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Investigation of Mud Related Wellbore Problems in Drilling Well-A in the Niger Delta Region

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ABSTRACT: *Wellbore instabilities due to mud related issues during well construction in the wetland Niger Delta region were analyzed, reviewing well A as a case study. Time distribution plots and activity break down summary were evaluated for the candidate well. From the analyses, drill bit and bottom hole assembly balling, largely due to soft sticky and reactive gumbo shale with high swelling and dispersive tendencies in the mud system, severe down hole losses, hole pack off, pipe stuck potentials and kicks are some likely mud related challenges often encountered drilling in the Niger Delta region. Consequent upon which there would be reduced rate of penetration, tight spot, increased torque and drag, as seen in well-A. The drilling fluids play pivotal roles in oil extraction processes as their type; design and formulation determine the ultimate success of the entire drilling operation and overall production performance of the well. A poorly designed mud system may trigger wellbore instability that could lead to non-productive time, loss of drilling equipment, even loss of the entire well, kick and blowout scenarios due to loss of primary and secondary barriers. Formation damage may occur, which ultimately leads to reduction in permeability and poor well performance,*

KEYWORDS: reactive gumbo, torque/drag, wellbore instability, non-productive time, well performance.

INTRODUCTION

The formations of the Niger delta region are the marine Agbada formation, the petroliferous Akata formation and the Benin continental sand (sandstone and unconsolidated sand). The basin is an intercalation of sand and shale mainly. Except for the Calabar flank which lies to the extreme Northeast of the Niger Delta basin with high carbonate content due to limestone deposit. Okafor *et* al., 2017 reported that 75% of formations drilled worldwide are shale formations. Shale formations are sedimentary rocks, composed mainly of clay, silts and sometimes sand particles. Shale formations range from clay-rich, weak formation to shaly siltstone highly cemented

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formation (Shaughnessy *et al*., 1999). Sedimentary rocks usually contain fines loosely attached to rock surfaces. These fines when released from the rock surfaces, migrate, and plug pore throats resulting in constrictions, thereby reducing the rock permeability. This may also occur in reservoirs with low consolidated sands and heavy oil (Fallah and Sheydai, 2013). Shale is most susceptible to wellbore instability, over 90% of wellbore problems during and after drilling occur in shale. Clay minerals such as smectite, illite and a mixed layer of these, with high cation exchange capacity (CEC) are prone to swelling and dispersion (Li *et al*., 2012). This is compounded by the affinity and extra ordinary manner in which they take up water and gets hydrated/swell. The troublesome nature of these clay minerals are due to the weakly bonded inter layer cations with swelling and dispersive capabilities.

Generally, stability of the wellbore during drilling depends largely on the interactions between the drilling fluids system and the exposed formation; these interactions cause pressure variation around the wellbore (Azim, 2017). Wellbore instability in the Niger Delta region can constitute nuisance and undesirable conditions when the chemical composition of formation fluid, shape and structural integrity of the near wellbore region are compromised. Especially so with poorly designed drilling fluids, with high rate of fluid filtration into the formation. This causes the development of a thick, soft and incompetent mud cake across permeable formation. This gives rise to an increase in the contact area between the drill string and formation, causing wellbore/hole instabilities like differential sticking, where the drill string cannot be moved or rotated along the axis of the wellbore (Islam and Hossain, 2020). A thick mud cake usually with drill solids (low gravity solids) embedded across a porous formation may lead to excessive torque and drag due to the high fluid loss to the formation. Torque/drag, stuck pipe occurence and casing not getting to bottom are some associated problems with wellbore closure (Aregbe, 2017). Drilling surface holes from (0- 2000ft) in this region can be dramatic, characterized by severe seepage and whole mud losses in unconsolidated sands. Unconsolidated formations are porous with little or no bond between particles. Such loose aggregate particles can pack-off on down hole tools, increase torque and drag, consequently leading to wellbore instability (Nmegbu and Ohazuruike, 2014).

Wellbore instabilities may be as a result of mechanical failure due to alteration in the earth's *in-situ* stresses, when the rocks are subjected to twists, bend and fracture and the rock stress exceeding the rock strength. Erosion due to fluid circulation and chemical interaction between the drilling fluids and formation fluids/minerals, loss of drilling fluids (whole mud loss) into the formation as a result of wellbore breakdown and hole enlargement would add to drilling days on the well, thus increasing overall costs of well delivery. A conservative yearly estimate of $1billion is lost globally due to unscheduled drilling events attributed solely to wellbore instability. Too high or too low drilling fluids hydrostatic pressure can lead to serious wellbore challenges. Inadequate mud density; when the drilling mud is unable to strengthen and support the integrity of the wellbore, resulting in movement (influx) of formation fluids into the wellbore. Uncontrolled influx of formation fluids into the wellbore can lead to a blowout, stuck pipe incident, loss of drilling bottom hole assembly (BHA), even loss of the entire well. Fracture occurs when the density of the drilling fluid is relatively more than the formation fracture pressure. Lost circulation results in the reduction of the hydrostatic head in the wellbore, this will also trigger the influx of formation fluid into the wellbore.

