University of Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: M.Sc, Petroleum Engineering/ Drilling	Spring semester, 2010 Open / Restricted access
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Title of thesis: Drilling Optimization- Drill Bit Performance Optimization Using DROPS Simulator (Ekofisk/Eldfisk Field)	
Credits (ECTS): 30	
Key words:	Pages: …127……………… + enclosure: ………… Stavanger,..June 15/2010……….. Date/year

Acknowledgement

This Masters' thesis "Drilling Bit Perfomance Optimization Using DROPS Simulator" was prepared in the Spring of 2010 in collaboration with Conocophillips and Halliburton, Tanager-Norway and Petroleum Engineering Department, University of Stavanger. Data were obtained from Conocophillips fields via Halliburton and simulated with DROPS Simulator provided by Impetro International, Oslo-Norway.

I would like to express my immeasurable thanks to Professor Bernt Aadøy (Faculty Supervisor), Jackob Steina and Knut Skinnaland (Impetro International), Mike Herbert (Conocophillips contact among others) and Tonje Helgaland (Sperry Drilling – Halliburton) for their encouragement, contributions and guidance.

My appreciation goes to God Almighty for his bestowed courage and strength for the completion of this project work. Thanks to my classmates and friends for their co-operations and understanding.

Stavanger, June 15, 2010.

Vincent Akpojevwe Oteri

Abstract

Two drilled Wells: Well A and Well B were analysed under the following input data; drilling parameter, survey data, lithology data and bit information using DROPS simulator to showcase the bit performance optimization potentials. Apparent Rock Strength Logs (ARSL) were generated automatically by the simulator for the two drilled wells to give an idea of how hard is the formatiom and the rate of penetration possible for the bits.

Interesting plots of the Apparent Rock Strength, Rate of Penetration, Weight on Bit, Revolution per minute, pump flow rate, Plastic Viscosity, mud Weight and Bit wear versus depth for the Well A and Well B were expressly presented in this project work.

Appreciable cost per foot savings was made after the bit performance optimization simulation have been performed and a much more better savings could have been made if actual figures and parameters were used rather than assumed.

A better bit selection was made using ROP, drilling time, bit wear constant (automatic evaluation by DROPS simulatior), bit cost and cost per foot for selection criteria.

Bit hydraulics analysis as relevant to cutting removal was adequately explained and evaluated for each bit used during the drilling in the bit performance optimization using the DROPS simulator.

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CHAPTER 1 INTRODUCTION

Drilling optimization Simulator (DROPS) is a program designed to facilitate the reduction of drilling costs for oil companies. This is done by implementing actual drilling data for relevant wells from the company and generating an Apparent Rock Strength Log (ARSL) sometimes referred to as Geological Drilling Log (GDL) for a field. Once a proper ARSL has been generated, the user can easily simulate the forthcoming wells in that particular field.

The Apparent Rock Strength Log (ARSL) and its creation forms the basis for all simulations performed in DROPS Drilling Simulator (later referred to as DDS). The ARSL is a representation of the rock strength in a particular well or section, derived from the actual historical drilling data. When an ARSL has been generated and professionally verified for its accuracy, the planning of the drilling of any well is facilitated through its availability. The user can use DDS to simulate and test different makes as well as geometrical and hydraulic properties of drill-bits and thereby the detailed planning of the drilling of a well can be based on the simulated optimal cost. The ARSL is created by using reported Rate of Penetration (ROP) based on data from the field. The required three data registers for generating an ARSL are **<BITFILE>.bit**, **<DRILLFILE>.drill**, and **<LITHOLOGY>.lith**. The survey file **<SURVEY>.path** is optional in terms of the actual ARSL creation.

<BITFILE>.bit shall contain the detailed information about the drillbits that were actually used in a particular section with in-depth description of each bit as specified. The bit file is recognized by the ***.bit file** extension.

<DRILLFILE>.drill shall contain all relevant operating parameters and other data for the particular section that will be used for the generation of an ARSL.

The operation data file is recognized by the ***.drill** file-extension.

<LITHOLOGY>.lith shall contain all relevant information about the types of formations in the selected section, this is done by listing the percentage of occurrence of the different rock types. The lithology file is recognized by the ***.lith** file-extension.

<SURVEY>.path shall contain all relevant information about the directions and changes in direction that occurred during the drilling of the section. The survey file is recognized by the ***.path** extension.

Once the program has generated the ARSL or GDL, it verifies that it is accurate according to the relevant theoretical ROP models by performing a DrillBehind(Appendix). The DrillBehind conducts a reverse ARSL calculation, where the calculated apparent rock strength is used to calculate the theoretical ROP, this is then compared to the field reported ROP. Both the ARSL creation and the Drillbehind are automatically performed by the program and do not require the user to do anything but to prepare the input files needed.[2]

The Simulator optimizes two wells from the Ekofisk/Eldfisk field: Well A and Well B.

CHAPTER 2 LITERATURE REVIEW

The drilling bit is arguably the most amazing tool on the rig. Its operating environment, thousands of meters below the surface is the most hostile. Its duty, the destruction of rock millions of years old is the most demanding. We routinely pump thousands of gallons of mud through it; apply thousands of weight to it while simultaneously spinning it at different RPM. If it does not perform properly, a multi-million dollars drilling rig is wasted tripping pipe hence optimizing drill bit performance and drilling optimization at large is recommended.

With so much riding on the drilling bit, it is imperative that we select the best bit available which will produce the lowest cost per foot. Bit selection should involve more than just a check of what was run on the last well, or simply running what you happen to have on location. Selecting a bit should be a reasoned, conscious effort because it is a choice the entire operation is going to have to live with for the next several hours while the bit is on bottom.

Bit performance optimization addresses two issues:

First, a bit must be selected for the upcoming bit run which will stay in the hole a long time and give overall penetration rates.

Second, the bit must be operated properly while on bottom and while running-in so that we do not needlessly reduce its potential.

The basis for selection of a particular drilling bit is cost per foot. We want to select the bit which will provide the lowest cost per foot over the upcoming interval. This decision will involve an investigation into a variety of wellbore factors including formation hardness and hole angle. In addition, there are design aspects to all drilling bits, such as offset and journal angle, which make them superior performers in specific environments. Bit design is at the heart of proper bit selection.

2.1 ROLLER CUTTER ROCK BITS – DESIGN FEATURES

This section describes the components of a roller cutter rock bit and the variations which are possible to tailor a bit to drill a specific formation.

Bearings

There are three basic types of bearings utilized in roller cutter rock bits;

-The non-sealed roller bearings.

-The sealed and lubricated roller bearings.

-The sealed and lubricated journal bearings.

The choice bearing depends on the wellbore environment and cost per foot economics.

Non-Sealed Roller Bearings (NSRB) are the least technically advanced of the bearing types and are generally the least expensive. They incorporated an anti-friction roller bearing between the inside of the cone and the leg. The roller bearing supports the radial load which is placed on the cone when weight is applied to the bit. There is also a friction bearing in the nose of the cone which takes some of the radial loading. In addition to roller bearings, these bits also include a race of ball bearings which support the longitudinal loading applied to the cone. These ball bearings also keep the cone from falling off of the leg or from being driven into the shirt tail of the bit.

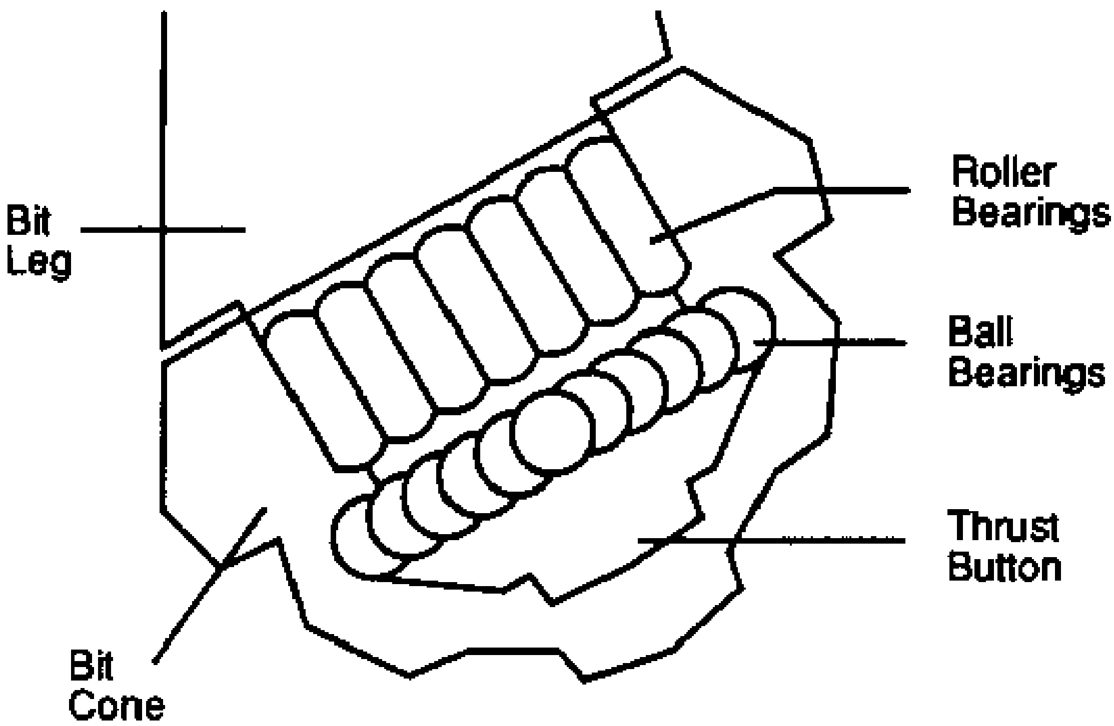

Figure 2.1 **Typical Roller Bearing Construction.**

As the name implies, the bearing assembly is neither sealed or nor grease lubricated, and drilling fluid is free to make its way into the workings of the bearing. As a result, solid particles in the mud abrade the metal of the rollers and races and the cones become “loose”. A loose bearing cannot evenly distribute the load, and continued rotation causes severe metal loss at the contact points. The ball bearings begin to take radial loading until, finally the bearing is shot and the cones are at risk of being lost in the hole.

Non-Sealed Roller Bearing are usually recommended on large diameter milled steel tooth bits. These bearings can usually last as long as the cutting structure because the bearing surface is relatively large and the drilling weight are small. These bearings may also be found on bits used to drill out short runs of cement within casing or when high RPMs are required for short durations.

Sealed and Lubricated Roller Bearings (SLRB) also uses roller and ball bearing elements to support the drilling load that is applied to the bit. However, SLRB’s include a sealed between the back face of the Cone and the leg which effectively eliminates drilling mud invasion into the workings of the bearing. Because the bearing is sealed, it is possible to keep it well greased. SLRBs contain grease reservoirs which have connecting passages to the bearing cavities. The reservoir is covered by a flexible rubber diaphragm which allows wellbore hydrostatic pressure to equalize as the bit is being run or pulled from the hole.

As a result of these design enhancements, SLRBs can be expected to last longer than NSRBs but there widespread application still remains in conjunction with milled tooth cutters. One objective in bit selection is to choose a bit which will become dull at about the same time that the bearing wear out. Tungsten carbide insert cutters will almost always outlast a sealed roller bearing.

Since sealed bearing life is more a function of bit weight than rotary speed, the higher weights required to drill smaller holes at deeper depths can be especially destructive to the rollers. On the other, in a soft abrasive formation, it is possible that the bearings outlive the milled teeth. Most bit manufacturers recommend a maximum bit weight of 5000 lbs per inch of bit diameter for sealed roller bearing bits. If it takes most of this weight to make the bit drill acceptably, serious consideration should be given to running a journal bearing bit on the next trip.

In a **Sealed and Lubricated Journal Bearings (SLJB)**, the radial load is distributed over a much larger area than that in a roller bearing. As a result, more loads can be supported without metal deformation or fatigue. Instead of a series of rollers to bear the radial load, the journal bearing makes use of two circular bearing surfaces which mate within very close tolerances of each other. A thin layer of grease must separate the two surfaces to prevent seizing and galling, so a grease reservoir and injection mechanism is employed. Dirt and contamination is especially harmful to journal bearings, so a highly effective "O" ring seal is used to keep grease in and trash out.

There are two methods of cone retention which are used on journal bearing bits. The conventional system uses ball bearing to support the longitudinal loads, just as in roller bearing bits. However, the Hughes Tools Co. system uses a lock ring instead of ball bearing to secure the cones to the leg and to absorb the thrust loads. The lock
ring occupies much less space than the ball bearings, so the journal surfaces can be significantly larger (and support more bit weight without falling).

Journal bearing are also sometimes called friction bearings and they can generate a lot of internal heat as they rotate. The tight clearances found in the bearings leave little room for the heat of rotation to dissipate. Hence it is important not to spin a journal bearing bit too fast.

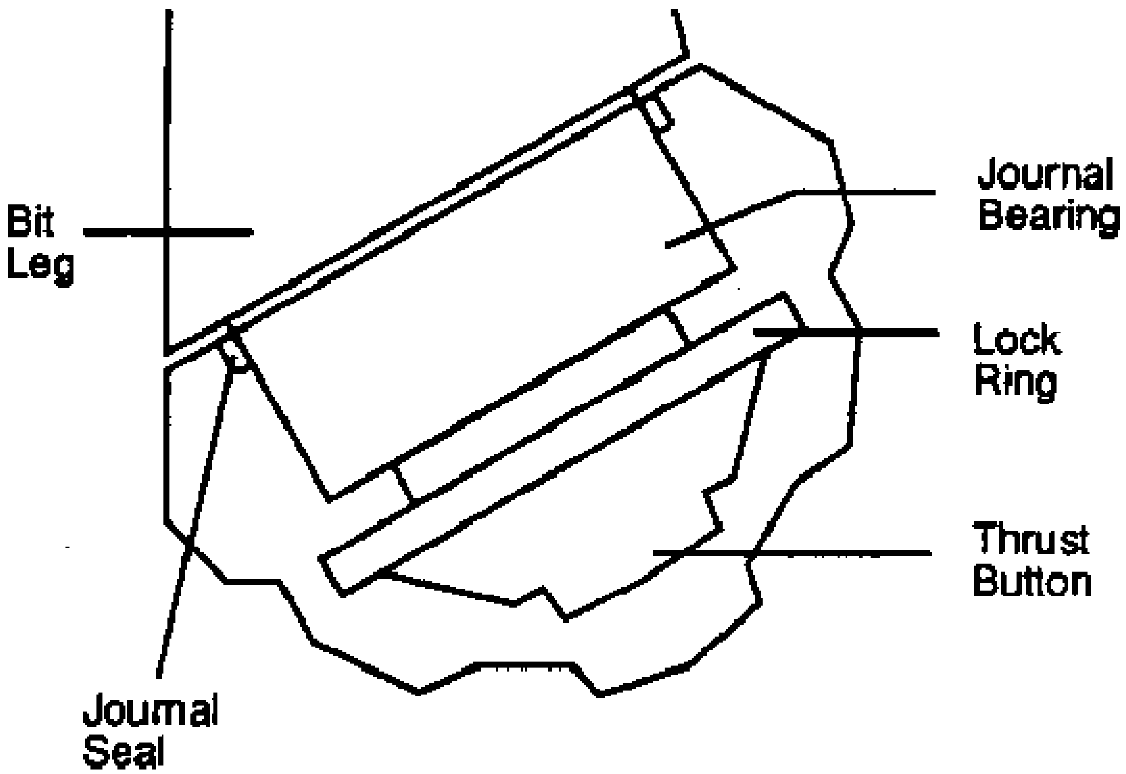

Figure 2.2 Typical Sealed Journal Bearing construction.

Cutting Elements

The cutting elements found on roller cutter rock bits are either made of milled steel (teeth) or tungsten carbide inserts. The length, shape and spacing of the cutters generally adhere to the following design philosophies:

Soft Formations composed of materials having low compressive strengths (less than 5000 psi). Typical soft formation materials are clay, shale, loosely cemented sand, chalk and soft limestone. In soft formations, the biggest concerns with milled teeth are bit balling and abrasive wear. A bit is said to be "balled" when sticky formation is paced so tightly in between the teeth that it holds the teeth away from the face of the formation.

The problem is solved by placing fewer teeth on each cone. This leaves more room between the teeth so that the sticking formation is not nearly as well supported and is more easily dislodged. Tooth wear is a problem because soft formation bits are designed to drill with a gouging and scraping action which is inherently abrasive.
Bit designers minimize this problem by adding tungsten carbide hard-facing to the teeth. The teeth are as long as possible into the formation to generate the largest cuttings.

When tungsten carbide insert teeth are used, abrasion is not a concern due to the exceptional wear resistance of the material. Long inserts are used for maximum bite, and are usually chisel or conical in shape. However, bit balling remains a problem, so the inserts are spaced widely apart with a good degree of tooth interfit.

Medium Hard formations are composed of material having moderate compressive strengths between 5000 and 10000 psi. Typical medium hard formations include limestone and sandstone. In medium hard formations, the bit relies on a combination of chipping and twisting action to make hole. Milled tooth breakage becomes a problem because higher drilling weights are required; so the teeth are shorter and less pointed. Hard-facing is still applied to the inner rows of teeth to make the bit more versatile under a variety of conditions.

The teeth on insert bits are more closely spaced to reduce the incident load on each tooth while maintaining high protrusion. The inserts are more conically shaped and blunter. The inserts' resistance to abrasion allows the bit to incorporate a fair amount of offset to still produce a gouging action.

Hard Formations are composed of material having high compressive strengths (greater than 10000 psi). Typical hard formations include dolomite, hard limestone, granite and chert. In hard formation, the rock destruction mechanism is primarily by crushing. The milled teeth impact directly on the formation face and pulverize it. With high drilling weights, the bending forces on a tooth can be severe so the teeth are short, stubby and numerous to minimize breakage. Because there is very little tooth scraping action, hard-facing is usually applied only on the gauge row of teeth.

Insert are set deeply into the cone with little protrusion to reduce their tendency to pop-out. The inserts have a spherical or elliptical shape.

Pitch Breaks

Pitch is the distance between adjacent teeth on a bit cone. If the pitch is the same for all teeth on a given row, then there is a tendency for the bit to track the same path against the formation on each rotation. When this occurs, the teeth impact the formation in the same location on each rotation, resulting in the generation or 'rock teeth' into which the bit teeth mesh. When this occurs, the bit will simply track round and round into the rock teeth without making any hole. To prevent this from happening, the pitch between the teeth is varied. This results in a cutting pattern variation on each revolution which destroys the rock teeth as soon as they are generated.

Cone Offset

When the axis of rotation for the three cones of a bit does not converge at a common point at the center of bit rotation, the cones are said to be offset. The degree of offset is measured perpendicularly from a point on the cone axis to the center of bit rotation. The effect of offset is to cause the cone to want to rotate through a different arc than the one to which the bit body has it constrained. This causes the cone to slip which scrapes and gouges the formation rock in front of the bit. Soft formations are especially responsive to this type of cutting action and drill well with a high amount of cone offset. In harder formations, where the rock must be physically broken or fractured, the scraping gouging action produced by cone offset contributes little to rock removal. In addition, scraping and gouging against a hard formation is very abrasive to the cutting structure, and can wear the teeth down quickly. As a result, hard formation bits are designed with little or no cone offset.

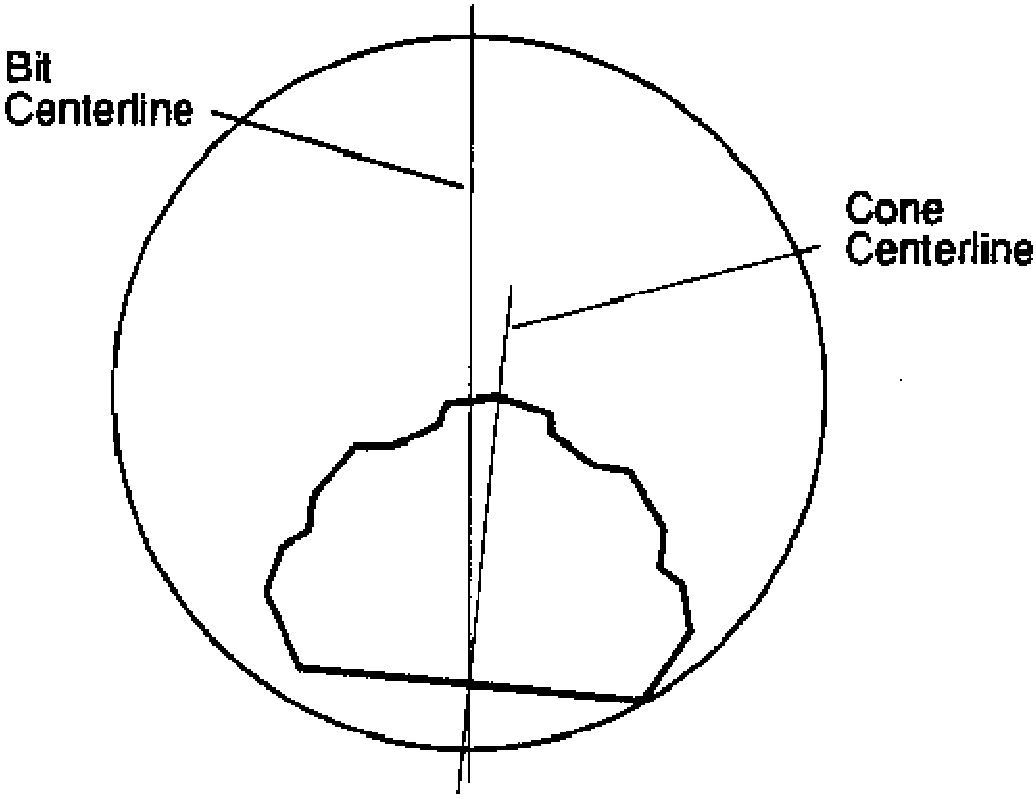

Figure 2.3 Cone Offset

Journal Angle and Cone Angle

The journal angle is the angle measured between the cone axis of rotation and a horizontal plane; it is the angle on which the cones are mounted to the bit. If the axis of rotation of the cone is parallel to the bottom of the bit, then the cone has zero journal angles. Most cones are mounted with a journal angle between 33 and 37 degrees which increases to suit harder formations.

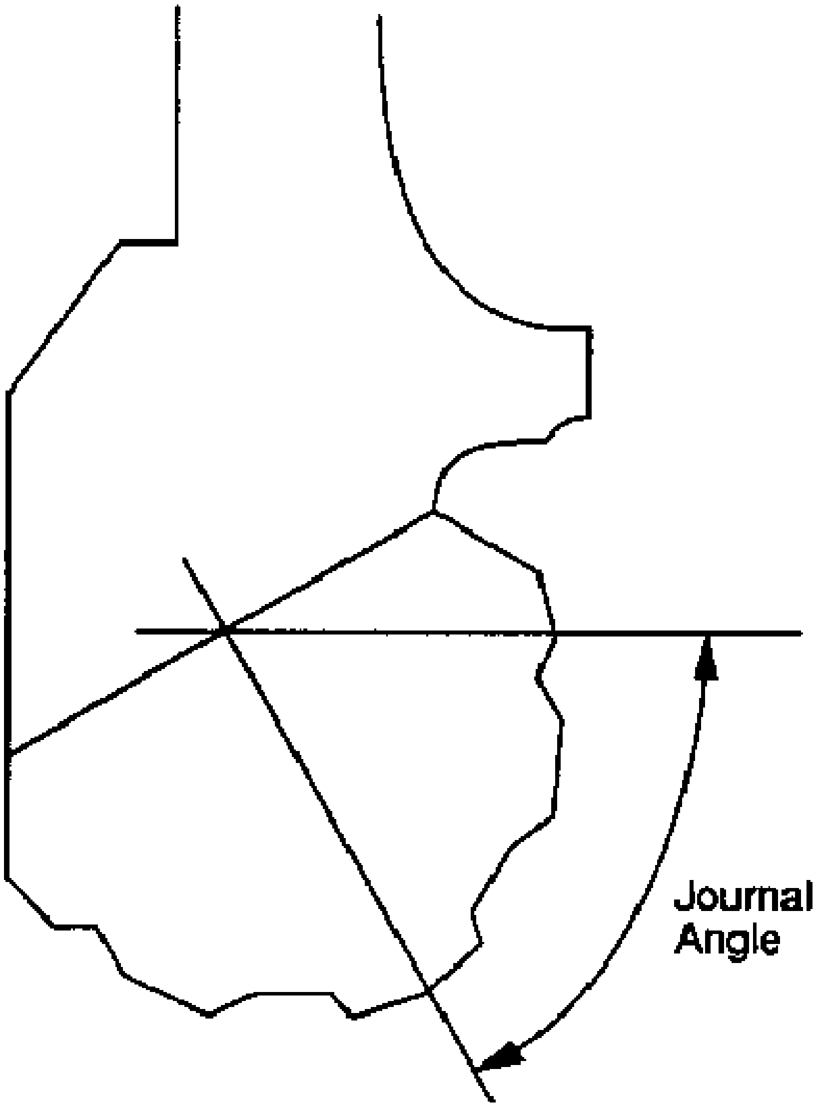

Figure 2.4: Cone Journal Angle

The cone angle is the angle formed by the outside profile of the cone. Most cones have either two or three cone angles, depending on the number of rows of teeth.

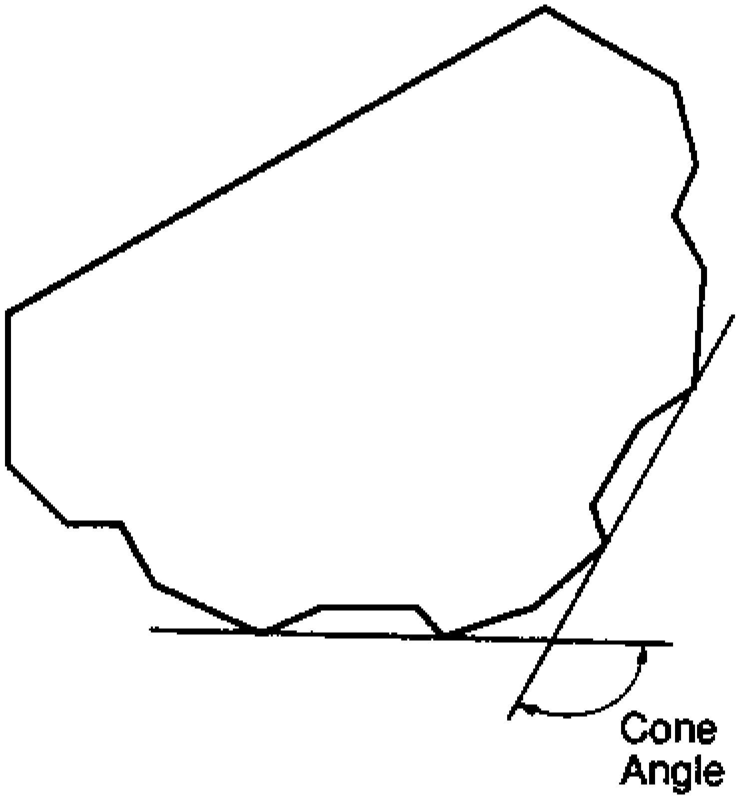

Figure 2.5: One cone angle of a bit.

The cone angle and journal angle interact to help generate the specific cutting action of the bit. As the cone angle approaches a value which is twice that of the journal angle, the cone profile becomes flush with the bottom of the hole. This creates a true rolling motion which is suitable for hard formation bits. If the cone angle is less than twice the journal angle, the outer rows of teeth will want to rotate faster than the inner rows of teeth which cause a gouging/scraping cutting action suitable for soft formation bits.

Small journal angles increase the radial load on the bearing, but also provide the most room for bearing design. As a result, the bearing and cone diameter can be larger (which is preferable for soft formation bits). One drawback to a small journal angle is the need to trim the outer base of the cone so it does not extend beyond the shirttail and create over-gauge conditions. This increases the gauge reaming area of the cone which can cause problems in a abrasive environment. Larger journal angles increase the thrust load on the bearing, and by necessity require that the cone angle be smaller.

Interfit

The degree to which the teeth from one mesh within the spaces between the rows of teeth on another cone is called interfit. The teeth do not actually mesh as in a gear, but rather a relief ring is cut into the surface of a one cone to provide space for the tooth rotation of an adjoining cone. Interfitting the cones gives the bit designer more room to build better components with. The result may be longer teeth for soft formation bits or bigger bearings for hard formation bits. Interfitting also helps to prevent bit balling, as the teeth serve as a mechanical way to dislodge sticky cuttings.

When interfitting is used to produce longer teeth, the effective cone angle is increased. This will normally increase the degree of gouging/scraping action unless the journal angle is also increased, which may be impractical. For this reason, high degrees of tooth interfit are usually associated only with the soft formation bits.

Nozzles

Nozzles and nozzle placement are an important aspect of bit design. The purpose of the nozzle is to normally increase the velocity of the mud as it exits the drillstring. High velocity fluid flow is advantageous at the bit. Nozzles are made of tungsten carbide for washout resistance.

Effective nozzle placement is critical both for cutter cleaning and formation erosion. However, the two cannot be fully accommodated simultaneously. To optimize cutter cleaning, the high velocity fluid stream leaving the nozzle is directed at the cones in a glancing angle. Direct impact on the cutters would cause maximum cleaning but unacceptable fluid washout of the cone itself.

The high velocity stream fluid loses its energy as it travels through the mud once it exits the nozzle. Therefore, for maximum hydraulic formation erosion, the fluid should exit the nozzle just above the formation face. Unfortunately, that area is occupied by bit manufacturers have gone to two cone bits which have the necessary space needed to extend the nozzle below their normal location within the bit body. These so-called "extended nozzle bits" have found to be very effective in certain formations, while not so effective in others. Tri-cone extended nozzle bits are also available. The main formation characteristic which seems to be conducive to high penetration rates when these bits are used is erodibility.

A bit cleaning problem arises with extended nozzle bits because the cutters are not impacted and cleaned by the energy fluid flow. As a solution, center jets are run to direct flow over the cones and clean the teeth before formation contact.

2.2 ROLLER CUTTER ROCK BITS – BIT SELECTION AND APPLICATION

In 1987 the IADC revised its system for classifying roller cone rock bits. The new IADC codes based on a 4-character designation which describes the bit's cutting structure, formation compatibility and any special features. The old code used a 3-chracter designation which had become inadequate since its adoption in 1972.

The new code is designed to include special designators for recent technical advances and also allow sufficient room for the code to expand as bit designs continue to evolve.

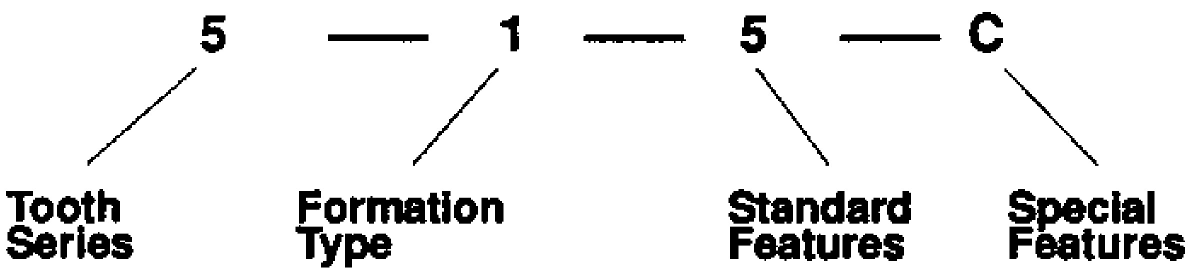

Figure 2.6: IADC bit code.

The first character of the code is a numeral which indicates the type of cutting structure found on the bit.

The second character of the code is a numeral which indicates the relative hardness of the formation for which the bit was designed to drill.

The third character of the code is a numeral which indicates the standard bearing features of the bit.

The fourth character of the code is a letter which indicates any special features of the bit.

2.2.1 Tooth Series (Numerals 1-8):

Numerals 1-3 indicate the bit has milled steel teeth. Smaller numbers indicate fewer and longer teeth for soft formations while higher numbers indicate more but shorter teeth for hard and abrasive formations.

Numerals 4-8 indicate the bit has tungsten carbide insert teeth. Smaller numbers indicate fewer and longer teeth for soft formations while higher numbers indicate more but shorter teeth for hard and abrasive formations.

2.2.2 Formation Type (Numerals 1-4):

Within each series the formation is subdivided into four types depending on relative formation hardness. Smaller numbers indicates soft formations relative to the tooth series while higher numbers indicates hard formations relative to the tooth series.

2.2.3 Standard Features (Numerals1- 7):

The numerals indicate the type of bit bearing and the presence of gauge protection.

They are:

1 – Standard Roller Bearing

2 – Air Cooled Roller Bearing

3 – Roller Bearing with Gauge Protection

4 – Sealed Roller Bearing

5 – Sealed Roller Bearing with Gauge Protection

6 – Sealed Friction Bearing

7 – Sealed Friction Bearing with Gauge Protection

2.2.4 Special Features (Letters A-Z)

These letters indicates any special features which the bit may have. They are:

A – Air Application

C – Center Jet

D – Deviation Control

E – Extended Nozzles

G – Extra Gauge Protection

J – Jet Deflection

R – Reinforced welds

S – Standard Steel Tooth (no special features)

X – Chisel Shaped Inserts

Y – Conical Shaped Inserts

Z – Other Insert Shape

2.3 ROLLER CUTTER ROCK BITS – OPERATING PROCEDURES

The moment a bit passes through the rotary, it begins to wear out. The trip to the bottom of the hole can be arduous one. Wellbore obstructions such as blowout preventers and under-gauge hole can act to wear a bit out before it ever makes us a single foot of hole.

Proper operation of a bit is at least as important to a good bit run as the bit selection itself. This section will discuss those actions which we should practice to avoid needlessly detracting from a bit's hole-making potential.

Surface Bit Handling

When a new bit arrives on location, it may or may not have nozzles in it. Bits should be ordered without jet nozzles installed. If a bit shows up with nozzles already in it, it should be removed. This will give an opportunity to dress and inspect the bit when it is next in the hole. Do not doghouse your hydraulic calculations and have the bit peddler similarly dress all bits with three twelve. Make sure the bit peddler has left a variety of nozzles to cover all expected operating conditions.

New bits should be stored in their boxes in a dry place. It is best to place them on pallets to keep them out of the mud. The bit serial number should be recorded in the rig's bit inventory with the date of arrival. Re-run bits should be hosed-off, re-greased if possible and stored with a liberal coating of pipe on the threads.

Picking-Up the Bit

When the decision has been made to run a particular bit in the hole, the drill bit should be inspected thoroughly which should include:

- A check to see that the box has not been mislabeled and that the type of bit to be run is actually contained within.
- A check to see that the bit has the desired features such as gauge protection and proper insert shape.
- Inspect the bit for any broken teeth, missing inserts, or protruding bearing seals. Make sure the grease reservoir equalization ports are not clogged.
- Always check and record the bit diameter with a gauge ring regardless of whether it is new or re-run.
- Always use a lifting eye when bringing the bit up to the rig floor. Do not use slings which can slip off and injure someone or damage the bit.
- The drilling representative should witness to nozzles installation. Proper nozzle installation is a simple but critical operation which the drill rep should be well practiced in.
- Always use new nozzles and accessory equipment such as o-rings and retaining rings.
- Never force a nozzle into the bit body or tap on it with a hammer (nozzles are made of tungsten carbide and are very brittle).
- Confirm the size of the nozzle opening with a nozzle gauge.

The bit should be made up with a properly sized bit breaker in good mechanical condition.

- Clean the threads of all foreign substances before applying dope.
- Use the recommended make-up torque for the bit thread form but remember, new tool joints need to be made-up slowly to prevent galling.

Tripping in the Hole

The bit should be always being passed as slow as necessary to get through known ledges or restrictions in the wellbore. There are both cased hole and open hole restrictions with which we must be concerned. Blowout preventers, casing heads, whipstocks, liner tops, casing patches and casing shoes, all present steel obstruction which can prevent a bit form passing. Hitting these obstructions too fast can break teeth and damage bit bearings. Drillstrings have also been known to jump the elevator when bits have hung-up while running in the hole. Even if a potential obstruction such as a casing shoe has never been a problem, it should be approached cautiously each time while running-in.

Bits have the ability to worm their way through an obstruction that other full-bore tools cannot. A little rotation is necessary at times to get through a liner top but indiscriminate reaming inside casing with a bit is never recommended; a swage or dressing mill is more appropriate for these purposes.

Once the bit is in open hole, potential restrictions may not be so predictable. Running-in speed will generally be reduced in open hole with a close eye kept on the weight indicator. Special care should be taken when approaching those areas which were tight on the way out of the hole. Reaming may be necessary to get back to bottom but keep in mind that excessive reaming can damage a bit. Low bit weighs, fairly high rotary speeds and lots of pump should be used while reaming. Remember that the weight you are applying is being supported only by the outer row of gauge teeth on the bit and that while the total weight being applied at the surface may be small, the psi loading on the gauge teeth will be very high. Reaming also produces a very unbalanced loading condition for the bearing and damage may result over prolonged periods.

