

## Advancing 3DHD wide-tow multi-source streamer acquisition at Endurance CCS: pushing 3D efficiency whilst maintaining data quality

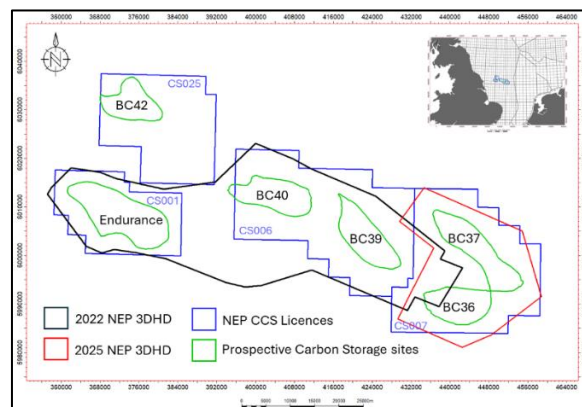
### Introduction

The Greater Endurance area contains six prospective CO<sub>2</sub> storage structures within 4 carbon storage licences (Figure 1) in the UK Southern North Sea. The first phase of the project, which will store 100 MtCO<sub>2</sub> over 25 years within the Triassic Bunter saline sandstone reservoir at the Endurance structure, was sanctioned in December 2024 with the construction phase underway. Future storage capacity plans to utilise additional Bunter reservoir stores, are currently being appraised.

Legacy 3D seismic datasets available across the area, predominantly acquired in the 1990s, have several critical limitations for CCS site characterisation and development planning. These include gaps in 3D coverage, poor shallow imaging and sub-optimal resolution at reservoir level. Improved baseline datasets are also required for future 4D seismic monitoring of the stores during injection.

In 2022, NEP and TGS acquired a wide-tow quad-source 3D High Density (3DHD) streamer survey extending across the Endurance carbon store in licence CS001 and the prospective stores within the CS006 licence. The motivation for utilising a wide-tow multi-source 3D configuration was to obtain high resolution imaging for overburden integrity and reservoir characterization efficiently over large areas. The survey successfully delivered much higher near-offset fold than legacy hydrocarbon-focused surveys that had deeper imaging targets, improving imaging and resolution at all geological levels (Cooper, 2022, Widmaier *et al.*, 2023, Tarasewicz, 2024).

In 2025, NEP and TGS, acquired a second 3DHD survey over Carbon Storage licence CS007, containing the prospective BC36 and BC37 stores. This paper outlines how this novel style of wide-tow quad-source acquisition has evolved from the 2022 to the 2025 configuration; details the relevant technical elements that allow for large-scale 3DHD surveys and suggests areas for future advancements.



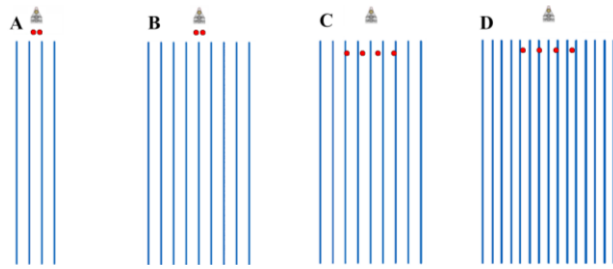
**Figure 1** Map of the Greater Endurance area showing NEP carbon storage licences, prospective CO<sub>2</sub> storage sites and the 2022 and 2025 seismic survey areas.

### Method

Historically, 3D towed streamer seismic surveys in the UK North Sea have been acquired using single or dual source configuration towed in front of a variable number of streamers (Figure 2). Many early surveys used small streamer spreads (Geometry A), that acquired data with good coverage at near offsets to provide imaging at shallow and deep geological levels, but proved to be inefficient for large areas. Adding streamers to this acquisition (Geometry B) increased overall survey efficiency, but reduced the spatial coverage of near offsets available for shallow imaging. In both cases, the arrangement for towing the equipment introduced a significant inline offset between source and receiver which further limited near offset availability.