This paper evaluates the causes, indicators and preventive steps to tackle mud related wellbore instabilities in the Niger Delta. Precise drilling practices, good drilling parameters such as adequate flow rate, ROP, revolution per minute (RPM) and weight on bit (WOB) play crucial roles in stabilizing the wellbore. Appropriate drilling fluids design, proactive composition and choice of drilling fluids, knowledge of interaction and chemistry between drilling mud systems and formation are some solutions to wellbore instability.

MATERIALS AND METHODS

Well-A (Exploratory) which was drilled in the Niger Delta region was selected for the study. The objective was to evaluate the hydrocarbon potentials of deep 5.0, 7.0 and 8.0 fault/dip closures and associated seismic farces at depth 14,000ft–18,300ft, with deep 5.0 as the minimum achievable, with the possibility of 7.0 and 8.0 depending on formation strength and pressure profile below deep 5.0 (16,000ft), with the sole aim of proving sufficient recoverable oil volumes in well A prospect to justify an economically robust development of the entire block. Sources of data were operations summary reports, mud summary reports, well programs and deviation summary reports. Every drilling phase of the well was carefully examined, noting the actual time spent drilling, rate of penetration (ROP), flow rate, WOB, torque level and other drilling parameters. Related hole problems such as bit/BHA balling, tight spots, increased torque/drag, differential sticking, pipe stuck incident, and all other unplanned events leading to non-productive time (NPT) were monitored. Well A was drilled as an offshore, exploratory, vertical, high temperature high pressure (HPHT) well.The spud date was 30/12/02 and was drilled in five sections to a depth of 14, 090ft in 205days as against six hole sections planned to a supposed total depth of 18,415ftah.

8 ½" pilot hole section was drilled following the shallow gas procedures, using Bentonite/KCl/Polymer mud system to a depth of 6010ft, at controlled ROP of 79ft/hr; WOB = 10-20klbs; Mud Weight (MW) = 0.430-0.500psi/ft.; loss rate = 2-4bbl/hr. The 26" hole opening section from 549ft to 6010ft was with same mud system (Bentonite/KCl/polymer). Mud weight ranged between 0.530-0.590psi/ft. Drilling this section was characterized by series of hole problems largely due to poor clay inhibition which resulted in bit and stabilizer balling, inappropriate mud weight increase leading to severe mud losses and poor hole cleaning. At 4,202ft there was increased clay dispersion in the mud system with intermittent erratic torque of 30klbs. Observed a reduction in ROP (5ft/hr) between 4747ft -5232ft with static loss rate of 25-30bbl/hr. Prepared and spotted 120bbls of lost circulation material (LCM) pill. POOH for bit change. Pulled from 5232ft to 5045ft, had 40klbs over pull picking up. Back reamed for 48hrs in order to stabilize hole. Worked through tight spot with 20klbs over pull at 4548ft and 3366ft. M/U top drive, back reamed to 3270ft. Flow checked well, had 25bbls/hr losses. POOH with BHA, observed that stabilizer and drill bit were badly balled up. Stabilizer were under gauged, tungsten carbide on

blades were worn out severely. M/U new bit and BHA. RIH with 26" bit to 5145ft,. Last stand (15ft) to bottom was reamed. Drilling (opening 8 ½" pilot hole) continued from 5232ft to 5583ft; rate of penetration (ROP) appeared to be a function of formation drilled, rather than responding to varying drilling parameters. MW was 0.478psi/ft (9.3ppg) with a continuous addition of LCM and KCl to the mud system. Drilled 26" hole section (8 ½" hole opening) to 6020ft. Finished with 15bbl/hr. dynamic loss rate. Dropped rice and circulated same out. Estimated 16.6% hole wash out. Circulated hole clean. POOH (Check trip) to 5200ft. Worked through tight spots at 5460ft, 5398ft and 5233ft. tripped in hole, tagged bottom at 5980ft (40ft of fill). Washed down and ream to bottom (6020ft). 100bbls of hivis/LCM was pumped to circulate hole clean. Static loss rate of 14bbl/hr. was recorded.

POOH wet to 5221ft, pumped slug and continued to POOH to 280ft. Changed handling equipment, retrieved 10" diverter packer and HT55 saver sub. POOH with BHA, cleared rig floor. Held pre-job safety meeting. R/U 20" casing handling gears. Ran casing as per tally. Had tight spot at 2315ft that took 520klbs to pull free. Unable to free casing pipe at 2460ft. Pulled 900klbs and slacked off 100klbs. Continued to work pipe, unable to free pipe. Established circulation at 225gpm, built 700bbls of seawater/caustic pill. Worked pipe and circulate at 800gpm with 800psi. Pumped 700bbls of pill, followed by 0.484psi/ft (9.3ppg) mud. Casing pipe came free after pumping 728bbls of mud (with seawater nearly filling annulus with 700klbs. Ran 20" casing to 4700ft. Casing got stuck. Worked pipe (900klbs up; 100klbs down). Pumped 800bbls of KCl/Caustic pill at 850gpm with 880psi. pumped and circulate 1664bbls of 0.478psi/ft (9.2ppg) mud, displacing water out of pipe. Casing became free. Ran 20"casing to 6005ft. Carried out cementing operations as per program.

