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ENVIRONMENTALAND GEOPHYSICAL IMPLICATIONS OF DRILLING TECHNIQUESEMPLOYED IN ONSHORE SEISMIC DATA ACQUISITION

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Abstract: **Seismic survey which primarily involves using artificially generated seismic energy to examine the subsurface is a common exploration practice in Nigeria. The manner which seismic exploration is carried out affects not only the expected outcome but also the environment, the flora and fauna. In this study, implications of employing the following drilling techniques, the single deep hole technique and the pattern drilling technique were x-rayed as it affects the expected sampling of the subsurface and the human environment in line with the united nations sustainable development goals on sustainable environment and energy.To achieve this assessment, a 3D seismic acquisition design was employed within the study area, having a survey block consisting of 30 receiver lines oriented northeast to southwest, and 47 source lines running northwest to southeast. Safe shooting distances for acquisition were stipulated as a guide to preserve the environment and as well achieve the desired result. Linear acquisition was not consistently carried out due to some obstacles seen within the lines; hence, different types of point movement or offset were employed depending on the type of obstacle encountered. The following offset types - point shift, smooth curve and**

laminar flow were employed when obstacles were encountered on line. In this research, different drilling techniques, Single Deep Hole (SDH) and Pattern Drilling techniques were considered to ascertain the one with most desirable output, having the least negative impact on personnel, equipments, environment etc. SDH was adjudged to give a better result and with least or no environmental implications as compared to pattern drilling technique. Challenges of drilling operations which include drilling on wrong positions, drilling substandard depths, inaccurate measurement of hole spacing and stuck drilling stems were encountered minimally, and measures were taken to effect correction.

Keywords: **Single Deep Hole, Pattern Holes, Offset, source line, receiver line**

Article Highlights

- Single Deep Holes produces a better imaging of the subsurface structures than pattern drilling technique. This is as a result of depth of burial of energy source, mostly explosives in the Niger Delta region, which is buried beyond the weathered layer.
- The Seismic Acquisition technique poses big treat to the environment against the United Nations Sustainable Development Goals on sustainable environment as the pattern drilling technique is seen to have more adverse effect on the environment as compared to the Single deep Hole technique.
- Relationship between Uphole time and Loaded depth was generated statistically from SDHs sampled as UpT = 0.0006LD - 0.0028 (UpT = Uphole Time; LD = Loaded Depth)
- The velocity of energy propagation was deduced to be 1,666.7m/s which is within the range observed in Niger Delta
- Acquisition carried out employing pattern drilling technique is less tedious and fast to execute.

I. INTRODUCTION

Seismic survey is the examination or imaging of subsurface via transmission of seismic wave into the ground. Seismic energy is generated using vibroseis, hammer, explosives etc, depending on the nature of the terrain and investigation involved. In deserts or open field with strong and undulating surface, vibroseis is more preferable due toenhanced low and high-frequency performance, moderate harmonics, and rise in the accuracy of sweeps in terms of fundamental ground force. In production shooting, the advantages of vibroseis technology combined with sweeps designed to meet low-frequency requirements produces significant energy output as low as 1-3 Hz. [1]. In this study, explosives were employed as energy source due to the terrain involved which is predominately rain forest with swampy, muddy and undulating surface at regularly spaced grids on the surface.

One of the aims of conducting seismic survey is to probe vital information relating to reservoir characteristics and composition which could lead to discovering petroleum in commercial quantities.

Over time, the method adopted has moved from 2D in the early 60's to 3D in the 80's till date. However, with the quest for more information (fluid migration, flow rate, etc) about the proven reservoirs, the 4D survey has evolved.3D surveys have some advantages over 2D in the sense that 3D data from a prospect area can be viewed as a volume and as well asa spatial resolution in the cross-line direction [2].

4D technique isthe most recent seismic technology which is simply time-lapse 3D seismic. This process involves carrying out 3D seismic survey over an area that has already been surveyed with the same technique and both results are used to comparedand as well measure the changes observed in reservoir characteristics. 4D seismic also measures the progress of production, enhances oil recovery, and makes development and production of the field more efficient.

The River Nun and environs 3D acquisition program was designed to provide an improved symmetrical seismic data output for a more accurate imaging of the geological features over the densely faulted field and improve the signal-to-noise ratio at the intermediate – deeper horizons, where the bulk of the already established hydrocarbon bearing layers are found while analyzing the environmental impact.

It has been discovered that the energy source, even the drilling technique employed during acquisition is one of the major factors which influences not just data quality and but the environment at large. This source energy variation would affect the amplitude, frequency and wavelet of the seismic data and subsequently influence the fidelity of the imaging and reservoir inversion [3]. Therefore, the depth of the shot should be specified so as not to obscure the integrity of the data and have minimal environment impact.

The design also provides proper azimuth, offset distribution and higher multiplicity for enhanced velocity accuracy required for amplitude versus offset (AVO) and other quality interpretation (QI) techniques, which will further improve signal-to-noise ratio of deeper reflectors while suppressing multi-reflections. This research provides information for full evaluation of the different drilling techniques employed and as well exposes how useful, environmental friendly and result oriented each technique employed can be in the exploration Nun River area

Study area

The study area is situated in central NigerDelta, Bayelsa, Nigeria. It is located about 80km east of Portharcourt. River Nun is the largest river within the NigerDelta and the 500-600 meters wide channel bisects the study area.The study area is mostly lowlands, with an elevation of20m below sea level.

Akpokodje et al., 2014[4], recognized five major geomorphologic units within the NigerDelta, namely:

- active and abandoned coastal beaches
- salt water mangrove swamps
- freshwater swamps and meander belt
- Sombreiro Warri plain, dry deltaic plain with abundant swamp zones.
- dry flat land plain

Short & Stauble(1967) [5] also recognized these five geomorphologic units, and these units are divided into three main environments, namely continental, transitional and marine environments.
Niger Delta basin forms part of the sedimentary portion of geology of Nigeria and it is located in the Gulf of Guinea, West Africa, between latitudes 3° N and 6° N and longitudes 5° E and 8° E [6]. It is bounded on the northwest by an underground continuation of the West African Shield and the Benin Flank. The eastern end of the basin met with the Calabar Flank to the south of the Oban Masif[7]. The Niger Delta province is a large arcuate wave and tide dominated delta, with sediments ranging in age from Eocene in the north to Quaternary in the south, with a thickness of over 12000m and an area of 7500km^2[7].

