COMBINING WIDE-TOW MULTI-SOURCES WITH A NON-UNIFORM STREAMER CONFIGURATION: A CASE STUDY FROM THE SARAWAK BASIN

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Summary

New survey design solutions for marine towed streamer acquisition were recently introduced by Widmaier et al. (2019). One of the key technical elements was the concept of wide-tow multi-sources, i.e., the distribution of multiple sources along the front of a streamer spread. All the wide-tow source case studies acquired in recent years have made use of uniform multi-source and multi-streamer spreads (i.e., regular streamer and source separations), thus following the same industry standards as in marine seismic surveys with narrow source configurations. However, uniform configurations may not always be feasible or optimal due to operational or geophysical constraints. In this article, we revisit the basics of the wide-tow multi-source method and make the step from a uniform to a non-uniform design. The first seismic survey using this novel method is currently being acquired in a challenging area offshore Malaysia.

Combining wide-tow multi-sources with a non-uniform streamer configuration: A case study from the Sarawak Basin

Introduction

New survey design solutions for marine towed streamer acquisition were recently introduced by Widmaier et al. (2019). One of the key technical elements was the concept of wide-tow multi-sources, i.e., the distribution of multiple sources along the front of a streamer spread. The method was launched as an alternative to the marine survey design method of reducing the streamer spread width, which is commonly used to decrease the distance between the sources and the outermost streamers and improves near-offset coverage. Decreasing the streamer spread width also reduces the sail line separation, and consequently, lowers survey efficiency and increases cost. Widmaier et al. (2020) presented a series of case studies that illustrated how wide-tow sources enabled higher streamer counts, and thus higher survey efficiency, without comprising the near offset coverage.

All the wide-tow source case studies acquired in recent years have made use of uniform multi-source and multi-streamer spreads (i.e., regular streamer and source separations), thus following the same industry standards as in surveys with narrow source configurations. However, uniform configurations may not always be feasible or optimal due to operational or geophysical constraints. In this article, we revisit the basics of the wide-tow multi-source method and make the step from a uniform to a non-uniform design based on the first case study from the Sarawak Basin offshore Malaysia.

Best practice survey design for wide-tow sources

Seismic sources have traditionally been towed in front of the two innermost streamers of a streamer spread. The standard source separation for a towed streamer survey is commonly defined by dividing the streamer separation L by the number of sources S. A typical example with a triple source and a 12 x 75m streamer spread is shown in Figure 1A and the key parameters are given in Table 1. The sail line separation or the size of the areal common midpoint (CMP) coverage per sail line is usually defined as a function of the streamer spread, i.e., $0.5 * number\ of\ streamers * streamer\ separation$. The areal CMP coverage per sail line is sometimes referred to as the 'CMP-brush'.

Wide-tow source separation is typically an integer multiple n of the standard source separation. Note that some values of n need to be excluded to ensure uniform 3D CMP coverage. E.g., the rule $n \neq S$ keeps the wide-tow source separation from equaling the streamer separation. This combination would generate duplicate fold for some CMP lines and lead to zero-fold for others. Wider tow of sources extends the areal CMP coverage per sail line, i.e., the 'CMP-brush' becomes wider. However, the number of CMP lines or sublines acquired per sail line is equal to the product of the number of sources S and the number of streamers N. Thus, the wider 'CMP brush' that results from a wider source separation is the result of partially sparser spatial sampling in crossline direction, and not from acquiring additional data. Figure 1B shows a 12-streamer spread with a wide-tow triple source with a source separation factor $n = 4$. The source separation increases from 25m for the standard triple source (example A) to 100m for the wide-tow triple source (example B). This is an increase of 75m between each source (see Table 1). With the increased 'CMP brush' generated by the wide-tow triple source, one may consider increasing the sail line separation by 75m from 450m (example A) to 525m (example B) without increasing the streamer count. The efficiency increase comes however at a cost. As predicted above, the CMP coverage modelled for example B (Figure 2B) shows CMP lines with zero-fold.

A sail line separation of 525m is the natural separation of a 14 x75m streamer configuration. Adding the two "missing" streamers to example B results in the configuration shown in Figure 1C and a uniform CMP coverage without gaps (Figure 2C). The uniform CMP coverage is possible, as the 'CMP brushes' generated by example C overlap in a complementary manner for adjacent sail lines. Overlapping 'CMP brushes' do not occur for traditional configurations as represented by example A.

