

## Principles of Streamer Overlap Shooting

### Introduction

Streamer overlap is a robust method to maximize the repeatability of azimuths at sail line boundaries for time-lapse 3D ("4D") applications. It is most notably applied when the vessel is sailed along the pre-plot sail line locations. It is typically observed that overlap shooting has a simultaneous benefit of reducing primary infill requirements. A question naturally arises regarding the potential suitability of streamer overlap shooting in exploration or appraisal 3D surveys to reduce infill shooting requirements. The following discussions address the applicability of streamer overlap shooting for both 4D and Infill objectives. Note that "primary infill" refers to additional sail lines to the pre-plot positions being acquired during the "prime" acquisition phase, and

"secondary infill" refers to additional sail lines being acquired after the "prime" acquisition phase.

### Streamer Overlap Fundamentals

Reference to Figure 1 illustrates the following:

- A given streamer spread ( $n$  streamers with  $d$  streamer separation in meters) will have a nominal sail line separation equivalent to the product of the CMP bin width and the number of CMP lines. For both single-source and dual-source shooting the nominal sail line separation is equivalent to  $0.5nd$ . Streamer overlap involves additional streamers being towed with the same nominal sail line separation. Streamer overlap will provide a surplus of CMP traces in a broad zone along each sail line boundary. The

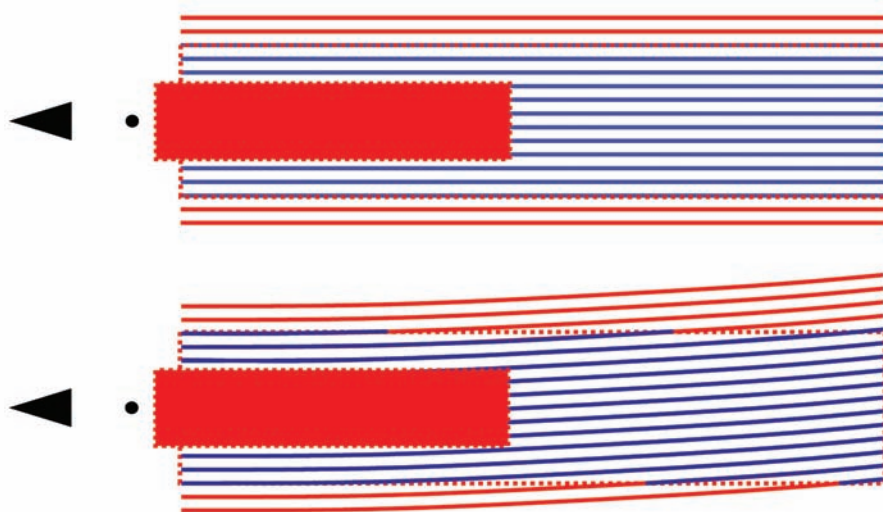


Figure 1: Demonstration of CMP binning with streamer overlap. The "live" area of CMP bins populated during acquisition is highlighted in solid red. For zero feathering the "excess" overlap streamers are plotted in red also. Streamer feathering allows the overlap streamers to contribute to CMP binning, as seen in the lower part of the figure.

### Summary

Unless a strict geophysical criterion such as the pursuit of 4D source-receiver repeatability, or an upper threshold upon maximum acceptable acquisition footprint is being applied, it will generally be the case that the maximum logistically practical streamer spread should be used in acquisition – without streamer overlap shooting. Streamer overlap shooting is a fundamental requirement for 4D applications, and has applications to high-end processing steps such as 3D SRME and 3D data regularization schemes. The case for streamer overlap shooting in conventional exploration or appraisal applications to reduce primary infill is less clear, and must be carefully planned to incorporate all known geophysical, operational and risk factors for a given survey location and environment.

width of the overlap zone is proportional to the degree of streamer overlap used. Typical overlap configurations are one or two streamers, e.g. 10 or 12 streamers on an 8 streamer pre-plot.

- As demonstrated in Figure 1, the additional streamers only contribute

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## Streamer Overlap Fundamentals

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CMP traces when feathering moves one side of the streamer spread into the CMP bin locations near the sail line boundary. Consequently, the outer streamers allow each CMP to be populated with more traces than would otherwise be available with "conventional" shooting. Hence, there is a reduced requirement (often none) to reduce the nominal sail line separation in order to maintain acceptable CMP coverage. In other words, overlap shooting reduces the primary infill requirements in the case of variable streamer feathering between adjacent sail lines.