Materials and method
In this research, the methods and materials employed are disclosed under the subheadings as seen below

Parameter and geometry of acquisition design
The survey block was designed to contain 30 receiver lines arrayed from northeast to southwest and 47 source lines lying in the northwest-southeast direction. The receiver lines were numbered from 5655 to 5887 in increments of 8. The source lines were also numbered from 1160 to 1630 in increments of 10. The subsurface full fold coverage area was estimated to be 183.52 square kilometers (after design) with bin sizes of 25 m X 25 m. The source/receiver geometry generates full fold coverage of forty-eight (48).
Receiver spread of 960 channels broken into six lines of 160 groups each were used for the whole prospect, except for the tapering off ends. Hydrophones were used for recording, depending on the terrain condition of the receivers. Twenty eight (28) shots were located at the off ends of the active spread and 40 shots within the spread, which makes ninety-six (96) shots per salvo. This resulted to cross spread geometry of 6 lines multiplied by 160 channels and 96 shots respectively

Source and receiver lines peg numbering system
The numbering system adopted in this conventional 3D prospect is shown in Fig.1 for a complete salvo (source line). The pegs denoting the shot points on the source line were labeled in red, while that of receiver stations on receiver lines in blue. The first receiver line in the prospect is numbered 5655 and receiver line numbers were increased by 8 from west to east (i.e. if 8 is added to 5655, the next receiver line will be 5663). The last line is 5887.
Similarly, the first source line in the prospect is numbered 1160 and source lines were increased by 10 from south to north (i.e. if 10 is added to 1160, the next source line will be 1170). The last line was assigned the number, 1630. The numbering of all shot and receiver points were increased from the low side to high side by 1, starting from 5635 to5658 (eastward) for source points and 1154 to 1163 (northwards) for receiver points. The azimuth or orientation for source and receiver were 135.433333^0 and 45.433333^0 respectively.

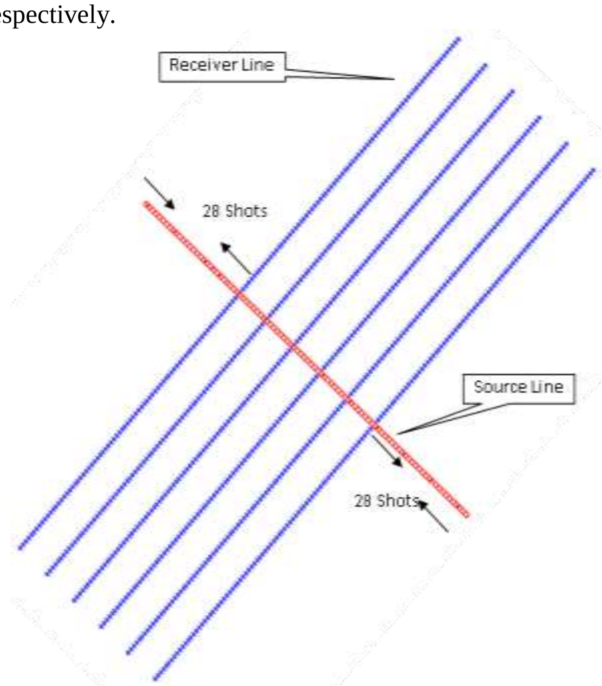

Fig.1 Prospect numbering system

When traversing or moving along a receiver line (e.g. 5665) from the low station, at all the intersection points between a source and receiver line, the station immediately after a source line (e.g. SL 1160) is located at a distance of 25m from the source line while traversing northward. The numbering convention becomes 5665 / 1160.
If traversing or moving along a source line (e.g. 1160) from the low station, at all the intersection points between a source and receiver line, the points immediately after the receiver line (e.g. RL 5655) is located 25m from the receiver line traversing eastward.This point numbered 1160

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/ 5655 is as shown in Fig.2. The pink rectangle in Fig.2 is magnified inFig.3.

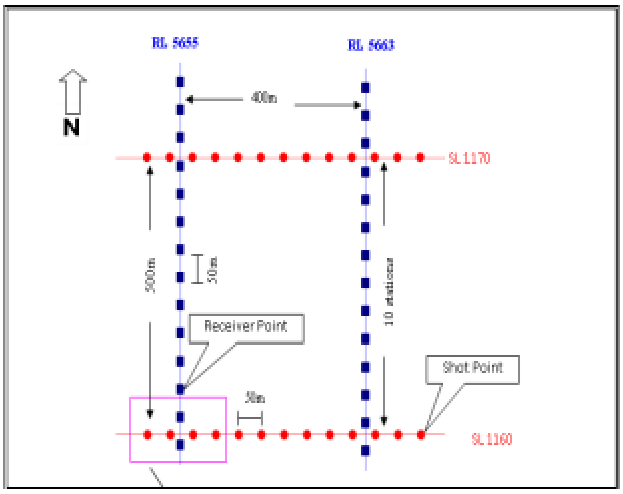

Fig.2 Receiver and source lines set up

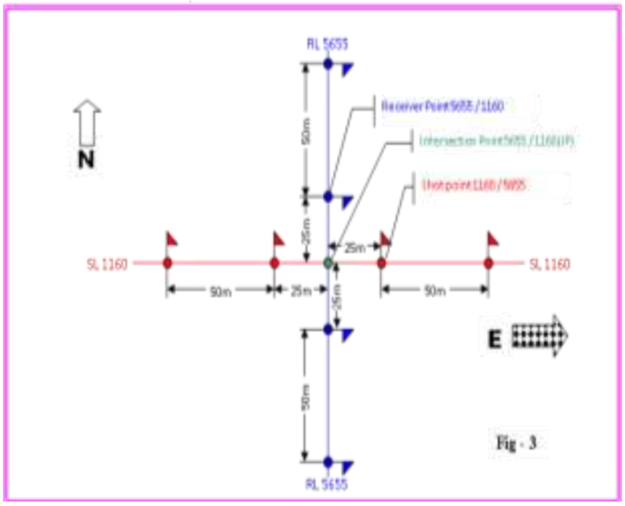

Fig.3 Enlarged pink set up from Fig.2

Field position identification

Fig. 4 is the acquisition design map superimposed on the location map of the prospect area. A position is assumed on the map to be able to locate any point on the field. Note that the assumed position is indicated in Fig.4 with a small black circle.

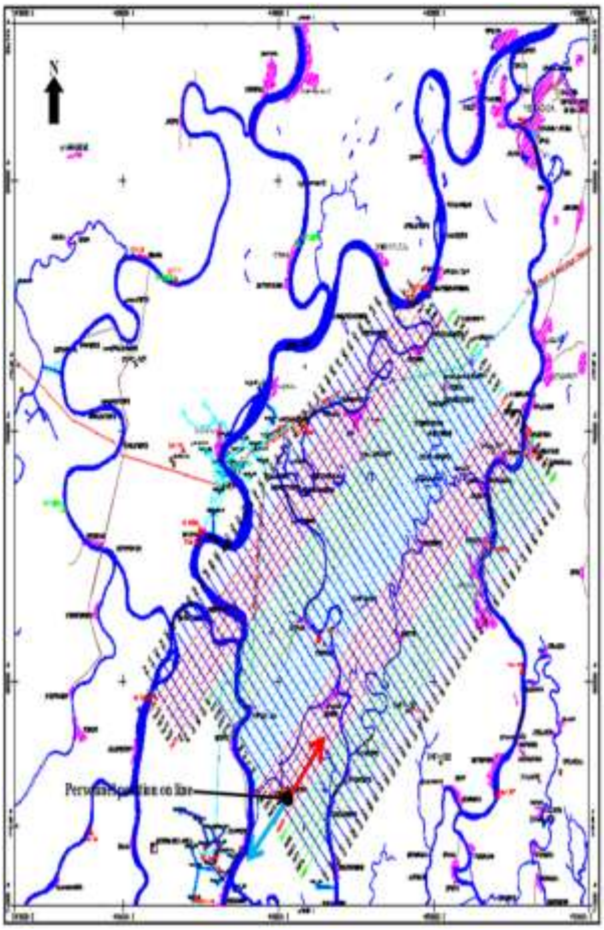

Fig.4 Acquisition map superimposed on location map

From the assumed position (indicated with a small black circle in Fig.4), and taking the direction of the red arrow; it implies that:

- Movement is made towards the high side of the prospect, which is northeast direction with respect to the location map.
- The light blue arrow is pointing to the low side of the receiver line, which is in southwest direction with respect to the location map.

