



P-210

## Challenges in Using Hybrid Streamer Configuration-A Case Study

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### Summary

Objective of this paper is to analyze the characteristics of offshore seismic signatures recorded using combination of solid and liquid sections, within a streamer length, under the cumulative influence of wind, waves, and lunar phases. Shot records acquired at different weather conditions viz calm and marginal sea state over the same study area were examined to study the performance of hybrid streamer configuration at different weather conditions. Moreover, integrated analysis of data pertaining to wind velocity, swell height, lunar phase with RMS amplitude maps helped to identify the limits of hybrid streamers and revalidate the effectiveness of solid streamers in addressing weather related noise.

**Keywords:** Offshore, Swell, Noise, Wind, Streamer, RMS Amplitude, Spectrum, Sensitivity

### Introduction

The study to examine performance of hybrid streamer configuration and contribution of key weather factors such as swell heights, wind velocity and lunar phase on the quality of offshore seismic data was carried out on the datasets pertaining to Gulf of Mannar recorded between mid of March, 2011 to the first week of April, 2011.



Figure 1. Geographical location of the study area in the Gulf of Mannar.

Gulf of Mannar is the south east coast of India. Western and northern side of the study area is surrounded by Indian coastline whereas eastern side by the Srilankan coastline. The study area (Figure 1) exhibits tropical climatic condition where contribution of southwest monsoon is very little to the annual rainfall. Majority of rainfall is during the month of October and December under the influence of northeast monsoon. The sea is rough between April and August and calm during September. Average tidal amplitude is about half a meter. Wind velocity over the area is generally high and is north to northeasterly from June to December and westerly during the rest of the period. The predominant wind directions is S to SW during Southwest monsoon and NE during the Northeast monsoon seasons respectively.

### Data Acquisition Geometry and Streamer Properties.

Four streamers each separated from the other by 100m were towed at a depth of 7m (Figure 2). A flip-flop shooting arrangement was used keeping the source interval at 25m and the source was towed at a depth of 5m. Each streamer had 480 channels out of which 396 channels corresponding to the solid sections were placed in the front

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and 84 channels corresponding to liquid sections were placed in the rear part of the streamer. Each solid and liquid section consisted of 150m length and had 12 groups. The solid sections were having 12.5 m group spacing with 8 hydrophones per group and sensitivity of 19.7 V/bar at 200C where as the liquid sections were having 12.5 m group spacing with 16 hydrophones per group and sensitivity of 17.4 V/bar at 200C. Sequences were recorded with an approximate bearing of 900 and 2700 in a racetrack manner.

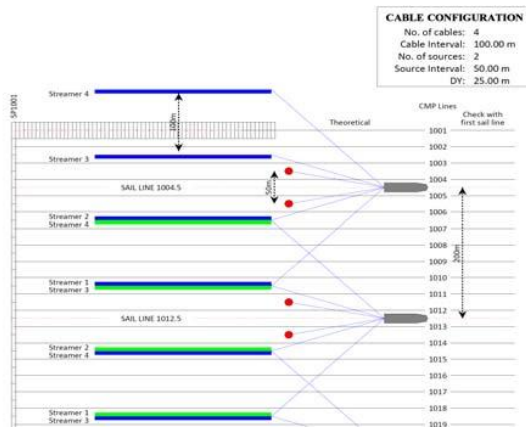


Figure 2. Streamer separation and overlapping used while recording the data.

## Theory & Methodology

Noise level in offshore seismic data recording is dominated by factors such as sea state, wind, streamer properties (type and sensitivity) as well as effect of the celestial bodies on the liquid particles of the ocean. If the data about sea state, wind and lunar phase is available along with the seismic data over a study area, the same can be compiled together to establish their cumulative weight on the quality of seismic data and also performance of the type of streamers.

Furthermore, consistent flow of wind with high velocity over the sea surface can change the magnitude of waves which in turn impacts the quality of seismic data and operation time. Since all these factors are either known or recorded during the survey it was desired to revalidate the effect of wind velocity, swell heights, lunar phases on solid and liquid sections. Although experiments and observations have been carried out in other parts of the world to see the effectiveness of solid and liquid streamers but this paper attempts to compile, analyze and integrate weather,

celestial and seismic information together to establish relationship between them with respect to a unique geographical location called Gulf of Mannar.