- The surplus of traces in the overlap zone ensures that a consistency in azimuth repeatability is provided when using the PGS 4D acquisition strategy.
- Overlap streamers can be used prior to CMP binning to optimize cross-line processing operations such as "true 3D" data regularization and interpolation schemes, 3D SRME, and "true 3D" noise attenuation schemes.
- Overlap shooting enables a suite of binning strategies to be available for all cross-line CMP locations. This optimizes 4D repeatability during binning.
- Surplus traces from the additional streamers used in the overlap zone will be rejected after binning so that fold normalization for imaging is uniform everywhere throughout the survey area.
- The cost of streamer overlap (typically in 4D mode) is small compared to "conventional" shooting when Ramform vessel technology is

available, as the vessel is operationally capable of towing 12 - 16 streamers.

## Application of Streamer Overlap Shooting to 4D Surveys

PGS has demonstrated the effectiveness of its 4D acquisition strategy many times since its original publication more than two years ago in *TechLink* v. 3, No. 1 ("A strategy for optimal marine 4D acquisition"). This strategy combines the following: 1. Shot point repetition, 2. Streamer overlap shooting, 3. Dense streamer configurations (HD3D methodology), and 4. An appropriate CMP binning strategy in 4D processing. The recent Draugen 4D survey in the North Sea is a compelling example of the PGS HD3D-4D acquisition strategy yielding outstanding source-receiver azimuth repeatability (Figure 2). Consequently, the acquisition imprint on the 4D signal was minimized.

## Streamer Overlap Strategy for Reduced Infill

So what is the optimal strategy to use when additional streamers are available to be deployed in the pursuit of reduced infill? There are essentially two approaches possible during acquisition:

**1. Steer the vessel along the pre-plot sail lines, using a sail line separation corresponding to the nominal number of streamers.**

As an example, if the nominal streamer configuration is 8 streamers at 100 m separation, and 2 additional streamers in overlap mode are to be used (i.e. 10 streamers), the sail line separation will be 400 m. Steering by the pre-plot sail lines (and shot positions) is part of the PGS 4D acquisition strategy.

Operationally, this is the easiest approach to QC for CMP coverage, as the vessel is steered along geometrically simple trajectories. Unacceptable holes in coverage are recovered by secondary infill, i.e. the acquisition of specific sail lines to fill coverage holes. PGS global experience consistently demonstrates that this approach typically yields survey infill rates less than 10%, however, areas of extreme feathering variability (e.g. 20° between adjacent sail lines) may invoke severe secondary infill requirements in this scenario. Note that all duplicate traces in the overlap zone between each adjacent sail line will be rejected in the CMP binning phase of processing, particularly in the case where no variability occurs in streamer feathering

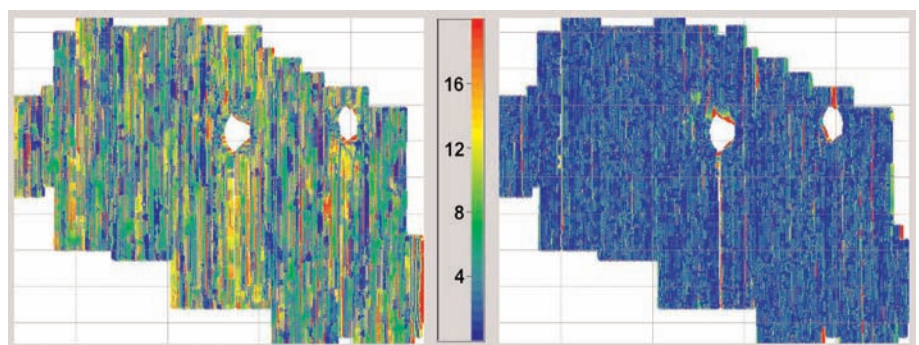


Figure 2: 4D source-receiver azimuth difference plots between two sets of successive surveys. The colour maps display azimuth differences from 0 (blue) to 20 (red) degrees. The comparison on the left is the 1998 vs. 2001 surveys (overlap, but no shot point repetition on the monitor survey), and the comparison on the right is the 2001 vs. 2004 surveys (shot point repetition + HD3D-4D).

between adjacent sail lines. If the overlapping traces are not used for any processing objective (e.g. 4D azimuth matching or high-end applications – see below) then the effort of streamer overlap will be “wasted”. Note also that the **lateral overlap distance in meters** is the critical parameter that influences the CMP coverage, and not the “number of streamers overlapping”.

A key issue that arises is the criteria used to establish the optimum **nominal** sail line separation. Is that criteria based upon conservative logistical expectations, or is it based on rigorous geophysical criteria? In the latter case, it may have been established by comprehensive pre-survey planning and modelling that the cross-line acquisition footprint (after appropriate pre-stack processing and imaging steps) at the shallowest target depth will be unacceptably high if the sail line separation exceeds a certain threshold. If there is no geophysical constraint upon the maximum acceptable sail line separation it is obvious that the largest sail line separation (and streamer spread width) should be pursued in the name of optimum efficiency and reduced cost, and no streamer overlap will be used.

