Assessing the Accuracy of 3D SBP Buried Boulder Pre-cable Lay Surveys using Post-cable Lay 3D SBP Data

Introduction

Successful subsea cable installation comes down to informed planning and the optimal installation method(s) based on the shallow soil conditions of the installation route (Jaign, 2021). The challenge is accurately defining the shallow soil conditions along the installation route as a misinterpretation, or an incomplete understanding can result in project delays, unachieved burial targets, inadequate cable installation methods, damaged subsea cables, damaged installation equipment, unanswered questions, and loss of profit.

The Sub-Bottom Imager (SBI) 3D Sub-bottom profiler (SBP) mounted within the SeaKite Remotely Operated Towed Vehicle (ROTV) was used to assess the shallow soil conditions along a planned cable route, with the primary aim of identifying dense accumulations of buried boulders, which could influence the successful installation of the cables. Following this initial pre-cable lay survey, the SBI was mounted to a remotely operated vehicle (ROV) to carry out a post-lay cable survey, with the aim of imaging the cable to provide its final position following trenching operations. This provided the unique opportunity to compare the results from both the pre-lay and post-lay cable surveys to determine the accuracy of the pre-lay shallow soil interpretations and whether they influenced the final burial depth of the cables. This assessment involved combining the interpretation from the pre-lay and post-lay SBI surveys and included the results from: trenching and ploughing logs, seabed boulder interpretation, geotechnical reports and shallow soil isopachs of boulder bearing units. The integration of these results/interpretations provided insights on how accurate the pre-lay buried boulder survey interpretations correlated with the the final depth of lowering (DoL).

Interpretation Guidelines

For the pre-lay route surveys, the interpretation methodology was split into discrete anomalies and dense accumulations of discrete anomalies (Figure 1). Each discrete anomaly was evaluated and assigned a size classification based on a predetermined size classification code using the discrete anomaly diameter (A: 0.3-0.5 m, B: 0.6-1.0 m, C: 1.1-1.5 m, D: 1.6-2.0 m, E: 2.1-2.5 m, F: 2.6-3.0 m, G: 3.1-5.0m, and H: >5.0 m). Dense accumulations of discrete anomalies were defined by shapefiles covering their horizontal extents within the data. Each polygon was then assessed for the probability of encountering sub-seabed boulders using the results and location of the geotechnical reports, shallow soil isopachs, presence of seabed boulders, and finally the relative amplitude of the acoustic anomalies within the SBI data. With assigning a score of 1 for each attribute, the higher the score, the higher the probability of encountering sub-seabed boulders within the digitised area (Low: 0-1, Moderate: 2, High: 3-4). Finally, for areas which were defined as moderate or high probability, the top and bottom of the accumulations of buried boulders along the cable route positioning listing (RPL) within the SBI data were defined providing the thickness of the potentially boulder bearing units along the survey route.

The post-installation survey interpretation was performed by defining the cable diffraction within the SBI data every 1 m, with the deliverable consisting of the cables lateral, horizontal and vertical position (XYZ). This was correlated with the acquired bathymetry data which allowed calculation of the depth of cover (DoC) and DoL for the buried subsea cables relative to the undisturbed seabed level.

