Sand Control Selection for Wells in Tukau Field

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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BACHELOR OF ENGINEERING (Hons)
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Approved by,

____
(Assoc. Prof. Dr Razali Bin Hamzah)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NUR HAFIZ BIN AHMAD ZUBIR

ABSTRACT

The objective of this research was to determine the effective method of sand control for wells in Tukau field. In Tukau Field which was located offshore in Sarawak Baram Delta area, several wells were experiencing sand problem. In this research, TK-54L was selected as case study. The main problems with this well were significant reduction of gross liquid production which results in closing down the well. TK-54L well was completed using through tubing screen to prevent sand production but has shown to be ineffective. Therefore, a proper study was required to select an effective sand control method specifically for Tukau field.

The scopes of study were (a) examine on the sand sample, (b) study on the liquid and reservoir properties, (c) study on the available types sand control methods and (d) selection of appropriate sand control methods. Sand sample from TK-54L was used to determine the particle size distribution using sieve analysis. This test determined the uniformity coefficient which suggested several sand control methods. Precise selection done by analysis using existing computer simulation software named WellFlo to simulate the conditions obtained from options available based on the highest production rate.

The average sand uniformity coefficient obtained from particle size distribution test was 1.52. This value indicates that the distribution consist of highly uniform sand. The three available sand control methods considered from this research were metal mesh screen, wire wrap screen and gravel pack. Based on the results obtained, wire wrap screen shows the highest operating rate which is at 645.98 STB/day where it is 3.5 times more than the current sand control method using through tubing screen. This concludes that the wire wrap screen was selected for well TK-54L.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Sand production from unconsolidated formations in oil and gas fields has been a worldwide challenge for the petroleum industry for many decades. Sand influx into producing wells can cause reduce productivity and increase the expenses to prevent equipment erosion. Sanding results in high removal costs, equipment erosion, and significant maintenance expenditure. Even in a sand free or clean well where sand production rate is only a few pounds per day, erosion damage could be very severe at high production velocities. Sand management involves the development and monitoring of optimal sand control strategies that recognize the particular problems and constraints of the field but yet maximize the productivity and completion longevity. Understanding the sensitivity of productivity to different sand control methods is essential to the longer term economic success.

1.2 PROBLEM STATEMENT

In Tukau Field located at Sarawak Baram Delta Operations, several existing wells were experiencing sand production. Wells which were drilled and completed with sand control application failed to prevent sand production due to weak sand formation and gravel pack failure. The challenge was not merely to avoid or stop sand production, but to be able to maintain commercial well productivity after efforts to control sand are implemented. At the same time, the control method selected must be economically feasible to the well.

The well candidate selected for this research would be TK-54L. TK-54L completed in year 1987 with no gravel pack installed. The first sand production reported in 2001 where sand found accumulated in the separator. In 2005, the well was installed with through tubing screen which is metal mesh screen type but was found ineffective. Sanding still produced into the completion and the gross production of the well still low from expected. The study of this research is to determine the best sand control alternative for the well.

1.3 OBJECTIVES AND SCOPE OF STUDY

1.3.1 Objectives of Study

This project was essential to select the suitable sand control method for wells in Tukau field. The main objectives of this research are:

a) To identify the sand and fluid properties of Tukau field.
b) To select the most effective sand control alternative for wells in Tukau field.

1.3.2 Scope of Study

The scope of work of this project will emphasize on the best sand control method for wells in Tukau which will suits the above objective listed. Various parameters need to be considered such as:

a) Examine the sand sample.
b) Study on the reservoir and liquid properties.
c) Study on the types of available sand control methods.
d) Selection on the appropriate sand control methods.

The operating conditions shall be different for each sand control methods, so the effect of those parameters is vital towards permeability and good separation. At the same time, the control method selected must be justified by a reasonable payback time of the investment cost.

1.3.3 Significant of the Project

This project would emphasize on comparing the different types of sand control method based on skin value provided for each sand control method. The finalize results of this research should increase the performance of this well and overcome the sanding problem. Furthermore the results of this research could play a vital role in selecting different types of sand control method to reduce sanding problem which is suitable for the well and helps operator to reduce the cost of maintenance.

CHAPTER 2

LITERATURE REVIEW

2.1 SAND PRODUCTION PHENOMENA

Sand production and control remain as one of the critical challenges in reservoir management and production operations. Sand results in high removal costs, equipment erosion, and significant maintenance expenditure. The common causes of sand production are it can plug up upstream and downstream equipment such as completion tubing, tubing manifold, separator, pipeline and also access to enter wellbore. Excessive sand production in oil and gas industry may require production shut in. Sand production is not an exact science although theoretical analytical and numerical model exist. It is necessary to approach the problem with a good engineering based understanding of the limitations of the rock, well and reservoir data, and an appreciation of all the other sources of information that can be targeted on the problem [11].

2.1.1 Sand Failure

Sand failure occurs when stress acting on the wellbore exceeds the strength of the overlying rock in the reservoir. High velocity viscous fluid and water can mobilize the failed rock or weaken sand into the wellbore. There are two failure mechanism occur on the rock formation which is shear failure and tensile failure.

a) Shear failure

This type of failure occur when the shear stress acting on the rock exceed the shear strength where the rock can sustain. This phenomenon will result in the grain breakage of the rock into small particles where sand is produce. Excessive amounts of shear yielding can result in severe sand production problem and potentially catastrophic collapse of boreholes and perforations.

b) Tensile failure

Tensile stress occurs when the effective normal stresses become negative. Tensile stresses act to force a solid body apart. Tensile stresses develop in producing wells when a steep pressure gradient exists near the borehole or perforation wall. If they exceed the tensile strength of the rock, this result in tensile yielding where grain breakage occur on the rock and induced sand production [5].

2.1.2 Sand Particle Size

The sizes of particles that make up sand formation vary over wide range. Sand formations are generally divided into gravel, sand, silt, or clay, depending on the predominant size of particles within the formation. To describe the soils by their particle size, several organizations have developed particle-size classifications [3]. **Table 2.1** shows the particle size classifications for each grain size.

Table 2.1: Particle size classifications

Source	Particle Size (micron)			
	Gravel	Sand	Silt	Clay
Massachusetts Institute of Technology (MIT)	>2000	2000 to 60	60 to 2	<2
U.S. Department of Agriculture (USDA)	>2000	2000 to 60	60 to 2	<2
American Association of State Highway and Transportation Officials	76200 to 2000	2000 to 75	75 to 2	<2
Unified Soil Classification System	76200 to 4750	4750 to 75	Fines (i.e., silts and clay) <75	

2.1.2 Sand Particle Analysis

Particle analysis is the determination of the size range of particles present in a sand sample which is expressed as a percentage of the total dry weight. The general method which is used to find the particle-size distribution of sand is called *sieve analysis.*

Sieve analysis consists of shaking the sand sample taken from the well through a set of sieves that have progressively smaller opening. U.S. standard sieve numbers and the sizes of openings are given in the table below. **Table 2.2** shows the size of sieve opening respect to each sieve number.

Table 2.2: U.S. Standard sieve sizes

Sieve Number	Opening (mm)
4	4.75
5	4
6	3.35
7	2.8
8	2.36
10	2
12	1.7
14	1.4
16	1.18
18	1
20	0.85
25	0.71
30	0.6
35	0.5
40	0.425
50	0.355
60	0.25
70	0.212
80	0.18
100	0.15
120	0.125
140	0.106
170	0.09
200	0.075
270	0.053

The sieves used for soil analysis are generally 203 mm (8 in.) in diameter. To conduct sieve analysis, the soil first need to be oven-dry and all lump break into small particles. The soil is then shaken through a stack of sieves with openings of decreasing size from top to bottom. The mass of soil retained on each sieve is determined after the soil is shaken [3].

2.1.3 Particle-Size Distribution Curve

A particle-size distribution curve can be used to determine the following four parameters from the sand sample which are:

a) **Effective Size (D_{10}):** This parameter is the diameter in the particle-size distribution curve corresponding to 10% fines. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil

b) **Uniformity coefficient (C_u):** This parameter is defined as

$$C_u = \frac{D_{60}}{D_{10}}$$

………………..... (1)

Where D60 = diameter corresponding to 60% fines.

c) **Coefficient of gradation (C_z):** This parameter is defined as

$$C_z = \frac{D_{30}^2}{D_{60} \times D_{10}}$$

………………..... (2)

d) **Sorting coefficient (S_0):** This parameter is another measure of uniformity and is generally encountered in geologic works and expressed as

$$S_0 = \sqrt{\frac{D_{75}}{D_{25}}}$$

……………….... (3)

The percentage of gravel, sand, silt, and clay size particles present in a soil can be obtained from the particle distribution curve [3]. The result from this test will affect the selection of the suitable sand control method for Tukau field.

2.2 SAND CONTROL MANAGEMENT

If a well is to be completed in unconsolidated formation without a sand-control treatment, several completion practices should be followed to minimize the possibility of formation failure and subsequent loss of production. In general, these practices are intended to reduce the stresses caused per unit of production by enhancing the ability of the formation to produce fluid rather than sand. Sand management is a combination of competent prediction of sand. Limiting the sand to an acceptable level and occasionally involves handling sand at surface.

Sand management consists of competent prediction of sand production at rock surface, well and facilities. It has to limiting the sand production to a level which is acceptable to the wells and facilities. There are two practices that are used in controlling sand production.

2.2.1 Passive Control

Passive method incorporates well production techniques to minimize or eliminate the amount of sand produced and also to reduce the amount of produced sand without mechanical sand exclusion method. Depending on the risk associated with produced sand on well integrity and safety, sand prevention measures are usually applied in combination with monitoring and removal techniques and equipments [5].

Passive sand control method which are commonly practiced:

i) Reducing production rate
ii) Increase the number of perforations
iii) Increase perforation diameter
iv) Oriented and selective perforation
v) Drawdown control

2.2.2 Active Control

Active control method is widely used in combating sand production. This type of control consist two methods which are:

a) Mechanical method

Screens or gravel particles are used to retain sand inclusion from flowing into the well by bridging it at the formation face [2].

b) Chemical method

Chemicals are used to control sand inclusion by means of increasing the strength of the formation in order that sand particles will not loose from rock formation [2].

2.3 ACTIVE SAND CONTROL TECHNIQUES

There are two types of sand control techniques which are widely used in sand producing wells which are:

2.3.1 Mechanical Sand Control

The basic theory behind the mentioned sand control technique is that a control section is place around the wellbore to act as filter media. Formation particles migrating towards the wellbore are bridged of this controlled section. Below are the types of various mechanical sand control methods used:

a) Through Tubing Screen

This type of screen will be installed inside the tubing which is set at the tubing Sliding Sleeve Door (SSD) or tubing nipple. Usually it will be installed after sand accumulation reported inside the well. It works in open and cased holes, gravel and non gravel packed and horizontal and multilateral wells. Sand particles are not uniform in size, yet most sand control media have uniform pore sizes. The intelligent alternative is the engineered pore structure of PPM (Porous Metal Membrane) and PMF II (Porous Metal Fiber).

A controlled distribution of pore sizes gives these patented media the unique ability to extend screen service life while providing sand control across a broader range of particle sizes than all other sand control devices, which simply repackage conventional media. **Figure 2.1** shows the cross section of the through tubing screens. This cross section details also apply for pre-packed screens, woven and non-woven wire meshes, slotted liners and high-performance screens [14].

Figure 2.1: Weatherford through tubing sand screens cross section details

b) Gravel Pack

Another method of sand control which is mainly used is gravel pack. It involves placing accurately sized coarse-grain material to prevent the production of the finer-grained material while fluids are produced. A screen is located concentrically inside the layer of gravel to prevent gravel entry into the well. Recently several varieties of wire-wrapped screen have been used for this purpose. There are two types of gravel packs, Open-Hole Gravel Packs and Cased-Hole Gravel Packs [12]. Gravel pack diagram illustrated in **Figure 2.2**.

Requirements for successful gravel pack are:

i) Size the gravel to stop sand movement (but allow fluid to be produced).
ii) Pace the gravel in a tight pack, with radius of pack as large as possible.
iii) Maximize well productivity by minimizing formation damage.