For this rule to be effective, a movement of at least 2 pegs forward and backward is required regardless of your initial position on the field (for source or receiver line), to ascertain if the peg numbering is increasing or decreasing. If the peg numbering increases, it means movement is made towards the high side of the line on which you are traversing. However, if the numbering decreases, the reverse is the case.

It is of importance to constantly check the acquisition map as submerged in the location map to identify your position on the field in relation to natural or man-made features. It is worthy of note that these rules apply to both source and receiver lines.

Safe shooting distances for non-seismic objects or structures

The following safe shooting distances were strictly obeyed during seismic survey to avert any damage of any sort on non-seismic objects (NSOs) as a result of vibrations from shot detonations and as well have minimal negative impact on the environment. Instructions and directions were sought from the planning seismologist where some NSOs sited in the field are not listed in Table 1,to ensure a safe acquisition process. The planning seismologist, based on the information available, determines if the affected shot point or points are to be killed or moved to a new offset position for safe acquisition.

Table 1 List of NSOs and safe shooting distances

Objects to be protected	Minimum distance from the nearest shot hole	Shot description - single deep holes (SDH), with 2kg explosive
Tarmac roads	25m	SDH
Overhead cables	50m	SDH
Houses	150m	SDH
Pumping station	100m	SDH
Dyke structures	100m	SDH
Pipelines	100m	SDH
Water / oil wells	200m	SDH

Types of point or points movement (offset types)

During acquisition, shot points which are close to NSOs, were moved away (or offset) from the NSOs to ensure safe shooting. There are different types of this offset. They include:

- **Point shift:** Where minor obstacles prevent the linear continuity or linear positioning of solitary points, a maximum of ± 20 meters shift from the theoretical position in the in-line directions shall be applied to shot points within safe limits.

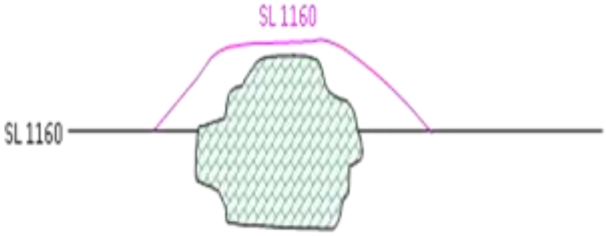

Fig.5 Point shift

- **Smooth curve:** This is an offset type in which shot points obstructed by a large obstacle are smoothed around the obstacle with an inclination or deviation angle of 17 – 27 degrees, flattened at the crest or trough of the obstacle and returned to the base line with the same take off angle of 17 – 27 degrees in a continuous manner. In the process of smoothing, it may affect other shot points at the inclination and declination points which ordinarily, could not have been moved in order to maintain a symmetrical shape as smooth curves shall not intersect another pre-designed grid line(s). The theoretical line number will be used with the actual coordinates of the offset points in the finalshell processing support (SPS) file. This offset pattern shall be applied in settlements, pipeline or oil well networks, forbidden or shrine areas, burial grounds, family tree (raffia palms) etc. This offset type shall take the first applicable priority in large obstacle areas.

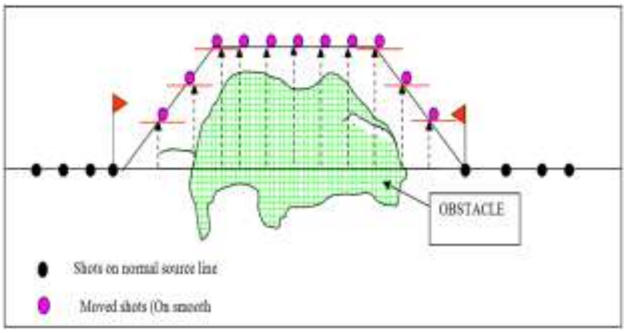

Fig.6 Smooth curve

A typical smooth curve offset is as shown in Fig.6.All shot point position on the smooth curve is pegged and drilled in a similar manner as shots on normal source line. That is to say that the linear array of a peg or pegs on a smooth curve is parallel to the main line direction.

- **Modified smooth curve:** Smooth curve offset line where possible, should take off from the theoretical line with a deviation angle of 17^0 to 27^0 degrees and if it is not possible to return to the line at the same angle because of very large obstacle, it could terminate at a given peg position. This situation must be agreed with the client representative before implementation.

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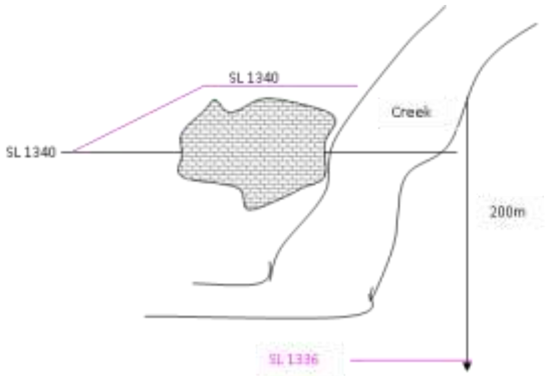

Fig.7 Modified smooth curve

- **Laminar flow:** In areas where the smooth curve option is not feasible, a different strategy is employed. This involves moving the points perpendicular to their original position (straight laminar flow) northward or southward as source lines primarily runs in the east-west direction. This will ensure optimal offset distribution. This is often the last option and it is applied only if the smooth curve option is not applicable. The line number will bear the name of the new position as depicted in Fig.8.

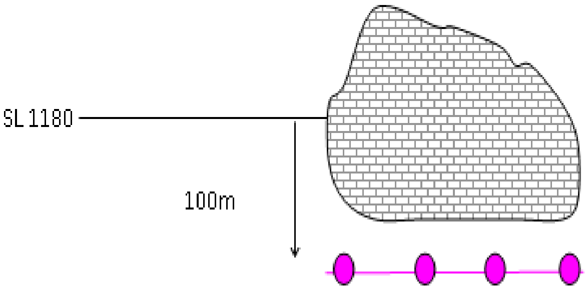

Fig.8 Laminar flow

In-line & cross-line shifts (lateral movement)
This is a composite offset method involving shifts in both X and Y axes. In this offset type, shot points that fall in an obstacle region are moved to a new position, with both coordinates changing. Specifically, the X-axis offset distance shall be +/- 400m in order to maintain a corresponding shot offset position (in X-direction) from its original location. The new offset line name and shot point number will appear as shown in Fig.9.