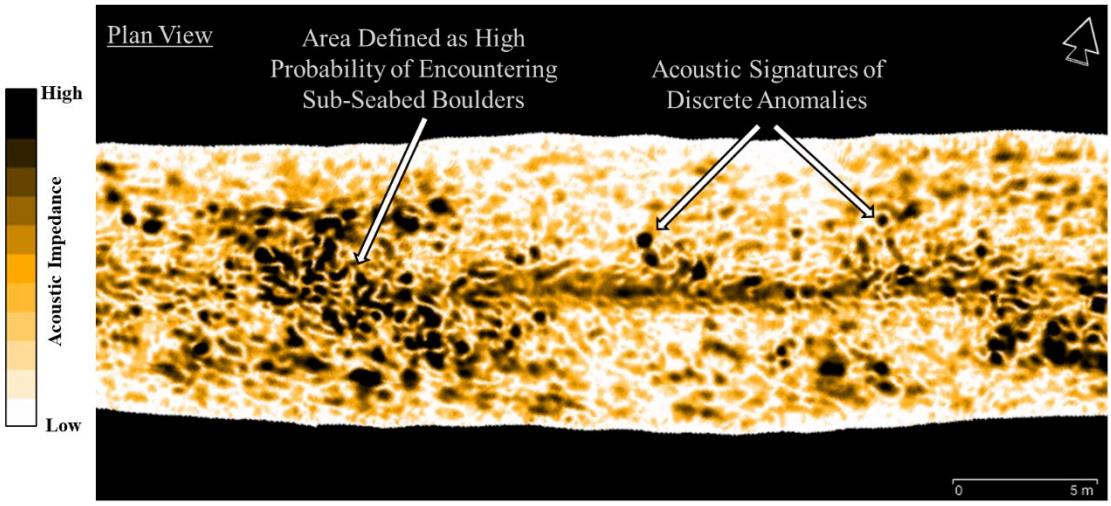

Figure 1 *Plan view image of the SBI data from the pre-lay survey highlighting an area which was interpreted as having a high probability of encountering buried boulders along with highlighting some of the discrete anomaly situated outside of this area. Other smaller acoustic anomalies are observed outside the high confidence area; however, they are below the minimum reportable size (likely to be cobbles).*

Correlation Parameters

The results from the post-lay survey were compared against the interpretation of the pre-lay survey to determine if there was correlation between the results. Particular focus was placed on areas where dense accumulations of buried boulders were interpreted as these were expected to be the most challenging areas to install the cable. However, areas where no dense accumulations of buried boulders were interpreted were also investigated as it was expected that the cable would likely be buried to the required depth. The trencher installation speed and the location of seabed boulders were integrated into the analysis. Combining the aforementioned results, sections of the cable route were classified as either high, moderate, or poor correlation, which corresponds to the accuracy of the interpretation of buried boulders from the pre-lay cable survey (Table 1). A high correlation was assigned to a section where the target cable depth was not achieved in areas defined as having a high probability of buried boulders being present. In addition, the trencher speed was erratic or decreasing, there were seabed boulders present and/or the section underwent ploughing. Similarly, a high correlation was assigned if the target cable depth was achieved in areas where no or a low probability of buried boulders being present was assigned, the trencher speed was continuous or increasing, there were no seabed boulders presents, and/or ploughing did not occur. On the contrary, a section was defined as having poor correlation if the results from the post-lay survey did not align with the interpretation of the pre-lay survey interpretation. This included scenarios such as an area interpreted as having a high probability of buried boulders being present, however the target cable depth was achieved, the trencher speed was either constant or increasing, no seabed boulders were present, and/or no ploughing took place. The moderate correlation corresponded to areas where some, but not all the results aligned to a clear result following the post-lay survey.

It is important to note that isolated areas underwent pre-lay ploughing, which were decided by the cable installation contractor using all available data, including the buried boulder interpretation. It is possible that prior to the cable installation, seabed and buried boulders were removed using the pre-lay plough, which influenced the correlation assessment in these areas. In these areas, the resulting correlation surrounding the limits of the pre-lay ploughing was built into the assessment of the correlation on top of the four previously mentioned variables (buried boulders being present, cable DoL being achieved, trenching speed and seabed boulders being present).

Table 1 *Matrix for determining if there is high, moderate, or poor correlation between the pre-lay buried boulder interpretation and the post-lay cable results. All scores are in relation to the pre-lay survey dense accumulations of buried boulders interpretation*

Results from post-installation cable survey	**Cable installation trenching speed**			**Pre-lay seabed boulders present? (1)**		**Pre-lay dense accumulations of buried boulders interpreted?**		**Results correlation**	**Other results in agreement with buried boulder interpretation (out of 4)**
Target cable depth	**Increases (*1*)**	**Constant (*0.5*)**	**Decreases/ Erratic (*1*)**	**Yes**	**No**	**Yes**	**No**		
Achieved (*2*)	X			X		X		Moderate	1
							X	High	3
					X	X		Poor	0
							X	High	4
		X		X		X		Moderate	1.5
							X	High	2.5
					X	X		Poor	0.5
							X	High	3.5
			X	X		X		Moderate	2
							X	Moderate	2
					X	X		Moderate	1
							X	High	3
Not Achieved (*2*)	X			X		X		High	3
							X	Moderate	1
					X	X		Moderate	2
							X	Moderate	1
		X		X		X		High	3.5
							X	Poor	0.5
					X	X		High	2.5
							X	Moderate	1.5
			X	X		X		High	4
							X	Poor	0
					X	X		High	3
							X	Poor	0

Notes:
1 - Scoring criteria: <1 = Poor, 1-2 = Moderate, >2 = High. Scores for each category are presented in Italics within brackets.
2 - For trenching speeds; an increase in trenching speed would suggest a decrease in the probability that buried boulders/coarse deposits were present. A decrease in trenching speed would suggest an increase in probability that buried boulders/coarse deposits were encountered.
3 - It also be taken into consideration that pre-lay ploughing may have been utilised to clear boulders.
4 - Seabed boulders detected during the pre-lay surveys may have been removed prior to trenching.

