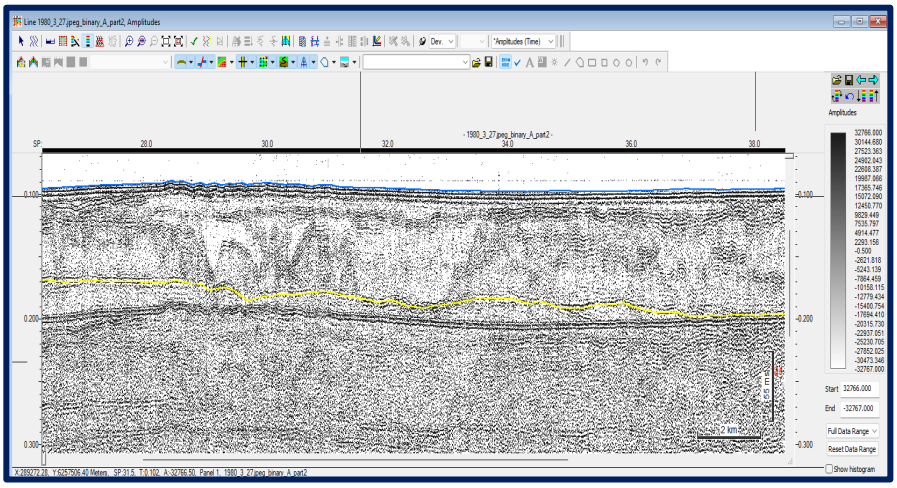
British Geological Survey

Conversion of scanned seismic sections to SEG-Y format with navigation-aware header encoding

Marine Geoscience programme

Open report OR/26/064



BRITISH GEOLOGICAL SURVEY
Marine Geoscience Programme
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Conversion of scanned seismic sections to SEG-Y format with navigation-aware header encoding

K Ezenwaka

Contributor/editor

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) aimed at developing a methodology to convert legacy scanned seismic data into SEG-Y.

The preservation and effective utilisation of legacy seismic data remain important challenges in geoscience, particularly where historical analogue records represent valuable geological information that is no longer available in its original digital form. Although advances in seismic acquisition and processing have transformed modern geophysical investigations, substantial archives of historical seismic records remain accessible only as scanned images or raster reproductions. Recovering the information contained within these records and integrating it into contemporary interpretation workflows present both technical and methodological challenges.

This report presents a systematic methodology for converting scanned seismic sections into spatially referenced SEG-Y datasets through a combination of digital image processing, geometric correction, navigation integration and seismic trace reconstruction. It addresses key stages of the conversion process including:

- image pre-processing
1. gridline removal
- shotpoint calibration
- horizontal re-mapping
- amplitude reconstruction
- navigation interpolation
- SEG-Y generation

Particular attention is given to maintaining the spatial relationship between reconstructed seismic traces and their original acquisition geometry, which is essential for reliable interpretation and integration with other geoscientific datasets.

The work reflects the practical application of scientific principles to a real-world data recovery problem. By documenting the underlying procedures, processing decisions and quality control considerations, this report aims to provide a transparent and reproducible methodological framework that can be evaluated, adapted and applied to other legacy seismic archives. It is intended to support geoscientists, researchers and organisations seeking to recover historical seismic information and extend its usefulness in modern geological and geophysical investigations.

Beyond its immediate application, the methodology highlights the continuing value of historical geophysical datasets and the opportunities offered by combining established image-processing techniques with contemporary digital data formats. It is hoped that this contribution will encourage further research, methodological refinement and wider collaboration in the preservation and re-use of legacy seismic data.

Contents

Foreword ii

Contents iii

Summary v

1 Introduction 1
- 1.1 Software environment 2

2 SEG-Y conversion workflow 3
- 2.1 Gridline removal 3
- 2.2 Navigation-constrained re-mapping, trace extraction and amplitude reconstruction 6
- 2.3 SEG-Y construction and header population 15

3 Workflow outcomes, assumptions and limitations 17
- 3.1 Demonstration of workflow outcome 17
- 3.2 Key assumptions 17
- 3.3 Limitations and quality considerations 20

4 Conclusion and recommendations 23
- 4.1 Key strengths 24
- 4.2 Recommendations 24
- 4.3 Software availability 25

Appendix 1 26
- Input fields and file selection 27
- Shotpoint calibration and interactive re-mapping 28
- Trace reconstruction and navigation interpolation controls 29
- Pre-processing options 30
- Spatial shifting (navigation shift) 31
- CSV export settings 32
- Start processing 33

Glossary 34

References 39

FIGURES

Figure 1 Overview of the scanned seismic image to SEG-Y conversion workflow. BGS © UKRI 2026..... 2

Figure 2 Original and detected grid masks before removal. BGS © UKRI 2026. 5

Figure 3 Scanned seismic image before removal of vertical and horizontal gridlines. BGS © UKRI 2026. 6

Figure 4 Scanned seismic image after removal of vertical and horizontal gridlines. BGS © UKRI 2026. 6

Figure 5 Workflow of seismic trace reconstruction from a re-mapped raster image. Each vertical image column is extracted as an individual seismic trace; grey-scale intensities are converted to seismic amplitudes; the resulting amplitudes are normalised prior to SEG-Y encoding. BGS © UKRI 2026. 10

Figure 6 Comparison of seismic data before (first image) and after (second image) navigation shifting, showing the effect of spatial correction applied to the reconstructed SEG-Y dataset. The red horizons are the bathymetry, which perfectly aligns with the seabed geometry after the spatial shifting has been applied to the data. BGS © UKRI 2026. 14

Figure 7 SeiSee display of written SEG-Y headers from a converted scan. BGS © UKRI 2026. 16

Figure 8 Original scanned seismic section used as input to the reconstruction workflow with associated gridlines and scanning artefacts. BGS © UKRI 2026. 18

Figure 9 Seismic section following gridline removal and navigation-constrained horizontal re-mapping, prior to trace extraction. BGS © UKRI 2026. 18

Figure 10 Reconstructed SEG-Y dataset displayed in interpretation software, demonstrating the successful conversion of the scanned seismic section into a spatially referenced, digital seismic dataset with preserved seismic character. The blue horizon is the seabed while the yellow horizon is the interpreted top of bedrock surface. BGS © UKRI 2026. 18

Figure A1 GUI for image to SEG-Y conversion. BGS © UKRI 2026..... 26

Figure A2 Mode selection in the image to SEG-Y conversion GUI. BGS © UKRI 2026. 27

Figure A3 Input, metadata and output folder selections in the GUI. BGS © UKRI 2026. 27

Figure A4 Sample of metadata formatting. BGS © UKRI 2026. 28

Figure A5 Toggle button for shotpoint calibration in the GUI. BGS © UKRI 2026..... 28

Figure A6 Shotpoint calibration GUI showing a calibrated scan. BGS © UKRI 2026..... 29

Figure A7 Trace reconstruction selection modes in the GUI. BGS © UKRI 2026. 29

Figure A8 Horizontal/vertical ratio and dilation width/height for gridline removal. BGS © UKRI 2026..... 31

Figure A9 Pop-up window in the GUI to select the image(s) to convert. BGS © UKRI 2026. .. 32

Figure A10 Shift rule panel within the GUI. BGS © UKRI 2026. 32

Figure A11 Export function in the GUI for the trace metadata CSV. BGS © UKRI 2026. 33

TABLES

Table 1 Principal SEG-Y trace header fields populated by the workflow during SEG-Y construction. 16

Summary

This report presents a systematic methodology for converting scanned legacy seismic sections into spatially referenced SEG-Y datasets suitable for use in modern seismic interpretation and geospatial analysis. The workflow addresses key challenges associated with historical seismic records, including:

- image degradation
- gridline interference
- non-uniform spatial scaling
- loss of original amplitude information
- reconstruction of acquisition geometry

The proposed methodology integrates adaptive thresholding, morphological filtering and inpainting to remove unwanted image artefacts while maintaining seismic reflector continuity. Interactive shotpoint calibration and navigation-constrained horizontal re-mapping are then used to correct geometric distortions and establish a consistent spatial relationship between the scanned image and the original acquisition geometry. Seismic traces are subsequently reconstructed from the corrected image, with grey-scale pixel intensities converted into digital amplitude values. Alternative trace reconstruction approaches are provided to accommodate different image characteristics and processing requirements, including trace-per-pixel extraction and navigation-based reconstruction.

The reconstructed traces are assigned interpolated shotpoint values and Universal Transverse Mercator (UTM) coordinates derived from supplied navigation data before being encoded into SEG-Y format. Additional functionality includes configurable amplitude enhancement, sequential spatial shifting and metadata export to support quality control and geospatial validation.

The methodology has been implemented within a Python-based graphical processing environment to facilitate consistent application and parameter configuration. Although the software was developed for in-house operational use and is not publicly distributed, this report documents the underlying scientific principles, mathematical procedures and processing stages to support independent evaluation and implementation.

Overall, the study provides a transferable framework for recovering and integrating historical seismic information into modern geophysical workflows, extending the practical value of legacy seismic archives for geological interpretation, research and geospatial applications.

1 Introduction

The conversion of scanned seismic sections into SEG-Y format represents a crucial step in the digitisation of legacy geophysical data. Many valuable seismic records exist only as scanned paper records or rasterised images, particularly from mid-20th century surveys. These scans often contain vital geological and structural information but are not directly usable within modern interpretation environments. To restore their utility, it is essential to convert them into SEG-Y, which is a standardised digital format that supports full trace-by-trace exploration in geoscience interpretation software.

Legacy seismic datasets continue to represent an important source of subsurface information for both academic research and commercial applications. In many regions, these surveys provide the only available geophysical coverage or offer valuable historical context that complements more recent investigations. The ability to recover and re-use such datasets can support regional geological studies, basin-scale interpretation, infrastructure planning and resource assessment while maximising the value of existing data assets. Consequently, methods that enable the integration of legacy seismic records into modern digital workflows have the potential to extend the lifespan and utility of historical geophysical archives while reducing the need for costly data re-acquisition.

Producing an accurate SEG-Y output from scanned images requires a robust and scientifically rigorous conversion workflow. Challenges with this task include:

- gridline interference from printed shotpoint and two-way time (TWT) intervals
- non-uniform trace spacing due to by-hand plotting or scanning distortions
- loss of original trace amplitude values
- alignment with navigation data to ensure geospatial accuracy

This report details a technically sound, Python-based approach with supporting graphical user interface (GUI)-based parameter tuning for converting scanned seismic sections into SEG-Y format, incorporating true spatial positioning and georeferencing for each seismic trace. The approach maintains alignment with industry standards (SEG Technical Standards Committee, 2017) and accommodates variability in scanned image resolution, acquisition geometry and navigation spacing.

This method specifically addresses the challenges of:

- removing visual grid artefacts from scans
- shotpoint calibration and geometric re-mapping
- converting two-diemsional (2D) image pixel intensity values into amplitude values on spatially positioned digital seismic traces
- reconstructing shotpoint coordinates from navigation files
- encoding header metadata into SEG-Y files to retain interpretability in geophysical software
- supporting GUI-based parameter tuning for accessibility

The methodology presented in this study was developed and evaluated using legacy two-dimensional (2D) seismic reflection profiles acquired using sparker and boomer systems. These high-resolution seismic sources are widely used in shallow-marine geophysical investigations and engineering site assessments due to their ability to image near-surface geological structures and sedimentary features. The conversion workflow is shown in Figure 1.

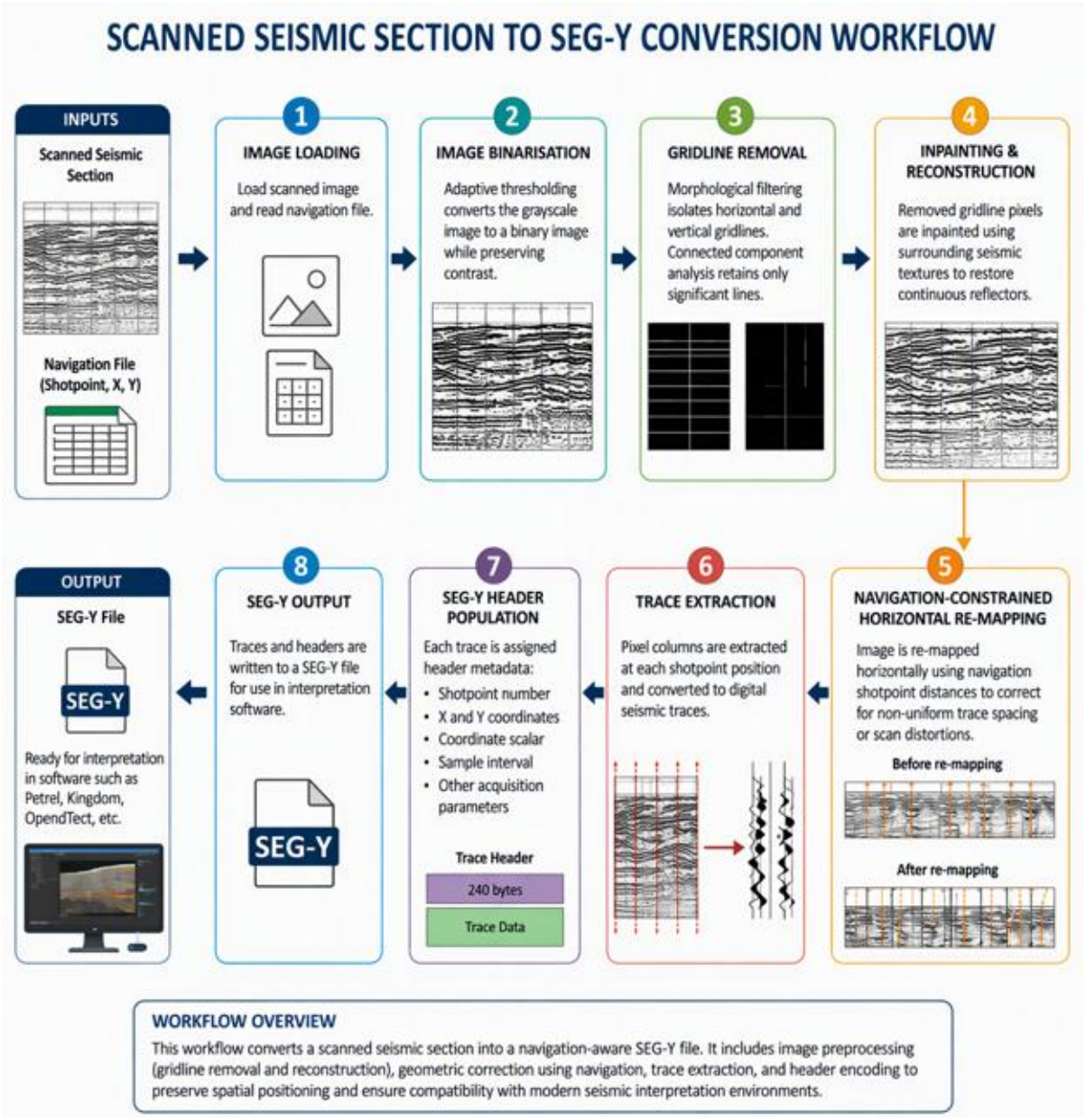


Figure 1 Overview of the scanned seismic image to SEG-Y conversion workflow. BGS © UKRI 2026.

