Evaluating the Impact of Sand and HBS&W on Crude Oil Production at Egbema Field of Niger Delta

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Abstract
Sand and HBS&W (High basic sediments and water) production is a serious problem in many oil and gas assets worldwide. Both can drastically affect production rates; damage downhole, subsea, and surface facilities, increase the risk of catastrophic failures; and cost operators tens of billions of dollars annually. Water handling costs are high and sand management is complicated that cannot be addressed by a one-size-fits-all approach. Operators have developed multifaceted approach, exploiting the vast array of technologies and expertise available to manage this problem. This study investigates the economic impacts of sand and high-water production at Egbema field in Niger Delta. The selected wells have case history of aggravated problems of sand and water production which has caused intermittent closure over long periods of time. Historical production and well-test records from these wells were analyzed and diagnostic plots were developed to examine the extent and severity of elevated sand and water-cut problems. The post-intervention success rate of the last workover operation was also investigated economically to ascertain the economic viability of the operations. And it was observed that the operation was a success and provides huge financial benefit to the operator.

Keywords: BS&W, Diagnostic plots, Sand, economics, Niger Delta, unconsolidated sandstone, work-over

1. INTRODUCTION

Sand production is the disaggregation of formation due to in-situ stress, fluid flow and other factors inherent in the reservoir that promotes sanding [1]. It is widespread during production of hydrocarbons from unconsolidated sandstone reservoirs [2]. This is particularly a characteristic of most reservoirs in the Niger Delta following their shallow depths of completion below 10,000ft. The process of disintegration develops progressively in three stages: failure of rocks surrounding an open hole or perforation from which free sand grains are generated; detachment of sand grains from failed materials, and transport of those free grains by the effluents into the wellbore and up to surface. Sand failures are likely caused by shear, compressive, tensile, and cohesive stresses.

In competent (i.e consolidated) formations, sand production is due to shear failure while for weak and unconsolidated formations, sand production occurs when the drag forces caused by flowing fluid exceed the natural inherent cohesion of the formation [3]. The cohesive binding forces holding the formation particles together could be broken when the flow rate exceeds its critical value. When this in-situ cohesive binding force is exceeded, fines dislodge from their matrix structure and start migrating with the flowing fluids. Experimentally, it has been shown that reduction of hydrocarbon flow rates reduces fines from migrating in reservoirs; howbeit, this is not feasible because of the daily increasing demands of crude oil [4].

The effects of sanding inadvertently include loss of oil production and hence, revenue due to formation sand and fines plugging or reducing well productivity. In addition to damaging pumps and downhole equipment, erosion of casing and surface facilities may also occur. Sand failure can cause wellbore-stability problems, reduced production, and in extreme cases, loss of wells and prolong production downtime. Disposal of produced sands is costly because of strict regulations due to concerns on safety and the environment.

Water, on the other hand, affects every stage of oilfield life from exploration, through development, production and finally, abandonment. As oil is produced from a reservoir, water from an underlying aquifer or from injectors eventually will be mixed and produced along with the oil. This movement of water through the reservoir, into production tubing and then surface processing facilities, and eventually extracted for disposal or injected for maintaining reservoir pressure is termed water cycle or the vicious water cycle [5]. Produced water can be classified into two categories: bad and good water [6]. Produced water that flows into the wellbore from a path different from the path of oil production and does not result to incremental oil production is termed bad water. Whereas water from the aquifer that helps to sweeps hydrocarbon oil and contributes to incremental oil production is called good water [7].

The hydrocarbon industry is constantly looking for economic ways to improve production efficiency. Water control services are proving to be one of the fastest and least costly routes [6]. The economics of water production throughout the production life of a well/reservoir depends on several factors such as total flow rate, production rates, oil gravity, water salinity, and the ultimate disposal method for the water produced. Operational expenses including lifting, separation, filtering, pumping and reinjection, add to the overall cost.

Understanding the causes of sand and water production in a field helps to accurately predict sanding and rates. It also helps to overcome the difficulty of determining whether control is required in areas where there is little or no production experience and where reservoir factors or operating conditions are different from previous experiences.

This work is a case study that investigates the impact of sand and water production and a post-intervention performance of Field ND L/S which is prone to excessive water and sand production. This is achieved through post evaluation of the amount of water and sand production after a period and followed by detailed economic analysis.

