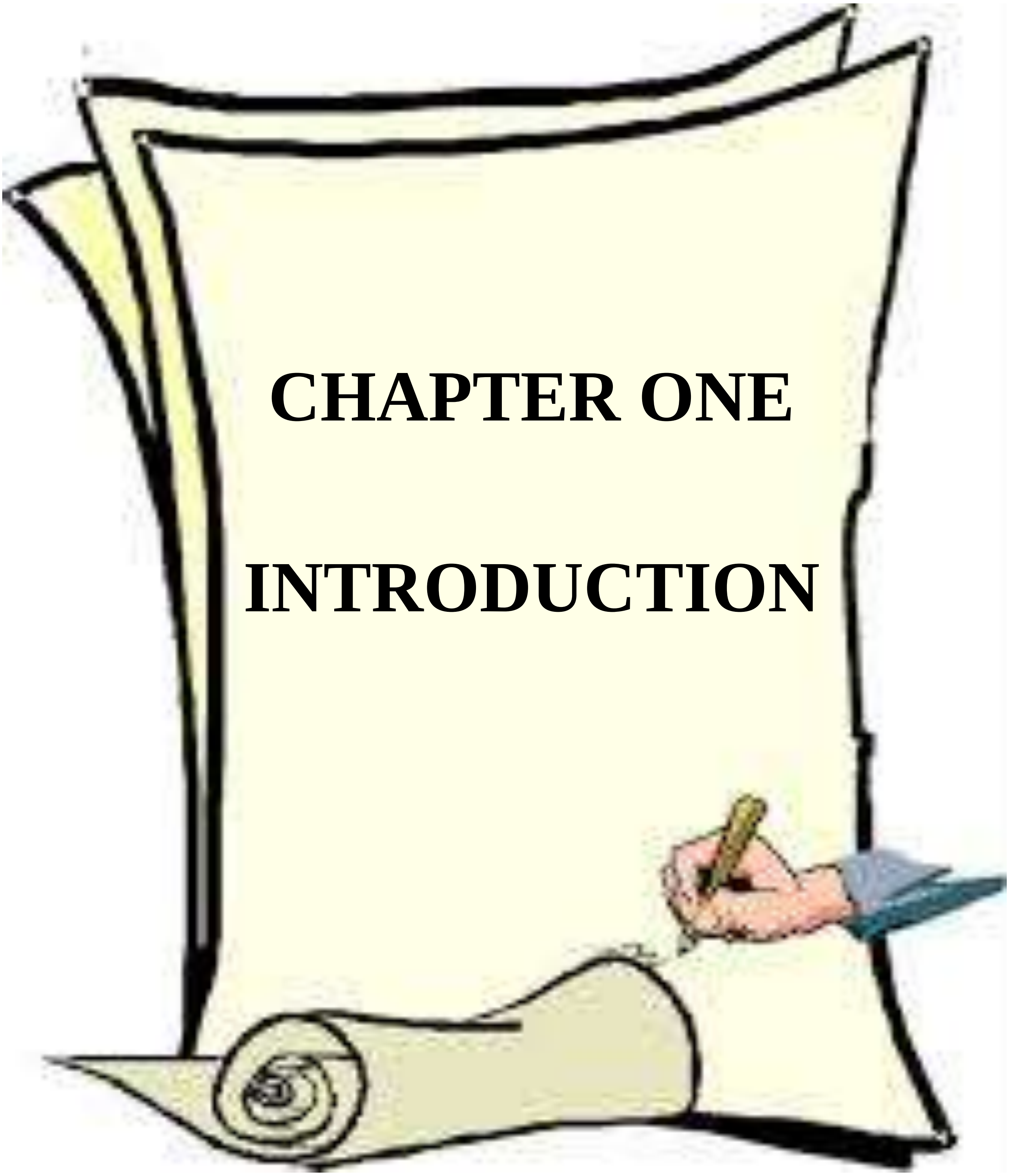


CHAPTER ONE

INTRODUCTION

Chapter one

Introduction

1.1. Enhanced Oil Recovery:

1.1.1. Reservoir and Production life:

When a reservoir is first drilled and produced, the production is referred to as primary production utilizing the natural energy of the reservoir. The range of oil recovery for primary production is 5% to 20% of the original oil in place and the average recovery is 18% of OOIP.

At a point in time it will no longer be effective or economical to continue oil production. The reservoir is then either abandoned or secondary production methods are utilized. The most common method of secondary production is the water flood. Water is injected to sweep some of the oil to the producers and to add energy to the reservoir. Since water and oil do not mix , some of the oil is left behind. The recovery ranges from 25% to 45% of OOIP, and the average recovery is 32% of OOIP.

So we have more than 50% of the OOIP had been abandoned in the reservoir, so we use the tertiary methods to extract it.

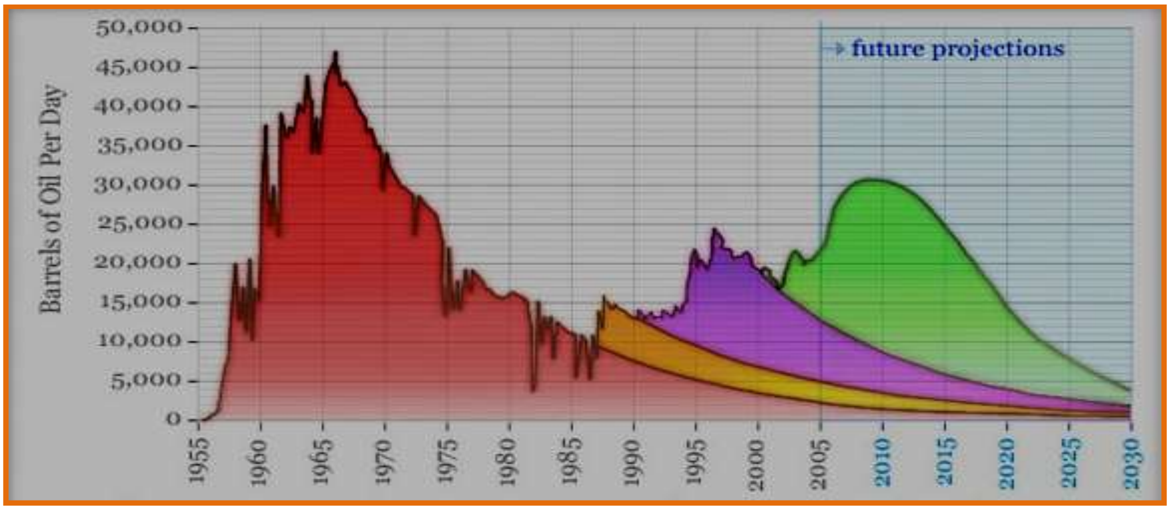


Figure 1.1 Division Of Oil Recovery Phases (After Khalil, 2009)

Depending on the producing life of a reservoir, oil recovery can be defined in three phases: primary, secondary, and tertiary, as shown above we see four sections colored with red, yellow , purple and green ,respectively, they refers to Primary production , production enhancement ,Secondary recovery and Tertiary recovery respectively.

Primary recovery is recovery by natural drive energy initially available in the reservoir.

Primary recovery methods includes:

1. Water drive.
2. Solution Gas drive.
3. Gas Cap drive.
4. Gravity Drainage Drive.
5. Fluid & Rock Expansion.
6. Combination Drive.

Secondary recovery is recovery by injection of external fluids, such as water and/or gas, mainly for the purpose of pressure maintenance and volumetric sweep efficiency.

And the Secondary recovery methods includes:

1. Water Flooding.
2. Gas Flooding.

Tertiary recovery refers to the recovery after pressure drop due to secondary recovery.It is characterized by injection of special fluids such as chemicals, miscible gases, and/or the injection of thermal energy.

Finally the tertiary methods include EOR methods and it classified to:**Chemical Processes:**

1. Polymer Flooding.
2. Alkaline-Polymer Flooding
3. Surfactant-Polymer Flooding
4. Alkaline-Surfactant-Polymer Flooding

Gas Injection Processes:

1.Carbon Dioxide ($C0_2$) Miscible Flooding

2. Hydrocarbon Miscible Flooding

3. Nitrogen (N2) Miscible Flooding

4. Immiscible Gas Flooding

Thermal Processes:

I. Cyclic Steam Stimulation.

2.Steam Flooding

3. Steam Assisted Gravity Drainage (SAGD)

4. In-Situ Combustion

Others

1. Foamy Heavy Oil Production
2. Microbial Flooding.

1.1.2. Importanceof EOR In Sudan:

Enhanced oil recovery (EOR) processes include all methods that use external sources of energy and/or materials (injection of gases or chemicals or thermal) into the reservoir to recover oil that cannot be economically produced by conventional means.

EOR process is very important. In Sudan it`s more important for many reasons which are:

1. High amount of oil remaining reserve:

Reserve is defined as the cumulative oil to be recovered commercially in the future.The remaining reserve in Sudan has high amount, which is attractive reason to do EOR.

2. High of oil remaining in place (STOIIP):

"STOIIP" is defined as the total amount of oil found in the reservoir (will not being all produced).The remaining oil in place in Sudan has very high amount which is attractive reason to do EOR.

3. High water cut:

Water cut defined as the percentage of water rate in the total liquid produced. It is measured in percentage the average water cut is very high in Sudan.Chemical EOR can reduces WC to lower values.

4. Good oil price:

The objective of EOR is to maximize the recovery factor (RF) by increasing oil production rate, whichis more cash and benefits. Oil price became one of the main attractive reasons of doing EOR.