Do not force the bit into a situation from which you cannot retrieve it. Do not ream an entire Kelly down without checking to see if you can pick it up. Unless the rig is equipped with a top drive, it probably would not be able to up-ream. Being stuck with a buried Kelly is no fun!

While on Bottom

As a new bit approach the bottom, it is good practice to pick up the Kelly and wash the last two joints to bottom. Avoid running into fill as this may plug your nozzles or ball the cutting structure. Bring the pumps online slowly to prevent pressure surges which can blow the nozzles out of the bit. If junk is suspected on bottom, give your pumps a chance to circulate it up into the junk basket before making hole.

When drilling is started, low weight and rotary speed is used to break-in the new bit. The few minutes gained by quickly “running heavy” on a bit can easily be negated by early bearing damage and a resultant short bit run. Wait until the bit has established its new bottom-Hole pattern and has drilled a couple of feet before really stacking-it-out for the first drill-off test.

Do not exceed the manufacturer's published maximum bit weight and rotary speed without first consulting the Drilling superintendent.

Drill shale and other plastic formations with high RPM and low weight to reduce the chances of bit balling.

Drill lime, dolomite and brittle formations with high weight and low RPM to induce fractures. Drill abrasive formations with the lowest RPM to reduce gauge wear.

Pulling Out of the Hole

When a bit is dull and being pulled out of the hole, it still has the potential to lower the cost per foot of the next bit in the hole. Tight spots encountered while pulling out of the hole should be reamed with the dull bit being pulled rather than the new bit on its way in the hole. In this manner, the life of the new bit may be extended because it will not have to ream as much.

2.4 ROLLER CUTTER ROCK BITS – DULL BIT GRADING

In 1987 the IADC revised its system for grading used roller cutter rock bits. The new IADC codes are based on an 8-character designation which describes the bit's remaining cutting structure, bearing condition and gauge condition. The old code used a 3-character "T,B,G" designation which had slowly become inadequate since its adoption in 1961.

The new code is designed to include special designators for specific wear patterns observed on both fixed cutter and roller cutter rock bits and to include the reason the bit is pulled. An example using the new IADC grading system is explained in the figure below.

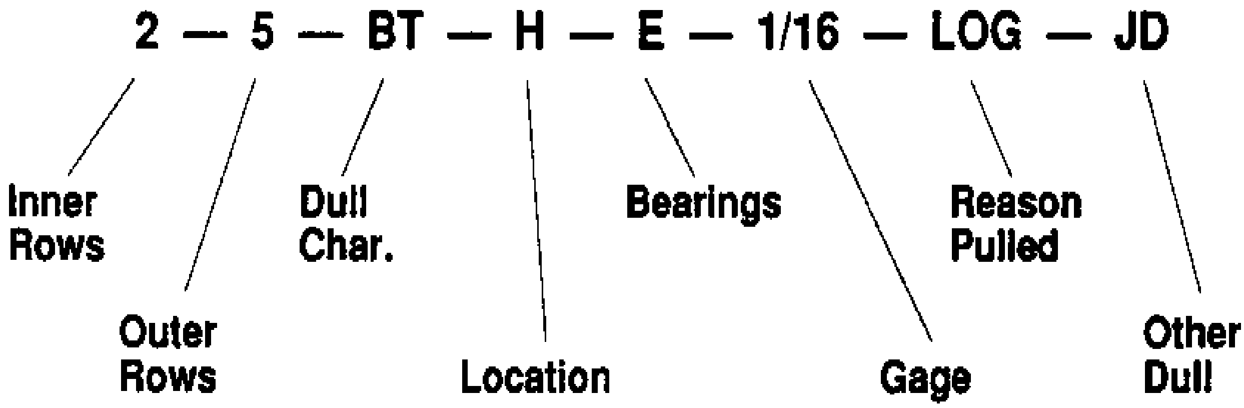

Figure 2.7: Revised IADC Code

Inner Rows (Numerals 0-8): indicates the reduction in cutting structure on the inner rows of teeth due to loss, wear, or breakage. Smaller numbers indicates less reduction.

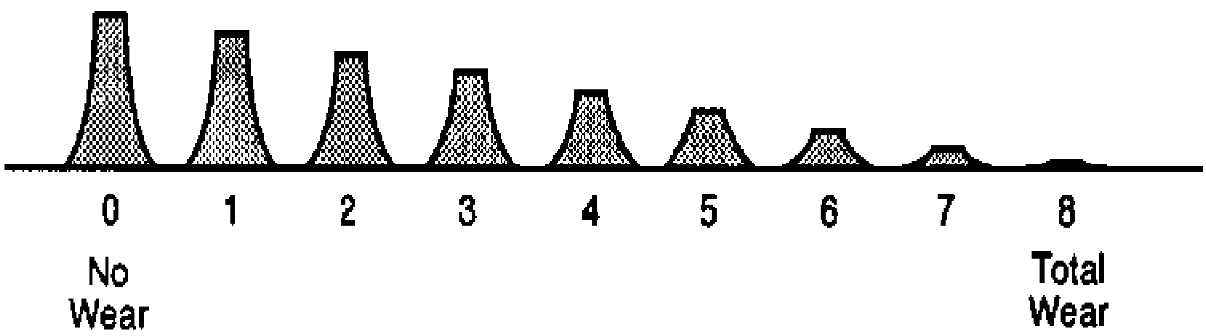

Figure 2.8: Dull Cutting Structure Grading

Outer Rows (Numerals): indicates the reduction in cutting structure on the outer rows of teeth due to loss, wear or breakage. Smaller numbers indicates less reduction.

Dulling Characteristic (2-letter Codes): indicates any extraordinary wear patterns observed on the cutting structure of the bit. These are:

BC –Broken Cone

BT – Broken Teeth

BU – Balled Up
CC - Cracked Cone
CD – Cone Dragged
CI – Cone Interference
CR – Cored
CT – Chipped Teeth
ER – Erosion
FC – Flat Crested Wear
HC – Heat Checking
JD – Junk Damage
NO – No Extraordinary Wear Detected
LC – Lost Cone
LN – Lost Nozzle
LT – Lost Teeth
OC – Off Center Wear
PB – Pinched Bit
PN – Plugged Nozzle
RG – Rounded Gauge
ST – Shirttail Damage
SS – Self-Sharpening
TR - Tracking
WO – Washed-Out
WT – Worn Teeth

Location (Alphanumeric): Indicates the location of the extraordinary wear described in the Dulling Characteristics. These locations are:

N – Nose Rows of Teeth
M – Middle Rows of Teeth
H – Heel Rows of Teeth
A – All Rows of Teeth
1 – Number One Cone
2 – Number Two Cone
3 – Number Three Cone

Bearing (Alphanumeric): Indicates the reduction in non-sealed bearing life using a linear scale from 0-8. Smaller numbers signify less wear. Use an "F" (failed) or an "E" (effective) to signify the seal condition when sealed roller or journal bearings are used.

Gauge (1/16"): Indicates the degree of gauge wear on the bit reported in sixteenths of an inch. Use an "I" if the bit is in gauge.

Other Dulling Conditions (2-letter Code): Indicates any additional extraordinary dulling condition not reported elsewhere in the report.

Reason Pulled (2- or 3-letter Codes): Indicates the reason for the bit out of the hole. These are:

BHA – Change BHA
DMF – Mud Motor Failure
DSF – Drillstring Failure
DST – Drill String Test
DTF – MWD Failure
LOG – Run Logs
CM – Condition Mud
CP – Core Point
DP – Drill Plug
FM – Formation Change
HP – Hole Problems
HR – Hours on Bit
PP – Pump Pressure
PR – Penetration Rate
RIG – Rig Repairs
TD – Total Casing Depth
TO –Torque
TW – Twist Off
WC – Weather

2.5 PDC BITS - DESIGN FEATURES

The PDC bit is a one-piece cutting tool using numerous polycrystalline diamonds compact to cut the rock. The polycrystalline diamonds cutters consist of a thin layer of synthetic diamonds adhere to a tungsten carbide disc.

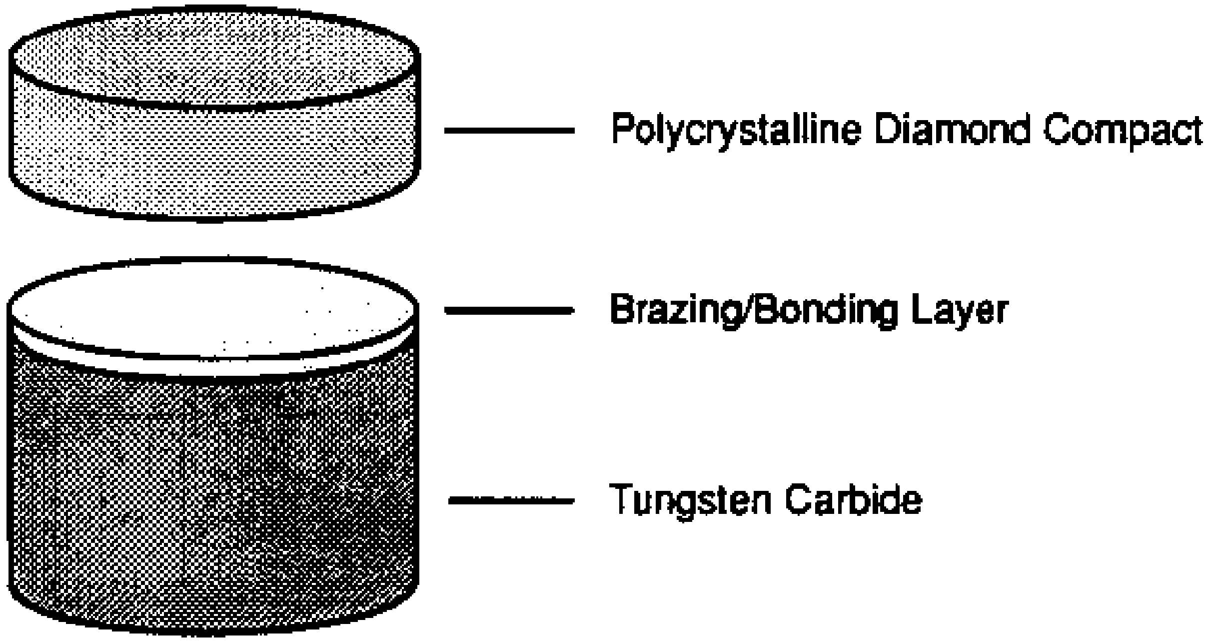

Figure 2.9: Typical PDC construction

These compacts are produced as an integral blank by a high pressure, high temperature process. The diamond layers of many tiny diamond crystals which are bonded together with their cleavage planes randomly oriented to each other so that shock-induced breakage in an individual diamond crystal does not propagate though the entire cutter. This result is a wafer thin diamond layer with the hardness and abrasion resistance of a diamond and the impact resistance of tungsten carbide. These bits are a high technology revival of the first type of rotary drilling bit the drag bit.

PDC bits drill by shearing the rock rather than crushing it as rock bits do or grinding it as natural diamond bit does. Rock fails with significantly less energy in shear than in compression, thus a more efficient drilling action can be obtained with less WOB.

In the right formation, PDC bits can drill long and hard. They routinely double the time in the hole and triple the footage of conventional roller cone bits but running PDC bit in the wrong formation will quickly destroy it.

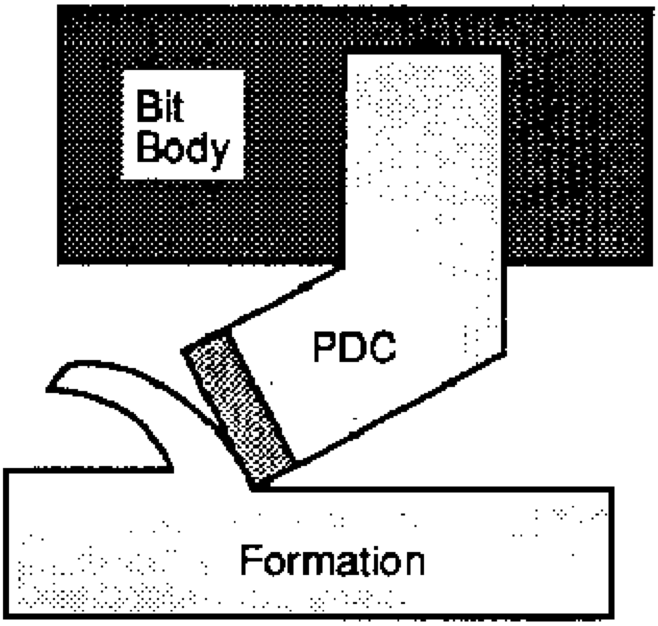

Figure 2.10: PDC Bit Cutting Action (shearing)

PDC bits are expensive and unforgiving. They can be destroyed by hard formations or rendered impotent by gumbo-type formations. Their application should never be indiscriminate. Instead, PDC bits should be put in the hole only after a detailed analysis of formation lithology has been performed and a compatible formation with sufficient thickness has been predicted to make a PDC bit run economical.

The technology of PDC bits is evolving rapidly. As a result, there are many bit designs available from a variety of vendors all trying to approve their product's superiority. A detailed field analysis of these designs has yet to be completed, leaving it difficult to determine the best designs. In many instances, it will be necessary with only a small amount of data to help.

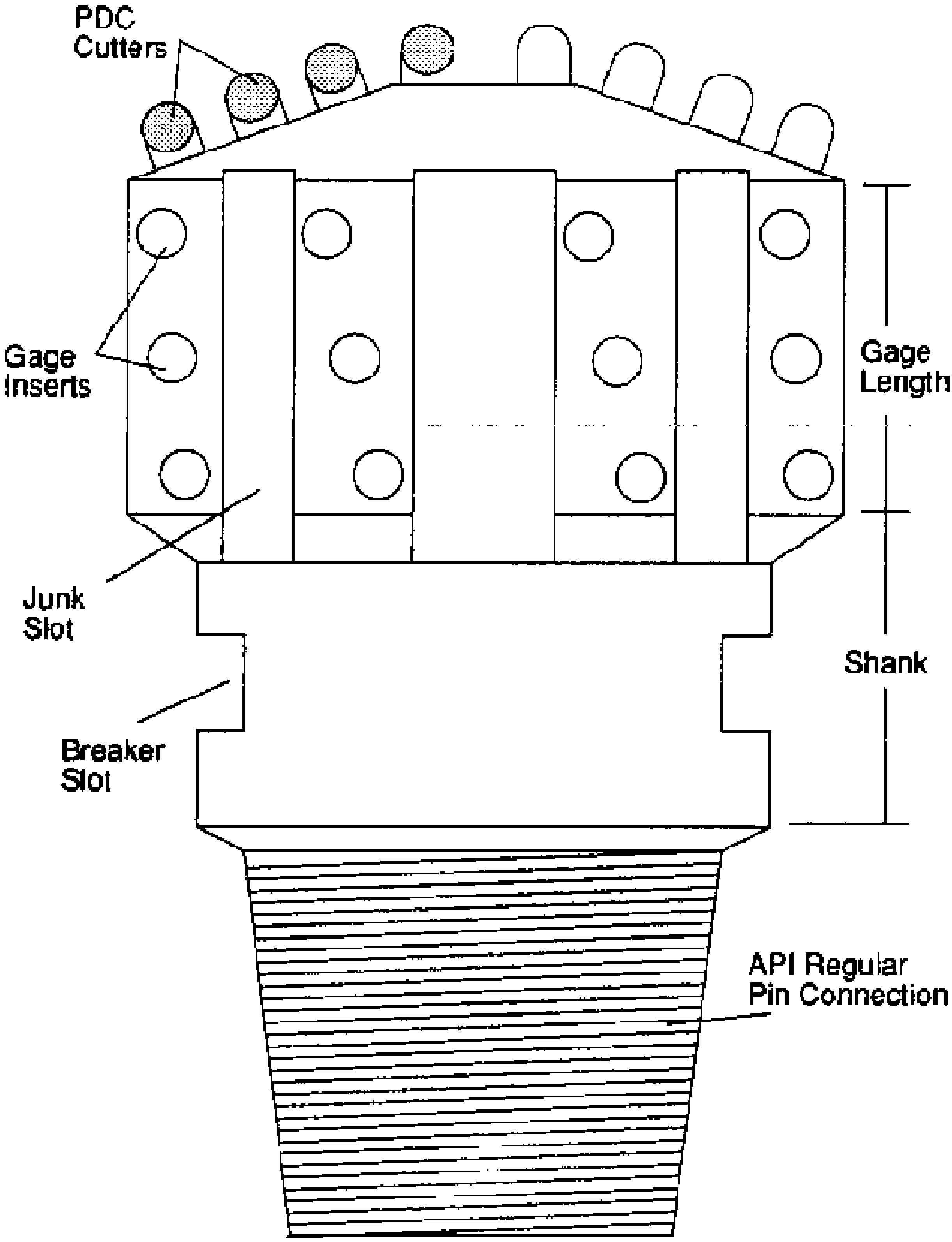

Figure 2.11: Typical PDC Bit Nomenclature

Bit Body Material

The material which is used to make the body of a PDC bit takes a real beating while drilling. Because these bits stay in the hole a long time, the possibility for fluid erosion and mechanical abrasion of the bit body is a real possibility. Most PDC bits experience some fluid erosion while drilling, but this only becomes a problem if the bit body material washed out to the point where a nozzle or a PDC cutter is lost in the hole. When PDC bits are in the hole, junk begets more junk and bit is quickly destroyed.

Basically, there are two types of body materials for PDC bits:
Steel and Tungsten Carbide matrix

Steel Body: The most common and inexpensive bit body material is heat treated steel. These steel body bits are usually used in conjunction with PDC "studs" which are diamond compacts on tungsten carbide posts. These stud cutters are typically secured to the bit body by interference fit or shrink fit into a hole located in the bit body.

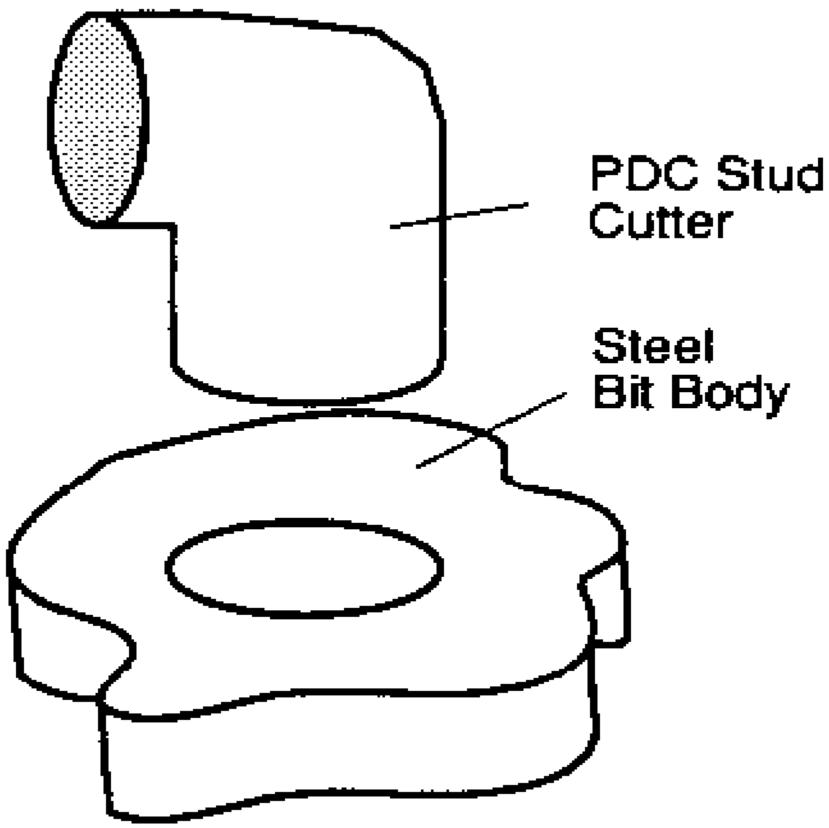

Figure 2.12: PDC Stud Cutter

Steel body bits usually incorporate three or more carbide nozzles (often interchangeable), and carbide buttons on the gauge length to resist wear. Steel body bits have limitations due to fluid erosion of the bit face by drilling mud and the wear of the gauge section. Some steel body bits are offered with wear resistant coatings applied to the bit face to limit mud erosion.

Steel body PDC bits will generally perform well in most soft to medium formations. Body erosion will usually not be the limiting factor which brings the bit runs to an end unless super-high flow rates are in use. In those instances where loss of body material is a problem through abrasive formations, a matrix body should be used.

Matrix Body: A second type of bit body which is much more abrasion and erosion resistant than the steel body is the matrix body. The matrix bit body is composed of a combination of copper and tungsten carbide to provide durable wear resistance. Greater bit design freedom is generally available with tungsten carbide matrix body bits because they are "cast" in a mold as are natural diamond bits. Thus, matrix body bits typically have more complex profiles and incorporate cast nozzles and waterways. In addition to the advantages of advanced bit face configuration and erosion resistance with matrix body bits, PDC matrix bits often use natural diamonds on the gauge hole. Matrix body bits generally have long cylinder shaped cutters secured directly to the bit by brazing.

Matrix body bits will usually not drill any faster than their steel body brothers but they can stay in the hole longer if formation abrasion has been a problem. Matrix body bits are more expensive than steel body bits.

Bit Profile

Bit profile can significantly affect bit performance. The bit profile will have a direct influence on bit cleaning, bit stability and hole deviation control. Several bit profiles are offered with specific design motivations behind each.

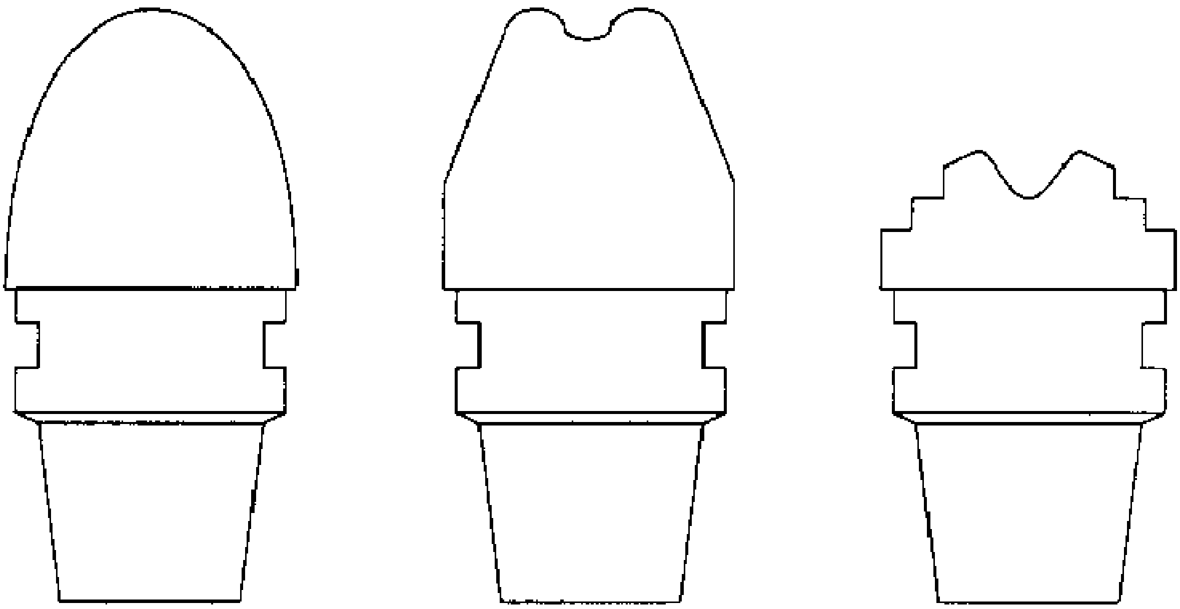

Figure 2.13: PDC Bit Profile

Parabolic: The parabolic or "sharp" nose profile is designed for soft and sticky formations. This bit profile will attack and drill the formation aggressively while the apex and reaming flank stabilize the bit. Conversely, the long taper profile may be more vulnerable to damage when a hard stringer is encountered as only the cutters on the nose will support the impact loading. It is possible to build and drop angle to a limited degree with these bits but they will often exhibit a tendency to walk to the left through harder formations.

Short Concave: The short concave profile shown above is designed to drill medium strength formations but also tends to help maintain a straight hole. Building or dropping angle with these bits is difficult due to the few numbers of cutters on the flanks. This profile relies heavily upon a long gauge section for directional stability. These bits should always be run with stabilizer on top of them to assure that the bit face is seated evenly on the bottom of the hole so that the drilling fluid is evenly distributed. The short concave cone profile appears to be the easiest to clean due to the concentration of hydraulics on the reduced surface area of the bit face.

Step Profile: The step profile shown above places the cutters at maximum exposure from the body of the bit. On these bits, an individual cutter will make contact with the formation on both the bottom and sides of the hole. The resulting dual cutting action creates both horizontal and vertical shearing of the rock which may increase

bit stability, deviation control and penetration rate. The dual contact produces high stresses on each cutter so these bits operate with less total weight on bit. This makes step profile bits good candidates for mud and turbine runs where high speeds but low weights need to be run.

Cutter Placement

The number and placement of cutters on a bit depend upon the formation being drilled, the bit design and style, the expected operating limits and the hydraulics design. Generally, the greater the cutters concentration, the lower the wear rate and lower the rate of penetration. High numbers of cutters are usually placed on the harder formation bits which reduce the load per cutter and the occurrence of PDC breakage. Fewer numbers of cutters are placed on soft formation PDC bits to reduce the chances of bit balling.

PDC cutters are available in a wide variety of patterns, too numerous to mention here. Until a clearly superior pattern steps out from the rest of the crowd, the determination of the best designs will have to be determined by trial and error.

Cutter Exposure

Cutter exposure is the distance between the cutting edge and the bit face. See figure 2.14 for diagrammatic details. Steel body bits which use stud cutters typically have full exposure which proves very aggressive in soft formations for maximum hole making potential. In harder formations, less than full exposure may be preferred for added cutter durability. Partially exposed cutters are harder to clean and are most often found on matrix body bits which are backed-up with matrix material to give the cutters added strength.

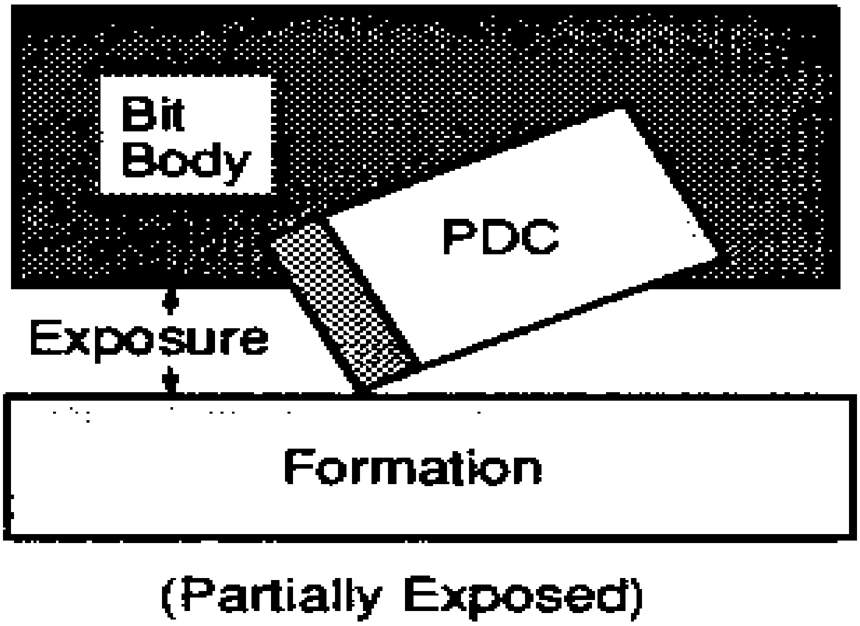

Figure 2.14: PDC Exposure

Cutter Clearance

Another PDC bit enlargement is a cavity which is cut into the face of the bit to provide clearance for cuttings removal. Without the clearance area, cuttings may "jam up" in front of the cutter and inhibit further cuttings generation. The clearance area provides a cavity for the newly created cuttings to peel into before they are circulated away to the outside of the bit.

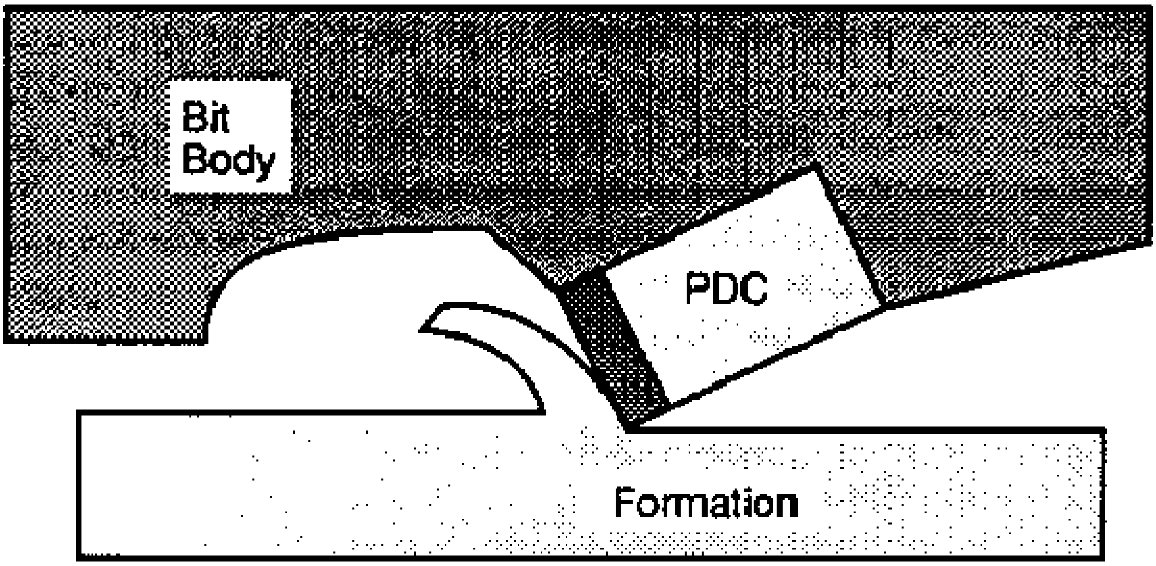

Figure 2.15: Clearance Area

Cutter Orientation

The orientation and direction of the cutters on a PDC bit play a major role in determining the bit's cutting action. Bit designers can alter the angle of attack of individual cutters against the formation to vary the bit's rock shearing mechanism. The side rake angle and back rake angle are two PDC parameters which will determine a PDC bit's effectiveness in drilling through a specific formation.

The action of the PDC bit drilling through rock is similar to that of a snow plow. Just as the angle and depth of the snow plow is adjusted to suit specific snow conditions, the back and side rake angles of a PDC cutter are set to produce optimum penetration rates. The back and side rake angles describe how the face of a PDC cutter is oriented with respect to the body of the bit.

Back Rake Angle

When a PDC cutter has no back rake, the face of the cutter is orientated straight up and down in a plane which is parallel to the longitudinal axis if the bit. With 0 degrees back rake on a cutter, the angle formed between the formation and the face of the cutter is 90 degrees. A pictorial representation of back rake is provided in the figure below.

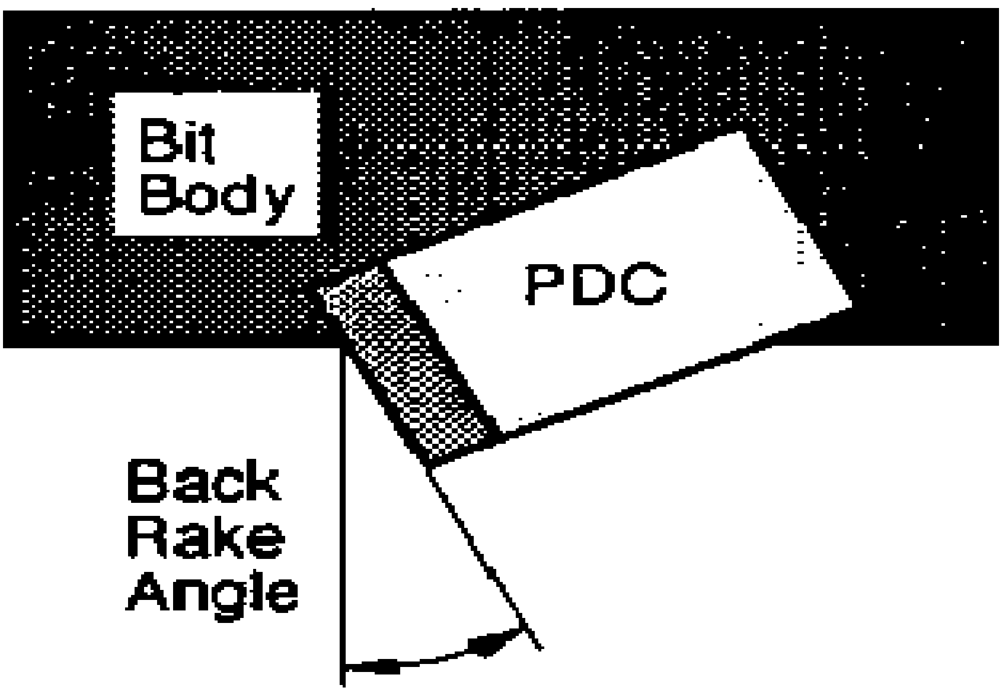

Figure 2.16: Back Rake Angle

When back rake is added, the bottom edge of the figure 2.16 – Back Rake Angle cutter is tilted away from the direction of rotation, so that the angle of incidence with the formation is less than 90 degrees. The addition of back rake increases the life of a cutter because the cutting edge is less susceptible to micro-chippage caused by shock induced loads which can occur when hard stringers are encountered. Also, cutters which are set with a back rake will usually run smoother with less torque. By the same token, back rake makes a cutter less aggressive and creates more of a tendency for the cutter to slide over the formation face rather than shear it. For this reason, penetration rates will usually be lower.

Back rake angles usually vary between 0and 25 degrees, depending on the overall formation hardness and the likelihood of encountering hard streaks. The addition of back rake will not make a PDC bit drill any through hard sections but it will allow the bit to drill through it with sustained damage.

Side Rake Angle

Side rake describes the radial orientation of the face of a PDC cutter to the bit body. With no side rake, the face of the cutter is situated parallel to a radial line drawn from the center of the bit. When back rake is added, the outer edge of the cutter is tilted away from the direction of rotation so that the angle exists between the face of

the cutter and the radial line. This angle is called the side rake angle. Side rake on a PDC cutter performs the same function as angling the direction of a snow plow blade.

Angling the snow plow blade causes the snow to be directed to one side of the plow. Adding side rake to a PDC cutter causes a mechanical displacement of the cuttings to the outside of the bit where they are more easily removed and circulated up the junk slots in the bit. Side rake helps to the cuttings from jamming-up underneath a PDC bit and therefore reduces the chances of bit balling. Figure 2.19 shows how a PDC cutter is placed with a positive side rake angle.

