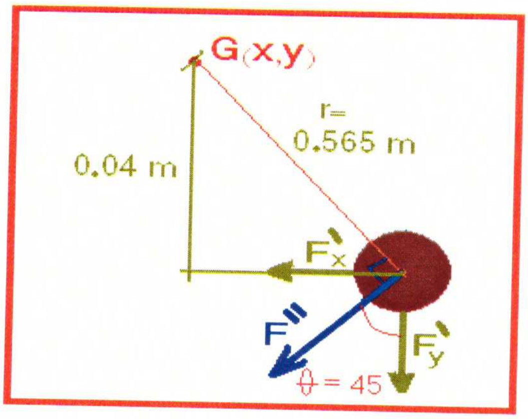
8.3.3.3 Design the bolt of the cub

- To calculate the diameter of the bolt we must take all forces that act on the bolt and shear stress in the consideration.
- The forces on the bolt cause a primary and secondary shear stress and its will calculated after analyses all forces that cause these shear stress as it shown in figure(8.27).



Figure(8.27):Primary and secondary shear stress on the bolt

Our design will construct on the bolt number three because all shear stress collecting in one quadrant so, it more danger to cause cutting in the bolt and as we see in figure(8.28)that show free body diagram of the bolt number three(3).



Figure(8.28): Shear stress on bolt

Now we can calculate each of the primary and secondary shear stress by applying the following equation:

$$F'_x = \frac{F_j}{n}$$

Where:

n : number of bolt that will use.

n=4.

- Primary shear stress:

  - ☒ In x- axis shear stress

$$F'_x = \frac{F_j/2}{n}$$

$$F'_x = \frac{145.710*10^3}{4}$$

$$F'_x = 36427.5 \quad N$$

  - ☒ In y- axis shear stress

$$F'_y = \frac{(F_c/2)+(W/2)}{n}$$

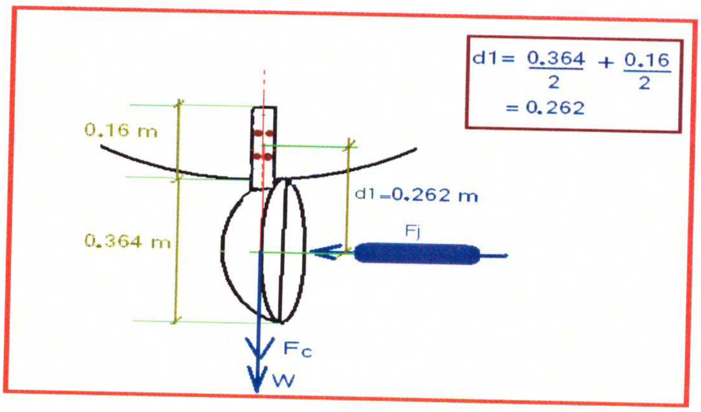
$$F'_y = \frac{14.993+88.657}{4}$$

$$F'_y = 37705339 \quad N$$

- Secondary shear stress.

$$F'' = \frac{Mr}{4r^2} = \frac{M}{4r}$$

Moment can be estimated as shown in figure(8.29).