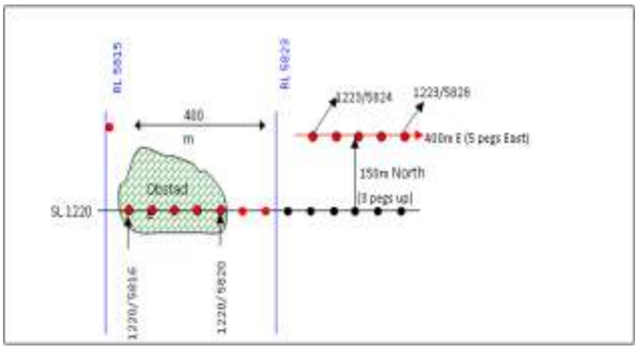

Fig.9 Lateral offset movement

When offsets are made on receiver lines, whether on a smoothed line or simple laminar flow, the original theoretical names are to be maintained on pegs.

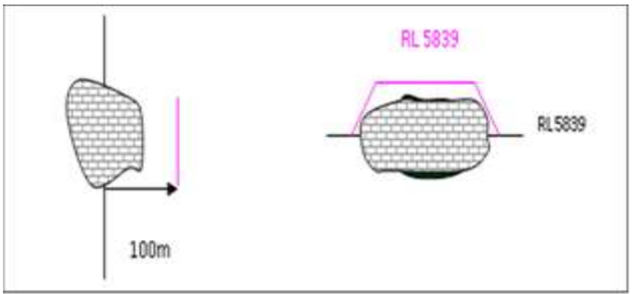

Fig.10 Offset movement on receiver

Drilling techniques
Types of hole drilling techniques
In this research, we employed Single Deep Holes (SDH) technique, drilled to 45m, 3m by 5-hole pattern drilling and 6.5m by 5-hole pattern drilling at interval of 50m apart. The shot point numbers were increased by 1 for each successive next shot point position.

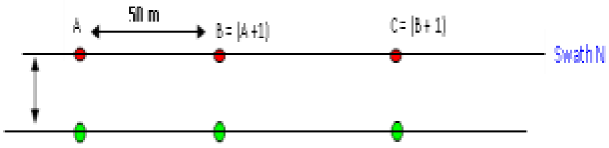

Fig.11 Shot point numbering pattern

Single deep hole (SDH) at shot point (peg) position
This drilling was carried out at peg position or shot point position. This SDH drilling was carried out once or twice at a peg position. The number of times SDHs were drilled on a shot point position was determined by the position of the shot point being acquired. Points overlapping other swath were acquired for respective swaths. It is of note that the more a position is drilled, the greater the negative environmental impact it has around the same position. SDHs were drilled to a depth of 45m, which is the recommended depth for SDH within Niger Delta, and

loaded to a minimum depth of 42m. For shot points that were drilled twice, the first drilling was carried out at the peg position and the second SDH was positioned at 3m offset from the peg position, irrespective of the direction. Figures 12 and 13 show a single deep hole drilled once and twice respectively.

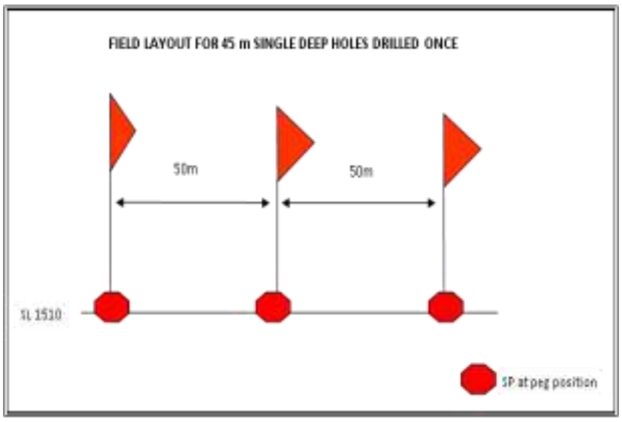

Fig.12 SDH drilled once

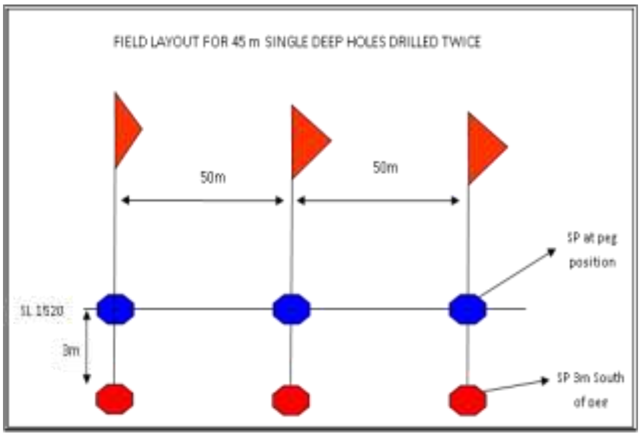

Fig.13 SDH drilled twice

Linear 5-hole pattern

The five-hole pattern in a shot point was arranged such that the peg position was on the central hole with the remaining four holes positioned two apiece left and right of the peg hole. Horizontally, each hole was positioned 10m apart from the next and they were drilled either 1m or 3m vertically from the top about the peg for both 4m and 6.5m holes respectively as illustrated in Figs.14 and 15.

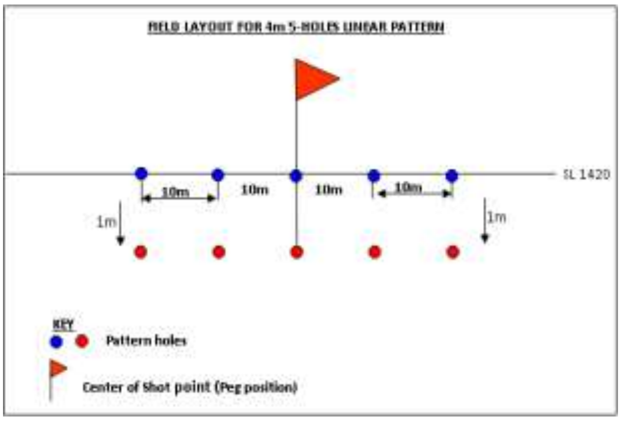

Fig.14 4m 5-hole linear pattern

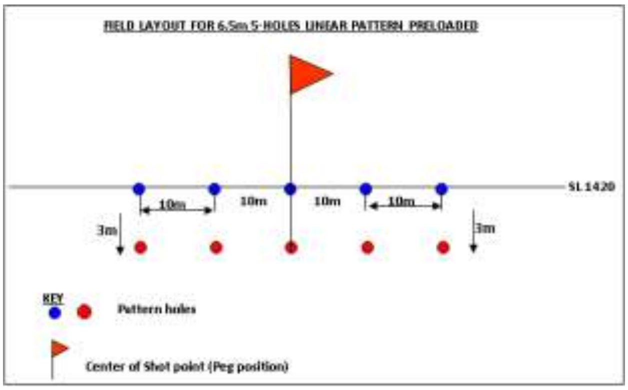

Fig.15 6.5m 5-hole linear pattern

Circular pattern

Circular Pattern hole drilling were employed where an obstacle such as edges of creeks, ponds, roads and other NSOs disturbed linear array. The five holes were evenly distributed around a circle drawn with radius R ranging from 0.3m to 1.0m as shown in Fig.16.