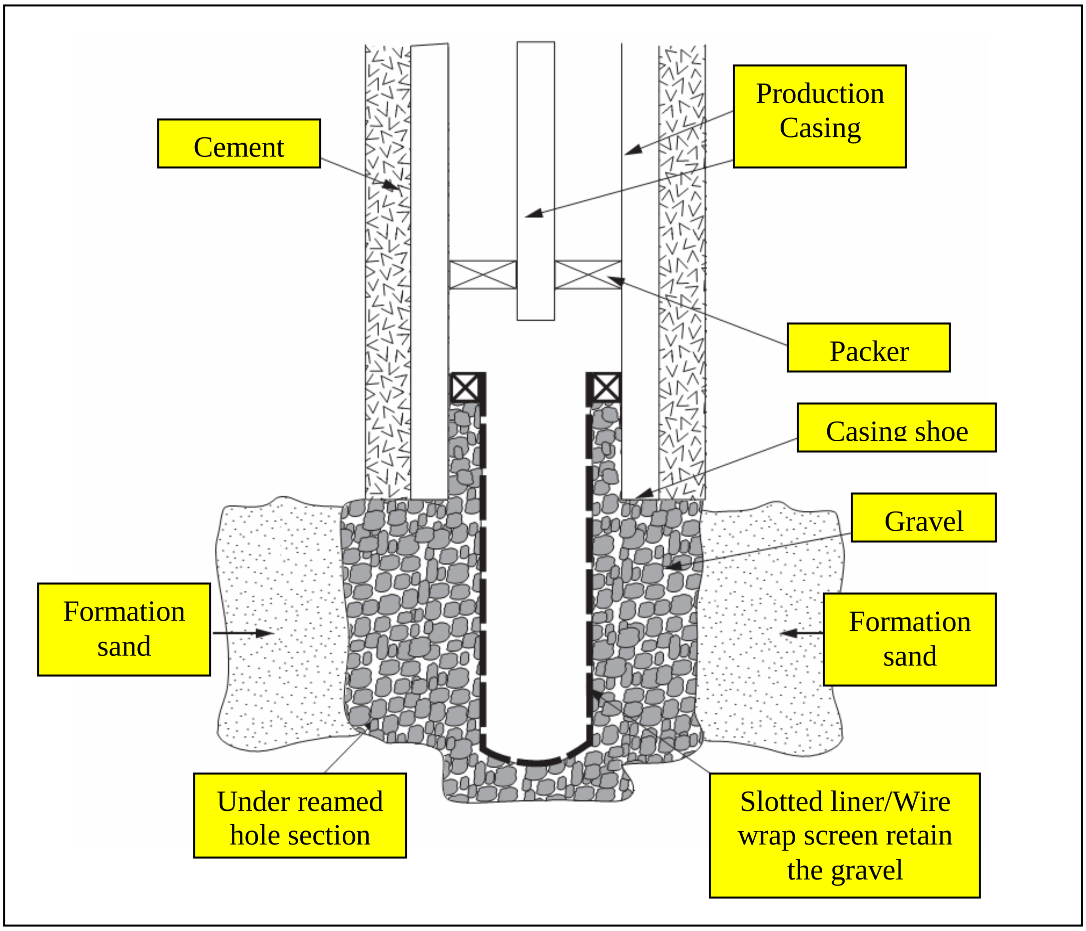

Figure 2.2: Gravel pack in opened hole well

c) Frac Pack

The frac-pack theory simply allows for the bypassing of near wellbore damage created during drilling, perforating and fluid management process. Initially companies drawn to frac and pack for higher production and lower drawdown. But after a few years producing their wells, operators are becoming more convinced that the reduced sand control failure rates are equally as important. For a successful frac & pack, it requires two different processes, tip screen-out (TSO) and fracture inflation and packing (FIP).

TSO occurs when the sand or proppant reach the tip of fracture tip at an early stage of the treatment, preventing the fracture from growing further. Further injection after TSO, the second stage, results in FIP. Combining these two stages is called ‘Frac’ and

‘Pack’. By bypassing the near wellbore damage and creating a stimulation effect for the completion, typical skin values of +25 to +30 for gravel pack completions have dramatically reduced to +2 for frac pack completions. Thus, with lower skin would results in higher PI and higher production rate [9].

d) Expandable Sand Screen (ESS)

A new expandable screen has been developed to provide a solution to prevent hole-sloughing and sand production in horizontal wells. Laboratory testing has shown that the expandable screen possesses acceptable collapse and burst resistance. Results of the system testing and the field trial have shown that the expandable screen can be a reliable method for controlling sand production. This technology offers a viable alternative to horizontal gravel packing, and in some environments, the expandable screen system may prove to be even more effective in controlling sand production than gravel packing.

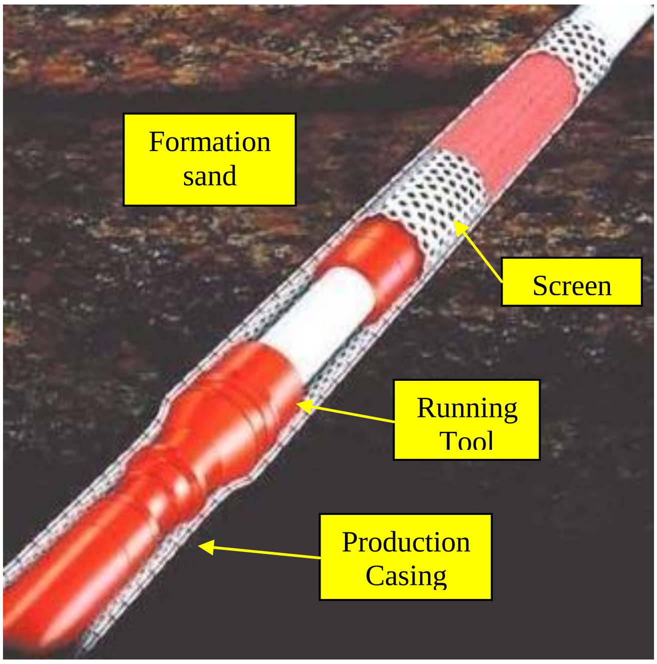

Figure 2.3: Expandable sand screen

The ESS expands when a tapered mandrel or cone is pushed, from the top down, through the screen inner diameter, causing both inner and outer layers to conform to the required diameter. During this expansion phase of setting the screen, the overlapping filter membrane expands by one layer (of three), sliding radially and axially over another until the final diameter is achieved, while remaining firmly sandwiched between the other two layers [7][8]. **Figure 2.3** shows an ESS being running in hole inside the wellbore.

2.3.2 Chemical Sand Control

Other alternative besides mechanical method is the chemical method. This method uses the injected fluid into the well to increases the strength around the wellbore or to remove the sand accumulated inside the well. Below are the types of chemical control method:

a) Sand Consolidation

Hydrocarbon formations often contain loosely and separate sandy material. In the production phases, sand tends to be carried along with the oil into the wellbore. The flow of sand can be prevented by consolidating or cementing together the sand particles of the formation around the well bore. The cementing has to be accomplished while maintain the flow channels between sand particles open.

In the first step of the process, resin is injected into the formation where it fully saturates the interstices between sand grains. Permeability is established in the second step by displacement of the excess resin from the interstices, thereby leaving a thin film of resin on the sand grains. In the third step, polymerization is activated by migration of catalyst from the inert fluid into the thin resin film on the sand. The process has the advantage that resin is placed and permeability is established before the resin is catalyzed [10].

2.4 CASE STUDY: TK-54L

The Tukau Field is located some 30 km offshore Sarawak, Malaysia in water depth of about 160 ft as illustrated in **Figure 2.4**. The field, discovered by TK-2 in 1966 found 235 ft net oil sand and 16 ft wet gas sand. After further seismic data acquisition and interpretation, six appraisal wells were drilled from 1973 to 1975 before the field could be commercially developed. Well TK-54L had been selected as a case study for this project.

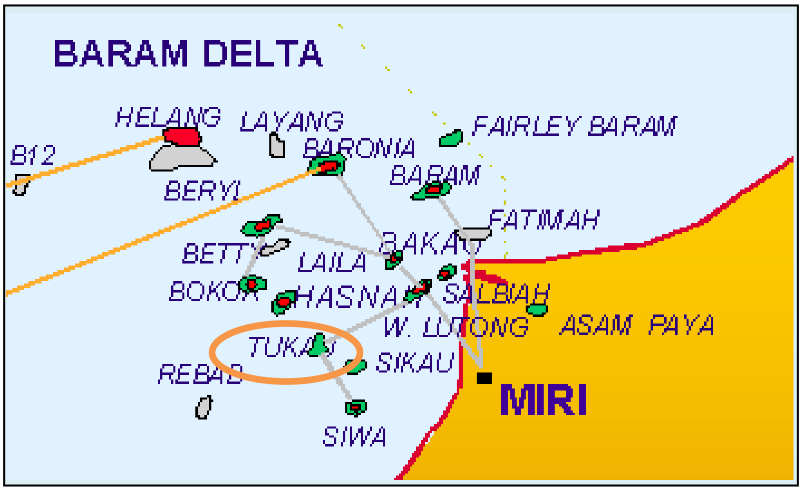

Figure 2.4: Location of Tukau Field in Baram Delta Operation

2.4.1 Well Candidate

Candidate selected for this research would be TK-54. This well is a dual string completion and was completed on 22 February 1987. Study will concentrate on the long string TK-54L since this string accumulates with sand production. It consist of three reservoirs namely 1A-G5.0 upper zone, 1A-H2.0/H3.0 middle zone and 2-J5.0/J6.0/J7.0/J9.0 for bottom zone (**Appendix 1**). Zone 1A-H2.0/H3.0 was perforated in year 2000. This well completion does not equip with Internal Gravel Pack (IGP). Currently the well installed with trough tubing screen called *Stratapac* with PMF 12/20 mesh wire since March 2005. **Table 2.3** summarizes the details for well TK-54L.

Table 2.3: TK-54L well details

Platform	TKJT-H
Well	TK-54L
Completion Type	Dual String
Production Mode	GLI (Gas Lift Injection)
Well Status	Idle
Production Zone a)	1A-G5.0
b)	1A-H2.0/H3.0
c)	2-J5.0/J6.0/J7.0/J9.0
Maximum Deviation	50.5 deg@3443ft BTHF

2.5 FURTHER ANALYSIS

Apart measure the performance of the well as explained above, there are further analysis need to be done to study the performance and economic value of the well. Among the studies are:

a) Formation Damage
b) Productivity Index (PI)
c) Net Present Value (NPV)

2.5.1 Formation Damage

Sometimes a well completion can cause damage to the formation of the reservoir. There are analysis needs to be carry out to determine the level of formation damage. The studies are skin analysis and pressure transient analysis

There are 2 major types of skin which are:

a) Mechanical Skin

Caused by a reduction in absolute permeability of the formation, reduction in the absolute permeability of the produce fluid, or an increase in the viscosity of the produced fluid, i.e. actual physical damage to the formation.

b) Apparent Skin

Due to the development of non radial flow around the wellbore resulting from the wells production having to flow through a smaller vertical thickness near the well than away from the well.

Total Skin is obtained from a pressure transient test:

$$S = \frac{h_t S_d}{h_p} + S_p$$

……………...... (4)

S = Total Skin

h_t = Height of the entire formation interval (feet)

h_p = Height of the perforated interval (feet)

S_p = Apparent Skin Factor

S_d = Mechanical Skin Factor

2.5.2 Productivity Index

The Productivity Index, J, is a measure of the flow capacity of a well per unit reservoir drop across the formation (drawdown). The PI is used to compare well performance before and after completion and well workovers, and after water breakthrough.

$$J = \frac{q_0}{P_{RES} - P_W}$$

………………..... (5)

J = Productivity Index (bbl/d/psi)

q_o = Flowrate (bbl/d)

P_{RES} = Average reservoir pressure (psi)

P_{wf} = Flowing bottomhole pressure (psi)

CHAPTER 3
METHODOLOGY

3.1 PROCEDURE IDENTIFICATION

Well TK-54L from Tukau field was selected as a case study. Sand sample from the well was collected to run Particle Size Distribution (PSD) test to ensure the mean size and distribution of sand. The particle shape was analyzed using Scanning Electron Microscope to study the characteristics. The distribution curve determined the suggested types of sand control method and sand screens that used. Calculation on the production performance was done using computer software named WellFlo to compare between the available sand control methods and finally the selection of the best methods to suits the objectives listed. The Gantt Chart for this project is available in **Appendix *2***.

This project was divided into four main methodologies summarize in **Figure 3.1**.

3.1.1 Literature Review

a) Literature review of types of sand control method.
b) History on main sanding cases in Tukau.
c) Properties of formation.
d) Discuss with Tukau Production Technologist.

3.1.2 Laboratory Test and Experiment

a) Particle Size Distribution (PSD) Test on sample using Particle Size Analyzer Machine.
b) Study on particle shape using Scanning Electron Microscope (SEM)

3.1.3 Computer Modeling and Simulation Work

a) Familiarization of available computer modeling software.
b) Calculate production performance through sand screens.
c) Gathering data of a specific reservoir with sanding cases.