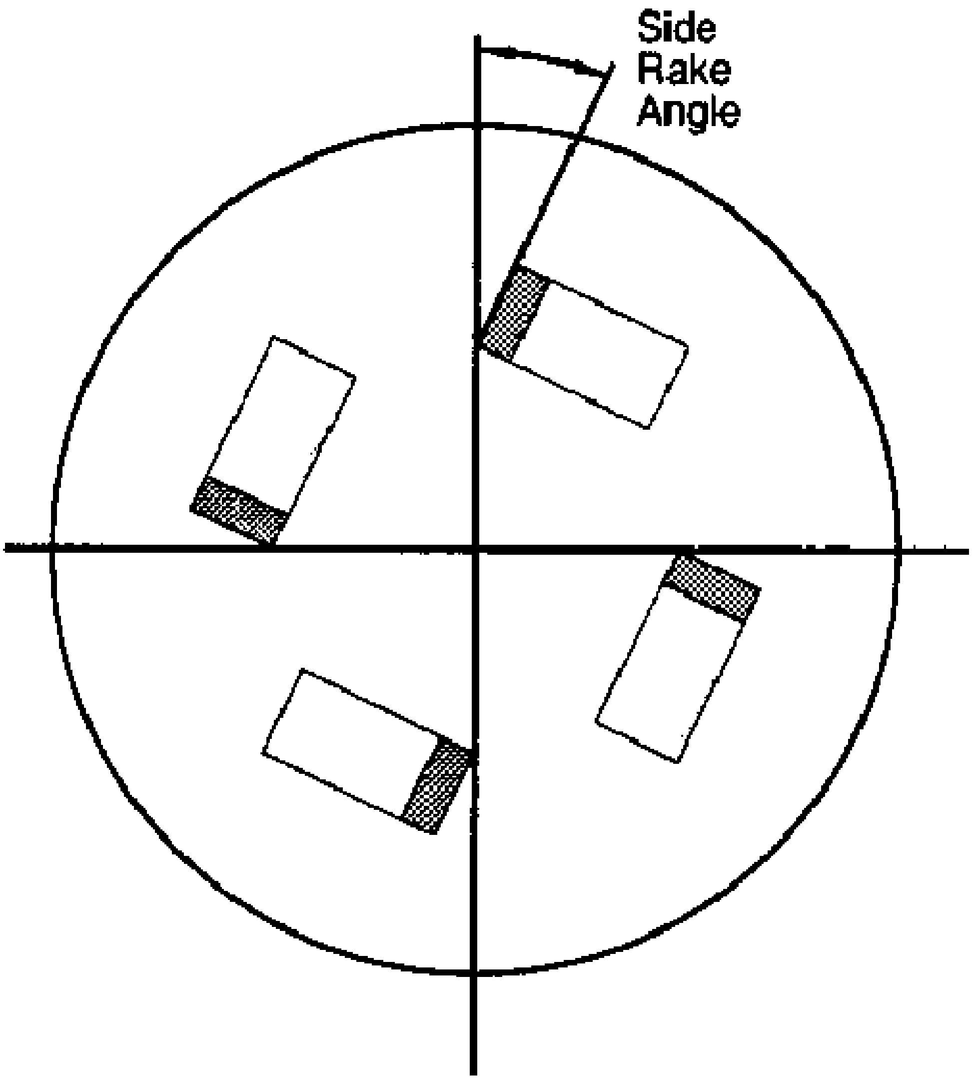

Figure 2.19: Side Rake Angle

Bit Hydraulics

Bit hydraulics is more important to PDC bit performance than to other bit types. PDC bits drill fast and generate large cuttings which must be removed from the face of the bit and up the annulus. Depending on bit profile, the cuttings path from cutter to annulus may be quite tortuous and bit balling is a possibility if they get hung-up along the way. The nozzles on PDC bits are located very close to the bottom of the hole and this aid greatly in cutting removal.

PDC bits are designed with 3-7 nozzles where mud enters the face of the bit from the inside of the drill pipe. Junk slots are cut into the gauge lengths of the bit to serve as fluid exit points from the

face of the bit. Mud and cuttings are transported to the junk slots through watercourses cut into the face of the bit or by natural flow paths defined by cutter placement. Effective bit design involves placing the nozzles, junk slots and watercourses in a way which produces the optimum flow pattern for cutter cleaning and cooling.

The penetration rate of PDC bits through soft formations is usually limited only by the hydraulic cleaning effectiveness. As pump volume or hydraulic energy is decreased, penetration rate is reduced as cutting removal slows. This results in a regrinding of the cuttings or the possible clogging or balling of the bit.

It is usually assumed that hydraulic horsepower rather than impact force is the necessary ingredient to have at the bit to create good cleansing turbulence. Generally, hydraulic horsepower at the bit should be in the range from 2.5 to 4.5 HP/in^2 for steel body bits and up to 7.5 HP/in^2 for matrix bits in sticky formations.

2.6 PDC – BIT SELECTION AND APPLICATION

Compatible Formations

The PDC bit is best suited to drill soft to medium sedimentary formations. Since it drills with a shearing action, it is most effective when drilling formations that fail easily in shear. Some of the most compatible formations for drilling with PDC bits are clays and shale. Good PDC bit runs have also been obtained through evaporate formations such as gypsum, anhydrite and rock salt. While sandstone does not fail in shear, good runs have been reported through soft sandstones that are not well cemented or too abrasive.

The PDC bit is not a good choice to use in hard formations. The brittle PDC cutters can be easily destroyed by hard formations such as chert, granite, calcite and hard dolomite. In addition, well-cemented sedimentary sandstones should not be drilled with PDC bits because of their abrasive nature.

It should also not be used in sticky formation such as “gumbo shale” because the bit is likely to be ball-up. Several manufacturers are working on new versions of their PDC bits with improved hydraulics to serve this application.

Tri-Cone Applications

Formations which may drill well with PDC bits can sometimes be identified by the tri type of tri-cone bits which have been used to drill them in the past. Where good bit runs have been turned in with the following tri-cone bit types, PDC bits should be examined as an improved alternative for future runs:

Tri-Cone Bit	Equivalent PDC Bit Features
Steel Tooth	High Cutter Exposure
IADC Codes	Low Back Rake Angle
	Steel Body
114, 116	Long Taper or Step Profile
124, 125	Low/Medium Cutter Density
TCI Tooth	High or Partial Exposure
IADC Code	High Back Rake Angle
	Matrix Body
517, 527	Flat or Short Profile
	High Cutter Density

Reference: Chevron Drilling Reference Series Volume 9

Table 2.1: General Roller Cone versus PDC Bit Comparison.

An additional requirement for a successful PDC bit run is that the compatible formation be of sufficient thickness to keep the PDC bit in the hole for a long time. The section should be homogeneous with an absence of hard stringers. Sometimes however, it is possible to “nurse” a PDC bit through a hard section by feathering the formation with reduced rotary speed.

Downhole Turbines or Dynadrills

PDC bits drill best with high RPM’s and low bit weights. Therefore, mud motors are a natural compliment to their drilling ability. The absence of roller bearings on PDC bits allows them to handle the high RM’s without coming apart.

Slimhole Drilling

When the OD of a tri-cone bit gets below 6-1/2”, the strength of its bearings is greatly reduced. This requires reduced bit weight and causes slower drilling. PDC bits do not have bearings so they are not similarly restricted. For a PDC bit, the total weight on bit is restricted only by the weight per cutter which remains constant regardless of bit diameter.

High Bottomhole Temperature

Roller cone bearing seals are prone to fail in high temperature environments. PDC bits may be a good substitute in hot holes if bearing seal failures are a problem. As always, the formation lithology should be checked for compatibility.

Oil Base Mud

Roller cone bits will often drill more slowly in oil base mud than in fresh water mud. PDC bits however have had some exceptional bits runs through compatible formations when oil base mud has been in use. It is reasoned that oil mud penetrates the formation ahead of the bit and adds lubricity along the shear planes. The rock then fails more easily when a shear stress is applied by the bit.

Drilling Overbalanced

When the mud overbalance is greater than 500psi, the shearing action of a PDC bit will help to keep the penetration rate up. The cutting action of a PDC bit lifts the cuttings naturally and minimizes the “chip hold down effect” experienced with roller cone bits.

Deviation Control

Dropping angle by reducing bit weight on a roller cone bit will often cause the penetration to drop dramatically. Running light weight on a PDC will sometimes allow the hole to drop angle without reducing the ROP. In non-directional wells, the combination of low bit weight and high RPM on a well stabilized string will usually keep the hole straight.

Multi-Well Drilling Programs

A PDC bit can be run in successive wells to justify the cost when it would not pay out on a single well. If a used PDC bit is kept on location, extreme care should be taken to see that it is handled and stored properly.

2.7 PDC OPERATING PROCEDURES

On a drilling rig, where the most difficult problems are frequently solved by obtaining a bigger hammer, instructions to "take it easy" often go unheeded. It can therefore be difficult to obtain the kind of careful treatment for a PDC bit that it must have in order to make a good run.

Many of the following rules for running PDC bits are concerned with handling and running procedures. It seems odd that the instrument of destruction can itself be destroyed by something as simple as rough handling but many a PDC bit has been partially destroyed because these rules were not followed.

2.7.1 Rules For Running PDC Bits

- Note the rotary torque under normal drilling conditions before pulling out of the hole.
- Gauge the bit to determine if reaming will be required.
- Examine the bit for any broken inserts, lost nozzles, etc., which could mean junk in the hole.
- Do not run the PDC bit on junk. Run a junk bit or cleanup mill and junk basket if necessary. A good practice is to run a junk basket on the bit preceding the PDC bit run.

2.7.2 Handle the PDC carefully on the floor

- Use all handling precautions normally used on diamond bits to protect the brittle and expensive PDC cutters.
- Carefully remove the bit from its container and place it on a piece of plywood or a rubber mat.
- Do not roll the PDC bit on steel floor plates.

2.7.3 Examine the PDCbit making it up

- Gauge the bit to ensure it is the right size.
- Inspect the cutters for any damage.
- Record the serial number, nozzle number, sizes and date.
- Nozzle up the bit, if required, taking care not to damage the O-ring seals in the nozzle seats.

2.7.4 Make up the Bit carefully

- Use the appropriate bit breaker. Make up the bit to the API torque specifications for the standard pin size.

2.7.5 Use extreme caution while tripping in the Hole

- Be careful going through the rotary table, BOP's casing shoes and liner tops.
- Be wary of tight spots or ledges in the hole. PDC bits are not flexible like roller cone bits when going through tight spots. You must ream your way through tight spots to ensure that the bit is not stuck or damaged.
- If a tight spot is encountered, pick up the Kelly and pump at maximum flow rate. Turn the rotary about 60 RPM and advance slowly through the tight spot using no more than 4000lbs weight. Remember when reaming, all WOB is supported by gauge cutters making them heavily loaded even at light WOB.
- If the previous bit was under gauge, reaming to bottom will be necessary using the reaming procedure described above.
- Always wash the last joint slowly to bottom. PDC bit nozzles are very close to bottom and are easily plugged if the bit is jammed into fill. It is good practice to use nozzle protectors. Also, the bit could be easily balled-up if jammed into fill. Drillpipe screens at the surface can also prevent nozzle plugging.
- Locate bottom carefully using both rotary and WOB. Because PDC bits can generate high torque with their aggressive cutters and very little WOB, a sudden torque increase is often the first on-bottom indication especially on small diameter bits.
- After bottom is found, lift the bit 6" off bottom while circulating and rotating slowly for 10 minutes to make certain the bottom of the hole is clean.

2.7.6 Establish a new bottom hole pattern

- Use about 60 RPM and approach bottom carefully allowing no more than 100 lbs WOB per PDC cutter on the bit. For example, if the bit has 40 cutters then use no more than 4000 lbs WOB.
- Drill one foot in this manner to establish the new bottomhole pattern before beginning to optimize weight and WOB. The bit will be in the hole for a long time; do not rush. Apply weight slowly and gradually increase rotary speed until the observed rotary torque is slightly higher than it was with the last roller cone bit. This will be close to the optimum WOB and RPM combination.
- Operating bit weights should be in the range from 600- 2700 pounds per square inch of bit diameter. Higher rotating speeds (when mud turbines are used) will require bit weights in the lower range.

2.7.7 Optimize Weight on bit and rotary speed.

- Drill-off tests should be conducted in the good manner. Do not "bet the bank" early-on and stack out the entire collar on the first drill-off test. Add just a few increments of 1000- 2000 pounds for each DOT and examine the results before adding more weight.
- PDC bit torque is very responsive to changes in bit weight. Notify your driller of this fact.
- If a hard streak is encountered, slow down the rotary table to reduce heat input into the cutters and avoid excessive cutter wear.
- Never spud a PDC bit.
- Generally, hydraulic horsepower at the bit should be in the range from 2.5 to 4.5 HP/in^2 for steel body bits and up to 7.5 HP/in^2 for matrix body bits in sticky formations with water base mud.

2.8 DIAMOND BITS

Diamonds used in oilfield bits are of natural origin and range from as small as 15 tonnes per carat to as large as seven carats per stone. Diamonds are resistant to abrasion, extremely high in compressive strength (the hardest material known) but are low in tensile strength and have high thermal capacity. The low tensile strength reduces its ability to withstand impacts.

A diamond bit (either for drilling or coring) is composed of three parts: Diamonds, Matrix and Shank. The diamonds are held in place by the matrix which is bonded to the steel shank. The matrix is principally powdered tungsten carbide infiltrated with a metal bonding material. The tungsten carbide is used for its abrasive wear and erosion resistant properties (but far from a diamond in this respect). The shank of steel affords structural strength and makes a suitable means to attach the bit to the drill string.

2.8.1 Uses of Diamond Bits.

The decision to run a diamond bit should be based on a detailed cost analysis in combination with many bit selection. The drilling situations which indicate the likelihood of an economical application for diamond bits includes the followings;

Very Short Roller Cone Bit Life: If Roller Cone bit life is very short due to bearing failure, tooth wear or tooth breakage, a diamond bit can increase on-bottom time dramatically. Diamond bit have no bearings and each diamond has a compressive strength of 1,261,000 psi (approximately 1.5 times that of sintered tungsten carbide).[3] The relative wear resistance is approximately 100 times that of tungsten carbide.

Lower Penetration Rates with Roller Cone Bits: When Roller Cone bits drill at slow rates (especially 5ft/hr or less), due to high mud weights or limited rig hydraulics, diamond bit can provide a savings. Since the drilling fluid is usually distributed between the bit face and the formation in a smooth uniform sheet, it takes less hydraulic horsepower per inch to clean under a diamond bit than under the same size roller cone bit.

Deep, Small holes: Roller cone bits that are 6" and smaller have limited life due to the space limitation on the bearings, cone shell thickness, etc. Diamond bits being one solid piece often last much longer in very small boreholes.

Directional drilling: Diamond side tracking bits are designed to drill "sideways" making it a natural choice for "kicking off" in directional drilling situations.

Limited Bit Weight: Diamond bits drill at higher rates of penetration with less weight than normally required for roller cone bits in the same size range.

Downhole Motor Application: Roller Cone bits generally have bearing failures on motor applications due to high rotary speeds. Diamond bits will have a very long life under these conditions.

Cutting Casing Windows: Window cutting through casing using diamond bits is now an effective, field-proven method for re-entering older wells to increase production, to apply directional drilling techniques or to sidetrack.

Coring: The use of diamond bits for coring operations is essential for smooth, whole cores. Longer cores are possible with increased on-bottom time and cores "look better" because of the cutting action of diamond bits as compared to roller cone bits.

2.8.2 Limitations of Diamond Bits

Very Hard Broken Formation: Broken formations can cause severe shock loading on diamond bits resulting in diamond breakage and a short bit life.

Formation Containing Chert or Pyrite: Chert and Pyrite tend to break apart in large pieces and "roll" under a under a diamond bit, causing diamond damage.

Reaming Long Sections In Hard Formations: The hydraulic cooling and cleaning are extremely poor during reaming since the nozzles of a diamond bit are formed by the formation on side and bit matrix on the other side.

2.8.3 Bits Stabilization

A diamond is extremely strong in compression but relatively weak in shear and needs constant cooling when on bottom. The bit is designed and the rake of the diamonds set, so that a constant vertical load on the bit keeps an even compressive load on the diamonds and even distribution of coolant fluid over the bit face. If there is lateral movement or tilting of the bit, an uneven shear load can be put on the diamonds with coolant leakage on the opposite side of the bit.

CHAPTER 3 DRILLING OPTIMAZATION MODELS

A good number of drilling optimization models have been published by different authors and they shall be expressly reviewed in this section of this project work.

3.1 SeROP MODEL

The Specific Energy Rate of Penetration (SeROP) model has been proved valuable for improving drilling performance. The SeROP model reduces well cost by improving bit performance prediction, bit selection and determination of optimum drilling parameters.
This technology makes it possible to select the optimum drill bits and stands to reduce the bit optimization learning curve from several wells to one. The method is global and robust, based on specific energy principles and confined compressive strength (CCS). It requires little or no calibration. Any calibration that may be required is intuitive and simple.

Specific energy theory is not new. Specific energy principles have been used for years to provide a method to predict or analyze bit performance. Specific energy is based on fundamental principles related to the amount of energy required to destroy a unit volume of rock and to the efficiency of bits to destroy the rock[23]. The specific energy parameter is the most useful measurement tool for predicting the power requirements (torque) for a particular bit might be expected to achieve in any rock type. The equation (1) shows the specific energy equation derived for rotary drilling at atmospheric conditions[23, 21].

$$S_e = \frac{WOB}{A_B} + \frac{120 * \pi * N * T}{A_B * ROP} \quad \text{(3.1)}$$

Where

S_e = Specific energy (psi)

WOB = Weight on bit (pound)

A_B = Borehole area (sq-in)

N = Revolution per minute

T = Torque (ft-lbf)

ROP = Rate of Penetration (ft/hr)

Because the majority of field data consists of surface measurements of weight on bit (WOB), rpm (N) and rate of penetration (ROP), a bit-specific coefficient of sliding friction (μ) was introduced to express torque (T) as a function of WOB[23].

$$\mu = 36\frac{T_B}{D_B * WOB} \quad (3.2)$$

Where

T_B = Bit torque (ft-lbf)

D_B = Bit size (inches)

μ = Bit-specific coefficient of sliding friction (dimensionless)

Specific energy theory also defines the concept of minimum specific energy and maximum mechanical efficiency[23]. The minimum specific energy is reached when the specific energy approaches or is roughly equal to the rock strength being drilled. The mechanical efficiency (EFF_M) for any bit type is then calculated as shown in equation (3):

$$EFF_M = \frac{E_{Smin}}{E_S} * 100 \quad (3.3)$$

Where

E_{Smin} = Rock strength (CCS in psi)

EFF_M = Bit mechanical efficiency (%)

The SeROP model uses confined compressive strength (CCS). This new proprietary methodology differs from existing ROP prediction methods that are based on unconfined compressive strength (UCS). UCS can be erroneous and or require calibration whenever the drilling environment changes. Because of this, UCS lacks the accuracy needed to predict ROP.

CCS calculates the altered pore pressure at the bottom of the hole directly below the bit. It also promotes a more accurate prediction of the confining stress (due to mud ECD and pore pressure differential), leading to a more accurate prediction of confined rock strength or “apparent” strength to the bit.

Chevron developed this proprietary, unique and revolutionary method of predicting the coefficients required for equation (4) as a function of rock strength (CCS). This method was done for all predominant bit types including steel tooth, insert tooth, PDC, TSP, impregnated and natural diamond bit types. The relationships for bit-specific coefficient of sliding friction (μ) mechanical efficiency (EFF_M) as a function of rock strength (CCS) were accurately determined from full-scale drilling simulator tests[23].

Using this new capability and the globally-applicable rock property determination techniques, the ROP for all of the bit types with reasonable accuracy and no calibration can quickly be calculated. The approach can also be easily updated as technology advances because it is based on fundamental rock destruction principles and on conservation of methodology and work process is relatively simple in comparison to other ROP predictive processes used in the industry. A skilled drilling engineer could use the methodology. It does not require a specialist.

By substituting specific energy in terms of mechanical efficiency and CCS and torque as a function of WOB and solving equation (1) for ROP, the rate of penetration for any bit type can be calculated with equation (4) as follows:

$$ROP = \frac{13.33 * \mu * N}{D_B\left(\frac{CCS}{EFF_M * WOB} - \frac{1}{A_B}\right)} \quad \text{..........} (3.4)$$

The effect of mud weight, mud system, blade count, back rake angle, cutter size to the coefficient of sliding friction and mechanical efficiency are also considered in the ROP predictions.

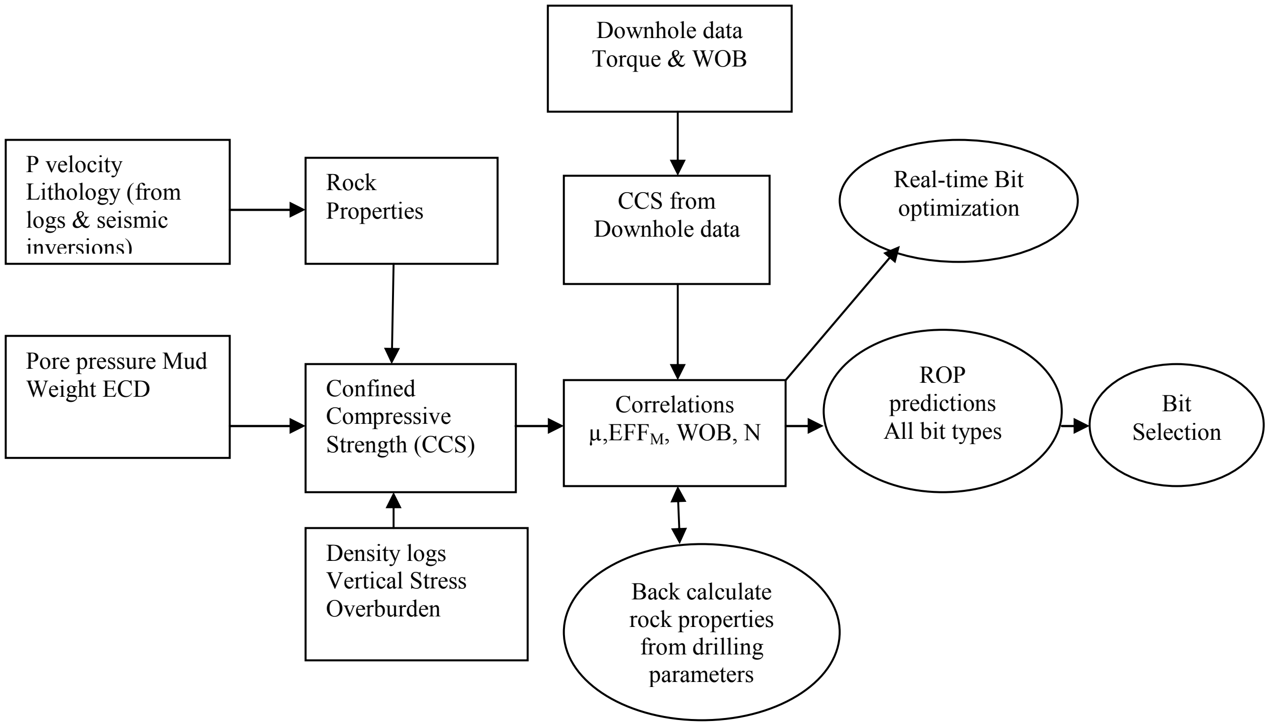

Figure 3.1: Rock Mechanics (RMA), Confined Compressive Strength (CCS) and Specific energy Rate of Penetration (SeROP) flowchart.

3.2 RATE OF PENETRATION (ROP) MODELS

Hareland, et al[4] introduced ROP model approach for bit performance. The general form of ROP equation for a 100 percent efficient bit cleaning is:

$$ROP = W_f * \left(\frac{G.RPM_l^{\gamma}.WOB^{\alpha}}{D_B S}\right) \quad (3.5)$$

G is a coefficient determined by the bit geometry, cutter size and design (backrake and siderake angles) and cutter-rock coefficient of friction. W_f is standing for wear function, estimating how much of new bit ROP is approachable by a bit with certain bit wear value. Equation (3.6) is developed to estimate Wear function based on single cutter experimental data[4].

$$W_f = k_{wf}\left(\frac{WOB}{N_c}\right)^{\rho} * \frac{1}{S^{\tau} A_w^{\rho+1}} \quad (3.6)$$

A_w is wear flat area underneath of a single cutter which is a function of wear depth on cutter face and PDC layer thickness. It has to be mentioned that rock strength value in equation (3.5) and (3.6) is confined rock strength. The effect of confining pressure on rock strength can be estimated by:

$$S = S_o(1-a_s.P_c^{\,b_s}) \quad (3.7)$$

S_o and P_c are rock unconfined strength and confinement pressure respectively. Confinement pressure is defined as pressure difference of mud hydraulic pressure and rock pore pressure which is a positive value in overbalanced situation.

"a_s" and "b_s" are coefficients depending on rock lithology.

Wear depth on cutter face or equivalent IADC bit wear is defined to be a function of removed cutter volume due to friction. Removed cutter volume is assumed to be proportional to cumulative effect of applied operational parameters (WOB, RPM) and rock confined strength and its relative abrasiveness in previously drilled footages by the bit as:

$$V_{eq}=C_a.\sum_{d=d_{in}}^{d_{out}}\left(\frac{WOB_d}{1000.N_c}\right)^{C_1}.RPM_{td}^{\;C_2}.\left(\frac{S_d}{1000}\right).Abr_d \quad (3.8)$$

The proportionality factor is a function of PDC layer material durability (C_a) and relative hardness of cutter Tungsten carbide matrix to PDC layer material.

Based on approach followed for developing ROP model, required torque for drilling in perfect cleaning condition can be estimated by:

$$T = C_{T1}.\frac{S.ROP}{RPM_l} + C_{T2}.WOB.D_B \quad (3.9)$$

C_{T1} and C_{T2} are coefficients which are determined from bit design, cutter geometry and coefficient of friction between rock and cutters. It is clear that bit cutter wear affects drilling torque which is obtained from the ROP value.

Several ROP models have been proposed to combine known experimental or mathematic derived relationship between operating conditions and rate of penetration. These models make it possible to apply formal optimization methods to the problem of selecting the best weight on bit rotary speed to achieve the minimum cost per foot. By utilizing ROP models significant drilling cost reductions and increase in rate of penetration has been reported (Nygaard, et al. 2002, Hareland et al 2007).

3.2.1 Borgouyne & Young ROP Model

In this model, penetration rate is a function of several variables such as sediments compaction, pore pressure, bit weight, rotary speed, impact force, bit hydraulics; cutter wear (Borguoyne and Young 1974). The model is mathematically expressed as:

$$ROP = f_1 * f_2 * f_3 * f_4 * f_5 * f_6 * f_7 * f_8 \quad (3.10)$$

Where f_1 to f_8 expresses the different effects on ROP such as rock drillability, operational parameter and bit wear. In the f_1 to f_8 functions formulas a_1 to a_2 are experimental model constants. f_1 is the effect of rock drillability which is proportional with formation rock strength and is given by;

$$f_1 = e^{2.303 a_1} \quad (3.11)$$

The second term is the depth effect given as:

$$f_2 = e^{2.303 a_2 (1000-D)} \quad (3.12)$$

where D is depth in feet. The third term is the effect pore pressure has on ROP where overpressure will increase ROP and f_3 is given:

$$f_3 = e^{2.303 a_3 D^{0.69} (g_p - 9)} \quad (3.13)$$

where g_p is the pore pressure in pounds per gallon equivalent. The fourth term is the effect of overbalance on ROP caused by mud weight increase.

$$f_4 = e^{2.303 a_3 D^{0.69} (g_p - P_c)} \quad (3.14)$$

where P_c is mud weight in pounds per gallon. The fifth term is the effect on ROP caused by changing the weight on bit.

$$f_5 = \left[\frac{\left(\frac{w}{d_B}\right)-\left(\frac{w}{d_B}\right)_t}{4-\left(\frac{w}{d}\right)_t}\right]^{a_5} \quad \text{(3.15)}$$

where w is weight on bit, d_B is the bit diameter. The sixth term is the effect of rotary speed on ROP.

$$f_6 = \left(\frac{N}{60}\right)^{a_6} \quad \text{(3.16)}$$

where N is revolution per minute. The seventh term is the effect of bit wear on ROP.

$$f_7 = e^{-a_7 h} \quad \text{(3.17)}$$

where h gives the amount of bit wear for a bit. The last is the jet impact force effect which includes the effect of bit hydraulics on ROP. F_j is further described in Borgouyne and Young (1974).

$$f_8 = \left(\frac{F_j}{100}\right)^{a_8} \quad \text{(3.18)}$$

3.2.2 Mechanical Specific Energy (MSE)

The concept of Mechanical Specific Energy is defined as the work required to destroy a given volume of the rock. The MSE monitoring process can provide the ability to detect changes in drilling efficiency which possibly can be used to optimize operating parameters. By definition it can be defined as input energy to the output ROP. The MSE equation can be expressed in terms of drilling parameters can as:

$$MSE = \frac{WOB}{A_B} + \frac{120\pi NT}{A_B ROP} \quad \text{(3.1)}$$

In above formula A_B is bit surface area (*inch*^{2}), N is rotary speed (*Round per minute*), T is measured Torque (*lbf*ft*) and MSE in *psi* (B Rashidi).[21]

In equation 3.19, torque is used as a variable in the MSE calculation formula. Torque at the bit can be measured by a MWD system but in most cases no bit's torque measurement exist. Bit specific coefficient of sliding friction (μ) is introduced to express torque as a function of the WOB and to let the MSE to be calculated in the absence of reliable torque measurement.

$$T = \mu \frac{D_B WOB}{36} \quad \text{(3.2)}$$

Combining equations 3.1 and 3.2, a new form of MSE is derived and is called the modified MSE shown as :

$$MSE_{mod} = WOB\left(\frac{1}{A_B} + \frac{13.33\mu N}{D_B ROP}\right) \quad \text{(3.19)}$$

The “sliding” coefficient” friction coefficient is a constant dimensionless number which is used with a specific value for Roller Cone and PDC bits. The exact bit “sliding” friction coefficient value can be obtained using the measured torque and WOB in the laboratory[21].

3.2.3 Real-Time Bit Wear Model Development

In the Burgouyne and Young ROP model, the ROP is defined as the effect of eight functions which can be inverted to obtain the drillability noted as the f_1 function (*ft/hr*).

Offset well drilling data such as ROP, WOB, RPM, flow rate, mud weight and pore pressure from each meter or foot of drilled well can be used to estimate the rock drillability value as below:

$$f_1 = \frac{ROP}{f_2 f_3 * f_4 * f_5 * f_6 * f_7 * f_8} \quad \text{(3.20)}$$

Fractional bit wear is simplified and assumed as linear decreasing using the below equation:

$$h = \frac{(Depth_{current} - Depth_{in})}{(Depth_{out} - Depth_{in})} * \frac{DG}{8} \quad \text{(3.21)}$$

DG in above equation is the IADC dull grade bit wear state which is reported when the bit is pulled and has a value between 0 and 8 and is shown in Figure 2.8 for both Roller Cone and PDC bits.

Mechanical specific energy uses the ROP value directly in its formula. To find a relationship between MSE value and rock drillability a new model was suggested [21].

The new model is originally proposed in the power form as:

$MSE = K_1\left(\frac{1}{f_1}\right)^{K_2}$ .... (3.22)

where K_1 and K_2 are constants verifiable with offset drilling data. The constants vary from field to field.

3.2.4 Rock Strength Calculations

The rock mechanical parameters most important when conducting drilling analysis is unconfined compressive rock strength (UCS).[16] the UCS can be determined from Mohr Coulomb failure criteria. The Mohr-Coulomb failure criterion in terms of peak loads is given as:

$S'_v = UCS + S'_h \tan\alpha$ ……………………………………………………………………… (3.23)

where S'_v is vertical effective stress, S'_h is horizontal effective stress and α is failure angle. Effective stresses are defined as the difference between total stresses and pore pressure.

$S'_v = S_v - pp$ ……………………………………………………………………………… (3.24)

S_v is the total stress and pp is the pore pressure.

The Apparent Rock Strength based on the inverted ROP model for a specific bit has been presented for a roller cone bit as follows[10].

$ROP = \left[f(hyd)\left[\frac{aS^{(2-bs)}{d_b}^2}{RPM.WOB^{(2-bs)}}\right]\right]^{-1}$ ………………………………………………………….. (3.25)

ROP is Rate of Penetration, W_f is wear factor that takes into account wear of the bit, *f(hyd)* is a function that takes into account any of the hydraulic effects such as flow and mud properties, *S* is the rock strength named ARSL, *RPM* is revolution per minute, *WOB* is weight on Bit, d_b is bit diameter and *a, bs* are laboratory derived model constants. After a well is drilled all information is known except the Rock strength *S*. The rock strength can be calculated by inverting the Roller Cone bit ROP model in equation 3.25.

There are several methods to obtain Unconfined Compressive Strength (UCS) of rock along the well bore. In most cases, the availability of data determines which methods to choose. Different methods of obtaining UCS are described below:

Rock mechanical laboratory testing on preserved core samples are the most accurate method for calculating rock strength.

The use of logs (sonic velocity logs, neutron logs, Porosity or combination) to determine elastic properties of rock is well established. Several correlations between rock strength and sonic travel have been published.[16]

To overcome the time-consuming tri-axial, rock mechanical strength from cuttings is conducted on small cutting samples.

The use of drilling data to predict rock strength has been developed based on Rate of penetration (ROP) models.[4-23]

3.3 THE COST PER FOOT EQUATIONS

Drilling optimization is the application of technology which yields a reduction of drilling costs associated with making hole. The following optimization techniques are popular in drilling:

-Cost per foot equation
-Time value of money
-Expected value method
-Lagrangian multiplier
-Multiple regression
-Confidence intervals
-Lagrange's interpolation formula.

Only the cost per equation will be given light here. The cost per foot equation is used for the comparison of alternative equipment, chemicals and procedures for the drilling of a formation or an interval. The comparisons are often called break-even calculatios and are usually between drill bit types or manufacturers; however, any of the variables may be compared.

$$C = \frac{Bit + Tools + Mud + [DrillTime + Trip + Lost][Rig + Support + ToolRental]}{Drill\ Rate * Drill\ Time}$$

Where

C = cost per foot for interval of concern, \$/ft

Bit = Cost of delivered bit at the drill site, \$

Tools = Cost of tools or Repairs totools, \$

Mud = Cost of mud to drill the interval, \$

Drill Time = Time required to drill the interval or bit life, hr

Trip = Time to pull and run a bit, hr

Lost = Time chargeable to non-drilling task, hr

Rig = Contract rental rate of a rig, \$/hr

Support = Third party contractors rates, \$/hr

Tool Rental = Rental of tools, \$/hr

Drill Rate = Average drilling rate over the interval, ft/hr

In a comparison of drill bits, the drilling rate and life of the proposed bit will always be in question. The usual procedure is to compute the cost per foot with the data from a standard bit with the proposed bit; and then construct a chart of required drilling rate and bit life for the proposed bit.[22]

CHAPTER 4 BIT PERFORMANCE OPTIMIZATION SIMULATION

The first phase of the optimization process involves the selection of a reference well which closely matches the planned well. Using the data from the reference well, a Geologic Drilling Log (Apparent Rock Strength Log- ARSL)[4,1,2] is generated by the inversion of the bit specific rate of penetration models. The effects of operating parameter, bit design and wear, drilling hydraulics, mud rheology and pore pressure being integral to the model.

The inverted rate of penetration provided a calibrated measure of the rock strength under actual drilling conditions and simultaneously determines the wear characteristic of the bits used in drilling the relevant sections.

The wear characteristic is a statistical evaluation of the bits performance while drilling varying formation types and under a variety of operating conditions and includes detailed bit geometry and its resistance to wear.

4.1 APPARENT ROCK STRENGTH LOG (ARSL) APPLICATIONS

ARSL is applied in the determination of wellbore stability profile. This is important to minimize the occurrences of wellbore collapse, pipe sticking, loss circulation and the host of others. The ARSL represents the compressive strength of the rock in the same plane as the bit's trajectory.

The application of ARSL is also in the determination of the ability of 3D rotary assemblies to steer effectively. The relationship between the behavior of a rotary steerable bottom hole assembly and changes in apparent rock strengths has been determined by correlating tool behavior with data obtained from ARSL.

ARSL is used in combination with established casing points, well paths, drilling mode (rotary o r steerable system), mud types, bit types, pull depths, operating conditions and mud rheology/hydraulics to perform simulations. The ARSL with information from simulator modules, known limitations to operating parameters and rig equipment constraint dictates parameter to be used[14].

4.2 DROPS SIMULATOR OPTIMIZATION

In the actual optimization of bit performance simulation, two reference wells A and B were used. They are Conoco Phillips wells selected from Ekofisk/Eldfisk field of the North Sea.
Halliburton (Sperry Drilling Services) was the Drilling vendor who provided the drilling operating parameters, some of the bit information, survey data and drilling fluid properties needed while the lithology information, the rest of the bit information and pore pressure profile were obtained directly via a contact from Conoco Phillips.

In order for the Drill Bit performance optimization to be simulated using the DROPS Simulator, the obtained data were categorized into the drilling operating parameters, survey data, lithology information and the bits information.

For the purpose of emphasis, only the obtained data for reference well A will be presented in the project work. Well B will be implied with the DROPS Simulator because of large depth volume it entails.