17 ½" hole section: P/U & M/U BHA + bit, RIH with 5 1/2" drill pipes to 5978ft. Washed down from 5978ft, tagged cement at 5992ft. Drilled 8ft of cement, float shoe from 5992ft to 6005ft. Using same mud type (Bentonite/KCl polymer); MW: 0.473psi/ft, drilled out old rat hole from 6005ft to 6020ft. Drilled 20ft of new formation to 6040ft. Logged section. Drilled from 6040ft to 7070ft, taking survey every stand. Average ROP = 45ft/hr; flow rate = 1000gpm. Increased MW from 0.473psi/ft to 0.545psi/ft; estimated pressure@ 6779ft = 0.509psi/ft; lithology = 50:50 sand/shale composition. Drilled (sliding) to 8508ft with a continuous reduction in average ROP. ROP = 4fph; WOB = 30klbs; flow rate = 950gpm. Flow checked well, no flow. POOH (wet), had 40klbs over pull @ 8340ft. Back reamed from 8340ft to 7256ft, pumping 640gpm with 1200psi. Continued to back ream from 7256ft to casing shoe (6005ft), pumping 0.577psi/ft mud, encountering resistance every stand, up to 25klbs over pull and rotary stalling at 30klbs. Pumped 640gpm with 1200psi, flow checked well, ok. Circulated until shakers were clean, getting fair amount of cuttings from back reaming. Flow checked, ok. Pumped slug and POOH. Observed well not taking fill up at 3869ft, flow checked well, ok. POOH 4 more stands, well not taking proper fill up, flow checked well, ok. Rotated string inside casing and continued POOH to BHA, fill up Ok. Changed elevator and POOH with BHA. No balling on stabilizers or bit.

M/U stabilizer, run the remaining BHA from derrick. TIH with drill pipes to 6028ft (23ft out of casing), tagged with 20klbs down. Reamed from 6028ft to 6037ft, pumping 855gpm with 1700psi. Attempted to continue RIH, string taking 40klbs at 6047ft. Reamed from 6047ft to 8298ft, pumping 850gpm with 2040psi and 0-5klbs WOB; string torqueing on almost every stand. Estimated pore pressure =0.548psi/ft. Reamed from 8300ft to 8476ft. Had 32ft of fill. Reamed to bottom at 8506ft. Circulated and conditioned mud why raising the KCl concentration and lowering fluid loss. Breaking in new bit drilling (rotating with mud motor) from 8508ft to 8766ft; varying drilling parameters to maximize ROP, pumping 850-1050gpm with 3300psi; WOB = 0-30klbs; 50-60rpm; AROP = 14ft/hr. Had 200-300psi differential pressure at mud motor. Maximum gas at 8666ft = 19units. Dynamic mud losses up to 25bbl/hr. added 2.5ppb LCM to mud system. Flow checked well, static loss rate =5bbl/hr. Continued to drill from 8787ft to 9169ft. Had 71 units maximum gas at 8871ft; dynamic losses = 15-20bbl/hr; AROP = 27ft/hr. Attempted to increase WOB (up to 45klbs) to get 400-500psi differential, no ROP increase and string experienced bouncing and vibration. Started experiencing shocks (consistent and often severe) to MWD tool at 9110ft. Observed sudden increase in pump pressure from 3500psi to 4600psi, with no hole returns. Torque increased considerably (hole appeared pack off). Worked string (reciprocating and rotating) and stage up pump slowly in 30spm increments, ended with 3950psi at 1000gpm, while circulating pressure dropped. Metal recovered from ditch magnet: daily = 510.75g; cummulative1.271kg.

Resumed drilling (rotating with mud motor) from 9310ft to 9313ft; WOB = 10-50klbs, getting 100-200psi differential pressure at motor. ROP decreasing to +/- 4ft/hr, string torqueing at 25klbs when on bottom. Varied drilling parameters, no response. Flow checked well, static losses = 13bbls/hr. Pulled six (6) stands of 5 ½” drill pipe to 8759ft. Had a tight spot at 8900ft; pulling 10klbs over pull P/U weight. RIH to 9729ft, pumped 100bbls high weight (0.634psi/ft) viscous pill. Washed down to bottom (9313ft). Raised mud weight from 0.582 – 0.587psi/ft. Unable to drill. No additional cuttings or junk observed when pill returned to surface. Flow checked well, static losses = 13bbl/hr. POOH to casing shoe. Continued to POOH with BHA; found large washout in sub between measured depth reference (MDR) and compensated dual sensitivity (CDR). Backed out sub and L/D MWD. Pulled up last stand of BHA; found out that bearing housing on mud motor backed out of bent housing. Cleared rig floor, service top drive and handling equipment. P/U new bit, mud motor, CDR, sub and MWD; RIH with rest BHA and HWDPs to 664ft. Continued to RIH on 5 ½” drill pipes to casing shoe at 6005ft. Continued to RIH, breaking circulation every ten (10) stand to 9140ft.