1.1 SOFTWARE ENVIRONMENT

The workflow was developed in Python using a combination of open-source scientific and image-processing libraries.

- Image pre-processing, gridline detection, morphological filtering and inpainting were implemented using OpenCV (Bradski, 2000)
- Numerical computations were performed using NumPy (Harris et al., 2020)
- Seismic trace generation and SEG-Y file creation were implemented using ObsPy (Beyreuther et al., 2010)
- Segyio was used for SEG-Y validation and post-processing

The workflow is accessible through a custom GUI developed to support parameter adjustment, quality control and workflow execution without requiring the direct modification of source code. Throughout this report, references to the ‘software’, ‘workflow’ or ‘methodology’ refer to the implementation of the procedures described here.

For ease of reference, definitions of technical terms and acronyms used throughout this report are provided in the Glossary.

2 SEG-Y conversion workflow

2.1 GRIDLINE REMOVAL

Legacy scanned seismic images often include horizontal or vertical gridlines representing shotpoints or TWT intervals. These visual grids can distort trace extraction and introduce undesired noise or artificial amplitudes if directly sampled. To mitigate this, the gridlines must be removed without degrading the seismic waveform.

2.1.1 Method for gridline removal

1. Adaptive thresholding converts the grey-scale seismic image into a binary image while preserving local contrast variations
    - enhances the distinction between seismic reflections and unwanted gridline features
    - provides a robust basis for subsequent feature detection
2. Morphological filtering identifies and isolates gridline features based on their geometric characteristics
    - directional morphological operations are used to detect horizontal and vertical linear features
    - connected component filtering removes short artefacts and retains only gridlines that span a significant portion of the image
3. Inpainting reconstructs image regions affected by gridline removal by estimating replacement pixel values from surrounding seismic textures
    - helps preserve reflector continuity
    - minimises visual artefacts introduced during gridline extraction

2.1.1.1 ADAPTIVE THRESHOLDING

Adaptive thresholding is a local image-binarisation technique particularly suited for processing images with non-uniform illumination or contrast, which are common issues in scanned seismic records, especially when they originate from aged or unevenly digitised media (Gonzalez and Woods, 2018). In contrast to global thresholding methods that apply a single threshold value across an entire image, adaptive thresholding computes a unique threshold for each pixel based on the statistical properties of its surrounding neighbourhood (for example, mean or Gaussian-weighted mean of nearby pixels).

In this workflow, adaptive thresholding is applied as the first step in the gridline removal pre-processing stage. If the background is predominantly white, a grey-scale seismic image is first inverted as most thresholding algorithms are designed to identify bright features against a darker background. The image is then subjected to adaptive mean thresholding, whereby the threshold assigned to each pixel is determined from the mean intensity of its surrounding neighbourhood, adjusted by a constant offset. This localised approach enables robust binarisation under the varying image brightnesses and contrast conditions commonly encountered in legacy scanned seismic records. The procedure was implemented using the adaptive thresholding functionality available within the OpenCV image-processing library.

This is formally described as:

$$T(x,y) = \mu(x,y) - C$$

Where:

- $T(x,y)$ is the threshold at pixel (x,y)
- $\mu(x,y)$ is the mean intensity in a neighbourhood around (x,y)
- C is a constant subtracted to fine-tune sensitivity
- x is the horizontal image coordinate, that is the column/pixel position along the seismic section
- y is the vertical image coordinate, that is the row/pixel position representing the vertical or time direction

This technique is particularly effective for enhancing vertical and horizontal grid lines because these features exhibit consistent local contrast differences, regardless of large-scale variations in grey-scale intensity or other scanning-related inconsistencies.

Once binarised, the gridlines are separated by morphological operations (dilation) and selectively removed via inpainting. This pre-processing ensures that only the seismic reflection signal is preserved in the final output, which is a critical requirement for scientifically valid SEG-Y conversion.

In this method, adaptive thresholding is preferred over global thresholding, for example Otsu's method (Otsu, 1979), because it ensures that even weak gridlines are enhanced without affecting the trace signal, since seismic image scans are known to suffer from non-uniform pixel intensity variations caused by scanner glare, paper warping, ink fading across the image width or height and variability in grey-scale tone across the same gridline. Moreover, compared with frequency-domain filtering methods such as Fourier-domain notch filtering (Gonzalez and Woods, 2018), the adaptive thresholding approach used here is computationally simpler and provides direct spatial localisation of candidate line features. By operating in the spatial domain and targeting geometrically defined line features, this approach avoids the frequency-selective attenuation associated with conventional frequency-domain filtering while reducing the likelihood of suppressing genuine seismic reflectors with similar frequency content.

2.1.1.2 MORPHOLOGICAL FILTERING

Morphological filtering is a fundamental technique in image processing used to analyse and manipulate binary images based on the shape and structure of features (Serra, 1982; Soille, 1999). In the context of seismic image pre-processing, morphological operations such as dilation, erosion and connected component analysis are essential for isolating and removing undesired linear artefacts, namely gridlines. Erosion removes pixels from feature boundaries, causing small objects and noise to shrink or disappear, whereas dilation expands feature boundaries and can reconnect fragmented structures. Connected component analysis identifies groups of connected pixels as individual objects, allowing features to be filtered according to their size, shape and orientation.

In the seismic image-to-SEG-Y conversion pipeline, morphological filtering is applied immediately after adaptive thresholding has binarised the image. At this stage, the gridlines appear as bright lines against a dark background. Morphological operations are then selectively applied to extract gridlines in either orientation, allowing them to be filtered while minimising disruption to the actual seismic reflections.

In the workflow, the following morphological steps were applied.

1. Structuring elements: two orientation-specific rectangular structuring elements (vertical and horizontal kernel) are generated within OpenCV
    - the vertical kernel is defined as a narrow, column-shaped element to enhance vertical line features
    - the horizontal kernel is defined as a row-shaped element to enhance horizontal line features
2. Morphological opening: a combination of erosion followed by dilation, this is used to retain image features that match the shape and orientation of the selected structuring element (the filter shape), while suppressing other image features
    - a vertical opening targets vertically oriented gridline features
    - a horizontal opening targets horizontally oriented gridline features
3. Mask creation: the result of morphological filtering produces binary masks (mask_vertical; mask_horizontal) that highlight gridlines while minimising the inclusion of seismic trace content (Figure 2)
4. Line filtering: connected component analysis is applied to each mask to remove components that do not meet a minimum length threshold, further ensuring only prominent gridlines are targeted

This sequence is essential to ensure that gridline artefacts are removed cleanly without smearing or distorting actual seismic reflection data.

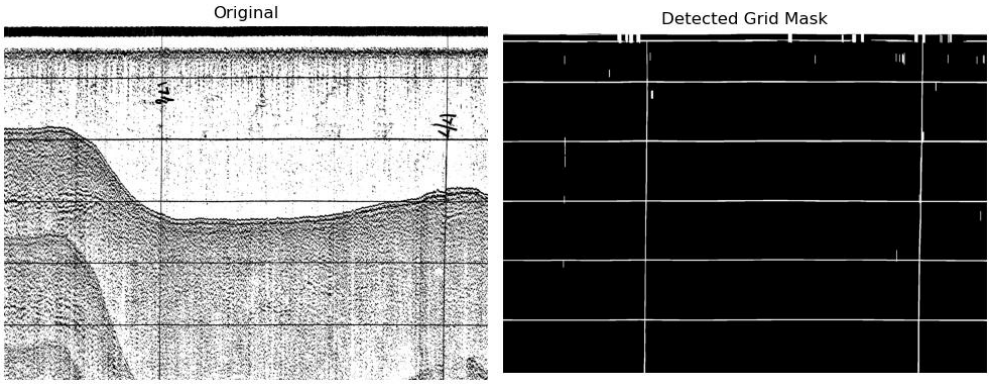


Figure 2 Original and detected grid masks before removal. BGS © UKRI 2026.

This method is justified for seismic image data because these data contain reflection events that commonly have approximately horizontal or gently inclined orientations, whereas gridlines are typically orthogonal and have relatively uniform spacing and thickness. Morphological filtering exploits these differences in geometry to:

- isolate gridline structures without affecting seismic reflections.
- avoid over-smoothing or generalisation that could occur with Gaussian or median filters
- enable selective inpainting only at gridline locations, preserving amplitude fidelity elsewhere

Additionally, unlike edge detection methods that are sensitive to noise and amplitude, morphological operations are topological: they depend on the presence and continuity of features, making them ideal for structured artefacts like grids.

2.1.1.3 INPAINTING

Inpainting is a technique used in image processing to reconstruct missing or corrupted regions by inferring pixel values from surrounding, undamaged areas. In the context of scanned seismic image conversion, inpainting serves as a crucial post-processing step to restore the image after gridline removal, ensuring seismic reflectors remain continuous and interpretable.

In the current workflow, gridlines are first detected through adaptive thresholding and morphological filtering, resulting in a binary mask highlighting unwanted vertical and horizontal lines. These masks are then passed to an inpainting algorithm to fill in the gaps left by removed gridlines without introducing significant visual or numerical artefacts.

The reconstruction is performed using the fast-marching inpainting method of Telea (2004), which estimates replacement pixel values from neighbouring, undamaged regions. The method is computationally efficient and particularly well-suited to the reconstruction of thin linear artefacts, producing visually coherent results while preserving the continuity of seismic reflections.

Alternative approaches, such as replacing gridlines with a fixed colour or reconstructing missing regions through simple averaging, can introduce edge artefacts or blurred zones that disrupt reflector continuity. Inpainting provides a more robust solution by preserving local image texture and contrast during reconstruction (Bertalmio et al., 2000; Gonzalez and Woods, 2018). Consequently, amplitude variations and reflection continuity are better maintained following gridline removal. An example of a scanned image before gridline removal is shown in Figure 3 and after gridline removal in Figure 4.

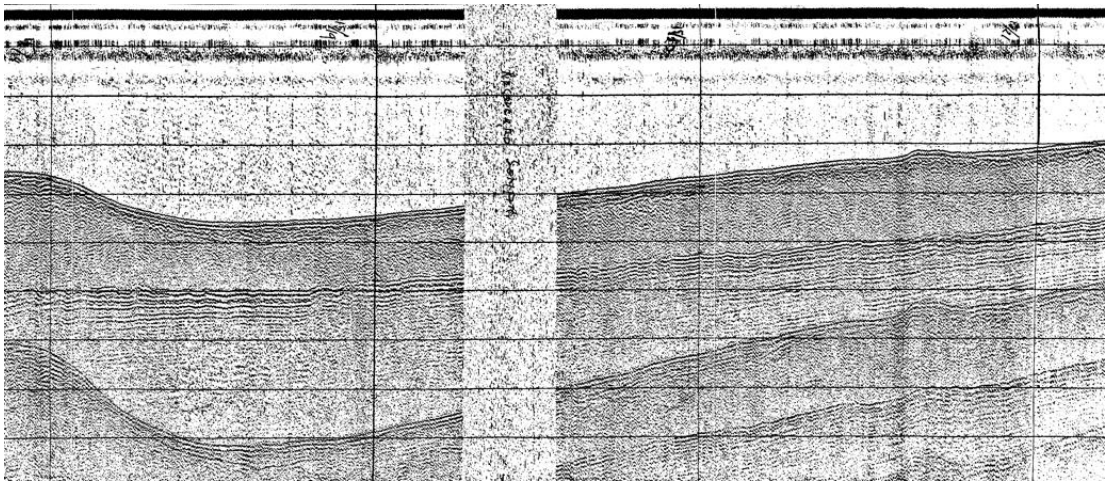


Figure 3 Scanned seismic image before removal of vertical and horizontal gridlines. BGS © UKRI 2026.

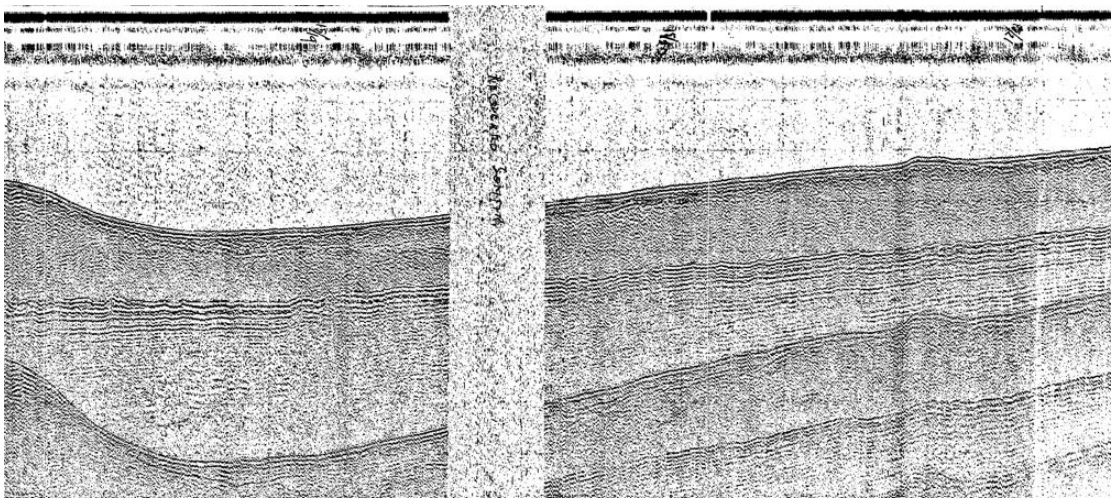


Figure 4 Scanned seismic image after removal of vertical and horizontal gridlines. BGS © UKRI 2026.

2.2 NAVIGATION-CONSTRAINED RE-MAPPING, TRACE EXTRACTION AND AMPLITUDE RECONSTRUCTION

The reconstruction of scanned seismic sections into georeferenced SEG-Y data requires more than the simple extraction of image columns into seismic traces. Legacy seismic images commonly contain geometric distortion introduced during scanning, printing, stretching or rasterisation processes. Such distortions frequently produce non-uniform horizontal scaling and spatial warping, resulting in mismatches between reconstructed seismic trace positions and their true acquisition geometry. Similar geometric inconsistencies in scanned geospatial and geophysical imagery have been widely documented in image processing and raster georeferencing studies (Sonka et al., 2013; Gonzalez and Woods, 2018).

Consequently, this workflow first applies a navigation-constrained re-mapping procedure designed to spatially calibrate the seismic image using known shotpoint locations and navigation coordinates prior to trace reconstruction. Once the seismic section has been geometrically corrected and transformed into distance-linearised space, seismic amplitudes and traces are reconstructed in a manner that preserves both temporal sampling and real-world spatial geometry. The following sections describe the shotpoint calibration, geometric re-mapping, navigation-aware trace reconstruction and amplitude recovery procedures implemented in the workflow.