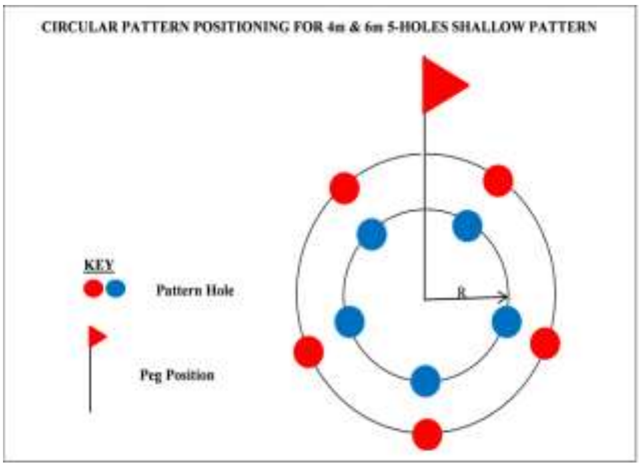

Fig.16 Circular drill pattern

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II. RESULT AND DISCUSSION

Two pronounced drilling techniques were sampled in this research to ascertain the method that is best fit for desirable outcome, with minimal negative impact environment and human lives.

Geophysical Implications

The Single Deep Hole (SDH) which involved drilling a depth of 45m into the subsurface before burying the energy source, which are explosives, was employed. According to Uko et al (1992) [8], the low velocity or weathered layers depth within the Niger Delta, ranges between 2.9m to 45m deep, with average depth of about 20m. Putting this into consideration, a depth of 45m was drilled for SDH in order to avert or minimize to the barest minimum, the effect of weathered zone on energy generation and transmission into the subsurface and reflection back to the surface as weathered layers or zones attenuates signal transmission rapidly when compared to consolidated layers.

Fig. 18 is a sample of a raw shot imaging the subsurface gotten from SDH technique. Each of the cone-like crests indicates separate arrivals of reflected energy at different receiver positions. These arrivals occur at different time intervals for respective receivers activated for the shot. The arrival time disparity depends on the positions of these laid receivers employed in the acquisition process. Disturbances like noise were also recorded alongside the reflected signal and were also captured by the receivers as part of the raw shot.

An onsite quality check was carried out on the raw shot acquired to filter out noise. Fig. 19 is the expression of the noise which interfered with the acquired shot during acquisition process. This noise which is predominantly surface noise, is primarily influence by environmental occurrences which are majorly human activities with the area.

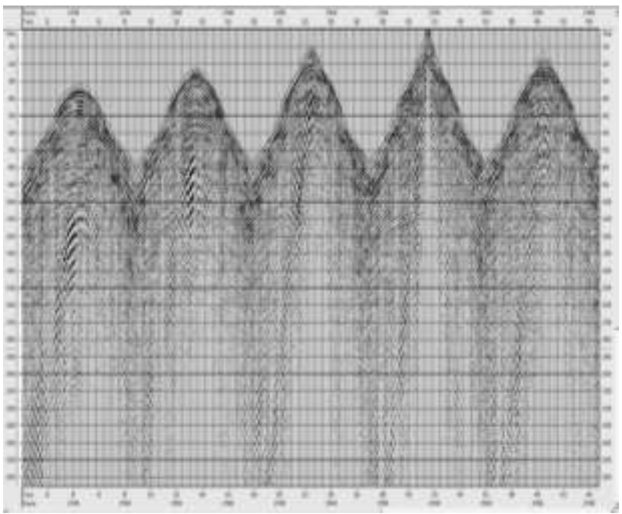

Fig. 18: Pictorial Representation of Raw Shot

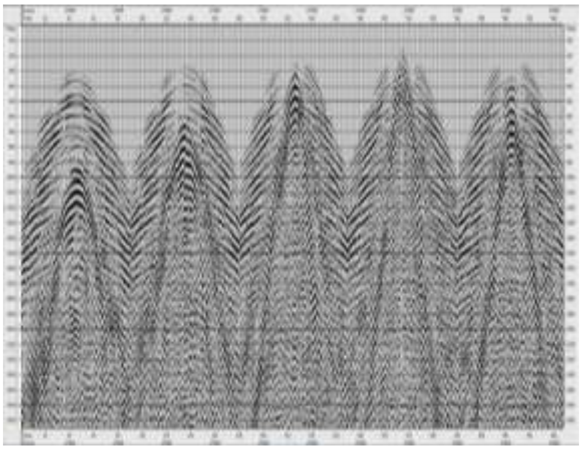

Fig.19: Noise within the Raw Shot.

To extract the needed and accurate subsurface information, these noises present within the raw shot werefiltered out, giving rise to the actual needed picture of the subsurface. Fig 20 shows the raw shot image affect noise attenuation.

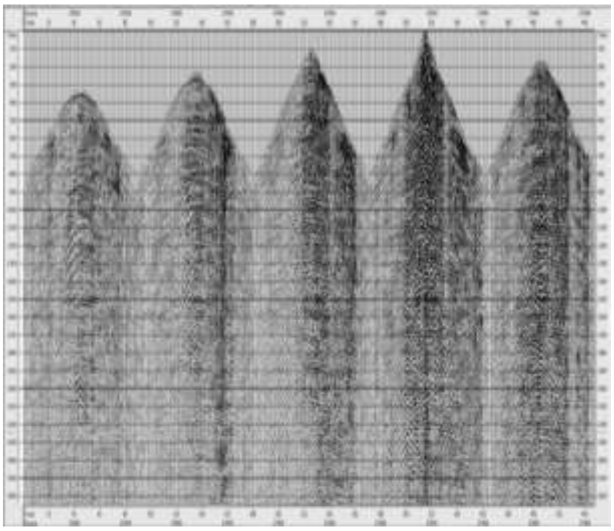

Fig 20: Raw shot affecter noise filtration and Attenuation

Agoha et al (2015) [9], established the average velocity of weathered zone within the Niger Delta to be 407m/s and that of the consolidated layer to be 1,738m/s. This implies that energy travels faster within the consolidated zone when compared to the weathered zone. For SDHs in this study, a depth of 45m was drilled to avert any effect the low velocity layer will have on signal or energy transmission. With this, the target area will be reached faster and sampled before the energy dies down. Other advantages of SDHs include explosives used as source of energy will have no direct contact with the surface or near surface, thereby preventing weakening and possible destruction of the top soil as a result of near surface vibrations and possible blowout. With this, the negative effect of vibration from the detonated explosives will be extremely minimal on surface structures. The possibilities of blowouts are rarely present due to the depth of explosive burial, thereby ensuring safety of lives, equipments and environment. The effect of ground rolls which is primarily as a result of weathered layer is removed from the acquired data. All these cannot be said about Pattern drilling technique. Table 2 shows some selected shot points which were drilled, loaded and acquired.