It is well known that seismic trace contains many peak amplitudes and any one of them cannot be representative of amplitude of the noise. In addition, one can't take the average of instantaneous amplitudes also since negative and positive values counters each other yielding an average value of zero. To avoid this, RMS amplitude for each channel for two separate windows was computed seeing that RMS values can well represent periodic vibration like sinusoids as well as noise (Equation 1 & Figure 3).

$$RMS = \left( \sum_{i=0}^{i=n} (A_i^2) / n \right)^{1/2} \text{----- (1)}$$

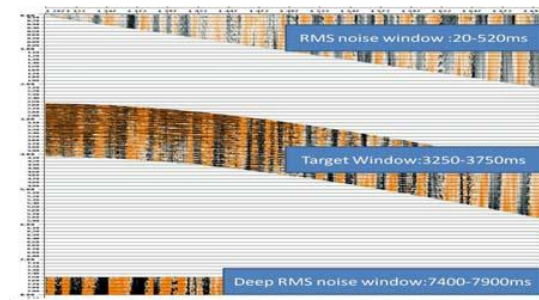


Figure 3. Graphical representation of analysis window over a shot record.

Moreover, solid and liquid streamer sections have different sensitivity and hydrophone array arrangement.

Accordingly their response to the same background will be different. Windowed RMS amplitude was computed and separate conversion factors were applied carefully while generating the background noise map for solid and liquid sections.

## Integration of Weather Data.

Information such as wind velocity, tide tables of nearest location, swell heights, lunar phase), were compiled from DPR, DOR, navigation report and weather reports for the period between the month of March and April, 2011 and RMS map of seismic data pertaining to the same period was generated to analyze the weight of each on the quality of



recorded seismic data. Seismic data (Sequence-A, Good records) recorded during the period P1 (18 to 21 March, 2011) represents the calm environment whereas Sequence-B (NTBC records) recorded during Period P2 (31st March, 2011 to 5th of April, 2011) represents the marginal weather condition.

Wind Speed, direction, swell height and lunar phase were compiled for the period P1 and P2 (Figure 4 & 5). It is very interesting to note that wind direction shifted from N-NE to S-SW between the month of March and April. Moreover, average wind speed during period P1 was 8 Knts and sea was quite calm with an average swell height of 0.75 m, whereas it was very challenging at times to acquire quality seismic data during the period P2. Strong southwesterly winds with average speed of 15 knts and swells of height 2m dominated the study during this period of time. Thus it can be observed that the swell was controlled by wind velocity. During P1 wind was blowing from N to NE with a speed of 8Knts and swell was less whereas during P2 wind was consistently blowing from S to SW with a speed of 20 Knts and their interaction with the sea surface caused swells with height of 2 m in an area where average swell height is 0.5 m only.

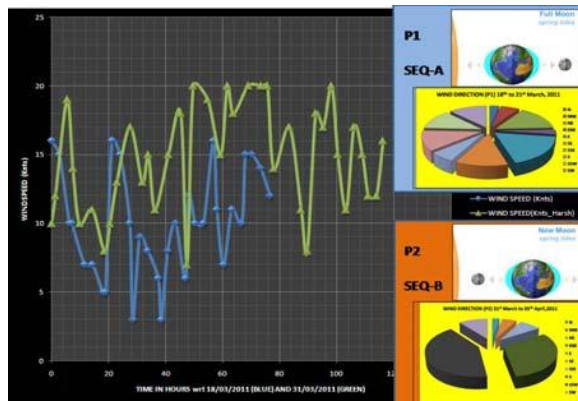


Figure 4. Wind speed and direction for the period between 18th to 21st March, 2011 (P1) is represented by blue line and right top pie chart. Green line and right bottom pie chart shows the wind velocity distribution between 31 March, 2011 to 05th April, 2011 (P2).

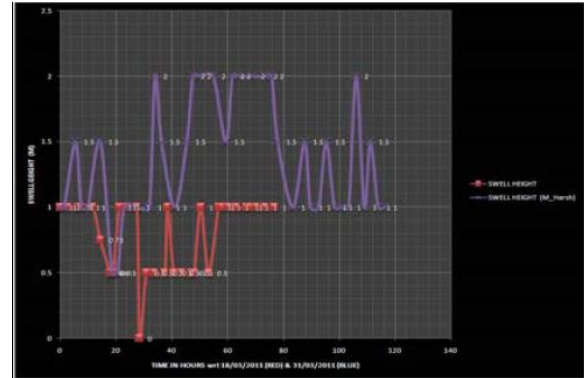


Figure 5. Swell heights recorded during the period between 18th to 21st March, 2011 (P1) is represented by the red line where average swell height is 0.5m. Whereas Blue Line represent swell heights for the period 31st March, 2011 to 05 April, 2011 (P2).

