

**USE OF INSTANTANEOUS TIME PRODUCTION DATA IN SAND MONITORING OF
SOME NIGER DELTA WELLS.**



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**A PROJECT SUBMITTED TO THE DEPARTMENT OF
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**DEPARTMENT OF PETROLEUM ENGINEERING
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OCTOBER, 2025

CERTIFICATION

I certify that this project work was carried out by **ODIA OSARETIN GODSPOWER**
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DEDICATION

I dedicate this project to the Almighty God, whose grace, wisdom, and strength have guided me through every step of this journey. To my wonderful parents, Mr. and Mrs. ODIA, whose endless love, encouragement, and sacrifices have been my greatest source of motivation this accomplishment is as much yours as it is mine.

ACKNOWLEDGEMENT

All glory and thanks be to the Almighty God for His divine guidance, provision, and grace throughout the course of this project. His wisdom and strength made this work a success and saw me through every challenge.

My heartfelt appreciation goes to my supervisor, Prof(Dr.) Onaiwu David Oduwa, for his invaluable guidance, patience, and dedication. His insightful advice, constructive criticism, and unwavering support were instrumental in the successful completion of this research.

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ABSTRACT

One of the most significant threat to petroleum production is that of sand production resulting from the migration of formation sand caused by the flow of reservoir fluids. Conventional well completions in soft formations commonly produce formation sands or fines with fluids. Today's operators need access to complete production system, delivering intelligent real time information and operation alongside existing instrumentation. Hence, Acoustic Sand Monitors and Intrusive Erosion Probes are invaluable tools in detecting the presence and effect of solids production. Accurate monitoring coupled with analysis and interpretation of the real time data can guarantee improved longevity of the asset and greatly reduce cost JK of repairs, replacement and downtime. Detailed, real-time information can also help to optimise production, and in many cases adjustments can be made to individual wells to increase oil production where sand is not an issue. This study presents an analytical assessment of sand production monitoring from an offshore field in the Niger Delta region from real time oil field production data. The data used in this study have been obtained from sand signals generated from acoustic sound detectors installed along flow paths in the oil production facility. In this study, sound signals generated by solids particles (sands/fines) along the flow paths of the facility are analysed to monitor sand production from the wells in the field over a period of nine years of production. These wells were consequently categorized as high sand producers or low sand producers following the percentage deviation of the sand signal averages for the wells from the corresponding baselines for each of the wells in comparison to the established percentage deviation threshold. At the end of this study, four wells were categorized to be high sand producers while nine were categorized as low sandproducers.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO STUDY

Sand production remains one of the most persistent technical challenges encountered during hydrocarbon extraction from unconsolidated or weakly consolidated sandstone reservoirs. A considerable share of global oil and gas reserves is located in formations with low cementation strength, making them naturally prone to disaggregation when subjected to changes in stress, pressure drawdown, and fluid flow. As the mechanical integrity of the reservoir rock deteriorates, grains can detach from the formation matrix and migrate into the wellbore, especially when the pressure gradient created during production generates sufficient drag forces to mobilize loose particles.

The phenomenon of sanding is influenced by a combination of geomechanical, petrophysical, and operational factors. These include in-situ stress distribution around the wellbore, pore pressure depletion, fluid viscosity, rock strength, perforation design, completion type, and the operational history of the well. Cyclic loading during shut-ins and re-starts, drilling-induced damage, reservoir compaction, or water breakthrough can further weaken formation strength, making sand failure more likely. Once released, sand particles are transported with produced fluids, and depending on flow conditions, they may accumulate in tubing, fill the wellbore, or erode equipment.

Although technological advancements have been made in predicting sanding behaviour, current prediction tools still struggle to achieve complete accuracy under diverse field circumstances. As

a result, many operators rely on well testing, field experience, and monitoring systems to understand sanding tendencies and implement control measures.

Globally, the issue is heightened by the fact that most oil and gas fields are aging. More than two-thirds of current production is derived from mature assets, where increasing water-cut, higher gas production, and elevated flow velocities intensify the likelihood of sand occurrence. Produced sand, although worthless as a commodity, creates substantial operational, economic, and environmental burdens. If left unmanaged, sand can erode pipelines, damage pumps and valves, reduce production efficiency, clog separators, and expose facilities to failure risks. Because such deterioration often evolves silently within flow lines and cannot be easily observed, there is a growing need for continuous sand monitoring using robust sensors that provide real-time data.

Unconsolidated reservoirs with permeability ranging between 0.5 and 8 Darcy are especially susceptible. Sand production may begin during initial flowback or appear later as the reservoir depletes or water breaks through. While low levels of sand can sometimes be tolerated for short periods, prolonged or excessive sand influx can compromise well integrity, reduce production, or cause severe damage to both surface and subsurface systems. The degree of acceptable sand production depends on factors such as separator handling capacity, erosion resistance of the equipment, disposal constraints, and artificial lift sensitivity. Often, reducing production is not economically viable, making sand control or monitoring an essential part of field management.

Recognizing that uncontrolled sand production threatens well integrity and facility safety, modern petroleum operations prioritize early detection. Non-intrusive sand monitoring systems, especially acoustic sensors, have gained prominence. These systems listen for high-frequency

impacts generated when sand strikes the pipe wall. With appropriate interpretation through visualization platforms such as the Integrated Visualization Manager (IVM) by Petroleum Experts (PetEx), operators can obtain reliable real-time sanding profiles from producing wells.

In this study, real-time acoustic monitoring was applied to thirteen wells in a deep-offshore Niger Delta field. Ultrasonic sensors were installed along strategic points in the flow path to detect sand impacts. By analysing the resulting acoustic signatures, wells were classified according to their sanding tendencies—distinguishing those with high sand production from those producing minimal or negligible solids.

1.2 Statement of the Problem

Sand production has long been recognized as a major operational concern in the petroleum industry. When sand enters the wellbore, it restricts flow, clogs perforations, interferes with equipment functionality, and accelerates wear in production infrastructure. The presence of sand particles in produced fluids reduces productivity, increases operating costs, and raises maintenance frequency. It also presents environmental and safety risks, particularly regarding sand disposal and erosion-induced equipment failures.

The financial implications are substantial. Every year, operators spend millions of dollars on sand clean-out operations, equipment repairs, and deferred production resulting from sanding-related shutdowns. As wells mature, they become increasingly susceptible to sanding due to reservoir depletion and loss of formation strength. The challenge is not only to prevent sand entry but to optimize production without compromising the integrity of the well and associated facilities.

Given the operational, economic, and environmental consequences of sanding, there is an urgent need for efficient methods of monitoring and managing sand production. Without accurate, real-time sand information, operators may fail to detect early warning signs, resulting in equipment failure, costly interventions, or catastrophic well damage. Addressing this persistent issue requires a systematic approach to understanding sanding behaviour and adopting monitoring systems capable of supporting safe and economic production.

1.3 Aim of the Study

The aim of this research is to utilize instantaneous real-time production data to monitor and evaluate sand production behaviour in selected Niger Delta wells.

1.4 Objectives of the Study

The specific objectives are to:

- Analyse sand production activity using available real-time and historical production data from the field.
- Monitor and quantify sand production levels in each well throughout the study period.
- Classify the wells based on their sanding tendencies—identifying high and low sand-producing wells—while considering differences in riser branches and production loops connected to each well at various times.

1.5 Significance of the Study

Optimizing hydrocarbon production requires accurate understanding and control of solids production. In unconsolidated sandstone reservoirs, sand monitoring is indispensable for ensuring safe and efficient operations. Reliable real-time sand detection enables operators to:

- Improve productivity by managing sanding before it escalates.
- Enhance personnel safety by minimizing the risk of equipment failure and loss of containment.
- Protect surface and subsurface facilities from erosion and mechanical damage.
- Extend reservoir and wellbore lifespan through informed operational decisions.
- Reduce operational and workover costs by preventing catastrophic failures.
- Facilitate effective sand management planning and early intervention strategies.

For a major oil-producing region like the Niger Delta, where unconsolidated reservoirs are widespread, a real-time sand monitoring system offers valuable insight that supports safer, more economic, and more sustainable field development.

1.6 Limitation of the Study

This study is limited to a single offshore oil field located in the Gulf of Guinea. The analysis relies exclusively on real-time acoustic data generated by non-intrusive sand detectors positioned along the production flow lines. The findings are therefore specific to the field under investigation and may not necessarily represent sanding behaviour in other reservoirs or production environments.