Figure(8.29):Moment on the cub

$$M = F * d_1$$

$$M = 145.710 * 10^3 * 0.262$$

$$M = 38176.02 \quad N.m$$

r= 0.565 m

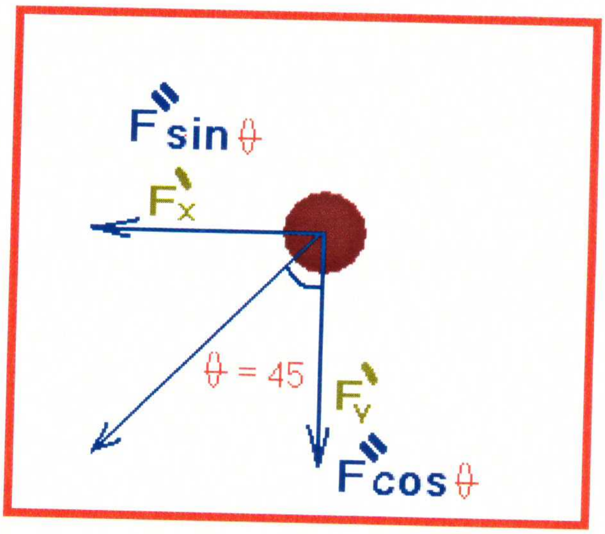
so the secondary shear stress is

$$F'' = \frac{Mr}{4r^2} = \frac{M}{4r}$$

$$F'' = \frac{38176.02}{4 * 0.565}$$

$$F'' = 1689.204 \quad N$$

Now by combining the primary and secondary shear stress in plane axis as x-axis – y axis as shown in figure(8.30).]



Figure(8.30):Primary and secondary shear stress

Now we can find the equivalent shear in x,y axis by:

$$\tau_x = \tau'_x + \tau'' \cos\theta$$

$$\tau_x = \frac{F'_x}{A} + \frac{F''}{A}\cos\theta$$

$$\tau_x = \frac{36427.5}{A} + \frac{1689.204}{A}\cos 45$$

$$\tau_x = \frac{37621.947}{A}$$

$$\tau_y = \tau'_y + \tau'' \sin\theta$$

$$\tau_y = \frac{F'_y}{A} + \frac{F''}{A}\sin\theta$$

$$\tau_y = \frac{3770.539}{A} + \frac{1689.204}{A}\sin 45$$

$$\tau_y = \frac{4964.986}{A}$$

$$\tau = \sqrt{(\tau_x)^2 + (\tau_y)^2}$$

$$\tau = \sqrt{\left(\frac{37621.947}{A}\right)^2 + \left(\frac{4964.986}{A}\right)^2}$$

$$\tau = \sqrt{\left(\frac{1440062059}{A^2}\right)^2}$$

If we select the material of the bolt is steel ,the yield strength is equal to $S_y = 385\ Mpa$ as seen in (appendix A)

$$\tau = \frac{S_y}{n}$$

$$\sqrt{\left(\frac{1440062059}{A^2}\right)^2} = \frac{385*10^6}{3}$$

$$A = \sqrt{1.59*10^{-7}}$$

$$A = 3.994*10^{-4}$$

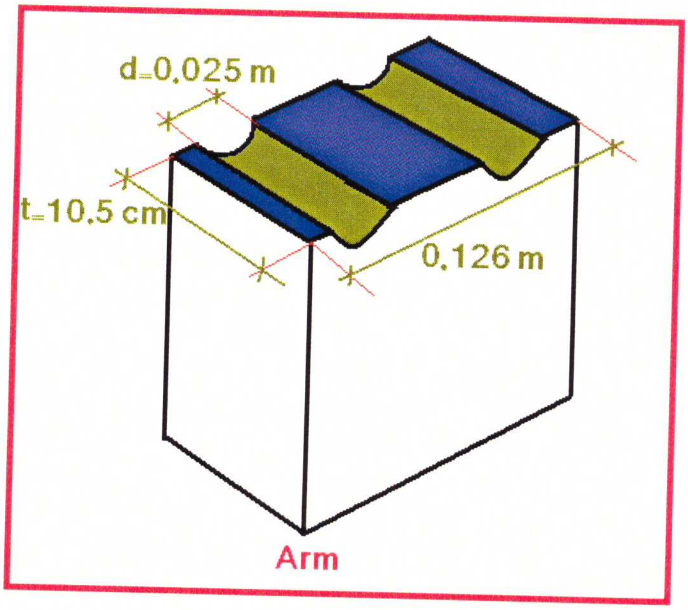
The diameter of the bolt can be determine by the following equation:

$$A = \frac{\pi * d^2}{4}$$

$$d = \frac{4A}{\pi} = \frac{4 * 3.994 * 10^{-4}}{3.14} = 0.0225 \ m$$

$$d = 2.25 \ cm$$

Figure (8.31) show the arm cross section at the bolt and the two molt occupied an area is equal to.