## Analysis of Seismic Data

**Calm weather (P1):** RMS map of one the sequence (Sequence A) acquired (Figure 6 and 7) during the period P1 shows low background noise level for both shallow and deep window. Average RMS noise for the shallow and deep window is around 2.2  $\mu$ bar and 2.9  $\mu$ bar respectively which is quite less, an indication of calm sea state further confirmed by the compiled weather information (Figure 9). Another interesting thing which can be observed in figure 6 (b) and 7 (b) is that average RMS value for the solid section is 2.6  $\mu$ bar whereas the liquid section gives a value of 1.6  $\mu$ bar. This shows that in calm environment liquid streamers can perform better than the solids. This is so because liquid streamers contain 16 hydrophones per group in the array arrangement whereas solid streamers contain only 8 hydrophones. Due to higher number of hydrophones per group ambient noise cancellation is powerful in liquid streamers than solid (Figure 8). Thus liquid streamers can provide equivalent or better data than solid streamers in calm environments.

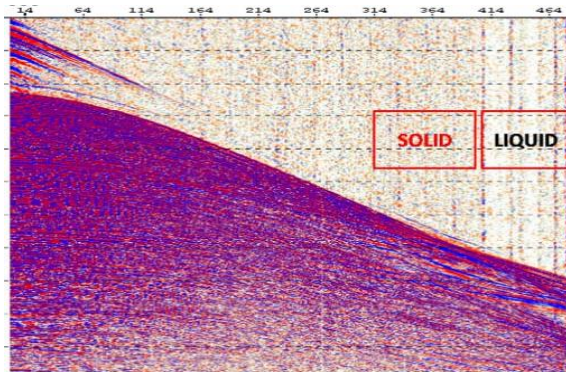


Figure 8. Channel 1 to 398 corresponds to solid section and 399 to 480 correspond to the liquid section. Background noise strength is low in liquid section as compared to solid in calm weather condition.

**Marginal weather (P2):** NTBC records of sequence-B were recorded at the time when lunar phase was of new moon. Alignment of sun, moon and earth exerts pull on the water bodies surrounding the earth and causes turbulence in the sea. This turbulence was further complemented by the consistently blowing Southwesterly wind flowing at a speed of 20 knts (Figure 9). Thus it is obvious that the background noise level will be high during this period and quality of seismic data will be compromised.

RMS map for shallow and deep section shows bright high amplitudes for the liquid sections. Liquid sections recorded noise level of as high as  $20\mu\text{bar}$  whereas solid sections recorded a maximum of  $5\mu\text{bar}$  only. It is clear from Figure 10(b) and 11 (b) that in a sea state of spring tides, consistent wind speed of 20 knts and 2m high swell solid streamers perform much better than the liquid ones. Average RMS value for the solid sections remains at  $4.3\mu\text{bar}$  where as liquid sections are severely affected by the swell and bulge waves and shows an average value of  $5.8\mu\text{bar}$ .

Both the sequences were acquired during spring tides, Sequence A in full moon and Sequence B in new moon, but the spectrum of Sequence-B contains low frequencies of higher strength than the spectrum of Sequence-A.. It can also be observed (figure 12) that swells energy strength decreases as the frequency increases. The noise dominating the records of Sequence-B is of low frequency in nature and is less than 20Hz. This low frequency noise is due to the turbulence of fluid surrounding the streamer. Swells hitting the liquid sections create bulge waves which travel through

the liquid sections to the hydrophones and appear as low frequency since liquid sections are not effective like solid sections in cancelling bulge wave propagation through them.

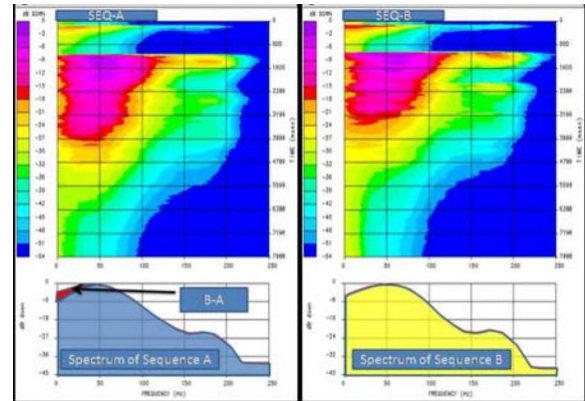


Figure 12. TF and power spectrum computed for sequence- A and Sequence-B. Red polygon indicates the difference in spectrum between Sequence-A and B.