Table 2SDHwith defineddrilled depth, loaded depth and uphole time for each shot point

Drilled depth (m)	Loaded depth (m)	Real uphole time (sec)
45	42.0	0.024
45	40.5	0.023
45	41.0	0.023
45	42.5	0.020
45	40.5	0.029
45	41.0	0.025
45	40.0	0.027
45	40.0	0.025
45	40.5	0.026
45	42.0	0.023
45	42.3	0.020
45	43.0	0.030
45	42.8	0.029
45	40.5	0.026
45	41.0	0.021
45	41.7	0.020
45	41.5	0.027
45	40.5	0.020
45	40.0	0.017
45	40.7	0.023
45	42.5	0.023
45	42.5	0.021
45	43.0	0.023
45	43.0	0.020
45	42.0	0.020
45	40.5	0.021
45	40.5	0.020
45	40.0	0.020
45	42.0	0.027
45	41.0	0.026
45	42.0	0.021
45	43.0	0.024
45	40.0	0.022
45	40.0	0.025

45	40.5	0.024
45	41.0	0.020
45	41.0	0.026
45	43.0	0.029
45	42.0	0.027
45	40.5	0.020
45	42.5	0.020
45	42.3	0.026
45	40.0	0.021
45	41.0	0.023
45	42.0	0.022
45	43.0	0.029
45	41.0	0.020
45	40.5	0.024
45	41.3	0.021

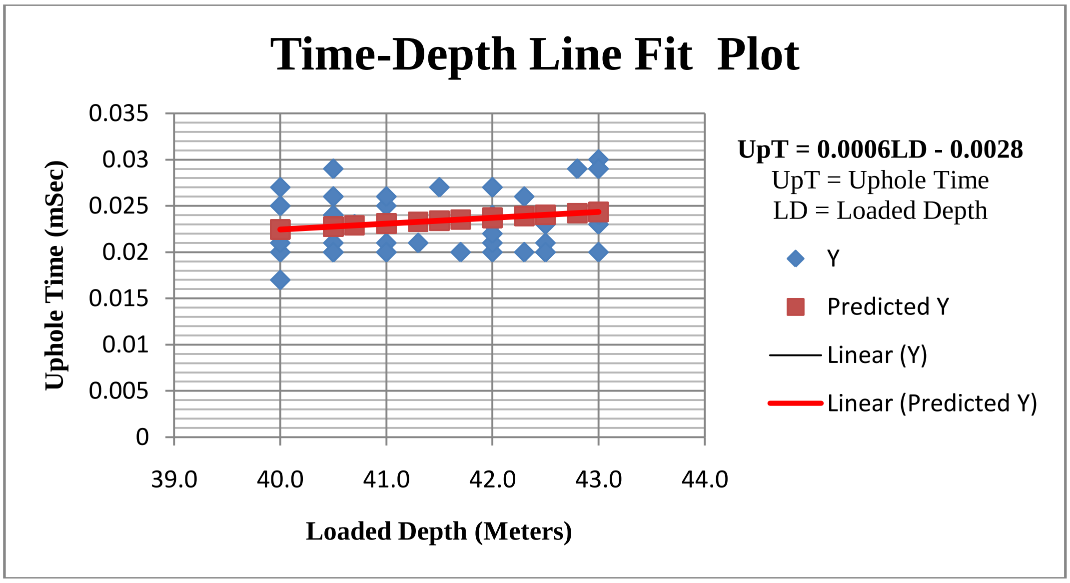

Fig.21 Uphole time versus loaded depth plot

From Fig.21, the predicted trend line or line of best fit equation for uphole time versus loaded depth was generated and it is given as:

$$UpT = 0.0006LD - 0.0028 \qquad (1)$$

(UpT = uphole time; LD = loaded depth)

From equation 1, the coefficient of LD, 0.0006, which is the slope of the linear expression in Fig.21, represent the inverse of velocity of transmission.

$$\text{Coefficient of LD} = \frac{\text{Uphole Time}}{\text{Loaded Depth}} = \frac{1}{\text{Velocity}} \qquad (2)$$

Velocity = $\frac{1}{\text{Coefficient of LD}} = \frac{1}{0.0006}$ = 1,666.7m/s.

In this research, the velocity of transmission for SDHs was deduced to be 1.666.7m/s, which is within the range of 1,449m/s and 1,812m/s as inferred by Agoha et al (2015). The minor value disparity observed results from the inhomogeneity of the earth.

Table 2: Predicted uphole time, residual uphole time and real uphole time

Predicted uphole time (sec)	Residual uphole time (sec)	Uphole time (sec)
0.023717877	0.000282123	0.024
0.022771695	0.000228305	0.023
0.023087089	-0.000087089	0.023
0.024033271	-0.004033271	0.020
0.022771695	0.006228305	0.029
0.023087089	0.001912911	0.025
0.022456301	0.004543699	0.027
0.022456301	0.002543699	0.025
0.022771695	0.003228305	0.026
0.023717877	-0.000717877	0.023
0.023907113	-0.003907113	0.020
0.024348665	0.005651335	0.030
0.024222507	0.004777493	0.029
0.022771695	0.003228305	0.026
0.023087089	-0.002087089	0.021
0.02352864	-0.003528640	0.020
0.023402483	0.003597517	0.027
0.022771695	-0.002771695	0.020
0.022456301	-0.005456301	0.017
0.022897852	0.000102148	0.023
0.024033271	-0.001033271	0.023
0.024033271	-0.003033271	0.021
0.024348665	-0.001348665	0.023
0.024348665	-0.004348665	0.020
0.023717877	-0.003717877	0.020
0.022771695	-0.001771695	0.021
0.022771695	-0.002771695	0.020
0.022456301	-0.002456301	0.020
0.023717877	0.003282123	0.027
0.023087089	0.002912911	0.026
0.023717877	-0.002717877	0.021
0.024348665	-0.000348665	0.024
0.022456301	-0.000456301	0.022
0.022456301	0.002543699	0.025
0.022771695	0.001228305	0.024
0.023087089	-0.003087089	0.020

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0.023087089	0.002912911	0.026
0.024348665	0.004651335	0.029
0.023717877	0.003282123	0.027
0.022771695	-0.002771695	0.020
0.024033271	-0.004033271	0.020
0.023907113	0.002092887	0.026
0.022456301	-0.001456301	0.021
0.023087089	-0.000087089	0.023
0.023717877	-0.001717877	0.022
0.024348665	0.004651335	0.029
0.023087089	-0.003087089	0.020
0.022771695	0.001228305	0.024
0.023276325	-0.002276325	0.021

From Table 2, the summation of the predicted uphole time and that of the residual uphole time gives the real uphole time. The predicted and residual values were statistically calculated from the values of Table 1 using the regression method of data analysis.

Fig. 22 demonstrates the difference between the real uphole time and the fitted or predicted values. It is an expression of random scatter points emanating from an almost constant width band around the identity line.