1.1 ASSET DESCRIPTION

For data confidentiality, the case study Field shall be assigned the name ND. ND is a field located some 75 km North of Port Harcourt Niger Delta, that was discovered in 1965. The field currently has 21 wells drilled, penetrating seven hydrocarbon-bearing sands (6 oil and 1 gas reservoirs) between 5900 and 8500 fts. The reservoirs are rollover anticlines, bounded to the north by a major boundary fault and by an erosive clay-filled channel to the east. The field came fully on stream in August 1974 at an initial offtake of 5 Mbopd. During the period 1974-1979, production from the 15 drainage points in the reservoir peaked at 32 Mbopd.

This work investigates 4 of the 7 reservoirs in this field. Again, for the purpose of confidentiality, these reservoirs are assigned the nomenclature A1, A2, B1 and B2 respectively. ND_A L/S was completed in May 1967 as a Two-String-Dual (TSD) oil producer on the A1 and A2 sands without top packer and Surface-controlled Subsurface Safety Valve, SCSSV. Both intervals were consolidated for sand control purposes. Both intervals were also thought not to be in communication as at completion. The upper interval (7898-7904ftah) produced up to a maximum rate of 3000bopd with a gradual increase in sand production that subsequently led to choke size reduction in April in 1972. The attempt to re-consolidate this interval on the short string with eposand in 1973 was not successful. The Short string and the annulus were confirmed plugged with epicote after the chemical consolidation operation. Well intervention history however, showed that the well became a casing producer and the short string flow line was hooked up to the annulus.A storm choke was installed in the short string. The last pressure taken on this string was CITHP=220psi before it was secured on 27th May 2006. The deeper interval (7968-7974 ftah) produced up to 3200BPD. Continuous bean up from initial bean size of 36in 1972 to bean size 72in 1979 led to water breakthrough in the deeper A1 interval. Subsequent bean down attempts had little or no effect on the volume of water production. The interval was reported to quit in 2000, which set the motion for investigation. During nitrogen lifting activity of May 2003, the interval was confirmed watered. The interval produced 100% water throughout the two-day lifting period.Reservoir Saturation Test, RST conducted in 2004 shows that the perforations are completely flushed. The well was killed/secured in May 2006 by installing a PX plug at 7831 ftss and a 27/8" Non-return Valve (NRV) in the tubing hanger. The last production test in March 2000 shows production of 1640blpd, GOR of 924scf/bbl, BSW 29% and THP 760psi on bean 32/64". A workover operation was carried out in 2015 and the well was recompleted as a Two-string-multiple (TSM) on the A1 and B1 with the B2 behind sleeve.

The well was successfully recompleted as a two-string multiple (TSM) producer with the B2 (behind sleeve) and A1 sands on the long string and the B1 sand on the short string with SCSSV's installed on both strings. B2 and B1 sands were gravel packed. The operation took a total of 59 AFE (authority for expenditure) days to complete as against the planned 33 days largely due to epicote bonding of the tubing and casing strings that prevented their easy retrieval. This was a shortfall of the unsuccessful episand consolidation operation performed in 1973 and is a pointer to the fact that care must be taken when selecting the course of action to take when conducting workover operations for sand control. The total project cost was estimated to be $11.8MM for the 59 days.

2.0 METHODOLOGY

To investigate the impact of sand and water on production, different pre- and post-performance evaluations of the wells was carried out. Raw field data were obtained and used to evaluate the performance and parameters delineated in different groups as they contribute to (or affect) sand and water production.

The pre-performance gives insight into the current operating conditions while the post-performance evaluations investigate the impact of the interventions to curb excess water and sand production. The efficiency of the recompletion job was determined and parameters that directly affects sand and water production for control purposes was ascertained. An economic analysis was also performed to determine the profitability, or otherwise of the intervention work.

3. RESULTS AND DISCUSSION

As at June 2016, the well was producing 800 bopd from the short string, ND/S_B1, with 0% BSW and THP of 700psi; while the long string, ND/L_A1 produced 360 bopd with 60% BSW at a tubing head pressure (THP) of 150psi as shown in Table 1. Obviously, these values do not represent the potential of the well as the activities of pipelines vandals have scupper production from the field.

Table 1: Average Production Data obtained from Reservoirs A1 and B1

S/N	PROPERTIES	SAND A1	SAND B1
1	Gross rate	900 bopd	800 bopd
2	BS&W	60%	0%
3	Net oil rate	360 bopd	800 bopd
4	Average net output from ND well	1160 bopd	

Figure 1 is the bean performance plot showing the gross liquid production rate and bean size against time. Expectedly, as the bean size increases steadily to a maximum of 72%, the gross production rate also increases. However, due to high BS&W, the bean size was decreased from 72 to 32 % and the well shut down December 31, 2001 when there were no improvements in the cumulative oil production.