Figure(8.31):Arm cross section

$$\text{Area of the bolt} = 2 * (d * t)$$

$$\text{Area of the bolt} = 2 * (0.0225 * 0.105)$$

$$\text{Area of the bolt} = 4.725 * 10^{-3} m^2$$

Total area of the arm = area of the two bolts + area of the old arm

Total area of the arm = $4.725 * 10^{-3}$ + 0.01334

Total area of the arm =0.0180 m²

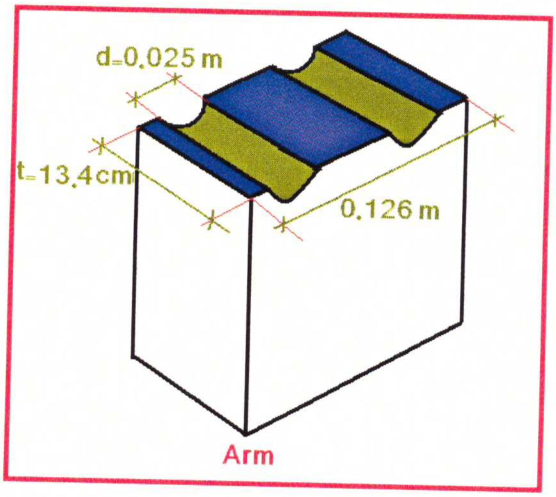
$$Area = L * t$$

$$t = \frac{A}{L}$$

$$t = \frac{0.0180}{0.126} = 0.134 \ m$$

$$t = 13.4 \ cm$$

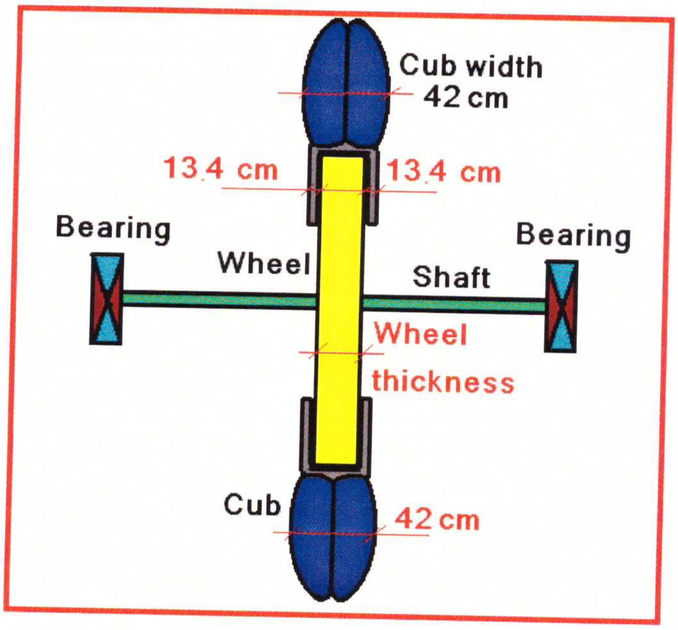
Now the dimension of the arm and bolt that will design to prevent cub from failure can be shown in figure(8.32).



Figure(8.32):Dimension of the bolt and cub

8.3.3.4 Design wheel thickness

For design the wheel thickness we assume a simple method and make a check to ensure if it is suitable for the usage material or no so , figure (8.33) show an estimated graph to evaluate the wheel thickness.