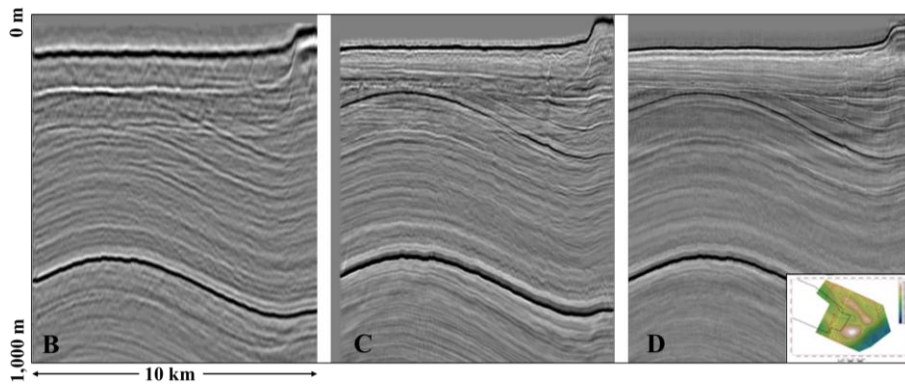
Increasing the number of sources towed behind the vessel provides both the efficiency of a large streamer spread and the near offsets required for shallow imaging. In 2022, this concept was successfully applied using a wide-tow quad-source array with 9 streamers (Geometry C). In addition, the sources were towed over the streamer spread, zero and negative offset data, further increasing the amount of near offset data available for shallow imaging.

In 2025, this concept was further developed by utilising 15 streamers with increased source separation but narrower streamer spacing (Geometry D). This resulted in a 30% increase in sail-line spacing compared to the 2022 survey whilst preserving the abundance of near offsets available for shallow imaging.



**Figure 2** Geometry A (left), B (centre left), C (centre right), & D (right) acquisition configurations. Note that sail-line spacing increases from left to right, increasing survey efficiency.

The 2022 acquisition configuration delivered an efficient dataset that successfully provided High-Resolution images of both shallow and reservoir level geology (Tarasewicz, 2024). The 2025 solution continues to advance the technique. Fast track images of the 2025 data (Figure 3) show that the larger spread continues to improve data quality whilst improving survey efficiency. Note that in parallel, advances in data processing, particularly challenges of shallow water (20m-90m), have also contributed improvement to the 2025 image compared to that from 2022 (Merry, 2025, Helgebostad, 2025).



**Figure 3** Comparison of crossline from; legacy 3D survey acquired using geometry B (left); 2022 3DHD survey acquired with geometry C (centre); & the 2025 survey acquired with geometry D (right).

## Theory

The fundamental character of wide-tow multi-source acquisition is the deliberate dilution of near-offset coverage, across a wider swath of subsurface lines, and into a finer cross line bin size, than can be achieved by dual source geometries. This distribution of near offset traces is taken advantage of during processing to improve shallow image resolution.

Figure 4 shows natural and normalized subsurface bins for each geometry, A through D. Surveys with geometries A and B have a natural acquisition bin size of 6.25 m x 12.5 m, while wide-tow multi-source surveys have a natural bin size of 6.25 m x 6.25 m (geometry C) and, more aggressively, 6.25 m x 4.69 m (geometry D). In geometries A and B, near offsets are concentrated in a narrow swath. However, with wide-tow sources, near offsets are distributed into the finer bin spacing over a much wider swath.

This data can then be super-binned into a nominal bin spacing to provide consistent near offset coverage. Here, a bin size of 12.5 m by 12.5 m, is selected for all surveys. Note, that super-binning is not required to maintain a sufficient level of fold, but required to ensure that each bin contains enough near offsets shallow imaging. Note also, that gaps in subline coverage at the edges of the spread in wide-tow multi-source geometries C and D are filled by adjacent sail line passes

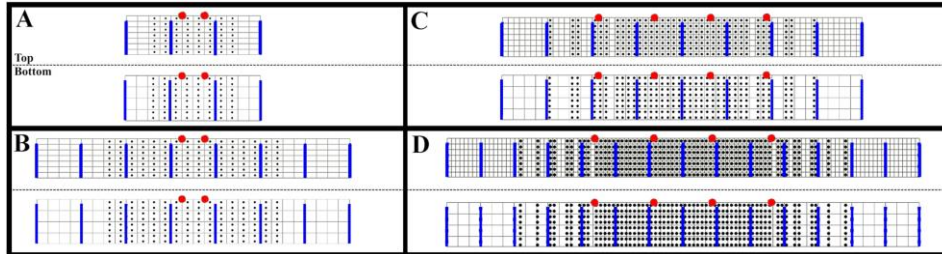


Figure 4 Common midpoints (CMPs) for survey's A - D plotted with both natural bin grids (top) and 12.5m x 12.5m nominal bin grids (bottom).