5. **It is the time for tertiary recovery:**

Oil production is dropping, primary recovery period is ended, secondary recovery can not be implemented due to high oil viscosity.

6. **Low recovery factor:**

Recovery factor is defined as the total amount of produced oil divided by the STOIIP.

7. **Availability of technology.**

1.1.3. Reservoir Engineering ParameterstounderstandTEOR:

To understand the basic principles of EOR some reservoir engineering parameters have to be fully known.

Mobility Ratio, Relative Permeability, Wettability and Interfacial Tension are the most important reservoir engineering parameters, In addition to all the required data to do EOR analysis.

The permeability of a rock K is the description of the ease with which fluid can pass through the pore structure two types of permeability measured from the core Horizontal permeability and Vertical permeability. Horizontal permeability in a reservoir is generally higher than vertical permeability.

Wettability: is defined as the tendency of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids. The wettability dependant on both rock and fluid properties .The wettability of reservoir rocks to the fluids is important in that the distribution of the fluids in the porous media is a function of wettability.

With the wettability two processes have been reminded Drainage Process and Imbibition process.

Drainage process:means taking water out, wetting phase is displaced by non-wetting phase (called migration process).

Imbibition's Process: means taking oil out, non-wetting phase is displaced by wetting phase (called production process).

Mobility is the ability of one fluid to flow faster (higher speed) than the other(s).Mobility ratio for any fluid is the ratio between permeability and viscosity Mobility ratio is used in EOR, in both thermal and miscible gas injection it deals with oil viscosity, and in chemical flooding it deals with water viscosity.

Problem Statement:

Production of heavy oil today have many techniques and ways, they vary according to reservoir parameters, injection conditions, required production rate and recovery factor from the process. Cyclic Steam Stimulation(CSS) one of the successful and suitable methodsused in heavy oil fields in Sudan. We are approaching this research to discuss the process and an important parameter which affect the success of the process which is the steam quality and temperature, while others parameters are constant,-such as injection rate , injection amounts and injection pressure-,there for two cases had been discussed versus the base case to reach the optimal one, with high production rate and less fuel consumption.

Objective:

1. Optimize CSS operation parameters under study –injection quality and temperature-.
2. Design the new parameters case according to the high production rate,
3. Study the economic evaluation cases and suggest the optimum case accordingly.
4. To proof its purpose on an economic level regarding its high expenses.

CHAPTER TWO

Theory and Litreture review

Chapter two

Theory and Litreture review

2.1. Cyclic Steam Stimulation:

2.1.1.Introduction:

Thermal methods have been tested since 1950's, and they are the most advanced among EOR methods, as far as field experience and technology are concerned. They are best suited for heavy oils (10-20° API) and tar sands (≤10° API). Thermal methods supply heat to the reservoir, and vaporize some of the oil.

CSS is one of EOR methods sometimes applied to heavy-oil reservoirs to boost recovery during the primary production phase. During this time it assists natural reservoir energy by thinning the oil so it will more easily move through the formation to the injection/production wells. It can also be used, however, as a single-well procedure.

To utilize this EOR method, a predetermined amount of steam is injected into wells that have been drilled or converted for injection purposes. These wells are then shut in to allow the steam to heat or "soak" the producing formation around the well.

After a sufficient time has elapsed to allow adequate heating, the injection wells are back in production until the heat is dissipated with the produced fluids. This cycle of soak-and-produce, or "huff-and-puff," may be repeated until the response becomes marginal because of declining natural reservoir pressure and increased water production.

At this time a continuous steam flood is usually initiated to continue the heating and thinning of the oil and to replace declining reservoir pressure so that production may continue. When the steam flooding is started, some of the original injection wells will be converted for use as production wells, along with the others drilled or designated for that purpose.

Cyclic steam stimulation (CSS) is an extremely successful recovery process and is widely used worldwide for enhancing the production from heavy oil fields. This method is called steam soak or huff and puff. In this process steam is injected in a well for several days then well is shut-in for few days to allow the heat to dissipate in the reservoir and then well is put on production. Beauty of this method is that a small volume of steam reaps large volume of oil. It has been observed that successful CSS applications have provided average 0.5-2 bblofoil/barrel of steam injected, even higher in some cases. The cycle of injection, soaking and production is repeated many times

2.2.Litretaure Review:

CSS had been used in many countries since it's first application in America , looks like :

United States:

Cyclic steam injection is the most common thermal recover processes. It has been used extensively in heavey oil field in Califfornia in the US since 1940 .the first cycle respone reported additional oil recovery per barrel of steam injected ranges from 0.21 bbl at Poso Creek to 5.0 bbl at huntington Beach , which includes contributions due to natural production mechanisms, is slightly larger from 0.38 to 6.5 bbl. The ratio of oil production rate after stimulation to that before ranges from 2.4 to 47 but centers on a factor of 12. Net sand intervals range from 22 to 250 ft, and the steam injection range from 24 to 260 bbl per foot of net sand. Total steam injection per well ranges from 4400 to 14000 bbl. (Prats , 1982) (Ebogah, et.al, 2003) (Humphries, 2008)

Venezula:

The amount of steam injected is generally larger in Venezula than in the nighborhood of 5000 bbl per cycle. Also the oil recovery is larger than that in california. The higher Oil/steam ratios common in the bolivar Coast are considered to be influenced significantly by compaction of the oil-bearing sands during production, the importance of whivh cannot be overemphasized in that area. (Payne,et.al.,1965) (Dusseault,2001)

China:

In China, cyclic steam stimulation is the most widely applicable method for the development of common and ultra-heavy oil, and about 80% of thermal production is by CSS. Henan oilfield is one of the main producing areas of heavy oil in China and oil viscosity mainly ranges from 10000 to 30000mPa.s, belonging to ultra-heavy oil. After 6~8 cycles' huff and puff, the heating radius reaches to its economic limit and both oil and water recovery is low due to the unfavorable reservoir pressure.

It applied in many fields there such as Gaosheng field, and the result was increasing in average production rate per well by more than 1000 per year. (White, 2003)

Egypt:

Cyclic-steam stimulation has increased oil production to 4,000 b/d from 50 b/d under primary recovery in Egypt's Issaran oil field. The field is 290 km southeast of Cairo and 3 km inland from the western shore of the Gulf of Suez. The Issaran concession has 20,000 acres, the developing started in the field in 1999.

Iran:

One of the successful experiments of cyclic steam stimulation in heavy oil reservoirs is Iran. S.D Razavi and R. khartat had applied it on Sarvak formation at depth of 1150m of 90 km length and 16km width, oil viscosity of 2700 cp with 7.24 API, and the bubble point of the oil was 624 psi. The horizontal length and average depth of wells were 200 ft and 1800 ft from the sea level. The initial pressure was 927 psi. And the initial oil in place was 2.4 MMM bbl.

About the number of wells, after seeing the results from 20 wells and 30 wells they found that in the beginning of the production the 30 well give higher production rate than 20 well, but after many years the production rate becomes the same, so the 20 wells choice is better from the cost view, due to the equal recovery factor in the 30 wells case and lower WOR and the SOR is less than 5 bbl/bbl.

Canada:

Canadian natural's oil sand is bitumen, which is too viscous to flow only about 7%. Of Canada's oil sands can be mined the majority has to be covered using steam injection that is targeted to add 40,000 bbl/day. Canada began to produce its oil sand in1967 with reservoir permeability ranges from 0.5 to 5 Darcy and oil gravity ranges from 8.5 to 15 API, viscosity for less than 15 API is less than 1000cp and excess 1 million cp for surface oil and asphaltene content of 15% in light oil and the heavy oil have less than light (similar to Faja) oil. (Kllinginger, 2010)

2.2.1. CSS Stages:

CSS has three stages:

Cyclic steam stimulation represents a widely used thermal recovery process that can be optimized to achieve higher oil recovery.

Two important parameters that distinguish heavy oil from conventional oil are viscosity and density.

Huff or Steam injection: steam injected into the well for short period of time from 2 to 30 days. The stem injected usually wet (60 -80%). This important from an operational view point in order to keep undesirable compounds such as calcium and magnesium salts dissolved in the water because it can make corrosion or scale to the casing.

Steam soak: in this stage the shut- in and thermal gradient are allowed to equalize. This period of time range from 5 to 30 days.

Puff or Oil production: here the well brought on back to production, a hot water and oil is produced.

These three stages together make up one complete CSS. This process can be repeated over several cyclic.