Moreover, it can also be observed in this case of hybrid streamer configuration that amplitude response to the same background is different in terms of amplitude due to difference in sensitivity between solid and liquid sections. The ration of solid to liquid sensitivity in this case is 1.13 i.e. 1bar of pressure will cause a development of 19.73 V in the solid section where as 17.4 V in the Liquid section. This difference is significant and the acquired data will be ineffective for relative amplitude based study such as AVO and pre-stack inversion. It was tried to address the issue of difference in sensitivity by scaling the channels pertaining to liquid sections with a scalar of 1.13. Subtracting the scaled data with the original data shows significant improvement in the strength of liquid section (Figure 13) but difference in amplitude between the solid and liquid section is still visible. Amplitude balancing is an issue with hybrid streamer configuration and due to this reason offshore seismic industry slowly replaced the liquid streamers by hybrid configuration and hybrid configuration by complete length of solid sections.

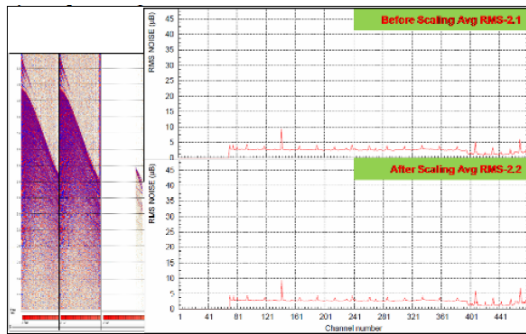


Figure 13. Amplitude balancing using scalar multiplication.

## Conclusions

Wind velocity plays a very important role in offshore seismic operation. Interaction of consistently blowing wind with sea surface, which is already in turbulence due to spring tides, can create high level of background noise.

Streamers towed at a depth experiences wing and flow or wave related turbulence. This turbulence, surrounding the streamer, creates bulge waves within the liquid streamers during rough weather. Bulge wave travels through the streamer liquid and affects the hydrophones directly. This type of noise exhibits low frequency characteristics and remains below 15-20 Hz.

Hybrid streamers can be used in calm environment but the data can only be used efficiently for structural interpretation. Amplitude based studies such as AVO and Inversion will be compromised due to difference in response of the solid and liquid sections.

Operation down time and propeller related noise which used to be of high concern in liquid streamers can be reduced by using hybrid configuration but it can further be reduced with solid streamers.

Performance of solid streamers was excellent in calm as well as rough weather. Solid streamers can considerably decrease operational downtime due to bad weather.

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## Acknowledgement

The Author acknowledges the help received from Open Access Digital Repository of Ministry of Earth Sciences (MoES) during this study. Author also thanks the management of Oil India Limited for providing permission to publish this work.

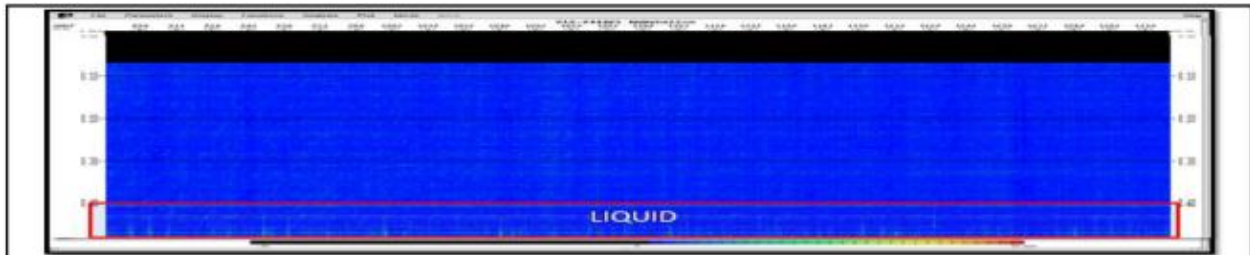


Figure 6 (a) Shallow Window P1

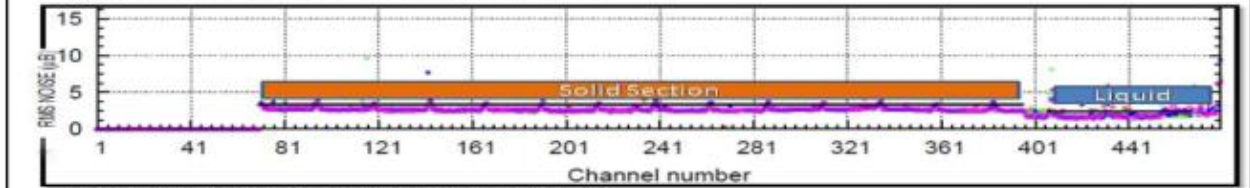


Figure 6 (b) Shallow Window P1

Figure 6. RMS amplitude map of one of the streamers, the data was acquired during P1 in calm sea state. Difference in the response of solid and liquid streamer for calm environment is depicted in 6(b).