3.1.4 Data Analysis and Report Preparation

a) Study the screens effectiveness in minimizing sanding problems.
b) Build clear comparisons based on the simulation between simulated sand-control screen completion
c) Prepare final report.

Summary of Methodology

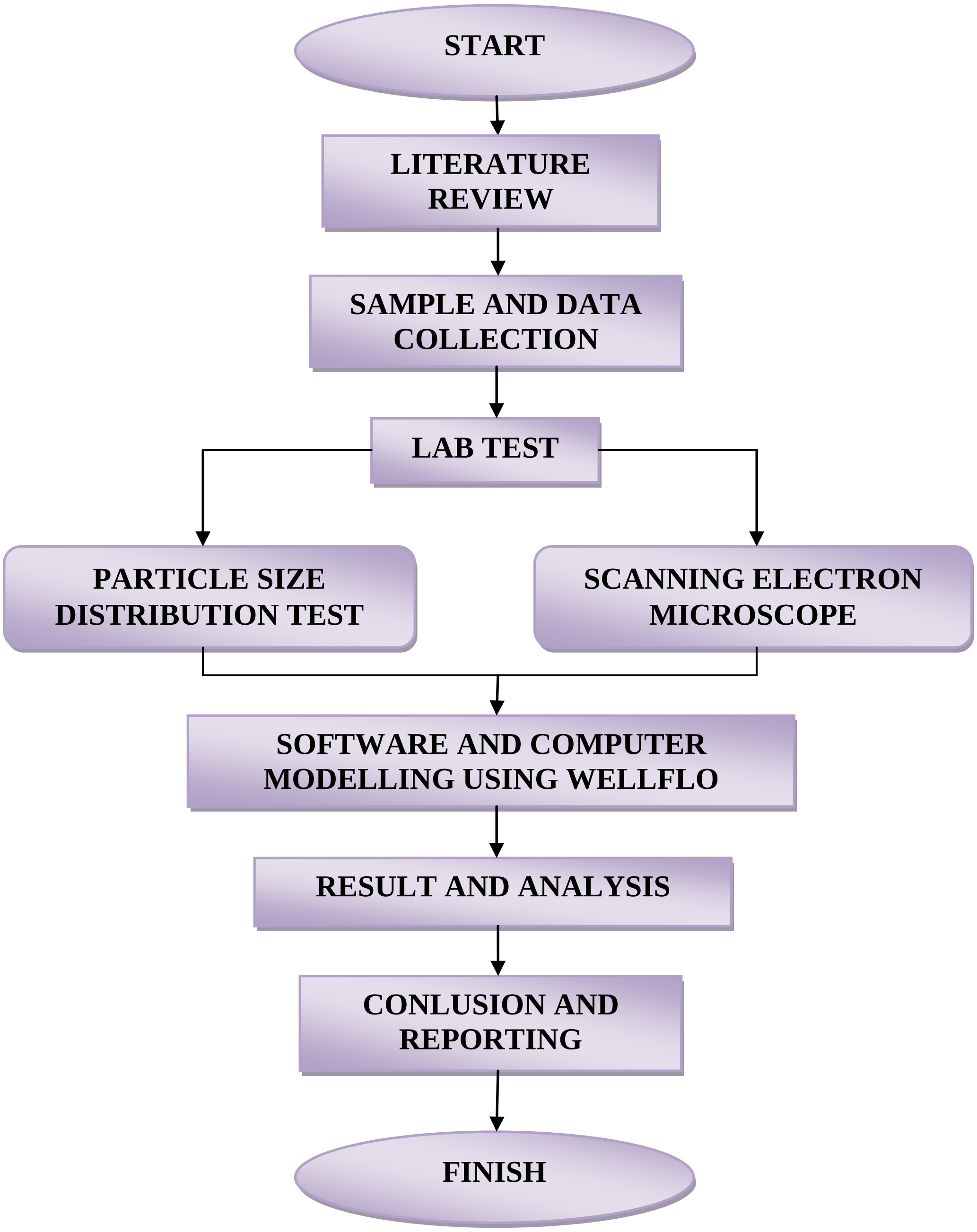

Figure 3.1: Project flowchart

3.2 TOOLS AND EQUIPMENT REQUIRED

The equipment required for this research would be the particle size analyzer or sieving machine which is use to run the particle size distribution test and the Scanning Electron Microscope (SEM) to analyze the particle shape. This project also required computer software which was used to simulate and model the performance called WellFlo^{TM}. Other tools used for this project are the basic software used in computers to produce the documentations.

3.3 SCANNING ELECTRON MICROSCOPE

The scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity.

The types of signals produced by an SEM include secondary electrons, back scattered electrons (BSE), characteristic x-rays, light, specimen current and transmitted electrons. These types of signal all require specialized detectors for their detection that are not usually all present on a single machine. The signals result from interactions of the electron beam with atoms at or near the surface of the sample. In the most common or standard detection mode, secondary electron imaging or SEI, the SEM can produce very high-resolution images of a sample surface, revealing details about 1 to 5 nm in size. Due to the way these images are created, SEM micrographs have a very large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample [17].

3.4 PARTICLE SIZE DISTRIBUTION TEST

Particle size distribution test was used to determine the physical makeup of samples specifically the size in a sample. Commonly particle size distribution will measure zeta potential, a measure of the magnitude of the repulsion or attraction between particles [8]. This test will use the sieving method. Sieving is an old fashioned, but cheap and readily usable technique for large particles, such as those found in mining and some food processing applications. It allows separation into some size bands if required. Using this technique, it is not possible to measure sprays or emulsions, and dry powders under 38mm are difficult. The longer the measurement times the smaller the answer, as particles orient themselves to fall through the sieve.

The method use for this particle size distribution test is commonly using sieving analysis. Petronas Research Sdn. Bhd. and Sarawak Shell Berhad are currently using sieve analysis for the test. Sieve analysis requires 50g to 100g of the sand sample.

3.4.1 Sieve Analysis Procedure

The particle size distribution of a sample is determined by shaking the sample in a prescribed manner through an appropriate succession on test sieves. Portion retained on each sieve are collected separately and oven dried before the mass retained on each sieve is measured [3].

i. Determine the mass of sand retain on each sieve (i.e., $M_1, M_2, \ldots M_n$) and in the pan (i.e., M_p).
ii. Determine the total mass of sand: $M_1 + M_2 + M_i + \ldots + M_n + M_p = \sum M$.
iii. Determine the cumulative mass of soil retained above each sieve. For the *i*th sieve, it is $M_1 + M_2 + \ldots + M_i$.
iv. The mass of soil passing the *i*th sieve is $\sum M - (M_1 + M_2 + \ldots + M_i)$.
v. The percent of soil passing the *i*th sieve is:

$$F = \frac{\sum M - (M_1 + M_2 + \ldots + M_i)}{\sum M} \times 100$$

.... (6)

Once the percent finer for each sieve is calculated, the calculations are plotted and referred to as the particle size distribution curve discussed in chapter 2.

3.5 WellFlo™ SOFTWARE

WellFlo™ is a computer modeling and simulation software use to design, model, optimize and troubleshoot naturally flowing or artificially lifted individual oil and gas wells.

3.5.1 Introduction

WellFlo™ systems analysis software is a powerful and simple to use stand alone application to design, model, optimize and troubleshoot individual oil and gas wells, whether naturally flowing or artificially lifted. With this software, the engineer builds well models, using a guided step-by-step well configuration interface. These accurate and rigorous models display the behavior of reservoir inflow, well tubing and surface pipeline flow, for any reservoir fluid. Using WellFlo™ software results in more effective capital expenditure by enhancing the design of wells and completions, reduces operating expenditure by finding and curing production problems and enhances revenues by improving well performance [15].

3.5.2 Application

The WellFlo™ software package is a single well tool which uses nodal analysis techniques to model reservoir inflow and well outflow performance. WellFlo™ modeling can be applied to designing, optimizing and troubleshooting individual wells. Specific applications for which the software can be used include:

a) Well configuration design for maximum performance over life of well
b) Completion design to maximize well performance over the life of well
c) Artificial lift design
d) Prediction of flowing temperatures and pressures in wells and flowlines and at surface equipment for optimum design calculations
e) Reservoir, well and flowline monitoring
f) Generate vertical lift performance curves for use in reservoir simulators

As well as these applications, the software has two key internal sub-applications which can be used stand alone from the rest of the program and offer the user an excellent engineering toolkit.

a) Detailed reservoir inflow performance modeling
    i. Multiple completion and perforation models
    ii. Detailed skin analysis

b) Detailed fluid PVT modeling
    i. Black oil models for oil and gas
    ii. Equation of State models for condensate and volatile oil
    iii. Laboratory data matching
    iv. Fluid behavior prediction

CHAPTER 4
RESULTS AND DISCUSSION

4.1 SAND PRODUCTION FACTORS

4.1.1 Perforation Density

The effect of perforation density on unconsolidated formation failure revealed that sand problems in untreated intervals could be minimized by increasing the perforation density. **Figure 4.1** shows the result of 691 untreated completions in 3 offshore Louisiana fields. The cumulative production, before the sand problem occurs at 4-shots/ft exceeds 285,000 bbl of fluid. This represents a seven-fold improvement in total production over intervals perforated with only 1-shot.ft. Although 2-shots/ft were far more successful than 1-shot/ft completions, the average production life is only 66% that of a 4-shots/ft completion. **Figure 4.2** shows the effect of on sand production by applying higher shot perforation density on well completion [16].

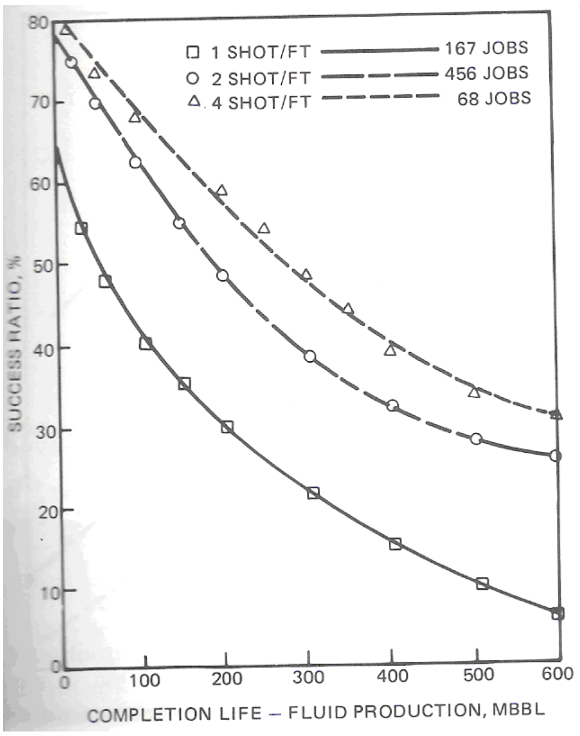

Figure 4.1: Effect of perforation density on successful production life

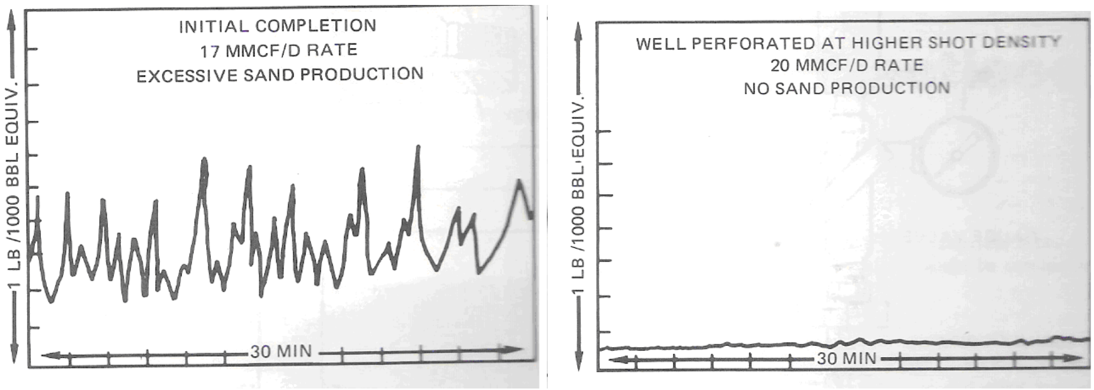

Figure 4.2: Response of sonic probe before and after perforation

The effect of increasing the perforation density of the completion will lower the risk of sand production by. Increasing perforation density will reduce flow from each perforation to achieve the same total production. At reduce flow from each perforation, the pressure differential between formation and tubing will reduce, hence less disturbance to the sand in formation.