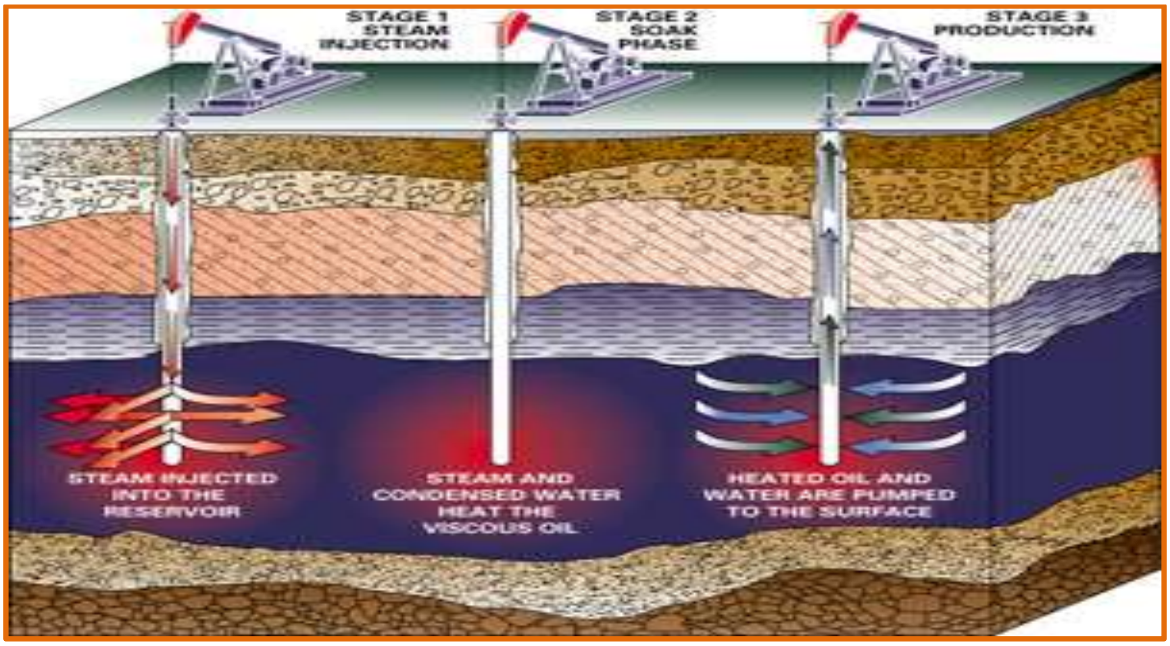


Figure 2.1**Cyclic Steam Stimulation Process (Lake,2007)**

We ensure we have the best optimization for CSS by, controlling the value of cumulative oil produced by maximizing and minimizing it and controlling the NPV (Net Present Value).

To apply CSS method on a reservoir we must have Large filed area and steam is selected to be implemented in the future, CSS is used to heat a part of the reservoir, low API (less than 22.1 Degree API), viscous oil (more than 100 cp),good net pay (10 m at least to avoid heat losses) and enough reservoir pressure to hold the injection pressure.

2.2.2 Process Advantages:

This process makes a lot advantages like:

1. Prepare the field for future steam flooding by heating a part of the reservoir.
2. Reduced oil viscosity and there for change the wettability around the well bore from oil to water wet in addition to mobility ratio reduction.
3. Reduces S_{or} (remaining oil in the reservoir).
4. Quick increment in oil rate once the production phase is started.

2.2.3. Process Disadvantages:

It`s disadvantages are:

1. Difficult to be applied in case of low current reservoir pressure.
2. Steam injection is not continuous.
3. Affected by strong water aquifer drive

Case study :

Introduction

X field lies in DQ part of Muglad Basin. The area is divided into four fields namely Y Main, Z North, N Central and DQ First three fields form the Greater X field. Operator companyhas drilled wells in different fault blocks and discovered oil in Aradeiba, Bentiu and Abu Gabra formations. Greater X was put on early production in November 2003 and wells have been drilled till first quarter of 2011 in different fault blocks of Greater X area for heavy and light oil production. Peak production from the field was around 40 kbopd and currently producing around 25 kbopd. Major share of production is from heavy oil. The majority of oil is viscous in these structures with degree API 16-19. Light is of 29 degree API. DQ is a satellite oil field of Greater X field and is located in NE direction of Greater X in Block-6 which occupies northwest part ofMuglad rift basin in Sudan. DQ Oil field was discovered in 2005 and has a long narrow structure from northwest to southeast, the biggest length of northwest-southeast is about 10 km the average width of northeast-south is about 1.5 Km. The field oil bearing area is around 12 Sq Km. The overall terrain in DQ Field is higher in the southwest and lower in the northeast (Figure-1)

Selection of EOR Process:

Oil fields, particularly like DQ where oil gravity is low or viscosity is more than 3000cp at reservoir conditions and is unfavorable for conventional methods of recovery, thermal recovery is the best technique for maximum ultimate oil recovery. Since the expected primary recovery in DQ field is lower around 19%, reservoir depth is shallower and crude oil is viscous, therefore, it is planned since beginning of the field development that it would be prudent to initiate for enhanced oil recovery (EOR) technique to maximize the recovery in the early phase of field development. It is detrimental to plan EOR after the exhaustion of primary stage of production. In this way not only project cost will be increased but change of reservoir dynamics may cause lower gain in recovery with EOR with respect to timely implementation of EOR efforts. There could be all Iikeiyhood of increased operational challenges also. All EOR processes are highly capital intensive, highly technical and complex in nature but implementation and management of thermal EOR processes are more complex than other techniques. It has been recognized quite early that heat will be needed to reduce the viscosity of the heavy crude oil of FNE field for increasing the well productivity and improving the overall recovery factor. TEOR techniques and technology have evolved over the years. Successful thermal EOR projects in shallower reservoirs are numerous while in deeper heavy oil reservoirs, applications are still limited with mixed result,

Screening study was carried out which suggest that reservoir and fluid characteristics of DQ field are most suitable and favorable for steam based enhanced oil recovery processes (1-2). The viscosity of oil will decrease with increased temperature and reduce the drag force in the formation and make fluid flow easy in the formation. It has been observed that more viscous crude exhibits greater change in viscosity with temperature. Oil mobility also improves with heating, resulting into increase in oil rate. A thermal process also reduces the residual oil saturation thus increases the movable oil volumes and better sweep efficiency is obtained higher temperature.

Significantamount of oil has been recovered with cyclic steam stimulation alone with closed well spacing. EOR study of DQ field suggest application of continuous steam flooding with envisagedrecovery of 46%. It is known

that steam flooding projects consume large amount of energy for steam generation and is

capital intensive. It is estimated that approximately 1 bbl of crude oil is burned for 3-4 bbl of EOR oil produced in steam flood projects. Therefore, before implementing the full field steam flood project it was essential to understand the few basic things related to the process. Additionally, Thermal EOR is new in this part of world. Therefore, it was decided to implement the cyclic steam stimulation first and estimate the steam injective
ity and test the efficacy of the process in DQ field. Steam flood projects differ with cyclic steam stimulation where average 4-6 bbl of steam/bbl of oil is required and large portion of reservoir rock is heated compared to CSS wherein small portion of reservoir is heated close to well bore. In addition to test the steam injection, it was also planned to deplete the reservoir pressure in order to make it more amenable for steam flooding and also gain the operational experience and identify problems and challenges likely to be encountered during steam operation. With this objectives Pilot tests were designed as CSS quickly stimulates the wells and increases the production rapidly and also provide the valuable data for steam infectivity,