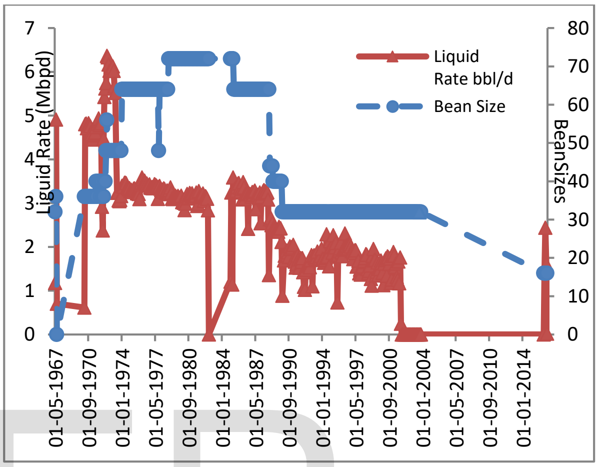

Fig. 1. Plot of Liquid Rate (bpd) and Bean Size against Time

The increase in water-cut can best be visualized in Figure 2. Figure 2 is the performance plot of oil rate, water-cut and sand cut against time. From the plot, at the early stages of production, the water cut was zero and this gives the highest oil production rates in the range between 5000 to 6200 bopd. As the water-cut increases to values between 70 to 85%, sand disengagement and subsequent sand production was initiated, leading to a drastic drop in oil production.

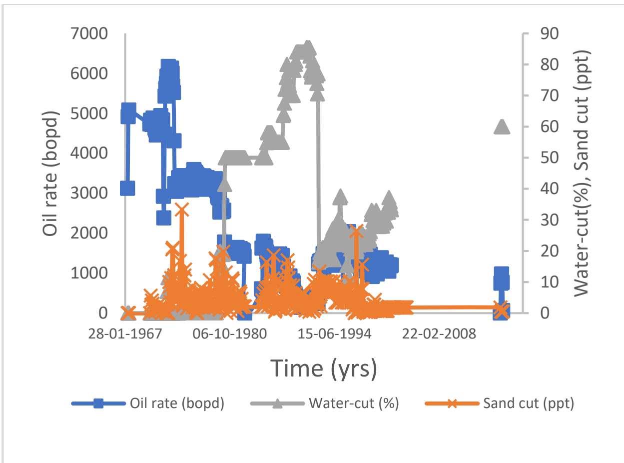

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Fig. 2. Performance plots showing oil rate, water-cut and sand-cut against time.

At the early-life period of the wells, there was no sand production encountered. The bean size exhibits a direct relationship with sand production as shown in Figure 3. Thus, sanding increased at higher bean sizes and reduced as the bean size is reduced. Both mechanical and chemical consolidation efforts to curtail the high sand-cut yielded no significant effect. However, recompletion with Gravel Packing in 2015 drastically reduced sanding to a manageable level.

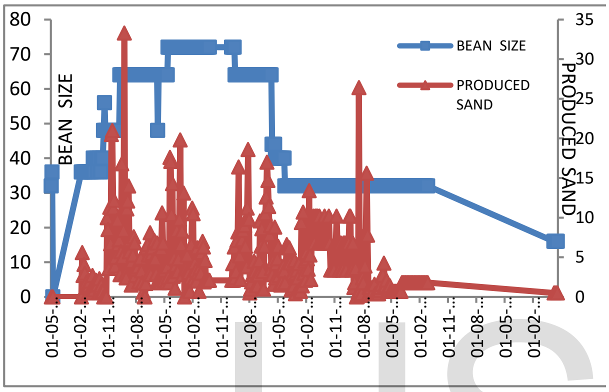

Fig. 3. Plot of Bean Size and Produced Sand (ppt) as function of Time

Like in the case of sand, water production was non-existent in the early-life period of the well. However, with steady beaning-up, water inflow increased in direct proportion with cumulative oil production as shown in Figure 4 up till the water break out in sand A1. As production from this sand was shut-in, a sharp drop in water-cut was observed even though the direct relationship with cumulative oil produced continued.