In summary, it is best practice to plan and acquire towed streamer surveys with uniform coverage and regular spatial sampling. When combining standard streamer spreads with wide-tow sources, regular sampling can be achieved by means of overlapping the 'CMP brushes'. Detailed introductions to wide-tow multi-sources can be found in publications by Widmaier et al. (2019), Widmaier et al. (2017), and Long (2017).

Non-uniform configurations with wide-tow sources

Wide-tow multi-source configurations and wide streamer geometries can bring new challenges and in certain scenarios may require solutions alternative to the best practice approach. E.g., the maximum achievable towing width on both the source and receiver side is typically constrained by a seismic vessel's towing capacity or its deflector size. In shallow water, the length of the umbilicals and lead-ins can be a limiting factor as these define the deepest point in a towing configuration. In some environments, steering for coverage with overlapping 'CMP brushes' may be challenging. In special cases, it may also be desired to limit the crossline distance between the sources and the outermost streamers. We developed a proprietary method based on non-uniform source and/or streamer separations which can overcome such challenges. Spreads with non-uniform streamer separations have been used in the past like for example in compressive sensing-based marine survey designs (Mosher et al., 2017), or in a Fresnel zone-driven configuration with increasing streamer separations for the outer streamers (Hager et al., 2015). The method introduced here mainly relies on geometrical considerations. Streamers (or sources, or both streamers and sources) are re-arranged from a uniform configuration to a configuration with non-uniform separations while aiming for the same nominally uniform or close-to-uniform 3D coverage and without sacrificing efficiency relative to the best practice solution.

Instead of extending the streamer spread from 12 to 14 streamers in the standard way (Figure 1C), the additional two streamers can also be interleaved as illustrated in Figure 1D. The resulting non-uniform configuration with 14 streamers has the same physical spread width (i.e., the distance between the two outermost streamers) as the 12-streamer configurations shown in Figure 1A and 1B. The corresponding 3D coverage is shown in Figure 2D. While the nominal crossline sampling achieved is not strictly uniform when compared to coverage for the standard 14-streamer solution (Figure 2C), one can observe that is close-to-uniform and provides good crossline sampling for all practical purposes. Figure 2D also shows that the "CMP brushes" from adjacent sail lines do not overlap as in the best practice wide-tow source acquisition approach (Figure 2C). Note that the example discussed here is a straightforward implementation of a non-uniform configuration, but many permutations are possible. The more sources and streamers are available, the larger the solution space for non-uniform alternatives becomes.

Case study from Sarawak Basin offshore Malaysia

The concept of combining a wide-tow multi-sources with a non-uniform streamer separation was deployed for the first time in a seismic survey in the Sarawak Basin. The area has relatively shallow secondary targets that benefit from denser near offsets sampling. Wide-tow sources can deliver the near offset coverage without compromising efficiency and turnaround (e.g., Widmaier et al., 2021). The survey area is divided in two polygons with one in moderate to shallow water depths and one in very shallow water (20m). The latter makes wide-tow source operations unfeasible and limits the streamer spread width to 12 x 93.75m. To maximize efficiency and to avoid a reconfiguration between the two polygons, the 12-streamer spread has been complemented by 2 "interleaved" streamers as explained conceptually in Figure 1D. Note that interleaving the 2 streamers has not increased the spread width beyond operational feasibility. However, combined with wide-tow sources the 12 + 2 configuration enables acquisition on a 14-streamer pre-plot in the polygon with moderate water depth. The reconfiguration effort between the polygons is reduced to a source-side modification from wide to a standard narrow configuration. As the shallow area is acquired with a standard triple source (no wide tow), the pre-plot is based on 12 streamers only with the interleaved streamers being redundant in a nominal sense. This unique survey is currently being acquired by Ramform Sovereign. Figure 3 shows the source and streamer configuration just before the start of the project.