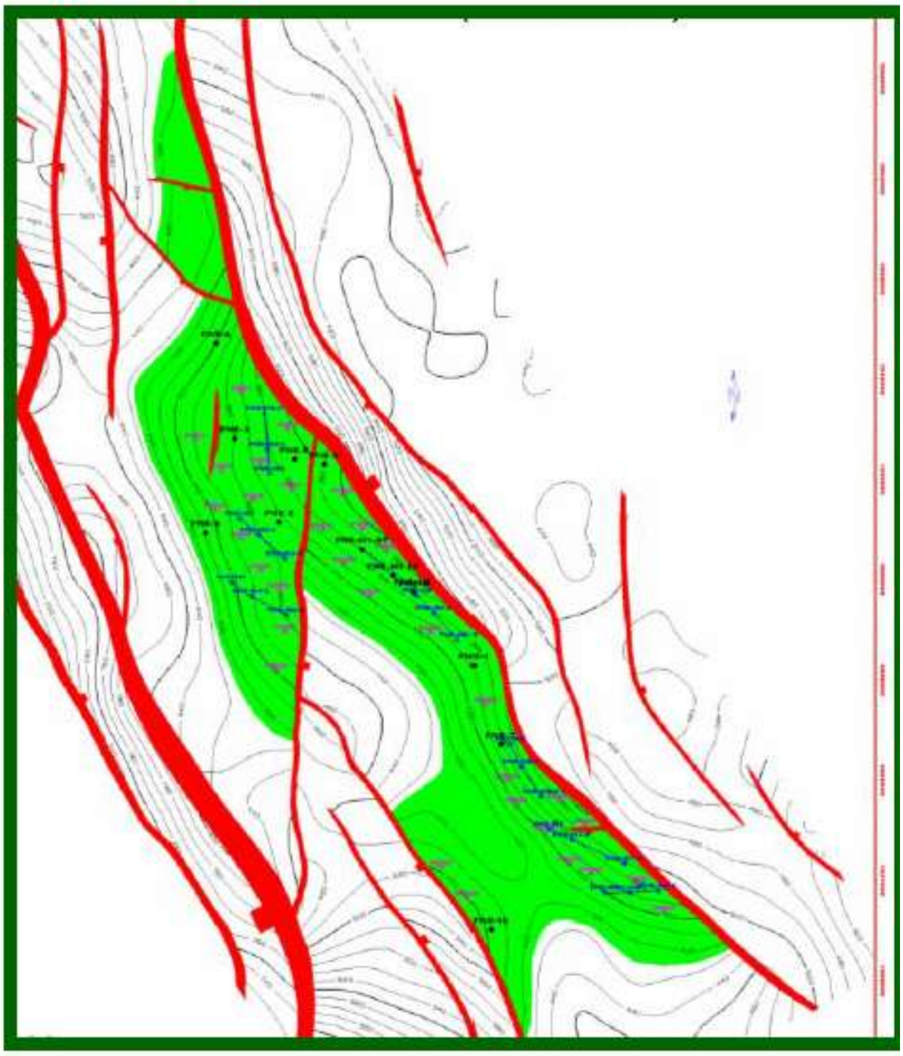
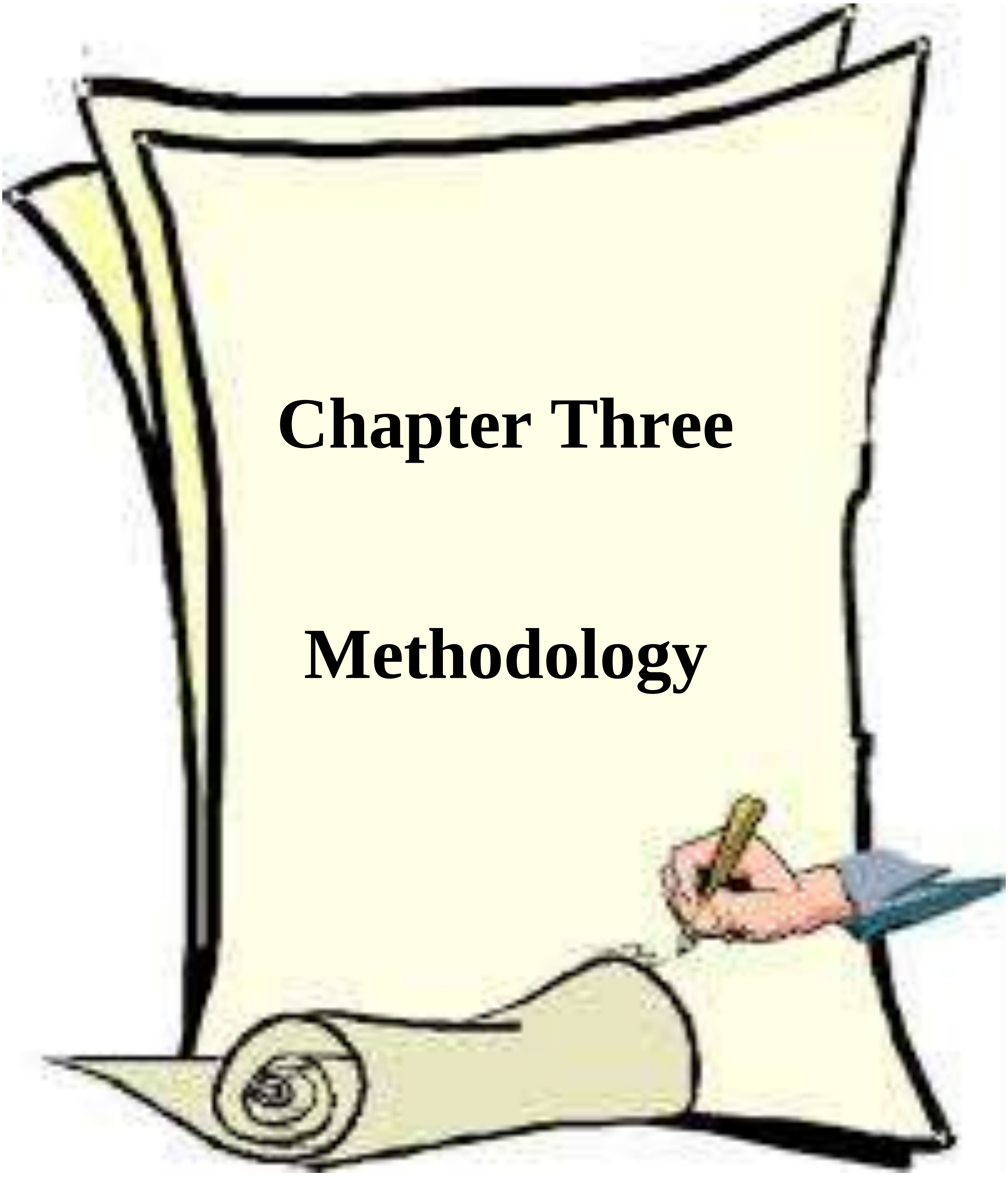


Fig: DQ field contour map - SPE 144638



Chapter Three

Methodology

Chapter Three

METHODOLOGY

CMG is the world's leading independent supplier of reservoir simulation technologies. We are focused on developing simulation technologies that enable our users to build models that accurately represent the physics of the recovery process. Since inception in 1978, CMG has focused on the development and delivery of the most accurate reservoir simulation technologies available. Today, CMG is a world-class software technology company with more than 525 oil and gas companies and consulting firms, in over 55 countries, using our simulation technologies. CMG's research and development team is at the forefront in simulating new recovery methods and is constantly developing innovative ways to overcome existing technological barriers.

CMG is devoted to providing the ultimate customer experience through our commitments to R&D investment, superior software technology, and unparalleled user support.

Introducing the CMG Technologies Launcher :

The CMG Technologies Launcher ("Launcher") is a project management application that allows you to keep track of your CMG simulations and launch jobs from one location.

Using Launcher, you may set up projects or folders on your computer that contain related simulation files. From these projects, you may start Builder to set up your dataset, start a simulator job to compute your results, and load Results Graph or Results 3D to analyze your results.

You may also use Launcher to schedule jobs to run on your computer overnight. Launcher will ensure that jobs are run in order so that each job has access to the computer resources it requires. You may also use Launcher to submit jobs to other scheduling technologies, such as Microsoft Windows Compute Cluster Server or Platform LSF, or to a collection of computers running the CMG Job Service.

CMG STARS:

STARS™, the industry standard in thermal reservoir simulation, is designed to accurately and efficiently capture reservoir dynamics, over the entire lifecycle of the reservoir.

Through accurate reservoir visualization, engineers will clearly see changes to the reservoir based upon fluid behavior, steam or air injection, electrical heating, or chemical flood.

By using STARS, engineers are able to identify the most appropriate recovery method for the reservoir; increase confidence in a field development plan to support capital expenditures; and reduce project risk.

Applications:

1. advanced process reservoir simulator can be used to models virtually any recovery process, but is especially suited to non-isothermal.
2. light and heavy oil recovery processes as well as those that require the modeling of chemical reactions and alkaline-surfactant-polymer (ASP) flooding.
3. foamy heavy oil production and cold heavy oil production.
4. In addition, STARS can model the in-situ formation of emulsions, wax precipitation and thermal desorption.

Benefits :

1. Robust modeling for dispersed components
2. Accurately model the physics of all in-situ recovery processes
3. Model single wells, to pad- and field scale projects.
4. Simulate formation of emulsions and foams ,and predict asphaltingprecipitation/deposition
5. Accurately visualize changing reservoir dynamics.
6. Increase confidence in field development plans and support capital expenditures.
7. Design accurate development plans.
8. Decrease GOR while increasing OOIP recovery with accurate foamy oil models.

Requirements:

It just requires the basic date which are , grid system , oil , rock and reservoir properties.

As we had seen , we used STARS in the project by editing the criteria that control the steam quality and essentially affect in the production rate

Steps:

The first step begins with opening the launcher and using “Builder” to establish the model by input reservoir and well parameters:

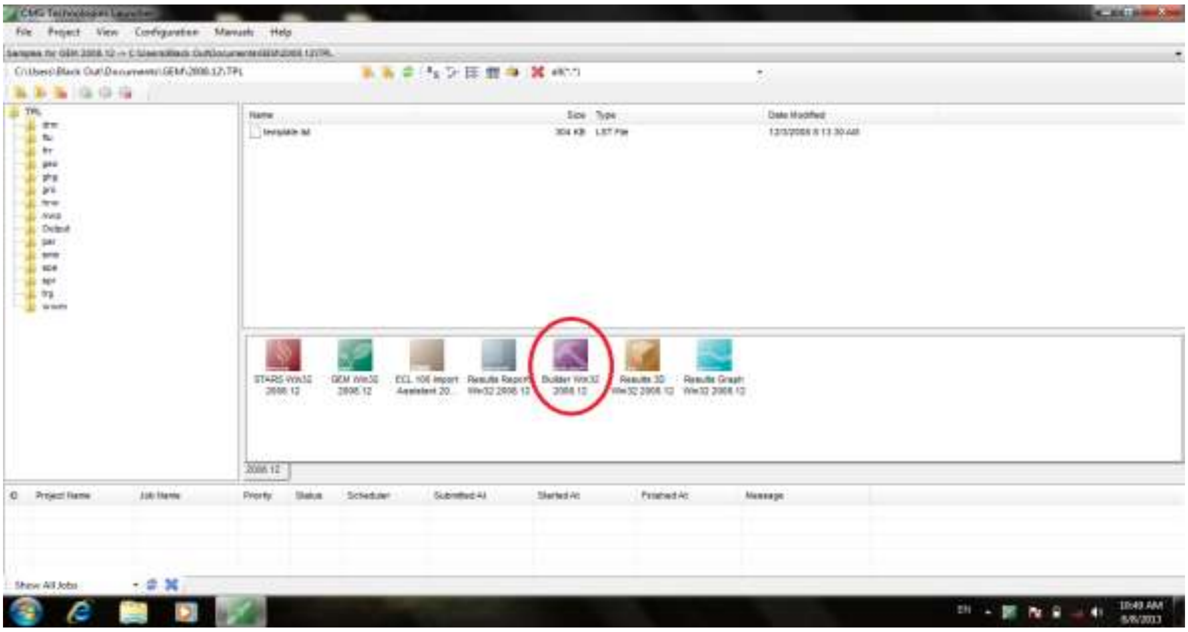


Fig 3.1 – Step 1

When we open it we meet the following window to set reservoir main setting and choose “STARS” as a simulator:

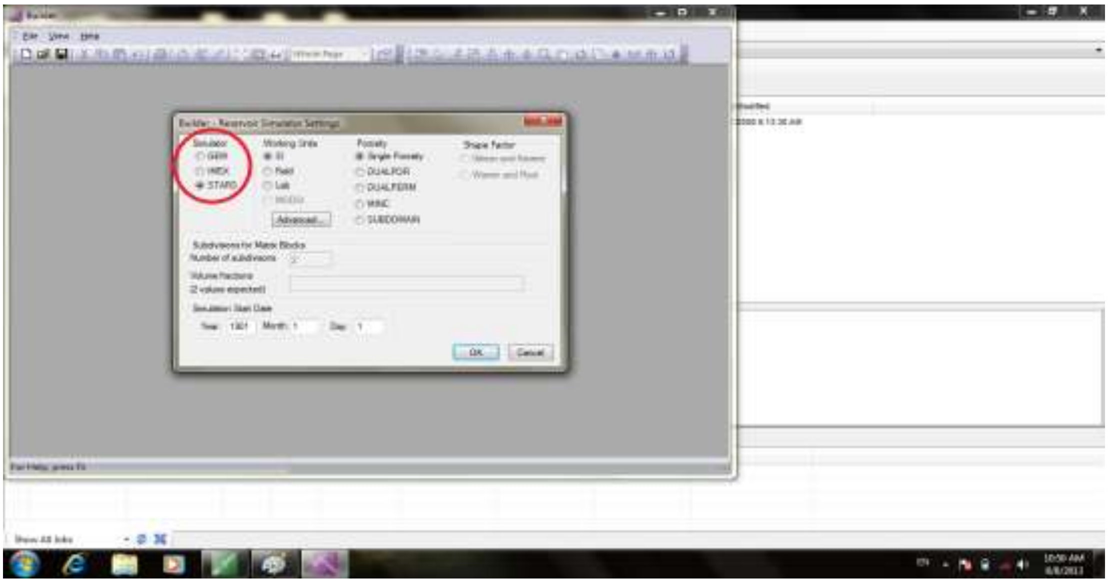


Fig 3.2 – Step 2

“Builder” now is ready to use and all the parameters of the reservoir and wells are shown on the left side of window in the name of “Model Tree View”, all marked with red are required and the simulator will not run without enter an accurate value for it:

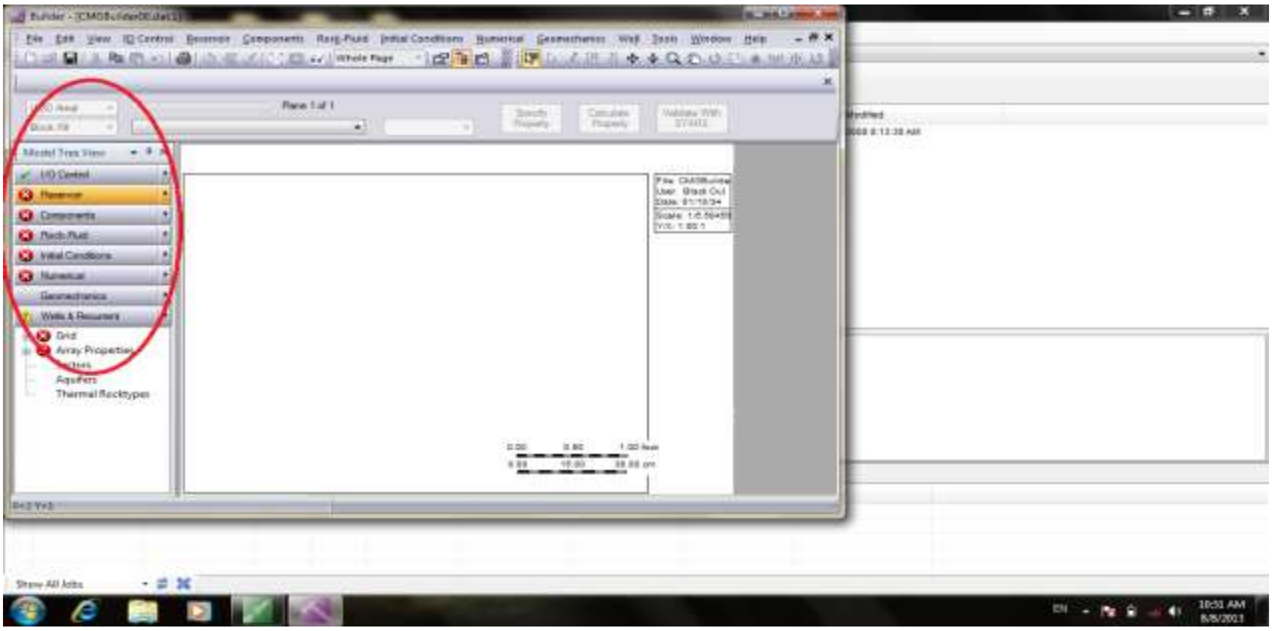


Fig 3.3 – Step 3

Now by entering all the parameters of the reservoir the result will be as :

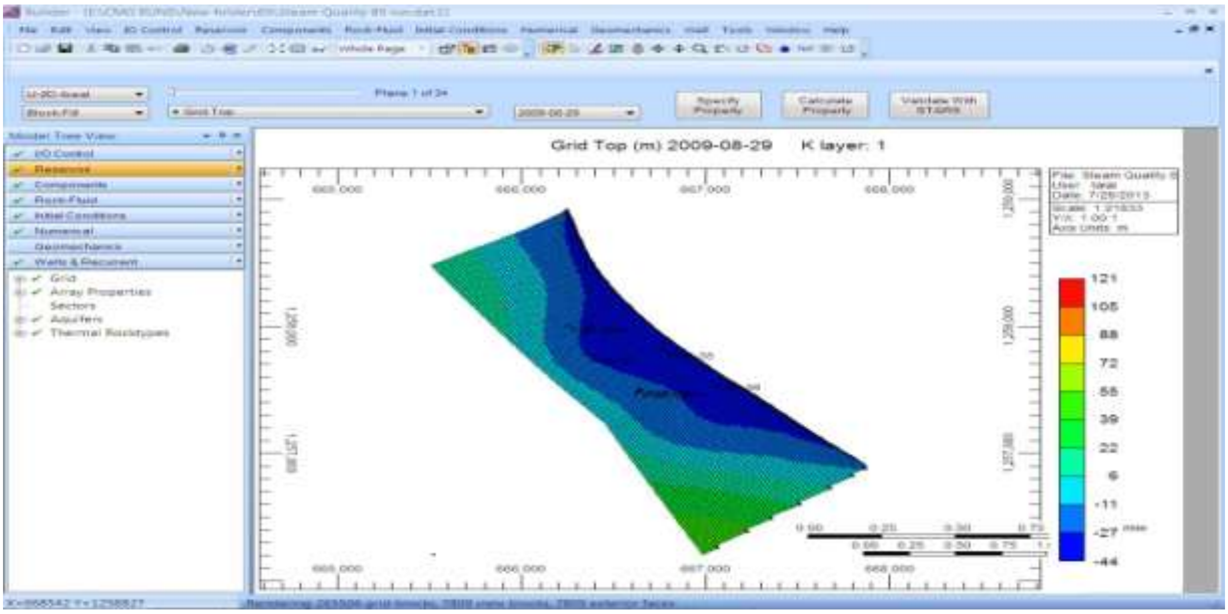


Fig 3.4 – Step 4

CHAPTER FOUR

RESULTS AND ANALYSIS

Chapter Four

Results And Analysis: Table 4.1 results and analysis

Case #	Well	Cycle No	Steam Parameters				Cycles Reservoir Data Data			
			Rate	Pressure	Temp	Steam Quality				
			M3/Day	Mpa	C	%	Startup	End	Oil Produced/ BBL	Water Produced / BBL
Base Case	DQ-38	1st	204.00	7.55	295.00	75.54	1-Oct-2009	23-Feb-2011	335498.00	19214.00
	DQ-38	2nd	192.00	5.87	278.00	73.20	10-Apr-2011	3-Dec-2012		
	DQ-38	3rd	192.00	5.34	270	75.26	18-Jan-2013	1-Sep-2014		
Case-1	DQ-38	1st	204.00	7.55	300	85	1-Oct-2009	23-Feb-2011	457717.00	27415.00
	DQ-38	2nd	192.00	5.87			10-Apr-2011	3-Dec-2012		
	DQ-38	3rd	192.00	5.34			18-Jan-2013	1-Sep-2014		
Case-2	DQ-38	1st	204.00	7.55	350	95	1-Oct-2009	23-Feb-2011	457717.00	27415.00
	DQ-38	2nd	192.00	5.87			10-Apr-2011	3-Dec-2012		
	DQ-38	3rd	192.00	5.34			18-Jan-2013	1-Sep-2014		

Assumptions:-

The base case idea was to evaluate the ability to increase the steam quality and temperature in order to get more oil from the well under the study, two cases was evaluated with the CMG STARS simulator and shown in the table ## .the Vis-oil consumption cost used to evaluate the increasing of the quality and temperature as shown in table ###.

Table4.2 : consumed oil / Cycle

Case #	Well	Cycle No	Consumed Vis Oil BBl
Base Case	DQ-38	1st	749.42
	DQ-38	2nd	708.75
	DQ-38	3rd	809.00
Case-1	DQ-38	1st	974.25
	DQ-38	2nd	921.38
	DQ-38	3rd	1051.70
Case-2	DQ-38	1st	1124.13
	DQ-38	2nd	1063.13
	DQ-38	3rd	1213.50

The Base Case:-

The steam quality is 0.75 and the temperature is275 C

Case 1:

The steam quality increased to 0.85 and the temperature increased to 300 C, the oil produced must be increased.