2.2.1 Shotpoint calibration and horizontal geometric correction

To reconstruct the spatial geometry of the seismic line prior to trace extraction, the workflow implements an interactive shotpoint calibration procedure constrained by external navigation data. The methodology combines automated image analysis with user-guided refinement to improve robustness when processing legacy seismic sections containing degraded annotations, faded print quality, irregular shotpoint spacing or incomplete marker visibility.

The calibration workflow consists of:

1. Automatic detection of vertical shotpoint markers using morphological image processing.
2. Manual refinement through interactive editing.
3. Assignment of shotpoint values to detected markers.
4. Navigation-constrained horizontal re-mapping of the seismic image.

Vertical shotpoint markers are detected using adaptive thresholding followed by morphological opening with a vertically oriented structuring kernel:

$$V = B \circ K_v$$

Where:

- *(B)* is the binarised seismic image
- *(K_v)* is the vertical morphological kernel
- *(o)* denotes the morphological opening operation
- *(V)* contains detected vertical shotpoint markers

The line detection technique applied here is similar to that described in gridline removal (Section 2.1).

Detected shotpoint positions are designed to be subsequently refined by the user interactively through the addition of missing markers, the removal of incorrect detections, manual repositioning and shotpoint orientation reversal. This semi-automated refinement stage is important because scanned seismic sections frequently contain print degradation, scanning artefacts and incomplete annotations that cannot always be resolved reliably using fully automated image processing techniques alone.

2.2.2 Navigation-constrained horizontal re-mapping

Following shotpoint calibration, the workflow performs horizontal geometric re-mapping of the seismic image using navigation-derived cumulative distance. The objective of this procedure is to transform the scanned seismic image into a distance-linearised section in which horizontal pixel positions correspond proportionally to the true acquisition distance along the survey line.

For a series of navigation coordinates (X_i, Yi) where X_i and Y_i represent the easting and northing coordinates of the i^{th} navigation point, the cumulative acquisition distance is calculated recursively as:

$$D_i = D_{(i-1)} + \sqrt{\left(\left(X_i - X_{(i-1)}\right)^2 + \left(Y_i - Y_{(i-1)}\right)^2\right)}$$

Where:

- D_i is the cumulative acquisition distance at navigation point i
- D_{i-1} is the cumulative acquisition distance at the previous navigation point
- $X_i \; and \; Y_i$ and are the easting and northing coordinates of navigation point i
- $X_{i-1} \; and \; Y_{i-1}$ and are the coordinates of the preceding navigation point
- the square-root term represents the Euclidean distance between successive navigation points

For the first navigation point, the cumulative acquisition distance is set to zero.

This approach preserves variations in acquisition spacing along the survey line and is consistent with the standard spatial interpolation and georeferencing methodologies used in GIS and geophysical positioning systems (Burrough and Mcdonnell, 1998; Hengl, 2009).

The calibrated shotpoints are then linked to their corresponding cumulative acquisition distances. This relationship enables seismic traces extracted from the scanned image to be positioned according to their true spatial location, rather than assuming uniform shotpoint spacing. The workflow automatically detects whether the seismic image orientation is reversed relative to the navigation order. If the calibration shotpoints increase in the opposite direction to the navigation shotpoints, the image coordinate system is automatically flipped to maintain monotonic spatial consistency between image coordinates and navigation geometry.

After orientation correction, the calibrated shotpoints are sorted and mapped to cumulative navigation distance using linear interpolation. The horizontal spatial scale of the seismic image is estimated as:

$$\mathrm{S} = \mathrm{median}\left(\frac{\Delta D}{\Delta x}\right)$$

Where:

- S is the estimated horizontal image scale (metres per pixel)
- ΔD is the change in cumulative navigation distance between two calibrated shotpoints
- Δx is the corresponding horizontal pixel distance between those shotpoints in the seismic image

The use of the median estimator improves robustness against local calibration outliers and irregular shotpoint spacing.

An adaptive output width is then calculated based on the total physical distance represented by the seismic line:

$$W_{out} = (D_{end} - D_{start})/S_{(m/px)}$$

Where:

- (W_{out}) is the estimated output image width in pixels after re-mapping
- (D_{start}) is the cumulative distance at the beginning of the calibrated seismic line
- (D_{end}) is the cumulative distance at the end of the calibrated seismic line
- $(D_{end} - D_{start})$ represents the total physical distance covered by the seismic section
- $\left(S_{m/px}\right)$ is the estimated spatial scale of the image in metres per pixel

A new distance-linearised image is generated by resampling the original seismic section onto a uniformly spaced cumulative-distance grid. This procedure effectively performs a one-dimensional geometric warping correction constrained by real navigation geometry. Similar resampling and geometric transformation approaches are routinely applied in remote sensing and raster georeferencing workflows to correct non-linear spatial distortions (Wolberg, 1990; Schowengerdt, 2006).

The re-mapping stage is particularly important because it compensates for:

- scanner-induced geometric distortion
- non-uniform image scaling
- print stretching
- raster warping
- inconsistent horizontal shotpoint spacing

Failure to apply this correction may result in significant spatial misties between the reconstructed SEG-Y dataset and external geospatial datasets such as bathymetry, navigation tracks, interpreted horizons or well-control data. In seismic interpretation environments, even small geometric inconsistencies may propagate into horizon positioning errors, mistied

structural interpretations and inaccurate spatial integration with ancillary datasets (Yilmaz, 2001).

2.2.3 Trace extraction and amplitude reconstruction

Following navigation-constrained geometric re-mapping, seismic traces are reconstructed from the corrected raster image geometry. Performing trace extraction after geometric correction is a critical aspect of the methodology because it ensures that reconstructed traces inherit spatial positions that are consistent with the true acquisition geometry of the seismic survey line. This approach minimises spatial distortion and reduces positional misties that commonly arise when traces are extracted directly from uncorrected scanned sections (Yilmaz, 2001).

The re-mapped seismic section is represented as a two-dimensional grey-scale image matrix:

$$I(x, y)$$

Where:

- *(x)* denotes horizontal trace position
- *(y)* denotes vertical time sample position
- $I(x, y)$ denotes the grey-scale intensity value at image location (x, y)

Each vertical image column is interpreted as an individual seismic trace. The intensity values contained within a given column are sampled sequentially from top to bottom to form the amplitude samples of the reconstructed trace.

Then:

> Let $Trace_i$ denote the seismic trace extracted from the i^{th} image column, where $i = 0,1,\ldots,N-1$ and N is the total number of horizontal pixel columns in the geometrically corrected seismic image.

This column-wise sampling approach is consistent with raster-based seismic reconstruction methodologies in which image intensity variations are treated as proxies for seismic reflection amplitudes (Sonka et al., 2013).

To reconstruct seismic amplitudes, grey-scale pixel intensities are inverted so that darker pixels correspond to higher positive seismic amplitudes:

$$A(x, y) = 255 - I(x, y)$$

Where:

- $A(x, y)$ represents the reconstructed seismic amplitude at image location (x, y)
- $I(x, y)$ represents the grey-scale intensity value at image location (x, y), ranging from 0 (black) to 255 (white)

Amplitude inversion is necessary because conventional seismic displays typically represent strong reflection events using dark, variable-density shading. Consequently, grey-scale inversion restores the polarity consistency between the scanned image and the reconstructed digital seismic signal.

Optional contrast enhancement may additionally be applied through percentile clipping and gamma correction to improve reflector continuity and enhance weak seismic events. Such image enhancement approaches are widely applied in digital image processing and seismic attribute visualisation to improve interpretability under variable scan quality conditions (Gonzalez and Woods, 2018).

The reconstructed amplitudes are subsequently normalised into a signed 16-bit integer range prior to SEG-Y encoding: $[-32768\ to + 32767]$. This normalisation maximises the usable dynamic range while preserving compatibility with standard SEG-Y integer sample formats and legacy seismic interpretation systems. Integer-based amplitude representation is particularly advantageous for interoperability because some interpretation platforms exhibit limited support for floating-point SEG-Y sample encodings.

Unlike conventional raster-to-SEG-Y workflows, in which traces are extracted directly from the original scanned image, the present methodology reconstructs traces only after navigation-constrained geometric correction has been completed. Consequently, the extracted traces preserve physically meaningful spatial geometry, allowing the resulting SEG-Y dataset to maintain improved positional consistency with external geospatial datasets such as navigation tracks, bathymetry and interpreted seismic horizons. The process of trace reconstruction from the geometrically corrected raster image is illustrated in Figure 5.

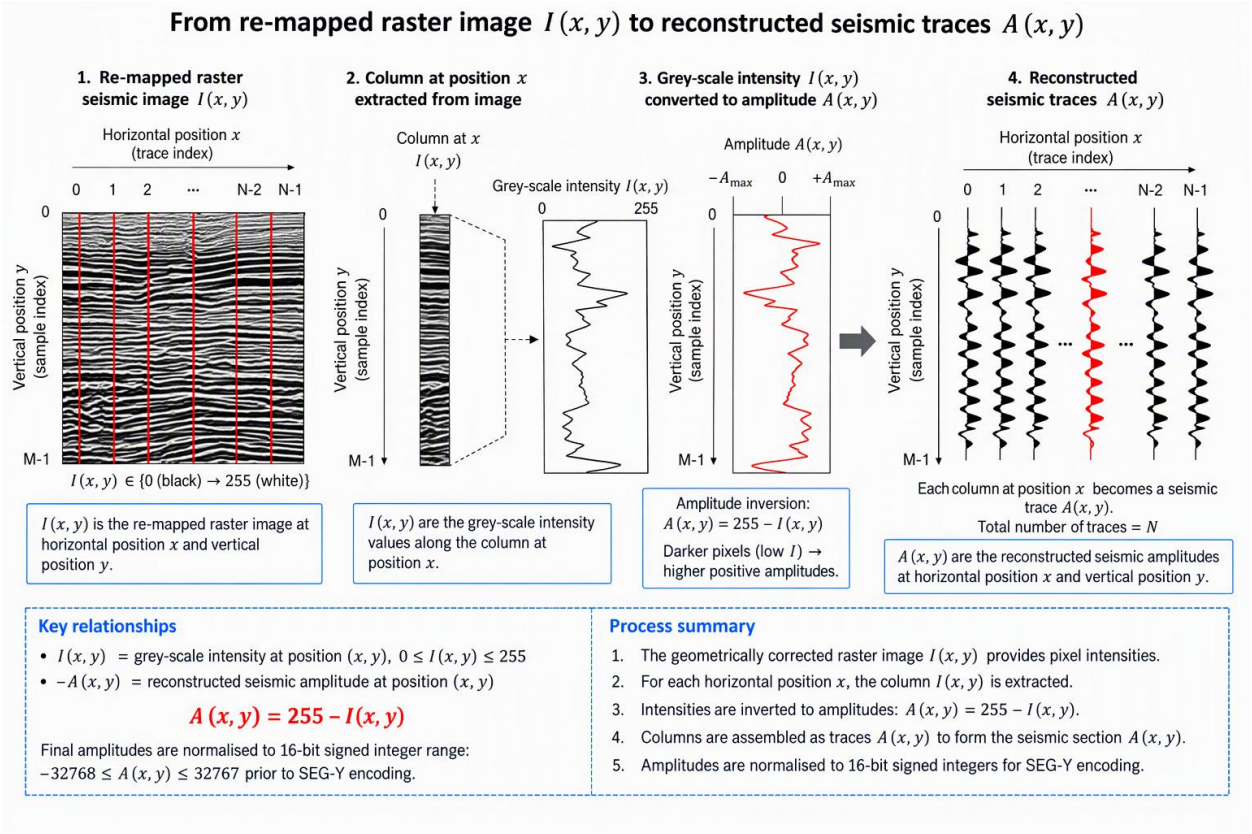


Figure 5 Workflow of seismic trace reconstruction from a re-mapped raster image. Each vertical image column is extracted as an individual seismic trace; grey-scale intensities are converted to seismic amplitudes; the resulting amplitudes are normalised prior to SEG-Y encoding. BGS © UKRI 2026.

2.2.3.1 NAVIGATION-AWARE TRACE RECONSTRUCTION

The trace extraction and amplitude reconstruction workflow described in Section 2.2.3 incorporates two approaches for reconstructing traces from scanned seismic images: trace-per-pixel reconstruction and navigation-based trace reconstruction. The appropriate approach depends on the characteristics of the scanned image and the availability of acquisition information.

Following trace reconstruction, navigation and shotpoint information are assigned to the resulting traces to establish their spatial relationship with the original seismic acquisition geometry. The procedures used to reconstruct traces and subsequently assign shotpoint and coordinate information for each approach are described here.

Trace-per-pixel reconstruction

In the trace-per-pixel reconstruction approach, each vertical image column of the re-mapped seismic section is exported directly as an individual seismic trace:

$$N_{\{trace\}} = W_{\{image\}}$$

Where:

- $(N_{\{trace\}})$ is the total number of reconstructed traces
- $(W_{\{image\}})$ is the width of the re-mapped seismic image in pixels

Under this approach, the spatial geometry of the reconstructed seismic line is inherited directly from the re-mapped raster image. Navigation coordinates are assigned by interpolating shotpoint values and UTM coordinates continuously along cumulative acquisition distance so that each reconstructed trace receives:

- an interpolated shotpoint value
- interpolated UTM easting
- interpolated UTM northing

This approach works especially well when the scanned seismic image preserves the original acquisition trace density and when the raster image resolution is sufficiently representative of the original seismic sampling interval.

Navigation-based trace reconstruction

In the navigation-based trace reconstruction approach, the number of positions of reconstructed traces are determined from the survey navigation geometry rather than directly from image columns. Traces are distributed uniformly along the cumulative acquisition distance using a target spacing of 6.25 m. This spacing is commonly adopted in high-resolution 2D marine seismic acquisition because it provides a practical balance between spatial resolution, computational efficiency and mitigation of spatial aliasing effects (Yilmaz and Doherty, 2001).