4.2.1 Drilling Operating Parameters for Well A

Table 4.1 Drilling Parameters for Well A

Mudtype(1=Oil,0=Water) and Drilling Mode (R=Rotary,A=AutoBHA)

Depth	TVD	ROP	WOB	RPMtotal	flow in	PV	MW	MUDTYPE	DMODE
ft	ft	fph	klb	rpm	gpm		ppg		
5078	4787.69	10.95	3.70	119.97	793.65	30	14.5	1	R
5079	4788.50	10.99	3.10	119.97	793.76	30	14.5	1	R
5080	4789.32	10.93	4.42	119.98	794.01	30	14.5	1	R
5081	4790.13	10.89	4.40	120.00	793.99	30	14.5	1	R
5082	4790.94	12.65	3.44	119.98	793.98	30	14.5	1	R
5083	4791.76	25.88	6.15	119.99	794.05	30	14.5	1	R
5084	4792.57	28.61	6.82	120.01	794.01	30	14.5	1	R
5085	4793.38	34.09	7.68	119.98	794.02	30	14.5	1	R
5086	4794.20	36.18	7.99	119.97	794.00	30	14.5	1	R
5087	4795.01	38.27	8.30	119.96	793.97	30	14.5	1	R
5088	4795.83	37.91	8.74	119.94	793.93	30	14.5	1	R
5089	4796.64	38.59	8.80	119.90	793.91	30	14.5	1	R
5090	4797.46	35.62	9.54	119.96	793.87	30	14.5	1	R
5091	4798.27	31.70	9.71	119.98	793.87	30	14.5	1	R
5092	4799.09	33.74	8.78	120.00	793.86	30	14.5	1	R
5093	4799.90	32.31	8.84	119.95	793.95	30	14.5	1	R
5094	4800.72	35.36	8.45	119.98	793.94	30	14.5	1	R
5095	4801.53	36.30	8.28	120.01	793.96	30	14.5	1	R
5096	4802.35	36.11	8.20	119.99	793.97	30	14.5	1	R
5097	4803.17	37.35	7.80	119.97	793.94	30	14.5	1	R
5098	4803.98	39.96	7.51	119.97	793.95	30	14.5	1	R
5099	4804.80	39.23	8.66	120.02	793.90	30	14.5	1	R
5100	4805.61	39.58	8.22	119.98	793.87	30	14.5	1	R
5101	4806.43	40.41	8.04	119.99	793.87	30	14.5	1	R
5102	4807.25	44.08	8.69	120.02	793.84	30	14.5	1	R
5103	4808.06	46.92	8.93	119.98	793.81	30	14.5	1	R
5104	4808.88	45.22	8.66	119.99	793.83	30	14.5	1	R
5105	4809.69	44.29	7.88	119.96	793.85	30	14.5	1	R
5106	4810.51	39.04	10.04	120.01	793.86	30	14.5	1	R
5107	4811.32	40.03	9.27	119.98	793.87	30	14.5	1	R
5108	4812.13	43.23	8.67	119.98	793.87	30	14.5	1	R
5109	4812.95	44.09	8.92	119.97	793.82	30	14.5	1	R
5110	4813.76	41.56	9.15	119.96	793.80	30	14.5	1	R
5111	4814.58	39.90	10.15	119.97	793.77	30	14.5	1	R
5112	4815.39	40.38	9.97	119.94	793.71	30	14.5	1	R
5113	4816.20	42.70	9.41	119.97	793.68	30	14.5	1	R
5114	4817.02	41.68	9.01	119.97	793.64	30	14.5	1	R
5115	4817.83	41.36	8.97	119.97	793.61	30	14.5	1	R
5116	4818.64	40.25	9.12	119.98	793.56	30	14.5	1	R
5117	4819.46	40.02	8.98	119.97	793.57	30	14.5	1	R

5118	4820.27	40.54	9.58	120.00	793.58	30	14.5	1	R
5119	4821.08	26.71	10.19	120.00	793.58	30	14.5	1	R
5120	4821.89	28.21	8.16	119.98	793.60	30	14.5	1	R
5121	4822.50	57.71	5.56	99.97	753.93	30	14.95	1	R
5122	4823.11	87.21	2.95	79.97	714.27	30	15.4	1	R
5123	4823.92	69.69	2.20	79.98	714.29	30	15.4	1	R
5124	4824.74	52.17	1.45	80.00	714.31	30	15.4	1	R
5125	4825.55	45.77	1.07	79.98	714.30	30	15.4	1	R
5126	4826.36	39.37	0.70	79.97	714.30	29	15.4	1	R
5127	4827.17	39.23	0.77	79.98	714.28	29	15.4	1	R
5128	4827.98	39.10	0.84	79.98	714.26	29	15.4	1	R
5129	4828.79	39.27	0.66	79.98	714.24	29	15.4	1	R
5130	4829.60	39.44	0.48	79.97	714.23	29	15.4	1	R
5131	4830.41	38.06	0.78	79.98	714.23	29	15.4	1	R
5132	4831.22	36.67	1.08	79.98	714.24	29	15.4	1	R
5133	4832.03	33.20	1.36	79.98	714.21	29	15.4	1	R
5134	4832.84	29.73	1.63	79.99	714.18	29	15.4	1	R
5135	4833.65	34.62	1.02	79.98	714.16	29	15.4	1	R
5136	4834.46	39.50	0.40	79.97	714.13	29	15.4	1	R
5137	4835.27	39.50	0.40	79.97	714.14	29	15.4	1	R
5138	4836.08	39.49	0.39	79.98	714.15	29	15.4	1	R
5139	4836.89	39.16	0.63	79.99	714.13	29	15.4	1	R
5140	4837.70	38.84	0.87	79.99	714.11	28	15.4	1	R
5141	4838.51	38.89	0.84	79.99	714.10	28	15.4	1	R
5142	4839.32	38.94	0.82	79.98	714.10	28	15.4	1	R
5143	4840.13	38.85	0.93	79.98	714.10	28	15.4	1	R
5144	4840.94	38.76	1.04	79.98	714.10	28	15.4	1	R
5145	4841.74	38.80	1.16	79.98	714.09	28	15.4	1	R
5146	4842.55	38.85	1.28	79.99	714.08	28	15.4	1	R
5147	4843.36	38.56	1.26	79.98	714.07	28	15.4	1	R
5148	4844.17	38.27	1.24	79.97	714.07	28	15.4	1	R
5149	4844.98	38.35	1.43	79.98	714.08	28	15.4	1	R
5150	4845.78	38.42	1.62	79.98	714.08	28	15.4	1	R
5151	4846.59	38.96	1.75	79.98	714.07	28	15.4	1	R
5152	4847.40	39.51	1.88	79.97	714.06	28	15.4	1	R
5153	4848.20	39.54	1.94	79.97	714.05	28	15.4	1	R
5154	4849.01	39.57	2.00	79.97	714.04	28	15.4	1	R
5155	4849.82	39.46	2.12	79.98	714.05	28	15.4	1	R
5156	4850.62	39.35	2.25	79.99	714.05	28	15.4	1	R
5157	4851.43	38.44	2.35	79.98	714.05	28	15.4	1	R
5158	4852.24	37.52	2.45	79.98	714.04	28	15.4	1	R
5159	4853.04	35.18	2.13	79.99	714.01	28	15.4	1	R
5160	4853.85	32.83	1.81	79.99	713.97	28	15.4	1	R
5161	4854.65	36.31	1.81	79.97	713.97	28	15.4	1	R
5162	4855.46	39.78	1.80	79.96	713.97	28	15.4	1	R
5163	4856.26	39.76	1.72	79.97	713.99	28	15.4	1	R

5164	4857.07	39.73	1.64	79.98	714.01	28	15.4	1	R
5165	4857.87	39.73	1.62	79.98	714.04	28	15.4	1	R
5166	4858.68	39.73	1.60	79.97	714.06	28	15.4	1	R
5167	4859.48	39.30	1.66	79.98	714.00	28	15.4	1	R
5168	4860.29	38.87	1.71	79.98	713.94	28	15.4	1	R
5169	4861.09	39.49	1.57	79.98	713.96	28	15.4	1	R
5170	4861.89	40.12	1.42	79.97	713.97	28	15.4	1	R
5171	4862.70	40.15	1.41	79.97	713.94	28	15.4	1	R
5172	4863.50	40.19	1.40	79.98	713.90	28	15.4	1	R
5173	4864.31	40.20	1.29	79.98	713.81	28	15.4	1	R
5174	4865.11	40.22	1.18	79.99	713.71	28	15.4	1	R
5175	4865.91	40.16	1.37	79.99	713.70	28	15.4	1	R
5176	4866.71	40.11	1.57	79.99	713.69	28	15.4	1	R
5177	4867.52	39.40	1.74	79.99	713.67	28	15.4	1	R
5178	4868.32	38.70	1.91	79.98	713.65	28	15.4	1	R
5179	4869.12	37.69	1.94	79.98	713.61	28	15.4	1	R
5180	4869.92	36.68	1.96	79.98	713.58	28	15.4	1	R
5181	4870.73	37.39	2.06	79.97	713.54	28	15.4	1	R
5182	4871.53	38.10	2.16	79.97	713.50	28	15.4	1	R
5183	4872.33	39.14	2.13	79.97	713.57	28	15.4	1	R
5184	4873.13	40.18	2.10	79.98	713.64	28	15.4	1	R
5185	4873.93	40.31	1.91	79.97	713.72	28	15.4	1	R
5186	4874.73	40.44	1.72	79.97	713.80	28	15.4	1	R
5187	4875.54	40.23	1.75	79.97	713.81	28	15.4	1	R
5188	4876.34	40.02	1.77	79.98	713.83	28	15.4	1	R
5189	4877.14	39.84	1.73	79.98	713.80	28	15.4	1	R
5190	4877.94	39.67	1.69	79.98	713.76	28	15.4	1	R
5191	4878.74	39.68	1.69	79.97	713.68	28	15.4	1	R
5192	4879.54	39.70	1.70	79.97	713.59	28	15.4	1	R
5193	4880.34	39.84	1.76	79.97	713.56	28	15.4	1	R
5194	4881.14	39.97	1.82	79.98	713.53	28	15.4	1	R
5195	4881.94	39.88	1.69	79.98	713.51	28	15.4	1	R
5196	4882.74	39.78	1.56	79.98	713.50	28	15.4	1	R
5197	4883.54	39.71	1.56	79.98	713.49	28	15.4	1	R
5198	4884.34	39.65	1.57	79.99	713.48	28	15.4	1	R
5199	4885.13	39.79	1.60	79.98	713.45	28	15.4	1	R
5200	4885.93	39.92	1.64	79.97	713.42	26	15.4	1	R
5201	4886.73	39.85	1.64	79.97	713.41	26	15.4	1	R
5202	4887.53	39.77	1.64	79.97	713.40	26	15.4	1	R
5203	4888.33	39.75	1.59	79.98	713.42	26	15.4	1	R
5204	4889.13	39.73	1.54	79.98	713.44	26	15.4	1	R
5205	4889.93	39.73	1.62	79.98	713.53	26	15.4	1	R
5206	4890.72	39.72	1.70	79.98	713.63	26	15.4	1	R
5207	4891.52	39.72	1.93	79.98	713.69	26	15.4	1	R
5208	4892.32	39.73	2.15	79.99	713.74	26	15.4	1	R
5209	4893.12	39.80	2.29	79.98	713.80	26	15.4	1	R

5210	4893.91	39.88	2.42	79.98	713.86	26	15.4	1	R
5211	4894.71	39.77	2.29	79.98	713.82	26	15.4	1	R
5212	4895.51	39.65	2.15	79.98	713.78	26	15.4	1	R
5213	4896.30	39.71	2.35	79.98	713.79	26	15.4	1	R
5214	4897.10	39.78	2.56	79.98	713.81	26	15.4	1	R
5215	4897.90	39.59	2.77	79.98	713.78	26	15.4	1	R
5216	4898.69	39.40	2.98	79.98	713.75	26	15.4	1	R
5217	4899.49	38.82	2.96	79.99	713.74	26	15.4	1	R
5218	4900.28	38.25	2.95	79.99	713.74	26	15.4	1	R
5219	4901.08	38.79	2.96	79.98	713.76	26	15.4	1	R
5220	4901.87	39.34	2.96	79.97	713.77	26	15.4	1	R
5221	4902.67	39.50	2.69	79.97	713.77	26	15.4	1	R
5222	4903.46	39.67	2.41	79.97	713.76	26	15.4	1	R
5223	4904.26	39.41	2.61	79.97	713.74	26	15.4	1	R
5224	4905.05	39.16	2.80	79.98	713.73	26	15.4	1	R
5225	4905.85	39.31	2.60	79.98	713.74	26	15.4	1	R
5226	4906.64	39.46	2.39	79.98	713.76	26	15.4	1	R
5227	4907.44	39.68	2.34	79.98	713.77	26	15.4	1	R
5228	4908.23	39.89	2.29	79.98	713.78	26	15.4	1	R
5229	4909.02	39.82	2.19	79.98	713.76	26	15.4	1	R
5230	4909.82	39.75	2.09	79.98	713.75	26	15.4	1	R
5231	4910.61	39.75	1.91	79.98	713.75	26	15.4	1	R
5232	4911.40	39.74	1.73	79.98	713.74	26	15.4	1	R
5233	4912.20	39.76	1.78	79.97	713.77	26	15.4	1	R
5234	4912.99	39.78	1.84	79.97	713.79	26	15.4	1	R
5235	4913.78	39.79	1.79	79.97	713.77	26	15.4	1	R
5236	4914.57	39.80	1.75	79.97	713.76	26	15.4	1	R
5237	4915.37	39.80	1.76	79.98	713.75	26	15.4	1	R
5238	4916.16	39.81	1.78	79.98	713.74	26	15.4	1	R
5239	4916.95	39.76	1.53	79.98	713.73	26	15.4	1	R
5240	4917.74	39.70	1.29	79.98	713.73	26	15.4	1	R
5241	4918.53	39.77	1.35	79.98	713.74	26	15.4	1	R
5242	4919.32	39.84	1.41	79.97	713.74	26	15.4	1	R
5243	4920.11	39.79	1.27	79.98	713.74	26	15.4	1	R
5244	4920.90	39.73	1.12	79.98	713.73	26	15.4	1	R
5245	4921.69	39.66	1.25	79.99	713.72	26	15.4	1	R
5246	4922.48	39.58	1.39	79.99	713.70	26	15.4	1	R
5247	4923.46	69.56	2.88	80.01	841.94	26	15.4	1	R
5248	4924.06	99.55	3.30	79.99	841.80	26	15.4	1	R
5249	4924.84	99.22	3.39	79.98	841.75	26	15.4	1	R
5250	4925.63	98.90	3.49	79.97	841.70	26	15.4	1	R
5251	4926.42	99.20	3.29	79.98	841.74	26	15.4	1	R
5252	4927.21	99.49	3.10	79.99	841.78	26	15.4	1	R
5253	4927.99	99.48	2.94	80.00	841.69	26	15.4	1	R
5254	4928.78	99.47	2.79	80.00	841.60	26	15.4	1	R
5255	4929.57	99.48	3.14	79.99	841.61	26	15.4	1	R

5256	4930.35	99.49	3.49	79.98	841.61	26	15.4	1	R
5257	4931.14	99.21	3.60	79.98	841.63	26	15.4	1	R
5258	4931.92	98.94	3.71	79.99	841.65	26	15.4	1	R
5259	4932.71	99.41	3.61	79.98	841.65	26	15.4	1	R
5260	4933.50	99.88	3.50	79.97	841.66	26	15.4	1	R
5261	4934.28	98.73	3.85	79.96	841.66	26	15.4	1	R
5262	4935.06	97.58	4.20	79.95	841.67	26	15.4	1	R
5263	4935.85	98.08	4.04	79.96	841.65	26	15.4	1	R
5264	4936.63	98.58	3.88	79.98	841.64	26	15.4	1	R
5265	4937.42	97.72	4.22	79.97	841.63	26	15.4	1	R
5266	4938.20	96.87	4.55	79.97	841.63	26	15.4	1	R
5267	4938.98	94.14	4.36	79.99	841.62	26	15.4	1	R
5268	4939.76	91.41	4.18	80.00	841.62	26	15.4	1	R
5269	4940.55	89.65	4.29	80.00	841.60	26	15.4	1	R
5270	4941.33	87.90	4.40	79.99	841.59	26	15.4	1	R
5271	4942.11	80.63	3.71	79.99	841.58	26	15.4	1	R
5272	4942.89	73.36	3.01	79.98	841.57	26	15.4	1	R
5273	4943.67	73.73	3.27	79.98	841.57	26	15.4	1	R
5274	4944.46	74.09	3.52	79.99	841.57	26	15.4	1	R
5275	4945.24	73.76	3.81	79.99	841.55	26	15.4	1	R
5276	4946.02	73.43	4.10	79.98	841.54	26	15.4	1	R
5277	4946.80	74.03	4.03	79.98	841.53	26	15.4	1	R
5278	4947.58	74.63	3.97	79.98	841.52	26	15.4	1	R
5279	4948.36	79.45	3.85	79.98	841.51	26	15.4	1	R
5280	4949.13	84.27	3.73	79.98	841.50	26	15.4	1	R
5281	4949.91	79.81	3.94	79.99	841.48	26	15.4	1	R
5282	4950.69	75.36	4.14	80.00	841.47	26	15.4	1	R
5283	4951.47	78.38	4.30	79.99	841.46	26	15.4	1	R
5284	4952.25	81.41	4.46	79.98	841.46	26	15.4	1	R
5285	4953.03	83.24	3.95	79.98	841.48	26	15.4	1	R
5286	4953.80	85.08	3.45	79.99	841.50	26	15.4	1	R
5287	4954.58	79.63	4.15	79.98	841.53	26	15.4	1	R
5288	4955.36	74.18	4.85	79.98	841.55	26	15.4	1	R
5289	4956.13	78.81	4.44	79.98	841.54	26	15.4	1	R
5290	4956.91	83.44	4.03	79.99	841.53	26	15.4	1	R
5291	4957.69	91.03	4.58	79.99	841.56	26	15.4	1	R
5292	4958.46	98.62	5.13	79.98	841.59	26	15.4	1	R
5293	4959.24	98.76	5.09	79.98	841.59	26	15.4	1	R
5294	4960.01	98.90	5.05	79.99	841.58	26	15.4	1	R
5295	4960.79	99.19	5.25	79.99	841.59	26	15.4	1	R
5296	4961.56	99.47	5.45	79.99	841.60	26	15.4	1	R
5297	4962.33	99.50	5.21	79.98	841.62	26	15.4	1	R
5298	4963.11	99.52	4.97	79.97	841.63	26	15.4	1	R
5299	4963.88	99.35	5.06	79.97	841.63	26	15.4	1	R
5300	4964.66	99.18	5.14	79.98	841.62	26	15.4	1	R
5301	4965.43	97.52	5.53	79.99	841.63	26	15.4	1	R

5302	4966.20	95.86	5.92	80.01	841.64	26	15.4	1	R
5303	4966.97	97.96	5.40	79.99	841.64	26	15.4	1	R
5304	4967.75	100.06	4.89	79.96	841.63	26	15.4	1	R
5305	4968.52	99.26	5.26	79.97	841.63	26	15.4	1	R
5306	4969.29	98.45	5.63	79.98	841.62	26	15.4	1	R
5307	4970.06	98.88	5.63	79.97	841.62	26	15.4	1	R
5308	4970.83	99.31	5.63	79.96	841.62	26	15.4	1	R
5309	4971.60	99.34	5.76	79.98	841.64	26	15.4	1	R
5310	4972.37	99.38	5.89	80.00	841.66	26	15.4	1	R
5311	4973.14	99.40	5.87	79.98	841.67	26	15.4	1	R
5312	4973.91	99.43	5.86	79.97	841.68	26	15.4	1	R
5313	4974.68	99.15	5.90	79.97	841.71	26	15.4	1	R
5314	4975.45	98.87	5.94	79.97	841.73	26	15.4	1	R
5315	4976.22	99.46	6.00	79.99	841.71	26	15.4	1	R
5316	4976.99	100.05	6.06	80.00	841.69	26	15.4	1	R
5317	4977.75	99.60	5.75	79.99	841.69	26	15.4	1	R
5318	4978.52	99.14	5.43	79.99	841.69	26	15.4	1	R
5319	4979.29	99.09	5.57	79.99	841.68	26	15.4	1	R
5320	4980.06	99.03	5.71	79.99	841.67	26	15.4	1	R
5321	4980.82	99.57	5.67	79.99	841.66	26	15.4	1	R
5322	4981.59	100.10	5.64	79.98	841.66	26	15.4	1	R
5323	4982.36	99.92	5.41	79.98	841.68	26	15.4	1	R
5324	4983.12	99.74	5.17	79.98	841.70	26	15.4	1	R
5325	4983.89	99.25	5.07	79.98	841.68	26	15.4	1	R
5326	4984.65	98.76	4.98	79.98	841.67	26	15.4	1	R
5327	4985.42	99.65	5.46	79.99	841.66	26	15.4	1	R
5328	4986.18	100.54	5.94	80.00	841.65	26	15.4	1	R
5329	4986.95	99.73	5.63	79.99	841.66	26	15.4	1	R
5330	4987.71	98.91	5.32	79.99	841.67	26	15.4	1	R
5331	4988.47	99.51	5.47	79.99	841.65	26	15.4	1	R
5332	4989.24	100.11	5.61	80.00	841.63	26	15.4	1	R
5333	4990.00	100.01	5.31	80.00	841.66	26	15.4	1	R
5334	4990.76	99.91	5.02	80.00	841.68	26	15.4	1	R
5335	4991.53	99.75	5.56	80.00	841.65	26	15.4	1	R
5336	4992.29	99.60	6.10	79.99	841.61	26	15.4	1	R
5337	4993.05	99.39	6.23	79.99	841.63	26	15.4	1	R
5338	4993.81	99.19	6.36	79.99	841.65	26	15.4	1	R
5339	4994.57	99.21	6.56	79.99	841.66	26	15.4	1	R
5340	4995.34	99.24	6.76	79.99	841.68	26	15.4	1	R
5341	4996.10	94.76	6.74	79.98	841.66	26	15.4	1	R
5342	4996.86	90.28	6.72	79.97	841.65	26	15.4	1	R
5343	4997.62	80.03	6.18	79.97	841.65	26	15.4	1	R
5344	4998.38	69.78	5.63	79.97	841.66	26	15.4	1	R
5345	4999.14	80.89	6.09	79.98	841.64	26	15.4	1	R
5346	4999.90	92.00	6.55	79.98	841.62	26	15.4	1	R
5347	5000.65	89.72	6.62	79.99	841.61	26	15.4	1	R

5348	5001.41	87.44	6.68	80.00	841.60	26	15.4	1	R
5349	5002.17	85.56	6.67	79.99	841.60	26	15.4	1	R
5350	5002.93	83.67	6.66	79.97	841.60	26	15.4	1	R
5351	5003.69	83.74	6.67	79.98	841.58	26	15.4	1	R
5352	5004.44	83.81	6.68	79.99	841.56	26	15.4	1	R
5353	5005.20	86.70	6.53	79.99	841.56	26	15.4	1	R
5354	5005.96	89.60	6.37	79.99	841.56	26	15.4	1	R
5355	5006.71	89.58	6.20	79.98	841.57	26	15.4	1	R
5356	5007.47	89.56	6.03	79.98	841.58	26	15.4	1	R
5357	5008.23	89.77	6.26	79.98	841.59	26	15.4	1	R
5358	5008.98	89.99	6.48	79.98	841.59	26	15.4	1	R
5359	5009.74	89.66	6.67	79.97	841.59	26	15.4	1	R
5360	5010.49	89.34	6.86	79.96	841.59	26	15.4	1	R
5361	5011.25	89.31	6.61	79.97	841.61	26	15.4	1	R
5362	5012.00	89.27	6.37	79.98	841.63	26	15.4	1	R
5363	5012.76	88.98	6.62	79.99	841.63	26	15.4	1	R
5364	5013.51	88.69	6.88	80.00	841.64	26	15.4	1	R
5365	5014.26	89.00	6.66	80.00	841.65	26	15.4	1	R
5366	5015.02	89.31	6.44	79.99	841.65	26	15.4	1	R
5367	5015.77	88.99	6.50	79.99	841.63	26	15.4	1	R
5368	5016.52	88.66	6.57	79.98	841.60	26	15.4	1	R
5369	5017.27	89.18	6.39	79.98	841.65	26	15.4	1	R
5370	5018.03	89.69	6.21	79.97	841.71	26	15.4	1	R
5371	5018.78	89.10	6.52	79.97	841.71	26	15.4	1	R
5372	5019.53	88.51	6.83	79.97	841.70	26	15.4	1	R
5373	5020.28	88.73	6.62	79.98	841.72	26	15.4	1	R
5374	5021.03	88.95	6.41	79.99	841.73	26	15.4	1	R
5375	5021.78	88.70	6.58	79.98	841.69	26	15.4	1	R
5376	5022.53	88.44	6.74	79.98	841.66	26	15.4	1	R
5377	5023.28	85.88	6.66	79.98	841.66	26	15.4	1	R
5378	5024.03	83.32	6.58	79.98	841.67	26	15.4	1	R
5379	5024.78	74.30	5.84	79.99	841.68	26	15.4	1	R
5380	5025.53	65.28	5.10	79.99	841.69	26	15.4	1	R
5381	5026.28	82.54	5.08	79.98	841.70	26	15.4	1	R
5382	5027.03	99.80	5.06	79.97	841.70	26	15.4	1	R
5383	5027.77	99.32	5.22	79.96	841.71	26	15.4	1	R
5384	5028.52	98.84	5.39	79.96	841.72	26	15.4	1	R
5385	5029.27	99.44	5.39	79.98	841.73	26	15.4	1	R
5386	5030.02	100.04	5.38	79.99	841.74	26	15.4	1	R
5387	5030.76	99.23	5.65	79.98	841.72	26	15.4	1	R
5388	5031.51	98.41	5.91	79.97	841.70	26	15.4	1	R
5389	5032.26	98.93	5.93	79.98	841.71	26	15.4	1	R
5390	5033.00	99.45	5.96	79.99	841.72	26	15.4	1	R
5391	5033.75	99.67	5.62	79.98	841.73	26	15.4	1	R
5392	5034.49	99.89	5.29	79.98	841.74	26	15.4	1	R
5393	5035.24	99.54	5.36	79.99	841.69	26	15.4	1	R

5394	5035.98	99.19	5.43	80.00	841.64	26	15.4	1	R
5395	5036.73	99.47	5.65	79.99	841.59	26	15.4	1	R
5396	5037.47	99.76	5.87	79.98	841.54	26	15.4	1	R
5397	5038.22	99.08	5.84	79.98	841.57	26	15.4	1	R
5398	5038.96	98.41	5.82	79.98	841.60	26	15.4	1	R
5399	5039.70	99.24	5.73	79.98	841.61	26	15.4	1	R
5400	5040.45	100.07	5.65	79.99	841.62	26	15.4	1	R
5401	5041.19	99.79	5.86	79.99	841.63	26	15.4	1	R
5402	5041.93	99.51	6.07	79.99	841.63	26	15.4	1	R
5403	5042.67	98.94	6.02	79.99	841.60	26	15.4	1	R
5404	5043.41	98.37	5.97	79.99	841.58	26	15.4	1	R
5405	5044.16	99.31	5.79	79.99	841.58	26	15.4	1	R
5406	5044.90	100.25	5.61	80.00	841.59	26	15.4	1	R
5407	5045.64	99.73	5.41	79.99	841.58	26	15.4	1	R
5408	5046.38	99.21	5.21	79.98	841.58	26	15.4	1	R
5409	5047.12	99.01	5.45	79.98	841.58	26	15.4	1	R
5410	5047.86	98.80	5.68	79.97	841.57	26	15.4	1	R
5411	5048.60	99.38	5.99	79.97	841.53	26	15.4	1	R
5412	5049.34	99.96	6.29	79.98	841.49	26	15.4	1	R
5413	5050.08	99.82	5.92	79.98	841.53	26	15.4	1	R
5414	5050.81	99.69	5.54	79.99	841.58	26	15.4	1	R
5415	5051.55	99.62	5.66	79.99	841.59	26	15.4	1	R
5416	5052.29	99.55	5.78	80.00	841.60	26	15.4	1	R
5417	5053.03	99.47	5.76	79.99	841.61	26	15.4	1	R
5418	5053.77	99.39	5.75	79.99	841.62	26	15.4	1	R
5419	5054.50	99.36	5.88	79.98	841.65	26	15.4	1	R
5420	5055.24	99.33	6.02	79.98	841.68	26	15.4	1	R
5421	5055.98	99.38	6.20	79.98	841.65	26	15.4	1	R
5422	5056.71	99.42	6.38	79.98	841.62	26	15.4	1	R
5423	5057.45	99.51	6.98	79.99	841.63	26	15.4	1	R
5424	5058.18	99.59	7.58	79.99	841.63	26	15.4	1	R
5425	5058.92	99.23	7.54	79.98	841.62	26	15.4	1	R
5426	5059.65	98.88	7.50	79.96	841.62	26	15.4	1	R
5427	5060.39	94.76	7.21	79.97	841.61	26	15.4	1	R
5428	5061.12	90.64	6.92	79.97	841.60	26	15.4	1	R
5429	5061.86	95.04	7.16	79.96	841.59	26	15.4	1	R
5430	5062.59	99.44	7.41	79.96	841.57	26	15.4	1	R
5431	5063.32	99.37	7.07	79.97	841.57	26	15.4	1	R
5432	5064.06	99.31	6.74	79.97	841.56	26	15.4	1	R
5433	5064.79	99.20	6.60	79.97	841.58	26	15.4	1	R
5434	5065.52	99.10	6.47	79.97	841.59	26	15.4	1	R
5435	5066.62	203.16	7.99	79.99	918.42	26	14.5	1	R

4.2.2 Survey Data for Well A

Table 4.2 Survey Data for Well A

Depth	Inclination	Azimuth	TVD
ft	(degree)	(degree)	ft
5078	36.06	137.59	4787.69
5079	36.06	137.59	4788.50
5080	36.06	137.59	4789.32
5081	36.06	137.59	4790.13
5082	36.06	137.59	4790.94
5083	36.06	137.59	4791.76
5084	36.06	137.59	4792.57
5085	36.06	137.59	4793.38
5086	36.06	137.59	4794.20
5087	36.06	137.59	4795.01
5088	36.06	137.59	4795.83
5089	36.06	137.59	4796.64
5090	36.06	137.59	4797.46
5091	36.06	137.59	4798.27
5092	36.06	137.59	4799.09
5093	36.06	137.59	4799.90
5094	36.06	137.59	4800.72
5095	36.06	137.59	4801.53
5096	36.06	137.59	4802.35
5097	36.06	137.59	4803.17
5098	36.06	137.59	4803.98
5099	36.06	137.59	4804.80
5100	36.06	137.59	4805.61
5101	36.06	137.59	4806.43
5102	36.06	137.59	4807.25
5103	36.06	137.59	4808.06
5104	36.06	137.59	4808.88
5105	36.06	137.59	4809.69
5106	36.06	137.59	4810.51
5107	36.06	137.59	4811.32
5108	36.06	137.59	4812.13
5109	36.06	137.59	4812.95
5110	36.06	137.59	4813.76
5111	36.06	137.59	4814.58
5112	36.06	137.59	4815.39
5113	36.06	137.59	4816.20
5114	36.06	137.59	4817.02
5115	36.06	137.59	4817.83
5116	36.06	137.59	4818.64
5117	36.06	137.59	4819.46
5118	36.06	137.59	4820.27
5119	36.06	137.59	4821.08

5120	36.06	137.59	4821.89
5121	36.06	137.59	4822.50
5122	36.06	137.59	4823.11
5123	36.06	137.59	4823.92
5124	36.06	137.59	4824.74
5125	36.06	137.59	4825.55
5126	36.06	137.59	4826.36
5127	36.06	137.59	4827.17
5128	36.06	137.59	4827.98
5129	36.06	137.59	4828.79
5130	36.06	137.59	4829.60
5131	36.06	137.59	4830.41
5132	36.06	137.59	4831.22
5133	36.06	137.59	4832.03
5134	36.06	137.59	4832.84
5135	36.06	137.59	4833.65
5136	36.06	137.59	4834.46
5137	36.06	137.59	4835.27
5138	36.06	137.59	4836.08
5139	36.06	137.59	4836.89
5140	36.06	137.59	4837.70
5141	36.06	137.59	4838.51
5142	36.06	137.59	4839.32
5143	36.06	137.59	4840.13
5144	36.06	137.59	4840.94
5145	36.06	137.59	4841.74
5146	36.06	137.59	4842.55
5147	36.06	137.59	4843.36
5148	36.06	137.59	4844.17
5149	36.06	137.59	4844.98
5150	36.06	137.59	4845.78
5151	36.06	137.59	4846.59
5152	36.06	137.59	4847.40
5153	36.06	137.59	4848.20
5154	36.06	137.59	4849.01
5155	36.06	137.59	4849.82
5156	36.06	137.59	4850.62
5157	36.06	137.59	4851.43
5158	36.06	137.59	4852.24
5159	36.06	137.59	4853.04
5160	36.06	137.59	4853.85
5161	36.06	137.59	4854.65
5162	36.06	137.59	4855.46
5163	36.06	137.59	4856.26
5164	36.06	137.59	4857.07
5165	36.06	137.59	4857.87

5166	36.06	137.59	4858.68
5167	36.06	137.59	4859.48
5168	36.06	137.59	4860.29
5169	36.06	137.59	4861.09
5170	36.06	137.59	4861.89
5171	36.06	137.59	4862.70
5172	36.06	137.59	4863.50
5173	36.06	137.59	4864.31
5174	36.06	137.59	4865.11
5175	36.06	137.59	4865.91
5176	36.06	137.59	4866.71
5177	36.06	137.59	4867.52
5178	36.06	137.59	4868.32
5179	36.06	137.59	4869.12
5180	36.06	137.59	4869.92
5181	36.06	137.59	4870.73
5182	36.06	137.59	4871.53
5183	36.06	137.59	4872.33
5184	36.06	137.59	4873.13
5185	36.06	137.59	4873.93
5186	36.06	137.59	4874.73
5187	36.06	137.59	4875.54
5188	36.06	137.59	4876.34
5189	36.06	137.59	4877.14
5190	36.06	137.59	4877.94
5191	36.06	137.59	4878.74
5192	36.06	137.59	4879.54
5193	36.06	137.59	4880.34
5194	36.06	137.59	4881.14
5195	36.06	137.59	4881.94
5196	36.06	137.59	4882.74
5197	36.06	137.59	4883.54
5198	36.06	137.59	4884.34
5199	36.06	137.59	4885.13
5200	36.06	137.59	4885.93
5201	36.06	137.59	4886.73
5202	36.06	137.59	4887.53
5203	36.06	137.59	4888.33
5204	36.06	137.59	4889.13
5205	36.06	137.59	4889.93
5206	36.06	137.59	4890.72
5207	36.06	137.59	4891.52
5208	36.06	137.59	4892.32
5209	36.06	137.59	4893.12
5210	36.06	137.59	4893.91
5211	36.06	137.59	4894.71

5212	36.06	137.59	4895.51
5213	36.06	137.59	4896.30
5214	36.06	137.59	4897.10
5215	36.06	137.59	4897.90
5216	36.06	137.59	4898.69
5217	36.06	137.59	4899.49
5218	36.06	137.59	4900.28
5219	36.06	137.59	4901.08
5220	36.06	137.59	4901.87
5221	36.06	137.59	4902.67
5222	36.06	137.59	4903.46
5223	36.06	137.59	4904.26
5224	36.06	137.59	4905.05
5225	36.06	137.59	4905.85
5226	36.06	137.59	4906.64
5227	36.06	137.59	4907.44
5228	36.06	137.59	4908.23
5229	36.06	137.59	4909.02
5230	36.06	137.59	4909.82
5231	36.06	137.59	4910.61
5232	36.06	137.59	4911.40
5233	36.06	137.59	4912.20
5234	36.06	137.59	4912.99
5235	36.06	137.59	4913.78
5236	36.06	137.59	4914.57
5237	36.06	137.59	4915.37
5238	36.06	137.59	4916.16
5239	36.06	137.59	4916.95
5240	36.06	137.59	4917.74
5241	36.06	137.59	4918.53
5242	36.06	137.59	4919.32
5243	36.06	137.59	4920.11
5244	36.06	137.59	4920.90
5245	36.06	137.59	4921.69
5246	36.06	137.59	4922.48
5247	36.06	137.59	4923.46
5248	36.06	137.59	4924.06
5249	36.06	137.59	4924.84
5250	36.06	137.59	4925.63
5251	36.06	137.59	4926.42
5252	36.06	137.59	4927.21
5253	36.06	137.59	4927.99
5254	36.06	137.59	4928.78
5255	36.06	137.59	4929.57
5256	36.06	137.59	4930.35
5257	36.06	137.59	4931.14

5258	36.06	137.59	4931.92
5259	36.06	137.59	4932.71
5260	36.06	137.59	4933.50
5261	36.06	137.59	4934.28
5262	36.06	137.59	4935.06
5263	36.06	137.59	4935.85
5264	36.06	137.59	4936.63
5265	36.06	137.59	4937.42
5266	36.06	137.59	4938.20
5267	36.06	137.59	4938.98
5268	36.06	137.59	4939.76
5269	36.06	137.59	4940.55
5270	36.06	137.59	4941.33
5271	36.06	137.59	4942.11
5272	36.06	137.59	4942.89
5273	36.06	137.59	4943.67
5274	36.06	137.59	4944.46
5275	36.06	137.59	4945.24
5276	36.06	137.59	4946.02
5277	36.06	137.59	4946.80
5278	36.06	137.59	4947.58
5279	36.06	137.59	4948.36
5280	36.06	137.59	4949.13
5281	36.06	137.59	4949.91
5282	36.06	137.59	4950.69
5283	36.06	137.59	4951.47
5284	36.06	137.59	4952.25
5285	36.06	137.59	4953.03
5286	36.06	137.59	4953.80
5287	36.06	137.59	4954.58
5288	36.06	137.59	4955.36
5289	36.06	137.59	4956.13
5290	36.06	137.59	4956.91
5291	36.06	137.59	4957.69
5292	36.06	137.59	4958.46
5293	36.06	137.59	4959.24
5294	36.06	137.59	4960.01
5295	36.06	137.59	4960.79
5296	36.06	137.59	4961.56
5297	36.06	137.59	4962.33
5298	36.06	137.59	4963.11
5299	36.06	137.59	4963.88
5300	36.06	137.59	4964.66
5301	36.06	137.59	4965.43
5302	36.06	137.59	4966.20
5303	36.06	137.59	4966.97