CHAPTER TWO

LITERATURE REVIEW

2.1 PAST WORK DONE

Production of formation sand remains one of the most persistent operational challenges in the oil and gas industry because of its damaging impact on well productivity, facility integrity, and the significant financial burden it imposes. For production engineers, managing and controlling sand is a primary concern, especially in fields developed in unconsolidated or weakly cemented sandstone formations. Sand production occurs when formation grains are mobilised by reservoir fluids, typically after the rock surrounding the perforations fails and loose particles are swept into the wellbore. This failure often develops when reservoir flow conditions exceed critical thresholds determined by the in-situ stress regime, mechanical strength of the rock, and the nature of the completion installed. The sand grains must first detach from the formation before entering the fluid stream, and this detachment is common in geologically young formations with little natural cementation to bind the grains together.

Sand monitoring therefore remains an essential element of well integrity management, helping operators determine whether sand control measures are required and enabling them to optimise production while protecting equipment. Several detection techniques exist, including wellhead shakeout tests, sand traps, volumetric sampling, erosion probes, acoustic devices, and corrosion monitoring systems. According to Osisanya (2010), more than 70% of the world's oil and gas reserves lie in sandstone reservoirs where sand production is likely to be an issue throughout the productive life of a well. As global energy prices fluctuate and the cost of remedial interventions

increases, the need for effective sand monitoring and control becomes even more critical. Young and poorly consolidated sediments—common in regions such as the U.S. Gulf Coast, California, Indonesia, Trinidad, Venezuela, and Nigeria—present particularly severe sand production challenges. Even older formations may produce sand when poor drilling or production practices weaken the in-situ rock fabric.

In the Niger Delta, where reservoir formations are predominantly unconsolidated, the likelihood of sand influx is high. Producing these fields safely and economically demands robust real-time monitoring systems and appropriate sand management strategies. The financial consequences of sand-related failures are substantial. As Coberly (1941) observed, expenditures associated with sand removal, equipment repairs, and lost production markedly affect profitability. Yet, despite these costs, efficient sand-control methods have enabled operators to exploit reservoirs that would otherwise have been abandoned.

Sand or formation fines may be produced from both clastic and carbonate reservoirs, mainly when flowing bottom-hole pressure drops below formation pressure, causing drag forces that mobilise grains. These solids have no economic value, yet they clog perforations, erode production equipment, and accumulate in surface vessels. Although production rate reduction can help mitigate sanding, it is usually not an economically attractive option. Thus, various sand control techniques—such as gravel packing, screen installation, chemical consolidation, and frac-pack systems—are widely used, although these methods can introduce additional completion skin and reduce productivity. Consequently, when designing a sand-control strategy, engineers must carefully evaluate the magnitude of skin and conduct economic analysis over the intended production period.

The strength of the inter-granular bonds in a formation remains the most important factor influencing sand failure. Compressive strength is widely regarded as a good indicator of bonding integrity (Penberthy and Shaughnessy, 1992). If production is increased to the point where flowing bottom-hole pressure falls below collapse pressure, even moderately consolidated formations may begin to disintegrate (Sanfilippo et al., 1997; Suman et al., 1991). Recent technological advances have produced acoustic and erosion-based sand sensors capable of providing rapid and accurate measurements of sand concentrations in multiphase flow. These devices detect the acoustic signatures generated by sand grain impacts and use this information to infer sand production levels.

Sand production behaviour is often classified into three categories:

(i) Transient sand production:

A temporary surge in sand output, usually associated with clean-up following perforation or stimulation activities, which declines with time under constant flow conditions.

(ii) Continuous sand production:

Typical of wells completed in unconsolidated sandstone without sand control, where sand inflow persists throughout production.

(iii) Catastrophic sand production:

A severe form of sanding caused by excessive reservoir drawdown, leading to large-scale formation failure and potentially complete loss of well integrity.

2.2 Causes of Sand Production (Improved)

Sand production may occur naturally due to the loose or unconsolidated nature of the formation, or it may be induced by operational activities. Reservoirs may be disturbed either by producing fluids or by injecting fluids into the formation. Sand production manifests when the stresses acting on the formation exceed its mechanical strength, resulting in failure. This failure may be triggered by tectonic stresses, overburden pressure, pore pressure reduction, stresses generated during drilling, or by drag forces exerted by flowing fluids. Once failure begins, loose grains disintegrate and are carried by hydrocarbon fluids toward the wellbore.

Mechanical rock failure, as documented by Anderson et al. (1986), arises from the combination of inherent rock strength, in-situ stresses, and induced stresses from drilling or production. In fully unconsolidated formations, sanding may begin at the very first instance of fluid flow due to the turbulence and drag forces that detach grains. Additional triggers include abrupt changes in production rate, water breakthrough, and variations in gas–liquid ratio. These challenges worsen over time as reservoir pressure declines, stress distribution changes, and flow conditions evolve, eventually increasing sanding risk and shortening the productive life of the field.

Key factors that intensify sand production include:

- Low formation strength
- Reduction in pore pressure
- High viscosity of reservoir fluids
- Increased water cut
- Increased gas production

2.3 Sand Management (Improved)

Sand management is a holistic operational strategy that balances the risks associated with allowing sand to reach the surface and the challenges involved in preventing sand entirely. The approach acknowledges that conventional sand control systems may not always be feasible or optimal. Instead, operators focus on controlling production parameters, monitoring sand influx, and ensuring that overall sand levels remain within acceptable operational limits.

Effective sand management requires understanding the entire “sand life cycle,” beginning with conditions that initiate sanding, continuing through transport in the wellbore, and concluding with surface handling and disposal. Sand monitoring technologies—particularly real-time acoustic systems—play a central role in this approach, allowing operators to detect sand inflow early and adjust production to minimise risk.

Globally, sand management affects more than 70% of producing oil and gas fields. It is not limited to choosing a control system but involves maximising production while keeping sand influx at safe levels. Operators spend millions annually on sand prevention and remediation.

According to Oluyemi and Oyenyin (2010), the economic, safety, and operational implications of sanding make real-time sand management indispensable.

Sand management has led to improved productivity in many wells because episodic sand bursts can help reduce near-wellbore skin and enhance inflow performance. As a result, sand-managed wells sometimes outperform wells with heavy sand-exclusion completions.

Design tools for sand management typically involve predicting:

- The onset of sanding
- Sand mass and rate of production

- Erosion risks to equipment
- Behaviour of sand in flowlines

Effective sand management relies on:

- Comprehensive field data acquisition
- Physical and numerical modelling
- Continuous monitoring of production trends
- Well testing to optimise operating envelopes

2.4 Sand Detachment (Improved)

Sand detachment is a hydro-mechanical process involving both rock failure and fluidisation.

Excessive drawdown or reservoir pressure decline may overstress the formation around the wellbore, leading to compressive or tensile failure. Formation weakening may also result from cyclic shut-down and start-up, water breakthrough, or changes in capillary forces that degrade grain cohesion. Once the material yields, hydrodynamic forces from fluid flow destabilise fragments and carry them toward the wellbore.

These processes are often episodic due to transient pressure gradients and flow regime changes, explaining why sand production frequently appears in bursts rather than as a constant stream.

2.5 Sand Exclusion and Separation (Improved)

Downhole sand screens and gravel packs remain common methods of preventing sand entry into the wellbore. These devices exclude particles above a certain size but also impose an additional pressure drop, making it necessary to balance productivity against sand-control efficiency. Even when screens are installed, fine particles may still cause erosion.

Sand separation may occur at:

- The topside processing facility

- Subsea separation modules
- Downhole separators integrated with water separation systems

Surface separation technologies include baffle-plate separators, vertical gravity separators, and centrifugal devices. Subsea and downhole separators typically rely on differences in wettability and density to remove sand.

2.6 Sand Transport (Improved)

Once detached, sand moves with reservoir fluids into the wellbore. Transport depends on several factors, including fluid properties, local velocity, system geometry, particle size, and well inclination. In long horizontal wells, sand may accumulate and later be remobilised, often being mistaken for renewed sanding when it is merely a clean-up process triggered by flow changes.

2.7 Sand Monitoring Methods (Improved)

2.7.1 Volumetric Methods

Volumetric sand monitoring includes:

- **Sand traps:** Installed at bends or tees but require manual emptying and do not provide real-time data.
- **Fluid sampling:** Measures sediment in produced fluids but may not capture total sand content.
- **Separator clean-out:** Involves disassembling equipment to measure accumulated solids but is labour-intensive.
- **In-line cyclones:** Separate sand and allow real-time quantification using load cells, though still relatively new.

2.7.2 Acoustic Transducers

Acoustic sensors detect sand by measuring sound generated when particles strike the pipe wall. The system includes an impact probe and an acoustic collar that captures vibrational signatures. These are widely used for real-time, non-intrusive monitoring.

2.8 Consequences of Sand Production (Improved)

The operational consequences of sand production are almost always negative, affecting both productivity and system integrity. While some wells tolerate small, manageable quantities of sand, reliance on long-term sand production is rarely sustainable.