Washed down from 9140ft to 9313ft (bottom). Reamed through the only tight spot encountered at 9254ft, where the string took 10klbs down. Continued to drill from 9313ft to 9372ft at a flow rate of 940gpm; dynamic losses: 15bbl/hr. Continued to drill to 10092ft. Changed drilling parameters for inclination control. AROP = 15ft/hr. Observed 500psi gradual surface pressure drop and decrease in down hole turbine RPM. Evaluated reasons for drop in pressure. POOH, looking for possible washouts. Had over pull at 10061ft, attempted to circulate slowly and pump out at 750gpm, no luck. Continued to POOH, pumping 345gpm and getting 10-40klbs over pull. Back reamed through tight spots at 10061ft, 9865ft, 9792ft 9504ft and 9254ft. Continued to POOH to 757ft, using rig tong and chain to back out connections, found wash out pipe body on stand of drill pipe above BHA. Evaluated damage to wash out pipe, L/D same. Continued to POOH with HWDPs, drill collars and MWD. R/U and tested BOPs. M/U bits to mud motor, CDR and MWD. Initialize MWD and RIH with same. Continued to TIH, breaking circulation every 15stand to 9918ft. Reamed through tight spots from 9158ft - 9178ft and at 9682ft. Reamed from 9702ft to 9918ft. Washed down from 9918ft to 10092ft.

Drilled from 10092ft to 10183ft with 0.588psi/ft. Lithology: 100% shale. Circulated hole with one pump, repairing suction dampener in mud pump #3 and swab on mud pump #2. Drilled from 10262ft to 10583ft with controlled WOB (max. 45klbs); ROP 10-30ft/hr. (21ft/hr. average). Continued to drill to 10949ft. No further increase in ROP. Circulated hole clean to change out drill bit. Took MWD survey, flow checked well. POOH to shoe. However, had intermittent over pull of 40klbs between 10850ft to 10040ft and 20klbs between 10040ft to 9570ft. Total losses = 25bbl. Continued to POOH to BHA, average loss rate during trip = 2.8bbl/hr. Inspected motor, break out bit, downloaded CDR data. RIH with BHA, shallow tested motor, MWD and reset CDR tool. RIH to shoe. Established circulation. Circulated at 700gpm; 1200psi. RIH to 10880ft. Reamed tight spots (20klbs set down weight) at 10075ft to 10170ft; 10550ft to 10634ft and 10762ft to 10790ft.Washed/reamed down from 10880ft to bottom at 10949ft. drilled from 10949ft to 11045ft at controlled WOB. Took survey and reamed stand on each connection. Pumped 20bbls of LCM every single. Maximum inclination = 1.20 degree at 11026ft, lithology: 70-100% Shale. Drilled ahead from 11486ft to 11500ft; 17 ½" section TD. Circulated hole clean with 100bbls of LCM-Hivis pill. POOH. L/D BHA. R/U wireline, logged section. Ran 13 3/8"casing as per tally. Cemented same in place.

12 ¼" section was drilled with oil based (Paradrill) mud system. Held pre-emptive information gathering in preparation for HPHT drilling. P/U and M/U assy. RIH and tagged cement at 11430ft. Drilled cement, shoe and rat hole to 11500ft. Drilled new formation to 11520ft. Established parameters and drilled ahead to 11548ft. Had persistent reduction in ROP. Varied drilling parameters to improve ROP, no success. AROP 4.45ft/hr. Continued to drill from 11548ft to 11551ft, ROP falling below 2ft/hr. Pulled back into casing shoe and troubleshoot MWD/CDR signal, without success (faulty link between CDR and MWD). Continued to drill with ROP less than 2ft/hr. Flow checked well, static. Slugged pipe and POOH from 11551ft to surface. Observed lost cutters and broken teeth on drill bit. Eight tungsten carbide insert on the wear band of the motor bearing housing missing, although bearing housing was intact. Serviced top drive system. M/U 12 ¼" mill tooth bit and junk sub on a slick assy, 5 ½" HWDPs from derrick on 5 ½" drill pipes and RIH. Break circulation and continued to RIH to 11479ft. Washed and light reamed to bottom at 11551ft. Worked junk sub between 11551ft to 11525ft. Total metal recovered 2.453kg for 12 ¼" section (cumulative). Established drilling parameters and drilled from 11551ft to 11568ft. Continued to drill to 12059ft. MW = 0.702psi/ft; WOB 30klbs; flow rate =780gpm, 90rpm; AROP suddenly increased from 11ft/hr. to 20ft/hr. Observed larger , thick cuttings at the shakers. ECD = 0.702psi/ft; max. gas = 21 units at 21005ft. Background gas 10-12 units. BHCT

(MWD) increased from 201-203°F. Estimated pore pressure increased from 0.666psi/ft to 0.697psi/ft (12.8ppg-13.4ppg). Stopped drilling to evaluate magnitude and impact of pore pressure increase. Dropped rice down the drill pipe, circulated out same. Drilled (controlled) from 12059ft to 12069ft at 10ft/hr. Circulated bottoms up and evaluated cuttings sample. Continued to get large, thick cuttings. No change in background gas, no connection gas. Raised MW to 0.707psi/ft (13.59ppg). Estimated pore pressure: 0.697psi/ft - 0.770psi/ft (13.4ppg -14.8ppg). Flushed choke manifold and mud gas separator with mud. Continued to drill from 12166ft to 12587ft. Stopped drilling due to hours on bit.