Figure(8.33):Wheel thickness

Wheel thickness = Cub width-2(arm width)

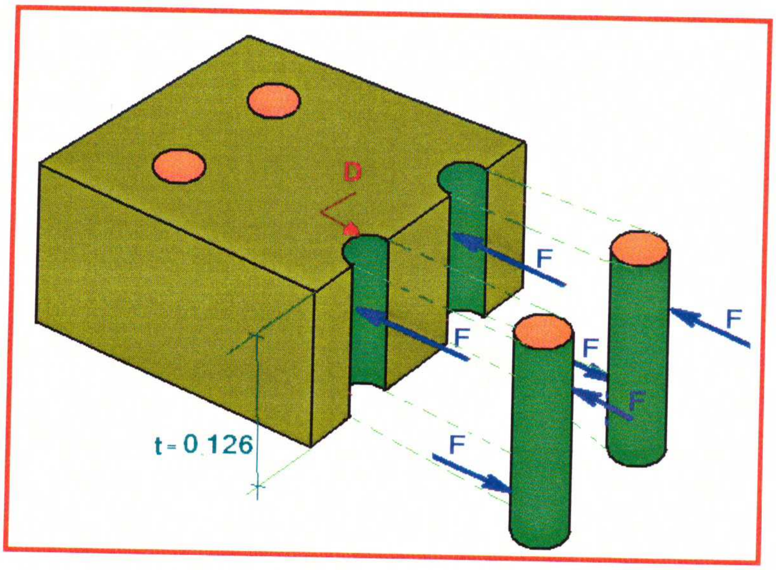
Wheel thickness = 42 -2(13.4)

Wheel thickness = 15.2 cm

The thickness of the wheel must be check if it is enough or no so we will chick it by using bearing and shear stress to ensure if it not fail and these stresses can be calculated by:

- **Bearing stress:**

Bearing stress is a stress occurred between the bolt and wheel thickness as shown in figure(8.34).



Figure(8.34):Bearing stress diagram

As we see in the figure(8.34),we can calculate the bearing stress as:

$$\text{Bearing stress } (\sigma_b) = \frac{F}{A}$$

$$\sigma_b = \frac{F_c + W}{2*(t*d)}$$

$$\sigma_b = \frac{29.987*10^3 + 177.315}{2*(0.134*0.0225)}$$

$$\sigma_b = 5 \ Mpa$$

S_y of the aluminum =169 Mpa

Bearing stress < Yield strength

$$\sigma_b \quad < S_y$$

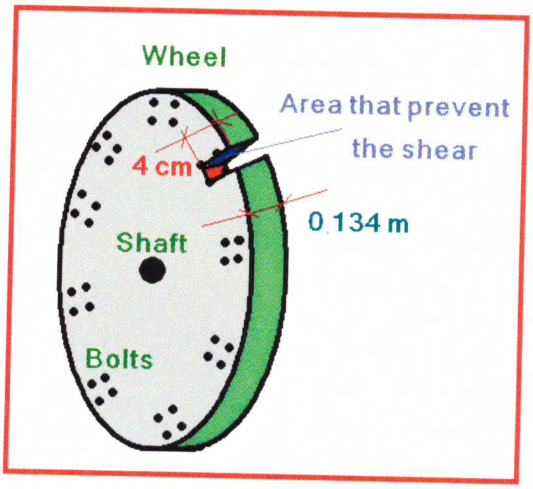
5 Mpa < 169 Mpa

So the wheel thickness is acceptable.

By comparing the bearing stress that obtain from the calculation for the bolt, wheel and the yield strength of the wheel ,we conclude that the wheel thickness suitable for designation.

- **Shear stress:**

We will check the shear stress of the wheel thickness and this shear stress can be used to compare the yield stress of the metal and shear stress of the wheel as will been in the figure(8.35).



Figure(8.35):Area of the shear stress.