Major consequences include:

(i) Downhole accumulation

Insufficient transport velocity allows sand to settle inside casing or tubing. As accumulation increases, production declines until the well becomes completely packed with sand (“sanded-up”). Remedial operations such as wireline bailers or coiled-tubing clean-outs are costly, time-consuming, and may be required frequently.

(ii) Surface equipment accumulation

If sand reaches the surface, it may settle in separators, heaters, or flowlines. Since these facilities are not designed to handle solids, their capacity and efficiency are reduced. Manual clean-out requires shutting in wells, resulting in deferred production and increased operational cost.

For instance, a two-phase separator designed for oil and water may accumulate significant sand over time. Even a seemingly small sand concentration (e.g., 0.03 pptb per 5000 bbl/day) can

result in substantial deposition over several months, eventually compromising separator performance.

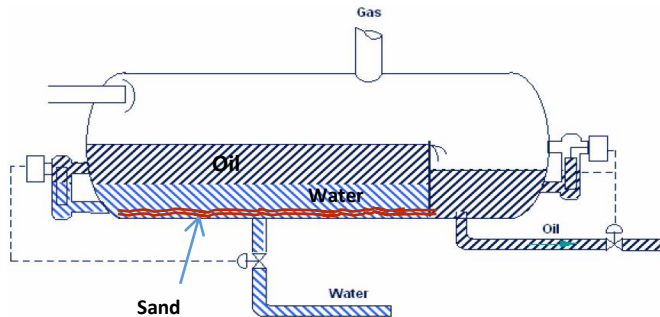


Fig 2.1: Illustration of sand settled at the bottom of a separator at the surface

Erosion of downhole and surface equipment

Pigging

The term PIG refers to ‘Pipeline Inspection Gauge’ or ‘Pipeline Intervention Gadget’. Pigging refers to the practice of using devices known as ‘pigs’ to perform various maintenance operation. This is done without stopping the flow of the product in the network. This is accomplished by inserting the pig into the ‘pig



Fig 2.2: Pig launcher at the downstream of a pipe section with some sand after a pigging operation

Sand acoustics

In sand acoustics, sand production is determined by using the integrated value of measured noise generated by collision of sand particles in the pipe wall.

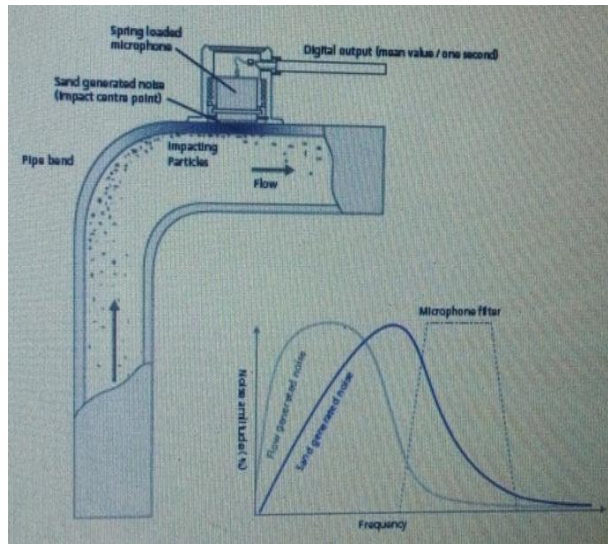


Fig 2.3: Operation of a sand acoustic transducer along a flowline.

Use of corrosion coupons

Accurate monitoring of corrosion rates in any environment is critical when viewed in terms of the maintenance and repair costs associated with corrosion and material failure. Test coupons provide an inexpensive means of in-line monitoring that will allow you to effectively measure the corrosivity within your system. By observing the mils-per-year corrosion rate of an exposed coupon, valuable information can be provided regarding the material's life expectancy. The simplest, and longest-established, method of estimating corrosion losses in plant and equipment is weight loss analysis. A weighed sample (coupon) of the metal or alloy under consideration is introduced into the process, and later removed after a reasonable time interval. The coupon is then cleaned of all corrosion products and is reweighed.



Coupon immediately after removal



Coupon after cleaning

Fig 2.4: Corrosion coupon installed on a facility before and after cleaning

CHAPTER THREE

METHODOLOGY

3.1. SIGNAL PROCESSING

The monitoring of sand production is a real-time detection during crude oil transmission in pipeline. On approaching a change in flow direction, sand's inertia causes it to deviate from the streamlines of the carrying fluid, generating vibration signals by particles impingement on the walls of the pipe. Sand does work for bend walls and the impact of kinetic energy will be converted to the strength of vibration.

Sand production rate is obtained from the measurement of the acoustic signals generated by sand impacting the pipe wall. The non-intrusive ultrasonic sensor can detect the acoustic signals and output an analog electrical signal. And the analog electrical signal is sent to an instrument that converts this analog signal into a digital signal, then the digital signal is converted into sanding rate in grams per second. These signals can be displayed and recorded. In addition to the recording, alarm levels can be established and set in relation to quick changes in the level of sand production. The installation of sand monitors at pipe bends is shown below.