Case 2:

The steam quality increased to 0.95 and the temperature increased to 350 C,the oil produced must be increased even more than case 1.

The steam performance ratio figure ## showSteaminjection processes:-

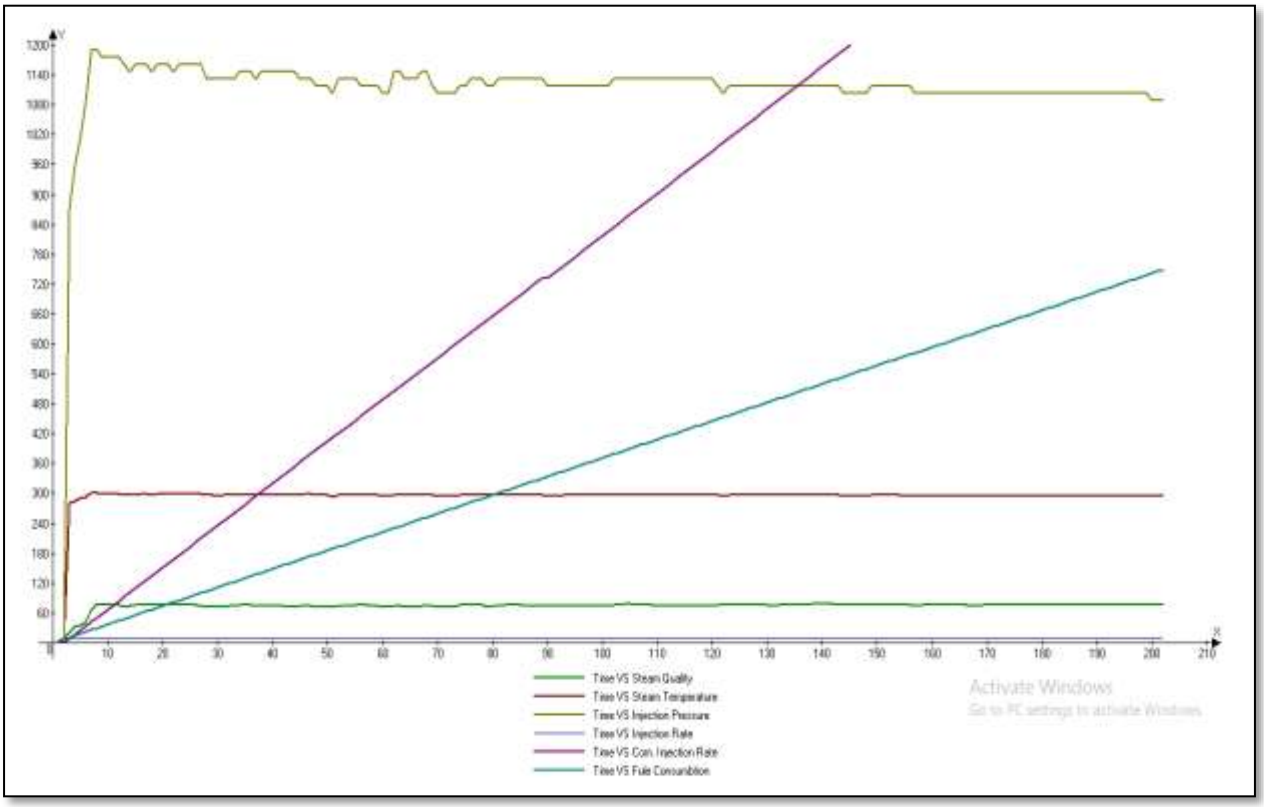


Figure 4.1 Cycle 1 Performance Curve

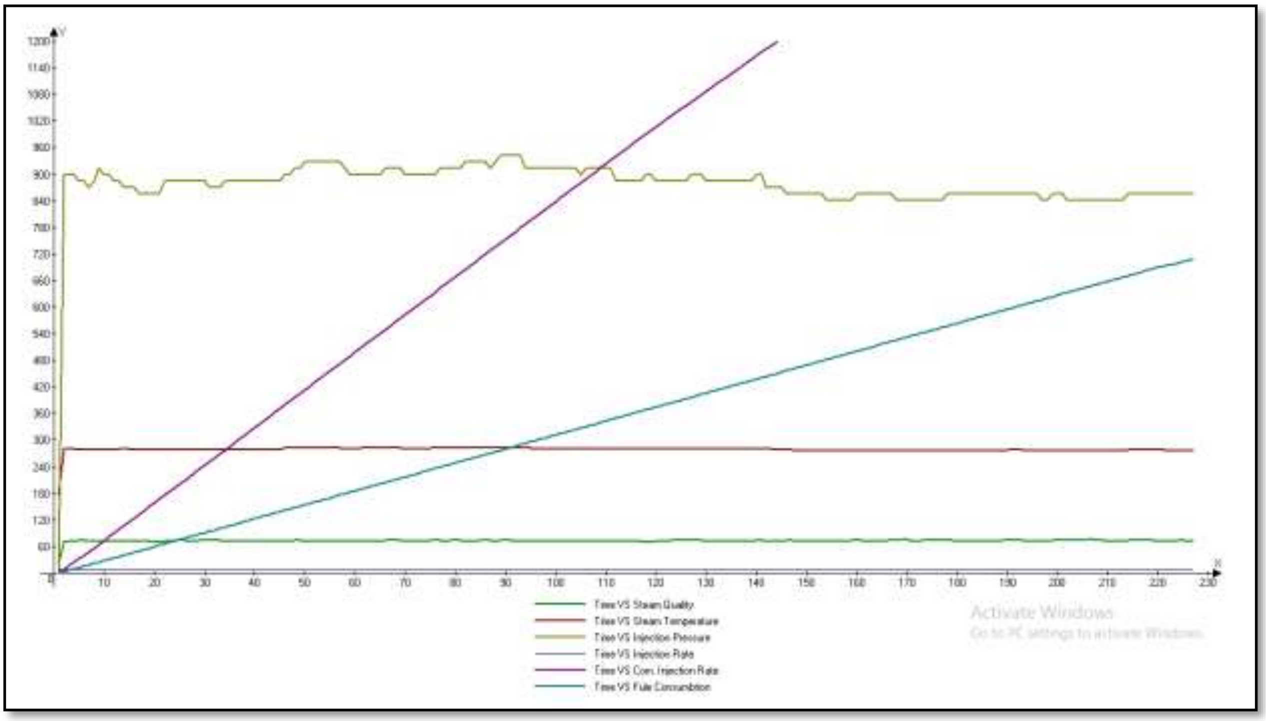


Figure 4.2 Cycle 2Performance Curve