5304	36.06	137.59	4967.75
5305	36.06	137.59	4968.52
5306	36.06	137.59	4969.29
5307	36.06	137.59	4970.06
5308	36.06	137.59	4970.83
5309	36.06	137.59	4971.60
5310	36.06	137.59	4972.37
5311	36.06	137.59	4973.14
5312	36.06	137.59	4973.91
5313	36.06	137.59	4974.68
5314	36.06	137.59	4975.45
5315	36.06	137.59	4976.22
5316	36.06	137.59	4976.99
5317	36.06	137.59	4977.75
5318	36.06	137.59	4978.52
5319	36.06	137.59	4979.29
5320	36.06	137.59	4980.06
5321	36.06	137.59	4980.82
5322	36.06	137.59	4981.59
5323	36.06	137.59	4982.36
5324	36.06	137.59	4983.12
5325	36.06	137.59	4983.89
5326	36.06	137.59	4984.65
5327	36.06	137.59	4985.42
5328	42.93	136.99	4986.18
5329	42.93	136.99	4986.95
5330	42.93	136.99	4987.71
5331	42.93	136.99	4988.47
5332	42.93	136.99	4989.24
5333	42.93	136.99	4990.00
5334	42.93	136.99	4990.76
5335	42.93	136.99	4991.53
5336	42.93	136.99	4992.29
5337	42.93	136.99	4993.05
5338	42.93	136.99	4993.81
5339	42.93	136.99	4994.57
5340	42.93	136.99	4995.34
5341	42.93	136.99	4996.10
5342	42.93	136.99	4996.86
5343	42.93	136.99	4997.62
5344	42.93	136.99	4998.38
5345	42.93	136.99	4999.14
5346	42.93	136.99	4999.90
5347	42.93	136.99	5000.65
5348	42.93	136.99	5001.41
5349	43.43	136.85	5002.17

5350	43.43	136.85	5002.93
5351	43.43	136.85	5003.69
5352	43.43	136.85	5004.44
5353	43.43	136.85	5005.20
5354	43.43	136.85	5005.96
5355	43.43	136.85	5006.71
5356	43.43	136.85	5007.47
5357	43.43	136.85	5008.23
5358	43.43	136.85	5008.98
5359	43.43	136.85	5009.74
5360	43.43	136.85	5010.49
5361	43.43	136.85	5011.25
5362	43.43	136.85	5012.00
5363	43.43	136.85	5012.76
5364	43.43	136.85	5013.51
5365	43.43	136.85	5014.26
5366	43.43	136.85	5015.02
5367	43.43	136.85	5015.77
5368	43.43	136.85	5016.52
5369	43.43	136.85	5017.27
5370	43.43	136.85	5018.03
5371	43.43	136.85	5018.78
5372	43.43	136.85	5019.53
5373	43.43	136.85	5020.28
5374	43.43	136.85	5021.03
5375	43.43	136.85	5021.78
5376	43.43	136.85	5022.53
5377	43.43	136.85	5023.28
5378	43.43	136.85	5024.03
5379	43.43	136.85	5024.78
5380	43.43	136.85	5025.53
5381	43.43	136.85	5026.28
5382	43.43	136.85	5027.03
5383	43.43	136.85	5027.77
5384	43.43	136.85	5028.52
5385	43.43	136.85	5029.27
5386	43.43	136.85	5030.02
5387	43.43	136.85	5030.76
5388	43.43	136.85	5031.51
5389	43.43	136.85	5032.26
5390	43.43	136.85	5033.00
5391	43.43	136.85	5033.75
5392	43.43	136.85	5034.49
5393	43.43	136.85	5035.24
5394	43.43	136.85	5035.98
5395	43.43	136.85	5036.73

5396	43.43	136.85	5037.47
5397	43.43	136.85	5038.22
5398	43.43	136.85	5038.96
5399	43.43	136.85	5039.70
5400	43.43	136.85	5040.45
5401	43.43	136.85	5041.19
5402	43.43	136.85	5041.93
5403	43.43	136.85	5042.67
5404	43.43	136.85	5043.41
5405	43.43	136.85	5044.16
5406	44.23	136.85	5044.90
5407	44.23	136.85	5045.64
5408	44.23	136.85	5046.38
5409	44.23	136.85	5047.12
5410	44.23	136.85	5047.86
5411	44.23	136.85	5048.60
5412	44.23	136.85	5049.34
5413	44.23	136.85	5050.08
5414	44.23	136.85	5050.81
5415	44.23	136.85	5051.55
5416	44.23	136.85	5052.29
5417	44.23	136.85	5053.03
5418	44.23	136.85	5053.77
5419	44.23	136.85	5054.50
5420	44.23	136.85	5055.24
5421	44.23	136.85	5055.98
5422	44.23	136.85	5056.71
5423	44.23	136.85	5057.45
5424	44.23	136.85	5058.18
5425	44.23	136.85	5058.92
5426	44.23	136.85	5059.65
5427	44.23	136.85	5060.39
5428	44.23	136.85	5061.12
5429	44.23	136.85	5061.86
5430	44.23	136.85	5062.59
5431	44.23	136.85	5063.32
5432	44.23	136.85	5064.06
5433	44.23	136.85	5064.79
5434	44.23	136.85	5065.52
5435	44.23	136.85	5066.62

4.2.3 Generic Overburden Pore Pressure Derivation Chart For Ekofisk field

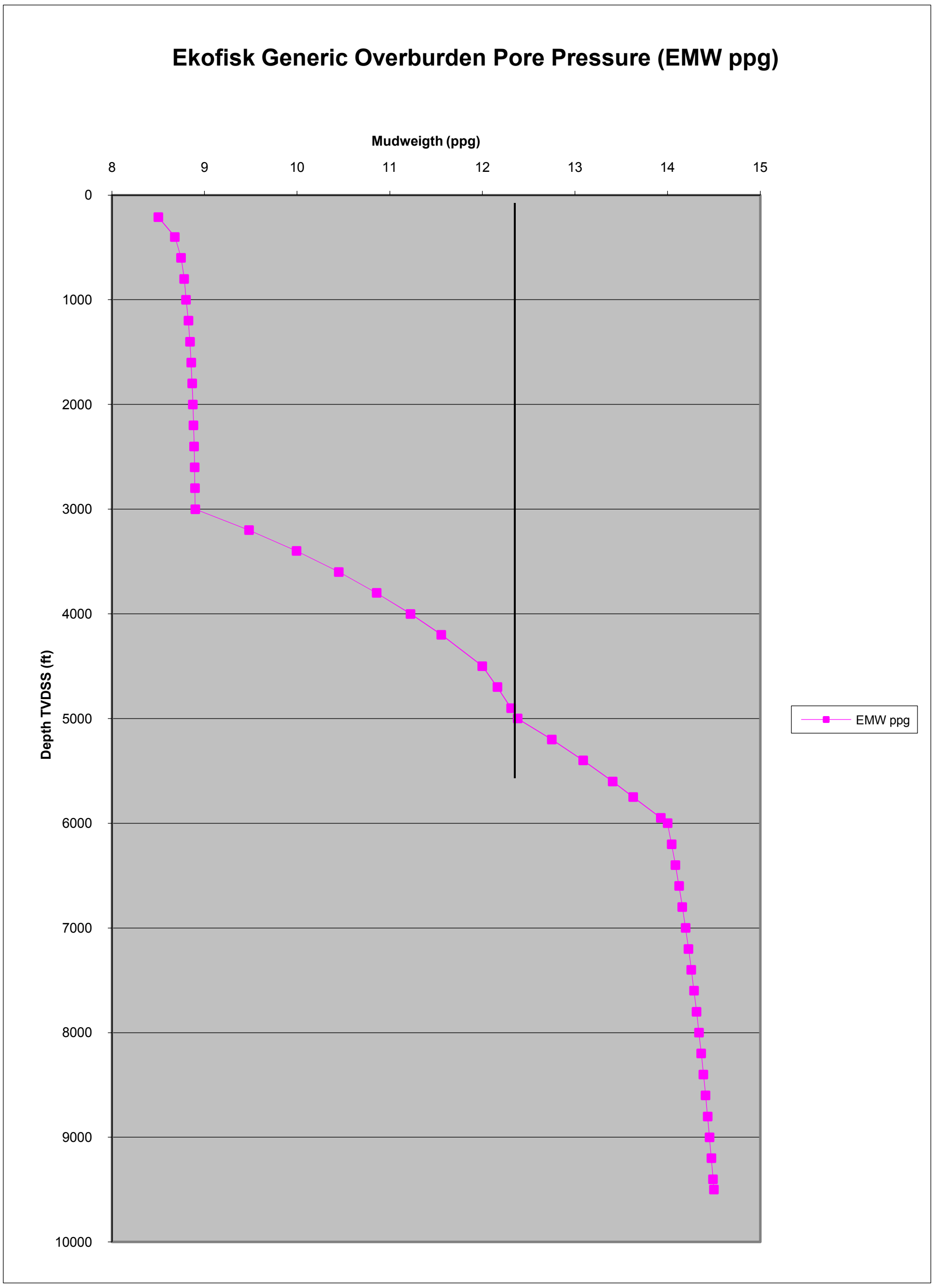

Figure 4.1 Ekofisk generic overburden pressure (EMW ppg) chart.

Table 4.3 Derived Ekofisk Overburden Porepressure (EMW) in psi and ppg.

Depth TVDSS feet	Pore Pressure Psi	EMW ppg
210	92.82	8.5
400	180.5518987	8.68037975
600	272.9012658	8.74683544
800	365.2506329	8.78006329
1000	457.6	8.8
1200	550.68	8.825
1400	643.76	8.84285714
1600	736.84	8.85625
1800	829.92	8.86666667
2000	923	8.875
2200	1016.08	8.88181818
2400	1109.16	8.8875
2600	1202.24	8.89230769
2800	1295.32	8.89642857
3000	1388.4	8.9
3200	1577.68	9.48125
3400	1766.96	9.99411765
3600	1956.24	10.45
3800	2145.52	10.8578947
4000	2334.8	11.225
4200	2524.08	11.5571429
4500	2808	12
4700	2972.32	12.1617021
4900	3136.64	12.3102041
5000	3218.8	12.38
5200	3447.218667	12.7485897
5400	3675.637333	13.0898765
5600	3904.056	13.4067857
5750	4075.37	13.63
5950	4309.474	13.9284874
6000	4368	14
6200	4527.714286	14.0437788
6400	4687.428571	14.0848214
6600	4847.142857	14.1233766
6800	5006.857143	14.1596639
7000	5166.571429	14.1938776
7200	5326.285714	14.2261905
7400	5486	14.2567568
7600	5645.714286	14.2857143
7800	5805.428571	14.3131868
8000	5965.142857	14.3392857
8200	6124.857143	14.3641115
8400	6284.571429	14.3877551
8600	6444.285714	14.410299
8800	6604	14.4318182
9000	6763.714286	14.452381
9200	6923.428571	14.4720497
9400	7083.142857	14.4908815
9500	7163	14.5

2010 Generic Ekofisk Overburden Porepressure Curves as used by drilling engineer. (extrapolated from ppt file by HHN)

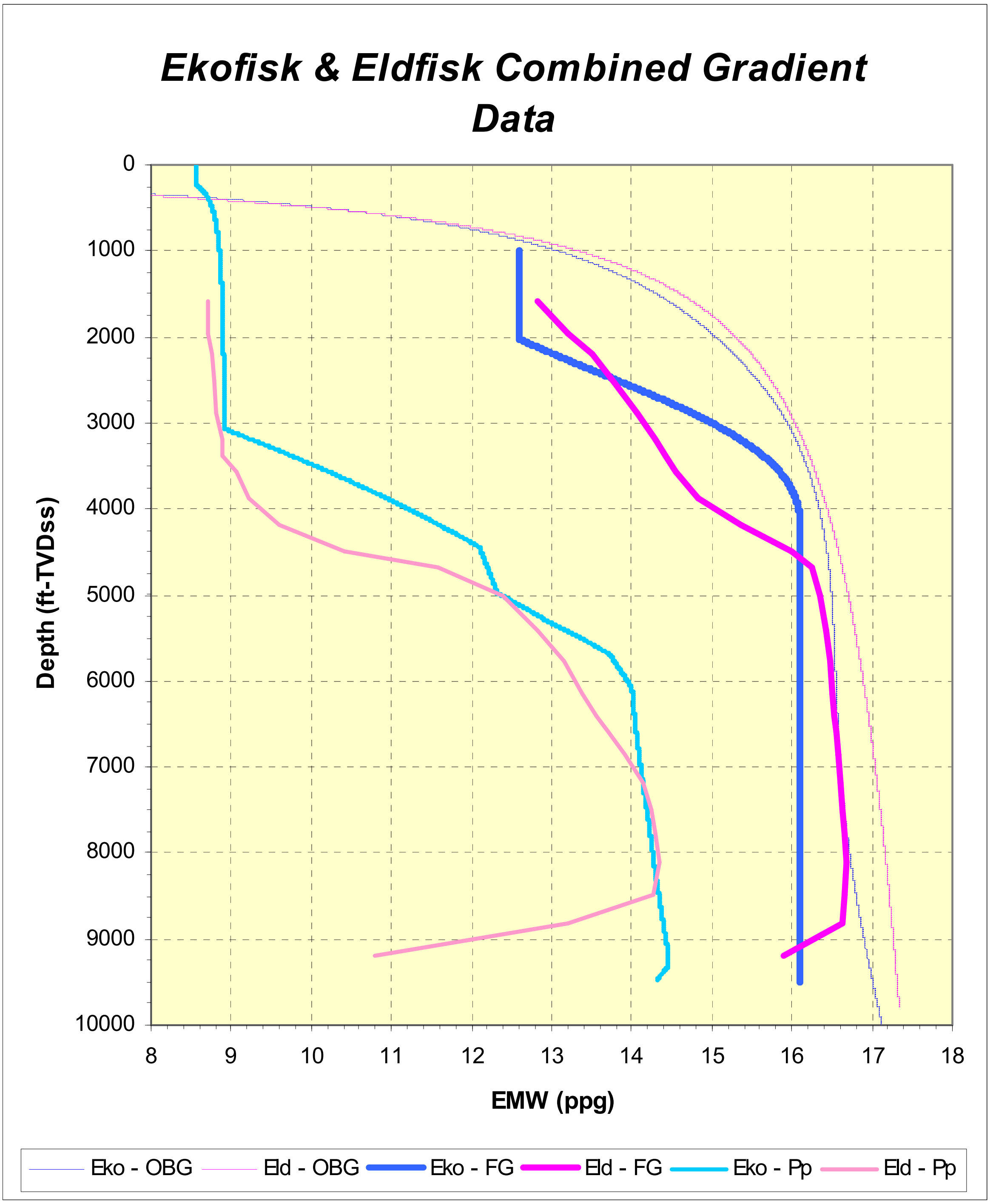

Figure 4.2 Ekofisk/Eldfisk combined Gradient Data.

LITHOLOGY DATA FOR WELL A

Table 4.4 Lithology Data For Well A

Depth	TVD	SAND	SHALE	LIME	DOLO	SILI	CONG	COAL	NULL	NULL	NULL	P.P	PERM
ft	ft												
5078	4787.69	0	1	0	0	0	0	0	0	0	0	12.40	0
5079	4788.50	0	1	0	0	0	0	0	0	0	0	12.40	0
5080	4789.32	0	1	0	0	0	0	0	0	0	0	12.40	0
5081	4790.13	0	1	0	0	0	0	0	0	0	0	12.40	0
5082	4790.94	0	1	0	0	0	0	0	0	0	0	12.40	0
5083	4791.76	0	1	0	0	0	0	0	0	0	0	12.40	0
5084	4792.57	0	1	0	0	0	0	0	0	0	0	12.40	0
5085	4793.38	0	1	0	0	0	0	0	0	0	0	12.40	0
5086	4794.20	0	1	0	0	0	0	0	0	0	0	12.40	0
5087	4795.01	0	1	0	0	0	0	0	0	0	0	12.40	0
5088	4795.83	0	1	0	0	0	0	0	0	0	0	12.40	0
5089	4796.64	0	1	0	0	0	0	0	0	0	0	12.40	0
5090	4797.46	0	1	0	0	0	0	0	0	0	0	12.40	0
5091	4798.27	0	1	0	0	0	0	0	0	0	0	12.40	0
5092	4799.09	0	1	0	0	0	0	0	0	0	0	12.40	0
5093	4799.90	0	1	0	0	0	0	0	0	0	0	12.40	0
5094	4800.72	0	1	0	0	0	0	0	0	0	0	12.40	0
5095	4801.53	0	1	0	0	0	0	0	0	0	0	12.40	0
5096	4802.35	0	1	0	0	0	0	0	0	0	0	12.40	0
5097	4803.17	0	1	0	0	0	0	0	0	0	0	12.40	0
5098	4803.98	0	1	0	0	0	0	0	0	0	0	12.40	0
5099	4804.80	0	1	0	0	0	0	0	0	0	0	12.40	0
5100	4805.61	0	1	0	0	0	0	0	0	0	0	12.40	0
5101	4806.43	0	1	0	0	0	0	0	0	0	0	12.40	0
5102	4807.25	0	1	0	0	0	0	0	0	0	0	12.40	0
5103	4808.06	0	1	0	0	0	0	0	0	0	0	12.40	0
5104	4808.88	0	1	0	0	0	0	0	0	0	0	12.40	0
5105	4809.69	0	1	0	0	0	0	0	0	0	0	12.40	0
5106	4810.51	0	1	0	0	0	0	0	0	0	0	12.40	0
5107	4811.32	0	1	0	0	0	0	0	0	0	0	12.40	0
5108	4812.13	0	1	0	0	0	0	0	0	0	0	12.40	0
5109	4812.95	0	1	0	0	0	0	0	0	0	0	12.40	0
5110	4813.76	0	1	0	0	0	0	0	0	0	0	12.40	0
5111	4814.58	0	1	0	0	0	0	0	0	0	0	12.40	0
5112	4815.39	0	1	0	0	0	0	0	0	0	0	12.40	0
5113	4816.20	0	1	0	0	0	0	0	0	0	0	12.40	0
5114	4817.02	0	1	0	0	0	0	0	0	0	0	12.40	0
5115	4817.83	0	1	0	0	0	0	0	0	0	0	12.40	0
5116	4818.64	0	1	0	0	0	0	0	0	0	0	12.40	0
5117	4819.46	0	1	0	0	0	0	0	0	0	0	12.40	0

5118	4820.27	0	1	0	0	0	0	0	0	0	0	12.40	0
5119	4821.08	0	1	0	0	0	0	0	0	0	0	12.40	0
5120	4821.89	0	1	0	0	0	0	0	0	0	0	12.40	0
5121	4822.50	0	1	0	0	0	0	0	0	0	0	12.40	0
5122	4823.11	0	1	0	0	0	0	0	0	0	0	12.40	0
5123	4823.92	0	1	0	0	0	0	0	0	0	0	12.40	0
5124	4824.74	0	1	0	0	0	0	0	0	0	0	12.40	0
5125	4825.55	0	1	0	0	0	0	0	0	0	0	12.40	0
5126	4826.36	0	1	0	0	0	0	0	0	0	0	12.40	0
5127	4827.17	0	1	0	0	0	0	0	0	0	0	12.40	0
5128	4827.98	0	1	0	0	0	0	0	0	0	0	12.40	0
5129	4828.79	0	1	0	0	0	0	0	0	0	0	12.40	0
5130	4829.60	0	1	0	0	0	0	0	0	0	0	12.40	0
5131	4830.41	0	1	0	0	0	0	0	0	0	0	12.40	0
5132	4831.22	0	1	0	0	0	0	0	0	0	0	12.40	0
5133	4832.03	0	1	0	0	0	0	0	0	0	0	12.40	0
5134	4832.84	0	1	0	0	0	0	0	0	0	0	12.40	0
5135	4833.65	0	1	0	0	0	0	0	0	0	0	12.40	0
5136	4834.46	0	1	0	0	0	0	0	0	0	0	12.40	0
5137	4835.27	0	1	0	0	0	0	0	0	0	0	12.40	0
5138	4836.08	0	1	0	0	0	0	0	0	0	0	12.40	0
5139	4836.89	0	1	0	0	0	0	0	0	0	0	12.40	0
5140	4837.70	0	1	0	0	0	0	0	0	0	0	12.40	0
5141	4838.51	0	1	0	0	0	0	0	0	0	0	12.40	0
5142	4839.32	0	1	0	0	0	0	0	0	0	0	12.40	0
5143	4840.13	0	1	0	0	0	0	0	0	0	0	12.40	0
5144	4840.94	0	1	0	0	0	0	0	0	0	0	12.40	0
5145	4841.74	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5146	4842.55	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5147	4843.36	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5148	4844.17	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5149	4844.98	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5150	4845.78	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5151	4846.59	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5152	4847.40	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5153	4848.20	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5154	4849.01	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5155	4849.82	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5156	4850.62	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5157	4851.43	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5158	4852.24	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5159	4853.04	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5160	4853.85	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5161	4854.65	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5162	4855.46	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5163	4856.26	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0

5164	4857.07	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5165	4857.87	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5166	4858.68	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5167	4859.48	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5168	4860.29	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5169	4861.09	0	0.8	0.2	0	0	0	0	0	0	0	12.40	0
5170	4861.89	0	0	1	0	0	0	0	0	0	0	12.40	0
5171	4862.70	0	0	1	0	0	0	0	0	0	0	12.40	0
5172	4863.50	0	0	1	0	0	0	0	0	0	0	12.40	0
5173	4864.31	0	0	1	0	0	0	0	0	0	0	12.40	0
5174	4865.11	0	0	1	0	0	0	0	0	0	0	12.40	0
5175	4865.91	0	0	1	0	0	0	0	0	0	0	12.40	0
5176	4866.71	0	0	1	0	0	0	0	0	0	0	12.40	0
5177	4867.52	0	0	1	0	0	0	0	0	0	0	12.40	0
5178	4868.32	0	0	1	0	0	0	0	0	0	0	12.40	0
5179	4869.12	0	0	1	0	0	0	0	0	0	0	12.40	0
5180	4869.92	0	0	1	0	0	0	0	0	0	0	12.40	0
5181	4870.73	0	0	1	0	0	0	0	0	0	0	12.40	0
5182	4871.53	0	0	1	0	0	0	0	0	0	0	12.40	0
5183	4872.33	0	0	1	0	0	0	0	0	0	0	12.40	0
5184	4873.13	0	0	1	0	0	0	0	0	0	0	12.40	0
5185	4873.93	0	0	1	0	0	0	0	0	0	0	12.40	0
5186	4874.73	0	0	1	0	0	0	0	0	0	0	12.40	0
5187	4875.54	0	0	1	0	0	0	0	0	0	0	12.40	0
5188	4876.34	0	0	1	0	0	0	0	0	0	0	12.40	0
5189	4877.14	0	0	1	0	0	0	0	0	0	0	12.40	0
5190	4877.94	0	0	1	0	0	0	0	0	0	0	12.40	0
5191	4878.74	0	0	1	0	0	0	0	0	0	0	12.40	0
5192	4879.54	0	0	1	0	0	0	0	0	0	0	12.40	0
5193	4880.34	0	0	1	0	0	0	0	0	0	0	12.40	0
5194	4881.14	0	0	1	0	0	0	0	0	0	0	12.40	0
5195	4881.94	0	0	1	0	0	0	0	0	0	0	12.40	0
5196	4882.74	0	0	1	0	0	0	0	0	0	0	12.40	0
5197	4883.54	0	0	1	0	0	0	0	0	0	0	12.40	0
5198	4884.34	0	0	1	0	0	0	0	0	0	0	12.40	0
5199	4885.13	0	0	1	0	0	0	0	0	0	0	12.40	0
5200	4885.93	0	0	1	0	0	0	0	0	0	0	12.40	0
5201	4886.73	0	0	1	0	0	0	0	0	0	0	12.70	0
5202	4887.53	0	0	1	0	0	0	0	0	0	0	12.70	0
5203	4888.33	0	0	1	0	0	0	0	0	0	0	12.70	0
5204	4889.13	0	0	1	0	0	0	0	0	0	0	12.70	0
5205	4889.93	0	0	1	0	0	0	0	0	0	0	12.70	0
5206	4890.72	0	0	1	0	0	0	0	0	0	0	12.70	0
5207	4891.52	0	0	1	0	0	0	0	0	0	0	12.70	0
5208	4892.32	0	0	1	0	0	0	0	0	0	0	12.70	0
5209	4893.12	0	0	1	0	0	0	0	0	0	0	12.70	0

5210	4893.91	0	0	1	0	0	0	0	0	0	0	12.70	0
5211	4894.71	0	0	1	0	0	0	0	0	0	0	12.70	0
5212	4895.51	0	0	1	0	0	0	0	0	0	0	12.70	0
5213	4896.30	0	0	1	0	0	0	0	0	0	0	12.70	0
5214	4897.10	0	0	1	0	0	0	0	0	0	0	12.70	0
5215	4897.90	0	0	1	0	0	0	0	0	0	0	12.70	0
5216	4898.69	0	0	1	0	0	0	0	0	0	0	12.70	0
5217	4899.49	0	0	1	0	0	0	0	0	0	0	12.70	0
5218	4900.28	0	0	1	0	0	0	0	0	0	0	12.70	0
5219	4901.08	0	0	1	0	0	0	0	0	0	0	12.70	0
5220	4901.87	0	0	1	0	0	0	0	0	0	0	12.70	0
5221	4902.67	0	0	1	0	0	0	0	0	0	0	12.70	0
5222	4903.46	0	0	1	0	0	0	0	0	0	0	12.70	0
5223	4904.26	0	0	1	0	0	0	0	0	0	0	12.70	0
5224	4905.05	0	0	1	0	0	0	0	0	0	0	12.70	0
5225	4905.85	0	0	1	0	0	0	0	0	0	0	12.70	0
5226	4906.64	0	0	1	0	0	0	0	0	0	0	12.70	0
5227	4907.44	0	0	1	0	0	0	0	0	0	0	12.70	0
5228	4908.23	0	0	1	0	0	0	0	0	0	0	12.70	0
5229	4909.02	0	0	1	0	0	0	0	0	0	0	12.70	0
5230	4909.82	0	0	1	0	0	0	0	0	0	0	12.70	0
5231	4910.61	0	0	1	0	0	0	0	0	0	0	12.70	0
5232	4911.40	0	0	1	0	0	0	0	0	0	0	12.70	0
5233	4912.20	0	0	1	0	0	0	0	0	0	0	12.70	0
5234	4912.99	0	0	1	0	0	0	0	0	0	0	12.70	0
5235	4913.78	0	0	1	0	0	0	0	0	0	0	12.70	0
5236	4914.57	0	0	1	0	0	0	0	0	0	0	12.70	0
5237	4915.37	0	0	1	0	0	0	0	0	0	0	12.70	0
5238	4916.16	0	0	1	0	0	0	0	0	0	0	12.70	0
5239	4916.95	0	0	1	0	0	0	0	0	0	0	12.70	0
5240	4917.74	0	0	1	0	0	0	0	0	0	0	12.70	0
5241	4918.53	0	0	1	0	0	0	0	0	0	0	12.70	0
5242	4919.32	0	0	1	0	0	0	0	0	0	0	12.70	0
5243	4920.11	0	0	1	0	0	0	0	0	0	0	12.70	0
5244	4920.90	0	0	1	0	0	0	0	0	0	0	12.70	0
5245	4921.69	0	0	1	0	0	0	0	0	0	0	12.70	0
5246	4922.48	0	0	1	0	0	0	0	0	0	0	12.70	0
5247	4923.46	0	0	1	0	0	0	0	0	0	0	12.70	0
5248	4924.06	0	0	1	0	0	0	0	0	0	0	12.70	0
5249	4924.84	0	0	1	0	0	0	0	0	0	0	12.70	0
5250	4925.63	0	0	1	0	0	0	0	0	0	0	12.70	0
5251	4926.42	0	0	1	0	0	0	0	0	0	0	12.70	0
5252	4927.21	0	0	1	0	0	0	0	0	0	0	12.70	0
5253	4927.99	0	0	1	0	0	0	0	0	0	0	12.70	0
5254	4928.78	0	0	1	0	0	0	0	0	0	0	12.70	0
5255	4929.57	0	0	1	0	0	0	0	0	0	0	12.70	0

5256	4930.35	0	0	1	0	0	0	0	0	0	0	12.70	0
5257	4931.14	0	0	1	0	0	0	0	0	0	0	12.70	0
5258	4931.92	0	0	1	0	0	0	0	0	0	0	12.70	0
5259	4932.71	0	0	1	0	0	0	0	0	0	0	12.70	0
5260	4933.50	0	0	1	0	0	0	0	0	0	0	12.70	0
5261	4934.28	0	0	1	0	0	0	0	0	0	0	12.70	0
5262	4935.06	0	0	1	0	0	0	0	0	0	0	12.70	0
5263	4935.85	0	0	1	0	0	0	0	0	0	0	12.70	0
5264	4936.63	0	0	1	0	0	0	0	0	0	0	12.70	0
5265	4937.42	0	0	1	0	0	0	0	0	0	0	12.70	0
5266	4938.20	0	0	1	0	0	0	0	0	0	0	12.70	0
5267	4938.98	0	0	1	0	0	0	0	0	0	0	12.70	0
5268	4939.76	0	0	1	0	0	0	0	0	0	0	12.70	0
5269	4940.55	0	0	1	0	0	0	0	0	0	0	12.70	0
5270	4941.33	0	0	1	0	0	0	0	0	0	0	12.70	0
5271	4942.11	0	0	1	0	0	0	0	0	0	0	12.70	0
5272	4942.89	0	0	1	0	0	0	0	0	0	0	12.70	0
5273	4943.67	0	0	1	0	0	0	0	0	0	0	12.70	0
5274	4944.46	0	0	1	0	0	0	0	0	0	0	12.70	0
5275	4945.24	0	0	1	0	0	0	0	0	0	0	12.70	0
5276	4946.02	0	0	1	0	0	0	0	0	0	0	12.70	0
5277	4946.80	0	0	1	0	0	0	0	0	0	0	12.70	0
5278	4947.58	0	0	1	0	0	0	0	0	0	0	12.70	0
5279	4948.36	0	0	1	0	0	0	0	0	0	0	12.70	0
5280	4949.13	0	0	1	0	0	0	0	0	0	0	12.70	0
5281	4949.91	0	0	1	0	0	0	0	0	0	0	12.70	0
5282	4950.69	0	0	1	0	0	0	0	0	0	0	12.70	0
5283	4951.47	0	0	1	0	0	0	0	0	0	0	12.70	0
5284	4952.25	0	0	1	0	0	0	0	0	0	0	12.70	0
5285	4953.03	0	0	1	0	0	0	0	0	0	0	12.70	0
5286	4953.80	0	0	1	0	0	0	0	0	0	0	12.70	0
5287	4954.58	0	0	1	0	0	0	0	0	0	0	12.70	0
5288	4955.36	0	0	1	0	0	0	0	0	0	0	12.70	0
5289	4956.13	0	0	1	0	0	0	0	0	0	0	12.70	0
5290	4956.91	0	0	1	0	0	0	0	0	0	0	12.70	0
5291	4957.69	0	0	1	0	0	0	0	0	0	0	12.70	0
5292	4958.46	0	0	1	0	0	0	0	0	0	0	12.70	0
5293	4959.24	0	0	1	0	0	0	0	0	0	0	12.70	0
5294	4960.01	0	0	1	0	0	0	0	0	0	0	12.70	0
5295	4960.79	0	0	1	0	0	0	0	0	0	0	12.70	0
5296	4961.56	0	0	1	0	0	0	0	0	0	0	12.70	0
5297	4962.33	0	0	1	0	0	0	0	0	0	0	12.70	0
5298	4963.11	0	0	1	0	0	0	0	0	0	0	12.70	0
5299	4963.88	0	0	1	0	0	0	0	0	0	0	12.70	0
5300	4964.66	0	0	1	0	0	0	0	0	0	0	12.70	0
5301	4965.43	0	0	1	0	0	0	0	0	0	0	12.70	0

5302	4966.20	0	0	1	0	0	0	0	0	0	0	12.70	0
5303	4966.97	0	0	1	0	0	0	0	0	0	0	12.70	0
5304	4967.75	0	0	1	0	0	0	0	0	0	0	12.70	0
5305	4968.52	0	0	1	0	0	0	0	0	0	0	12.70	0
5306	4969.29	0	0	1	0	0	0	0	0	0	0	12.70	0
5307	4970.06	0	0	1	0	0	0	0	0	0	0	12.70	0
5308	4970.83	0	0	1	0	0	0	0	0	0	0	12.70	0
5309	4971.60	0	0	1	0	0	0	0	0	0	0	12.70	0
5310	4972.37	0	0	1	0	0	0	0	0	0	0	12.70	0
5311	4973.14	0	0	1	0	0	0	0	0	0	0	12.70	0
5312	4973.91	0	0	1	0	0	0	0	0	0	0	12.70	0
5313	4974.68	0	0	1	0	0	0	0	0	0	0	12.70	0
5314	4975.45	0	0	1	0	0	0	0	0	0	0	12.70	0
5315	4976.22	0	0	1	0	0	0	0	0	0	0	12.70	0
5316	4976.99	0	0	1	0	0	0	0	0	0	0	12.70	0
5317	4977.75	0	0	1	0	0	0	0	0	0	0	12.70	0
5318	4978.52	0	0	1	0	0	0	0	0	0	0	12.70	0
5319	4979.29	0	0	1	0	0	0	0	0	0	0	12.70	0
5320	4980.06	0	0	1	0	0	0	0	0	0	0	12.70	0
5321	4980.82	0	0	1	0	0	0	0	0	0	0	12.70	0
5322	4981.59	0	0	1	0	0	0	0	0	0	0	12.70	0
5323	4982.36	0	0	1	0	0	0	0	0	0	0	12.70	0
5324	4983.12	0	0	1	0	0	0	0	0	0	0	12.70	0
5325	4983.89	0	0	1	0	0	0	0	0	0	0	12.70	0
5326	4984.65	0	0	1	0	0	0	0	0	0	0	12.70	0
5327	4985.42	0	0	1	0	0	0	0	0	0	0	12.70	0
5328	4986.18	0	0	1	0	0	0	0	0	0	0	12.70	0
5329	4986.95	0	0	1	0	0	0	0	0	0	0	12.70	0
5330	4987.71	0	0	1	0	0	0	0	0	0	0	12.70	0
5331	4988.47	0	0	1	0	0	0	0	0	0	0	12.70	0
5332	4989.24	0	0	1	0	0	0	0	0	0	0	12.70	0
5333	4990.00	0	0	1	0	0	0	0	0	0	0	12.70	0
5334	4990.76	0	0	1	0	0	0	0	0	0	0	12.70	0
5335	4991.53	0	0	1	0	0	0	0	0	0	0	12.70	0
5336	4992.29	0	0	1	0	0	0	0	0	0	0	12.70	0
5337	4993.05	0	0	1	0	0	0	0	0	0	0	12.70	0
5338	4993.81	0	0	1	0	0	0	0	0	0	0	12.70	0
5339	4994.57	0	0	1	0	0	0	0	0	0	0	12.70	0
5340	4995.34	0	0	1	0	0	0	0	0	0	0	12.70	0
5341	4996.10	0	0	1	0	0	0	0	0	0	0	12.70	0
5342	4996.86	0	0	1	0	0	0	0	0	0	0	12.70	0
5343	4997.62	0	0	1	0	0	0	0	0	0	0	12.70	0
5344	4998.38	0	0	1	0	0	0	0	0	0	0	12.70	0
5345	4999.14	0	0	1	0	0	0	0	0	0	0	12.70	0
5346	4999.90	0	0	1	0	0	0	0	0	0	0	12.70	0
5347	5000.65	0	0	1	0	0	0	0	0	0	0	12.70	0