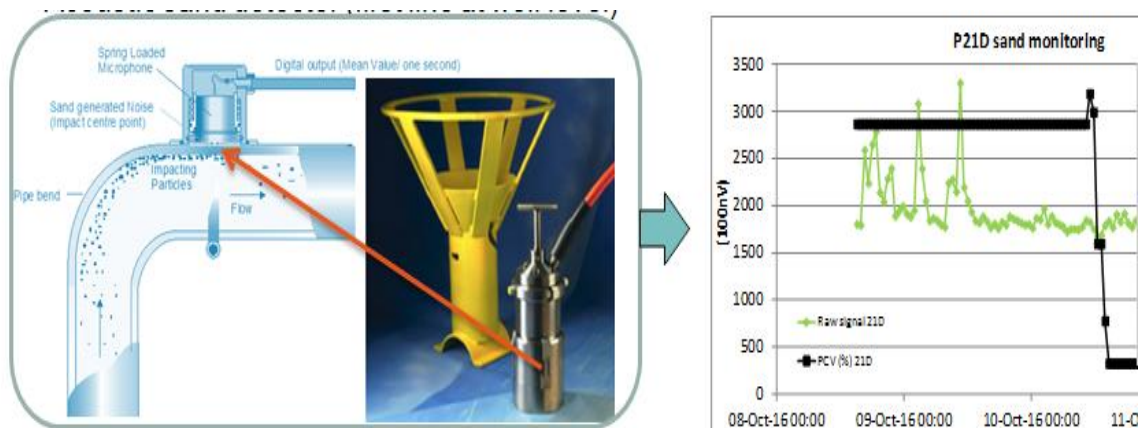


Figure 3.1: The installation of sand monitors at pipe bends

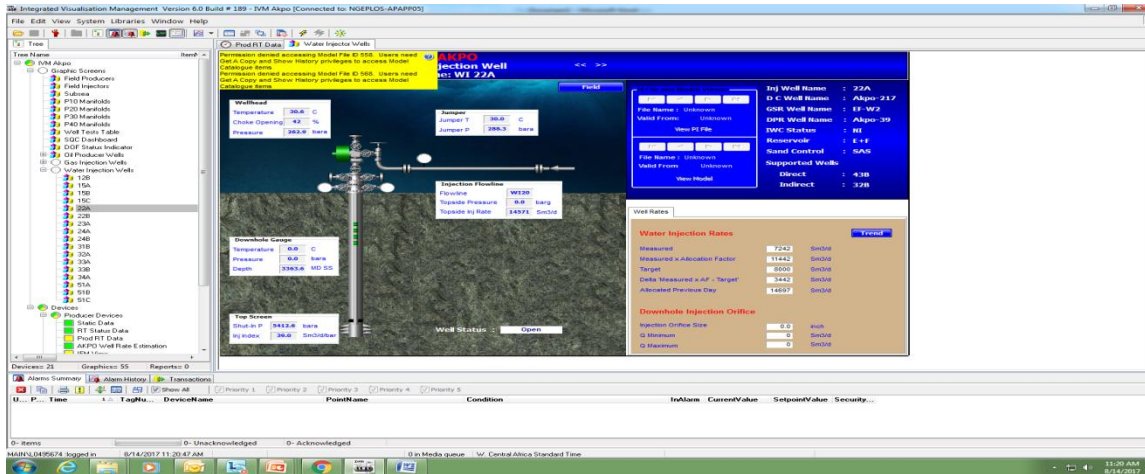


Fig 3.3a: IVM screen showing well properties for a particular well

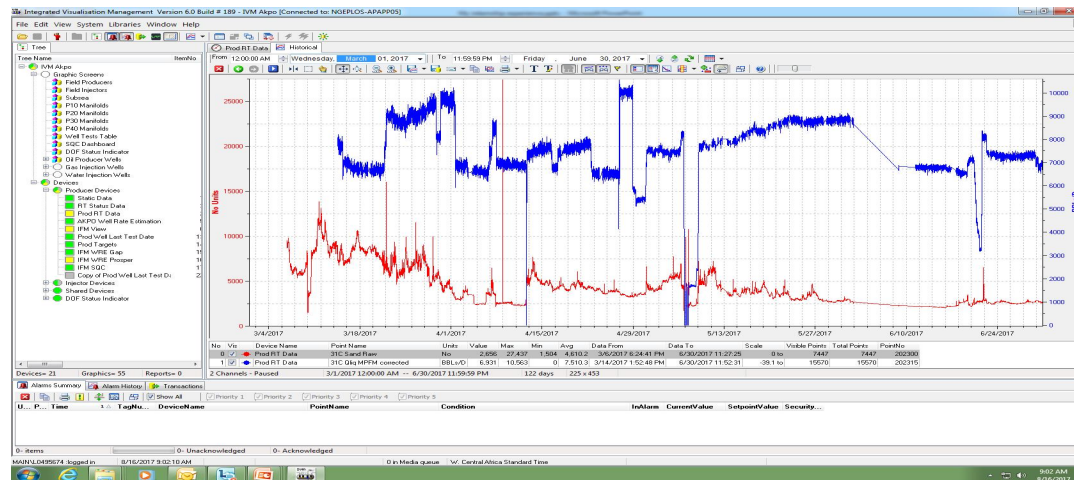


Figure 3.3b: IVM screen displaying two different production trends

3.7 PROCEDURE OF ANALYSIS

The real time sand production data for each of the wells was retrieved from IVM data historical. Thirteen wells were considered in this study from three different production loops. The raw sand signals were recorded in the system as numbers from zero (0) to fifty thousand (50,000)

depending on the magnitude of the signal generated at a particular time as displayed on the IVM plot. The production routing (left or right branch) was put into consideration for each well and the raw sand signal baseline was also obtained which is the level of most stable sand production for each of the wells. For each of the wells, the average sand signal was obtained as well as the average sand signal for the period the well was connected to the right branch and left branch of the production loop respectively.

The concept of percentage deviation from mean and average was used in determining the percentage deviations. Two different approaches were adopted for the analysis of the sand production data after establishing the percentage deviation threshold of 36%. The first was to calculate the percentage deviation of the sand signal average from the baseline for each well while the second entailed calculating the percentage deviation of the sand signal average of the left and right branches from the baseline. The percentage deviation shows the extent to which the sanding rate is deviated from the baseline for each of the wells.

Values of percentage deviations of sand signal average from the baseline below 36% indicates wells with low sand production while values from 36% and above indicates wells with high sand production rate. 36% was obtained as the yardstick for categorization by using the mean value of sand signal averages and sand signal baselines for all the wells to determine the rate of deviation of the mean sand signal average from the mean baseline for all the wells collectively and this value is consistent with previous field production history. For the two approaches, the wells were categorized under low sand producers and high sand producers and the results from the two procedures were compared for validation.

Non-intrusive ultrasonic sand monitoring faces the challenge of separating true sand-impact signals from the broad range of background noise generated within the production system. Mechanical equipment, pumps, flow turbulence and multiphase interactions all contribute to noise that often overlaps the sanding signal. Sand impacts typically generate acoustic frequencies within the 100–500 kHz range, which are generally higher and sharper than the low-amplitude, lower-frequency noise produced by bubbles, droplets or general flow disturbances (Nabipour et al., 2012).

The nature of the acoustic signal detected by the monitoring device is influenced by several parameters, including the concentration of sand within the flow, particle geometry, grain size distribution, the velocity at which particles strike the pipe wall, and the characteristics of the transporting fluid such as viscosity, rheology, and flow regime. Pipe geometry, bends, and internal diameters also shape how sound waves propagate. Consequently, monitoring systems must reliably distinguish the acoustic signature of true particle impacts from complex background noise patterns.

3.3 General De-Noising of Signals

Extracting sand-related frequencies from lower-frequency bands is difficult because mechanical sources—such as pumps, compressors, and rotating machinery—produce strong interference. While sand-impact vibrations occupy a relatively distinct high-frequency region, basic filtering alone cannot completely eliminate flow noise due to overlap in the vibration spectrum.

Vibration power spectra derived from sand-laden crude oil often show a correlation between sand production rate and the energy level of impact signals. Therefore, an effective de-noising process is essential to isolate genuine sanding events. In typical monitoring systems, vibration generated by sand-carrying flows is captured by high-frequency piezoelectric sensors, amplified, and then digitized. The resulting signal is transmitted to a computer where a signal-handling unit processes and displays the sand-production information, usually refreshed every ten seconds.

Relying solely on amplitude thresholds to detect sand impacts is inadequate, as non-sand noise can mimic similar amplitudes. For this reason, filtering based on frequency ranges is critical (Nabipour et al., 2012). Two general de-noising approaches are commonly employed:

1. **Hardware-Based Filtering (Band-Pass Filters):**

Physical filters are incorporated into the circuitry to emphasize the characteristic frequencies

associated with sand impacts while suppressing background noise. Piezoelectric transducers can also be tuned to respond predominantly within a specific high-frequency band.

2. **Software-Based Digital Filtering:**

After the analog signal is digitized, various signal-processing algorithms—such as adaptive filtering, wavelet transforms, or statistical noise suppression—are applied. These methods allow dynamic adjustments without adding electrical noise, though they require computational time and may impact real-time performance.

In many systems, hardware and digital filters are used together: hardware reduces broad-band noise, while algorithms refine and isolate remaining sand-impact signatures. This combination is particularly effective because sand-impact signals are inherently random due to the irregular timing and distribution of particle strikes (Geng et al., 2003).

3.4 Sand Monitoring Device

The **Roxar Sand Acoustic Monitor** was employed for detecting sand production in the system. This device is a non-intrusive sensor designed to capture and interpret the acoustic energy produced when sand particles strike the internal wall of a pipeline. Because sand grains experience inertia as they move through bends or changes in direction, they impact the pipe wall and generate distinct acoustic noise, which the device converts into quantitative sand-production data.

The monitor detects noise carried along the pipe wall, converts it to a digital signal, and transmits it to a **Calculation and Interface Unit (CIU)**. The CIU processes the signal using embedded algorithms to determine the instantaneous sand-production rate. Data are stored internally for up to 90 days using 10-second averaged intervals.

The Roxar monitor design is compact, lightweight, and requires no penetration of the pipeline, eliminating risks of pressure drop, leakage, or flow obstruction. It is designed for both onshore and offshore installations and offers an economical means of optimizing production while preventing equipment damage due to sanding.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS ANALYSIS

The raw data for this study in MS-Excel format are contained in the attached CD drive and all calculations and analysis have been carried using MS-excel. Two different approaches were considered for this study which are “analysis of data based on percentage deviation of overall well average from well baseline” and “analysis of data based on percentage deviation of the average of left and right branches for each well from the well baseline” as presented below.

4.1.1 Establishing the percentage deviation threshold

For this study, the percentage deviation threshold is the value which reflects the boundary between high sand production and low sand production. This has been obtained by using the equation below which captures the sand signal and baseline values for all the wells.

$$\% \text{ Deviation threshold} = \left[\frac{\text{Mean of average sand signal of wells}}{\text{Mean of sand signal baseline of wells}} \times 100 \right] - 100 \quad 4.1$$

The equation above is the model used for the analysis of this study and this approach shows the extent to which the sand signal values deviates from the baseline which is mean and stable level of sanding. From the Microsoft Excel calculations, the following values were obtained;

Mean of average sand signal of wells = 2385.9

Mean of sand signal baseline of wells = 1758.8

Hence, the value for the percentage deviation threshold was obtained as follows;

$$\% \text{ Deviation Threshold} = \left[\frac{2385.9}{1758.8} \times 100 \right] - 100 = 35.6\%$$

Therefore, by approximation, the percentage deviation threshold is taken to be **36%**.

This value was obtained by putting all the thirteen wells (13) wells into consideration. Hence it forms the threshold value for all the wells. Comparing this established threshold value with the percentage deviation values obtained for each of the wells using the same model as in equation 4.1, it was deduced that values of percentage deviation obtained for the individual wells higher than the threshold value indicates a high level of sand production while values below the established threshold indicates low level of sand production.