4.1.2 Interval Length

The frequency of sand problems in wells completed without sand-control measure decreases significantly with increasing length of exposed interval. Result from **Figure 4.3** shows total production in completion intervals only 4 ft long has been <60,000 bbl of fluid. Completion intervals of 5-6 ft maintained an average production of 180,000 bbl of fluid. About three-fold improvement. Interval lengths of 7-12 ft produced an average of five times the fluid of 4 ft intervals before sand problem occurred. Data for interval length >12 exhibit very little improved performance compared with the 7-12 ft group [16].

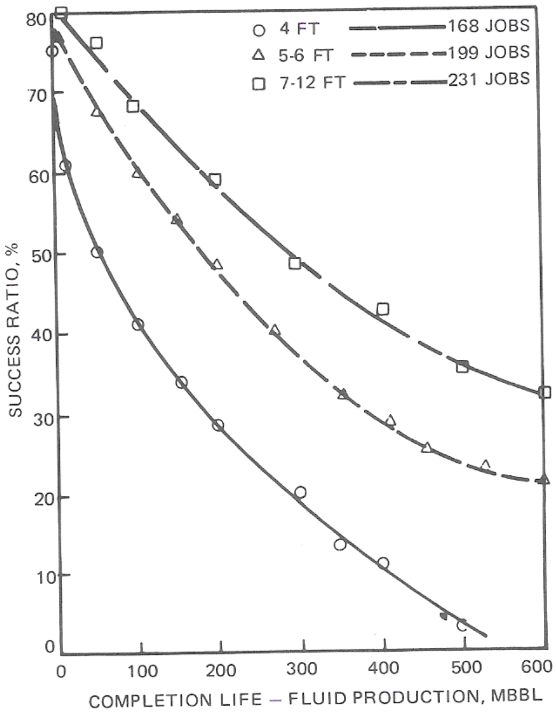

Figure 4.3: Effect of completion length on successful production life

The increase of interval length of the perforation can lower the sand production entering the wellbore. The effect is similar to the perforation density. Increasing the perforation interval reduce the pressure difference between formation and tubing, hence less disturbance to the formation resulting in reduced sand production. Completion intervals of 5-6 ft able to maintained an average production of 180,000 bbl of fluid.

4.1.3 Sand Quality

Sand problems are more severe in dirty, fine-grained formation rather than in relatively clean, well-developed sands. The data verified that high-permeability formations (cleaner and larger grain sand) were produced more successfully without sand control technique than low-permeability formation zones (smaller grain sand with streak of shale). **Figure 4.4** shows the effect of reservoir permeability on successful production life and the effect of permeability-thickness product [16].

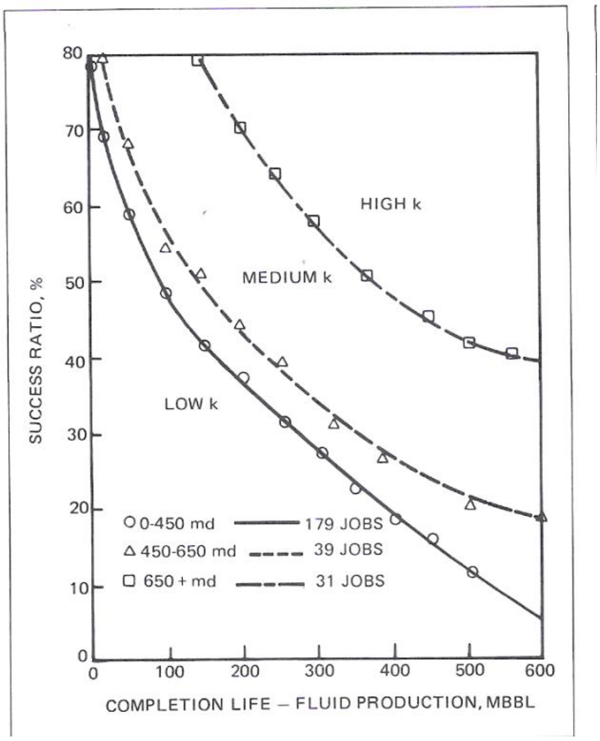

Figure 4.4: Effect of permeability-thickness product on successful production life

A high permeability formation which is cleaner and larger grain sand were produced more successfully without sand control technique than low permeability formation zones which contain smaller grain sand with streak of shale.

4.2 WELLTEST ANALYSIS

Welltest result which taken on 22nd June 2007 shows gross production from the test indicates low number as seen in **Table 4.1**. The well was suspected clogged with sand at the *Stratapac*. It flows from zone 1A-H2/H3 and sand production is suspected produce from this reservoir. First sand detection from the well test occurs on 7th September 2004 and this result into beaning downs the well to 20/64"choke size. Watercut was at at 30% and the gross production was acceptable.

Table 4.1: TK-54L welltest result

DATE	ZONE	BEAN (in.)	GROSS (STB/d)	WC (%)	NET (STB/d)	GASOUT (Mscfd)	FOR GAS	GASLIFT (Mscfd)	GOR (scf/stb)	FTHP (psig)	CHP (psig)
7-Sep-04	1A-H2/H3	20	162	30	114	306	12	294	107	300	540
2-Mar-05	1A-H2/H3	32	4.3	0	4.3	750	424	326	98605	140	580
22-Jun-07	1A-H2/H3	36	229	35	149	827	76	751	509	200	610

First sand control screen, *Stratapac* was installed on 28th February 2005 at SSD (Sliding Sleeve Door) at 4099ft BTHF. Welltest result on 2nd March 2005 was rejected due to low amount of gross. It is suspected the screen was pack with sand. The latest wireline intervention on 9th March 2008 record the HUD (Held Up Depth) was at 3852ft BTHF. This value shows an increasing amount of sand accumulation than previous numbers which is the HUD at 4228ft BTHF on 25th February 2005 shown in **Appendix 3**.

4.3 SAND PRODUCTION IDENTIFICATION

Crude oil analysis had been done on wells in Tukau field. This analysis is specifically to examine the sand presence in the crude oil. The quantity of sand contains in the crude oil is measure by pptb (pound per thousand barrel). The minimum quantity of sand accepted for this analysis is below 10 pptb. In 2007, TK-54L crude oil analysis indicates that the sand quantity exceed the maximum condition which it reach 77 pptb. The volume of sand obtain from the analysis is 5 litres. **Table 4.*2*** shows the crude oil analysis on wells for Tukau field in August 2007.

Table 4.2: Crude Oil Analysis Report on Tukau Wells

WELL	SAMPLE TAKEN		SAMPLE	SAND	Volume	REMARK
	DATE	TIME (hrs)	RECEIVED	(PPTB)	(litres)	
TK 54L	28/07/2007	1015	10/08/2007	77	5	HIGH SAND CONTENT
TK 48L	01/08/2007	1100	10/08/2007	1	5	
TK 51L	01/08/2007	1030	10/08/2007	1	5.5	
TK 56L	06/08/2007	NA	10/08/2007	1	5	
TK 56S	06/08/2007	NA	10/08/2007	1	5.5	
TK 55S	05/08/2007	1000	10/08/2007	1	5.5	
TK 45S	05/08/2007	1330	10/08/2007	1	4	
TK 43L	01/08/2007	1045	10/08/2007	1	4	

4.4 SAND PARTICLE SHAPE

The particle shape of sand had been examined by using Scanning Electron Microscope (SEM) to determine the angularity and sphericity of sand grains. **Figure 4.5** shows the shape of the sand particles were classified as low sphericity and very angular in shape. From **Figure 4.1**, the shape of the sand particles observed on this sand is more likely to fall under low sphericity and angular characteristics.

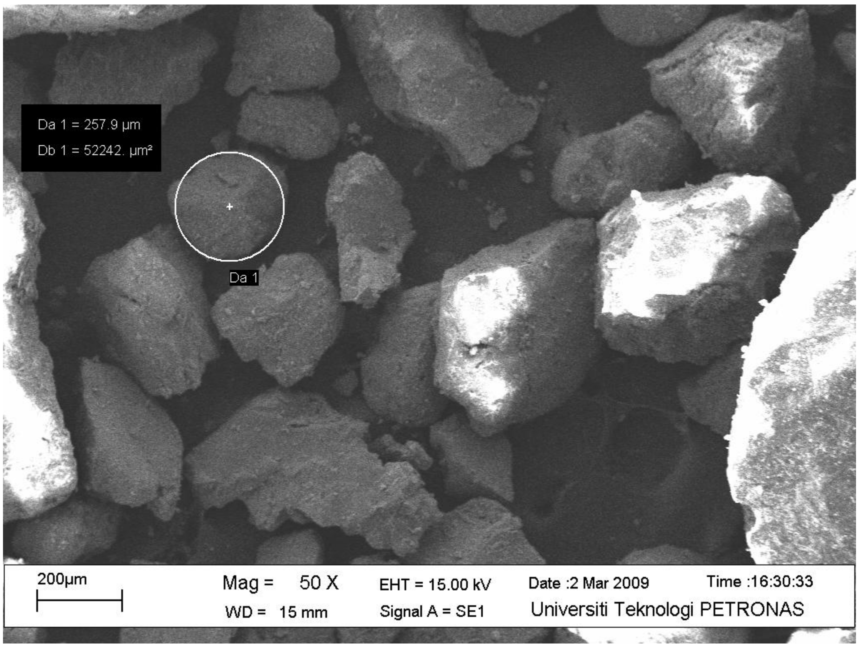

Figure 4.5: Electron micrograph of some fine subangular and subrounded quartz sand

4.5 PARTICLE SIZE DISTRIBUTION

Since the sand sample from TK-54L could not be obtained due to operation constraint, the test was completed by using the available sample which was from TK-20L to avoid any delays on this project. The sample should not differ that much from the actual sample from TK-54L since it is still from the same southern cluster reservoir. **Table 4.3** shows the particle size distribution result for TK-20L.

Table 4.3: Particle Size Distribution for TK-54L

Sieve no.	Sieve opening (mm)	Weight retained (g)	% weight retained (%)	Cumulative weight retained (%)
30	0.600	0.00	0.00	0.00
40	0.425	0.00	0.00	0.00
60	0.250	19.01	19.02	19.02
80	0.180	34.83	34.85	53.88
100	0.150	22.90	22.92	76.79
120	0.123	15.19	15.20	91.99
140	0.100	4.96	4.96	96.96
200	0.075	2.39	2.39	99.35
270	0.053	0.38	0.38	99.73
325	0.045	0.06	0.06	99.79
	< 0.045	0.08	0.08	99.87
Total		**99.80**	**99.87**	
Weight of sand sample (g) :		**99.93**		

This experiment was completed by using ten units of sieve opening ranging from 0.045 mm to 0.600 mm. The total weight of the sample use for this experiment was 99.93 g. The result of the particle distribution test was plotted shown in **Figure 4.6**.