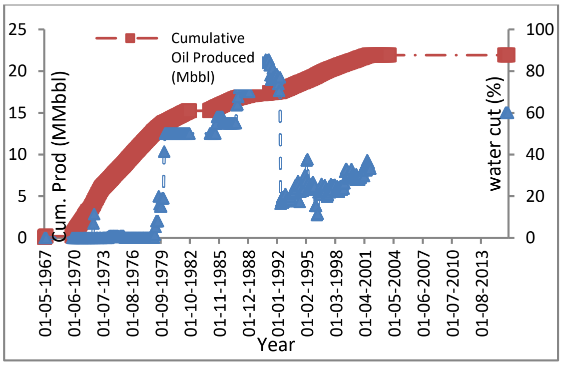

Fig. 4. Plot of Cumulative Oil Produced (MMbbl) and Water Cut as a function of Time

Figure 5 shows that although at early stages production between May 31, 1967 to April 30, 1970; both sand and water production were zero, by May 31, 1970 sanding has been initiated while the water cut remains zero percent. This implies that water-cut and sand production exhibit an inverse relationship throughout the life of the well as shown in Figure 5. This is in contrast with some earlier studies [8],[9],[10], that suggests that there exist direct instead of inverse relationship between water-cut and sand production. This is premised on the fact that water is a universal solvent and the changes in the wettability of the reservoir rock results in the weakening of the binding forces of the rock grains and thus, their disengagement. For the fact that sanding occurred prior to the commencement of water production suggests that such investigations and inferences need further clarifications; and thus, an affirmation that both events do not relate to each other and sand production may initiate prior or post-water breakthrough [11], [12].

The inverse relationship is made clearer in Figure 6 where it was obvious that at early stages of production, higher oil production rates correspond to zero water-cut, but sand production continued irrespective of continued increased in water and oil production. Hence, it can also be deduced that there is no relationship between oil production rate and sanding, although, high sand production has the tendency of reducing the near wellbore permeability by plugging the completions and thus, the tendency of reduced oil production. Water production have inverse relationship with oil production rate because of the reduced relative permeability oil following the incursion of water into the reservoir that was originally immobile [13].

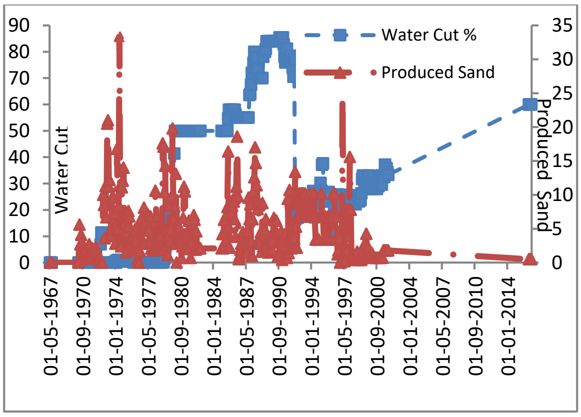

Fig. 5. Plot of Water Cut and Produced Sand (ppt) as a function of Time.

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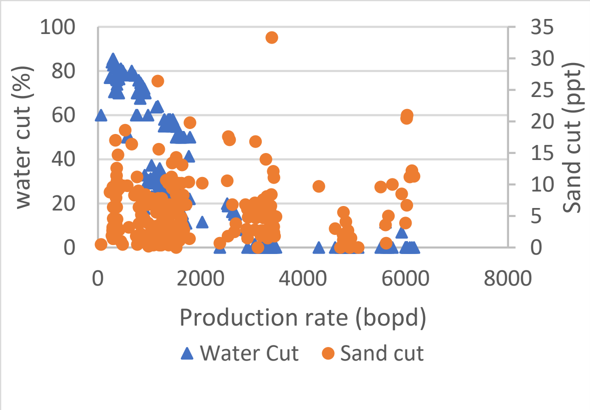

Fig. 6. Plot of production rate versus sand cut and water-cut.