4.1.2 Analysis of data based on percentage deviation of overall well average from well baseline

In this approach, the overall sand signal average was obtained for each of the wells and the percentage deviations of each of these well average from the baseline was calculated using equation 4.1 and the result is presented in table 4.1.

$$\left[\frac{\text{Average sand signal of well}}{\text{Sand signal baseline of well}} \times 100 \right] - 100 \quad 4.2$$

4.1.3 Analysis of data based on percentage deviation of the average of left and right branches for each well from the well baseline

For this approach, the average of the raw sand signal from left and right routes was obtained for each well and the percentage deviation of this value from the well baseline was calculated using equation 4.2. The results obtained is presented in table 4.2.

$$\left[\frac{\text{Average sand signal for left and right branches of well}}{\text{Sand signal baseline of well}} \times 100 \right] - 100 \quad 4.3$$

Table 4.1: Table of values showing the percentage deviation of sand signal average from the baseline for the wells

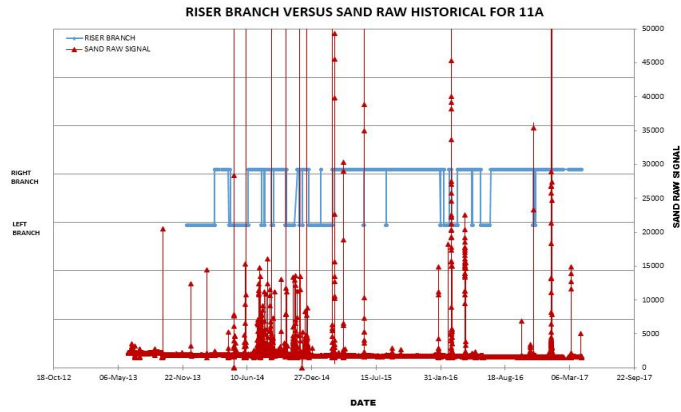
PRODUCTION LOOP	WELL	AVE. SAND SIGNAL OF WELL	SAND SIGNAL BASELINE	AVE. SAND SIGNAL OF LEFT BRANCH	AVE. SAND SIGNAL OF RIGHT BRANCH	% Deviation of average from Baseline	% Deviation of left branch average from Baseline	% Deviation of right branch average from Baseline
LOOP 1	P11A	2391.4	1696	2969.9	2195.7	41	75	29
	P11C	2330.4	1632	2604.5	2246.2	43	60	38
	P12B	1941.8	1536	1836.4	2257.8	26	20	47
	P12C	1935.3	1600	2054.3	1916	21	28	20
	P12D	1939.9	1600	1934.3	2095.3	21	21	31
LOOP 2	P21D	4520.9	1568	3120.7	4693.4	188	99	199
	P22A	1848.1	1568	1757	1958.9	18	12	25
	22B	1722.3	1504	1795.3	1648.1	15	19	10
	22C	2468.1	1632	2365.8	2383.3	51	45	46
LOOP 3	P32D	2177.7	2112	2061.1	2169.6	3	-2	3
	P42A	2510.1	2000	2335.4	2825.6	26	17	41
	P43B	2813.9	2112	2948.9	2560.4	33	40	21
	P43D	2416.6	2304	2419.2	2344.1	5	5	2

Table 4.2: Table of values for analysis based on percentage deviation of average of left and right branches of the wells

PRODUCT ION LOOP	WEL L	AVE. SAND SIGNAL OF WELL	BASELI NE	AVE. SAND SIGNAL OF LEFT BRANCH	AVE. SAND SIGNAL OF RIGHT BRANCH	Average of left and right branch sand signal	% Deviation for average of left and right branch sand signal from baseline
LOOP 1	P11A	2391.4	1696	2969.9	2195.7	2582.8	52.3
	P11C	2330.4	1632	2604.5	2246.2	2425.35	48.6
	P12B	1941.8	1536	1836.4	2257.8	2047.1	33.3
	P12C	1935.3	1600	2054.3	1916	1985.15	24.1
	P12D	1939.9	1600	1934.3	2095.3	2014.8	25.9
LOOP 2	P21D	4520.9	1568	3120.7	4693.4	3907.05	149.2
	P22A	1848.1	1568	1757	1958.9	1857.95	18.5
	22B	1722.3	1504	1795.3	1648.1	1721.7	14.5
	22C	2468.1	1632	2365.8	2383.3	2374.55	45.5
LOOP 3	P32D	2177.7	2112	2061.1	2169.6	2115.35	0.2
	P42A	2510.1	2000	2335.4	2825.6	2580.5	29.0
	P43B	2813.9	2112	2948.9	2560.4	2754.65	30.4
	P43D	2416.6	2304	2419.2	2344.1	2381.65	3.4

Two set of charts were plotted for each of the wells. That is, the plots of riser branch versus sand signal historical with respect to their corresponding date as well as the plot of the cumulative residence time for the two routings with respect to date. These charts are presented below.

These first set of charts represents plots of riser branch versus sand raw historical shown below;



P11A

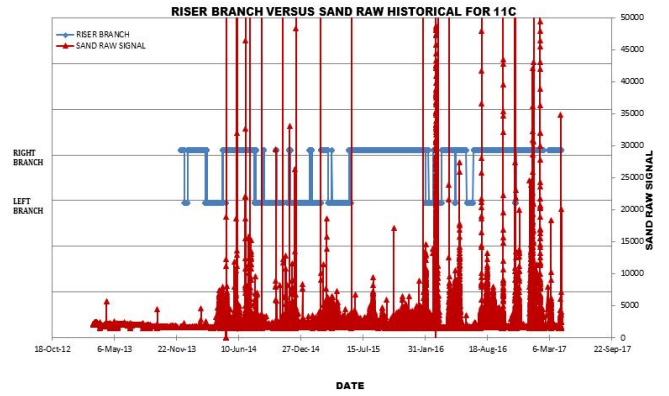
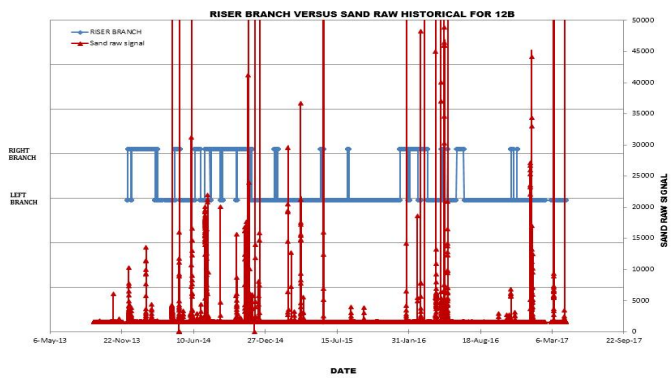


Fig 4.1.1: Riser branch versus sand signal for P11C
4.1. Fig 2: Riser branch versus sand signal for P11C



signal for P12B

Fig 4.1.4: Riser branch versus sand signal for P12C

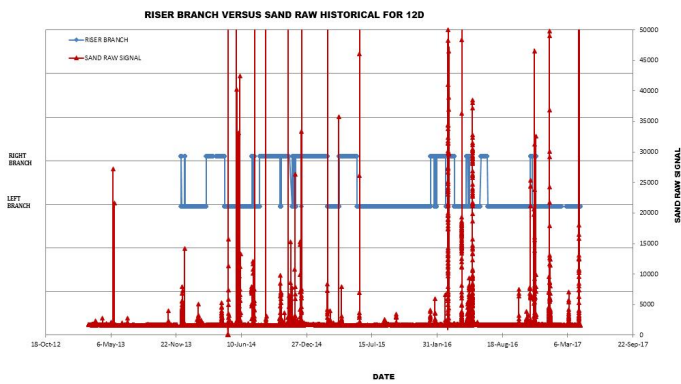
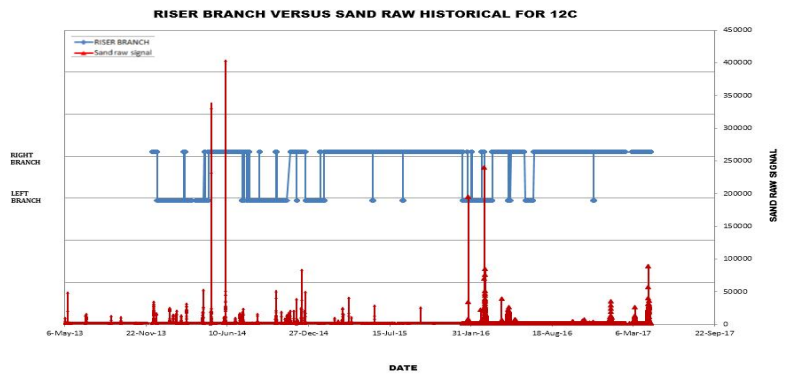