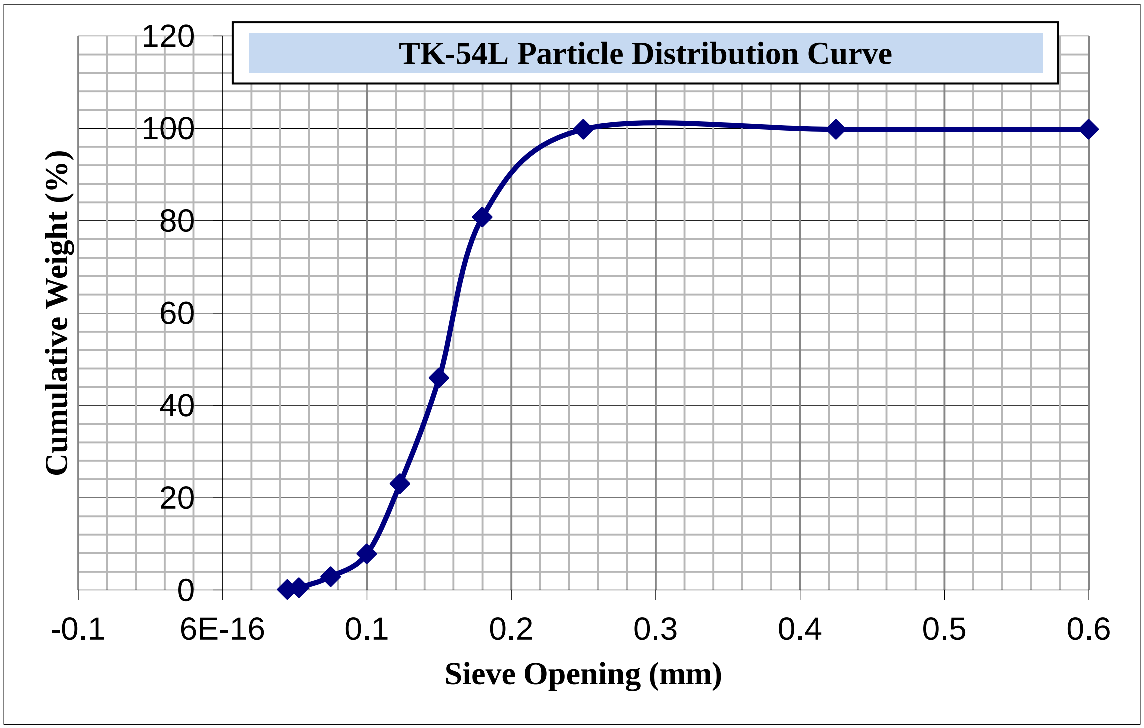

Figure 4.6: Particle Size Distribution for TK-54L

From **Figure 4.6**, we can find the uniformity coefficient by using equation 1 in chapter 2. The coefficient is defined as the the ratio of the sieve size that will permit passage of 60% of the media by weight to the sieve sieve size that will permit passage of 10% of the media material by weight.

$$Uc = \frac{D_{60}}{D_{10}}$$

$$Uc = \frac{160\mu}{105\mu}$$

$$Uc = 1.52$$

The uniformity coefficient for the sample is 1.52. This coefficient can determine the range of distribution for the sample by looking at the **Table 4.4** below.

Table 4.4: Uniformity Coefficient Classification

Uc	Sand Distribution
Uc < 3	Highly Uniform Sand
3 < Uc < 5	Uniform Sand
5< Uc < 10	Non-Uniform Sand
Uc > 10	Highly Non-Uniform Sand

By using Table 4.4, the distribution of the sample indicates it was highly uniform. This represent most of the grains are in the same sizes. There are three suggested sand control methods that can be use for this distribution range would be metal mesh screen, wire wrap screen and gravel pack according to **Appendix 4** where we use D_{50} = 150 μ from **Figure 4.6**.

4.6 COMPUTER SIMULATION

The three sand control methods obtained from the particle size distribution test will be analyze using computer software named WellFlo. This software will determine the most suitable sand control method for well TK-54L based on the highest operation rate which the well can produce from those three suggested sand control methods. There are several data required before start to model the well. The data are reservoir pressure data, test point data, well deviation, and equipment data prior matching the production from latest welltest result.

4.6.1 Current Performance

The well was modeled by referring to the latest update from the wellbore diagram since the last wireline intervention is in 2007 (Refer to **Appendix 5**). The test was run with two inactive gas lift valve at 3011ft bthf and 3330 ft bthf. The production for the test is only from reservoir 1A-H2.0/H3.0 while reservoir 1A-G5.0 was inactive. **Figure 4.6** shows the inflow vs outflow performance curve for the current condition of TK-54L.

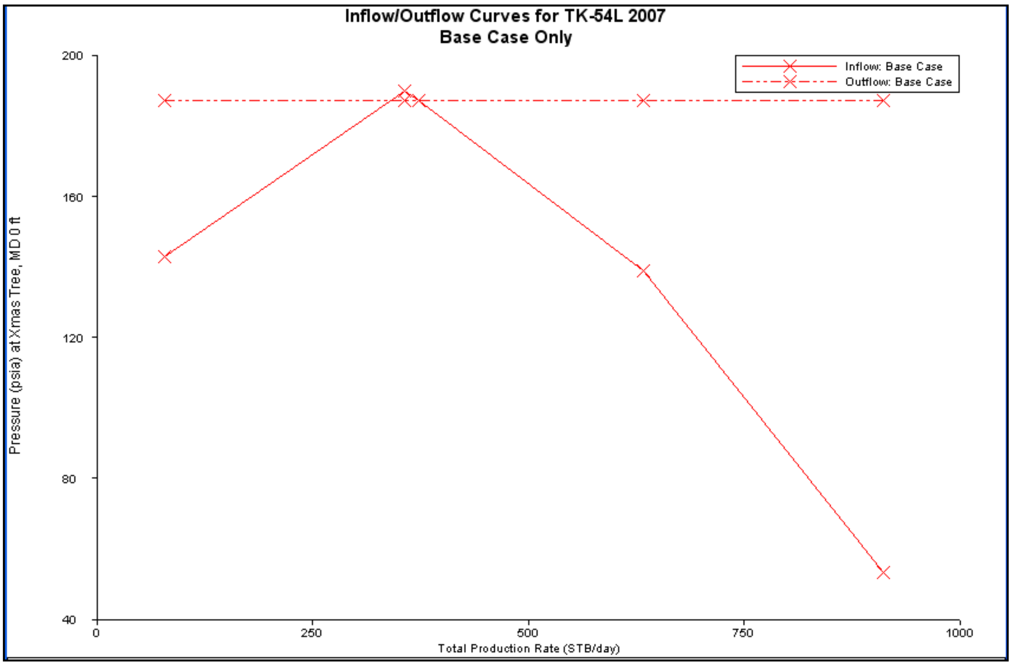

Figure 4.7: TK-54L Inflow/Outflow Performance Curve

Table 4.5 below shows the data obtain from the current performance analysis. This nodal analysis runs with the output node at the X-mas Tree and the bottom node is from reservoir 1A-H2.0/H3.0. Full Wellflo analysis report can be view in **Appendix 6**.

Table 4.5: Parameters obtained for current condition performance

Parameter	Value
Operating Pressure (psia)	187
Liquid Rate (STB/day)	371.58
Oil Rate (STB/day)	364.09
Water Rate (STB/day)	7.43
Gas Rate (MMSCF/day)	0.091
Water Cut (%)	2
GOR (SCF/STB)	250

4.6.2 Sensitivity Analysis

This analysis objective is to determine the operating rate which is the gross liquid produce from the well with respect to different skin values for each sand control methods. The skin value consider for this research is ranging from -2 to 15 with 9 steps increment. Other parameters for this analysis would such as the reservoir pressure, reservoir temperature and liquid properties remain unchanged. **Figure 4.8** shows the inflow vs outflow performance curve for TK-54L with respect to different skin value.

The curve shows that the increment of skin value will result in lowering the output performance of the well. Since there are three sand control method options choosen from the particle distribution test which are metal mesh screen, wire wrap screen and gravel pack, three estimated skin value will be selected. Full Wellflo analysis report can be view in **Appendix 7**. The trending for the operating rate which respect to the respective skin value is shown in **Figure 4.9**.

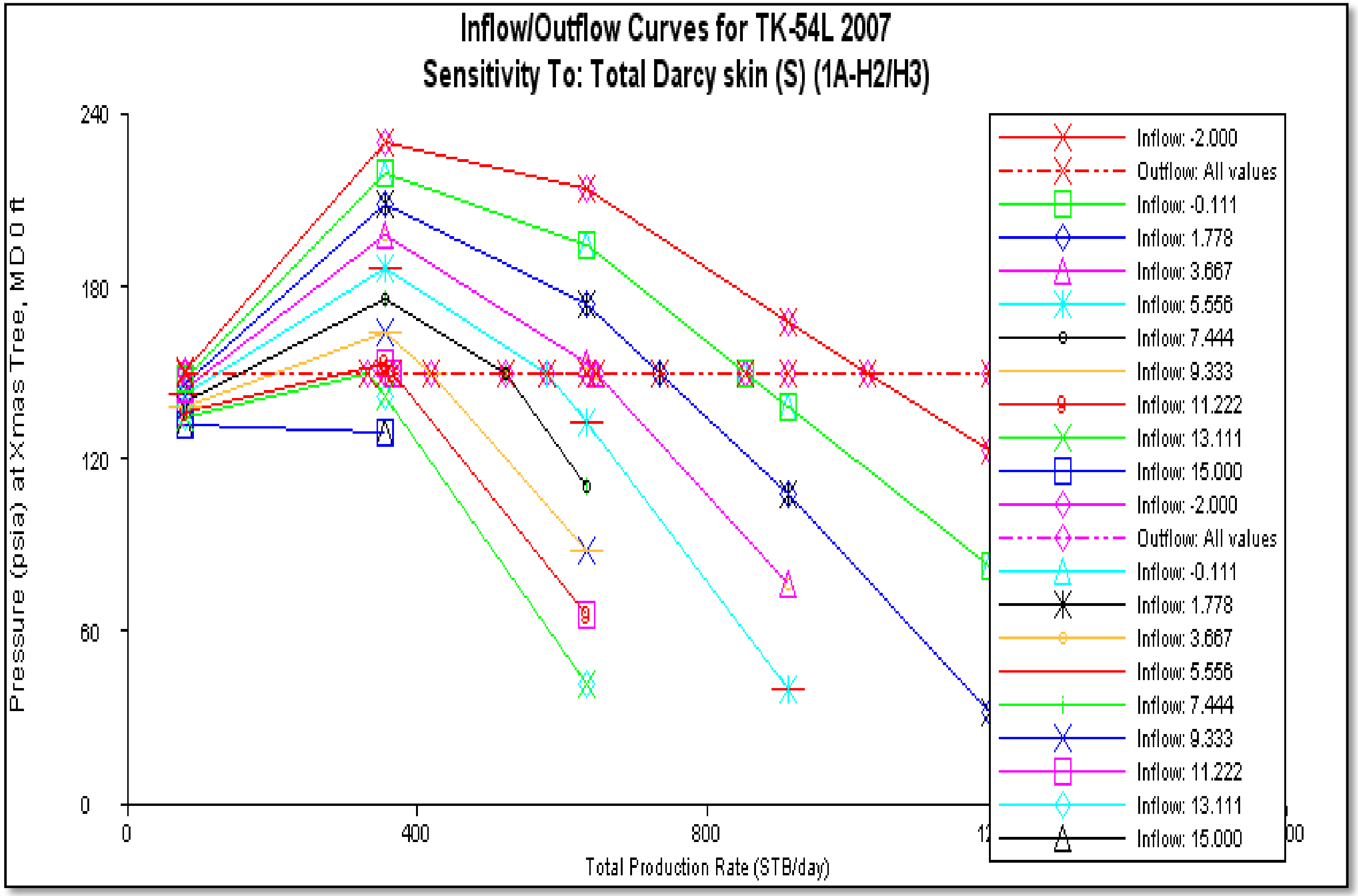

Figure 4.8: TK-54L Inflow/Outflow Performance Curve using sensitivity to different skin values

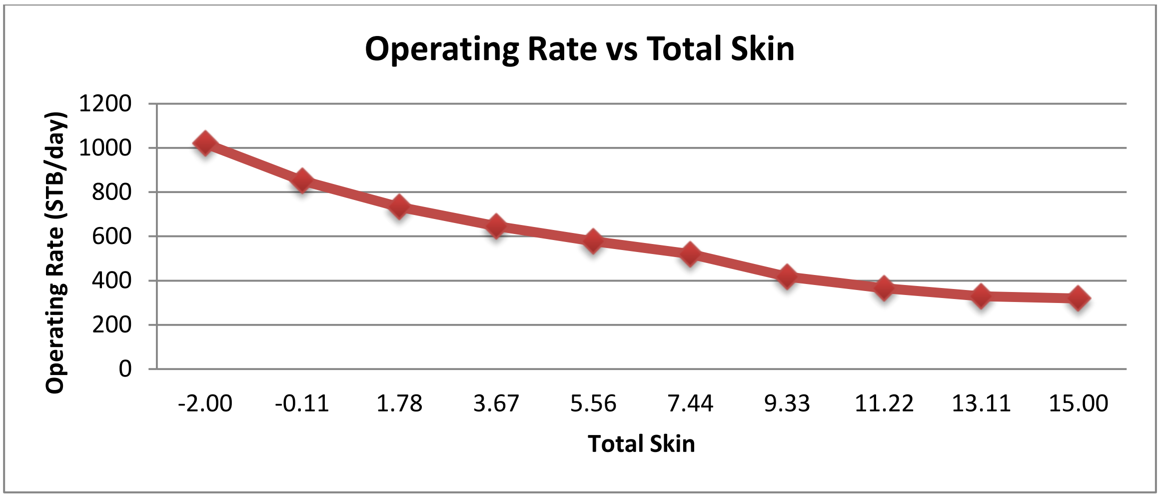

Figure 4.9: Operating Rate vs Total Skin for Well TK-54L

The uniformity coefficient obtained from the particle distribution test shows that the distribution of the sand particle is highly uniform. This represent most of the grains were in the same sizes. For this type of sand distribution, the selection of the sand control methods had been narrowed down according to the sand distribution of the reservoir. For Uc < 3 and D_{50} = 150 μ, the sand control methods which can be applied are wire wrap screen, metal mesh screen and gravel pack. Software simulation and modeling using WellFlo shows that wire wrap screen can deliver the highest operating rate which is at 645.98 STB/day.