Results

Overall, there was found to be high correlation of all available results from pre-lay surveys, installation logs, and post-installation surveys, which represents an accurate interpretation from the pre-lay survey for ~93 % (109.340 km) of the combined survey routes (117.684 km). There was found to be a moderate correlation and poor correlation of ~4% and ~3 %, respectively. To further understand the correlation

cause and result of both the moderate and poor correlation, each category was broken down into four sub-categories (Table 2) to define the cause of the moderate and poor correlation. These categories were: 1) Geological; if the shallow soil conditions within a highlighted area changes but the interpretation is still valid. Likely cause of this is change in complexity of the shallow soils or buried boulder concentration within an area. 2) Not covered during the pre-lay survey; if the cable was installed outside the SBI data coverage area of the pre-lay cable survey, no assessment could be made. 3) Misinterpretation; if it was found that the pre-lay buried boulder interpretation should have been different based on the available information. 4) Unknown – if there are missing results, such as trenching logs, which prevented an accurate determination of the cause of the correlation.

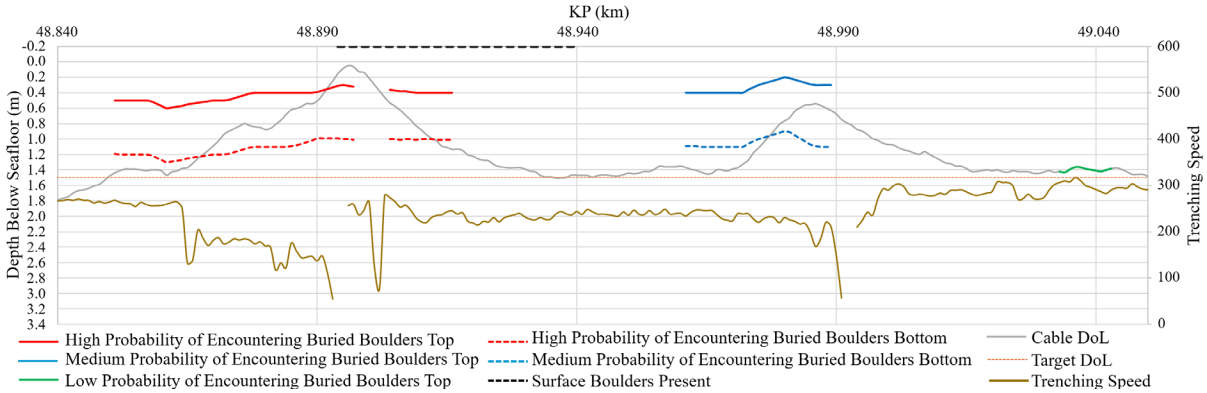

Figure 2 *Post-cable lay DoL results combined with the pre-lay buried boulder interpretation, trenching speed log, and area identified as having seabed boulders.*

Table 2 *Results of the correlation assessment across the entire survey route along with cause of correlation for areas defined as having moderate and poor correlation between the pre-lay survey interpretation and the post-installation results where 1 % represents approximately 1.18 km.*

Correlation	Total	Cause of resulting correlation			
		Geological	Not Covered During Pre-Lay Survey	Unknown	Misinterpretation
High	93 %	-	-	-	-
Moderate	4 %	2 %	1 %	<1 %	<1 %
Poor	3 %	2 %	0 %	<1 %	<1 %
Total		4 %	1 %	<1 %	<1 %

Conclusions

This paper has demonstrated that a pre-lay buried boulder survey incorporating 3D SBP data provides information to aid in the planning and mitigation of cable installation risk during the cable installation campaign. This was observed where there was correlation between the pre-lay survey results highlighting areas of possible buried boulders and the cable DoL not being achieved. Using 3D SBP data can allow for improved route planning and adaptation of installation methodology, which allows for mitigation of project delay, unachieved cable burial depth targets, damage to subsea cables, damaged installation equipment, and/or loss of profit.

References

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