Fig 4.1.5: Riser branch versus sand signal for P12D

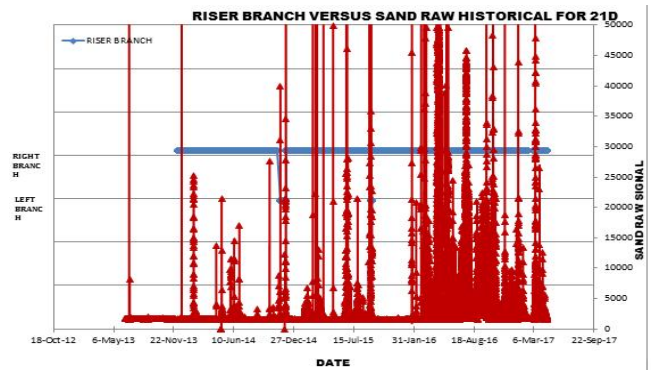


Fig 4.1.6: Riser branch versus sand signal for P21D

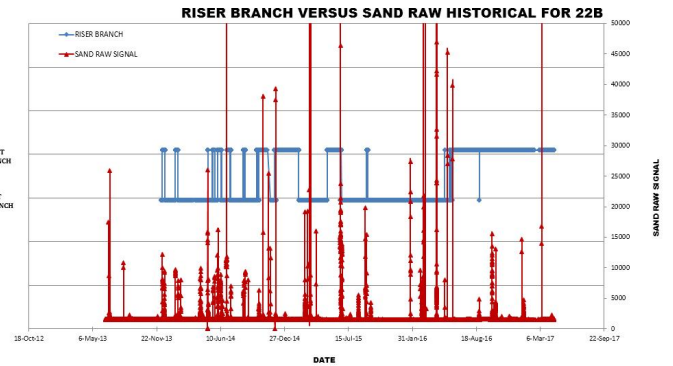
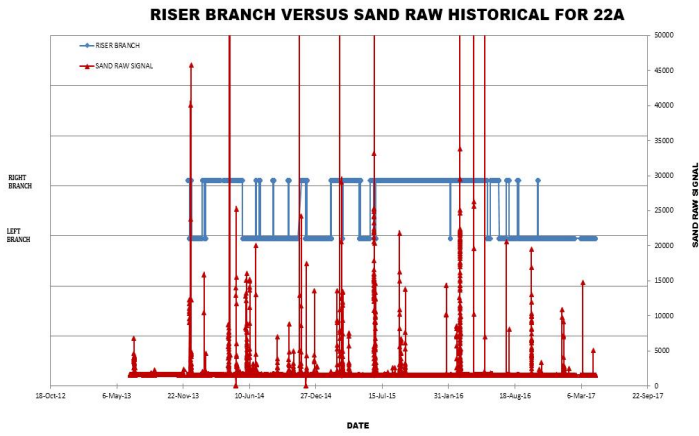


Fig 4.1.8: Riser branch versus sand signal for P22B

or P22A

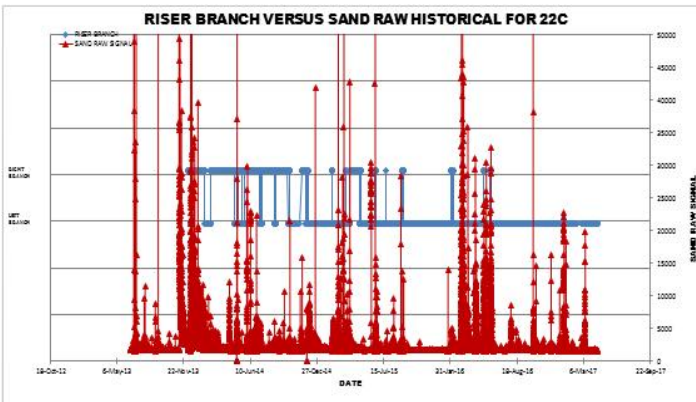


Fig 4.1.9: Riser branch versus sand signal for P22C

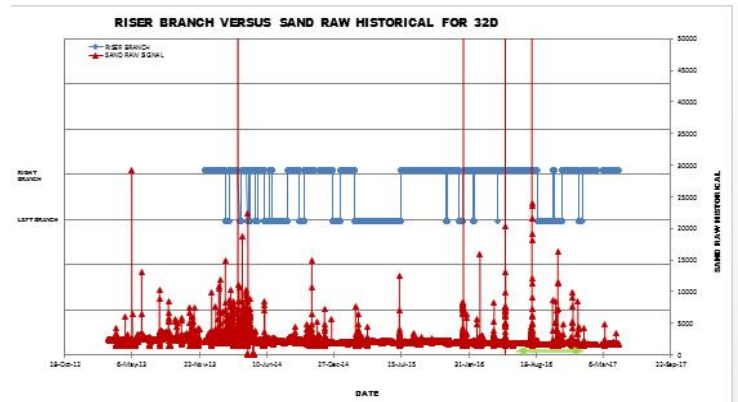


Fig 4.1.10: Riser branch versus sand signal for P32D

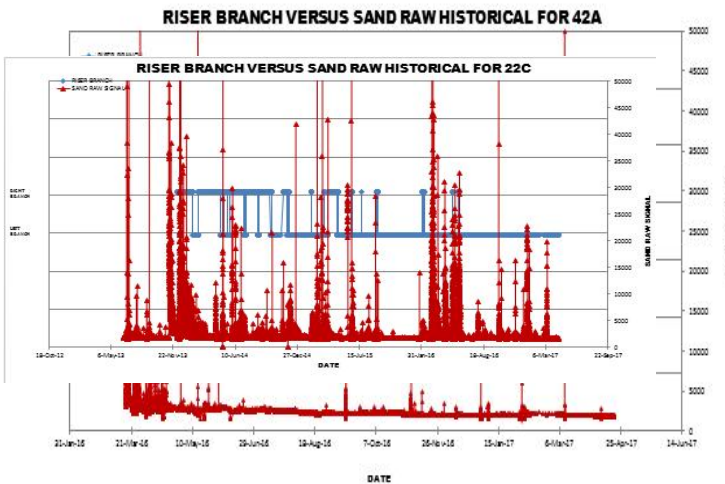


Fig 4.1.11: Riser branch versus sand signal for P42A

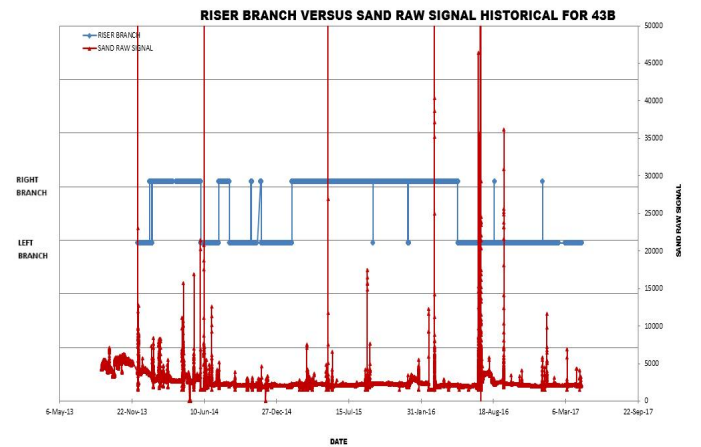


Fig 4.1.12: Riser branch versus sand signal for P43B

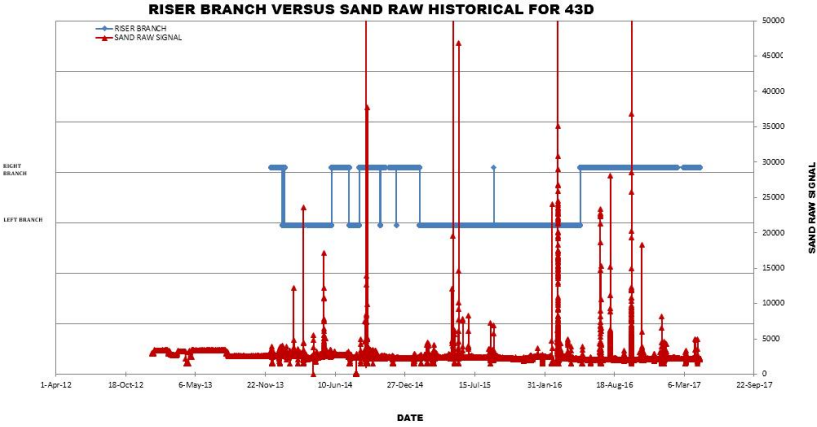


Fig 4.1.13: Riser branch versus sand signal for P43D

These second set of charts shows the plots of the cumulative branch residence time for the well routings as presented below.