5348	5001.41	0	0	1	0	0	0	0	0	0	0	12.70	0
5349	5002.17	0	0	1	0	0	0	0	0	0	0	12.70	0
5350	5002.93	0	0	1	0	0	0	0	0	0	0	12.70	0
5351	5003.69	0	0	1	0	0	0	0	0	0	0	12.70	0
5352	5004.44	0	0	1	0	0	0	0	0	0	0	12.70	0
5353	5005.20	0	0	1	0	0	0	0	0	0	0	12.70	0
5354	5005.96	0	0	1	0	0	0	0	0	0	0	12.70	0
5355	5006.71	0	0	1	0	0	0	0	0	0	0	12.70	0
5356	5007.47	0	0	1	0	0	0	0	0	0	0	12.70	0
5357	5008.23	0	0	1	0	0	0	0	0	0	0	12.70	0
5358	5008.98	0	0	1	0	0	0	0	0	0	0	12.70	0
5359	5009.74	0	0	1	0	0	0	0	0	0	0	12.70	0
5360	5010.49	0	0	1	0	0	0	0	0	0	0	12.70	0
5361	5011.25	0	0	1	0	0	0	0	0	0	0	12.70	0
5362	5012.00	0	0	1	0	0	0	0	0	0	0	12.70	0
5363	5012.76	0	0	1	0	0	0	0	0	0	0	12.70	0
5364	5013.51	0	0	1	0	0	0	0	0	0	0	12.70	0
5365	5014.26	0	0	1	0	0	0	0	0	0	0	12.70	0
5366	5015.02	0	0	1	0	0	0	0	0	0	0	12.70	0
5367	5015.77	0	0	1	0	0	0	0	0	0	0	12.70	0
5368	5016.52	0	1	0	0	0	0	0	0	0	0	12.70	0
5369	5017.27	0	1	0	0	0	0	0	0	0	0	12.70	0
5370	5018.03	0	1	0	0	0	0	0	0	0	0	12.70	0
5371	5018.78	0	1	0	0	0	0	0	0	0	0	12.70	0
5372	5019.53	0	1	0	0	0	0	0	0	0	0	12.70	0
5373	5020.28	0	1	0	0	0	0	0	0	0	0	12.70	0
5374	5021.03	0	1	0	0	0	0	0	0	0	0	12.70	0
5375	5021.78	0	1	0	0	0	0	0	0	0	0	12.70	0
5376	5022.53	0	1	0	0	0	0	0	0	0	0	12.70	0
5377	5023.28	0	1	0	0	0	0	0	0	0	0	12.70	0
5378	5024.03	0	1	0	0	0	0	0	0	0	0	12.70	0
5379	5024.78	0	1	0	0	0	0	0	0	0	0	12.70	0
5380	5025.53	0	1	0	0	0	0	0	0	0	0	12.70	0
5381	5026.28	0	1	0	0	0	0	0	0	0	0	12.70	0
5382	5027.03	0	1	0	0	0	0	0	0	0	0	12.70	0
5383	5027.77	0	1	0	0	0	0	0	0	0	0	12.70	0
5384	5028.52	0	1	0	0	0	0	0	0	0	0	12.70	0
5385	5029.27	0	1	0	0	0	0	0	0	0	0	12.70	0
5386	5030.02	0	1	0	0	0	0	0	0	0	0	12.70	0
5387	5030.76	0	1	0	0	0	0	0	0	0	0	12.70	0
5388	5031.51	0	1	0	0	0	0	0	0	0	0	12.70	0
5389	5032.26	0	1	0	0	0	0	0	0	0	0	12.70	0
5390	5033.00	0	1	0	0	0	0	0	0	0	0	12.70	0
5391	5033.75	0	1	0	0	0	0	0	0	0	0	12.70	0
5392	5034.49	0	1	0	0	0	0	0	0	0	0	12.70	0
5393	5035.24	0	1	0	0	0	0	0	0	0	0	12.70	0

5394	5035.98	0	1	0	0	0	0	0	0	0	0	12.70	0
5395	5036.73	0	1	0	0	0	0	0	0	0	0	12.70	0
5396	5037.47	0	1	0	0	0	0	0	0	0	0	12.70	0
5397	5038.22	0	1	0	0	0	0	0	0	0	0	12.70	0
5398	5038.96	0	1	0	0	0	0	0	0	0	0	12.70	0
5399	5039.70	0	1	0	0	0	0	0	0	0	0	12.70	0
5400	5040.45	0	1	0	0	0	0	0	0	0	0	12.70	0
5401	5041.19	0	1	0	0	0	0	0	0	0	0	13.10	0
5402	5041.93	0	1	0	0	0	0	0	0	0	0	13.10	0
5403	5042.67	0	1	0	0	0	0	0	0	0	0	13.10	0
5404	5043.41	0	1	0	0	0	0	0	0	0	0	13.10	0
5405	5044.16	0	1	0	0	0	0	0	0	0	0	13.10	0
5406	5044.90	0	1	0	0	0	0	0	0	0	0	13.10	0
5407	5045.64	0	1	0	0	0	0	0	0	0	0	13.10	0
5408	5046.38	0	1	0	0	0	0	0	0	0	0	13.10	0
5409	5047.12	0	1	0	0	0	0	0	0	0	0	13.10	0
5410	5047.86	0	1	0	0	0	0	0	0	0	0	13.10	0
5411	5048.60	0	1	0	0	0	0	0	0	0	0	13.10	0
5412	5049.34	0	1	0	0	0	0	0	0	0	0	13.10	0
5413	5050.08	0	1	0	0	0	0	0	0	0	0	13.10	0
5414	5050.81	0	1	0	0	0	0	0	0	0	0	13.10	0
5415	5051.55	0	1	0	0	0	0	0	0	0	0	13.10	0
5416	5052.29	0	1	0	0	0	0	0	0	0	0	13.10	0
5417	5053.03	0	1	0	0	0	0	0	0	0	0	13.10	0
5418	5053.77	0	1	0	0	0	0	0	0	0	0	13.10	0
5419	5054.50	0	1	0	0	0	0	0	0	0	0	13.10	0
5420	5055.24	0	1	0	0	0	0	0	0	0	0	13.10	0
5421	5055.98	0	1	0	0	0	0	0	0	0	0	13.10	0
5422	5056.71	0	1	0	0	0	0	0	0	0	0	13.10	0
5423	5057.45	0	1	0	0	0	0	0	0	0	0	13.10	0
5424	5058.18	0	1	0	0	0	0	0	0	0	0	13.10	0
5425	5058.92	0	1	0	0	0	0	0	0	0	0	13.10	0
5426	5059.65	0	1	0	0	0	0	0	0	0	0	13.10	0
5427	5060.39	0	1	0	0	0	0	0	0	0	0	13.10	0
5428	5061.12	0	1	0	0	0	0	0	0	0	0	13.10	0
5429	5061.86	0	1	0	0	0	0	0	0	0	0	13.10	0
5430	5062.59	0	1	0	0	0	0	0	0	0	0	13.10	0
5431	5063.32	0	1	0	0	0	0	0	0	0	0	13.10	0
5432	5064.06	0	1	0	0	0	0	0	0	0	0	13.10	0
5433	5064.79	0	1	0	0	0	0	0	0	0	0	13.10	0
5434	5065.52	0	1	0	0	0	0	0	0	0	0	13.10	0
5435	5066.62	0	1	0	0	0	0	0	0	0	0	13.10	0

4.2.5 Bits Information Provided.

Table 4.5.1 **Bits Wear information for Well A.**

Bit Runs	MD, ft	TVD, ft	Interval drilled, ft	Dull Bit Grading
1st	5078 - 5120	4787.69 – 4821.89	42	NA
2nd	5120 – 5435	4821.89 – 5017.27	315	1-1-NO-A-X-N-I-DTF

Table 4.5. 1 **Bits Wear information for Well B.**

Bit Runs	MD, ft	TVD, ft	Interval drilled, ft	Dull Bit Grading
1st	5078 – 5120	4787.7 – 4821.9	42	NA
2nd	5120 – 17837	4821.9 – 10172.7	12715	BHA lost in the hole

Table 4.5.3 Bits wear information for Well C in Ekofisk/Eldfisk field.

Bits Runs	MD, ft	TVD, ft	Interval drilled, ft	Dull Bit Grading
1st	4670 – 15960	4457.8 – 9897.1	11290	1-1-WT-A-X-I-CT-PR
2nd	15960 – 16740	9897.1 – 10169.6	780	1-2-WT-A-F-4-NO-TD
3rd	16740 – 17335	10169.6 – 10368.3	595	1-1-WT-A-E-I-NO-TD
4th	17335 – 18245	10368.3 – 10578.1	910	6-4-LM-NT-X-I-RO-DTF
5th	18245 – 20018	10578.1 – 10601.2	1773	4-5-LT-S-X-O-WT-DTF

Table 4.5.4 Bits Wear information for Well D in Ekofisk/Eldfisk field.

Bits Run	MD, ft	TVD, ft	Interval drilled, ft	Dull Bit Grading
1st	19542 – 21556	10595.2 – 10612.5	2014	3-5-LT-J-E-I-CT-TD

*Kick-off from Well C (4670-19542) ft to drill Well D from 19542ft.

Table 4.5.5 Bits Wear information for Well E in Ekofisk/Eldfisk field.

Bits Run	MD, ft	TVD, ft	Interval drilled, ft	Dull Bit Grading
1st	423 – 648	423 - 648	225	1-1-WT-A-E-I-NO-TD
2nd	648 – 1732	648 -1732	1084	1-1-WT-A-E-I-NO-TD
3rd	1732 – 5042	1732 – 4811	3310	0-0-NO-A-X-I-NO-TD
4th	5042 - 11482	4811 – 10186	6440	1-1-WT-A-X-I-BT-TD
5th	11482 -12600	10186 - 11211	1118	1-1-WT-A-E-I-NO-TD

Table 4.5.6 Bit design parameters for Bit performance Simulation.

Vendor	Bit designer
Bit Size	Inches
Bit Description	Dull Grading, etc
Nozzle 1	(1/32) inches
Nozzle 2	(1/32) inches
Nozzle 3	(1/32) inches
Nozzle 4	(1/32) inches
Nozzle 5	(1/32) inches
Nozzle 6	(1/32) inches
Nozzle 7	(1/32) inches
Nozzle 8	(1/32) inches
Primary Cutter Number	
Backup Cutter Number	
Primary Cutter Size	Inches
Backup Cutter Size	
Primary Backrake	Degrees
Backup Backrake	Degrees
Primary Siderake	Degrees
Backup Siderake	Degrees
Number of Blades	
Junk Slot Area	Square inches
Thickness	Inches
Backup Cutter Exposure	
Distance between Primary and Backup Cutters	Inches

Bit Runs Simulated Data:

Version = 1.1

Well = Well A

Prepared By = Vincent

Comment =

[PDC1]

Bit Type = pdc

IADC Code = 999

Bit Diameter = 12.25

TVD In = 4787.69

TVD Out = 4821.89

MD In = 5078

MD Out = 5120

Wear In = 0.0

Wear Out = 4

Cost = 52000

DHM Cost = 0

Manufacturer = Baker oil Tool

Bit Description = N/A (converted file)

Nozzle1 = 16

Nozzle2 = 16

Nozzle3 = 16

Nozzle4 = 14

Nozzle5 = 14

Nozzle6 = 14

Nozzle7 = 0

Nozzle8 = 0

Primary Number of Cutters = 69

Backup Number of Cutters = 0

Primary Cutter Size = 0.5

Backup Cutter Size = 0.0

Primary Backrake = 20

Backup Backrake = 0

Primary Siderake = 15

Backup Siderake = 0

Number of Blades = 6

Junk Slot Area = 28

Thickness = 0.5

Exposure = 0

Distance = 0

[PDC2]

Bit Type = pdc

IADC Code = 999

Bit Diameter = 12.25

TVD In = 4822.50

TVD Out = 5066.62

MD In = 5121

MD Out = 5435

Wear In = 0.0

Wear Out = 1

Cost = 56800

DHM Cost = 0

Manufacturer = SDBS

Bit Description = N/A (converted file)

Nozzle1 = 12

Nozzle2 = 12

Nozzle3 = 14

Nozzle4 = 13

Nozzle5 = 13

Nozzle6 = 13

Nozzle7 = 0

Nozzle8 = 0

Primary Number of Cutters = 102

Backup Number of Cutters = 0

Primary Cutter Size = 0.5

Backup Cutter Size = 0.0

Primary Backrake = 20

Backup Backrake = 0

Primary Siderake = 0

Backup Siderake = 0

Number of Blades = 6

Junk Slot Area = 28

Thickness = 0.076

Exposure = 0

Distance = 0

[Info]

Version = 1.1

Well = Well B

Prepared By = Vincent

Comment =

[PDC1]

Bit Type = pdc

IADC Code = 999

Bit Diameter = 12.25

TVD In = 4787.7

TVD Out = 4821.9

MD In = 5078

MD Out = 5120

Wear In = 0.0

Wear Out = 4

Cost = 52000

DHM Cost = 0

Manufacturer = baker oil Tool

Bit Description = N/A (converted file)

Nozzle1 = 16

Nozzle2 = 16

Nozzle3 = 16

Nozzle4 = 14

Nozzle5 = 14

Nozzle6 = 14

Nozzle7 = 0

Nozzle8 = 0

Primary Number of Cutters = 69

Backup Number of Cutters = 0

Primary Cutter Size = 0.5

Backup Cutter Size = 0.0

Primary Backrake = 20

Backup Backrake = 0

Primary Siderake = 15

Backup Siderake = 0

Number of Blades = 6

Junk Slot Area = 28

Thickness = 0.5

Exposure = 0

Distance = 0

[PDC2]

Bit Type = pdc

IADC Code = 999

Bit Diameter = 12.25

TVD In = 4822.5

TVD Out = 10172.7

MD In = 5121

MD Out = 17837

Wear In = 0.0

Wear Out = 3

Cost = 58000

DHM Cost = 0

Manufacturer = Reed Hycalog Bit

Bit Description = N/A (converted file)

Nozzle1 = 18

Nozzle2 = 18

Nozzle3 = 18

Nozzle4 = 18

Nozzle5 = 18

Nozzle6 = 18

Nozzle7 = 0

Nozzle8 = 0

Primary Number of Cutters = 102

Backup Number of Cutters = 0

Primary Cutter Size = 0.5

Backup Cutter Size = 0.0

Primary Backrake = 20

Backup Backrake = 0

Primary Siderake = 0

Backup Siderake = 0

Number of Blades = 6

Junk Slot Area = 28

Thickness = 0.076

Exposure = 0

Distance = 0

4.6 BIT PERFORMANCE OPTIMIZATION GENERATED PLOTS FOR WELL A

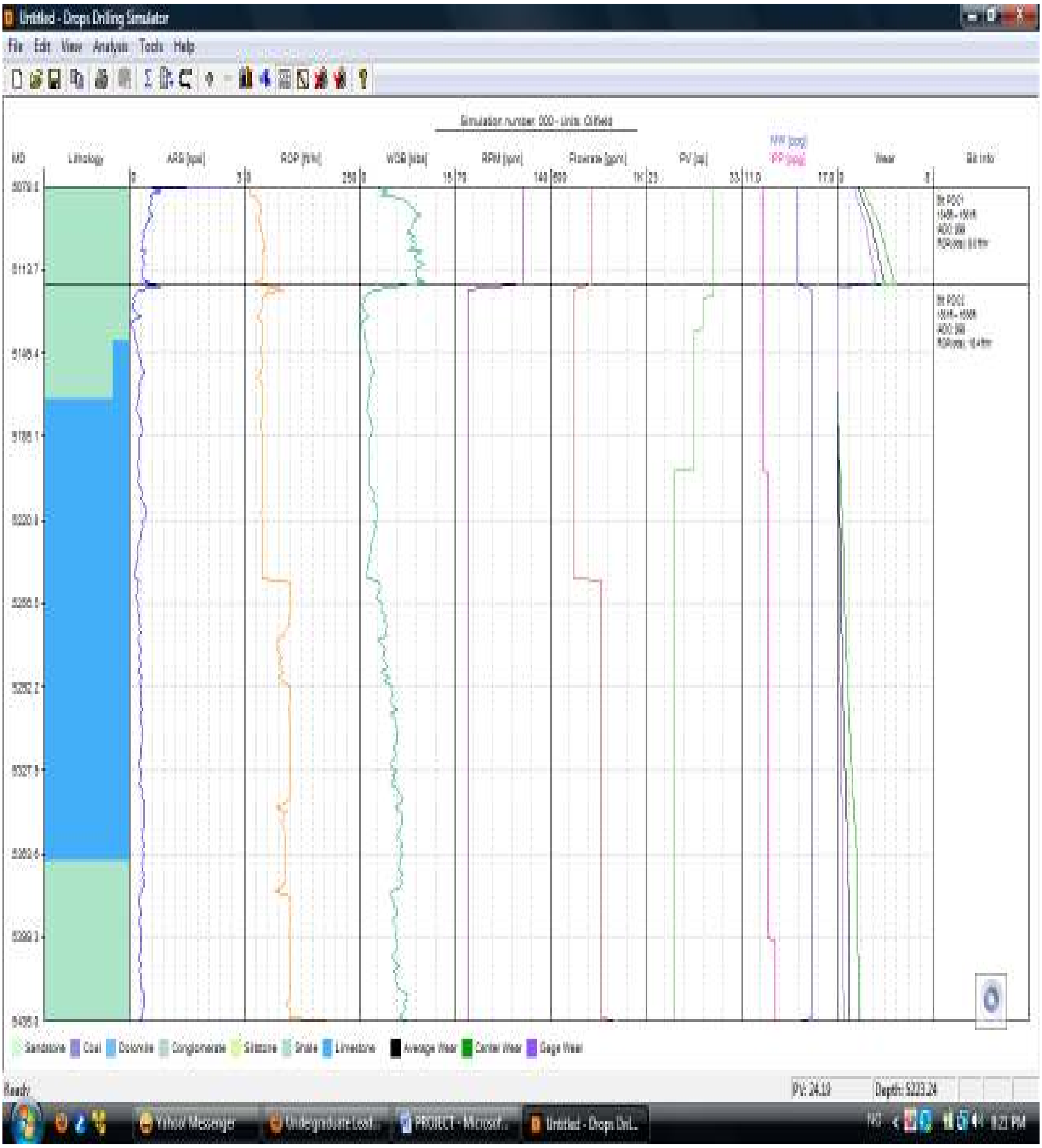

Figure 4.3 Plots of two sections unsimulated parameters for Well A

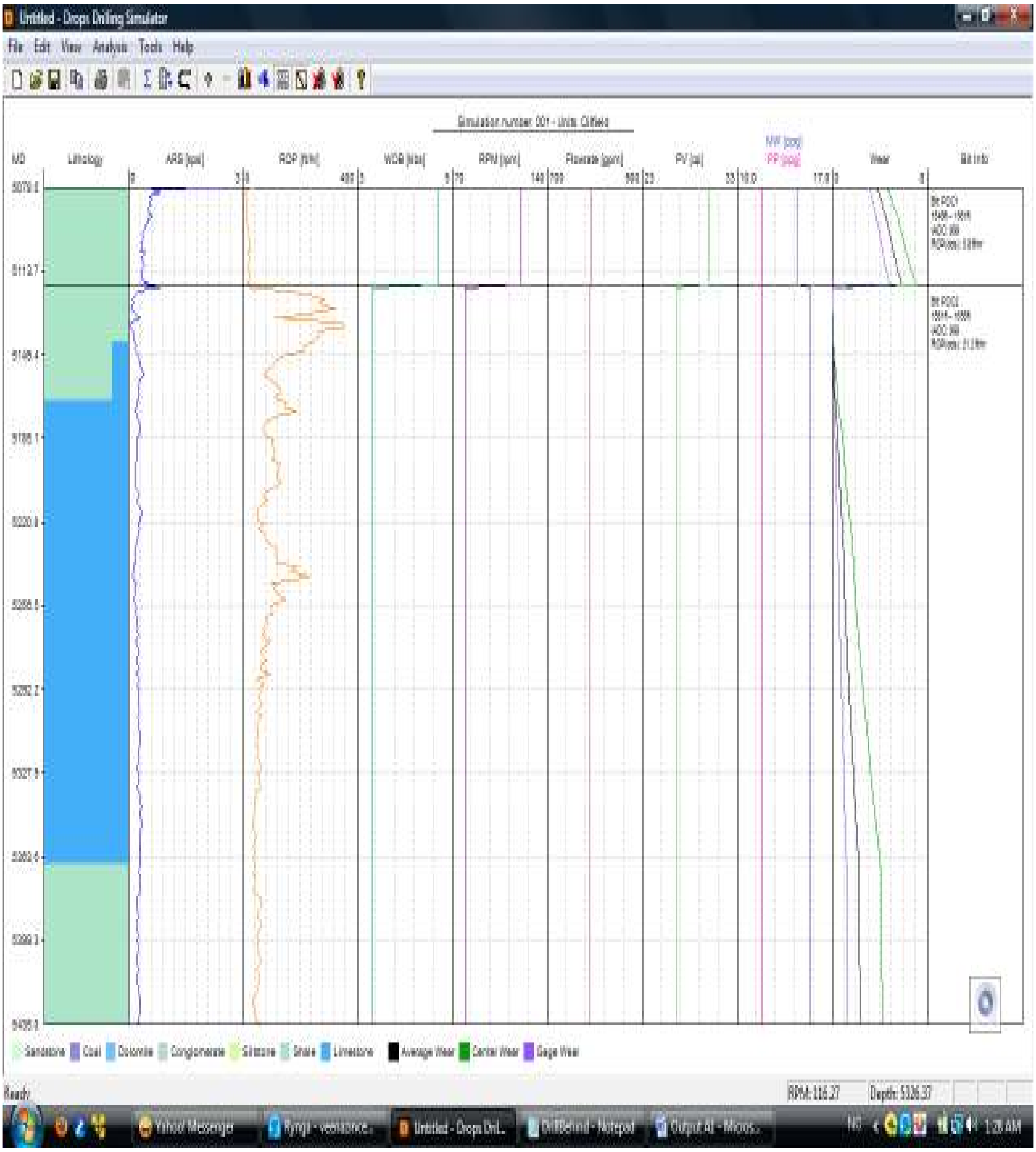

Figure 4.4 Plots of two sections simulated parameters for well A

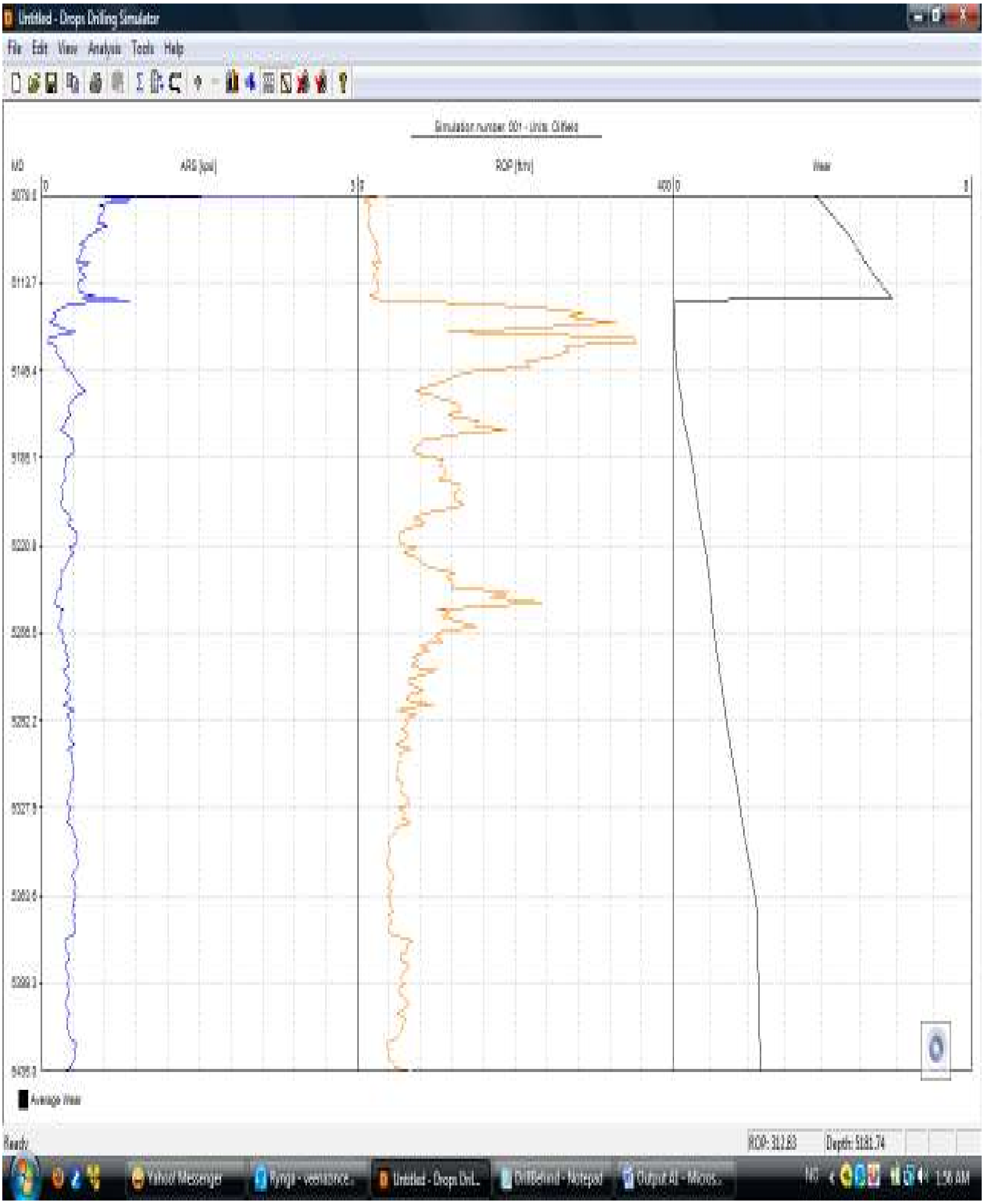

Figure 4.5 Enlarged Plots of two sections of ARSL, ROP and Bit wear Simulation for Well A

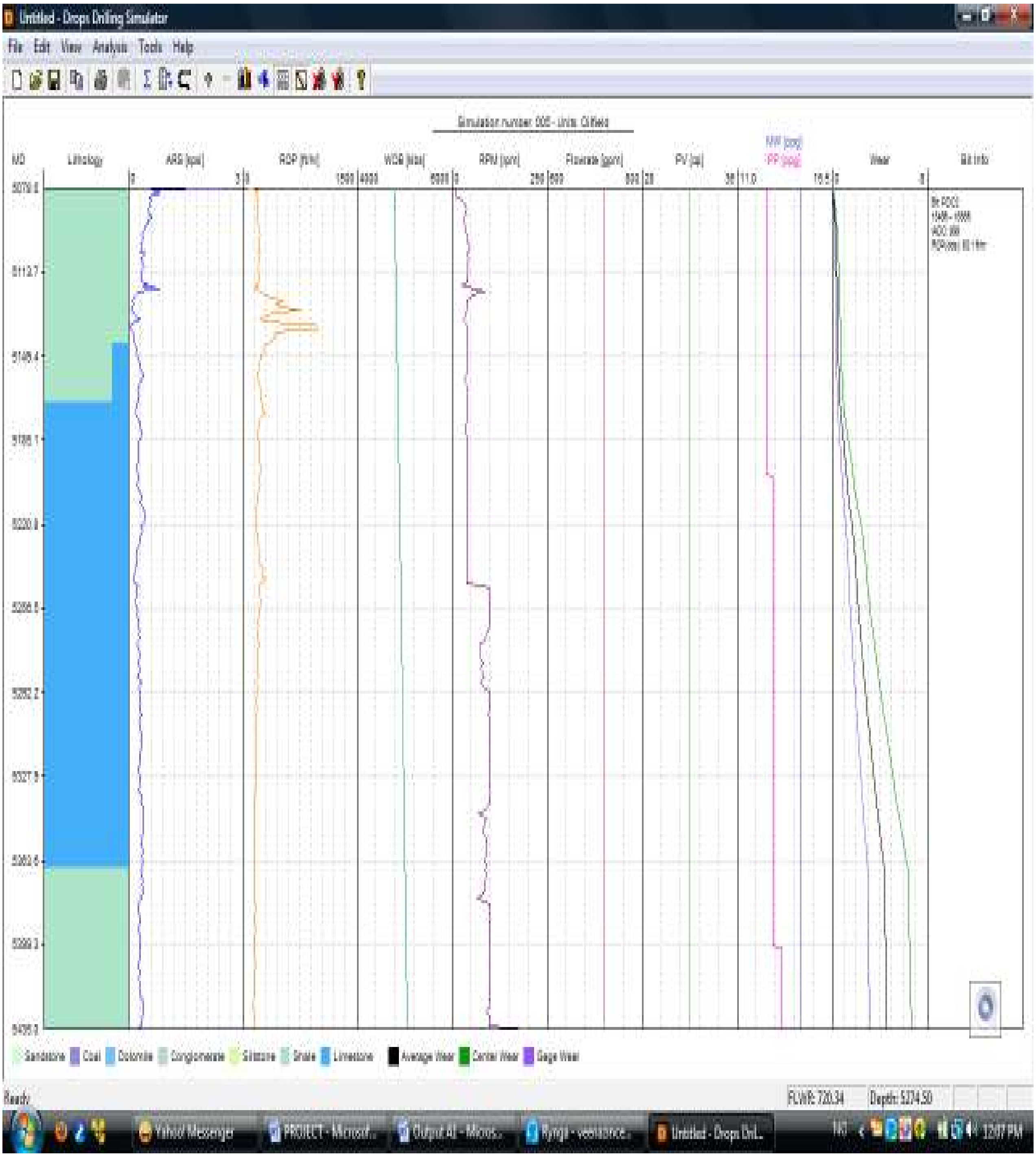

Figure 4.6 Plots of Whole section Simulated parameters with PDC2 for Well A

4.2.5 Simulation Results for Well A

Table 4.6.1 Well A Drilling Conditions

Sections	Run	BitID	From	To	Difference	Drilling Mode	Mud Type
1st	01	01-pdc	5078	5120	42	Rotary	Oil
2nd	02	02-pdc	5121	5435	314	Rotary	Oil

Table 4.6.2 Average Simulation Parameters for Well A Predicted by DROPS Simulator

WOB	RPM	Flowrate	PV	MW	Bit Wear	Total Bit Wear	ROP	Cost/ft
8.1	120	793.8	30.0	14.5	5.9	5.9	19.97	2358.03
4.1	80	790.9	26.6	15.4	1.0	1.0	68.77	453.63

Table 4.6.3 Simulated Results Summary for Well A (2-sections), Cost in thousand dollars.

Sim.	Bit	Trip	Connection	DHMotor	Rotation	Total	Cost/ft	Time	Remarks
000	108.8	84.3	8.2	000.0	54.3	255.59	709.4	6.6	Unsimulated
001	108.8	84.3	8.2	000.0	55.5	256.84	688.7	6.7	Simulated

Table 4.6.4 Simulated Results Summary for Well A (Whole section), Cost in thousand dollars.

Sim.	Bit	Trip	Connect	DHMotor	Rotating	Total	ROP	Cost/ft	Time	Bit S/N
001	60.0	42.7	8.2	000.0	33.1	144.01	26.8	396.8	4.0	123456
002	52.0	42.7	8.2	000.0	5801.3	5904.21	0.2	16270.3	724.4	Pdc1
003	56.8	42.7	8.2	000.0	14.8	122.43	60.1	337.4	1.8	Pdc2

Table 4.6.5 Wear Constants Predicted for Bits by DROPS simulator.

Bits Serial Numbers	Wear Constants
123456	7.344614 E -005
Pdc 1	1.770602 E -001
Pdc 2	1.999181 E -003