The total number of reconstructed traces is estimated as:

$$N_{trace} = \frac{D_{total}}{\Delta x} + 1$$

Where:

- N_{trace} is the total number of reconstructed traces
- D_{total} is the total cumulative navigation distance
- $(\Delta x = 6.25\ \text{m})$ is the assumed trace spacing

The reconstructed traces are subsequently distributed evenly along cumulative acquisition distance. For each reconstructed trace, the two neighbouring navigation control points that bound its position along the survey line are identified. The trace coordinates are then calculated by linear interpolation between these neighbouring navigation control points as:

$$X_t = X_i + \frac{d_t - d_i}{d_{i+1} - d_i}(X_{i+1} - X_i)$$

$$Y_t = Y_i + \frac{d_t - d_i}{d_{i+1} - d_i}(Y_{i+1} - Y_i)$$

Where:

- (X_t) and (Y_t) are the interpolated coordinates of trace (t)
- (d_t) is the cumulative distance associated with trace (t)
- (X_i) and (Y_i) are the coordinates of navigation control point (i)
- $(X_{\text{i+1}})$ and (Y_{i+1}) are the coordinates of the next navigation control point
- (d_i) and (d_{i+1}) are the cumulative acquisition distances associated with navigation control points i and $(i + 1)$
- (i) identifies the navigation interval within which reconstructed trace (t) occurs

Shotpoint values are interpolated similarly as:

$$SP_t = SP_i + \frac{d_t - d_i}{d_{i+1} - d_i}(SP_{i+1} - SP_i)$$

Where:

- (SP_t) is the interpolated shotpoint assigned to reconstructed trace (t)
- (SP_i) and (SP_{i+1}) are the shotpoint values associated with navigation control points i and $(i+1)$
- $d_t, d_i, and\ d_{i+1}$ are defined as before

Linear interpolation methods of this type are widely used in geospatial modelling and seismic navigation reconstruction because they preserve continuity between known control points while maintaining computational simplicity and spatial stability (Li and Heap, 2008; Hengl, 2009).

The use of continuously interpolated shotpoint values is particularly important for seismic interpretation workflows because it prevents the repeated shotpoint numbering patterns that commonly produce zig-zag horizon artefacts and positional inconsistencies in seismic interpretation software.

2.2.3.2 VERTICAL TIME SAMPLING AND TWO-WAY TRAVEL TIME CALIBRATION

The vertical sampling interval of the reconstructed seismic traces is derived from image geometry and user-supplied TWT calibration information.

Let:

- *h* = image height in pixels
- *ntwt* = number of TWT intervals
- *Δt* = TWT interval in milliseconds

The vertical sampling interval per pixel is computed as:

$$TWT_{per\ pixel} = \frac{(ntwt - 1)\Delta t}{h}$$

The corresponding SEG-Y sample interval is subsequently stored in microseconds according to SEG technical standards (Barry et al., 1975; SEG Technical Standards Committee, 2002). This procedure establishes a physically meaningful temporal sampling framework for the reconstructed seismic traces

2.2.3.3 SEQUENTIAL NAVIGATION SHIFTING WITH FEATHERED TRANSITIONS

In the context of seismic data conversion from scanned images to SEG-Y format, spatial alignment of navigation coordinates with the seismic image is crucial for ensuring spatial accuracy in interpretation and integration with other geophysical datasets.

The methodology allows for optional application of a navigation shift to adjust the start and end coordinates (X, Y) of the seismic line based on a specified distance and direction. This functionality is essential where scanned images or navigation files have known spatial discrepancies arising from digitisation offsets or other spatial reference inconsistencies. For legacy seismic data acquired before the widespread adoption of Global Navigation Satellite System (GNSS) positioning, the original navigation information is assumed to have a reasonable level of spatial accuracy, although some positional uncertainty may be present. Where a known or suspected discrepancy exists between the scanned seismic image and its associated navigation, a navigation shift can therefore be applied to improve the spatial alignment of the exported SEG-Y traces. Without such correction, the traces may appear spatially offset or misaligned in seismic interpretation software, particularly when overlaid with base maps or other survey data.

The navigation shift is implemented as a vector translation of the trace coordinates, specifically:

- the user specifies the starting and ending shotpoint numbers (SP_start; SP_end) across which the shift should be applied
- a total shift distance and a shift direction (for example, ‘130’; ‘SE’) are also provided

- the software calculates the unit shift per interpolated trace, distributing the total shift linearly across the specified segment
- the shift vector is decomposed into X (easting) and Y (northing) components based on the selected cardinal direction

The displacement in X and Y is computed using basic trigonometry:

$$\Delta X = d \,.\cos(\theta)$$

$$\Delta Y = d \,.\sin(\theta)$$

Where:

- d is the shift distance (in metres)
- θ is the azimuthal angle (in radians) corresponding to the chosen direction

Vector decomposition methods of this type are standard in navigation correction, coordinate transformation and geospatial positioning applications because they allow directional offsets to be resolved into orthogonal spatial components (Iliffe, 2000).

To prevent abrupt positional discontinuities at the boundaries of the shifted interval, the workflow applies a raised-cosine feathering function at both the beginning and end of each shift segment. Feathering functions are commonly employed in signal processing and spatial interpolation to smooth transitions between adjacent datasets and minimise edge artefacts (Bracewell, 1986).

For the transition zone at the beginning of the shifted interval, the feathering weight is defined as:

$$[w(t) = 0.5 - 0.5\cos(\pi t)]$$

For the transition zone at the end of the shifted interval, the weighting function becomes:

$$[w(t) = \ 0.5 \ + \ 0.5\, cos(\pi t)]$$

Where:

- $\big(w(t)\big)$ is the transition weighting factor
- (t) is the normalised transition distance varying between 0 and 1

The feathering weight controls the proportion of the total navigation shift applied at each trace within the transition zone. Values vary smoothly between 0 and 1, where $w = 0$ corresponds to no applied shift and $w = 1$ corresponds to the full specified shift. Intermediate values apply a proportionate fraction of the total shift, creating a smooth transition into and out of the shifted interval. The feathering operation ensures that spatial corrections are introduced progressively rather than instantaneously, thereby reducing geometric discontinuities and minimising visible navigation breaks within interpretation software environments.

Multiple shift rules may be applied sequentially along the seismic line. After each shift operation, the updated coordinates become the input for the subsequent rule, enabling cumulative spatial corrections to be propagated consistently throughout the navigation geometry. This sequential correction strategy is particularly important for legacy seismic datasets where multiple localised navigation inconsistencies may exist along different portions of the acquisition line. By combining directional vector translation with feathered transition weighting, the workflow improves spatial continuity while preserving overall navigation smoothness and interpretability. A sample of the converted SEG-Y with a spatial discrepancy before and after spatial shifting is shown in Figure 6.

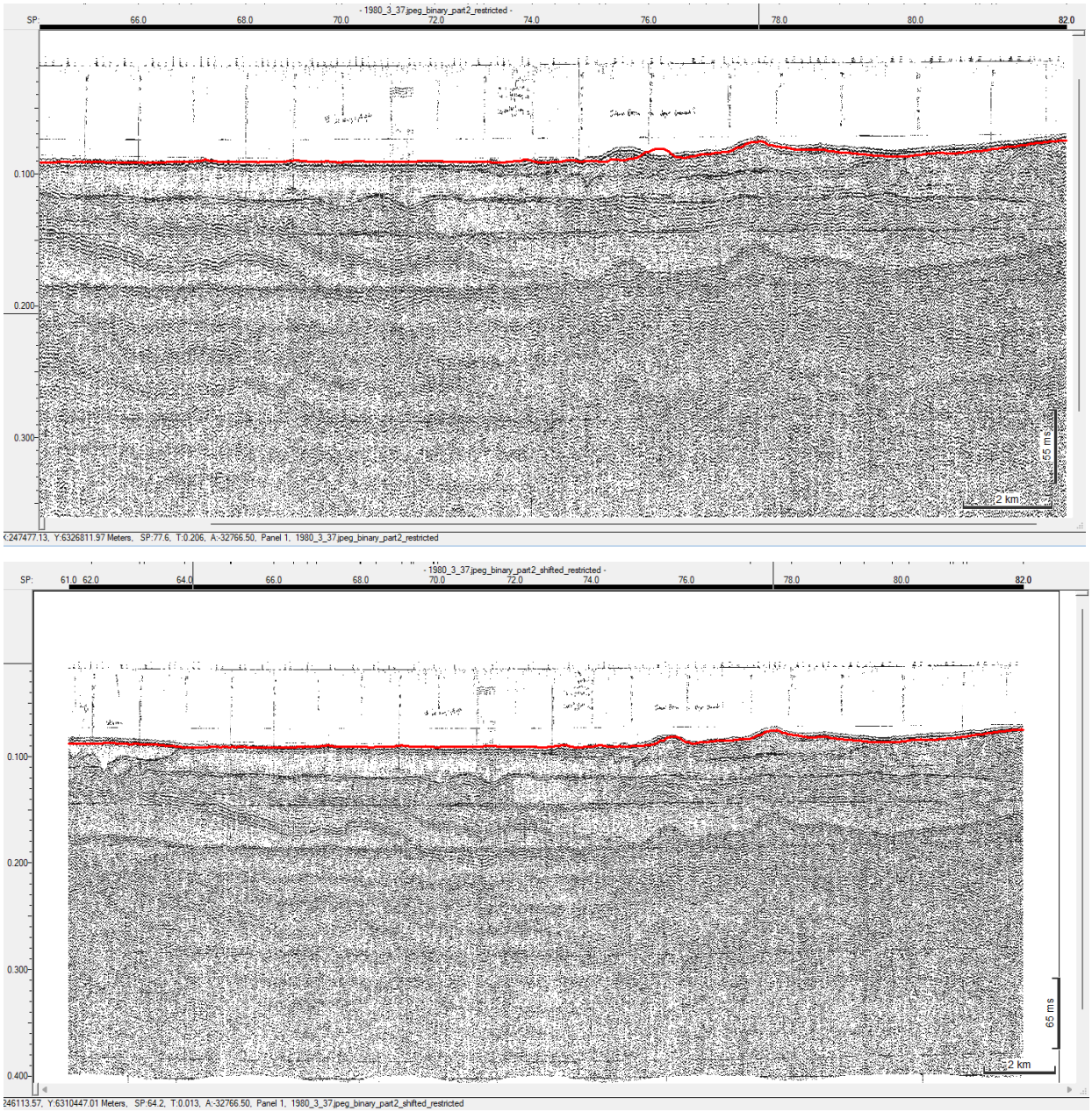


Figure 6 Comparison of seismic data before (first image) and after (second image) navigation shifting, showing the effect of spatial correction applied to the reconstructed SEG-Y dataset. The red horizons are the bathymetry, which perfectly aligns with the seabed geometry after the spatial shifting has been applied to the data. BGS © UKRI 2026.

2.2.3.4 COORDINATE SCALING AND HEADER ENCODING

SEG-Y coordinate fields store integer values, therefore real-world UTM coordinates require scaling prior to encoding (SEG Technical Standards Committee, 2002). The workflow applies a coordinate scalar (*Scalar = −100*) indicating that stored coordinate values must be divided by 100 during interpretation.

The stored coordinate value is therefore:

$$HeaderCoordinate = RealCoordinate \times 100$$

For example:

620585.98 → 62058598

The workflow stores X and Y coordinates using signed 32-bit integer values in the SEG-Y trace headers. Coordinates exceeding the maximum or minimum values permitted by the signed 32-bit integer format are automatically limited (clamped) to the nearest valid value. This prevents numerical overflow and ensures compatibility with SEG-Y header specifications.

The clamping is applied as:

$$Value_{clamped} = \max(MIN_{32}, \min(MAX_{32}, Value))$$

Where:

- MIN_{32} is the minimum value permitted by the signed 32-bit integer format $(-2,147,483,648)$,
- MAX_{32} is the maximum value permitted by the signed 32-bit integer format $(2,147,148,647)$
- $Value$ is the original coordinate value prior to range checking
- $Value_{clamped}$ is the coordinate value after application of the clamping operation

This prevents corruption of SEG-Y headers during export and ensures compatibility with interpretation software. Shotpoint values are similarly scaled by a factor of 1000 to preserve fractional shotpoint interpolation.

2.3 SEG-Y CONSTRUCTION AND HEADER POPULATION

The final stage of the workflow involves the generation of the SEG-Y dataset, including populating the trace headers required for spatial positioning and interpretation. The SEG-Y format (Barry et al., 1975; SEG Technical Standards Committee, 2002) is the industry-standard format for storing and exchanging seismic data and accurate population of its headers is vital for ensuring interoperability with seismic interpretation software.

Each reconstructed trace is written as a SEG-Y trace object accompanied by a populated trace header containing:

- trace sequence number
- shotpoint number
- source coordinates
- receiver coordinates
- coordinate scalar
- sampling interval
- trace sample count

The workflow stores the reconstructed seismic amplitudes as 16-bit signed integers, using SEG-Y data sample format code 3, which specifies the numerical representation of each seismic data sample. The principal SEG-Y trace header fields populated during SEG-Y construction are summarised in Table 1.

Table 1 Principal SEG-Y trace header fields populated by the workflow during SEG-Y construction.

Header field	Byte location	Value assigned by the workflow
Trace_sequence_number_within_line	1–4	Sequential index of the trace (starting from 1)
Shotpoint_number (SP)	17–20	Shotpoint ID (scaled to 1000 to allow for fractional SP along interpolated traces)
X_coordinate_of_ensemble_position	73–76	UTM easting (scaled and clamped)
Y_coordinate_of_ensemble_position	77–80	UTM northing (scaled and clamped)
Scalar_to_be_applied_to_all_coordinates	71–72	-100 (indicating coordinates are divided by 100)
Number of samples	115–116	Trace sample count
Sample interval	117–118	Sample interval in microseconds

The workflow can additionally generate tab-delimited .csv files containing reconstructed trace metadata. Exported attributes may include trace number, shotpoint value, UTM easting and UTM northing coordinates. These metadata provide an independent quality-control record that can be used to verify reconstructed navigation geometry, trace positioning and shotpoint assignment prior to interpretation or further processing.

An example of the populated SEG-Y trace headers as displayed in SeiSee is shown in Figure 7.

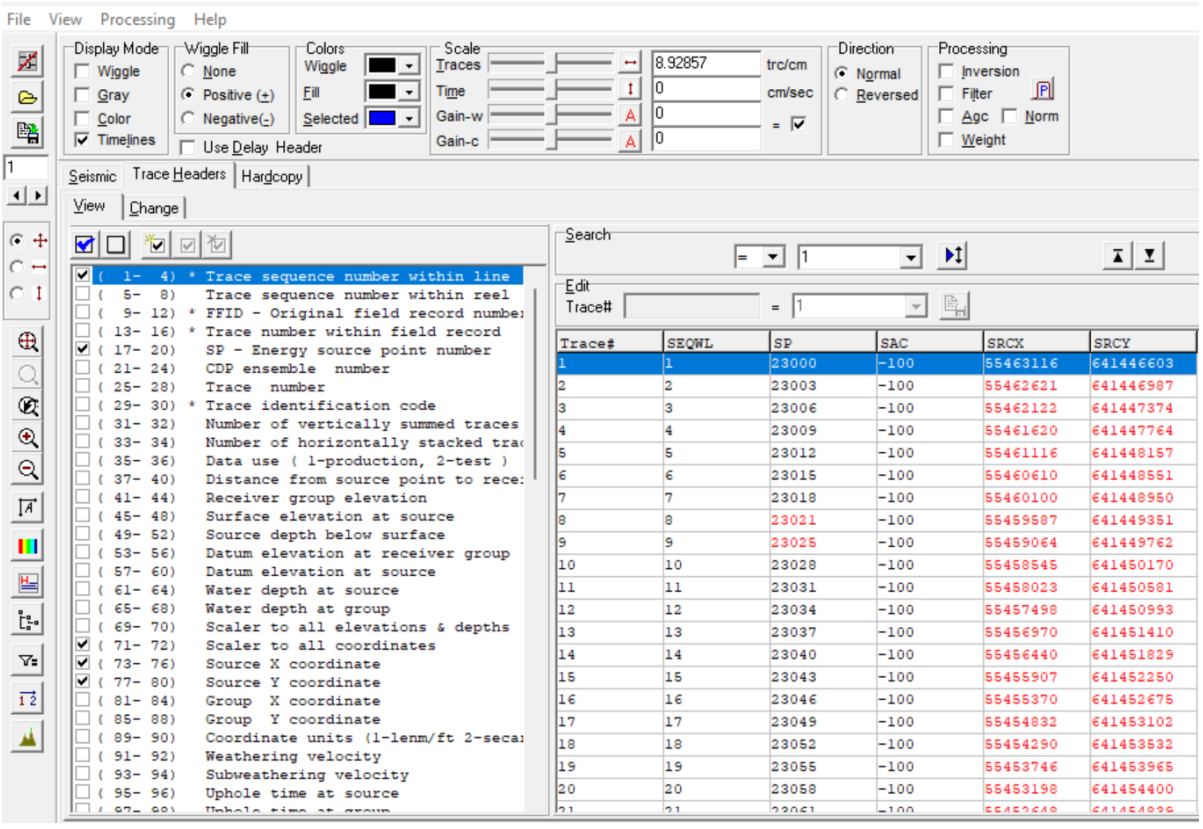


Figure 7 SeiSee display of written SEG-Y headers from a converted scan. BGS © UKRI 2026.