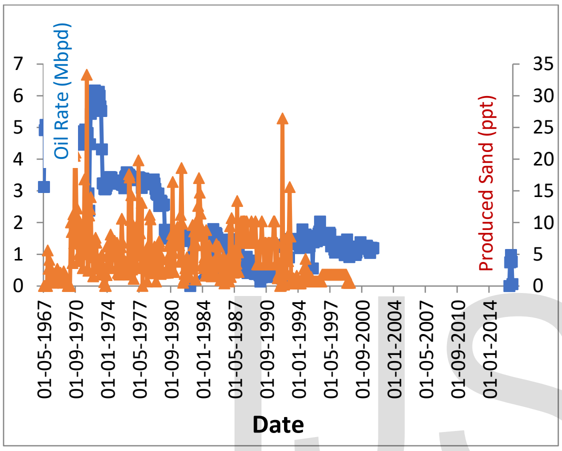

Fig. 7. Plot of Oil Rate and Produced Sand as a function of Time

4. ECONOMIC MODEL

The economic model was developed with Microsoft Excel spreadsheet using data shown in Table 2 while the associated production profile for this case is shown in Figure 8. In this model, peak production was assumed to plateau for 7 years before exponential decline sets in at 8% per annum until production reaches economic limit. The forecast was done for 20 years using 330days per year to give room for all unforeseen deferments.

Table 2: Input Data for Economic Model of ND L/S Workover Operation

S/N	Input	Quantity	Unit
1	Initial Oil Rate	1160	Bopd
2	Time to Peak	2	Years
3	Peak Production	1300	Bopd
4	Production	330	Days
5	Oil Price	50	$
6	Total CAPEX	11.8	$MM
7	Production OPEX	3	$/bbl
8	Discount Rate	13	%
9	Royalty	20	%
10	NDDC Levy	3	%
11	Education Tax	2	%
12	Petroleum Profit	85	%
13	Investment Tax	10	%
14	Well life	20	Years

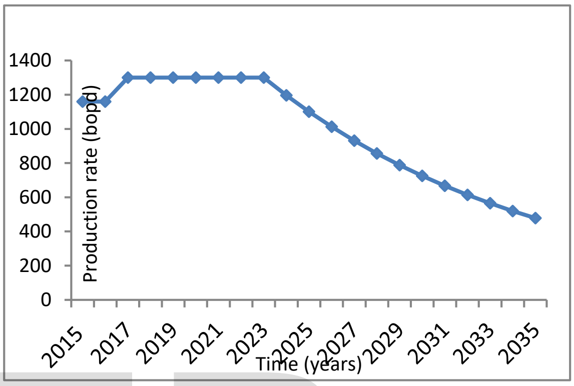

Fig. 8. Production profile from ND L/S post-intervention forecast.

Table 3 are the results from the economic analysis. The total net cash flow is $34.65MM which culminates to a net present value (NPV) of $84.66MM at 13% Discount rate. A positive NPV is an indicator that the project is economically viable [14]. The bounty internal rate of return (IRR) value of 54.53% also supports this fact. The total oil production for the projected period of 20 years remaining life of the well is 6.6MMbbl, and this is expected to yield a Gross Revenue of $330MM at an average oil price of $50/barrel.

Table 3: Parameters/Indicators from Economic Model of ND Well L/S Workover Operation

S/N	Output/	Quantity	Unit
1	Total Net Cash	34.65	$MM
2	Net Present	84.66	$MM
3	Internal Rate of	54.53	%
4	Payout Time	2.00	Years
5	DPI	7.2	-
6	Gross Oil	330.20	$MM
7	Maximum	**-6.19**	**$MM**

The project cost of $11.8MM as shown in Table 2 is significantly huge and will leave the

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investor/operator exposed to the tune of $6.19MM after the first year of investment. However, this financial burden is expected to be payout within the first two years of production.

5.0 CONCLUSION

Sand and water production affect both oilfield production operations and a projects economics life cycle significantly. From the inception of production operations in ND L/S, at least three work-over operations had been conducted that cost the operator tens of millions of dollars to curtail the nagging excesses of sand and water production. The outcomes of these enormous operations varied from unsuccessful, to counter-productive leading to loss of production and well shut-in for extended periods. Only the latest re-completion endeavors proved largely effective and fruitful. Niger Delta oilfield operators, by virtue of this and other cognate studies, are thus guided that understanding and controlling the trend and interrelationship of parameters affecting sanding and water production, bean sizing, liquid/oil production rates remain the most-effective approach in curbing these menaces in the fields. A good practice of sand and water control/management at the early stage would have prevented the undue downtime, delayed economic gains and the huge maximum economic exposure.

4.1. RECOMMENDATIONS

It is recommended that gravel packing should be employed from inception for newly drilled wells during completions to control sanding mechanism for largely unconsolidated formations in the Niger Delta.

It is also necessary to carry out adequate and extensive tests to ascertain the compatibility between formation sand and any chemical that is considered for use when carrying out chemical consolidation of hydrocarbon formations. This will eliminate the possibility of epicote bonding around downhole equipment and installations.

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