Circulated bottoms up. Took MWD survey. POOH, pumping 300gpm up to casing shoe. Back reamed through tight spots at 12284ft to 12304ft (max. pull 20klbs). Changed out bit. TIH, washed and light reamed from 12151ft to 12587ft as a precaution, no fill on bottom. Circulated bottoms up. Maximum gas = 51.5units; MW in: 0.715psi/ft (13.75ppg), ECD: 0.746psi/ft (14.34ppg); BHCT: 179°F. Control drilled to 13273ft at 20ft/hr. Exercising caution due to being in the area where well Koronama #2 took kick. Background gas: 48units; last connection gas: 96.6units. Lithology: 100% shale (Silty). Drilled ahead. Prior to connection at 13549ft, reamed 3 times to work out 10klbs torque. Attempted to resume drilling, gas increased from background of 35units to 104units. ESD recorded at 13507ft: 0.727psi/ft (13.98ppg). P/U to circulate out gas; hole packed off and string stuck with bit +/- 3ft off bottom. Worked and jar pipe, unable to free string. Maximum pull: 600k indicated (250k above string weight – 85% of pipe rating). Continued to work stuck pipe while awaiting wireline and fishing tools. Carried out wireline operations. POOH with wireline-shot misfired. Continued to jar (hole packed-off still). When putting 30klbs left hand torque in string, weight dropped to 350k and all torque on string was lost. Pulled up 10ft, observed pipe was freed. Break circulation with 400psi at 30spm (P/U=370k; S/O= 360k). Staged pump slowly, circulated bottoms up. Pumped hivis-weighted pill, circulated 2X hole volume. Average background gas: 20units. Maximum gas: 120units, with no mud cut. Pumped out of hole from 13399ft (top of fish: 13431ft). String appeared to have backed off in connection between non-magnetic drill collar and steel drill collar (length of fish: 120.55ft).

RIH with 5 ½” drill pipes, tagged top of fish at 13428ft. Set cement plug from 13419ft to 12869ft. Tagged top of firm cement at 12775ft. Dressed top of cement plug, drilled from 12775ft to 12890ft. WOB: 10k, ; 60rpm; 750gpm; ROP: between 90-120ft/hr. Drilled from 12890ft to 13284ft; attempting severally to kick off cement plug. Surveys indicated no success kicking off. Circulated bottoms up. Drilled from 13248ft to 13300ft for pockets to run logs. R/U baker-Atlas wireline and vertical seismic profile (VSP) equipment, M/U tool string. RIH to 13266ft and logged section up to 6000ft, taking check shots. Drilled to section TD at 13304ftah (13300TVD). Pumped hivis pill, circulated bottoms up with 700gpm. Pumped out of hole without rotation from 13304ft to 11850ft (400gpm, 1060psi) with no resistance. Flow checked well. Continued to POOH to 11381ft (casing shoe). RIH from 11381ft to 13262ft. Washed down to 13304ft (TD). Pumped hivis pill and circulated hole clean.

8 ½" Hole section: Cleaned out rat hole to 13308ft. Paradrill (synthetic base fluid) mud system was used to drill this hole section. Drilled out new formation from 13304ft to 13324ft. Circulated hole clean and conditioned mud. Mud weight: 0.769psi/ft in/out. Carried out leak off test. Drilled from 13324ft to 13333 in HPHT mode. Continued to drill to 13835ft, observed 64 units (1.3%) of gas at bottoms up. Lithology: 90% shale; 10% sand. Drilled from 13835ft to 13889ft. Flow checked well. Circulated bottoms up while reciprocating string. Observed hole packed off at 13873ft. Established circulation and back reamed. Experienced series of pack off and pipe stuck events, each time freeing string down. Pumped out of hole from 13864ft to shoe at 13252ft. Circulated and weighted up mud from 0.769psi/ft to 0.848psi/ft. Washed down from 13659ft to 13820ft. Reamed tight spot from 13820 to 13889ft. continued to drill from 13889ft to 14038ft applying full HPHT procedure. Circulated bottoms up prior to taking surveys and making connections. Had 222units of gas (4.5%) at bottoms up. Lithology: 80% shale; 20% sand. Drilled from 14052ft to 14090ft. Performed Dummy connection and circulated bottoms up. Observed a kick, after pumping 4040 strokes, pit gain of 6bbls. Shut in well and monitored casing and drill pipe pressures. Final pit gain: 10bbls. Well was shut in on the upper pipe rams. Bled off 2bbls of mud from the annulus, observed pressure for 10 minutes; DP: 1300psi; casing: 1550psi. Bled off 2bbl of mud in stages, observed pressures for 10 minutes, recorded same. Commenced well kill using the Drillers method. Kill rate: 15spm; 490psi slow circulation rate (SCR) pressures; mud weight: 0.848psi/ft. SPP: 1950psi; Choke pressure: 1500psi; Strokes: 9861. After first circulation, SICP: 1580psi, SIDPP; 1440psi, Noticed gas cut on mud returns. Monitored pressures while weighing up mud to 0.92psi/ft. Continued well kill with reduced pump rate of 15spm, holding 1500psi constant on the choke. Monitored returns on trip tank for one hour. Established down hole loss rate: 75bbls/hr.