4.7 BIT PERFORMANCE OPTIMIZATION GENERATED PLOTS FOR WELL B

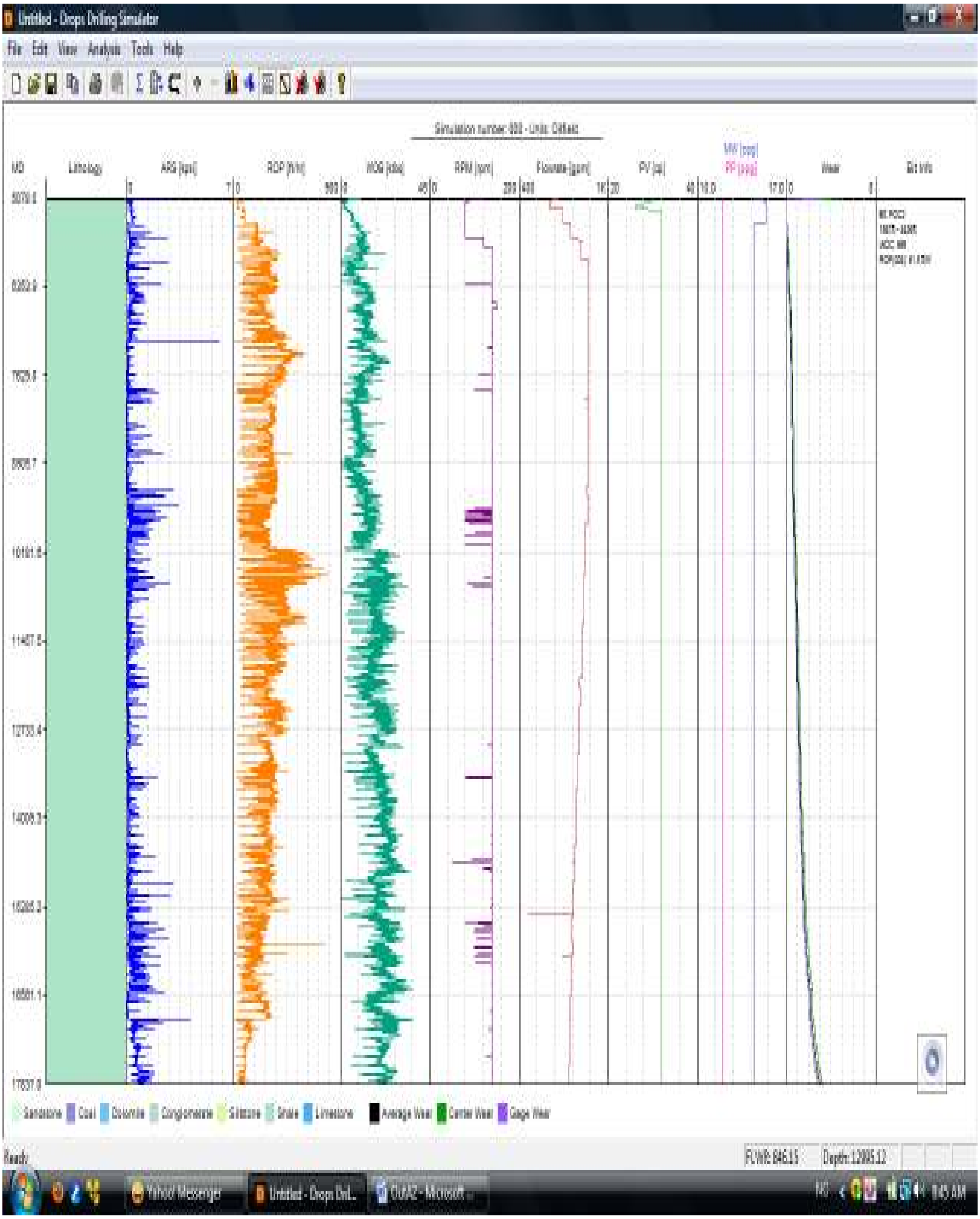

Figure 4.7 Plots of two sections unsimulated parameters for Well B

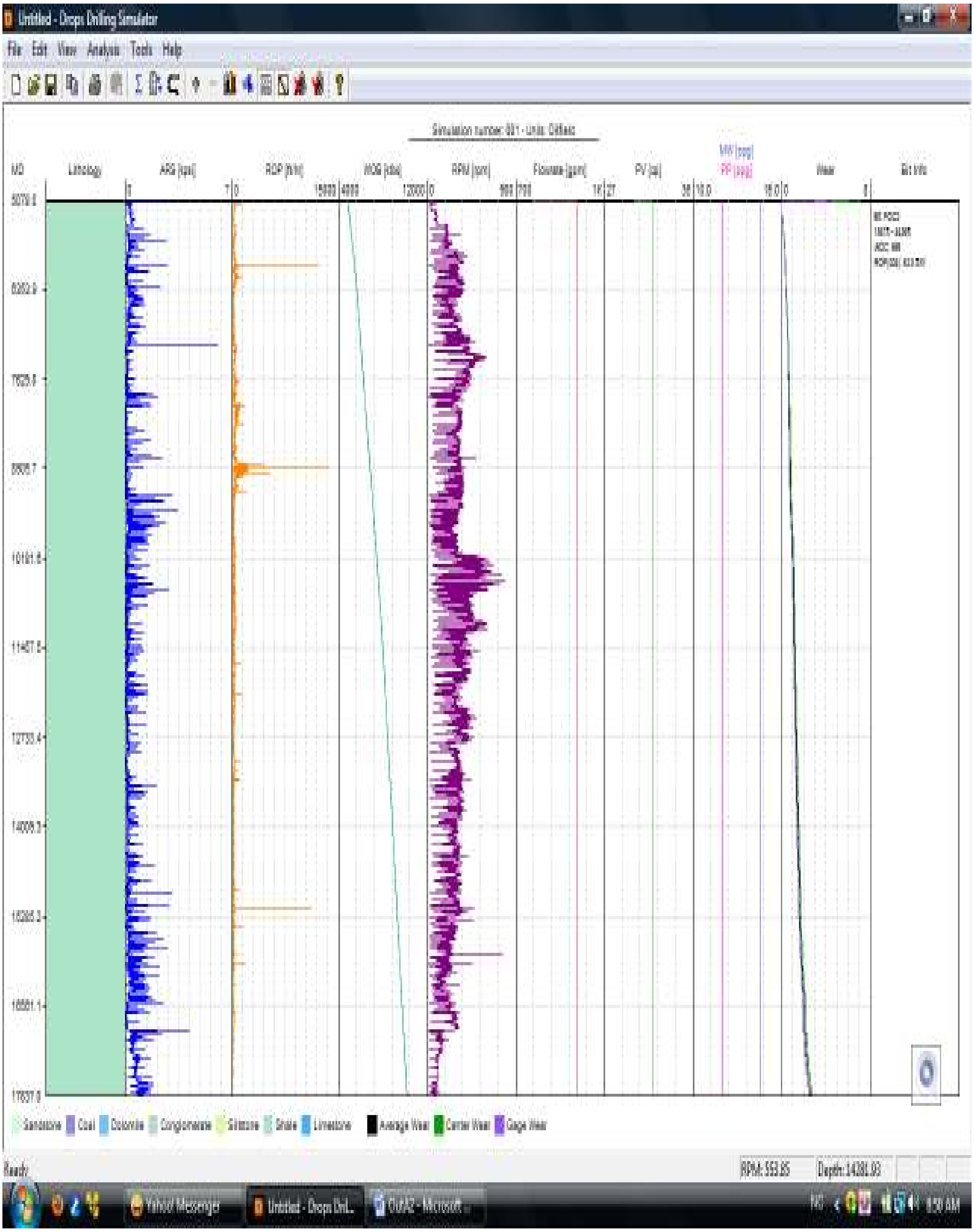

Figure 4.8 Plots of two sections simulated parameters for Well B

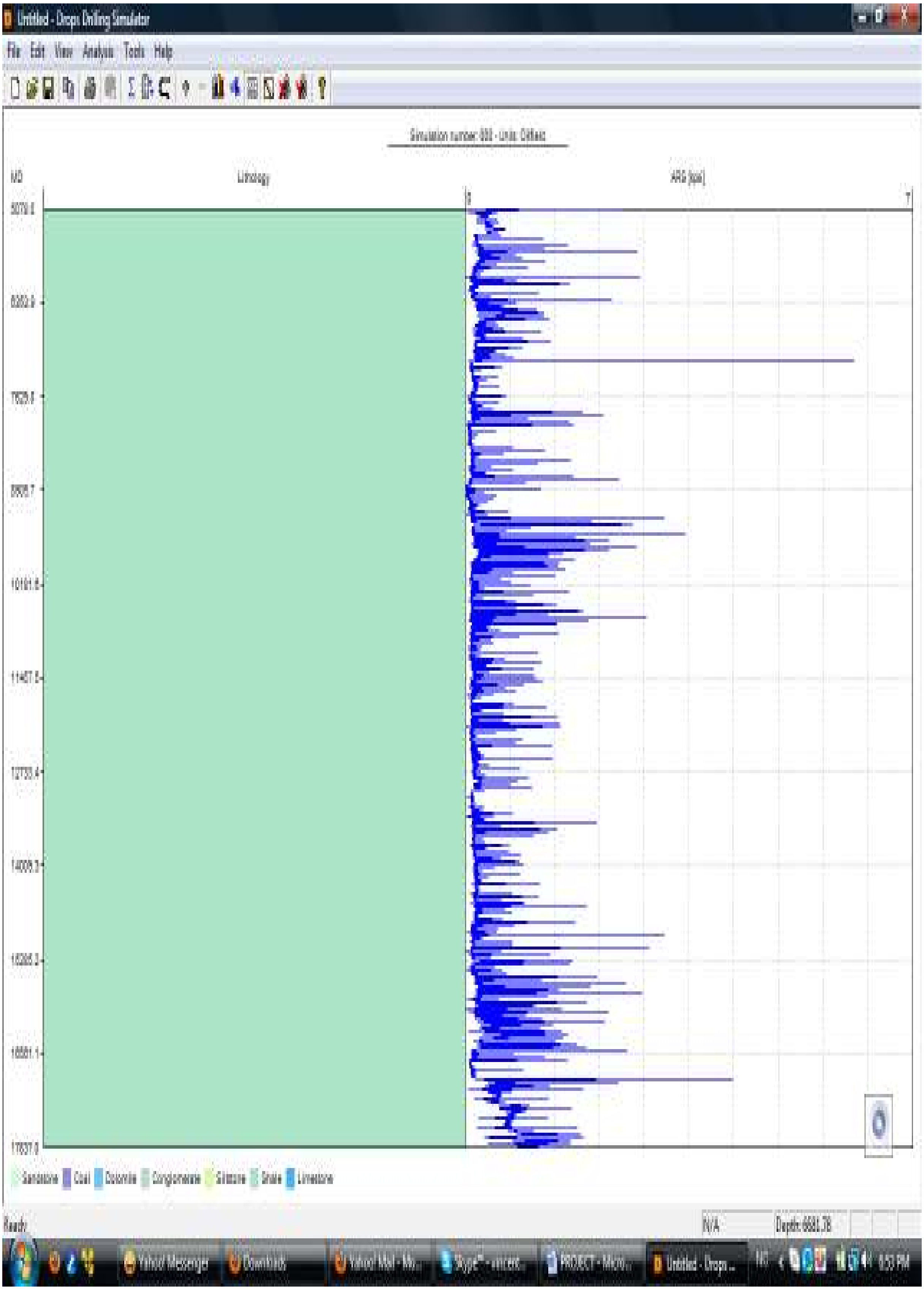

Figure 4.9 Plots of lithology and ARSL versus depth for Well B

4.7.1 Simulation Results for Well B

Table 4.7.1 Well B Drilling Conditions

Sections	Run	BitID	From	To	Difference	Drilling Mode	Mud Type
1st	01	01-pdc	5078	5120	42	Rotary	Oil
2nd	02	02-pdc	5121	17837	12716	Rotary	Oil

Table 4.7.2 Average Simulation Parameters for Well B Predicted by DROPS Simulator

WOB	RPM	Flowrate	PV	MW	Bit Wear	Total Bit Wear	ROP	Cost/ft
8.1	120	793.8	30.0	14.5	5.9	5.9	19.97	2358.03
16.1	137	1015.1	32	14.52	2.6	2.6	208.14	73.49

Table 4.7.3 Simulated Results Summary for Well B (2-sections), Cost in thousand dollars.

Sim.	Bit	Trip	Connection	DHMotor	Rotation	Total	Cost/ft	Time	Remarks
000	110	134.7	288.1	000.0	521.3	1054.1	87.6	64.1	Unsimulated
001	110	134.7	288.1	000.0	514.8	1047.6	82.1	63.2	Simulated

Table 4.7.4 Simulated Results Summary for Well B (Whole section), Cost in thousand dollars.

Sim.	Bit	Trip	Connect	DHMotor	Rotating	Total	Cost/ft	Time	Bit S/N
001	110.0	134.7	288.1	000.0	521.3	1054.1	82.1	63.2	Pdc1
002	110.0	134.7	288.1	000.0	521.3	1054.1	82.1	63.2	Pdc1
003	116	134.7	288.1	000.0	499.7	1038.5	81.4	61.5	Pdc2

Table 4.7.5 Wear Constants Predicted for Bits by DROPS simulator.

Bits Serial Numbers	Wear Constants
Pdc 1	1.770291 E -001
Pdc 2	1.093961 E -004

4.8 BITS HYDRAULICS ANALYSIS FOR WELL A: Flowrate Ranges from (720 -920) l/min

PDC 1: BIT PROPERTIES:

Bit Sizes: 12.25", Mud Weight(MW) = 14ppg, Nozzle Sizes:3X16",3X14"(in 32th inches)

Table 4.8.1 Bit Hydraulics Properties for PDC1 of Well A.

Flowrate (l/min)	Bit Pressure Drop (psi)	Pressure effect (HSI)
720	557.69	1.988
740	589.10	2.158
760	621.38	2.338
780	654.51	2.527
800	688.50	2.727
820	723.36	2.936
840	759.08	3.156
860	795.65	3.387
880	833.09	3.629
900	871.39	3.882
920	910.55	4.147

PDC 2: BIT PROPERTIES:

Bit Sizes: 12.25", Mud Weight(MW) = 14ppg, Nozzle Sizes:3X13",2X12",1X14"(in 32th inches)

Table 4.8.2 Bit Hydraulics Properties for PDC2 of Well A.

Flowrate (l/min)	Bit Pressure Drop (psi)	Pressure effect (HSI)
720	1044.15	3.722
740	1102.97	4.040
760	1163.39	4.377
780	1225.43	4.732
800	1289.08	5.105
820	1354.34	5.498
840	1421.21	5.910
860	1489.69	6.342
880	1559.78	6.795
900	1631.49	7.269
920	1704.81	7.764

4.9 BITS HYDRAULICS ANALYSIS FOR WELL B: Flowrate Ranges from (712 -1110) l/min

PDC 1: BIT PROPERTIES:

Bit Sizes: 12.25", Mud Weight(MW) = 14ppg, Nozzle Sizes:3X16",3X14"(in 32th inches)

Table 4.9.1 Bit Hydraulics Properties for PDC1 of Well B.

Flowrate (l/min)	Bit Pressure Drop (psi)	Pressure effect (HSI)
712	545.36	1.922
750	605.13	2.247
790	671.40	2.626
830	741.11	3.045
870	814.26	3.507
910	890.86	4.013
950	970.90	4.566
990	1054.38	5.167
1030	1141.30	5.819
1070	1231.67	6.524
1110	1325.48	7.283

PDC 2: BIT PROPERTIES:

Bit Sizes: 12.25", Mud Weight(MW) = 14ppg, Nozzle Sizes:6X18"(in 32th inches)

Table 4.9.2 Bit Hydraulics Properties for PDC2 of Well B.

Flowrate (l/min)	Bit Pressure Drop (psi)	Pressure effect (HSI)
712	265.35	0.935
750	294.43	1.093
790	326.67	1.278
830	360.59	1.482
870	396.18	1.706
910	433.45	1.953
950	472.39	2.222
990	513.01	2.514
1030	555.30	2.831
1070	599.27	3.174
1110	644.91	3.544

CHAPTER 5 DISCUSSIONS AND CONCLUSIONS

Two selected reference Wells: A and B were analysed using the DROPS Simulator provided by Impetro International. Well A and Well B are both horizontal wells. These wells are considered to be problematic as they were associated with one problem of lost BHA, MWD failure or the other during the on-going drilling operation.

5.1 DISCUSSIONS

The input operating drilling parameters included the Measured Depth (MD) of the range of 5078ft to 5435ft for Well A and 5078ft to 17837ft for Well B with its corresponding True Vertical Depth (TVD), feet to feet Rate of Penetration (ROP), Weight on Bit (WOB), Revolution per minute (RPM), Pump rate(GPM), Plastic Viscosity (PV), Mud weight (MW), mud type and drilling mode all in field units.

The aforementioned drilling parameters were used alongside with its survey data (angle of inclination and azimuth angle) on feet to feet basis.

The lithology for both wells is assumed to be Shale the entire section and the reservoir rock is limestone. Since Shale is porous but not permeable, it takes the value of zero for permeability.

Pore pressure from Ekofisk/Eldfisk field have been modeled and used widely from Figures 4.1 and 4.2. The pore pressure used in the lithology data was evaluated from these charts.

The bit information provided all bits run in the individual together with their dull bit grading, manufacturer, bit type, design, amongst other bit properties (backrake angles, siderake angles, number of cutters, number of blades, etc). An idea of bit dull grading in other wells drilled in the same field is presented in tables 4.5.3, 4.5.4 and 4.5.5 for comparison.

The bit performance optimization simulator puts together all the inpt data (drilling parameter, survey data, lithology and the bit information) and generated Apparent Rock Strength Log, average ROP, WOB, RPM, PV, MW, Bit Wear and predicts each section rate of penetration depending on the number of sectionsdrilled with different bits.

Using the simulator, the following assumption was made: 185000 $/day used as Rig cost/day, 10000 $/day used for Mud & MWD cost/day, 5 minutes/30feet used as connection time and 1 hour/1000feet real time used as trip time. Note: PDC1 and PDC2 in Well A are different from the

PDC1 and PDC2 in Well B in terms of design, manufacturer, configurations and drilling potentials.

Well A: The first section drilled with PDC1 has the length of 42ft which gave an average ROP of 19.97ft/hr with cost/ft of 2358.03 $/ft while the second section drilled with PDC2 has the length of 314ft having an average ROP of 68.77ft/hr with cost/ft of 453.63 $/ft given by the simulator.
The simulator combines the average results above to give an overall result summary before simulation of 709.4 $/ft of the two sections within the drilling time of 6.6 hours. After simulation, the cost/ft falls to 688.7$/ft within the same drilling time of 6.7 hours. This has saved 20.7$/ft and cumulatively saved $7,389.9 through the entire length of Well A.
If actual real-time data are used in the optimization and simulation process muchmore appreciable amount could be saved.

Different bits PDC1,PDC2 and Bit 123456 were used in simulating the whole sections to see the best bit performance. The simulator predicted for Bit 123456: 26.8ft/hr ROP,cost/ft of 396.8$/ft within the drilling time of 4 hours, for PDC1: 0.2ft/hr ROP,cost/ft of 16270.3$/ft withn the drilling time of 724.4 hours and for PDC2: 60.1 ft/hr ROP, cost/ft of 337.4$/ft within the drilling time of 1.8 hours. Based on wear constant, ROP, drilling time,and at large cost/ft PDC2 has given a better bit choice of selection among the available bits.

The lithology at the measured depth between 5078ft and 5120ft have Apparent Rock Strength (ARS) of the range of 0.4Kpsi to 1.2Kpsi corresponding with a higher ROP suggests a relatively harder formation. While the rest of the entire well have ARS of alower range 0.1Kpsi to 0.3Kpsi with higher ROP implies a relative softer formation.

Well B: Well B has the same first drilled section with Well A. 19.97ft/hr ROP and having average cost/ft of 2358.03 $/ft. The second drilled section, 1015.1ft, with PDC2 has average ROP of 208.1ft/hr having an average cost/ft of 73.49$/ft. The simulator on combining the two sections before running the simulation predicted cost/ft of 87.6$/ft within the drilling time of 64.1 hours while after simulation the cost/ft drops to 81.4$/ft within the drilling time of 63.2 hours. This is saving 6.2$/ft and a cumulative savings of $26,4332.04 through the entire length of Well B.

The whole section of Well B when simulated with PDC1 and PDC2 independently, PDC2 gave a much lower cost/ft of 81.4$/ft within the drilling time of 61.5 hours while PDC1 gave cost/ft of

82.1$/ft within the drilling time of 63.2 hours. Obviously PDC2 produced a better drilling potentials than PDC1. This could also be justified by the predicted wear constants evaluated by the DROPS simulator as tabulated in table 4.6.5. The lower the wear constant of a Bit, the higher the resistant tendencies to wear while in a drilling operation.

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At the measured depth of 7106ft, the highest ARS value of 6.1Kpsi is obtained while at 7150ft, 0.15Kpsi is obtained from the ARS log. Between 9220ft and 9940ft the range of ARS of 0.15Kpsi to 3.08Kpsi could be evaluated. A harder formation is suggested at the measured depth of 17070ft to 17837ft justified by the lower ROP. A better overview of the ARS can be gotten from the figures of plots generated in chapter 4 of this piece of research work.

The bit hydraulic analysis is another cardinal aspect to be considered when looking at Bit performance optimization, simulation and selection criteria. It is important as cuttings generated by bit needs to be removed as soon as they are produced to prevent bit-balling. Bit hydraulics is very necessary to all kinds of bit but more formidable to PDC bits as they have higher tendency of producing larger volume of cuttings than the rest type of bits.

From the bit hydraulic analysis conducted for Well A and Well B, a general trend is seen as the flowrate is varied from bit to bit. The larger the nozzle sizes and number, the lower the pressure drop across the bit and as well the lower the pressure effect. Conversely, the smaller the nozzle sizes and number, the higher the pressure drop across the bit and the higher the pressure effect as simulated by the DROPS simulator.

5.1.1 Limitations and Recommendations of this Research Work

This research work is limited by actual input data in the case of the complete bit information for Well A and Well B as the first section bit information was not available but assumed and that for the second section was lost in the hole hence the actual bit dull grading was assumed.

Again the percentage lithology composition was absolutely missing but ought to be explicitly input.

The models used by the DROPS simulator and how the plots for the various parameter is generated is beyond the scope of this project.

The Rig cost/day, Mud & MWD cost, Number of connection / 1000feet and connection time/ 30ft were all assumed to give a better understanding.

5.2 CONCLUSIONS

The conclusions presented here is strictly based on the assumptions made, data obtained within our reach, the DROPS simulator evaluations and any other conditions considered in this project and therefore could give an idea of the most probable bit performance optimization choices or alternatives.

- The bit performance optimization and simulation reveals the overall simulation result summary before running simulation the cost/ft of 709.4$/ft within the drilling time of 6.6 hours and after running the simulation, the cost/ft falls to 688.7$/ft for the two sections within the drilling time of 6.7 hours. This have save 20.7$/ft and cumulatively saved $7,389.9 through the entire length of Well A. Also, Well B has saving of 6.2$/ft and cumulative savings of $26,433.04 through the entire drilled length of Well B having cost/ft of 87.6$/ft within the drilling time of 64.1 hours before simulation and the cost/ft of 81.4$/ft within the drilling time of 63.2 hours after simulation. Appreciable savings can be made if adequate data information is given.

- Using ROP, drilling time, bit wear constant, bit cost and at large cost/ft criteria PDC2 bit in both Wells have a better drilling potentials than PDC1.

-It can also be concluded that the first section of both Wells simulated have relatively harder formation than the second section. Stringers of harder formation could be found along the entire section of both Wells.

-The larger the nozzle sizes and number, the lower the pressure drop across the bit and the lower the pressure effect simulated as the flowrate varied incrementally.

-The ROP obtained by the simulator compares well with those obtained from actual data (see Appendix), UCS prediction, Bit pressure effect automatic evaluation among others shows that the DROPS simulator is robust and versatile.

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Appendix:

Output data from Drillbehind
Well: Well A
Project by: Vincent
Exported: Monday 24 May 2010 01:22:39

Input files:
Project directory: C:\Users\vincent akpojevwe\Desktop\DDS1
Bit file: fibit1.bit
Drilling file: fidril1.drill
Lithology file: mfilith1.lith
Survey file: fisur1.path

MD: Measured depth
TVD: True Vertical Depth
ROP(in): ROP from input file
ROP(db): ROP DrillBehind.
nBit: Bit ID
nSec: Section ID
DBG: Delta wear
MW: Mud Weight

MD[ft]	TVD[ft]	ROP(in)[ft/h]	ROP(db)[ft/h]	nBit	nSec	DBG	MW[PPG]
5078.00	4787.69	10.950	10.950	000	000	1.719504e+000	14.50
5079.00	4788.50	10.990	10.990	000	000	4.359963e-002	14.50
5080.00	4789.32	10.930	10.930	000	000	8.488247e-002	14.50
5081.00	4790.13	10.890	10.890	000	000	7.716051e-002	14.50
5082.00	4790.94	12.650	12.650	000	000	3.945623e-002	14.50
5083.00	4791.76	25.880	25.880	000	000	7.524951e-002	14.50
5084.00	4792.57	28.610	28.610	000	000	8.045576e-002	14.50
5085.00	4793.38	34.090	34.090	000	000	8.408083e-002	14.50
5086.00	4794.20	36.180	36.180	000	000	8.092146e-002	14.50
5087.00	4795.01	38.270	38.270	000	000	7.819093e-002	14.50
5088.00	4795.83	37.910	37.910	000	000	8.142552e-002	14.50
5089.00	4796.64	38.590	38.590	000	000	7.601307e-002	14.50
5090.00	4797.46	35.620	35.620	000	000	8.842422e-002	14.50
5091.00	4798.27	31.700	31.700	000	000	9.202922e-002	14.50
5092.00	4799.09	33.740	33.740	000	000	6.699486e-002	14.50
5093.00	4799.90	32.310	32.310	000	000	6.622441e-002	14.50
5094.00	4800.72	35.360	35.360	000	000	5.409635e-002	14.50
5095.00	4801.53	36.300	36.300	000	000	4.894778e-002	14.50
5096.00	4802.35	36.110	36.110	000	000	4.793875e-002	14.50
5097.00	4803.17	37.350	37.350	000	000	4.135040e-002	14.50
5098.00	4803.98	39.960	39.960	000	000	3.589041e-002	14.50
5099.00	4804.80	39.230	39.230	000	000	4.750139e-002	14.50
5100.00	4805.61	39.580	39.580	000	000	4.158473e-002	14.50
5101.00	4806.43	40.410	40.410	000	000	3.850100e-002	14.50
5102.00	4807.25	44.080	44.080	000	000	4.173572e-002	14.50
5103.00	4808.06	46.920	46.920	000	000	4.149788e-002	14.50
5104.00	4808.88	45.220	45.220	000	000	3.930145e-002	14.50

5105.00	4809.69	44.290 44.290 000	000	3.244775e-002	14.50
5106.00	4810.51	39.040 39.040 000	000	5.656740e-002	14.50
5107.00	4811.32	40.030 40.030 000	000	4.634349e-002	14.50
5108.00	4812.13	43.230 43.230 000	000	3.781529e-002	14.50
5109.00	4812.95	44.090 44.090 000	000	3.892651e-002	14.50
5110.00	4813.76	41.560 41.560 000	000	4.197106e-002	14.50
5111.00	4814.58	39.900 39.900 000	000	5.223897e-002	14.50
5112.00	4815.39	40.380 40.380 000	000	4.902315e-002	14.50
5113.00	4816.20	42.700 42.700 000	000	4.133422e-002	14.50
5114.00	4817.02	41.680 41.680 000	000	3.793531e-002	14.50
5115.00	4817.83	41.360 41.360 000	000	3.727868e-002	14.50
5116.00	4818.64	40.250 40.250 000	000	3.872436e-002	14.50
5117.00	4819.46	40.020 40.020 000	000	3.716774e-002	14.50
5118.00	4820.27	40.540 40.540 000	000	4.140160e-002	14.50
5119.00	4821.08	26.710 26.710 000	000	6.096845e-002	14.50
5120.00	4821.89	28.210 28.210 000	000	3.689384e-002	14.50
5121.00	4822.50	57.710 57.710 001	001	2.014786e-002	14.95
5122.00	4823.11	87.210 87.210 001	001	3.305408e-003	15.40
5123.00	4823.92	69.690 69.690 001	001	2.133561e-003	15.40
5124.00	4824.74	52.170 52.170 001	001	1.123982e-003	15.40
5125.00	4825.55	45.770 45.770 001	001	6.674980e-004	15.40
5126.00	4826.36	39.370 39.370 001	001	3.166397e-004	15.40
5127.00	4827.17	39.230 39.230 001	001	3.840815e-004	15.40
5128.00	4827.98	39.100 39.100 001	001	4.580684e-004	15.40
5129.00	4828.79	39.270 39.270 001	001	2.819458e-004	15.40
5130.00	4829.60	39.440 39.440 001	001	1.486687e-004	15.40
5131.00	4830.41	38.060 38.060 001	001	4.020605e-004	15.40
5132.00	4831.22	36.670 36.670 001	001	7.901028e-004	15.40
5133.00	4832.03	33.200 33.200 001	001	1.338537e-003	15.40
5134.00	4832.84	29.730 29.730 001	001	2.069391e-003	15.40
5135.00	4833.65	34.620 34.620 001	001	7.317024e-004	15.40
5136.00	4834.46	39.500 39.500 001	001	1.030266e-004	15.40
5137.00	4835.27	39.500 39.500 001	001	1.030240e-004	15.40
5138.00	4836.08	39.490 39.490 001	001	9.796626e-005	15.40
5139.00	4836.89	39.160 39.160 001	001	2.571104e-004	15.40
5140.00	4837.70	38.840 38.840 001	001	4.943480e-004	15.40
5141.00	4838.51	38.890 38.890 001	001	4.604041e-004	15.40
5142.00	4839.32	38.940 38.940 001	001	4.382582e-004	15.40
5143.00	4840.13	38.850 38.850 001	001	5.645473e-004	15.40
5144.00	4840.94	38.760 38.760 001	001	7.070073e-004	15.40
5145.00	4841.74	38.800 38.800 001	001	1.813210e-003	15.40
5146.00	4842.55	38.850 38.850 001	001	2.205426e-003	15.40
5147.00	4843.36	38.560 38.560 001	001	2.146505e-003	15.40
5148.00	4844.17	38.270 38.270 001	001	2.088208e-003	15.40
5149.00	4844.98	38.350 38.350 001	001	2.772612e-003	15.40
5150.00	4845.78	38.420 38.420 001	001	3.552149e-003	15.40
5151.00	4846.59	38.960 38.960 001	001	4.104020e-003	15.40
5152.00	4847.40	39.510 39.510 001	001	4.688102e-003	15.40
5153.00	4848.20	39.540 39.540 001	001	4.985362e-003	15.40
5154.00	4849.01	39.570 39.570 001	001	5.291119e-003	15.40
5155.00	4849.82	39.460 39.460 001	001	5.951465e-003	15.40

5156.00	4850.62	39.350	39.350	001	001	6.710296e-003	15.40
5157.00	4851.43	38.440	38.440	001	001	7.425405e-003	15.40
5158.00	4852.24	37.520	37.520	001	001	8.191944e-003	15.40
5159.00	4853.04	35.180	35.180	001	001	6.455623e-003	15.40
5160.00	4853.85	32.830	32.830	001	001	4.876399e-003	15.40
5161.00	4854.65	36.310	36.310	001	001	4.554612e-003	15.40
5162.00	4855.46	39.780	39.780	001	001	4.234747e-003	15.40
5163.00	4856.26	39.760	39.760	001	001	3.865916e-003	15.40
5164.00	4857.07	39.730	39.730	001	001	3.514767e-003	15.40
5165.00	4857.87	39.730	39.730	001	001	3.427606e-003	15.40
5166.00	4858.68	39.730	39.730	001	001	3.341146e-003	15.40
5167.00	4859.48	39.300	39.300	001	001	3.621357e-003	15.40
5168.00	4860.29	38.870	38.870	001	001	3.868987e-003	15.40
5169.00	4861.09	39.490	39.490	001	001	3.225201e-003	15.40
5170.00	4861.89	40.120	40.120	001	001	7.986584e-003	15.40
5171.00	4862.70	40.150	40.150	001	001	7.860972e-003	15.40
5172.00	4863.50	40.190	40.190	001	001	7.736724e-003	15.40
5173.00	4864.31	40.200	40.200	001	001	6.275609e-003	15.40
5174.00	4865.11	40.220	40.220	001	001	5.124889e-003	15.40
5175.00	4865.91	40.160	40.160	001	001	6.771856e-003	15.40
5176.00	4866.71	40.110	40.110	001	001	8.648620e-003	15.40
5177.00	4867.52	39.400	39.400	001	001	1.035112e-002	15.40
5178.00	4868.32	38.700	38.700	001	001	1.205145e-002	15.40
5179.00	4869.12	37.690	37.690	001	001	1.198812e-002	15.40
5180.00	4869.92	36.680	36.680	001	001	1.181034e-002	15.40
5181.00	4870.73	37.390	37.390	001	001	1.222384e-002	15.40
5182.00	4871.53	38.100	38.100	001	001	1.258481e-002	15.40
5183.00	4872.33	39.140	39.140	001	001	1.139099e-002	15.40
5184.00	4873.13	40.180	40.180	001	001	1.037553e-002	15.40
5185.00	4873.93	40.310	40.310	001	001	8.206085e-003	15.40
5186.00	4874.73	40.440	40.440	001	001	6.423975e-003	15.40
5187.00	4875.54	40.230	40.230	001	001	6.504681e-003	15.40
5188.00	4876.34	40.020	40.020	001	001	6.509786e-003	15.40
5189.00	4877.14	39.840	39.840	001	001	6.081918e-003	15.40
5190.00	4877.94	39.670	39.670	001	001	5.686257e-003	15.40
5191.00	4878.74	39.680	39.680	001	001	5.563194e-003	15.40
5192.00	4879.54	39.700	39.700	001	001	5.511125e-003	15.40
5193.00	4880.34	39.840	39.840	001	001	5.773672e-003	15.40
5194.00	4881.14	39.970	39.970	001	001	6.032108e-003	15.40
5195.00	4881.94	39.880	39.880	001	001	5.095868e-003	15.40
5196.00	4882.74	39.780	39.780	001	001	4.270187e-003	15.40
5197.00	4883.54	39.710	39.710	001	001	4.210485e-003	15.40
5198.00	4884.34	39.650	39.650	001	001	4.206341e-003	15.40
5199.00	4885.13	39.790	39.790	001	001	4.293736e-003	15.40
5200.00	4885.93	39.920	39.920	001	001	4.458089e-003	15.40
5201.00	4886.73	39.850	39.850	001	001	4.394912e-003	15.40
5202.00	4887.53	39.770	39.770	001	001	4.334833e-003	15.40
5203.00	4888.33	39.750	39.750	001	001	4.016662e-003	15.40
5204.00	4889.13	39.730	39.730	001	001	3.718325e-003	15.40
5205.00	4889.93	39.730	39.730	001	001	4.063386e-003	15.40
5206.00	4890.72	39.720	39.720	001	001	4.414841e-003	15.40

5207.00	4891.52	39.720 39.720 001	001	5.607410e-003	15.40
5208.00	4892.32	39.730 39.730 001	001	6.831281e-003	15.40
5209.00	4893.12	39.800 39.800 001	001	7.569334e-003	15.40
5210.00	4893.91	39.880 39.880 001	001	8.238726e-003	15.40
5211.00	4894.71	39.770 39.770 001	001	7.200436e-003	15.40
5212.00	4895.51	39.650 39.650 001	001	6.218051e-003	15.40
5213.00	4896.30	39.710 39.710 001	001	7.444753e-003	15.40
5214.00	4897.10	39.780 39.780 001	001	8.704808e-003	15.40
5215.00	4897.90	39.590 39.590 001	001	1.007503e-002	15.40
5216.00	4898.69	39.400 39.400 001	001	1.151690e-002	15.40
5217.00	4899.49	38.820 38.820 001	001	1.129177e-002	15.40
5218.00	4900.28	38.250 38.250 001	001	1.116187e-002	15.40
5219.00	4901.08	38.790 38.790 001	001	1.098326e-002	15.40
5220.00	4901.87	39.340 39.340 001	001	1.074646e-002	15.40
5221.00	4902.67	39.500 39.500 001	001	8.752717e-003	15.40
5222.00	4903.46	39.670 39.670 001	001	6.945211e-003	15.40
5223.00	4904.26	39.410 39.410 001	001	8.128222e-003	15.40
5224.00	4905.05	39.160 39.160 001	001	9.327058e-003	15.40
5225.00	4905.85	39.310 39.310 001	001	7.957203e-003	15.40
5226.00	4906.64	39.460 39.460 001	001	6.662514e-003	15.40
5227.00	4907.44	39.680 39.680 001	001	6.329167e-003	15.40
5228.00	4908.23	39.890 39.890 001	001	6.010651e-003	15.40
5229.00	4909.02	39.820 39.820 001	001	5.478733e-003	15.40
5230.00	4909.82	39.750 39.750 001	001	4.975591e-003	15.40
5231.00	4910.61	39.750 39.750 001	001	4.140610e-003	15.40
5232.00	4911.40	39.740 39.740 001	001	3.387628e-003	15.40
5233.00	4912.20	39.760 39.760 001	001	3.576055e-003	15.40
5234.00	4912.99	39.780 39.780 001	001	3.810547e-003	15.40
5235.00	4913.78	39.790 39.790 001	001	3.596439e-003	15.40
5236.00	4914.57	39.800 39.800 001	001	3.428736e-003	15.40
5237.00	4915.37	39.800 39.800 001	001	3.460796e-003	15.40
5238.00	4916.16	39.810 39.810 001	001	3.531411e-003	15.40
5239.00	4916.95	39.760 39.760 001	001	2.605426e-003	15.40
5240.00	4917.74	39.700 39.700 001	001	1.850970e-003	15.40
5241.00	4918.53	39.770 39.770 001	001	2.022429e-003	15.40
5242.00	4919.32	39.840 39.840 001	001	2.200511e-003	15.40
5243.00	4920.11	39.790 39.790 001	001	1.784573e-003	15.40
5244.00	4920.90	39.730 39.730 001	001	1.387804e-003	15.40
5245.00	4921.69	39.660 39.660 001	001	1.729517e-003	15.40
5246.00	4922.48	39.580 39.580 001	001	2.139287e-003	15.40
5247.00	4923.46	69.560 69.560 001	001	5.995349e-003	15.40
5248.00	4924.06	99.550 99.550 001	001	6.174750e-003	15.40
5249.00	4924.84	99.220 99.220 001	001	6.506423e-003	15.40
5250.00	4925.63	98.900 98.900 001	001	6.884481e-003	15.40
5251.00	4926.42	99.200 99.200 001	001	6.083329e-003	15.40
5252.00	4927.21	99.490 99.490 001	001	5.373501e-003	15.40
5253.00	4927.99	99.480 99.480 001	001	4.820562e-003	15.40
5254.00	4928.78	99.470 99.470 001	001	4.330715e-003	15.40
5255.00	4929.57	99.480 99.480 001	001	5.471973e-003	15.40
5256.00	4930.35	99.490 99.490 001	001	6.739589e-003	15.40
5257.00	4931.14	99.210 99.210 001	001	7.160472e-003	15.40

5258.00	4931.92	98.940 98.940 001	001	7.593091e-003	15.40
5259.00	4932.71	99.410 99.410 001	001	7.139550e-003	15.40
5260.00	4933.50	99.880 99.880 001	001	6.666655e-003	15.40
5261.00	4934.28	98.730 98.730 001	001	8.103092e-003	15.40
5262.00	4935.06	97.580 97.580 001	001	9.682083e-003	15.40
5263.00	4935.85	98.080 98.080 001	001	8.891499e-003	15.40
5264.00	4936.63	98.580 98.580 001	001	8.144814e-003	15.40
5265.00	4937.42	97.720 97.720 001	001	9.656713e-003	15.40
5266.00	4938.20	96.870 96.870 001	001	1.124692e-002	15.40
5267.00	4938.98	94.140 94.140 001	001	1.048184e-002	15.40
5268.00	4939.76	91.410 91.410 001	001	9.786441e-003	15.40
5269.00	4940.55	89.650 89.650 001	001	1.040388e-002	15.40
5270.00	4941.33	87.900 87.900 001	001	1.104436e-002	15.40
5271.00	4942.11	80.630 80.630 001	001	8.283752e-003	15.40
5272.00	4942.89	73.360 73.360 001	001	5.789184e-003	15.40
5273.00	4943.67	73.730 73.730 001	001	6.795723e-003	15.40
5274.00	4944.46	74.090 74.090 001	001	7.831638e-003	15.40
5275.00	4945.24	73.760 73.760 001	001	9.177906e-003	15.40
5276.00	4946.02	73.430 73.430 001	001	1.062543e-002	15.40
5277.00	4946.80	74.030 74.030 001	001	1.017424e-002	15.40
5278.00	4947.58	74.630 74.630 001	001	9.788069e-003	15.40
5279.00	4948.36	79.450 79.450 001	001	8.801513e-003	15.40
5280.00	4949.13	84.270 84.270 001	001	7.921320e-003	15.40
5281.00	4949.91	79.810 79.810 001	001	9.143582e-003	15.40
5282.00	4950.69	75.360 75.360 001	001	1.046132e-002	15.40
5283.00	4951.47	78.380 78.380 001	001	1.095748e-002	15.40
5284.00	4952.25	81.410 81.410 001	001	1.145469e-002	15.40
5285.00	4953.03	83.240 83.240 001	001	8.823018e-003	15.40
5286.00	4953.80	85.080 85.080 001	001	6.617484e-003	15.40
5287.00	4954.58	79.630 79.630 001	001	9.986888e-003	15.40
5288.00	4955.36	74.180 74.180 001	001	1.426010e-002	15.40
5289.00	4956.13	78.810 78.810 001	001	1.143315e-002	15.40
5290.00	4956.91	83.440 83.440 001	001	9.040682e-003	15.40
5291.00	4957.69	91.030 91.030 001	001	1.099154e-002	15.40
5292.00	4958.46	98.620 98.620 001	001	1.303290e-002	15.40
5293.00	4959.24	98.760 98.760 001	001	1.277485e-002	15.40
5294.00	4960.01	98.900 98.900 001	001	1.252381e-002	15.40
5295.00	4960.79	99.190 99.190 001	001	1.346627e-002	15.40
5296.00	4961.56	99.470 99.470 001	001	1.443598e-002	15.40
5297.00	4962.33	99.500 99.500 001	001	1.314112e-002	15.40
5298.00	4963.11	99.520 99.520 001	001	1.191688e-002	15.40
5299.00	4963.88	99.350 99.350 001	001	1.233132e-002	15.40
5300.00	4964.66	99.180 99.180 001	001	1.270382e-002	15.40
5301.00	4965.43	97.520 97.520 001	001	1.482940e-002	15.40
5302.00	4966.20	95.860 95.860 001	001	1.713705e-002	15.40
5303.00	4966.97	97.960 97.960 001	001	1.399537e-002	15.40
5304.00	4967.75	100.060100.060001	001	1.127496e-002	15.40
5305.00	4968.52	99.260 99.260 001	001	1.308503e-002	15.40
5306.00	4969.29	98.450 98.450 001	001	1.503192e-002	15.40
5307.00	4970.06	98.880 98.880 001	001	1.493724e-002	15.40
5308.00	4970.83	99.310 99.310 001	001	1.484421e-002	15.40