As we see in the figure we will calculate the shear stress as the following:

$$\text{shear stress}\,(\tau) = \frac{F}{A}$$

$$F = F_c + W$$

$$F = 30164.315$$

We take the force that act for one bolt and its area as shown in figure(8.35).

$$Area = 2*(0.04*0.134)$$

$$Area = 0.01072$$

$$\text{shear stress}\ (\tau) = \frac{F}{A}$$

$$\tau = \frac{F_c + W}{A}$$

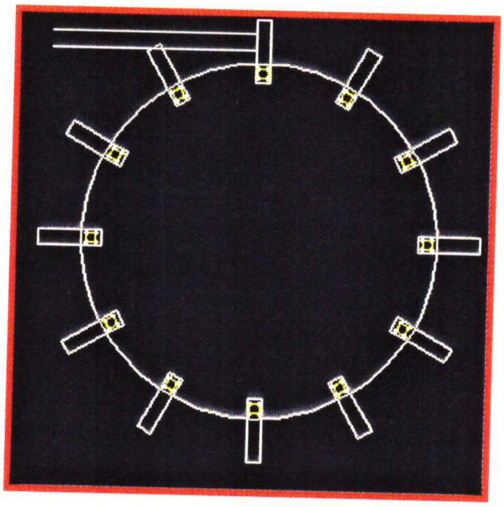
$$\tau = \frac{30164.315}{0.01072}$$

$$\tau = 2\ \ Mpa$$

So the shear stress of the aluminum is lower than the yield strength of the material, so the material is safety to design the wheel of the turbine.

8.3.3.5. Estimating number of the Buckets.

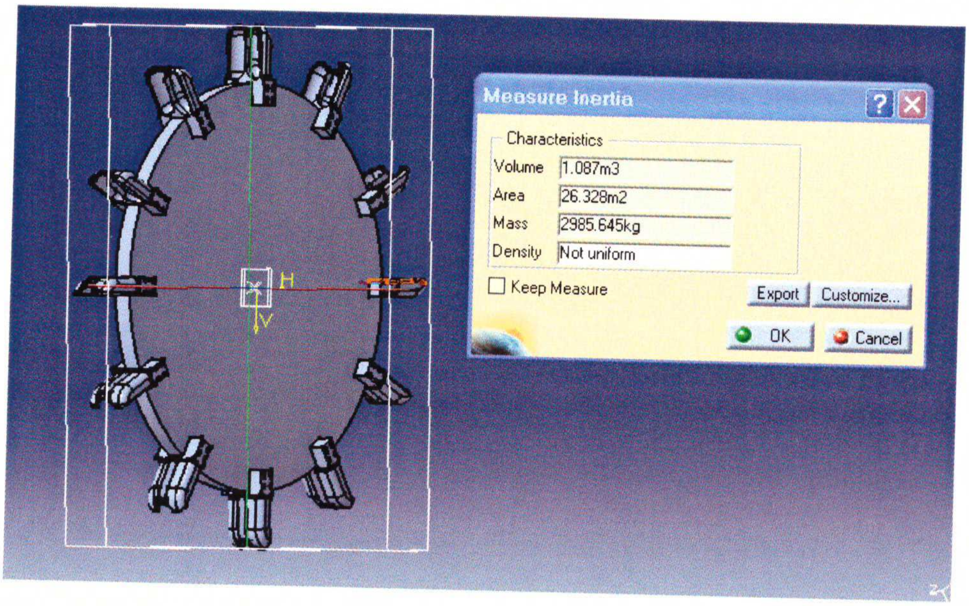
To estimate number of the bucket we use the method of drawing by autocad such that the water must transfer its energy to the center of the cub without touch other cub and this method can be estimating as shown in figure (8.36) .



Figure(8.36):Estimate number of bucket

8.3.3.6 Design shaft of the turbine .

Design of the turbine shaft depend on the weight of it so, the weight of it can be calculate by catia program and this weight shown in figure (6.37).