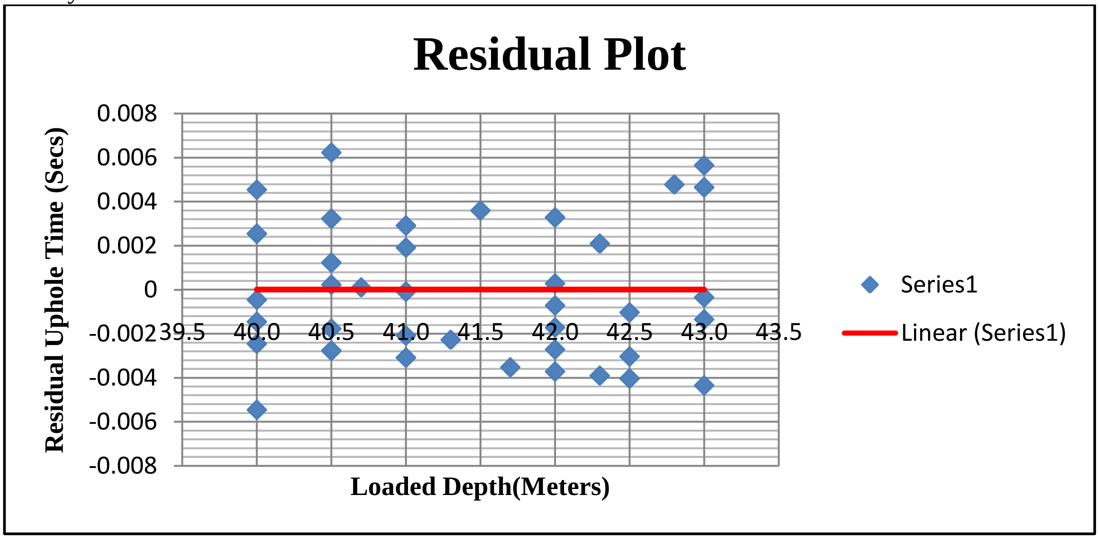

Fig.22 Plot of residual uphole time versus loaded depth

It was observed from Fig.22 that shot points loaded up to 40meters depth has residual uphole time values ranging from -0.005456301m/s to 0.004543699m/s. For points loaded up to 40.5m, 41m, 42m, 42.3m, 42.5m and 43m has their residual uphole time ranges as -0.002771695m/s to 0.006228305m/s, -0.003087089m/s to 0.002912911m/s, -0.003717877m/s to 0.003282123m/s, -0.003907113m/s to 0.002092887m/s, -0.004033271m/s to -0.001033271m/s and -0.004348665m/s to 0.005651335m/s respectively.

Table 3: Uphole time probability output table

PROBABILITY OUTPUT	
Percentile	Uphole time (sec)
1.020408163	0.017
3.061224490	0.020
5.102040816	0.020
7.142857143	0.020
9.183673469	0.020
11.224489796	0.020
13.265306122	0.020

15.306122449	0.020
17.346938776	0.020
19.387755102	0.020
21.428571429	0.020
23.469387755	0.020
25.510204082	0.020
27.551020408	0.021
29.591836735	0.021
31.632653061	0.021
33.673469388	0.021
35.714285714	0.021
37.755102041	0.021
39.795918367	0.022
41.836734694	0.022
43.877551020	0.023
45.918367347	0.023
47.959183673	0.023
50.000000000	0.023
52.040816327	0.023
54.081632653	0.023
56.122448980	0.023
58.163265306	0.024
60.204081633	0.024
62.244897959	0.024
64.285714286	0.024
66.326530612	0.025
68.367346939	0.025
70.408163265	0.025
72.448979592	0.026
74.489795918	0.026
76.530612245	0.026
78.571428571	0.026
80.612244898	0.026
82.653061224	0.027
84.693877551	0.027
86.734693878	0.027
88.775510204	0.027
90.816326531	0.029
92.857142857	0.029
94.897959184	0.029
96.938775510	0.029
98.979591837	0.030

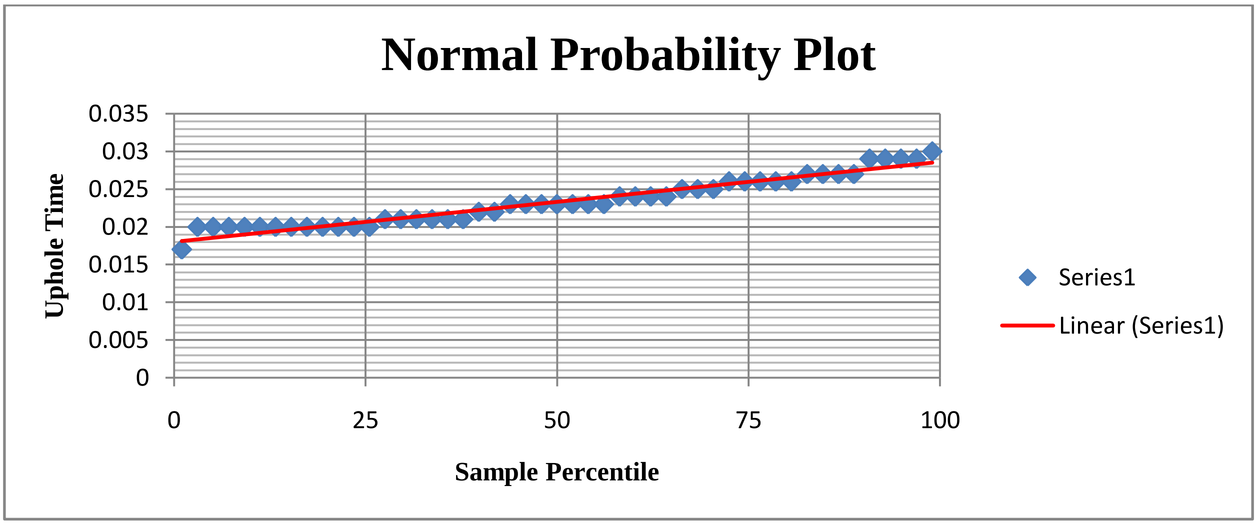

Fig.23: Uphole Time versus sample percentile plot

Table 3 and Fig.23 show the frequency of occurrence of uphole time for the 49 SDH shot points sampled. It was observed that only 2 shot points out of 49 shot points sampled has uphole time of 0.017s and 0.030s and they were loaded to depths of 40m and 43m respectively. It was observed that fairly majority of the shots sampled has their uphole time as 0.020s and they were mostly found in the first quartile of Fig.23.

The 3D geometry employed in this research gave a 3 dimensional view of the subsurface – the lateral view (X and Y direction) and the depth (Z-direction). This implies that 3D geometry samples the subsurface depth and as well

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as its lateral extent as it affects the entire acquisition. Unlike 2D geometry where both source and receivers are on one seismic line, the 3D geometry applies a different approach. In 3D, both source and receivers are on separate line and this enables the sampling of the space in-between different seismic lines for information that cannot be gathered when employing 2D design. In 2D geometry, the space in-between the lines are not sampled because of how the acquisition design is being set up – receiver and source on one seismic line. This means that linear-like information of the subsurface is gathered and this does not give the true picture of the subsurface.

Acquisition map in Fig.4 shows a3D geometric design for this research work. 3D geometry was also employed because it its ability to generate multiple fold coverage by reducing random and coherent noise. It enabled the studying of data in both shot order and common mid-point (CMP) order. In 3D geometry just as observed in this research, the effect of missing or killed shots as a result of the inability to either acquire or offset them due to the presence of non-seismic objects (NSOs) and other environmental featureswas reduced. It also attenuated multiple signals and as well provided the needed information to work out the velocities from the subsurface signal.Fig. 24 shows a Raw Shot Gather with geometry being applied to it.