3 Workflow outcomes, assumptions and limitations

This section evaluates the outcomes of the proposed workflow through representative examples of an original scanned seismic record (Figure 8), an intermediate processing output (Figure 9) and the final reconstructed seismic section (Figure 10). The assessment considers the preservation of seismic character, the consistency of reconstructed spatial geometry and the practical usability of the resulting datasets within seismic interpretation environments.

The section also examines the principal assumptions underlying the reconstruction process and discusses limitations that may influence its effectiveness under different data conditions. Particular consideration is given to image quality, geometric calibration, navigation reliability, amplitude reconstruction and the potential persistence of processing artefacts. These considerations help establish the conditions under which the methodology can be applied and provide guidance for the interpretation and validation of reconstructed datasets.

3.1 DEMONSTRATION OF WORKFLOW OUTCOME

The demonstration uses a representative legacy seismic section, illustrating its transformation from an original scanned image into a spatially referenced SEG-Y dataset. The example shows the effects of gridline removal and navigation-constrained horizontal re-mapping on the seismic image, followed by trace reconstruction and loading of the resulting SEG-Y file into seismic interpretation software.

Figure 8, Figure 9 and Figure 10 illustrate the successive stages of this process, providing a visual assessment of the workflow's ability to retain the principal seismic features while reconstructing the spatial geometry required for subsequent interpretation.

3.2 KEY ASSUMPTIONS

The reconstruction of scanned seismic sections into spatially referenced SEG-Y data is based on several assumptions concerning image geometry, acquisition navigation, seismic sampling and amplitude representation. These assumptions establish the methodological basis of the workflow and provide the context within which the reliability and applicability of the reconstructed datasets should be evaluated.

3.2.1 Image representation and seismic continuity

The scanned seismic image is assumed to preserve the essential spatial arrangement and continuity of the original seismic reflectors. Although scanning, image reproduction and subsequent processing may introduce geometric distortions and visual artefacts, the underlying seismic features are assumed to remain sufficiently identifiable for reconstruction. Image enhancement and artefact removal procedures are therefore intended to improve image quality while retaining the principal seismic characteristics required for subsequent interpretation.

3.2.2 Navigation accuracy and spatial correspondence

The supplied navigation data are assumed to represent the original acquisition geometry with sufficient positional accuracy. Shotpoint values and UTM coordinates are treated as reliable reference information for establishing the spatial relationship between the scanned image and the original seismic line. Where navigation information is available only at discrete positions, intermediate shotpoint values and coordinates are estimated through linear interpolation along cumulative acquisition distance.

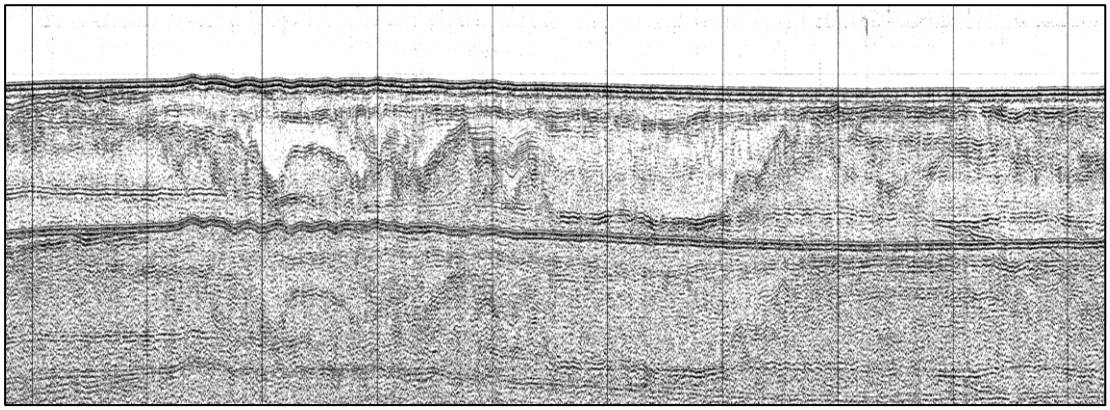


Figure 8 Original scanned seismic section used as input to the reconstruction workflow with associated gridlines and scanning artefacts. BGS © UKRI 2026.

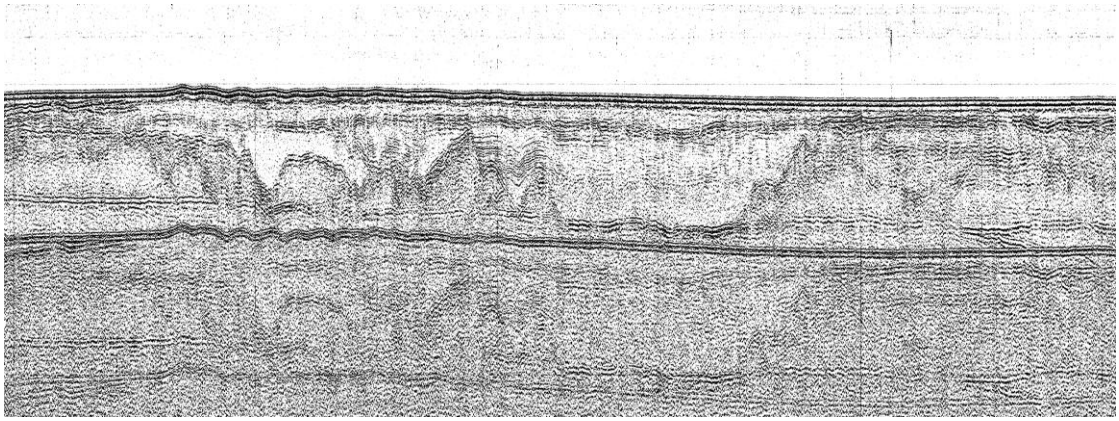


Figure 9 Seismic section following gridline removal and navigation-constrained horizontal re-mapping, prior to trace extraction. BGS © UKRI 2026.

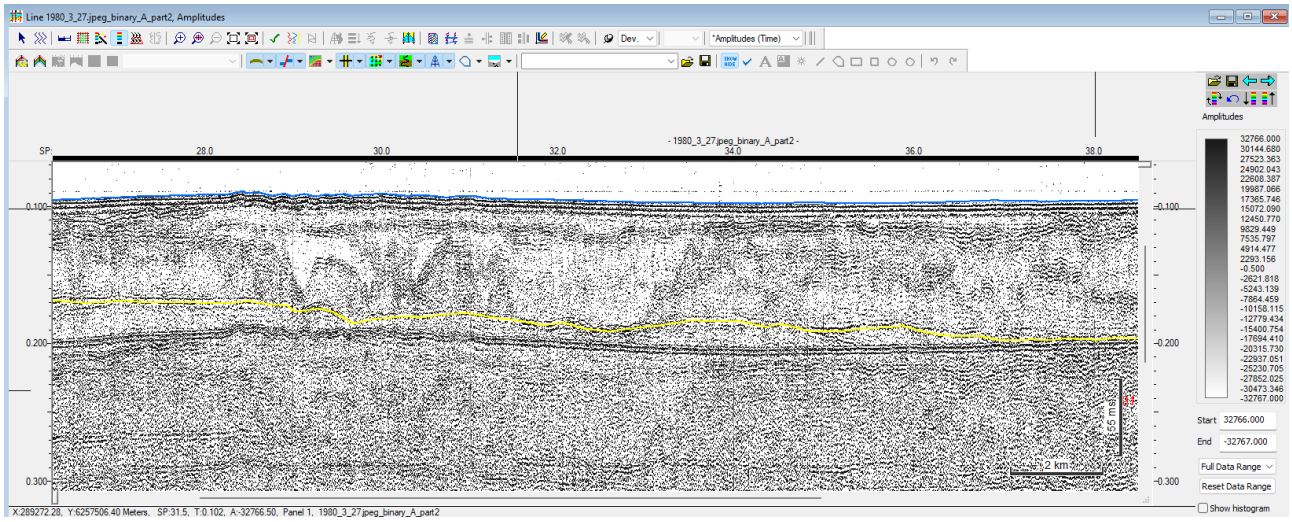


Figure 10 Reconstructed SEG-Y dataset displayed in interpretation software, demonstrating the successful conversion of the scanned seismic section into a spatially referenced, digital seismic dataset with preserved seismic character. The blue horizon is the seabed while the yellow horizon is the interpreted top of bedrock surface. BGS © UKRI 2026.

3.2.3 Horizontal geometric correction

Horizontal re-mapping assumes that the relationship between image position and acquisition distance can be established using the available shotpoint calibration points and navigation information. Following re-mapping, the image is treated as a distance-linear representation of the seismic line, allowing reconstructed traces to be assigned spatial coordinates consistent with the acquisition geometry. The effectiveness of this correction depends on the accuracy of the calibration points and the assumption that geometric distortion between them can be adequately represented through interpolation.

3.2.4 Vertical time calibration

The vertical dimension of the scanned seismic section is assumed to represent a consistent TWT interval. The total time range and corresponding sample interval are established using the specified horizontal timeline information and the associated TWT interval. This assumes that the original seismic section has not undergone significant vertical stretching, compression or non-uniform scaling that cannot be accounted for during pre-processing and calibration.

3.2.5 Amplitude reconstruction

Reconstructed seismic amplitudes are derived from the intensity values of the processed raster image. It is assumed that variations in image intensity retain sufficient information about the relative seismic reflection character to support meaningful visual interpretation. However, the recovered amplitudes are not assumed to represent the original recorded seismic amplitudes quantitatively as scanning, image reproduction, display scaling and enhancement may have modified the original amplitude information. Consequently, reconstructed SEG-Y data are primarily intended for qualitative interpretation and spatial integration rather than quantitative amplitude-dependent analysis, unless independently validated against suitable original data.

3.2.6 Trace reconstruction and spatial sampling

Trace reconstruction assumes that the horizontal sampling of the processed image or the selected navigation-based spacing provides an adequate representation of seismic features at the intended scale of interpretation. Following horizontal re-mapping, traces are extracted on a trace-per-pixel basis from the corrected image. Where re-mapping has not been performed, trace reconstruction may instead use navigation-based positioning at a nominal spacing of 6.25 m. The resulting trace density is therefore dependent on the selected reconstruction approach and the available image and navigation information.

3.2.7 Interpolation between navigation points

Linear interpolation is assumed to provide a reasonable approximation of the variation in shotpoint values and spatial coordinates between successive navigation points. This approach is particularly suitable where navigation points are sufficiently dense and the acquisition path does not contain abrupt changes in direction or irregularities that are inadequately represented by the available reference positions. The accuracy of interpolated coordinates is consequently dependent on navigation-point density and the fidelity of the supplied acquisition geometry.

3.2.8 Preservation of seismic information during processing

Image processing operations are assumed to suppress non-seismic artefacts while retaining the principal seismic reflectors and their continuity. Nevertheless, morphological filtering, inpainting, thresholding and other enhancement procedures may modify local image characteristics. The processed image should therefore be examined against the original scan to identify potential loss or alteration of seismic features before final trace reconstruction and SEG-Y export.

3.3 LIMITATIONS AND QUALITY CONSIDERATIONS

Several limitations and quality considerations are particularly relevant when interpreting or integrating the resulting datasets into subsequent geophysical workflows. Although the workflow provides a systematic approach for recovering spatially referenced seismic data from scanned analogue records, the quality of the reconstructed SEG-Y data remains dependent on:

- the condition of the source material
- the reliability of available acquisition information
- the assumptions inherent in image processing and trace reconstruction

The conversion process should therefore be regarded as a method of data recovery and geometric reconstruction rather than a complete restoration of the original digital seismic data.

3.3.1 Source image quality and information loss

The fidelity of reconstructed seismic traces is fundamentally constrained by the spatial resolution, contrast and condition of the original scanned image. Scanning, reproduction and archival degradation may introduce noise, blurring, compression artefacts and loss of fine-scale seismic detail. These effects cannot be fully reversed through image enhancement and information absent from the source image cannot be recovered during conversion. Consequently, the reconstructed seismic data may not preserve the full bandwidth, dynamic range or sampling characteristics of the original field records. The resulting SEG-Y should therefore be considered a digital representation of the information preserved in the scanned image rather than an exact reproduction of the original acquisition data.

3.3.2 Amplitude fidelity and reconstruction

Amplitude reconstruction presents an additional limitation because the original seismic amplitudes are not necessarily preserved in their native numerical form within scanned images. Image intensity values represent the tonal characteristics of the reproduced seismic section and may have been modified by display settings, printing, scanning, contrast adjustments or subsequent image processing. Although the workflow reconstructs trace amplitudes from image intensity values, the resulting amplitudes should not automatically be interpreted as quantitatively equivalent to those of the original seismic data. In particular, amplitude-dependent attributes, amplitude-versus-offset analysis, quantitative seismic inversion and other workflows requiring calibrated amplitudes should be approached with caution unless independent evidence of amplitude fidelity is available. The reconstructed traces are primarily intended to preserve seismic character and support qualitative interpretation, correlation and visual assessment.

3.3.3 Geometric calibration and navigation accuracy

The spatial reliability of the reconstructed SEG-Y depends on the accuracy of the shotpoint calibration, the quality of the navigation data and the effectiveness of horizontal re-mapping. Navigation-constrained re-mapping corrects non-uniform horizontal scaling and scanner-induced geometric distortion by establishing a relationship between image position and cumulative acquisition distance. However, this correction cannot compensate for errors already present in the original navigation data or inaccuracies in identifying calibration points. Where navigation coverage is inconsistent with the scanned record, interpolation may introduce local positional uncertainties. Similarly, the reconstructed spatial geometry represents the best available approximation based on the supplied acquisition information and should not be assumed to exceed the accuracy of the source navigation.