## 2. Steer the vessel for CMP coverage based upon the nominal streamer configuration.

Take the example again of a nominal streamer configuration with 8 streamers at 100 m separation, and 2 additional streamers in overlap mode. If overlap shooting is being considered in the pursuit only of reduced infill, then a question arises: Why not use the additional streamers for acquisition with 500 m **nominal** sail line separation and no streamer overlap? It is quite likely that about 20% extra survey efficiency would be obtained using 10 streamers instead of 8. If there is a

geophysical limit of 400 m maximum sail line separation, then a possible case for overlap shooting arises – if the vessel capability to tow a 900 m streamer spread width is available. A case must then be made for the operational effort of deploying additional streamers without increasing the sail line separation (and therefore, the survey efficiency).

If a vessel is steered for “conventional” CMP-based coverage, then the trace population of a specific offset range will be used as the criteria for acceptable coverage, e.g. “steering by near-mid offsets”. Confusion can easily arise when a streamer overlap configuration and the vessel is steered for coverage. How should the additional overlapping streamers be used? Should the vessel steer for coverage using 8 or 10 streamers? Is there a scenario where extra effort of towing two additional streamers in fact had a net detrimental overall effect

upon survey efficiency and cost? Consider the following description.

After the completion of the first sail line in the survey, there will be a strip of CMP coverage computed using the navigation-based positions of **all 10 streamers**. What is the value of the outer 2 streamers? One possible approach is to steer for coverage using all streamers, but using real-time binning to reject coverage that falls outside geophysically-determined cross-line offset limits. The outer 2 streamers, however, will result in more regular CMP coverage along the sail line seam, and consequently, the trajectory of the 2nd sail line can be steered **a larger distance from the 1st sail line than would be the case if the overlap streamers were not used**. This system is then repeated for all remaining sail lines required to complete the total 3D survey area.

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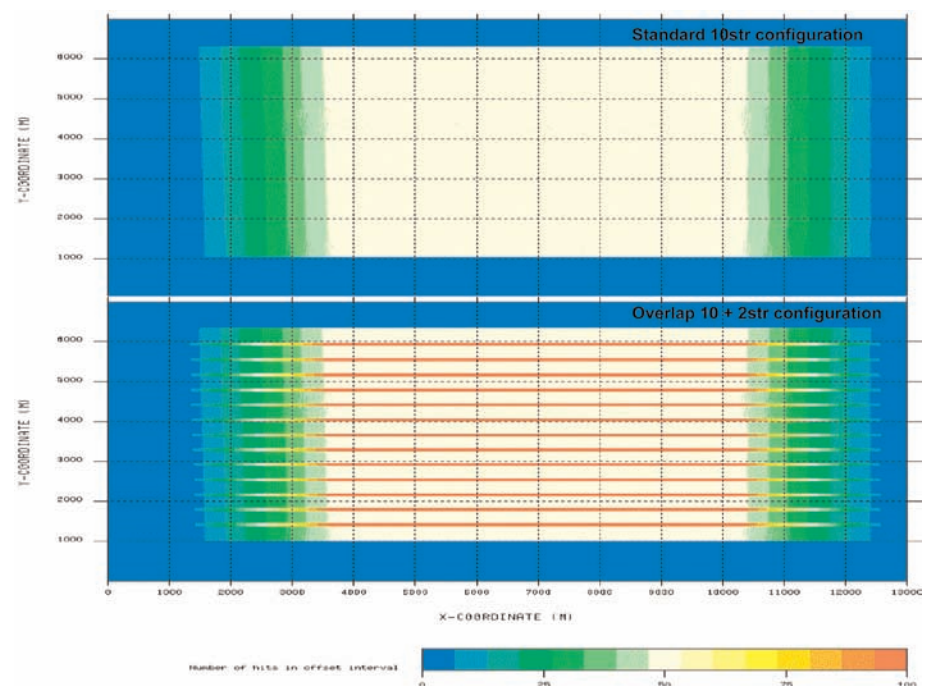


Figure 3: Pre-plot navigation data analysis of streamer overlap shooting for a 10 streamer configuration applied to a 10 streamer pre-plot with no feathering (upper), and a 12 streamer configuration applied to a 10 streamer pre-plot with no feathering (lower). The bands of excess CMP coverage in the lower part of the figure correspond to the streamer overlap zone at each sail line boundary. These excess traces would contribute nothing to infill rates in this scenario if there was no feathering variability between adjacent sail lines.