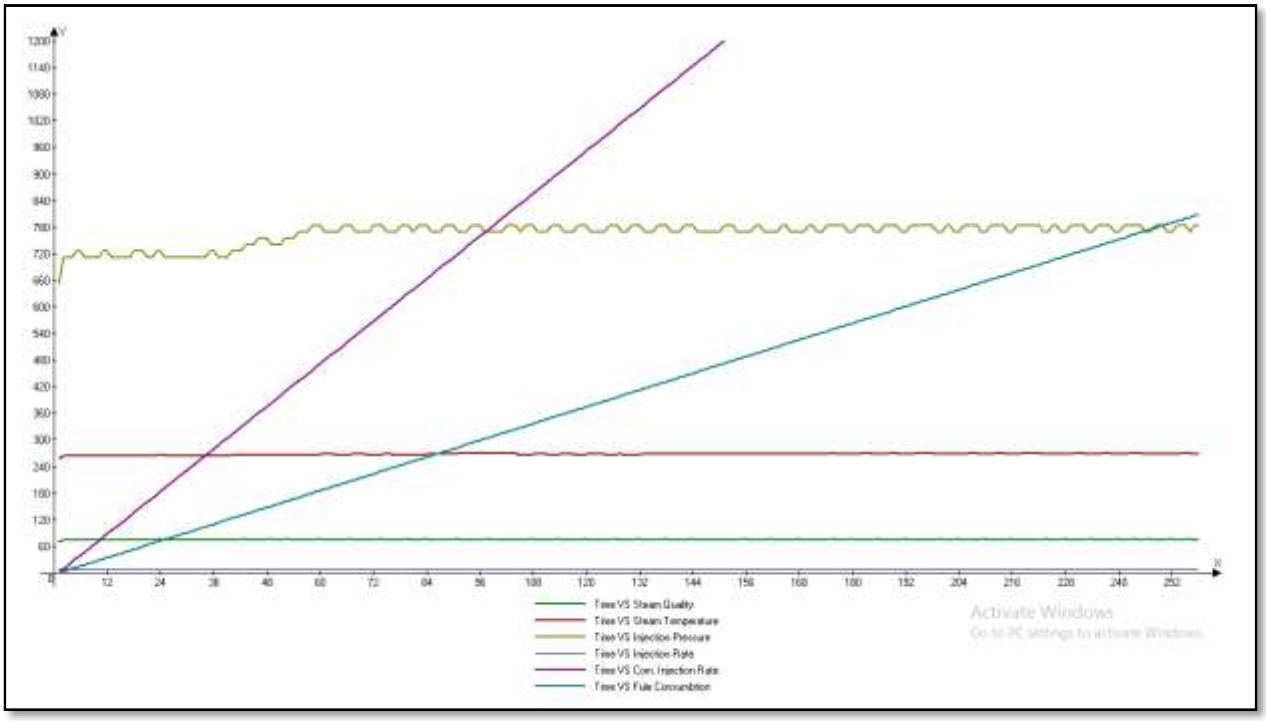


Figure 4.3 Cycle 3 Performance Curve

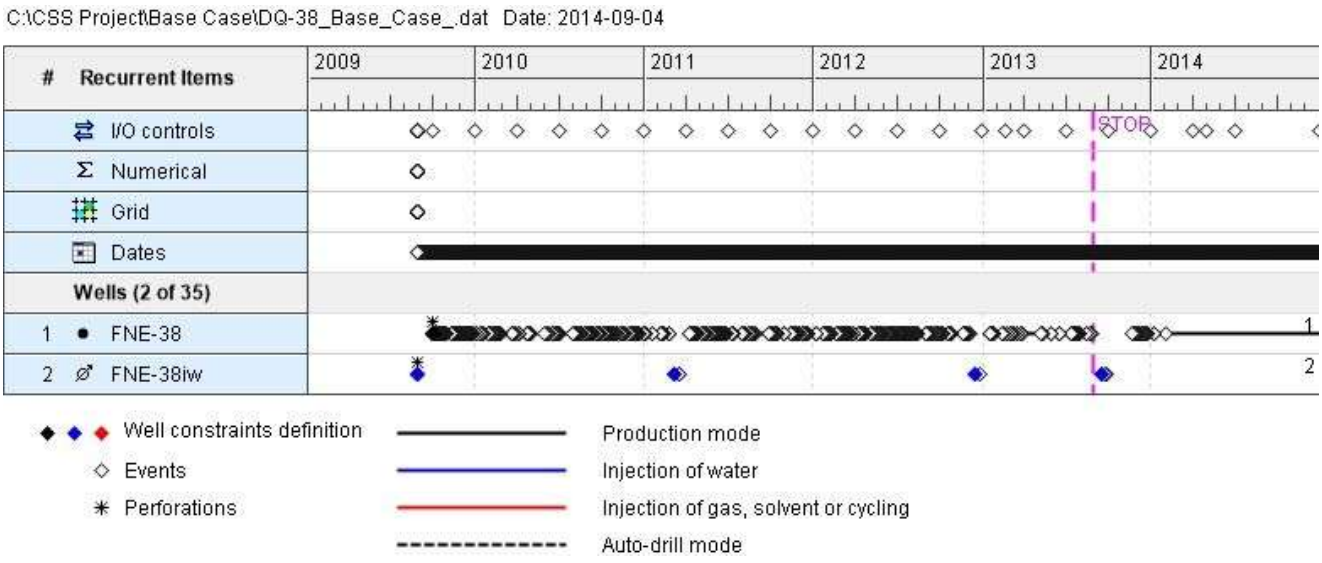


Figure 4.4 time line chart for the base case

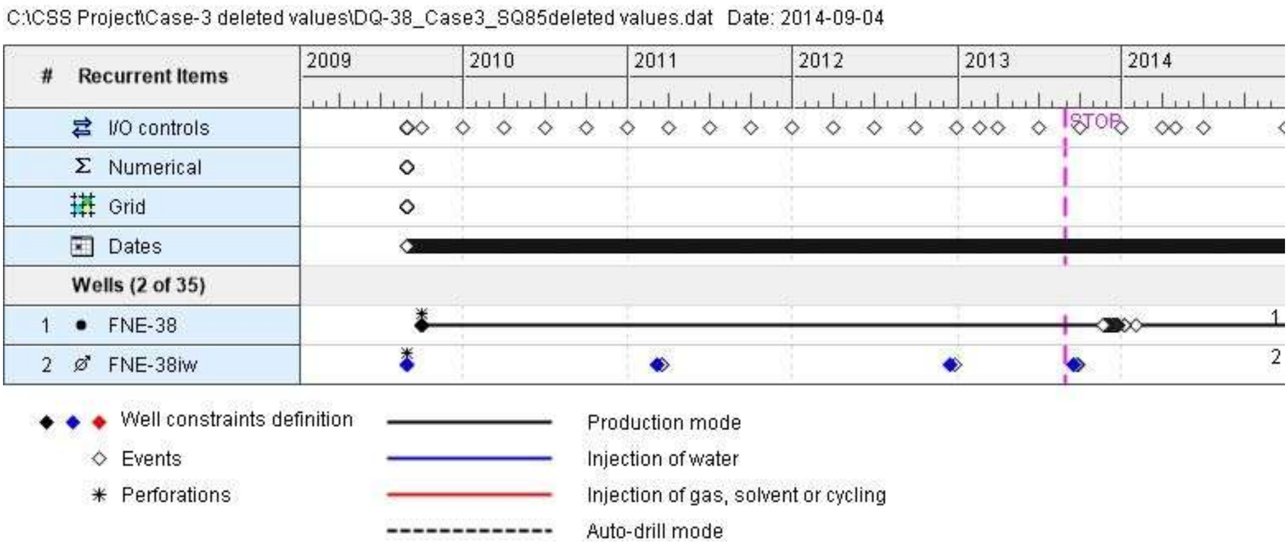


Figure 4.8 time line chart for the case 1 and case 2

Results:-

The base Case:-

The produced oil was 355.498 MBBL at almost 5 years of production and the cumulative water production was 19.124 MBBL.