Reduced kill rate to 10spm and continued well kill, while dosing LCM (Calcium Carbonate fine + medium Ultraseal at 10ppb each) into the active system. Loss rate reduced to 40bbls/hr. continued to pump and displaced string to 0.92psi/ft mud. SIDDP: 1150psi, SICP: 1560psi; with 0.92psi/ft mud at the bit, shut pumps and closed choke. Monitored pressures while weighing up active system to 0.92psi/ft. Continued to pump 0.92psi/ft mud at 10spm, maintaining a constant choke pressure at 650psi. Had 100% losses. Stopped pumping, shut in well. SICP: 640psi, SIDPP: 760psi. Monitored well pressure while preparing batch tank to mix 100bbls Frac-attack pill. Pumped 100bbls of Frac-attack at 1bbl/min, followed by 10bbls SBM. Initial pressure, SICP was 700psi. Monitored well pressure. SICP: 750psi, SIDPP: 1650psi. Shut in well. Continued to circulate 0.956psi/ft SBM at 1bpm through an open choke with 950psi on drill pipe, as a precaution for handling bottoms up. Conditioned mud to lower rheology. As mud was contaminated by rain water, had increased viscosity and reduced density in the active pits. Conditioned mud in the active pits. Had series of circulations and mud conditioning to ensure that the well was stable. Reamed from 13963ft to 14032ft at 90ft/hr. no resistance, no losses. Gas from connection (pumps off) was 319units, prior to bottoms up, gas rose to 393units. Well was shut in, pump staged up to 10spm and circulated through open choke. Observed erratic pump pressure due to fluid starvation. Shut in well, troubleshoot mud pumps. Flushed lines and cleaned pump suction screens.

Held pre-job safety meeting, prepared for stripping operations. Stripped out of hole 14000ft to 13937ft (pumped 2bbls in well). Opened well, pumped at 20spm; reciprocated and rotated string at 20rpm. Maximum gas: 188units (no gas cut mud). Reamed to TD (from 14032ft to 14090ft), with no resistance, no losses and no fill on bottom. Circulated bottoms up (well opened) pumping 20spm. Maximum gas reaming to TD: 179units, background gas: 125units. Samples from bottoms up at TD: shale 60%, sandstone: 25%, Frack-attack: 25%. Circulated out gas, reciprocating and rotating string at 20spm. Shut in well and monitored pressures for 1hr while preparing equipment for logging. R/D logging tools. Pumped out of hole at 8minutes per stand, pumping 20spm. Mixed and pumped 44bbls of cement (plug) from 14090ft to 13590ft. Washed down from 13069ft to 13778ft, limiting running speed to 20min/stand at 4spm (185ft below expected TOP for plug #1). No indication of cement, no mud contamination. Circulated bottoms up at 10spm, had losses from 28bbl/hr to 42bbl/hr. Mud weight in/out: 0.967psi/ft. Stabilized well by pumping 50bbls LCM with the rig pump at 1bbl/min. Set another plug at 13722ft. Tagged TOC (plug #2) at 13616ft. Stripped out of hole, pulled stand at controlled speed to 3249ft. Performed kick drill. Observed thick mud and cement in tool joint. Attempted to circulate, no success. Series of wellbore instabilities followed, ranging from severe losses to influx of formation fluid into the wellbore. Consequently, cut 9 5/8”, 20” and 30”casing. R/D equipment. End of well operations and well abandoned. Total days spent on well was 205.

RESULTS AND DISCUSSIONS

Time Distribution Plots

Table 3.0 gives the time distribution breakdown. It gives an insight into the time spent on each activity as percent total of total time spent. Figure 3.0 shows the time distribution plots analysis drilling Well A. These activities account for the cumulative time (205 days) on the well as a result of wellbore instabilities ranging from down hole losses, bit and stabilizer balling, increased torque/drag, pipe stuck event, pack off, excessive dispersion of cuttings and kick.