5309.00	4971.60	99.340 99.340 001	001	1.549034e-002	15.40
5310.00	4972.37	99.380 99.380 001	001	1.614541e-002	15.40
5311.00	4973.14	99.400 99.400 001	001	1.597525e-002	15.40
5312.00	4973.91	99.430 99.430 001	001	1.586309e-002	15.40
5313.00	4974.68	99.150 99.150 001	001	1.605866e-002	15.40
5314.00	4975.45	98.870 98.870 001	001	1.625517e-002	15.40
5315.00	4976.22	99.460 99.460 001	001	1.647133e-002	15.40
5316.00	4976.99	100.050100.050001	001	1.668466e-002	15.40
5317.00	4977.75	99.600 99.600 001	001	1.501518e-002	15.40
5318.00	4978.52	99.140 99.140 001	001	1.339279e-002	15.40
5319.00	4979.29	99.090 99.090 001	001	1.406082e-002	15.40
5320.00	4980.06	99.030 99.030 001	001	1.474290e-002	15.40
5321.00	4980.82	99.570 99.570 001	001	1.444406e-002	15.40
5322.00	4981.59	100.100100.100001	001	1.420026e-002	15.40
5323.00	4982.36	99.920 99.920 001	001	1.304658e-002	15.40
5324.00	4983.12	99.740 99.740 001	001	1.190003e-002	15.40
5325.00	4983.89	99.250 99.250 001	001	1.145660e-002	15.40
5326.00	4984.65	98.760 98.760 001	001	1.106667e-002	15.40
5327.00	4985.42	99.650 99.650 001	001	1.319877e-002	15.40
5328.00	4986.18	100.540100.540001	001	1.549420e-002	15.40
5329.00	4986.95	99.730 99.730 001	001	1.395297e-002	15.40
5330.00	4987.71	98.910 98.910 001	001	1.249594e-002	15.40
5331.00	4988.47	99.510 99.510 001	001	1.312799e-002	15.40
5332.00	4989.24	100.110100.110001	001	1.372333e-002	15.40
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5334.00	4990.76	99.910 99.910 001	001	1.095237e-002	15.40
5335.00	4991.53	99.750 99.750 001	001	1.342393e-002	15.40
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5337.00	4993.05	99.390 99.390 001	001	1.680499e-002	15.40
5338.00	4993.81	99.190 99.190 001	001	1.748580e-002	15.40
5339.00	4994.57	99.210 99.210 001	001	1.854397e-002	15.40
5340.00	4995.34	99.240 99.240 001	001	1.962495e-002	15.40
5341.00	4996.10	94.760 94.760 001	001	2.004855e-002	15.40
5342.00	4996.86	90.280 90.280 001	001	2.051030e-002	15.40
5343.00	4997.62	80.030 80.030 001	001	1.873218e-002	15.40
5344.00	4998.38	69.780 69.780 001	001	1.697973e-002	15.40
5345.00	4999.14	80.890 80.890 001	001	1.795555e-002	15.40
5346.00	4999.90	92.000 92.000 001	001	1.900542e-002	15.40
5347.00	5000.65	89.720 89.720 001	001	1.968169e-002	15.40
5348.00	5001.41	87.440 87.440 001	001	2.032328e-002	15.40
5349.00	5002.17	85.560 85.560 001	001	2.048574e-002	15.40
5350.00	5002.93	83.670 83.670 001	001	2.065421e-002	15.40
5351.00	5003.69	83.740 83.740 001	001	2.063752e-002	15.40
5352.00	5004.44	83.810 83.810 001	001	2.062103e-002	15.40
5353.00	5005.20	86.700 86.700 001	001	1.919984e-002	15.40
5354.00	5005.96	89.600 89.600 001	001	1.781798e-002	15.40
5355.00	5006.71	89.580 89.580 001	001	1.683042e-002	15.40
5356.00	5007.47	89.560 89.560 001	001	1.587878e-002	15.40
5357.00	5008.23	89.770 89.770 001	001	1.704233e-002	15.40
5358.00	5008.98	89.990 89.990 001	001	1.818103e-002	15.40
5359.00	5009.74	89.660 89.660 001	001	1.925025e-002	15.40

5360.00	5010.49	89.340 89.340 001	001	2.034452e-002	15.40
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5362.00	5012.00	89.270 89.270 001	001	1.744545e-002	15.40
5363.00	5012.76	88.980 88.980 001	001	1.883242e-002	15.40
5364.00	5013.51	88.690 88.690 001	001	2.032636e-002	15.40
5365.00	5014.26	89.000 89.000 001	001	1.894084e-002	15.40
5366.00	5015.02	89.310 89.310 001	001	1.761277e-002	15.40
5367.00	5015.77	88.990 88.990 001	001	1.793481e-002	15.40
5368.00	5016.52	88.660 88.660 001	001	2.899596e-003	15.40
5369.00	5017.27	89.180 89.180 001	001	2.730899e-003	15.40
5370.00	5018.03	89.690 89.690 001	001	2.567853e-003	15.40
5371.00	5018.78	89.100 89.100 001	001	2.841936e-003	15.40
5372.00	5019.53	88.510 88.510 001	001	3.131034e-003	15.40
5373.00	5020.28	88.730 88.730 001	001	2.935546e-003	15.40
5374.00	5021.03	88.950 88.950 001	001	2.746835e-003	15.40
5375.00	5021.78	88.700 88.700 001	001	2.898223e-003	15.40
5376.00	5022.53	88.440 88.440 001	001	3.045458e-003	15.40
5377.00	5023.28	85.880 85.880 001	001	3.030916e-003	15.40
5378.00	5024.03	83.320 83.320 001	001	3.017356e-003	15.40
5379.00	5024.78	74.300 74.300 001	001	2.564656e-003	15.40
5380.00	5025.53	65.280 65.280 001	001	2.131259e-003	15.40
5381.00	5026.28	82.540 82.540 001	001	1.807524e-003	15.40
5382.00	5027.03	99.800 99.800 001	001	1.579386e-003	15.40
5383.00	5027.77	99.320 99.320 001	001	1.685568e-003	15.40
5384.00	5028.52	98.840 98.840 001	001	1.802464e-003	15.40
5385.00	5029.27	99.440 99.440 001	001	1.795231e-003	15.40
5386.00	5030.02	100.040100.040001	001	1.781171e-003	15.40
5387.00	5030.76	99.230 99.230 001	001	1.974261e-003	15.40
5388.00	5031.51	98.410 98.410 001	001	2.171124e-003	15.40
5389.00	5032.26	98.930 98.930 001	001	2.177745e-003	15.40
5390.00	5033.00	99.450 99.450 001	001	2.191724e-003	15.40
5391.00	5033.75	99.670 99.670 001	001	1.944938e-003	15.40
5392.00	5034.49	99.890 99.890 001	001	1.720162e-003	15.40
5393.00	5035.24	99.540 99.540 001	001	1.769940e-003	15.40
5394.00	5035.98	99.190 99.190 001	001	1.820537e-003	15.40
5395.00	5036.73	99.470 99.470 001	001	1.966506e-003	15.40
5396.00	5037.47	99.760 99.760 001	001	2.117563e-003	15.40
5397.00	5038.22	99.080 99.080 001	001	2.104817e-003	15.40
5398.00	5038.96	98.410 98.410 001	001	2.099173e-003	15.40
5399.00	5039.70	99.240 99.240 001	001	2.022704e-003	15.40
5400.00	5040.45	100.070100.070001	001	1.955388e-003	15.40
5401.00	5041.19	99.790 99.790 001	001	2.106711e-003	15.40
5402.00	5041.93	99.510 99.510 001	001	2.263885e-003	15.40
5403.00	5042.67	98.940 98.940 001	001	2.234500e-003	15.40
5404.00	5043.41	98.370 98.370 001	001	2.205245e-003	15.40
5405.00	5044.16	99.310 99.310 001	001	2.060433e-003	15.40
5406.00	5044.90	100.250100.250001	001	1.921857e-003	15.40
5407.00	5045.64	99.730 99.730 001	001	1.792657e-003	15.40
5408.00	5046.38	99.210 99.210 001	001	1.667634e-003	15.40
5409.00	5047.12	99.010 99.010 001	001	1.826782e-003	15.40
5410.00	5047.86	98.800 98.800 001	001	1.986156e-003	15.40

5411.00	5048.60	99.380 99.380 001	001	2.199601e-003	15.40
5412.00	5049.34	99.960 99.960 001	001	2.415608e-003	15.40
5413.00	5050.08	99.820 99.820 001	001	2.140920e-003	15.40
5414.00	5050.81	99.690 99.690 001	001	1.876134e-003	15.40
5415.00	5051.55	99.620 99.620 001	001	1.958613e-003	15.40
5416.00	5052.29	99.550 99.550 001	001	2.043167e-003	15.40
5417.00	5053.03	99.470 99.470 001	001	2.029159e-003	15.40
5418.00	5053.77	99.390 99.390 001	001	2.022540e-003	15.40
5419.00	5054.50	99.360 99.360 001	001	2.114424e-003	15.40
5420.00	5055.24	99.330 99.330 001	001	2.215982e-003	15.40
5421.00	5055.98	99.380 99.380 001	001	2.348885e-003	15.40
5422.00	5056.71	99.420 99.420 001	001	2.485677e-003	15.40
5423.00	5057.45	99.510 99.510 001	001	2.972655e-003	15.40
5424.00	5058.18	99.590 99.590 001	001	3.502135e-003	15.40
5425.00	5058.92	99.230 99.230 001	001	3.471184e-003	15.40
5426.00	5059.65	98.880 98.880 001	001	3.439590e-003	15.40
5427.00	5060.39	94.760 94.760 001	001	3.268933e-003	15.40
5428.00	5061.12	90.640 90.640 001	001	3.100219e-003	15.40
5429.00	5061.86	95.040 95.040 001	001	3.213673e-003	15.40
5430.00	5062.59	99.440 99.440 001	001	3.338020e-003	15.40
5431.00	5063.32	99.370 99.370 001	001	3.038994e-003	15.40
5432.00	5064.06	99.310 99.310 001	001	2.761698e-003	15.40
5433.00	5064.79	99.200 99.200 001	001	2.648929e-003	15.40
5434.00	5065.52	99.100 99.100 001	001	2.546230e-003	15.40
5435.00	5066.62	203.160203.160001	001	2.357918e-003	14.50

ARSL Output data from well A
ARSL Created by: Vincent
Exported: Sunday 23 May 2010 09:41:20

Input files:
Project directory: C:\Users\vincent akpojevwe\Desktop\DDS1
Bit file: fibit1.bit
Drill file: fidril1.drill
Lithology file: mfilith1.lith
Survey file: fisur1.path

Number of parameters: 7
Index
True vertical depth
Confined bit pressure
Unconfined triaxial rock strength
Pe(Confining pressure)
Pore Pressure
Measured depth

Index	TVD[ft]	CBP[kpsi]	UCS[kpsi]	Pe[psi]	Pp[ppg]	MD[ft]
0	5078.00	9.51	2.44	3696.78	11.83	5078.00
1	5079.00	2.34	0.60	3697.51	11.83	5079.00
2	5080.00	3.28	0.84	3698.24	11.83	5080.00
3	5081.00	3.15	0.81	3698.97	11.83	5081.00
4	5082.00	2.15	0.55	3699.70	11.83	5082.00
5	5083.00	2.34	0.60	3700.42	11.83	5083.00
6	5084.00	2.35	0.60	3701.15	11.83	5084.00
7	5085.00	2.27	0.58	3701.88	11.83	5085.00
8	5086.00	2.19	0.56	3702.61	11.83	5086.00
9	5087.00	2.12	0.54	3703.34	11.83	5087.00
10	5088.00	2.17	0.56	3704.06	11.83	5088.00
11	5089.00	2.09	0.54	3704.79	11.83	5089.00
12	5090.00	2.32	0.59	3705.52	11.83	5090.00
13	5091.00	2.46	0.63	3706.25	11.83	5091.00
14	5092.00	2.06	0.53	3706.98	11.83	5092.00
15	5093.00	2.08	0.53	3707.70	11.83	5093.00
16	5094.00	1.82	0.47	3708.43	11.83	5094.00
17	5095.00	1.72	0.44	3709.16	11.83	5095.00
18	5096.00	1.70	0.43	3709.89	11.83	5096.00
19	5097.00	1.56	0.40	3710.62	11.83	5097.00
20	5098.00	1.42	0.36	3711.34	11.83	5098.00
21	5099.00	1.64	0.42	3712.07	11.83	5099.00
22	5100.00	1.52	0.39	3712.80	11.83	5100.00
23	5101.00	1.45	0.37	3713.53	11.83	5101.00
24	5102.00	1.47	0.38	3714.26	11.83	5102.00
25	5103.00	1.43	0.37	3714.98	11.83	5103.00
26	5104.00	1.41	0.36	3715.71	11.83	5104.00
27	5105.00	1.28	0.33	3716.44	11.83	5105.00

28	5106.00	1.77	0.45	3717.17	11.83	5106.00
29	5107.00	1.58	0.40	3717.90	11.83	5107.00
30	5108.00	1.39	0.36	3718.62	11.83	5108.00
31	5109.00	1.40	0.36	3719.35	11.83	5109.00
32	5110.00	1.48	0.38	3720.08	11.83	5110.00
33	5111.00	1.67	0.43	3720.81	11.83	5111.00
34	5112.00	1.60	0.41	3721.54	11.83	5112.00
35	5113.00	1.44	0.37	3722.26	11.83	5113.00
36	5114.00	1.39	0.35	3722.99	11.83	5114.00
37	5115.00	1.37	0.35	3723.72	11.83	5115.00
38	5116.00	1.41	0.36	3724.45	11.83	5116.00
39	5117.00	1.38	0.35	3725.18	11.83	5117.00
40	5118.00	1.45	0.37	3725.90	11.83	5118.00
41	5119.00	2.01	0.51	3726.63	11.83	5119.00
42	5120.00	1.53	0.39	3727.36	11.83	5120.00
43	5121.00	3.27	0.84	3728.09	11.83	5121.00
44	5122.00	1.12	0.29	3728.82	11.83	5122.00
45	5123.00	0.97	0.25	3729.54	11.83	5123.00
46	5124.00	0.78	0.20	3730.27	11.83	5124.00
47	5125.00	0.63	0.16	3731.00	11.83	5125.00
48	5126.00	0.45	0.12	3731.73	11.83	5126.00
49	5127.00	0.50	0.13	3732.46	11.83	5127.00
50	5128.00	0.55	0.14	3733.18	11.83	5128.00
51	5129.00	0.43	0.11	3733.91	11.83	5129.00
52	5130.00	0.31	0.08	3734.64	11.83	5130.00
53	5131.00	0.52	0.13	3735.37	11.83	5131.00
54	5132.00	0.73	0.19	3736.10	11.83	5132.00
55	5133.00	0.99	0.25	3736.82	11.83	5133.00
56	5134.00	1.27	0.33	3737.55	11.83	5134.00
57	5135.00	0.72	0.18	3738.28	11.83	5135.00
58	5136.00	0.26	0.07	3739.01	11.83	5136.00
59	5137.00	0.26	0.07	3739.74	11.83	5137.00
60	5138.00	0.25	0.06	3740.46	11.83	5138.00
61	5139.00	0.41	0.10	3741.19	11.83	5139.00
62	5140.00	0.57	0.15	3741.92	11.83	5140.00
63	5141.00	0.55	0.14	3742.65	11.83	5141.00
64	5142.00	0.54	0.14	3743.38	11.83	5142.00
65	5143.00	0.61	0.16	3744.10	11.83	5143.00
66	5144.00	0.68	0.17	3744.83	11.83	5144.00
67	5145.00	0.76	0.19	3745.56	11.83	5145.00
68	5146.00	0.84	0.21	3746.29	11.83	5146.00
69	5147.00	0.83	0.21	3747.02	11.83	5147.00
70	5148.00	0.82	0.21	3747.74	11.83	5148.00
71	5149.00	0.94	0.24	3748.47	11.83	5149.00
72	5150.00	1.07	0.27	3749.20	11.83	5150.00
73	5151.00	1.14	0.29	3749.93	11.83	5151.00
74	5152.00	1.21	0.31	3750.66	11.83	5152.00
75	5153.00	1.25	0.32	3751.38	11.83	5153.00
76	5154.00	1.29	0.33	3752.11	11.83	5154.00
77	5155.00	1.37	0.35	3752.84	11.83	5155.00
78	5156.00	1.45	0.37	3753.57	11.83	5156.00

79	5157.00	1.54	0.39	3754.30	11.83	5157.00
80	5158.00	1.63	0.41	3755.02	11.83	5158.00
81	5159.00	1.47	0.38	3755.75	11.83	5159.00
82	5160.00	1.31	0.33	3756.48	11.83	5160.00
83	5161.00	1.22	0.31	3757.21	11.83	5161.00
84	5162.00	1.14	0.29	3757.94	11.83	5162.00
85	5163.00	1.09	0.28	3758.66	11.83	5163.00
86	5164.00	1.04	0.27	3759.39	11.83	5164.00
87	5165.00	1.03	0.26	3760.12	11.83	5165.00
88	5166.00	1.02	0.26	3760.85	11.83	5166.00
89	5167.00	1.06	0.27	3761.58	11.83	5167.00
90	5168.00	1.10	0.28	3762.30	11.83	5168.00
91	5169.00	1.00	0.25	3763.03	11.83	5169.00
92	5170.00	0.89	0.23	3763.76	11.83	5170.00
93	5171.00	0.89	0.23	3764.49	11.83	5171.00
94	5172.00	0.88	0.22	3765.22	11.83	5172.00
95	5173.00	0.80	0.20	3765.94	11.83	5173.00
96	5174.00	0.73	0.18	3766.67	11.83	5174.00
97	5175.00	0.84	0.21	3767.40	11.83	5175.00
98	5176.00	0.95	0.24	3768.13	11.83	5176.00
99	5177.00	1.06	0.27	3768.86	11.83	5177.00
100	5178.00	1.16	0.30	3769.58	11.83	5178.00
101	5179.00	1.18	0.30	3770.31	11.83	5179.00
102	5180.00	1.20	0.30	3771.04	11.83	5180.00
103	5181.00	1.23	0.31	3771.77	11.83	5181.00
104	5182.00	1.25	0.32	3772.50	11.83	5182.00
105	5183.00	1.19	0.30	3773.22	11.83	5183.00
106	5184.00	1.14	0.29	3773.95	11.83	5184.00
107	5185.00	1.02	0.26	3774.68	11.83	5185.00
108	5186.00	0.91	0.23	3775.41	11.83	5186.00
109	5187.00	0.92	0.23	3776.14	11.83	5187.00
110	5188.00	0.92	0.23	3776.86	11.83	5188.00
111	5189.00	0.90	0.23	3777.59	11.83	5189.00
112	5190.00	0.87	0.22	3778.32	11.83	5190.00
113	5191.00	0.87	0.22	3779.05	11.83	5191.00
114	5192.00	0.87	0.22	3779.78	11.83	5192.00
115	5193.00	0.89	0.23	3780.50	11.83	5193.00
116	5194.00	0.91	0.23	3781.23	11.83	5194.00
117	5195.00	0.84	0.21	3781.96	11.83	5195.00
118	5196.00	0.78	0.20	3782.69	11.83	5196.00
119	5197.00	0.77	0.20	3783.42	11.83	5197.00
120	5198.00	0.77	0.20	3784.14	11.83	5198.00
121	5199.00	0.78	0.20	3784.87	11.83	5199.00
122	5200.00	0.80	0.20	3785.60	11.83	5200.00
123	5201.00	0.80	0.20	3786.33	11.83	5201.00
124	5202.00	0.80	0.20	3787.06	11.83	5202.00
125	5203.00	0.77	0.19	3787.78	11.83	5203.00
126	5204.00	0.74	0.19	3788.51	11.83	5204.00
127	5205.00	0.78	0.20	3789.24	11.83	5205.00
128	5206.00	0.81	0.21	3789.97	11.83	5206.00
129	5207.00	0.92	0.23	3790.70	11.83	5207.00

130	5208.00	1.01	0.26	3791.42	11.83	5208.00
131	5209.00	1.07	0.27	3792.15	11.83	5209.00
132	5210.00	1.12	0.28	3792.88	11.83	5210.00
133	5211.00	1.05	0.27	3793.61	11.83	5211.00
134	5212.00	0.98	0.25	3794.34	11.83	5212.00
135	5213.00	1.08	0.27	3795.06	11.83	5213.00
136	5214.00	1.16	0.29	3795.79	11.83	5214.00
137	5215.00	1.26	0.32	3796.52	11.83	5215.00
138	5216.00	1.35	0.34	3797.25	11.83	5216.00
139	5217.00	1.35	0.34	3797.98	11.83	5217.00
140	5218.00	1.35	0.34	3798.70	11.83	5218.00
141	5219.00	1.33	0.34	3799.43	11.83	5219.00
142	5220.00	1.31	0.33	3800.16	11.83	5220.00
143	5221.00	1.18	0.30	3800.89	11.83	5221.00
144	5222.00	1.05	0.27	3801.62	11.83	5222.00
145	5223.00	1.14	0.29	3802.34	11.83	5223.00
146	5224.00	1.23	0.31	3803.07	11.83	5224.00
147	5225.00	1.13	0.29	3803.80	11.83	5225.00
148	5226.00	1.04	0.26	3804.53	11.83	5226.00
149	5227.00	1.01	0.26	3805.26	11.83	5227.00
150	5228.00	0.98	0.25	3805.98	11.83	5228.00
151	5229.00	0.94	0.24	3806.71	11.83	5229.00
152	5230.00	0.90	0.23	3807.44	11.83	5230.00
153	5231.00	0.82	0.21	3808.17	11.83	5231.00
154	5232.00	0.74	0.19	3808.90	11.83	5232.00
155	5233.00	0.76	0.19	3809.62	11.83	5233.00
156	5234.00	0.78	0.20	3810.35	11.83	5234.00
157	5235.00	0.76	0.19	3811.08	11.83	5235.00
158	5236.00	0.74	0.19	3811.81	11.83	5236.00
159	5237.00	0.75	0.19	3812.54	11.83	5237.00
160	5238.00	0.76	0.19	3813.26	11.83	5238.00
161	5239.00	0.65	0.16	3813.99	11.83	5239.00
162	5240.00	0.55	0.14	3814.72	11.83	5240.00
163	5241.00	0.57	0.14	3815.45	11.83	5241.00
164	5242.00	0.60	0.15	3816.18	11.83	5242.00
165	5243.00	0.54	0.14	3816.90	11.83	5243.00
166	5244.00	0.47	0.12	3817.63	11.83	5244.00
167	5245.00	0.53	0.13	3818.36	11.83	5245.00
168	5246.00	0.59	0.15	3819.09	11.83	5246.00
169	5247.00	0.84	0.21	3819.82	11.83	5247.00
170	5248.00	0.75	0.19	3820.54	11.83	5248.00
171	5249.00	0.78	0.20	3821.27	11.83	5249.00
172	5250.00	0.80	0.20	3822.00	11.83	5250.00
173	5251.00	0.75	0.19	3822.73	11.83	5251.00
174	5252.00	0.70	0.18	3823.46	11.83	5252.00
175	5253.00	0.67	0.17	3824.18	11.83	5253.00
176	5254.00	0.63	0.16	3824.91	11.83	5254.00
177	5255.00	0.71	0.18	3825.64	11.83	5255.00
178	5256.00	0.79	0.20	3826.37	11.83	5256.00
179	5257.00	0.81	0.21	3827.10	11.83	5257.00
180	5258.00	0.84	0.21	3827.82	11.83	5258.00

181	5259.00	0.81	0.20	3828.55	11.83	5259.00
182	5260.00	0.78	0.20	3829.28	11.83	5260.00
183	5261.00	0.87	0.22	3830.01	11.83	5261.00
184	5262.00	0.95	0.24	3830.74	11.83	5262.00
185	5263.00	0.91	0.23	3831.46	11.83	5263.00
186	5264.00	0.87	0.22	3832.19	11.83	5264.00
187	5265.00	0.95	0.24	3832.92	11.83	5265.00
188	5266.00	1.03	0.26	3833.65	11.83	5266.00
189	5267.00	1.00	0.25	3834.38	11.83	5267.00
190	5268.00	0.98	0.25	3835.10	11.83	5268.00
191	5269.00	1.01	0.26	3835.83	11.83	5269.00
192	5270.00	1.05	0.26	3836.56	11.83	5270.00
193	5271.00	0.94	0.24	3837.29	11.83	5271.00
194	5272.00	0.81	0.20	3838.02	11.83	5272.00
195	5273.00	0.87	0.22	3838.74	11.83	5273.00
196	5274.00	0.94	0.24	3839.47	11.83	5274.00
197	5275.00	1.02	0.26	3840.20	11.83	5275.00
198	5276.00	1.09	0.28	3840.93	11.83	5276.00
199	5277.00	1.07	0.27	3841.66	11.83	5277.00
200	5278.00	1.04	0.26	3842.38	11.83	5278.00
201	5279.00	0.97	0.24	3843.11	11.83	5279.00
202	5280.00	0.90	0.23	3843.84	11.83	5280.00
203	5281.00	0.99	0.25	3844.57	11.83	5281.00
204	5282.00	1.08	0.27	3845.30	11.83	5282.00
205	5283.00	1.09	0.27	3846.02	11.83	5283.00
206	5284.00	1.10	0.28	3846.75	11.83	5284.00
207	5285.00	0.95	0.24	3847.48	11.83	5285.00
208	5286.00	0.82	0.21	3848.21	11.83	5286.00
209	5287.00	1.03	0.26	3848.94	11.83	5287.00
210	5288.00	1.26	0.32	3849.66	11.83	5288.00
211	5289.00	1.10	0.28	3850.39	11.83	5289.00
212	5290.00	0.96	0.24	3851.12	11.83	5290.00
213	5291.00	1.03	0.26	3851.85	11.83	5291.00
214	5292.00	1.09	0.27	3852.58	11.83	5292.00
215	5293.00	1.08	0.27	3853.30	11.83	5293.00
216	5294.00	1.07	0.27	3854.03	11.83	5294.00
217	5295.00	1.11	0.28	3854.76	11.83	5295.00
218	5296.00	1.15	0.29	3855.49	11.83	5296.00
219	5297.00	1.09	0.27	3856.22	11.83	5297.00
220	5298.00	1.04	0.26	3856.94	11.83	5298.00
221	5299.00	1.06	0.27	3857.67	11.83	5299.00
222	5300.00	1.07	0.27	3858.40	11.83	5300.00
223	5301.00	1.17	0.29	3859.13	11.83	5301.00
224	5302.00	1.26	0.32	3859.86	11.83	5302.00
225	5303.00	1.13	0.28	3860.58	11.83	5303.00
226	5304.00	1.01	0.25	3861.31	11.83	5304.00
227	5305.00	1.09	0.27	3862.04	11.83	5305.00
228	5306.00	1.17	0.29	3862.77	11.83	5306.00
229	5307.00	1.16	0.29	3863.50	11.83	5307.00
230	5308.00	1.15	0.29	3864.22	11.83	5308.00
231	5309.00	1.18	0.30	3864.95	11.83	5309.00

232	5310.00	1.20	0.30	3865.68	11.83	5310.00
233	5311.00	1.19	0.30	3866.41	11.83	5311.00
234	5312.00	1.19	0.30	3867.14	11.83	5312.00
235	5313.00	1.20	0.30	3867.86	11.83	5313.00
236	5314.00	1.20	0.30	3868.59	11.83	5314.00
237	5315.00	1.21	0.30	3869.32	11.83	5315.00
238	5316.00	1.21	0.30	3870.05	11.83	5316.00
239	5317.00	1.15	0.29	3870.78	11.83	5317.00
240	5318.00	1.09	0.27	3871.50	11.83	5318.00
241	5319.00	1.11	0.28	3872.23	11.83	5319.00
242	5320.00	1.14	0.29	3872.96	11.83	5320.00
243	5321.00	1.13	0.28	3873.69	11.83	5321.00
244	5322.00	1.11	0.28	3874.42	11.83	5322.00
245	5323.00	1.07	0.27	3875.14	11.83	5323.00
246	5324.00	1.02	0.26	3875.87	11.83	5324.00
247	5325.00	1.00	0.25	3876.60	11.83	5325.00
248	5326.00	0.99	0.25	3877.33	11.83	5326.00
249	5327.00	1.07	0.27	3878.06	11.83	5327.00
250	5328.00	1.16	0.29	3878.78	11.83	5328.00
251	5329.00	1.10	0.28	3879.51	11.83	5329.00
252	5330.00	1.04	0.26	3880.24	11.83	5330.00
253	5331.00	1.07	0.27	3880.97	11.83	5331.00
254	5332.00	1.09	0.27	3881.70	11.83	5332.00
255	5333.00	1.03	0.26	3882.42	11.83	5333.00
256	5334.00	0.97	0.24	3883.15	11.83	5334.00
257	5335.00	1.07	0.27	3883.88	11.83	5335.00
258	5336.00	1.18	0.29	3884.61	11.83	5336.00
259	5337.00	1.20	0.30	3885.34	11.83	5337.00
260	5338.00	1.23	0.31	3886.06	11.83	5338.00
261	5339.00	1.26	0.32	3886.79	11.83	5339.00
262	5340.00	1.30	0.32	3887.52	11.83	5340.00
263	5341.00	1.33	0.33	3888.25	11.83	5341.00
264	5342.00	1.36	0.34	3888.98	11.83	5342.00
265	5343.00	1.36	0.34	3889.70	11.83	5343.00
266	5344.00	1.35	0.34	3890.43	11.83	5344.00
267	5345.00	1.32	0.33	3891.16	11.83	5345.00
268	5346.00	1.30	0.32	3891.89	11.83	5346.00
269	5347.00	1.33	0.33	3892.62	11.83	5347.00
270	5348.00	1.36	0.34	3893.34	11.83	5348.00
271	5349.00	1.38	0.34	3894.07	11.83	5349.00
272	5350.00	1.39	0.35	3894.80	11.83	5350.00
273	5351.00	1.39	0.35	3895.53	11.83	5351.00
274	5352.00	1.39	0.35	3896.26	11.83	5352.00
275	5353.00	1.32	0.33	3896.98	11.83	5353.00
276	5354.00	1.26	0.31	3897.71	11.83	5354.00
277	5355.00	1.22	0.31	3898.44	11.83	5355.00
278	5356.00	1.19	0.30	3899.17	11.83	5356.00
279	5357.00	1.23	0.31	3899.90	11.83	5357.00
280	5358.00	1.26	0.32	3900.62	11.83	5358.00
281	5359.00	1.30	0.32	3901.35	11.83	5359.00
282	5360.00	1.34	0.33	3902.08	11.83	5360.00

283	5361.00	1.29	0.32	3902.81	11.83	5361.00
284	5362.00	1.24	0.31	3903.54	11.83	5362.00
285	5363.00	1.28	0.32	3904.26	11.83	5363.00
286	5364.00	1.33	0.33	3904.99	11.83	5364.00
287	5365.00	1.28	0.32	3905.72	11.83	5365.00
288	5366.00	1.24	0.31	3906.45	11.83	5366.00
289	5367.00	1.25	0.31	3907.18	11.83	5367.00
290	5368.00	1.26	0.31	3907.90	11.83	5368.00
291	5369.00	1.22	0.30	3908.63	11.83	5369.00
292	5370.00	1.18	0.29	3909.36	11.83	5370.00
293	5371.00	1.25	0.31	3910.09	11.83	5371.00
294	5372.00	1.31	0.33	3910.82	11.83	5372.00
295	5373.00	1.27	0.32	3911.54	11.83	5373.00
296	5374.00	1.22	0.31	3912.27	11.83	5374.00
297	5375.00	1.26	0.31	3913.00	11.83	5375.00
298	5376.00	1.29	0.32	3913.73	11.83	5376.00
299	5377.00	1.30	0.32	3914.46	11.83	5377.00
300	5378.00	1.31	0.33	3915.18	11.83	5378.00
301	5379.00	1.25	0.31	3915.91	11.83	5379.00
302	5380.00	1.19	0.30	3916.64	11.83	5380.00
303	5381.00	1.02	0.25	3917.37	11.83	5381.00
304	5382.00	0.89	0.22	3918.10	11.83	5382.00
305	5383.00	0.92	0.23	3918.82	11.83	5383.00
306	5384.00	0.96	0.24	3919.55	11.83	5384.00
307	5385.00	0.95	0.24	3920.28	11.83	5385.00
308	5386.00	0.95	0.24	3921.01	11.83	5386.00
309	5387.00	1.00	0.25	3921.74	11.83	5387.00
310	5388.00	1.05	0.26	3922.46	11.83	5388.00
311	5389.00	1.05	0.26	3923.19	11.83	5389.00
312	5390.00	1.05	0.26	3923.92	11.83	5390.00
313	5391.00	0.99	0.25	3924.65	11.83	5391.00
314	5392.00	0.93	0.23	3925.38	11.83	5392.00
315	5393.00	0.94	0.23	3926.10	11.83	5393.00
316	5394.00	0.96	0.24	3926.83	11.83	5394.00
317	5395.00	1.00	0.25	3927.56	11.83	5395.00
318	5396.00	1.03	0.26	3928.29	11.83	5396.00
319	5397.00	1.03	0.26	3929.02	11.83	5397.00
320	5398.00	1.03	0.26	3929.74	11.83	5398.00
321	5399.00	1.01	0.25	3930.47	11.83	5399.00
322	5400.00	0.99	0.25	3931.20	11.83	5400.00
323	5401.00	1.03	0.26	3931.93	11.83	5401.00
324	5402.00	1.07	0.27	3932.66	11.83	5402.00
325	5403.00	1.06	0.26	3933.38	11.83	5403.00
326	5404.00	1.06	0.26	3934.11	11.83	5404.00
327	5405.00	1.02	0.25	3934.84	11.83	5405.00
328	5406.00	0.98	0.24	3935.57	11.83	5406.00
329	5407.00	0.95	0.24	3936.30	11.83	5407.00
330	5408.00	0.92	0.23	3937.02	11.83	5408.00
331	5409.00	0.96	0.24	3937.75	11.83	5409.00
332	5410.00	1.00	0.25	3938.48	11.83	5410.00
333	5411.00	1.05	0.26	3939.21	11.83	5411.00

334	5412.00	1.10	0.27	3939.94	11.83	5412.00
335	5413.00	1.04	0.26	3940.66	11.83	5413.00
336	5414.00	0.97	0.24	3941.39	11.83	5414.00
337	5415.00	0.99	0.25	3942.12	11.83	5415.00
338	5416.00	1.01	0.25	3942.85	11.83	5416.00
339	5417.00	1.01	0.25	3943.58	11.83	5417.00
340	5418.00	1.01	0.25	3944.30	11.83	5418.00
341	5419.00	1.03	0.26	3945.03	11.83	5419.00
342	5420.00	1.05	0.26	3945.76	11.83	5420.00
343	5421.00	1.09	0.27	3946.49	11.83	5421.00
344	5422.00	1.12	0.28	3947.22	11.83	5422.00
345	5423.00	1.22	0.30	3947.94	11.83	5423.00
346	5424.00	1.32	0.33	3948.67	11.83	5424.00
347	5425.00	1.32	0.33	3949.40	11.83	5425.00
348	5426.00	1.31	0.33	3950.13	11.83	5426.00
349	5427.00	1.30	0.32	3950.86	11.83	5427.00
350	5428.00	1.28	0.32	3951.58	11.83	5428.00
351	5429.00	1.29	0.32	3952.31	11.83	5429.00
352	5430.00	1.29	0.32	3953.04	11.83	5430.00
353	5431.00	1.23	0.31	3953.77	11.83	5431.00
354	5432.00	1.17	0.29	3954.50	11.83	5432.00
355	5433.00	1.15	0.29	3955.22	11.83	5433.00
356	5434.00	1.13	0.28	3955.95	11.83	5434.00
357	5435.00	0.89	0.22	3956.68	11.83	5435.00