4.7 PERFORMANCE COMPARISON

The three sand control method applications which are selected for this project will be selected based on the operation rate which each sand control method can deliver. **Figure 4.10** shows the comparison for each sand control methods with their respective operating rate. From the chart, sand control method using wire mesh shows the highest operating rate which is at 645.98 STB/day. This method can increase the current production for well TK-54L which is at average production 180 STB/day up to three times higher.

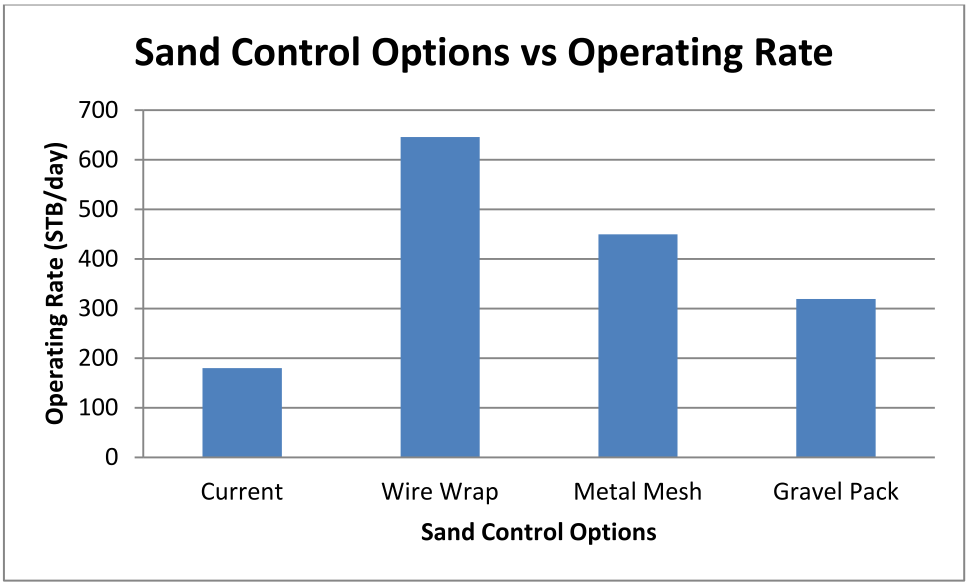

Figure 4.10: Sand Control Options vs Operating Rate

Selection of the sand control technique on well TK-54L were made by considering the thin reservoir boundaries, median grain size (D_{50}), sand distribution (D_{60}/D_{10}) and the operating rate which is net to gross ratio. Due to the highest operating rate which the wire wrap screen can deliver, this method was selected as the sand control method for TK-54L. Wire wrap screen was also selected because of this method is economically feasible compare to gravel pack where workover operation need to be include in the cost estimation.

CHAPTER 5
CONLUSIONS AND RECOMENDATIONS

5.1 CONCLUSIONS

The following conclusions could be drawn from the study.

a) Most of the wells in Tukau were completed without any sand control method installed. This is due to the high permeability formation which is cleaner and larger sand grains were produced during the early stages of exploration and production.

b) Throughout the production life of the well, the sand production in Tukau wells comes from the failure in the overlying rock inside the reservoir. It occurs when stress acting on the wellbore exceeds the strength of the overlying rock in the reservoir. This results into two types of rock failure which are shear and tensile failure.

c) Wire wrap screen is selected as the alternative sand control method for well TK-54L. The expected production by using this method would be 645.98 STB/day which is 3.5 times increment from the current installed sand control.

d) This method also is economically feasible because it is a through tubing screen method compare to gravel pack where workover operation is required.

5.2 RECOMENDATIONS

The study could be improved on the sand control selection if the following test could be carry on in the future.

a) Considering the due date and lack of data of this project it is advisable that the scope of work is lessen to only up to the selection of the sand control method. It is suggested that further analysis on wire wrap screen should be conducted.

b) It is found that analysis the performance of sand control technique with only computer software is difficult and would be best performed through analyzing the performance of real well. The only way in this project to analyze is through statistical report on nearby well such TK-20L which possessed the same properties with the reservoir and well.

c) Sand control on surface such as the sand desander could also be considered if the wire wrap screen installed shown to be ineffective.

d) However further analysis on its feasibility and economic aspects to implement this method on this field must be conducted.

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APPENDICES

1. **Appendix 1:** TK-54 Wellbore Diagram

2. **Appendix 2:** Gantt Chart
   a) Final Year Project I
   b) Final Year Project II

3. **Appendix 3:** Welltest Result
   a) Gross/Net/Bean Profile
   b) Gross/Net/Bean Profile II
   c) Gasout/Gaslift Profile
   d) FTHP/CHP/GOR Profile
   e) Gross/Net/WC Profile

4. **Appendix 4:** Screen Selection Guide

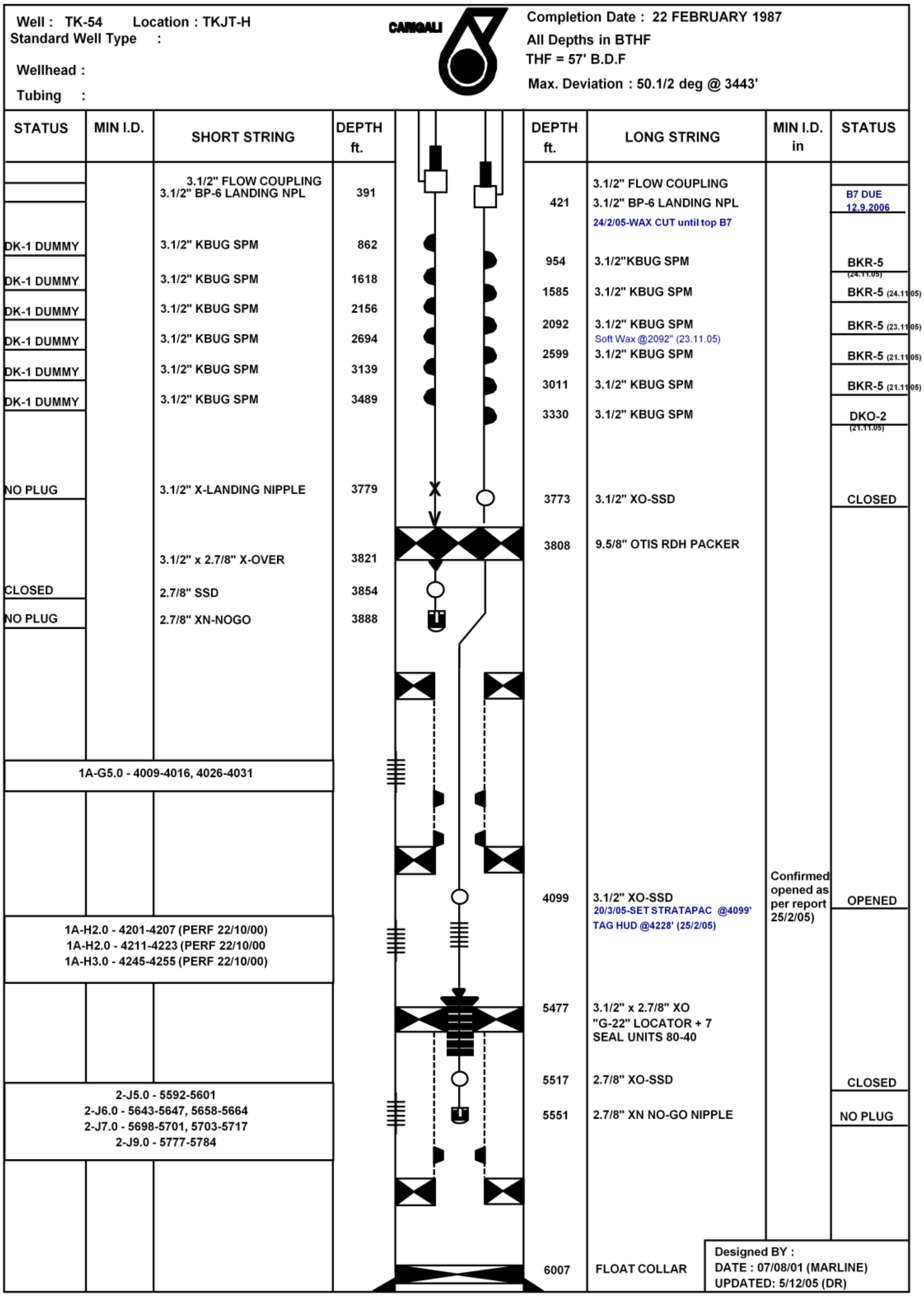
5. **Appendix 5:** TK-54L Well Model

6. **Appendix 5:** WellFlo Analysis Report - Current

7. **Appendix 7:** WellFlo Analysis Report – Sensitivity to Total Skin

APPENDIX 1 TK-54L WELLBORE DIAGRAM

SARAWAK OPERATIONS



APPENDIX 2(a) FINAL YEAR PROJECT 1 GANTT CHART

No.	Detail / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic								Mid-Semester Break							
	Propose Topic															
	Supervisor Approval															
2	Preliminary Research Work															
	Inroduction															
	Objective															
	List of reference/literature															
	Project planning															
3	Submission of Preliminary Report				15/8											
4	Project Work															
	Reference/Literature															
	Practical/Laboratary Work															
5	Submission of Progress Report									8/9						
6	Seminar									12/9						
7	Project Work Continue															
	Practical/Laboratary Work															
	Computer Modelling															
8	Submission of Interim Report														TBA	
9	Oral Presentation															TBA