Table 3.0: Time distribution analysis

Well A Drilling Activities	Percent (%) of Total Time
Drilling	17.98
Circ./Conditioning Mud	20.53
Tripping	26.83
Rig Services	2.37
Casing Run	7.86
Reaming	0.58
Pipe Stuck	0.58
Plug Back	1.58
Fishing	0.69
Logging	2.64
Survey	17
Others	1.36

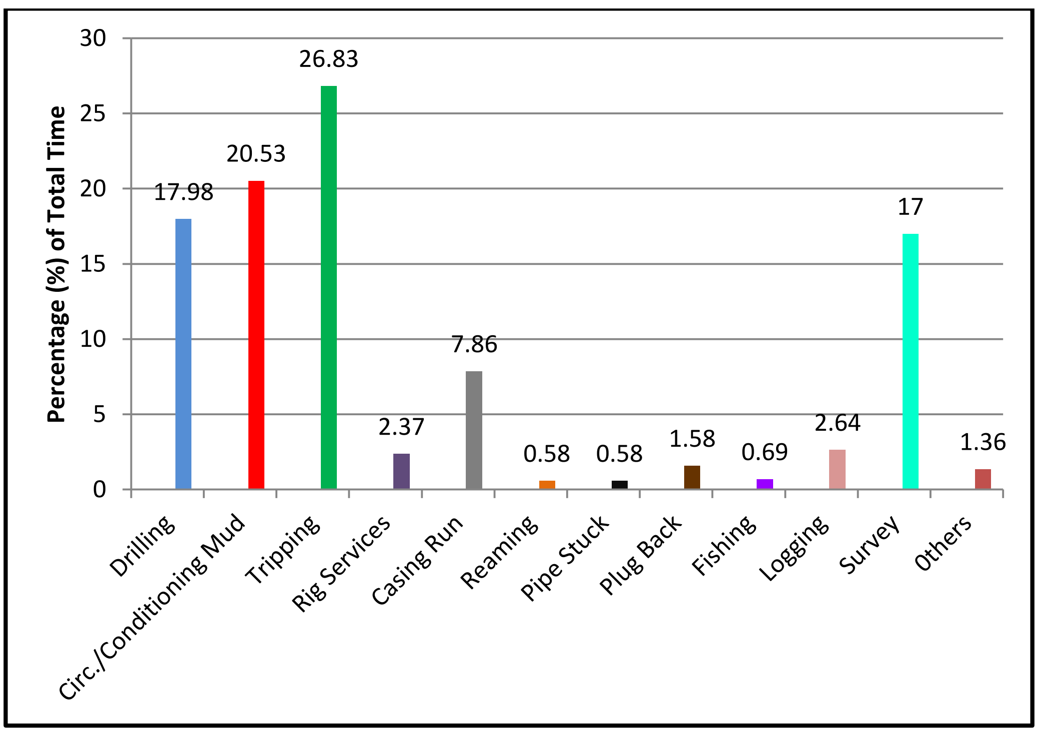

Figure 3.0: Well A Time Distribution Plot

From the analyses above, actual time spent drilling Well A was 37days. Circulation/mud conditioning/open hole exposure time took 42days. Incessant tripping in/out of hole took 55days, while running casing took about 16days. Bulk of the time was spent on unplanned events and well A was eventually abandoned. As seen in the course of well A construction, the drilling fluid performance can affect the overall well construction costs through wellbore instabilities which are major sources of well problems. Hamoodi *et al.,* 2018 reported that the cost of drilling fluid is about 20% of the total tangible costs of well construction. The selection of the best drilling fluids to meet the conditions of the formation to be drilled with minimal well costs is paramount, considering the formation lithology, temperature, pressure and environmental considerations (Okoro *et al.,* 2018; Amorin *et al.*,2015).

Drilling in the Niger Delta Region

Usually in the Niger Delta region as noticed in well A construction, 26” hole section (top hole) is often characterized by severe seepage & sometimes whole mud loss in unconsolidated sand. For surface hole, increasing mud density is very inconsequential because of the loose and unconsolidated sand. It is advisable to control drill & keep annular mud weight below 0.494psi/ft (9.5ppg) and sand content in the drilling mud below 5% by running mud cleaners. Dump/evacuate sand traps at intervals to minimize sand build up along the flow line and to reduce sand content in the mud. Proactively treat (pre-treatment) the mud system with 5ppb $CaCO_3$ fine and medium and 5ppb of micro cellulosic fibre (LCM) and per stand treatment of 2 X 25kg sacks of $CaCO_3$ fine and medium. These would help in bridging the loose particles, fluid loss control, wellbore strengthening and formation of good/competent filter cake. Maintain MFV: 70–80 sec/qt ; YP > 25 & MBT > 25 ppb which will have plastering effects. Optimize use of shaker screens on the primary shakers; use the finest shaker screens that can handle the rig (pump) flow. Ensure to change torn screens, monitor screens every connection.