3.3.4 Vertical time calibration

The reconstruction of the vertical seismic dimension assumes that the scanned section represents a consistent TWT interval, established from the specified time markers and their corresponding values. Significant vertical stretching, compression or non-uniform scaling introduced during scanning or reproduction may affect the accuracy of the reconstructed time

axis. Although the workflow uses the available time calibration information to establish the sample interval and reconstruct the vertical dimension, it cannot independently recover distortions that are not identifiable from the source image or calibration markers. Consequently, the vertical positioning of reconstructed seismic events should be verified against the original time annotations and any available reference data before quantitative time-based interpretation.

3.3.5 Image processing and seismic feature preservation

Gridline removal and image enhancement introduce a potential trade-off between suppressing unwanted artefacts and preserving genuine seismic information. Although adaptive thresholding, morphological filtering and controlled inpainting are designed to target annotation features while minimising interference with seismic reflectors, their effectiveness depends on the contrast, thickness, orientation and spatial continuity of the features being removed. Seismic events that intersect gridlines, exhibit similar intensity characteristics or contain fine-scale details may be partially affected during processing. Inpainting may also introduce local modifications where image information is obscured by removed features. Accordingly, processed images should be visually inspected against their original scans to identify potential alterations to reflector continuity, amplitude character and structural detail.

3.3.6 Trace sampling and reconstruction assumptions

The trace reconstruction approaches provide flexibility in adapting the conversion process to different image characteristics, but each involves assumptions that influence the resulting spatial sampling.

Where horizontal re-mapping has been performed, traces are extracted on a trace-per-pixel basis from the corrected image, irrespective of the selected trace-per-pixel or navigation interpolation settings. In this case, the number of reconstructed traces is determined by the horizontal resolution of the re-mapped raster rather than the original acquisition sampling interval.

Where re-mapping has not been performed, the trace-per-pixel option allows image-column-based extraction, whereas the alternative navigation-based approach distributes traces at a nominal spacing of 6.25 m along the cumulative acquisition distance. This spacing establishes a consistent reconstruction framework but does not recover the original trace positions or sampling characteristics where these are unavailable.

The selected spacing should therefore be understood as a reconstruction parameter rather than confirmation of the original acquisition geometry. In all cases, the reconstructed trace density may differ from that of the original seismic dataset and the creation of additional traces does not imply the recovery of information that was not preserved in the scanned image.

3.3.7 Navigation interpolation and spatial shifting

Continuous interpolation of shotpoint values and UTM coordinates provide a practical means of assigning spatial information to reconstructed traces. However, interpolation assumes that the supplied navigation points adequately represent the acquisition trajectory between known positions. Abrupt changes in vessel direction, acquisition geometry or navigation quality may not be fully represented by a continuous interpolation model.

Similarly, the optional spatial shifting functionality provides a means of adjusting reconstructed line positions to account for known or suspected discrepancies, but the resulting coordinates remain dependent on the accuracy of the specified shift parameters. Spatial shifting should therefore be applied only where justified by independent positional evidence, with the resulting geometry validated against suitable reference datasets wherever possible.

3.3.8 SEG-Y compatibility and downstream interpretation

Although the workflow produces SEG-Y files with navigation-aware trace headers suitable for use in established seismic interpretation platforms, successful import and visualisation do not, in themselves, establish the quantitative accuracy of the reconstructed data. Differences in

software implementation, coordinate conventions, sample intervals, amplitude scaling and header interpretation may influence how the output is displayed or processed by downstream applications. Furthermore, reconstructed SEG-Y files may not contain all the acquisition metadata, processing history or auxiliary information associated with the original digital survey. Users should therefore verify the exported data structure, trace headers, sample intervals, coordinate reference system and spatial positioning before incorporating the datasets into interpretation or regional compilation projects.

3.3.9 Quality control and recommended use

In view of these limitations, quality control should be considered an integral component of the reconstruction process rather than a final administrative step. The original scan, the processed and re-mapped image and the reconstructed SEG-Y should be compared to assess the preservation of seismic character and the consistency of geometric correction. Navigation coordinates and shotpoint values should be checked against available survey information, while spatial positioning should be independently verified using appropriate geospatial reference data where available.

Particular attention should be given to areas affected by image degradation, incomplete navigation coverage, extensive gridline interference or substantial spatial correction. Where possible, the reconstructed SEG-Y should also be examined within seismic interpretation software to confirm the continuity of seismic events and the consistency of their spatial positioning with the original record. Direct comparison with the source image is recommended to establish the fidelity of the reconstructed dataset.

Overall, the workflow provides a practical means of recovering and integrating legacy seismic information into modern digital interpretation environments. Its principal value lies in improving the accessibility, spatial usability and interpretability of historical seismic archives, particularly where original digital records are unavailable. However, the reconstructed data should be used with an understanding of their provenance and the limitations imposed by the source material and reconstruction assumptions. The suitability of the output for a particular application should ultimately be determined by the required level of geometric accuracy, amplitude fidelity and interpretative confidence, supported by appropriate quality-control procedures.

4 Conclusion and recommendations

This study presents a reproducible methodology for the conversion of scanned seismic sections into spatially referenced SEG-Y data through integrated image processing, navigation-constrained geometric correction, trace reconstruction and SEG-Y export. To recover legacy seismic information in a form suitable for subsequent interpretation and geospatial integration, the workflow combines:

- seismic image enhancement
- gridline removal
- shotpoint calibration
- horizontal geometric re-mapping
- amplitude reconstruction
- navigation interpolation
- spatial positioning

A key component of the methodology is the use of navigation-constrained horizontal re-mapping prior to trace reconstruction (where reliable shotpoint and navigation information are available). The re-mapping converts the horizontal image geometry to a distance-linear representation based on cumulative acquisition distance. Following re-mapping, the corrected image is reconstructed as one seismic trace per image column, thereby retaining the horizontal sampling density of the re-mapped seismic image. Navigation and shotpoint information are subsequently interpolated along the cumulative acquisition distance to provide spatial coordinates for the reconstructed traces.

Where horizontal re-mapping is not applied, trace reconstruction is controlled by the selected reconstruction approach. Trace-per-pixel reconstruction can be used to extract one trace from each image column, whereas the navigation-based reconstruction approach generates trace positions at a target spacing of 6.25 m along the cumulative acquisition distance derived from the supplied navigation geometry. In both cases, the reconstructed traces are associated with interpolated shotpoint, easting and northing values derived from the available navigation information.

The workflow also incorporates:

- adaptive gridline removal
- interactive shotpoint calibration
- cumulative-distance-based geometric correction
- amplitude reconstruction
- navigation-based trace positioning
- sequential spatial shifting with feathered transitions

Together, these procedures provide a structured approach for recovering usable seismic information from scanned legacy records while reducing geometric distortions and image artefacts introduced during scanning, rasterisation and reproduction.

The methodology has been implemented within a graphical processing environment to facilitate consistent application of the processing steps and parameter selection. The interface allows users to configure parameters without requiring direct modification of the underlying implementation, including:

- image pre-processing
- calibration
- trace reconstruction
- navigation processing
- spatial shifting
- export parameters

The graphical interface therefore provides an operational means of applying the methodology consistently across seismic datasets, while the scientific basis of the workflow remains independent of the particular software implementation.

4.1 KEY STRENGTHS

- Geometric correction: navigation-constrained horizontal re-mapping provides a distance-based correction of the scanned seismic image (where reliable shotpoint and navigation information are available)
- Signal preservation: orientation-specific gridline detection, morphological filtering and controlled removal of image artefacts reduce contamination from scan annotations while limiting modification of seismic reflection information
- Flexible trace reconstruction: the methodology provides alternative trace reconstruction approaches according to the processing circumstances
    - following horizontal re-mapping, the corrected image is reconstructed at one trace per image column
    - in the absence of re-mapping, traces can be reconstructed either directly from image columns or at a defined navigation-based spacing of 6.25 m
- Spatial consistency: shotpoint values and navigation coordinates are interpolated from the supplied navigation geometry, allowing reconstructed traces to retain a continuous spatial relationship with the original acquisition line
- SEG-Y compatibility: the reconstructed datasets are exported as SEG-Y files with trace-level shotpoint and coordinate information suitable for use in established seismic interpretation and visualisation environments
- Operational consistency: the graphical implementation provides a controlled interface for applying the methodology, including:
    - interactive calibration
    - configurable reconstruction parameters
    - navigation processing
    - spatial shifting
    - export settings

4.2 RECOMMENDATIONS

To maximise reconstruction quality and spatial reliability, the following practices are recommended.

- Scanned seismic sections should undergo appropriate image pre-processing and gridline removal before trace reconstruction, to minimise contamination of reconstructed amplitudes by annotation artefacts
- Reliable shotpoint and navigation information should be used wherever available
- Where the scanned image exhibits non-uniform horizontal scaling relative to the original acquisition geometry, navigation-constrained horizontal re-mapping should be applied before trace reconstruction
- The trace reconstruction approach should be selected according to the characteristics of the scanned seismic image and the available acquisition information
    - where horizontal re-mapping has been applied, trace extraction should follow the corrected image geometry
    - where re-mapping is not applied, the available trace reconstruction options should be selected according to the required spatial sampling and navigation information
- Spatially shifted SEG-Y outputs should be validated against independent geospatial datasets, such as bathymetry, navigation tracks, interpreted horizons or other spatially referenced seismic data, to confirm positional consistency
- Final SEG-Y products should undergo quality control using seismic visualisation and interpretation software before quantitative interpretation or integration into regional datasets

4.2.1 Recommended applications

The proposed workflow is particularly suitable for:

- digitisation and recovery of legacy seismic archives
- reconstruction of historical analogue seismic records
- regional seismic interpretation and seismic tie analysis
- academic teaching and geophysical research
- national seismic archive modernisation projects
- integration of historical seismic datasets with GIS, bathymetry and well-log information
- preliminary seismic interpretation in areas where original digital field data are unavailable

The methodology also provides a transferable framework for future development of automated seismic archive restoration workflows, including potential integration of machine-learning approaches, adaptive image enhancement, automated calibration and advanced geospatial correction techniques.

4.3 SOFTWARE AVAILABILITY

The methodology described in this report has been implemented as an in-house graphical processing application to support consistent application of the seismic image-to-SEG-Y workflow. The application was developed for internal operational use and is not currently distributed as open-source software nor as a publicly downloadable executable. Accordingly, the source code and application implementation are not included as part of this publication. The report instead describes the underlying scientific and technical methodology, processing principles, mathematical procedures and reconstruction approaches in sufficient detail to support independent evaluation and reproduction of the methodology using alternative software implementations.

Appendix 1

The methodology described in this report has been implemented as a standalone, Python-based software application incorporating a GUI. The GUI provides users with access to the image pre-processing, navigation reconstruction, geometric correction, trace extraction, SEG-Y generation and export functions described in this report without requiring modification of source code. The interface is intended to improve usability and workflow accessibility by allowing processing parameters to be configured interactively while maintaining consistency with the underlying methodology.

The following sections describe the principal GUI components and their influence on the resulting SEG-Y output. An overview of the graphical user interface is shown in Figure A1.

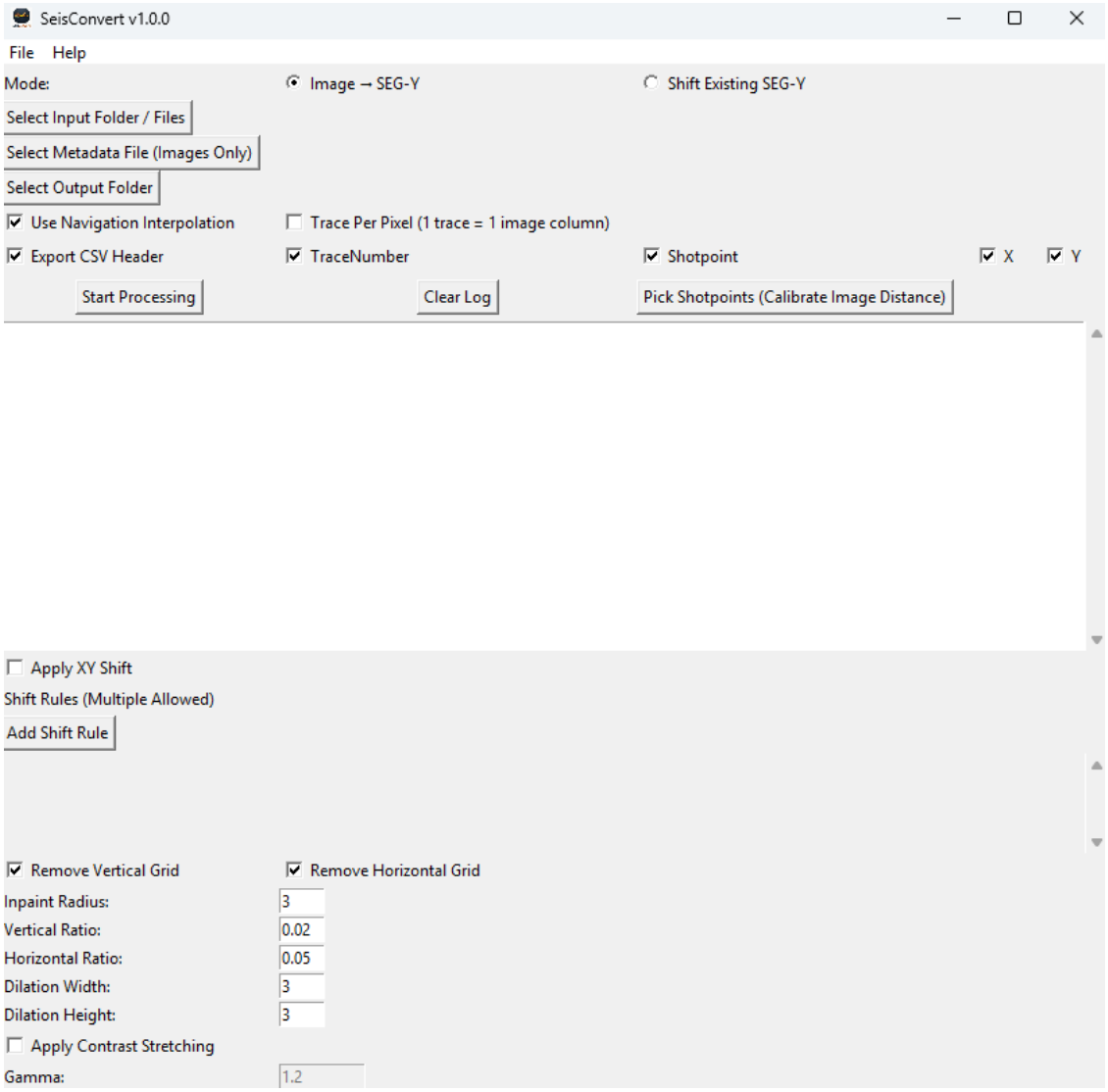


Figure A1 GUI for image to SEG-Y conversion. BGS © UKRI 2026.