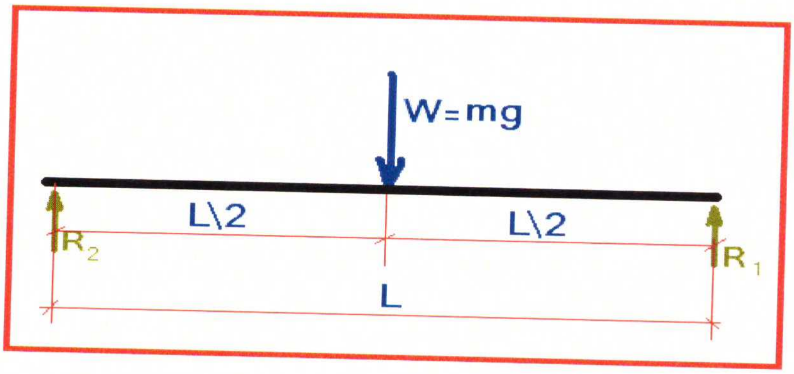
Figure(6.37):Weight of the turbine

- As we see in the figure the weight of the turbine is equal to 2985.645 Kg and this weight will be used as a force acting on the shaft as we will see in the next procedure.

- The weight on the shaft cause two type of loading and these loading will calculated as the following:

❖ Bending due to dead load "Weight"

This bending occur as a result of dead weight and this weight cause a moment proportion to the distance from the edges of the shaft and its maximum bending occur at the middle of the shaft as shown in figure(8.38).



Figure(8.38):Free body diagram of forces on shaft

Figure(8.38),show the free body diagram of forces that act on the shaft and its reaction so the moment can be calculated as the following.

The shaft take form of circular so,

$$\sigma_x = \frac{Mc}{I}$$

$$I = \frac{\pi d^4}{64}$$

$$\sigma_x = \frac{32M}{\pi d^3}$$

The moment on the shaft is multiply by four because we use four jet so,

$$M = 4*T$$
$$T = F_j * R_m$$
$$T = 291.420*10^3*1.681$$
$$T = 489877.02 \ \ N.m$$
$$M = 4*489877.02$$
$$M = 1959.508.08 \ N.m$$
$$\sigma_x = \frac{32M}{\pi d^3} = \frac{32*1959.508}{3.14*d^3}$$

- **Torsion loading**

The torsion can be calculated as the following:

$$\tau_{xy} = \frac{Tc}{j}$$
$$c = \frac{d}{2}$$
$$J = \frac{\pi*d^4}{32}$$

So by substituting we obtain on the torsion as

$$\tau_{xy} = \frac{16T}{\pi*d^3}$$
$$\tau_{xy} = \frac{16*489877.02}{3.14*d^3}$$
$$\tau_{xy} = \frac{2496188.637}{d^3} \ \frac{N}{m^2}$$

So as we see that the two type of load depend on the diameter of the shaft and these two equation can be solved by applying von misses theory as:

$$\sigma' = \sqrt{\sigma_x + 3\tau_{xy}}$$

$$\sigma' = \sqrt{\left(\frac{19969509.1}{d^3}\right) + 3\left(\frac{2496188.637}{d^3}\right)}$$

$$\sigma' = \sqrt{\frac{4.0501 * 10^{14}}{d^3}}$$

Now we can use the design equation by using known material for the shaft and suppose factor of safety to obtain on the diameter of the shaft as will be see.