## Streamer Overlap Strategy for Reduced Infill

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Note that the overlap streamer contributions must be incorporated in the binning analysis if they can have any value. The net benefit is that the overlap streamers may result in **less total sail lines**, and the total infill percentage is less. How much less? PGS has some experience to suggest that increasing the streamer spread without changing sail line separation will equate to some primary infill saving (refer to Figures 3 and 4), however, the benefit is not easily quantified prior to the survey, and this observation cannot be universally applied as a risk and operations analysis must be uniquely applied to each new survey location.

As a general case, the availability of a vessel with the capacity for towing high streamer counts will typically encourage the pursuit of the largest practical streamer spread (and sail line separation) in the name of higher efficiency, unless a credible geophysical constraint upon sail line separation can be made. In that case, streamer overlap may be a cost-

effective way to reduce primary infill, and may provide a useful platform for certain high-end processing algorithms.

Steering by CMP coverage in both non-overlap ("conventional") and overlap mode is more demanding in terms of onboard QC than simply steering by the pre-plot sail lines (option 1 above). Finally, it is noted here without elaboration that PGS is currently developing infill criteria based on local survey geology and data characteristics, in contrast to the historical approach based entirely upon surface navigation-based shot and receiver positions (CMP coverage).

## Conclusions

An inflexible geophysical restriction upon maximum sail line separation may incite consideration of streamer overlap shooting if it is logistically practical. The use of streamer overlap is generally more compelling for certain high-end processing applications than for the reduction of infill shooting. In specific cases where operational and risk factors are known it can be demonstrated that streamer overlap will reduce primary and/or secondary infill requirements.

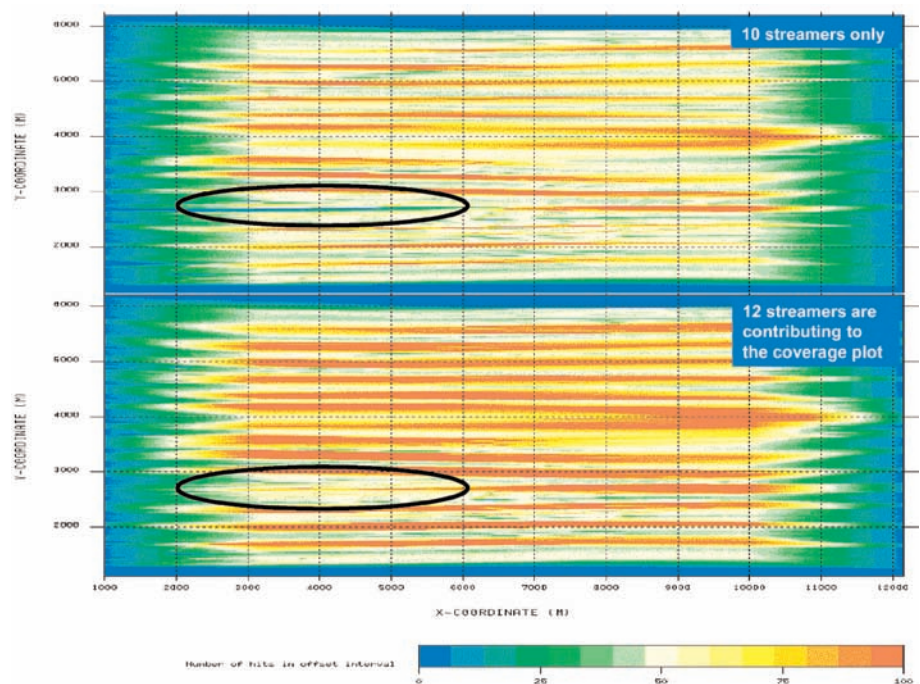


Figure 4: Real navigation data analysis of the actual CMP coverage for the corresponding two streamer scenarios in Figure 3. A large hole in CMP coverage along a sail line boundary (circled) is recovered by the use of the overlap streamers, however, the duplicate CMP coverage everywhere else is of no value to reduced infill! Note that the "red" zones of excess CMP coverage must have duplicate trace rejection applied in processing prior to the pre-stack imaging step. There is more incentive to increase sail line separation in the pursuit of increased efficiency in this example, rather than use the overlapping two streamers to reduce secondary infill only.

## CONTACT

### PGS Geophysical

#### London

Tel: 44-1932-260001

Fax: 44-1932-266465

#### Oslo

Tel: 47-67-52-6400

Fax: 47-67-52-6464

#### Houston

Tel: 1-281-509-8000

Fax: 1-281-509-8500

#### Singapore

Tel: 65-6735-6411

Fax: 65-6735-6413