INPUT FIELDS AND FILE SELECTION

Modes

The default mode used for converting scanned images to SEG-Y is 'Image → SEG-Y' (**Figure A2**). 'Shift Existing SEG-Y' is selected **only** when the user wants to apply navigation shift to converted SEG-Y files (Figure A2). Only SEG-Y-related files can be selected in this mode and no metadata is required.



Figure A2 Mode selection in the image to SEG-Y conversion GUI. BGS © UKRI 2026.

Input folder

The input folder is a directory containing scanned seismic images (for example, .jpeg; .png; .tif), SEG-Y file(s) and navigation files (.txt or .csv). See **Figure A3** for the input, metadata and output folder selections.

The folder enables selection and batch conversion of multiple seismic images within a single processing session. Each image is processed independently using its corresponding metadata and navigation information (specified within the metadata file).

The navigation files determine the real-world spatial positioning of traces in the SEG-Y output; incorrect or mismatched navigation can result in geospatially inaccurate SEG-Y files. It is prepared without headers, with the shotpoints and corresponding UTM coordinates listed in this order:

- shotpoint number
- easting (X)
- northing (Y)

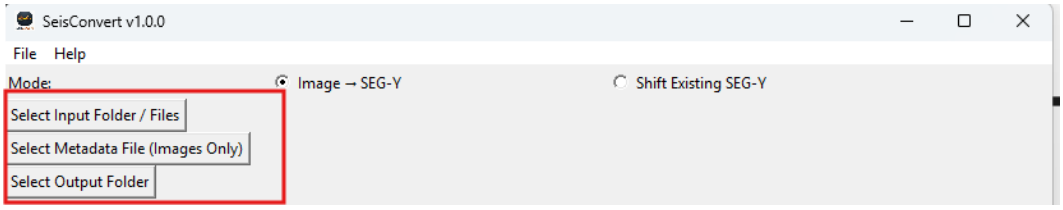


Figure A3 Input, metadata and output folder selections in the GUI. BGS © UKRI 2026.

Metadata file

The metadata file contains image-specific metadata without headers in this order, each separated by tab (**Figure A4**):

- filename
- no. of shotpoints
- no. of horizontal grid lines
- TWT interval
- navigation-filenames

The metadata file controls the spatial and temporal calibration of each seismic image. The number of horizontal grid intervals and their associated TWT intervals are used to estimate the vertical temporal sampling interval of the reconstructed seismic traces, while the navigation filename links each image to its corresponding spatial navigation dataset. Horizontal spatial geometry is subsequently reconstructed through navigation-constrained re-mapping and trace interpolation procedures.

```
1970-3-15.jpeg_binary(A).tif    16      7       40      1970-3-15_navigation(A).txt
1970-3-15.jpeg_binary(B).jpg    7       11      40      1970-3-15_navigation(B).txt
1970-3-15.jpeg_binary(C).jpg    36      7       40      1970-3-15_navigation(C).txt
```

Figure A4 Sample of metadata formatting. BGS © UKRI 2026.

Output folder

This folder is a directory specifying the location to save the converted SEG-Y file(s). Two subfolders ('SEGY' and 'Cleaned') are automatically created within the selected folder. All converted SEG-Y and output headers in .csv format are saved in the SEG-Y folder, while a cleaned image after grid removal is saved in the 'Cleaned' folder for visualisation.

SHOTPOINT CALIBRATION AND INTERACTIVE RE-MAPPING

Pick shotpoints (calibrate image distance)

The pick Shotpoint button (Figure A5) launches an interactive calibration interface used to identify and refine shotpoint marker positions within the seismic image prior to horizontal re-mapping.

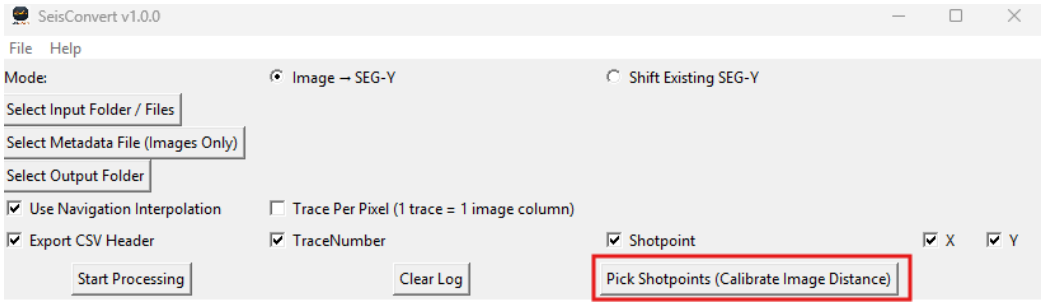


Figure A5 Toggle button for shotpoint calibration in the GUI. BGS © UKRI 2026.

The calibration interface supports the following sequence of operations, with interactive refinement steps applied as required.

1. Automatic detection of vertical shotpoint markers using adaptive thresholding and morphological filtering.
2. Adjustment of detection threshold and minimum line spacing parameters, where required, to refine marker detection.
3. Interactive addition or removal of calibration lines to correct missed or incorrectly detected markers.
4. Manual repositioning of detected markers through click-and-drag operations to align them with the corresponding shotpoint positions on the scanned section.
5. Automatic shotpoint renumbering following modification of the calibration markers.
6. Optional reversal of shotpoint orientation using the 'Flip SP Orientation' control when the image direction is opposite to the navigation order.

The calibration stage establishes the spatial relationship between image pixel coordinates and real-world navigation distance. These calibration points are subsequently used during navigation-constrained horizontal re-mapping to correct scanner-induced geometric distortion and enforce physically meaningful trace positioning.

The calibration interface also supports zooming and scrolling to improve precision when working with large or degraded legacy seismic sections.

A sample of the calibration GUI showing a calibrated seismic scan is shown in Figure A6.

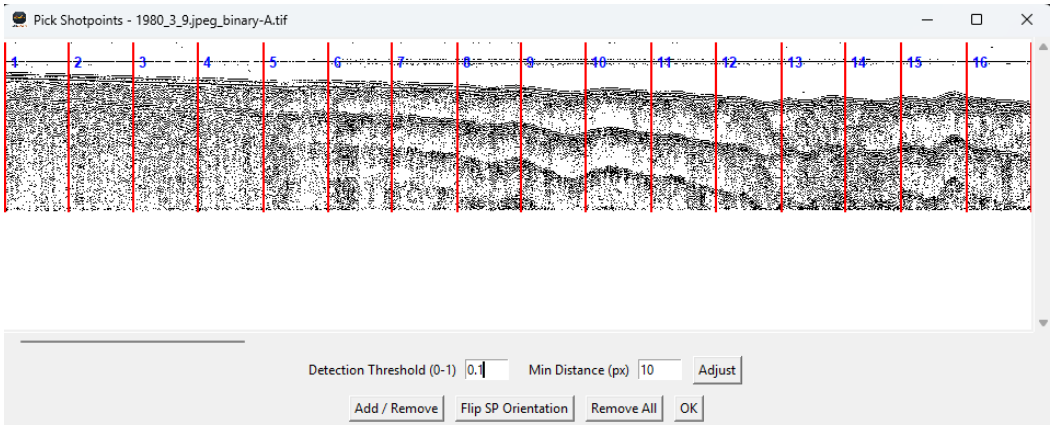


Figure A6 Shotpoint calibration GUI showing a calibrated scan. BGS © UKRI 2026.

TRACE RECONSTRUCTION AND NAVIGATION INTERPOLATION CONTROLS

The reconstruction workflow uses the processing state of the seismic image and the selected trace-generation option (Figure A7) to determine how reconstructed traces are generated and spatially positioned.

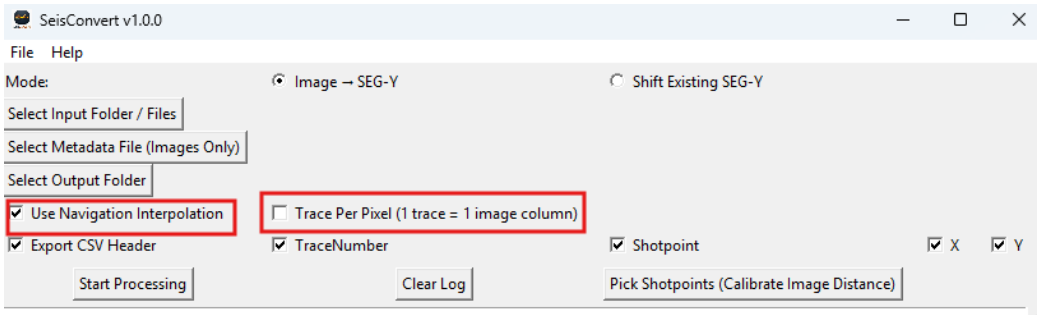


Figure A7 Trace reconstruction selection modes in the GUI. BGS © UKRI 2026.

Horizontal re-mapping (pick shotpoint)

Where shotpoint calibration has been applied, the seismic image is horizontally re-mapped so that its columns represent a distance-linear seismic section. Following this re-mapping, each image column is automatically exported as one seismic trace. The ‘Trace Per Pixel’ and ‘Use Navigation Interpolation’ controls do not alter this behaviour.

The spatial position of each reconstructed trace is subsequently assigned by interpolating the user-supplied navigation data along the cumulative acquisition distance. Each trace therefore receives an interpolated shotpoint (SP), UTM easting (X) and UTM northing (Y).

Trace per pixel

Where no horizontal re-mapping has been performed, the ‘Trace Per Pixel’ option (Figure A7) determines whether the original image-column density is retained during trace reconstruction. When selected, one seismic trace is generated for each column of the seismic image. The trace positions are distributed across the total cumulative navigation distance, and the corresponding SP, X and Y values are interpolated from the supplied navigation file.

Navigation interpolation

Where no horizontal re-mapping has been performed and ‘Trace Per Pixel’ is not selected, the ‘Use Navigation Interpolation’ processing route is used. In this case, the number and spacing of reconstructed traces are controlled by the navigation geometry rather than by the number of image columns.

Traces are generated at 6.25 m intervals along the cumulative acquisition distance. The corresponding shotpoint, X and Y values are interpolated from the supplied navigation file, while seismic amplitudes are sampled from the image at positions corresponding to the generated trace locations.

Processing logic

The trace reconstruction follows this sequence:

1. Horizontal re-mapping performed → one trace per re-mapped image column; navigation is interpolated to assign shotpoint and UTM coordinates.
2. No horizontal re-mapping + ‘Trace Per Pixel’ selected → one trace per image column; navigation is interpolated to assign shotpoint and UTM coordinates.
3. No horizontal re-mapping + ‘Use Navigation Interpolation’ selected → traces generated at 6.25 m intervals using the navigation-based reconstruction approach.

PRE-PROCESSING OPTIONS

Remove vertical/horizontal grid (checkbox)

When this is selected (checked), vertical and horizontal gridlines representing shotpoints and TWTs are automatically removed using adaptive thresholding, morphological filtering and inpainting. The result is a cleaner image from which seismic traces can be extracted without interference from overlaid grids. Without gridline removal, high-contrast lines may appear as false reflectors.

Parameters such as ‘vertical ratio’ and ‘horizontal ratio’ (Figure A8) determine the dimensions of the directional structuring elements (kernels) used for gridline detection. The ratios are applied to the corresponding image dimensions to calculate the kernel height for vertical-line detection and kernel width for horizontal-line detection. These kernel dimensions influence which linear features are isolated during morphological filtering, providing a balance between effective gridline detection and preservation of seismic signal.

For an image of size 1000 pixels (height) × 2000 pixels (width):

- If vertical_ratio = 0.02, vertical kernel height = 1000 × 0.02 = 20 pixels
- If horizontal_ratio = 0.05, horizontal kernel width = 2000 × 0.05 = 100 pixels

These orientation-specific kernels are then used during morphological filtering to isolate vertical and horizontal linear features from the binarised image.

If the ratio is too small, the kernel may isolate thin linear features, including seismic reflectors and inadvertently remove useful data. If the ratio is too large, it may fail to isolate the actual gridlines, reducing the effectiveness of gridline removal. To constrain the horizontal kernel size

across images of different dimensions, the workflow limits the effective horizontal ratio to the smaller of the user-defined value and 100/image width. The resulting horizontal kernel width is then constrained to a minimum of 10 pixels. This prevents excessively large kernels for wide images while maintaining a minimum kernel size for smaller images. These constraints help maintain effective gridline detection across images of different dimensions while reducing the risk of removing seismic reflections.

The dilation size determines the dimensions of the structuring element used to expand the gridline mask before inpainting. Dilation increases the thickness of the mask around detected gridlines, helping to bridge small gaps and ensure that the full extent of the gridline is included in the region removed during inpainting. Choosing values that are too large may result in the removal of nearby features, while values that are too small may result in parts of the grid being passed to the output file. For example, a 3 × 3 dilation kernel expands the gridline mask, helping to bridge small gaps and connect fragmented portions of detected gridlines before inpainting.

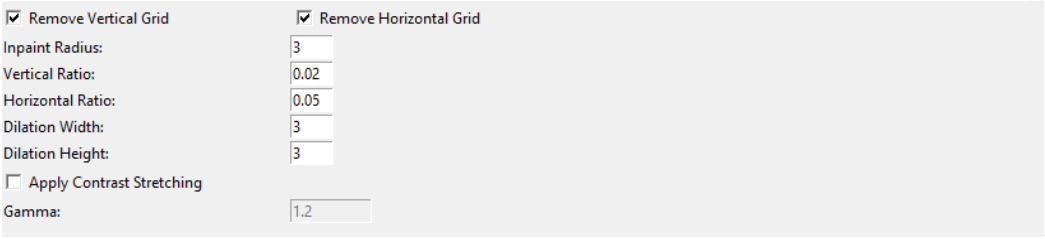


Figure A8 Horizontal/vertical ratio and dilation width/height for gridline removal. BGS © UKRI 2026.

Contrast stretching (checkbox)

Contrast stretching enhances image contrast before trace extraction. The suboptional gamma correction (non-linear contrast stretching; range is from 0.1 to 3.0 with a default of 1.0) adjusts the non-linearity of contrast enhancement. Gamma values below 1.0 brighten darker image features, whereas values above 1.0 increase the relative contrast of brighter features. The selected gamma value therefore affects the pixel intensities used for subsequent amplitude reconstruction. A low-quality image with faint reflectors might benefit from contrast stretching with gamma = 1.5 to enhance signal visibility.

SPATIAL SHIFTING (NAVIGATION SHIFT)

Apply XY shift (checkbox)

Selecting (checking) this applies a linear offset to navigation coordinates. It can be used either in the ‘Image → SEG-Y’ mode or in the ‘Shift Existing SEG-Y’ mode.