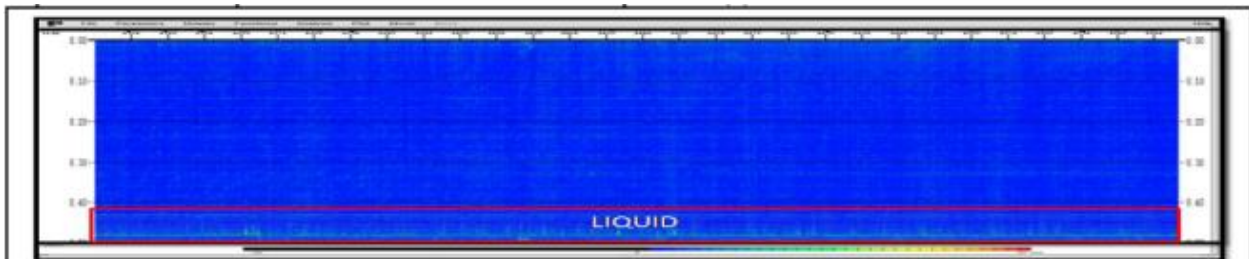


Figure 7 (a) Deep Window P1

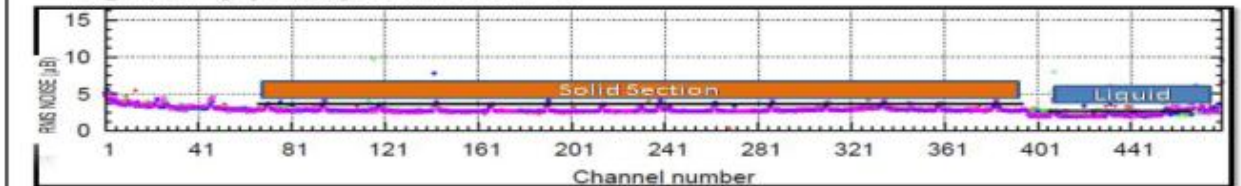


Figure 7 (b) Deep Window P1

Figure 7. RMS amplitude map of the deep section, average noise is 2.8μbar

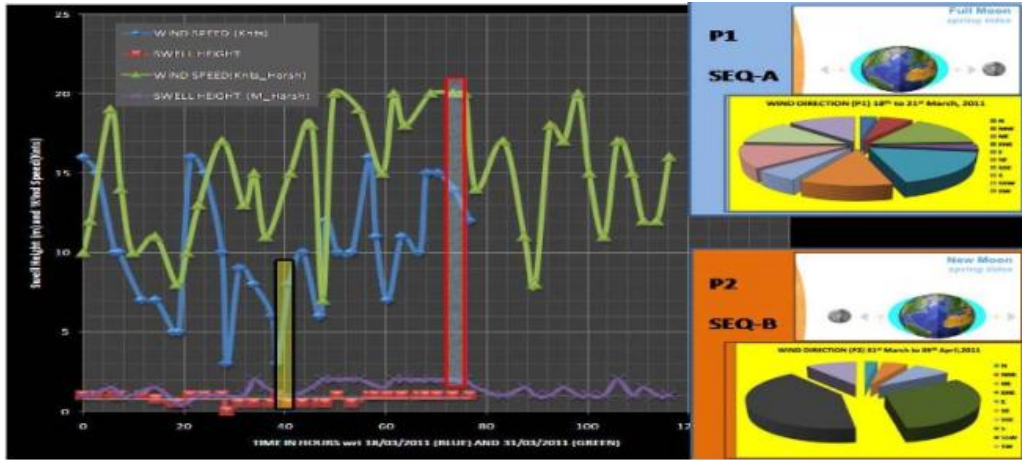


Figure 9. Read colour rectangle shows the operation time and weather condition of NTBP sequence whereas black colour rectangle indicates the operation window and sea state for the good record as shown in figure 6.