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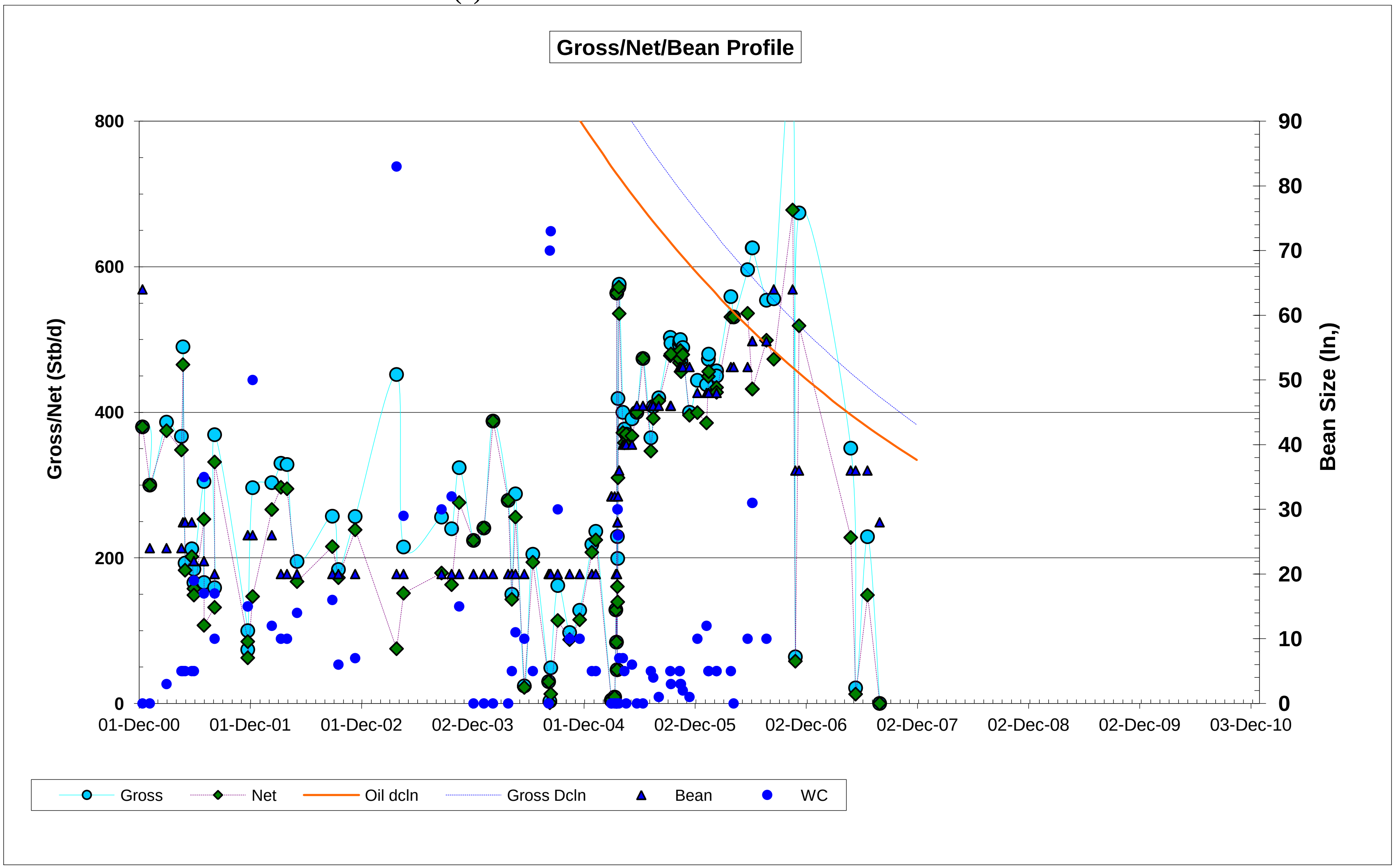
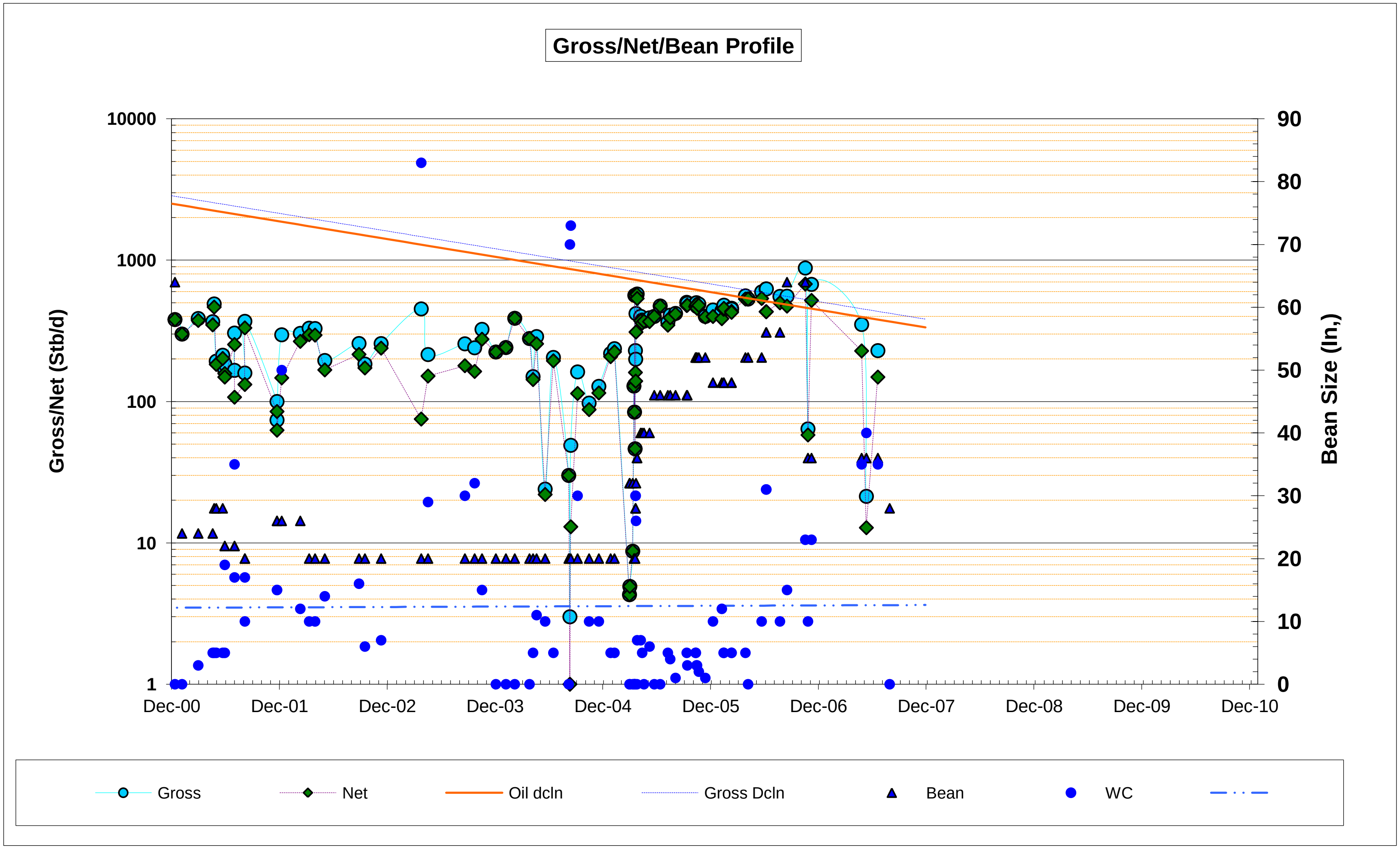
APPENDIX 2(b) FINAL YEAR PROJECT II GANTT CHART

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue	■	■	■					Mid-Semester Break							
2	Submission of Progress Report 1				●											
3	Project Work Continue				■	■	■	■								
4	Submission of Progress Report 2									●						
5	Seminar (compulsory)									●						
5	Project work continue									■	■	■	■			
6	Poster Exhibition											●				
7	Submission of Dissertation (soft bound)													●		
8	Oral Presentation														●	
9	Submission of Project Dissertation (Hard Bound)															●

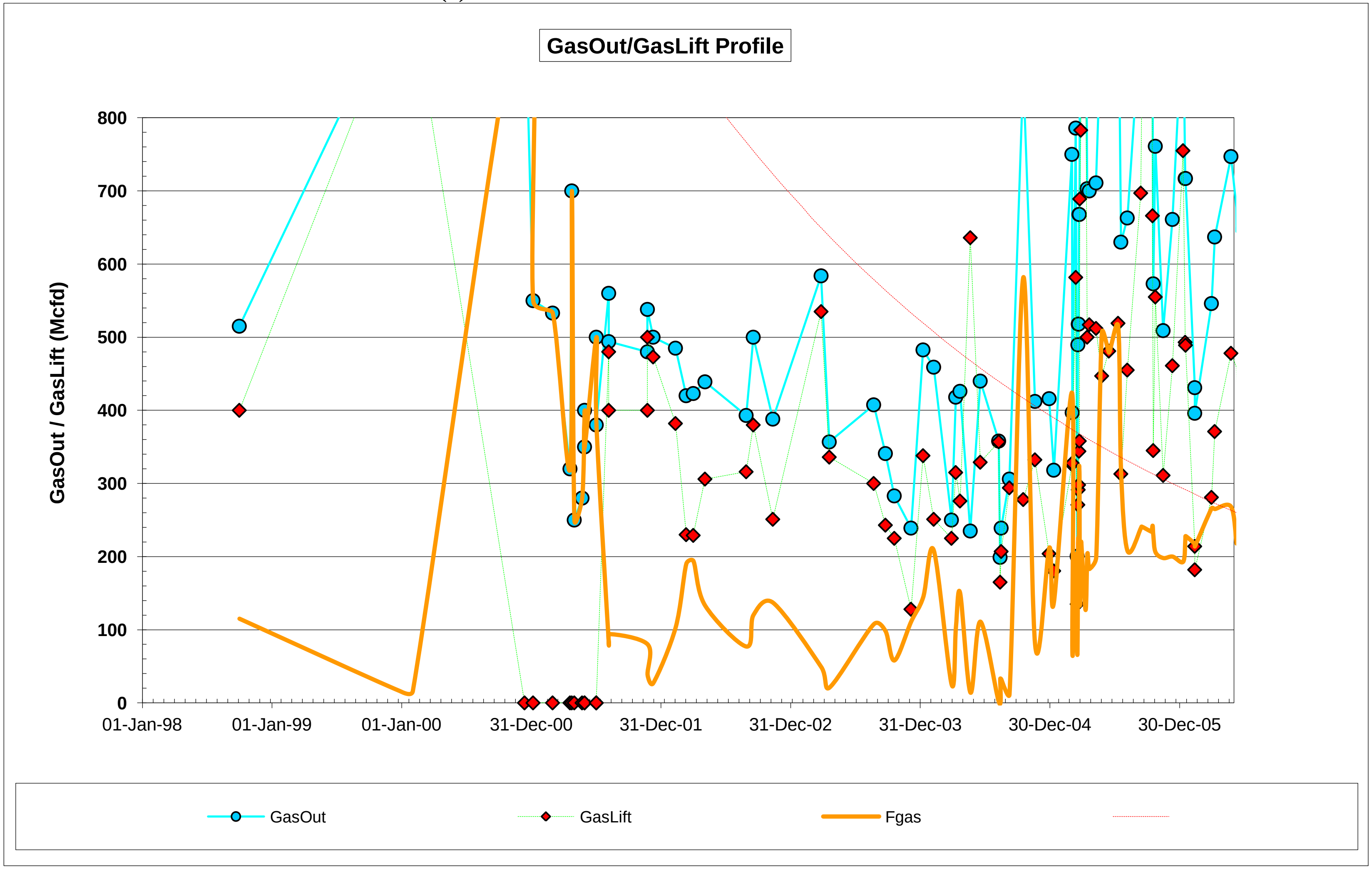
APPENDIX 3(a) WELLTEST RESULT – GROSS/NET/BEAN PROFILE



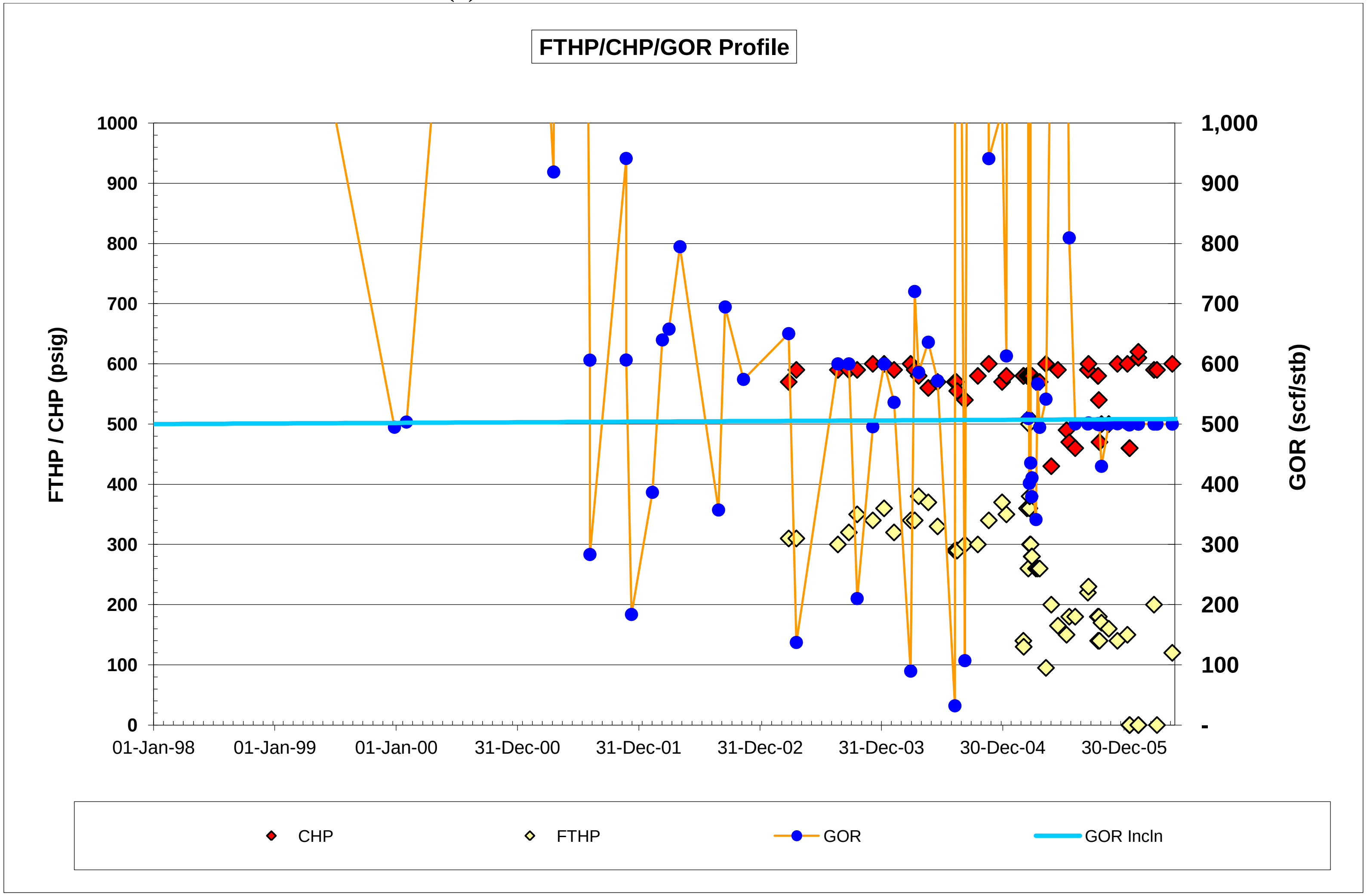
APPENDIX 3(b) WELLTEST RESULT – GROSS/NET/BEAN PROFILE II