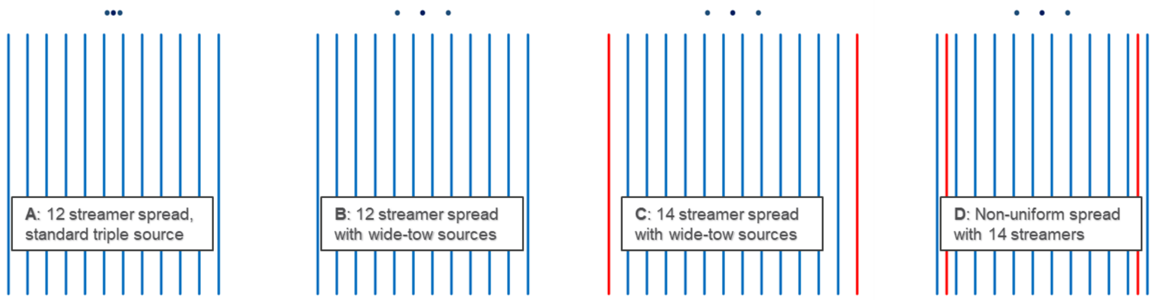

Figure 1 *Illustrations of the 4 triple source acquisition configurations as summarized in Table 1. The additional streamers (highlighted red) can either be added in the standard way to extend the spread-width (C) or can be interleaved resulting in a non-uniform streamer spread (D).*

configuration example	description of configuration	number of streamers N	streamer sep. L [m]	number of sources S	sail line separation [m]	source sep. scalar n	source separation [m]	total source spread width [m]	normalized efficiency (sailline separation)
A	12x75m streamer spread, standard triple source	**12**	**75**	**3**	**450**	**1**	**25**	**50**	**100%**
B	12x75m streamer spread, wide-tow triple source	**12**	**75**	**3**	**525***	**4**	**100**	**200**	**117%**
C	14x75m streamer spread, wide-tow triple source	**14**	**75**	**3**	**525**	**4**	**100**	**200**	**117%**
D	12(+2)x75m non-uniform spread, wide-tow source	**14**	**75**	**3**	**525**	**4**	**100**	**200**	**117%**

Table 1 *Description of the configurations A, B, C, and D as shown in Figure 1. The nominal CMP line spacing for all examples is 12.5m. *) Note that the sail line separation in B is based on 14 streamers while the streamer spread comprises 12 streamers only. Consequently, B generates a coverage with empty CMP lines as shown in Figure 2B.*