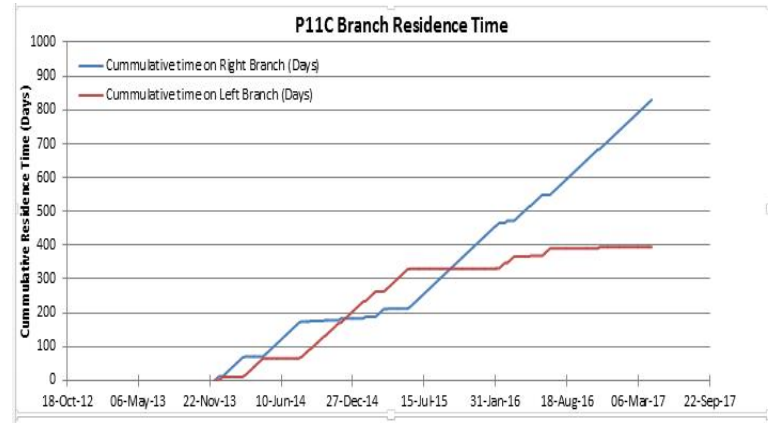
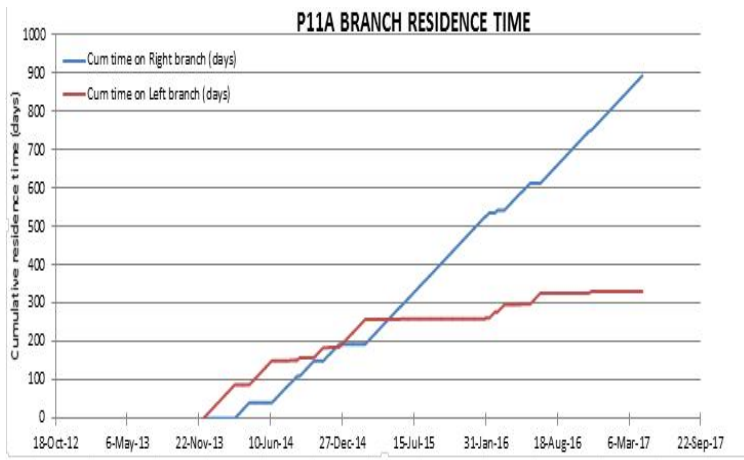


Fig 4.2.2: Cumulative residence time for P11C

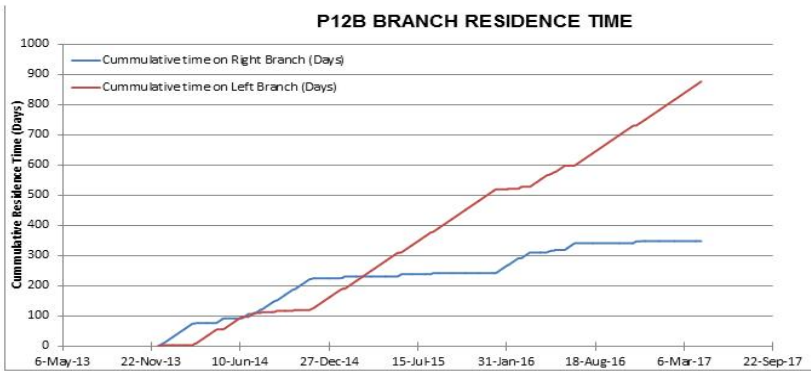


Fig 4.2.3: Cumulative residence time for P12B

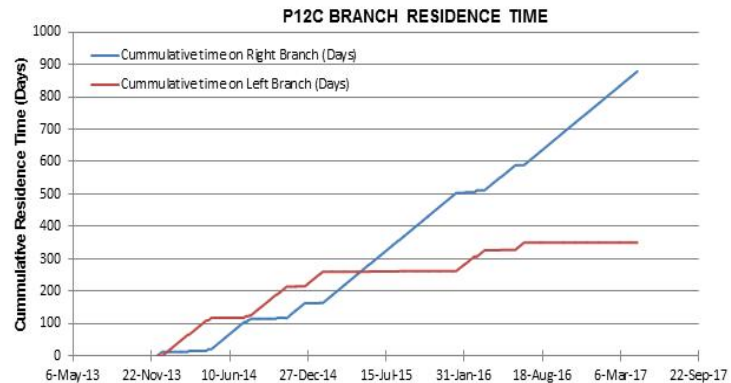
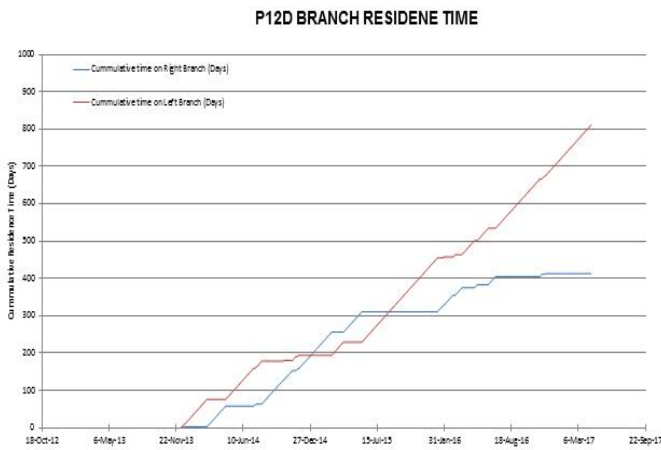


Fig 4.2.4: Cumulative residence time for P12C



for P12D

Fig 4.2.5: Cumulative residence time for P12D

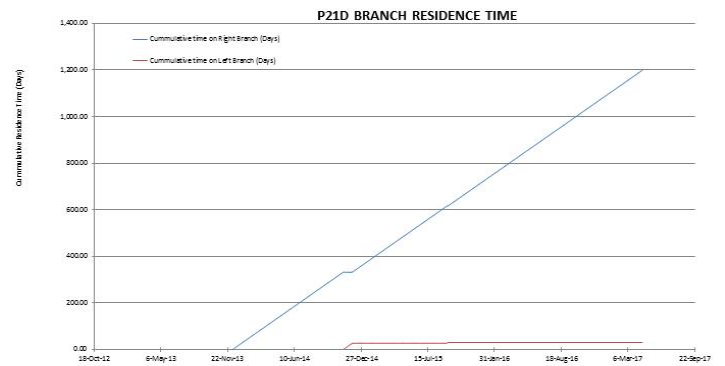


Fig 4.2.6: Cumulative residence time

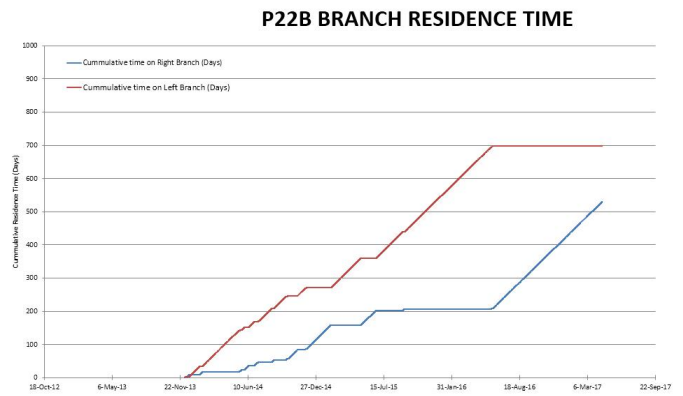
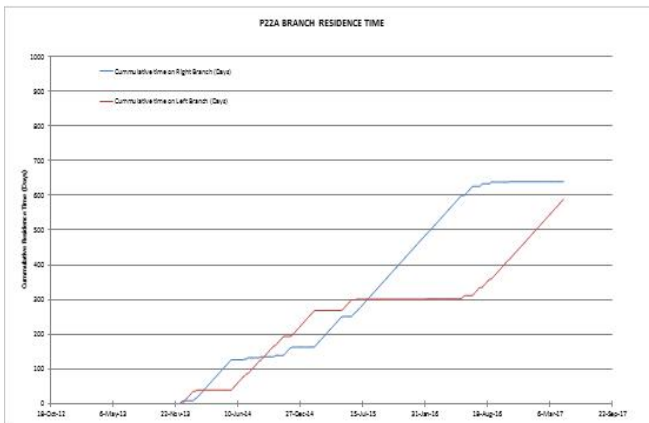