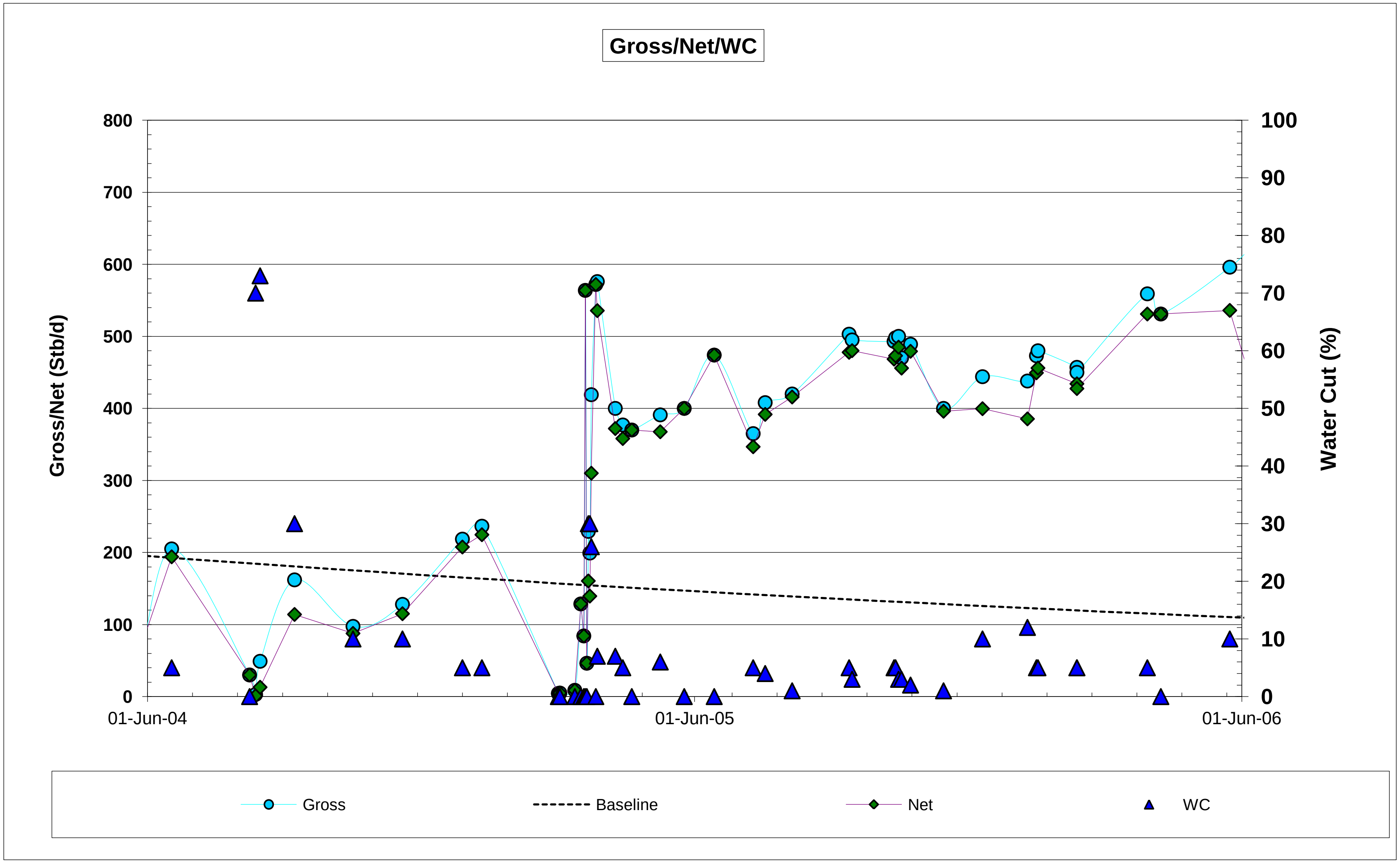
APPENDIX 3(c) WELLTEST RESULT – GASOUT/GASLIFT PROFILE



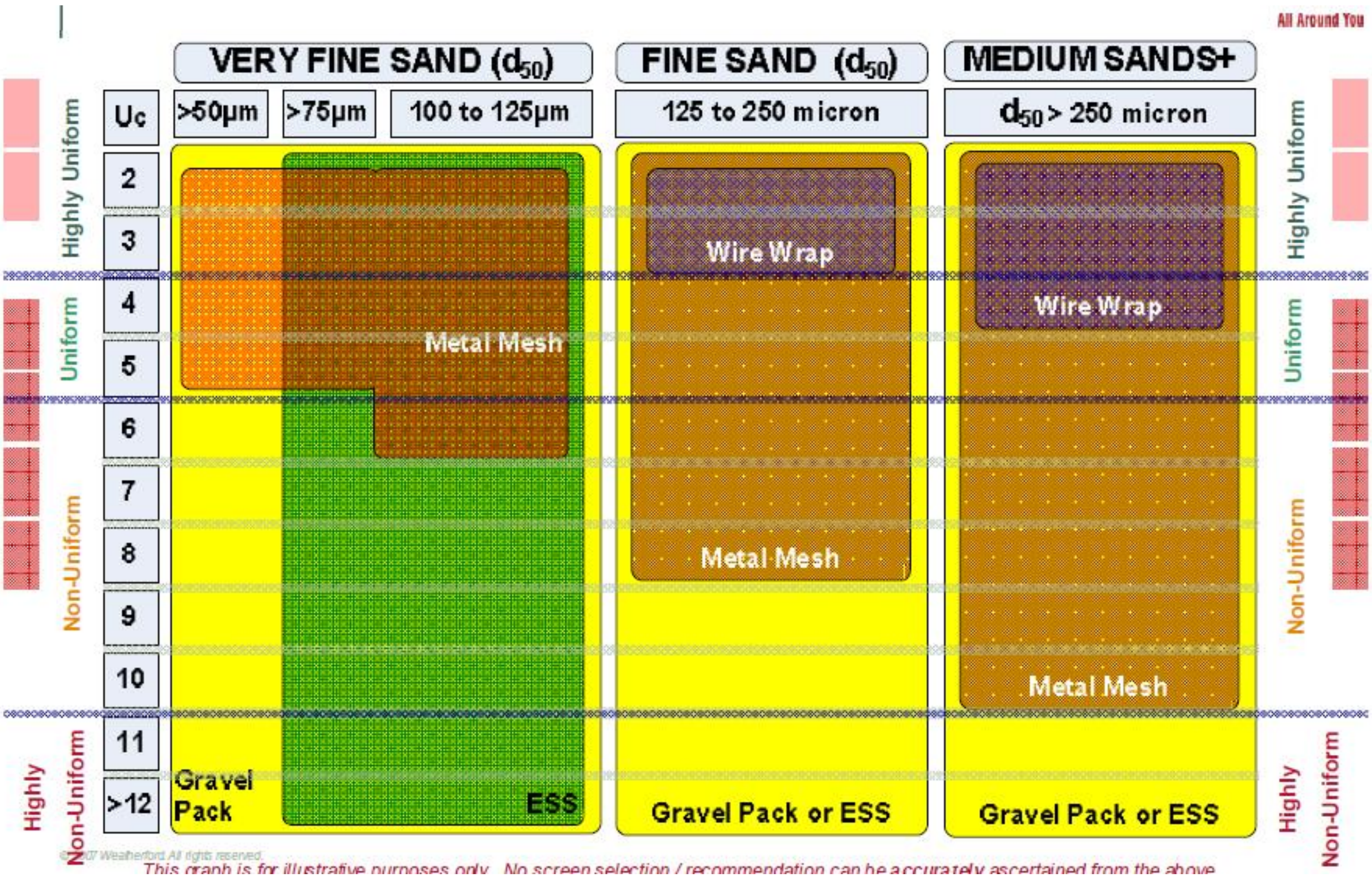
APPENDIX 3(d) WELLTEST RESULT – FTHP/CHP/GOR PROFILE



APPENDIX 3(e) WELLTEST RESULT – GROSS/NET/WC PROFILE



APPENDIX 4 SCREEN SELECTION GUIDE



WellFlo Analysis Report

Analysed by:	Nur Hafiz Ahmad Zubir
Company:	Universiti Teknologi PETRONAS
Field:	Tukau
Well:	TK-54L
Platform:	TKJT-H
Location:	Baram Delta Operations
Objective:	Sand Control Selection

WellFlo Fluid Properties Summary

Fluid Type:	Oil			
Number of PVT Layers:		2		
Pb correlation:	Standing	(tuned)	1.01116	40.41436
Rs correlation:	Standing	(untuned)	1.00000	0.00000
Bo correlation:	Standing	(untuned)	1.00000	0.00000
Uo correlation:	Beggs et al	(tuned)	0.83588	-0.34205
Ug correlation:	Carr et al	(untuned)	1.00000	0.00000
Surface Tension Model:		Advanced		

PVT Layer Number: 1

Oil API Gravity:	27.500 deg API
Oil Specific Gravity:	0.88994 sp grav
Gas Specific Gravity:	0.650 sp grav
Water Salinity:	18000.0 ppm
Produced Gas-Oil Ratio:	250.000 SCF/STB
Water Cut:	2.000 per cent

IPR Layer: 1A-H2/H3

IPR Model:	Vogel
Layer Pressure:	854.400 psia
Layer Temperature:	146.500 degrees F
Layer measured depth:	4228.00 ft
Effective Permeability:	200.000 md
Layer Thickness:	100.000 ft
Wellbore Radius:	4.248 in
External Radius:	1000.000 ft
Drainage Area:	3141592.500 ft2

Dietz Shape Factor:	31.620
Darcy Skin Factor:	5.000 (manual)
Productivity Index, J:	3.3075 STB/day/psi
Absolute Open Flow, AOF:	1543.0 STB/day

WellFlo Nodal Analysis Control Summary

Operating mode:	Determine operating point with exact iteration
Top node:	Xmas Tree at 187.000 psia
Bottom node:	1A-H2/H3 at 854.400 psia
Solution node:	Xmas Tree
Temperature model:	Calculated
T seawater:	70.000 degrees F
T atmosphere:	80.000 degrees F

The tubing annulus is assumed to be filled with gas
to a measured depth of 2599.000 ft.

Case 1

Sens 1: Unused.
Sens 2: Unused.

Flow Rate	Inflow Pressure	Outflow Pressure	Open Valve MD
77.152	142.871	187.000	2599.000
354.899	189.901	187.000	2599.000
632.646	138.832	187.000	2599.000
910.393	53.679	187.000	2599.000
1188.139	0	0	2599.000
1465.886	0	0	<none>
371.518	187.000	187.000	2599.000

The operating point is stable, was determined
by interpolation, and was refined by iteration.

Operating Pressure:	187.000 psia
Operating Temperature:	134.899 degrees F
Operating Rate:	371.518 STB/day
Completion P/drop at Operating Rate:	51.170 psia

APPENDIX 6 WELLFLO ANALYSIS REPORT – SENSITIVITY TO TOTAL SKIN

Operating Point Rate, STB/day:

-2.000	1019.903
-0.111	851.604
1.778	733.455
3.667	645.798
5.556	577.870
7.444	519.494
9.333	417.584
11.222	365.246
13.111	328.847
15.000	319.543

Operating Point Temperature, degrees F:

-2.000	141.558
-0.111	140.691
1.778	139.876
3.667	139.107
5.556	138.376
7.444	137.623
9.333	135.910
11.222	134.746
13.111	133.775
15.000	132.178

Operating Point Injection Depth, ft:

-2.000	2599.000
-0.111	2599.000
1.778	2599.000
3.667	2599.000
5.556	2599.000
7.444	2599.000
9.333	2599.000
11.222	2599.000
13.111	2599.000
15.000	2599.000