$$\sigma' = \frac{S_y}{n}$$

Where we will design the shaft from steel with

S_y =358 Mpa

n=2

$$\sigma' = \frac{S_y}{n}$$

$$\sigma' = \frac{358 * 10^6}{2}$$

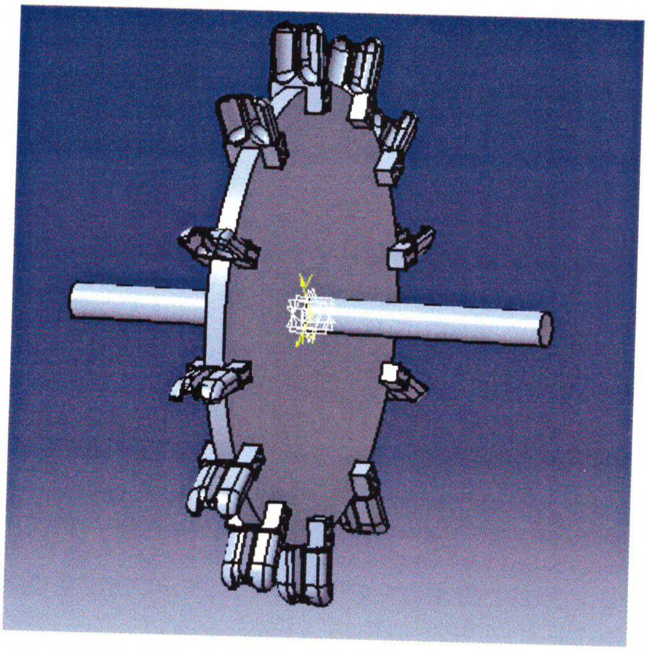
$$\sqrt{\frac{4.0501 * 10^{14}}{d^3}} = \frac{358 * 10^6}{2}$$

$$d = \frac{1.620 * 10^{15}}{1.281 * 10^{17}}$$

$$d = 0.232 \ m$$

$$d = 23 \ cm$$

As we see the diameter of the shaft that design to manufactured from steel with diameter of 23 cm and we will suppose its length 1.5 m to the right and left ,so the total weight of turbine can be estimated as shown in figure(8.39)with mass = 4037.768 kg.



Figure(3.38):Diameter of the shaft with turbine

Appendix

Appendix – A

sults of Tensile Tests of Some Metals* *Source:* J. Datsko, "Solid Materials," chap. 7 in Joseph E. Shigley and Charles R. Mischke (eds.-in-chief),
ndbook of Machine Design, 2nd ed., McGraw-Hill, New York, 1996, pp. 7.47–7.50.

			Strength (Tensile)				
Number	Material	Condition	Yield S_y, MPa (kpsi)	Ultimate S_u, MPa (kpsi)	Fracture, σ_f, MPa (kpsi)	Coefficient σ_0, MPa (kpsi)	Strain Strength, Exponent m
1018	Steel	Annealed	220 (32.0)	341 (49.5)	628 (91.1)†	620 (90.0)	0.25
1144	Steel	Annealed	358 (52.0)	646 (93.7)	898 (130)†	992 (144)	0.14
1212	Steel	HR	193 (28.0)	424 (61.5)	729 (106)†	758 (110)	0.24
1045	Steel	Q&T 600°F	1520 (220)	1580 (230)	2380 (345)	1880 (273)†	0.041
4142	Steel	Q&T 600°F	1720 (250)	1930 (210)	2340 (340)	1760 (255)'	0.048
303	Stainless steel	Annealed	241 (35.0)	601 (87.3)	1520 (221)†	1410 (205)	0.51
304	Stainless steel	Annealed	276 (40.0)	568 (82.4)	1600 (233)†	1270 (185)	0.45
2011	Aluminum alloy	16	169 (24.5)	324 (47.0)	325 (47.2)†	620 (90)	0.28
2024	Aluminum alloy	T4	296 (43.0)	446 (64.8)	533 (77.3)†	689 (100)	0.15
7075	Aluminum alloy	T6	542 (78.6)	593 (86.0)	706 (102)†	882 (128)	0.13

ues from one or two heats and believed to be attainable using proper purchase specifications. The fracture strain may vary as much as 100 percent.

ved value.

Abbreviations

- OS Occupation state
- DSRSC Dead Sea Red Sea Canal
- GWh Giga Watt hour
- m meter
- Mm^3 Million meter Cubic
- Q Flow rate
- V Velocity
- A Area
- P Pressure
- Z Elevation
- S second
- masl meter above sea level
- mbsl meter below sea level
- I : Second moment of area
- M : Moment.
- σ : Stress.
- τ : Shear stress.
- S_y : Yield strength
- J : Polar moment of inertia
- τ_{xy} : Shear in x-y plane
- N : Newton
- T : Torque