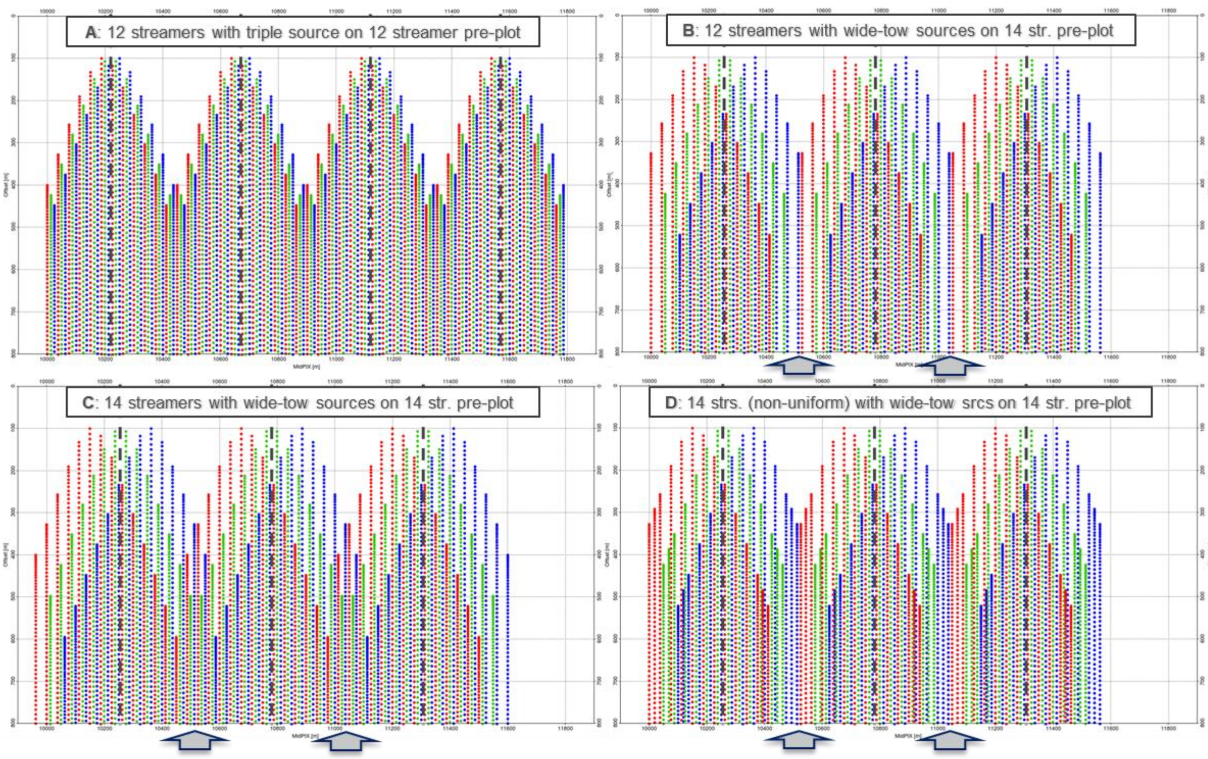

Figure 2 *CMP coverage comparison for the 4 acquisition scenarios described in Table 1 and Figure 1. The x-axis is crossline direction, and the y-axis is offset. The black dashed lines represent the sail lines. The colour coding (red, green, blue) of the CMP lines identifies the source that populates the subline. Example A is based on a 12-streamer pre-plot. Examples B, C, and D are based on a 14-streamer pre-plot which provides 17% higher efficiency. The grey arrows point to the sail line boundaries for the 14 streamer pre-plots. The differences in the coverage provided by configurations B, C, and D for this zone can be observed.*

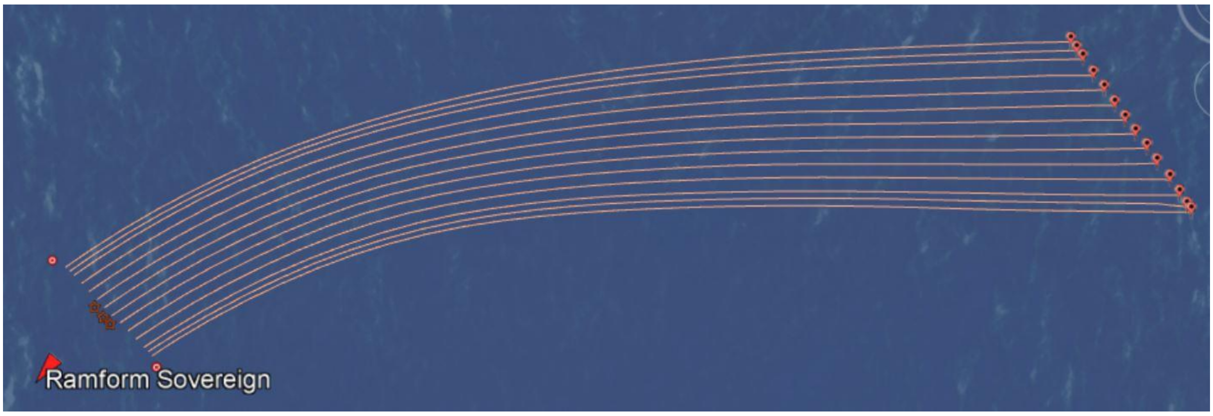

__Figure 3__ The Google Earth snapshot shows Ramform Sovereign preparing for the acquisition start in the Sarawak Basin/Malaysia. The streamer spread is non-uniform and consists of a 12 x 93.75m spread plus 2 interleaved streamers. The source separation is 125m and the total source spread width is 250m.

Conclusions

Wide-tow multi-source acquisition has gained a lot of traction in recent years. The best practice has been to design these surveys with uniform source and streamer configurations. In certain scenarios, the combination of wide-tow sources with non-uniform configurations may be an interesting alternative. If optimally designed, this new approach can deliver uniform or close-to uniform sampling and matches the efficiency of the equivalent best practice solution. The first seismic survey using this novel method has been designed and is currently being acquired in a challenging area offshore Malaysia.

Acknowledgements

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