In ‘Image → SEG-Y’ mode, when ‘Apply XY Shift’ is toggled ON, a pop-up window appears allowing the user to select the line(s) to which the shift will be applied (Figure A9). This is useful when multiple lines are present in the input folder, but the shift is only required for a subset of the lines. Non-selected lines are skipped for the shift operation and can proceed without the additional correction.

In ‘Shift Existing SEG-Y’ mode, the SEG-Y file(s) to be shifted are selected directly as the input files.

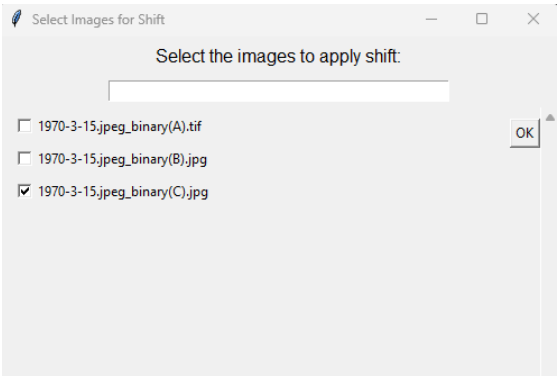


Figure A9 Pop-up window in the GUI to select the image(s) to convert. BGS © UKRI 2026.

Shift Rule

The application supports multiple shift rules, which are applied sequentially during processing. Each shift rule specifies a shift start and end shotpoint, shift distance and shift direction (Figure A10). To add a new shift rule, the user selects the 'Add Shift Rule' button. A scroll bar allows the user to view additional shift rules as they are added, while the 'Remove' button deletes an unwanted shift rule.



Figure A10 Shift rule panel within the GUI. BGS © UKRI 2026.

The shift functionality is useful for reconciling positional offsets in re-digitised lines:

- 'SP Start' and 'SP End' (shotpoint numbers) defines the segment of the navigation file over which the shift is applied, from the start shotpoint to the end shotpoint
- 'Distance' (metres) defines the distance by which the navigation coordinates are shifted.
- 'Direction' defines the direction of the coordinate shift using the corresponding angular bearing (for example, NW = 315°).
- options are 'N', 'NE', 'E', 'SE', 'S', 'SW', 'W' and 'NW'

The application performs validation checks on all shift rules prior to execution. Invalid directional inputs, overlapping shift intervals, non-positive shift distances and inconsistent shotpoint ranges are automatically rejected to prevent geometrically inconsistent navigation corrections.

CSV EXPORT SETTINGS

Export CSV header (checkbox)

Selecting (checking) this enables the export of a .csv file containing trace metadata generated during SEG-Y reconstruction. The exported .csv contains the metadata fields:

- trace number
- shotpoint
- X coordinate
- Y coordinate

The selected fields determine which metadata columns are included in the exported .csv (Figure A11). When ‘Export CSV Header’ is disabled, no .csv metadata file is exported and the individual field toggles are disabled.

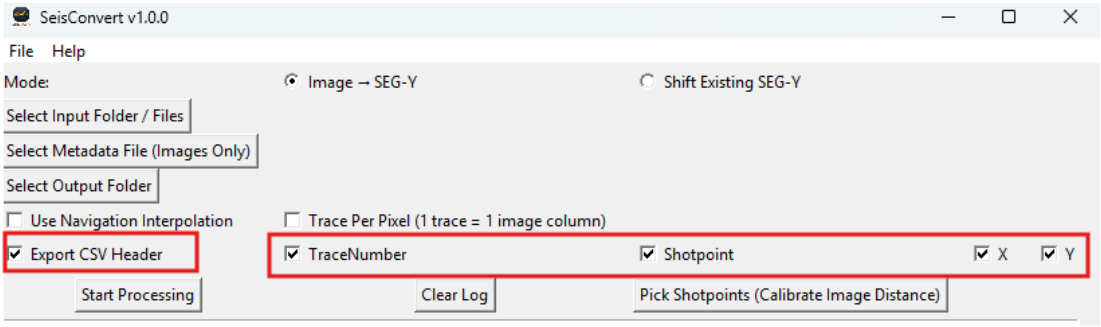


Figure A11 Export function in the GUI for the trace metadata CSV. BGS © UKRI 2026.

START PROCESSING

The ‘Start Processing’ button (Figure A11) executes the seismic image-to-SEG-Y processing workflow using the selected parameters and options. The reconstructed SEG-Y file is generated and, where enabled, so is the associated .csv trace metadata file.

Glossary

Adaptive thresholding	An image-binarisation technique in which the threshold applied to a pixel is determined from the characteristics of its local neighbourhood rather than from a single threshold value applied to the entire image. In this workflow, adaptive thresholding is used to identify gridlines and shotpoint markers under conditions of variable image contrast and scan quality.
Amplitude	The numerical magnitude of a seismic signal at a particular sample. In the reconstructed dataset, image pixel intensity is converted into a numerical amplitude representation for each seismic trace.
Amplitude inversion	The transformation of image intensity values so that the intensity convention of the scanned seismic display is converted into the amplitude convention used for the reconstructed seismic traces. In the workflow, this is implemented by inverting grey-scale intensity values before amplitude normalisation.
Amplitude reconstruction	The process of converting grey-scale pixel intensities from the scanned seismic image into numerical seismic amplitude values. In the workflow, image intensities are inverted and subsequently normalised to a signed 16-bit integer range before SEG-Y encoding.
Binarisation	The conversion of a grey-scale image into a binary image in which pixels are separated into foreground and background classes. Binarisation is used in the workflow as an intermediate step for identifying linear image features such as gridlines and shotpoint markers.
Cumulative acquisition distance	The distance measured progressively along the seismic acquisition line by summing the horizontal distances between successive navigation positions. It provides the spatial reference used for navigation-constrained re-mapping and trace positioning.
Coordinate scalar	A value stored in the SEG-Y trace header that specifies how stored coordinate values should be interpreted or scaled. In this workflow, a scalar of −100 is used so that stored UTM coordinates can represent the required spatial precision while remaining within the integer-based SEG-Y coordinate fields.
Connected component analysis	An image-processing procedure used to identify and measure groups of connected pixels within a binary image. In this workflow, connected components are used to distinguish sufficiently long linear features from smaller unwanted features during gridline detection.
Contrast enhancement	An image-processing operation used to increase or redistribute differences in pixel intensity so that seismic reflection features become more distinguishable. The workflow optionally applies contrast enhancement using percentile-based clipping and gamma correction.
csv/comma-separated values	A tabular, text-based file format used to store structured data. In this workflow, .csv output can be generated as an additional record of reconstructed trace metadata, including trace number, shotpoint, easting and northing.

Distance-linearised image	A raster image in which the horizontal pixel coordinate has been resampled so that equal horizontal increments correspond approximately to equal increments of real-world acquisition distance. This is the principal output of the navigation-constrained horizontal re-mapping stage.
Easting	The east to west component of a projected coordinate system. In this workflow, UTM easting values are assigned to reconstructed traces through interpolation of the supplied navigation data.
Feathering	A gradual transition applied at the boundaries of a spatial correction rather than introducing the correction abruptly. In this workflow, raised-cosine feathering is used to progressively introduce and remove navigation shifts, reducing spatial discontinuities.
Fourier-domain filtering	An image-processing approach in which an image is transformed from the spatial domain into the frequency domain so that selected frequency components can be modified or suppressed. Frequency-domain notch filtering is an alternative approach to removing periodic image artefacts such as regular lines.
Gamma correction	A non-linear transformation of image intensity used to alter the relative brightness of features within an image. In this workflow, gamma correction is an optional component of contrast enhancement and can alter the image intensities subsequently used for amplitude reconstruction.
Geometric re-mapping	The transformation of the horizontal geometry of a scanned seismic image so that image positions correspond more closely to the real-world acquisition geometry. The workflow performs navigation-constrained horizontal re-mapping using shotpoint calibration and cumulative navigation distance.
Gridline	A horizontal or vertical line printed or displayed on a seismic section to indicate information such as shotpoint intervals or two-way travel-time intervals. Gridlines are treated as image artefacts during pre-processing because they can introduce artificial amplitudes into reconstructed traces.
Gridline removal	The process of detecting and removing horizontal and vertical gridlines from a scanned seismic image before trace reconstruction. The workflow combines adaptive thresholding, morphological filtering, connected-component filtering and inpainting for this purpose.
GUI/graphical user interface	A software interface through which users interact with the processing workflow using graphical controls rather than directly modifying source code. The GUI developed for this workflow provides controls for image pre-processing, calibration, trace reconstruction, navigation shifting and SEG-Y export.
Inpainting	An image-processing technique used to reconstruct pixels within regions that have been removed or identified as corrupted by estimating suitable values from surrounding image information. In this workflow, inpainting is applied to areas occupied by detected gridlines after their removal.
Interpolation	A mathematical procedure for estimating values between known data points. The workflow uses linear interpolation to

	estimate shotpoint values and UTM coordinates for reconstructed traces between known navigation positions.
Legacy seismic data	Historical seismic records preserved in formats or media that may not be directly compatible with current digital seismic interpretation systems. In this workflow, scanned seismic images constitute the source data from which usable digital SEG-Y datasets are reconstructed.
Navigation coordinates	The spatial coordinates associated with positions along the original seismic acquisition line. In this workflow, navigation information consists principally of shotpoint, UTM easting and UTM northing values, and is used to establish the spatial geometry of reconstructed traces.
Navigation-based trace reconstruction	A trace reconstruction approach in which reconstructed traces are positioned at a defined spatial interval along cumulative acquisition distance rather than being generated solely from the number of image columns. In this workflow, a target spacing of 6.25 m is used when this approach is selected.
Navigation-constrained re-mapping	A geometric correction procedure in which the horizontal geometry of the scanned seismic image is transformed using known shotpoint positions and corresponding navigation-derived cumulative distances. The objective is to produce a distance-linearised seismic image before trace reconstruction.
Navigation shift direction	The cardinal or intercardinal direction in which a spatial correction is applied to trace coordinates. The workflow supports the directions N, NE, E, SE, S, SW, W and NW.
Northing	The north to south component of a projected coordinate system. In this workflow, UTM northing values are assigned to reconstructed traces through interpolation of the supplied navigation data.
Morphological filtering	A class of image-processing operations that analyse and modify binary images according to the shape and spatial structure of features. The workflow uses directional morphological operations to isolate vertical and horizontal linear features such as gridlines and shotpoint markers.
Morphological opening	A morphological operation consisting of erosion followed by dilation. It is used in the workflow with orientation-specific structuring elements to preferentially isolate linear features having the desired orientation.
Pixel	The smallest discrete element of a raster image. In the scanned seismic sections, each pixel contains an intensity value representing the appearance of the original seismic image. Pixel position and intensity provide the basis for subsequent geometric re-mapping and amplitude reconstruction.
Raster image	A digital image represented as a rectangular array of pixels. The scanned seismic sections processed by the workflow are raster images, typically supplied in formats such as .jpeg, .png or .tif.
Re-mapped seismic image	The seismic raster produced after navigation-constrained horizontal geometric correction. The re-mapped image is distance-linearised so that its horizontal pixel positions

	represent proportional positions along the real acquisition distance.
Sample interval	The temporal spacing between successive amplitude samples within a seismic trace. In the reconstructed SEG-Y data, the sample interval is stored in microseconds and is derived from the calibrated vertical sampling of the scanned seismic image.
SEG-Y	A standard digital data-exchange format widely used for storing and exchanging seismic reflection data. In this workflow, reconstructed seismic traces and associated navigation and acquisition metadata are encoded into SEG-Y files for use in seismic interpretation software.
SEG-Y data sample format	The numerical representation used to store seismic amplitude samples within a SEG-Y file. The workflow encodes reconstructed amplitudes using a signed 16-bit integer representation.
Seismic trace	A one-dimensional sequence of seismic amplitude samples representing the seismic response as a function of time or depth at a particular spatial position. In the workflow, traces are reconstructed from vertical image columns or from positions determined by navigation-based trace spacing.
Shotpoint	A numerical identifier used to reference a position along a seismic acquisition line. The workflow uses shotpoint information to both calibrate the scanned image and assign spatial metadata to reconstructed SEG-Y traces.
Shotpoint calibration	The process of establishing the relationship between shotpoint markers visible on a scanned seismic image and their corresponding positions in the supplied navigation data. The workflow supports automatic detection followed by interactive user refinement.
Shotpoint marker	A visible feature on the scanned seismic image used to identify a known shotpoint position. Detected markers are assigned shotpoint values and used as control points for navigation-constrained horizontal re-mapping.
Spatial aliasing	A loss or distortion of spatial information that can occur when data are sampled too sparsely relative to the spatial variation of the signal. The 6.25 m target trace spacing used in the navigation-based reconstruction approach provides a defined spatial sampling interval for reconstructed traces.
Spatial shifting	The application of a defined spatial offset to the navigation coordinates of seismic traces. In this workflow, shifts can be specified by start and end shotpoints, distance and direction and may be applied during image-to-SEG-Y conversion or to an existing SEG-Y dataset.
Structuring element	A small, predefined geometric kernel used by morphological image-processing operations to identify features having particular shapes or orientations. The workflow uses vertically and horizontally oriented rectangular structuring elements for linear feature detection.
Trace header	Metadata stored with an individual SEG-Y seismic trace. In this workflow, trace headers contain information including trace sequence number, shotpoint, source and receiver coordinates, coordinate scalar, sample interval and number of samples.

Trace-per-pixel reconstruction	A trace reconstruction approach in which each vertical pixel column of the re-mapped seismic image is exported as an individual seismic trace. The number of reconstructed traces therefore corresponds to the horizontal pixel width of the re-mapped image.
Trace sampling	The spatial interval or density at which seismic traces are reconstructed along the seismic line. The workflow supports image-column-based reconstruction and navigation-based reconstruction using a target spacing of 6.25 m.
TWT/two-way travel time	The elapsed time taken for a seismic signal to travel from the source to a subsurface reflector and return to the receiver. In the scanned seismic sections, TWT is represented along the vertical image axis and is used to establish the temporal sampling interval of the reconstructed traces.
UTM/Universal Transverse Mercator	A projected coordinate system used to represent geographical positions in metres. The workflow uses UTM easting and northing coordinates from the navigation data to establish the spatial positions of reconstructed seismic traces.
Vertical sampling interval	The time represented by each vertical pixel of the scanned seismic image after TWT calibration. It is calculated from the total TWT represented by the image and the number of vertical pixels and is subsequently stored in the SEG-Y trace header in microseconds.
Wiggle trace	A graphical representation of a seismic trace in which amplitude variations are displayed as a waveform or wiggle against time. In this report, wiggle traces are used illustratively to show how reconstructed seismic traces are represented after conversion from the scanned image.
UTM coordinate interpolation	The estimation of easting and northing coordinates for reconstructed traces between known navigation positions. The workflow performs this interpolation along cumulative acquisition distance to maintain spatial continuity.

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