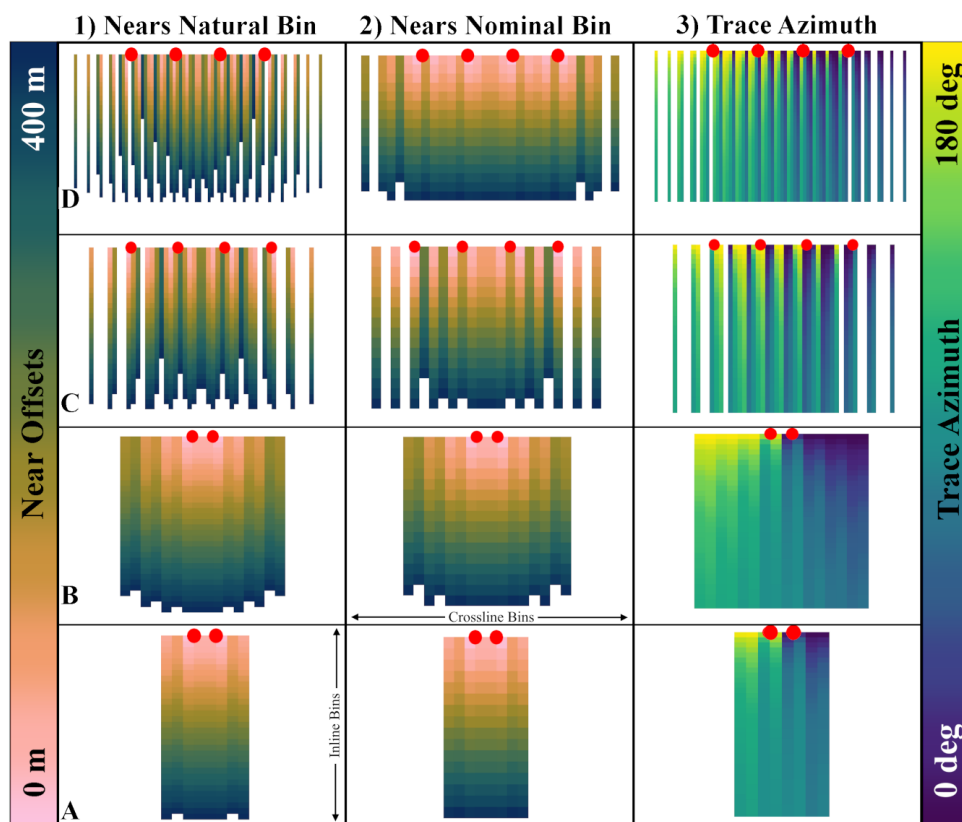


Figure 5 First 400m near offset for each survey on a map of natural bin grid (column 1). First 400m near offset for each survey on a map of nominal bin grid, 12.5 m x 12.5 m (column 2). First 400m offset trace azimuth on a map of natural bin grid (column 3).

The final distribution of near offset data for each geometry is shown in Figure 5 where column 1 shows the distribution of the first 0 m - 400 m of near offsets using natural bins for each geometry A - D. Geometry A maintains small near offsets for each bin, but with limited coverage. Geometry B acquires a wider swath of data, but near offsets get larger as streamers are added. Geometries C & D provide a distribution of near offsets all the way out to the outer streamers across a wide swath.

Figure 5 column 2 shows the near offsets for each geometry binned on a nominal 12.5 m x 12.5 m bin. For geometries A and B, the near offset coverage and distribution is unchanged. However, for geometries C & D, the acquisition consistently provides small near offsets across the large swath. It is for this reason that wide-tow multi-source acquisition is successful in delivering significantly improved

shallow images whilst maintaining survey efficiency. The 2025 survey acquired using geometry D provides a wider swath of well populated near offset bins when compared to 2022 geometry C, increasing survey efficiency, but also an improved near offset population. This demonstrates the continued development of this acquisition method.

Figure 5 column 3 highlights one significant challenge. The source-receiver azimuth ( $0^{\circ}$  -  $180^{\circ}$ ) of the first 400 m of near offsets varies in a stable manner for geometries A & B. However, for surveys C & D, azimuths alternate sharply between sublimes due to the geometry. This introduces complexity when combining data into super bins to obtain consistent near offset coverage.

## Conclusions

As has been shown in Figure 4 the diluted and distributed nature of near offsets, for wide-tow multi-source configurations, can be leveraged in data processing to provide efficient, high-quality data. Though it also presents nuance and challenges in pre-processing which continue to be addressed.

To build on from the 2025 survey, potential improvements could be made in the following areas:

- Adding additional sources, penta-, hexa-, and additional streamers to further increase productivity. Though, in shallow water, there will be operational challenges and with additional sources further dilution of fold to be carefully scrutinized.
- To alleviate the challenges of fold dilution and improve data quality further, increased source firing rate and self-simultaneous shooting will improve inline fold drastically. Though this comes with its own pre-processing challenges.
- With each of the above, it may be advantageous to re-assess the source and streamer depths that are most desirable to accommodate operationally challenging spreads in shallow water.

Wide-tow multi-source acquisition continues to advance. Developments in the processing of this novel technique, which naturally follow behind, will help the industry steer its efforts for better quality and more efficient acquisition.

## Acknowledgements

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