Fig 4.2.7: Cumulative residence time for P22A

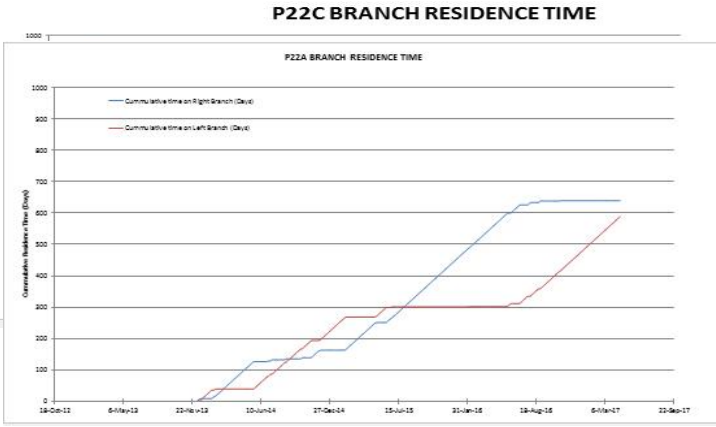
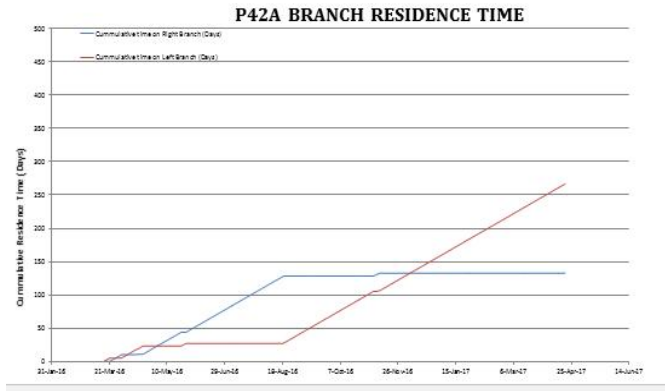


Fig 4.2.9: Cumulative residence time for P22C



ne for P42A

Fig 4.2.8: Cumulative residence time for P22B

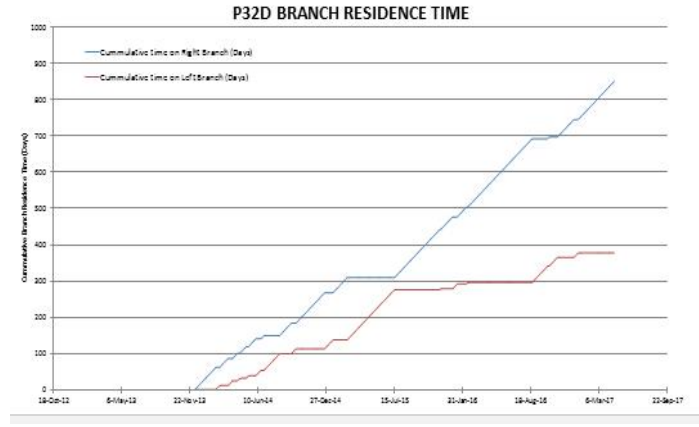


Fig 4.2.10: Cumulative residence time for P32D

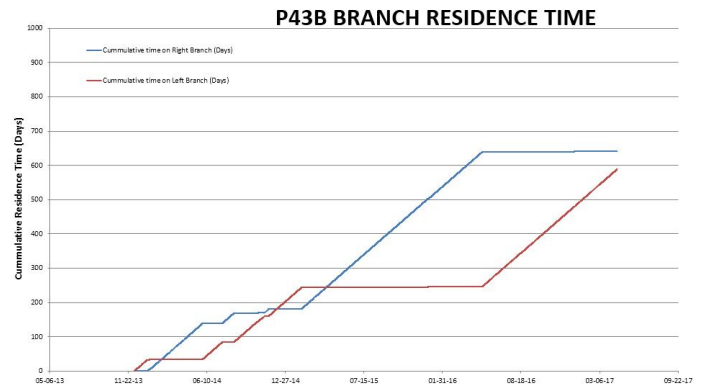


Fig 4.2.12: Cumulative residence time for 43B

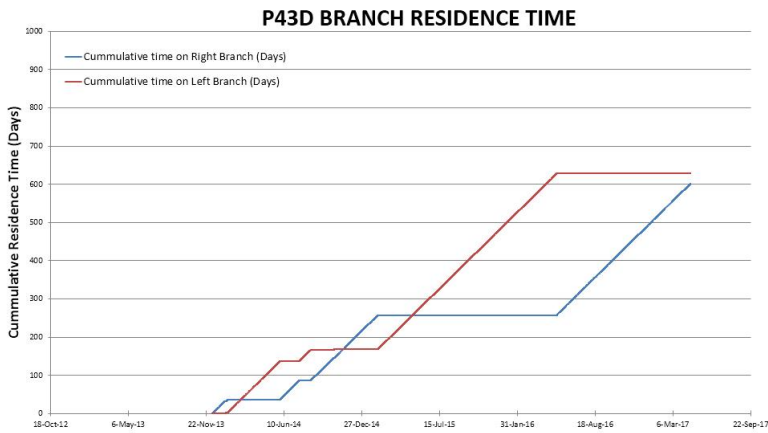


Fig 4.2.13: Cumulative residence time for P43D

4.2

DISCUSSION OF RESULTS

The raw sand-signal data obtained from the wells were first processed in Microsoft Excel. Since each well can be routed either to a left or right branch at different times, the routing configuration was taken into account during analysis. The production loop to which each well belongs was also considered, as this influences flow behaviour and the likelihood of sand transport.

A baseline sand-signal value was established for every well. This baseline represents a stable reference point for judging the degree of deviation in sand production. It was obtained by identifying the *mode* of the raw signal for each well, since the mode reflects the most frequently occurring value in a largely stable data stream. Using this as the central reference made it possible to quantify variations in sand production.

The concept of *percentage deviation from baseline* served as the core analytical tool. Wells that showed deviations of **36% or more** above the baseline were classified as **high sand producers**, while wells with deviations below this threshold were considered **low sand producers**.

Based on the results:

- Only **four wells** recorded deviations equal to or higher than 36%, placing them in the high-sanding category.
- These wells were **P11A and P11C** in Production Loop 1 and **P21D and P22C** in Production Loop 2.
- All other wells showed deviations below the threshold and were therefore classified as low sand producers.
These include: **P12B, P12C, P12D** (Loop 1); **P22A, P22B** (Loop 2); and **P32D, P42A, P43B, P43D** (Loop 3).

Importantly, the results obtained from the two analytical approaches used in the study showed complete consistency, reinforcing their reliability. No discrepancies were observed, suggesting that the deviation-based method is dependable for monitoring sand production levels across wells.

CHAPTER FIVE

CONCLUSION, RECOMMENDATION AND CONTRIBUTION TO KNOWLEDGE**

5.1 CONCLUSION

The overall findings of this study are summarized in the table below:

Table 5.1: Categorization of Wells Based on Sand-Signal Results

Production Loop	High Sanding Wells	Low Sanding Wells
Loop 1	P11A, P11C	P12B, P12C, P12D
Loop 2	P21D, P22C	P22A, P22B
Loop 3	—	P32D, P42A, P43B, P43D

From the table and analytical results:

- **P11A, P11C** (Loop 1) and **P21D, P22C** (Loop 2) exhibited high sand production.
- **P12B, P12C, P12D** (Loop 1), **P22A, P22B** (Loop 2), and **P32D, P42A, P43B, P43D** (Loop 3) produced low levels of sand.
- No high-sanding wells were identified within **Production Loop 3**.
- The two analytical methods used in the study produced the same outcome, indicating reliability and internal consistency.

5.2 RECOMMENDATIONS

Based on the results and the operational considerations for acoustic sand monitoring, the following recommendations are proposed:

- For optimal sensitivity, the sand monitor should be installed **downstream and as close as possible to a 90° bend**, but not more than **75 cm away**. This positioning takes advantage of particle inertia and pipe geometry to increase impact energy and improve signal quality.
- Installation should be avoided near known noise sources such as **choke valves** and **cyclonic desanders**. Excessive equipment noise may distort the acoustic signals and compromise accuracy.

- Sand-detector readings should be **correlated with other monitoring tools**, such as corrosion coupons or wall-thickness scanning technologies, to validate the data and identify potential erosion points.
 - Wells should be completed with **effective sand control systems** in place to minimize formation damage and prevent excessive sand influx.
 - Routine checks should be carried out to ensure that detectors, data-collection units, and software components are functioning optimally.
-

5.3 CONTRIBUTION TO KNOWLEDGE

This study provides practical insights into the real-time monitoring of sand production using non-intrusive acoustic sensors. As sand-laden fluids encounter bends in the pipeline, particle inertia leads to wall impacts that generate measurable vibration signals. Understanding these signals makes it possible to detect sand production early and accurately.

Key contributions include:

- Demonstration of the effectiveness of acoustic sand detectors in distinguishing sand-impact signals from crude-oil background noise through time-frequency analysis and digital-filtering techniques.
- Evidence that high-frequency vibration sensors can reliably monitor sand production in real time without the need for intrusive equipment.
- The study reinforces the usefulness of combining **signal baseline analysis** with **percentage-deviation evaluation** for practical field monitoring.
- The consistency between the two analytical approaches used provides a framework that field operators can adopt for sand-management decisions.
- The findings contribute to the broader understanding of sand-signal behaviour in pipeline systems and provide groundwork for refining mathematical models of real-time sand-production estimation.

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