Drilling 17 ½” section of well A was characterized by hole problems due to poor inhibition, poor hole cleaning and series of tight spots. In the Niger Delta region, this section is often laden with drill bit and BHA balling in soft sticky (gumbo) clays; large mud/clay balls and rings that can plug the annulus, the flow-line and shale shakers screens. Therefore, prior to drilling into the gumbo clay zone, typically from between 1200ft to 1500ft, the mud system must be converted to KCl/Polymer inhibitive water based mud system that can give ionic inhibition, clay encapsulation and preventing large mud balls or rings from forming. Treat the circulating mud with between 1 to 3% v/v drilling detergent (surface active agent) to help mitigate inter-particle attractive forces and sticky tendency of clay. Slick up the mud with 2-6 ppb lubricant/shale stabilizer or paraffin to help lubricate and reduce frictional forces (torque & drag). Optimize flow rate to assist hole cleaning. Optimize ROP to reduce annular loading and ECD build up. RPM must be kept between the defined range to maintain concentricity of the BHA with the well bore and cuttings agitation. Proper bit selection such as the use of long tooth tri-cone bits to drill soft, sticky clay formations better (gouging and scraping) than short tooth bits which drill by impact, and tend to ball up quickly in soft /sticky formations. Good drilling practices and proper drilling Parameters such as WOB (too high WOB causes bit balling in sticky formations), Rotary speed (RPM) and adequate mud

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flow rate (insufficient flow can increase rate of bit/stabilizer balling). Besides bit/BHA balling, water sensitive clays (Gumbo) can cause flowline to overflow and decrease the encapsulating property of polymers such as PACs and PHPA. Gumbo can cause tight spot, high torque & drag, slow ROP, excessive hydration and dispersion of cuttings, pack-off, tool plugging, higher ECD potentials, loss of circulation and pipe sticking tendency. Adequate flow rate (optimized hydraulics), good mud chemistry, pumping caustic/detergent pill in tandem with hivis, sweep and seal pill are recommended for optimal mud performance.

12 ¼" section was drilled using synthetic based mud (SBM) with its inherent thermal stability, excellent inhibition, good solids tolerance, relatively easy to maintain, high lubricity properties; will help mitigate frictional forces in this plastic and difficult-to-drill lithology. Oil based mud is widely used to drill through troublesome most water sensitive shale formations (Ahmed and Kalkan, 2019). Drilling this section was challenging for three reasons; persistently low AROP, drilling through a fault at 11700ft; got back large, thick irregular shaped cuttings at the shakers, pipe stuck incident and hole pack off. Sudden increase in rate of penetration (ROP) was also observed due to loss of pressure overbalance. The following recommendations would suffice;

For wellbore stability, adjust mud weight where necessary to balance formation pore pressure and near wellbore stresses, ensure sufficient overbalance to avoid hole pack-off and stuck pipe events. Ensure sufficient inhibition based on cuttings integrity (water phase salinity >250,000ppm) to provide osmotic force to influence the water activity of the mud system. Maintain good electrical stability (ES) >400volts, fluid loss should be <5ml (all oil), to reduce filter cake thickness. Ensure proper/optimized hydraulics (pump rate); maintain proper 6 rpm in respect to hole size for effective hole cleaning, ensure good rheological properties at all times; although the viscous properties and the particle size distribution of weight up materials are crucial in controlling the stability of the wellbore and the density of the drilling mud, drilling fluid that is too viscous or too thin would lead to wellbore problems. It is important to observe proper circulation practices before connections and before tripping. Pump appropriate hole sweep at predetermined intervals and observe shakers at every bottoms up and ECD properly monitored for good hole cleaning. Wiper trip as needed to check hole condition, especially after long period of sliding. Change BHA/bit where necessary. Carry out mud checks at regular intervals to ensure that the mud/hole is in good condition. Use wetting agents/secondary emulsifiers when adding barite (increasing mud weight) to avoid water wetting of the barite. Mud weight should be maintained as wellbore would allow, especially when drilling through depleted reservoirs. Reduce connection time and pump sweep and seal pill to seal thief zone. For loss circulation problems; avoid excessive trip speed to prevent swab and surge. Monitor hole closely and pump LCM when necessary. Ensure good mud formulation so as to form thin, tough and impermeable filter cake. Increasing the mud density should attract an increase in oil water ratio (OWR). Water is a more expensive contaminant than drilled solids. In this case (well-A), rainwater was the source of contamination. This led to oil water ratio decrease and poor emulsion stability, conditioning the contaminated mud would increase the total drilling cost.

Drilling the 8 1/2" section equally had instabilities ranging from hole pack off, tight spots, 100% losses and kick. Early detection of kick, as recorded in well A (gain of 6bbls) upon flow check was quite commendable.

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
BHCT	Bottom hole circulating temperature
ECD	Equivalent circulating density
ESD	Equivalent static density
GPM	Gallons per minute
HWDPs	Heavy weight drill pipes
Hivis	Highly viscous pill
M/U	Make up
MWD	Measurement while drilling
POOH	Pull out of hole
PPB	Pounds per barrel
P/U	Pick up
R/D	Rig down
RIH	Run in hole
SICP	Shut in casing pressure
SIDDP	Shut in drill pipe pressure
S/O	Slack off
SPM	Strokes per minute
TD	Target depth
TVD	True vertical depth
TIH	Trip in hole
TOC	Top of cement