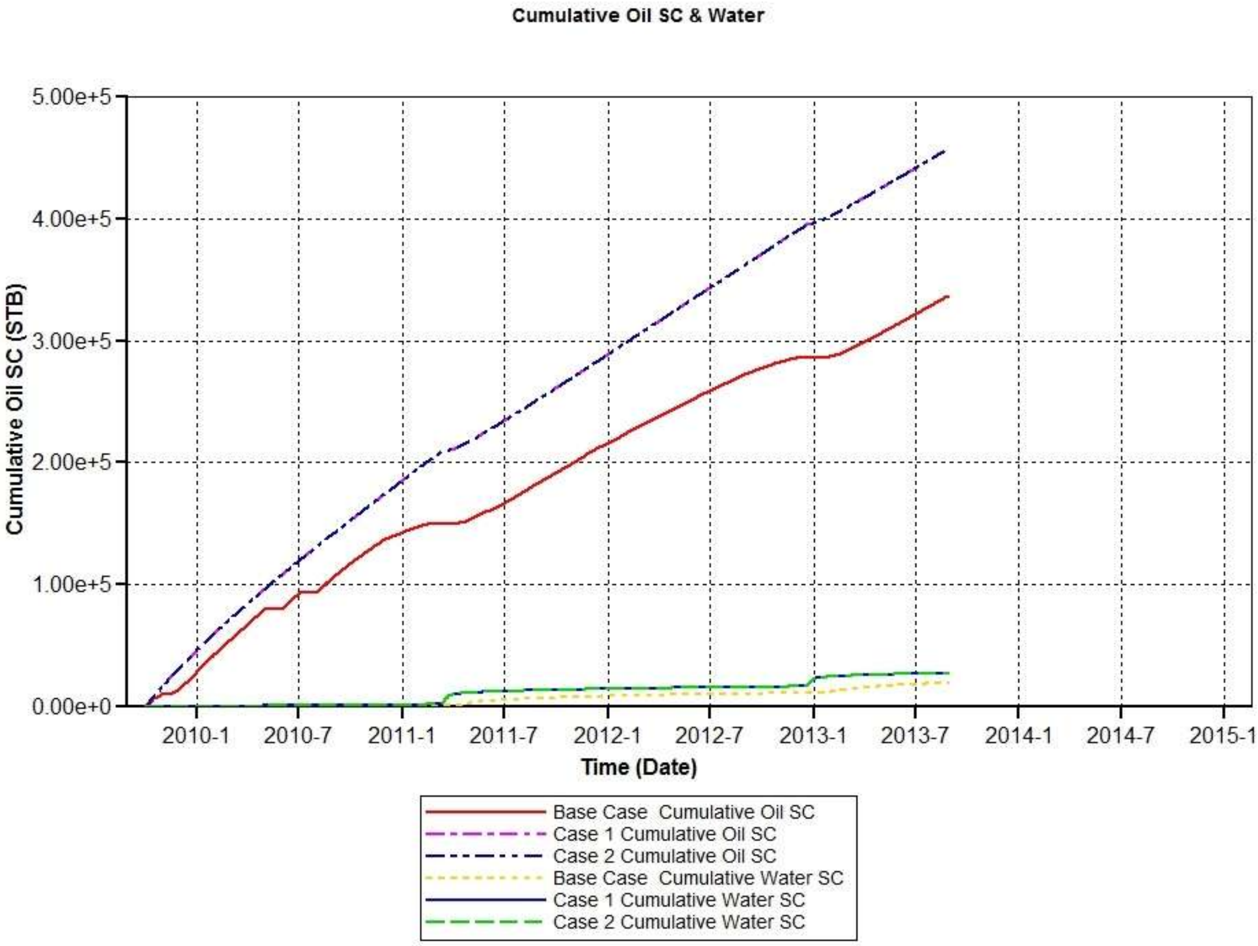
Case 1:-

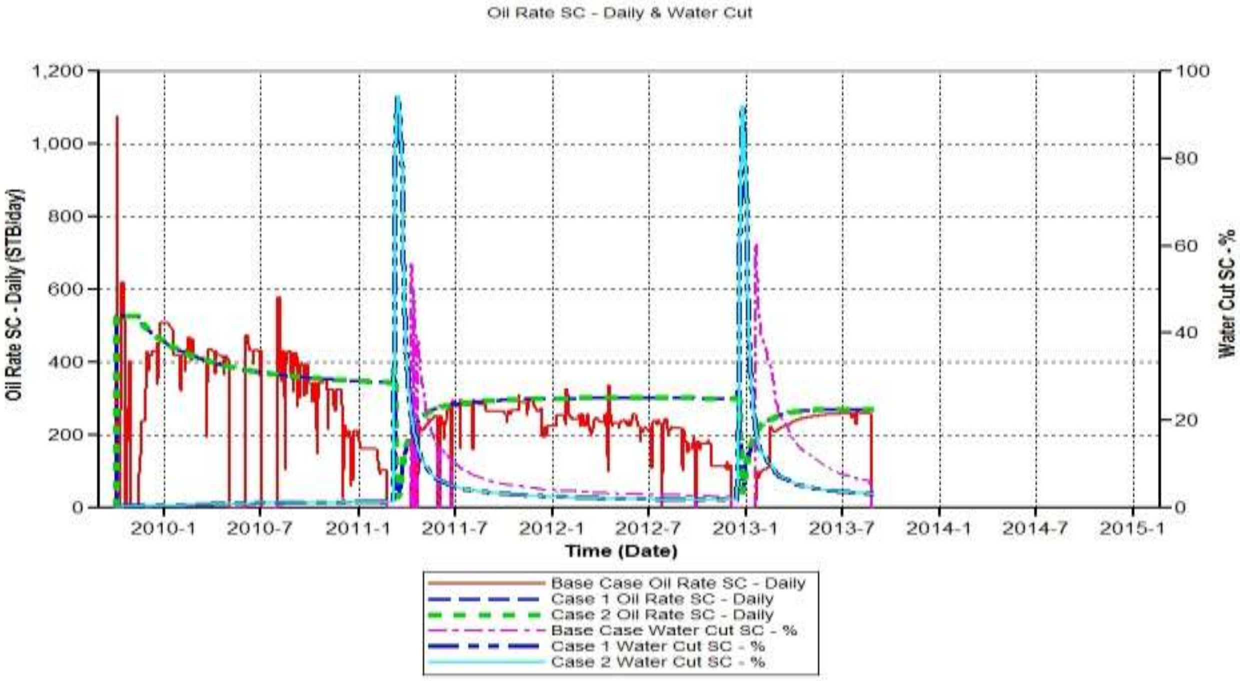
The produced oil was 477.717 MBBL at almost 5 years of production and the cumulative water production was 27.415 MBBL.

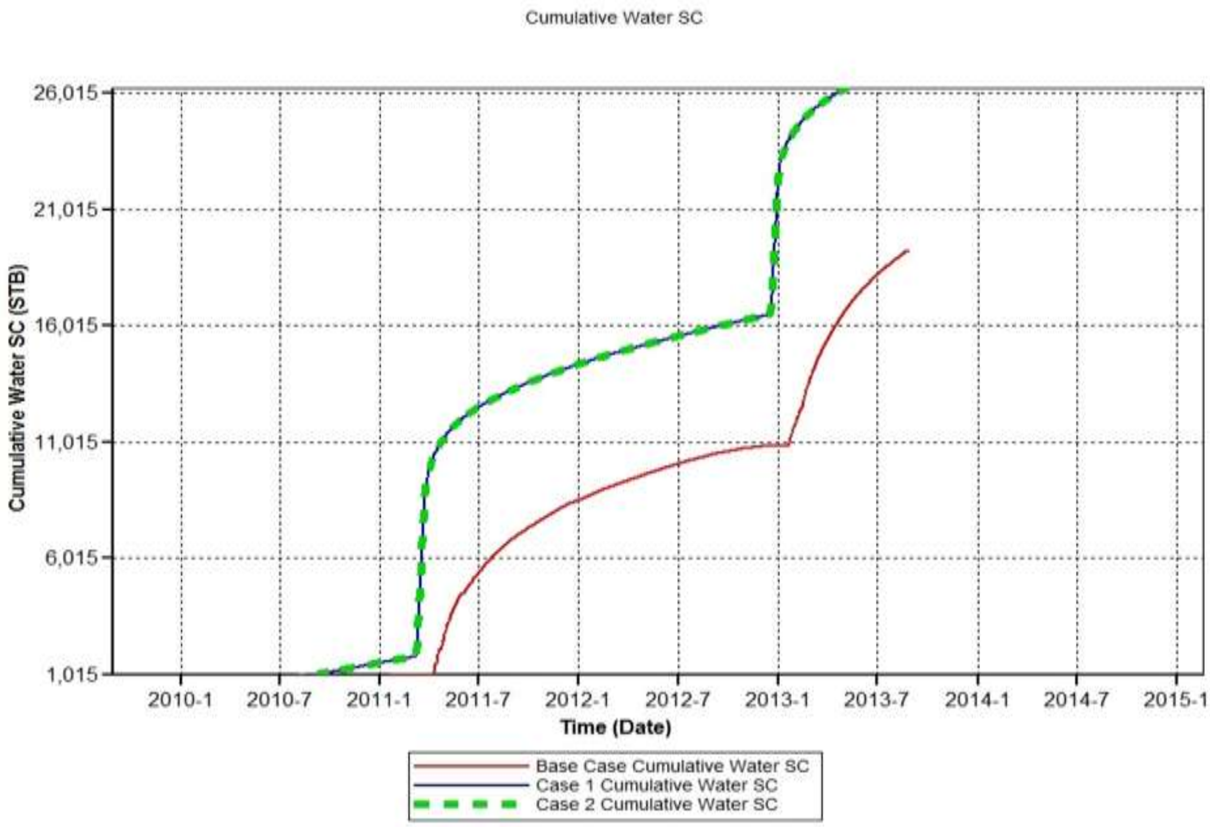
Case 2:-

Nothing was changed from case 1 even after increasing the temperature and the steam quality.

Graph## showing the results of the 3 cases and comparing between them, case1 and 2 are almost the same with no change at the cumulative oil.


Cumulative Oil SC & Water
5.00e+5
4.00e+5
3.00e+5
2.00e+5
1.00e+5
0.00e+0
Cumulative Oil SC (STB)
2010-1
2010-7
2011-1
2011-7
2012-1
2012-7
2013-1
2013-7
2014-1
2014-7
2015-1
Time (Date)
Base Case Cumulative Oil SC
Case 1 Cumulative Oil SC
Case 2 Cumulative Oil SC
Base Case Cumulative Water SC
Case 1 Cumulative Water SC
Case 2 Cumulative Water SC


Oil Rate SC - Daily & Water Cut
Oil Rate SC - Daily (STB/day)
Water Cut SC - %
1,200
1,000
800
600
400
200
0
100
80
60
40
20
0
2010-1
2010-7
2011-1
2011-7
2012-1
2012-7
2013-1
2013-7
2014-1
2014-7
2015-1
Time (Date)
Base Case Oil Rate SC - Daily
Case 1 Oil Rate SC - Daily
Case 2 Oil Rate SC - Daily
Base Case Water Cut SC - %
Case 1 Water Cut SC - %
Case 2 Water Cut SC - %


Cumulative Water SC
Cumulative Water SC (STB)
26,015
21,015
16,015
11,015
6,015
1,015
2010-1
2010-7
2011-1
2011-7
2012-1
2012-7
2013-1
2013-7
2014-1
2014-7
2015-1
Time (Date)
Base Case Cumulative Water SC
Case 1 Cumulative Water SC
Case 2 Cumulative Water SC

Analysis:-

From the results above the there is a 122.219 MBBLincrease in oil production and 8.201 MBBL in water production and the Vis-oil used in the boilers was 2947 Bbl.A of Vis-oil used to increase the temperature to 350 and the quality to 0.95 but with no return of any income from the oil. The table below summarizes the consumption of Vis-oil Cost:-

Table 4.3 consumption of Vis-oil Cost

Case #	Cycle No	Consumed Vis Oil BBl	Total Cost USD	Total Income USD
Base Case	**1st**	**2267.17**	**$226,717.00**	**$16,774,900.00**
	2nd			
	3rd			
Case-1	**1st**	**2947.32**	**$294,732.10**	**$22,885,850.00**
	2nd			
	3rd			
Case-2	**1st**	**3400.76**	**$340,075.50**	**$22,885,850.00**
	2nd			
	3rd			

CHAPTER FIVE

CONCLUSION

AND

RECOMMENDATIONS

CHAPTER FIVE

Conclusion and recommendations:-

1. As previously shown, cyclic steam stimulation is one of the most effective ways to increase the productivity and recovery factor in heavy oil production cases in Sudan and all over the world. One of the permanent factors of successful cyclic steam process is steam quality and steam temperature.
2. Steam quality affected by many factors such as heat losses and casing size. Heat losses can be through generators, surface flow line and wellbore, these heat losses can be minimized and relatively solved by many methods like insulating tubing or fill the annulus with gel crude oil to minimize the loss
3. From previous results we find that by using higher steam quality we can increase the production and recovery factor for the reservoir, but till certain values the recovery factors cannot been increase by the steam quality and temperature increase.
4. Diesel consumption is an important factor, cause at the boilers in order to increase the quality and temperature. But at case 2 it's only a cost due to no oil return.
5. A good optimization for steam injection parameters will lead to better operations and good results.
6. At the certain well there is no need to increase the quality above 85% and the oil income return will be over 6 M $.