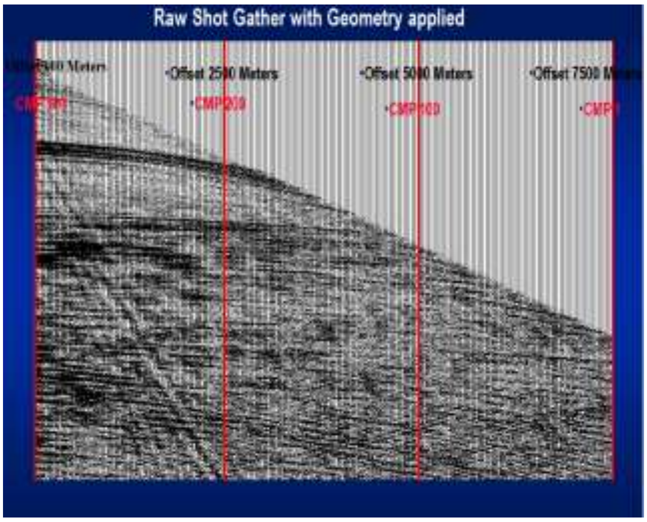

Fig.24: Geometry on Raw Shot Gather

The energy type or source used in this research was influenced by the terrain of acquisition. The Niger Delta area is a rain forest zone comprising of undulating swampy and marshy terrain, hence the choice of explosive as obstacles and nature of the terrain will not allow the use of vibroseis. 2kg explosives were chosen to be able to generate sufficient signal with minimum negative environmental impact. These choice explosives were buried to a depth of 40m minimum as seen in Table 2 after drilling holes of 45m depth into the subsurface for SDHs. When detonated, they generate the needed impulse which moves faster into the subsurface and get reflected with high energy.

In pattern drilling, whether linear or circular, the depth at which explosives are buried ranges from 1m to 3m. This primarily implies that the explosives are buried within the weathered layer and this has a wide range of consequences. The signal transmission will not be strong enough and cannot travel as fast as possible to hit the desired targets. This is because the velocity of transmission within the weathered layer is stipulated to be 407m/s as compared to that of the consolidated layer which is 1,738m/s [9]. The possibility of clear imaging and sampling of the subsurface does not arise as generated pulses attenuate before reaching the target

Pattern drilling in seismic data acquisition seems less tedious and faster as compared to SDH technique but the risk involved is unquantifiable. The quality of data acquired in pattern drilling method can never be compared to that of SDH, as SDH method provides very clear and high resolution image of the subsurface as compared to pattern drilling technique.

Environmental Implications

In seismic survey, acquisitions are carried out within seismic lines. These seismic lines, both receiver and source lines are established by cutting down of green plants found along the seismic line. This causes distortion within the environment, having a huge impact on both flora and fauna. The number of trees needed for carbon sequestration and release of oxygen will also be reduced. This action over time contribute to global warming as the quantity of greenhouse gases finding its way to the ozone layer will be on the rise and there are no adequate plan on ground to compensate for the fallen trees [10].The top soil is also exposed via the cutting of seismic lines to agents of erosion, thereby increasing the possibility of soil erosion, most especially where the top soils are loose. The habitat of some animal species are dislodged via establishment of seismic lines and this leads to both migration and sometimes extinction of these species thereby reducing the preservation of wild lives as entrenched in united nations treaties.

The generation of seismic energy, aside the exploration benefits, affects the environment adversely. This weakens the soil structure and as well deforms the soil binding matrix. With this, the soil bearing capacity is affected tremendously, making it impossible and extremely unsafe to set up developmental structures within the affected environment.The chances of forming craters within the environment are high. Surface and near surface structures like building, bridges, road etc are at high risk of collapse and damage as a result of energy transmitted upward as vibrations. Considering the fact these vibrations travels in all directions, vertically and horizontally, all the soil particles it encounters gets deformed elastically, and most often, these elastic deformations are permanent, thereby

causing a complete change of the subsurface posture. This increases soil porosity and possible permeability, thereby increasing the risk of high water peculation within the area and the possibility of erosion and other factors affecting the top soil are imminent. The possibility of explosive blowout cannot be over emphasized thereby endangering lives and properties as well. These effects are more with pattern drilling technique as compared to Single Deep Hole technique due to the shallowness of the explosives buried for this purpose, which ranges from 1m to 3m meters deep as compared to 45m drilled for SDHs.
The sound (noise) and vibrations generated during seismic data acquisition is also an environmental challenge as it does not only affect the hearing of humans around but also wild lives within the forest where this operation is domicile are affected. This may trigger their relocation and possible extinction from the environment [11].

III. CONCLUSION

Detailed practical field approaches of drilling techniques involved in seismic data acquisition, case study of River Nun and environs were x-rayed with respect to the acquisition design, which is 3D conventional method and possible effect on the environment. During this study, certain challenges which hampered the field operation were encountered. The challenges encountered during the acquisition are presence of obstacles and non-seismic objects on line which led to the offset of some shot points using the point shift method, smooth curve method or laminar flow method [12]. Other challenges encountered are during drilling, most especially while carrying out the SDH technique. Drillers' tendency of drilling off the programmed positions was also observed. This is as a result of not going to line with acquisition survey maps as to guide movement to programmed positions on the line. This challenge was curbed by the presence of a field seismologist, who ensured that programs are strictly adhered to as planned. The issue of carved and collapsed holes due to soil formation which is predominantly with SDHs was also observed during drilling operations. In most cases, it led to the loss of drilling stems as they were stuck to the ground. Appropriate drilling mud was subsequently used to avert a repetition of such an occurrence. With SDHs, the rate of litigations as a result of accidents, destruction of environment, facilities etc is reduced to the barest minimum and in most cases, does not arise.
It was also deduced that both techniques employed in this research has adverse environmental effects and both flora and fauna are affect during these processes. The soil where these drillings are carried out is impacted negatively. The felling down of trees to create seismic lines, reduces the rate of carbon sequestration and over time contribute to global warming due to the exposure of greenhouse gases to the ozone layer.

IV. RECOMMENDATIONS

It is therefore advisable that all forms of seismic exploration, most especially the use of explosives in explorations should be discouraged for sustainable environment and safety of lives and properties. Other geophysical methods like magnetic method, gravity method etc which has the ability of probing very deep into the subsurface should be used as a substitute to seismic method due to their ability of not having any known direct contact and effect on the environment. These methods are safer, faster and cheaper as compared to seismic method.

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Author Contributions:
Conceptualization and first draft of this article was done by Onwubuariri, C.N.
Supervision and corrections were done by Anakwuba, E. K.
Field Design Analysis was done by Mgbeojedo, T. I. and Nnanna, L.A.
Result Analysis was carried out by Onwubuariri, C.N.,Agoha, C.C. and Osaki, L.J.
Grammatical corrections were done by Nwaneho, F. U. and Mgbeojedo, T. I.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

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