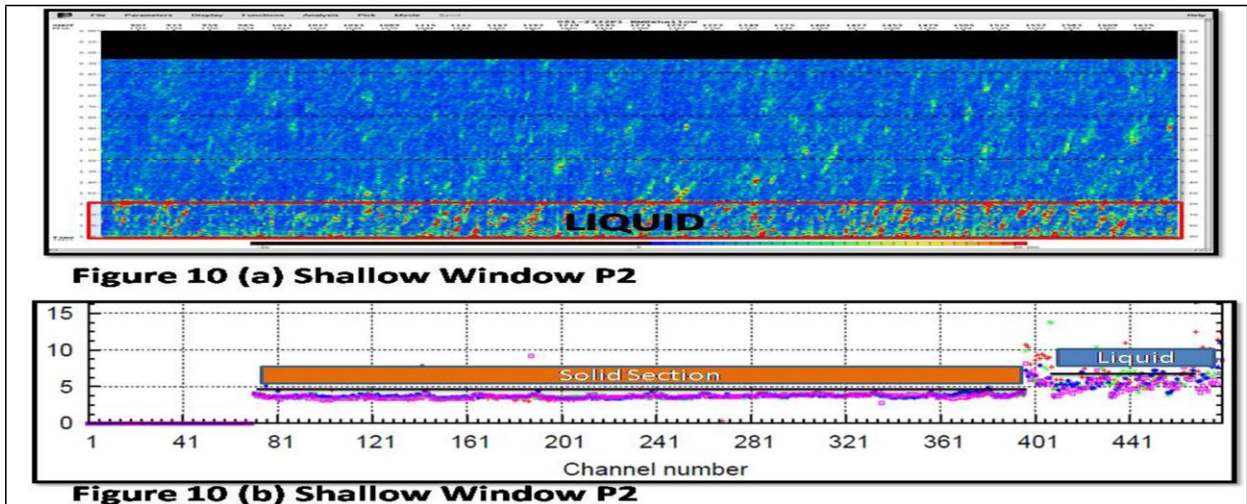


Figure 10. 10 (a) is the RMS map for all the shots recorded during the sequence B. Effect of swell hitting the solid and liquid section within the streamer is clearly visible. 10 (b) solid streamers, due to their weather resistant design, perform better than the liquid sections.

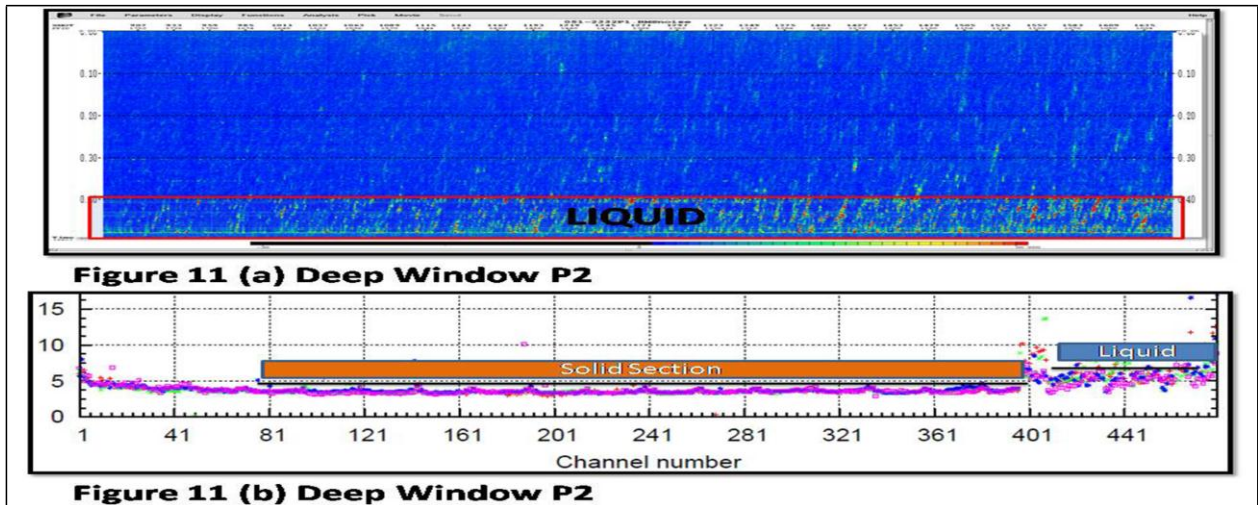


Figure 11. It is clearly evident from the plot that swells are affecting shallow as well as deeper sections of the shot record. Kinks in figure 10(b) & 11 (b) is due to wing generated turbulence. It is also present in calm environment figure 6(b).