Energie Beheer Nederland B.V.

2D Seismic PreSTM Processing for line L2EBN2020CUOBR017, SCAN Project GTO-19-C031-02, Onshore Netherlands - Processing Report

26 April 2021

DUGRef: sCAnPr_007

CONTENTS

1. INTRODUCTION

Note that this is a report for line L2EBN2020CUOBR017 (UOBR017) only. This line was processed together with data from line L2EBN2020ASCAN018 (SCAN018) which was acquired as a continuous line with line UOBR017 as part of the full project. A report for the processing for all lines will be made public when the project has completed.

This report summarises the seismic data processing of a single UOBR 2D line by DownUnder GeoSolutions for Energie Beheer Nederland (EBN) B.V. from December 2020 to March 2021. The data were processed from SEGY field records through a broadband anisotropic pre-stack time migration processing sequence in the DUG London office. 71.7 km of input data were received (46.7 km from line UOBR017) in the final copy of data from the field, consisting of 1150 explosive shots (720 from line UOBR017).

The processing objectives were to follow the sequence used for the previous project in the same area (GTO-19-C031-01/sCAnPr_005) in order to:

- Remove the effects of the near surface through statics modelling.
- Produce high quality structural images with good signal to noise ratios and a broad frequency spectrum.

The 2D explosive source survey is located in the SCAN areas in the Netherlands (Figure 1) and was acquired by Rossingh Drilling & Geophysics in June 2020 and September/October 2020. The full fold length is approximately 36.2 km with elevations ranging from +6.7 to +24.2 m. A range of 0.22-1.54 kg explosive charges were used with a nominal SP interval of 60 m. The survey was recorded with Geospace GS-One LF 5 Hz single sensor nodes with a nominal fold of 116.

In general, the seismic data quality are good, probably due to the deep shot holes (20 m) and relatively uniform near surface conditions. The main areas of concern were the ground roll, out of plane noise contamination, acquisition gaps due to omitted shots and irregular shot and receiver spacing, plus weak shots with poor signal to noise ratio.

The key processing steps applied to address these issues were:

- Refraction statics incorporating first breaks manually reviewed for every shot station.
- State of the art noise attenuation using various techniques applied in multiple domains.
- Careful attention to horizon consistent velocity picking.
- Comprehensive anisotropic PreSTM workflow.

One of the requirements of the project was to produce an intermediate "fast-track" product within two weeks of receipt of the field data in order for EBN to monitor data quality and gain an initial understanding of the geology. Horizons were interpreted on the fast-track stack in order to guide iterations of velocity picking.

A fast-track sequence had already been established in the previous project (GTO-19-C031-01/sCAnPr_005). Data for line UOBR017 were first received on Tuesday 8 September and a fast-track stack was delivered on Wednesday 21 October. A new copy of data for line UOBR017 including additional data acquired as part of line SCAN018 was received on Monday 14 December and a new fast-track of the combined UOBR017-SCAN018 line was delivered on Wednesday 30 December.

2. SURVEY DATUM

Projection zone:	Amersfoort/RD New, whole country (EPSG:28992)
Projection type:	Oblique Stereographic
Geodetic datum spheroid:	Bessel 1841, Semi-major axis=6377397.155, Semi-minor axis=6356078.963 1/f=299.1528128
Geodetic datum name:	RD 2008 (Netherlands)
Vertical datum:	MSL = NAP, Amsterdam/EGM 2008
Grid units:	Metres
Grid zone:	1
Longitude of central meridian:	5.387638888888889E
Grid origin:	0000000.000N, 5.387638888888889E
Grid coordinate at origin:	155000E,463000N
Scale factor:	0.9999079
Latitude scale factor:	52.15616055555555N
Longitude scale factor:	5.387638888888889E
Replacement velocity (Vr):	1700 m/s
Weathering velocity (Vw):	1000 m/s

3. SURVEY LOCATION

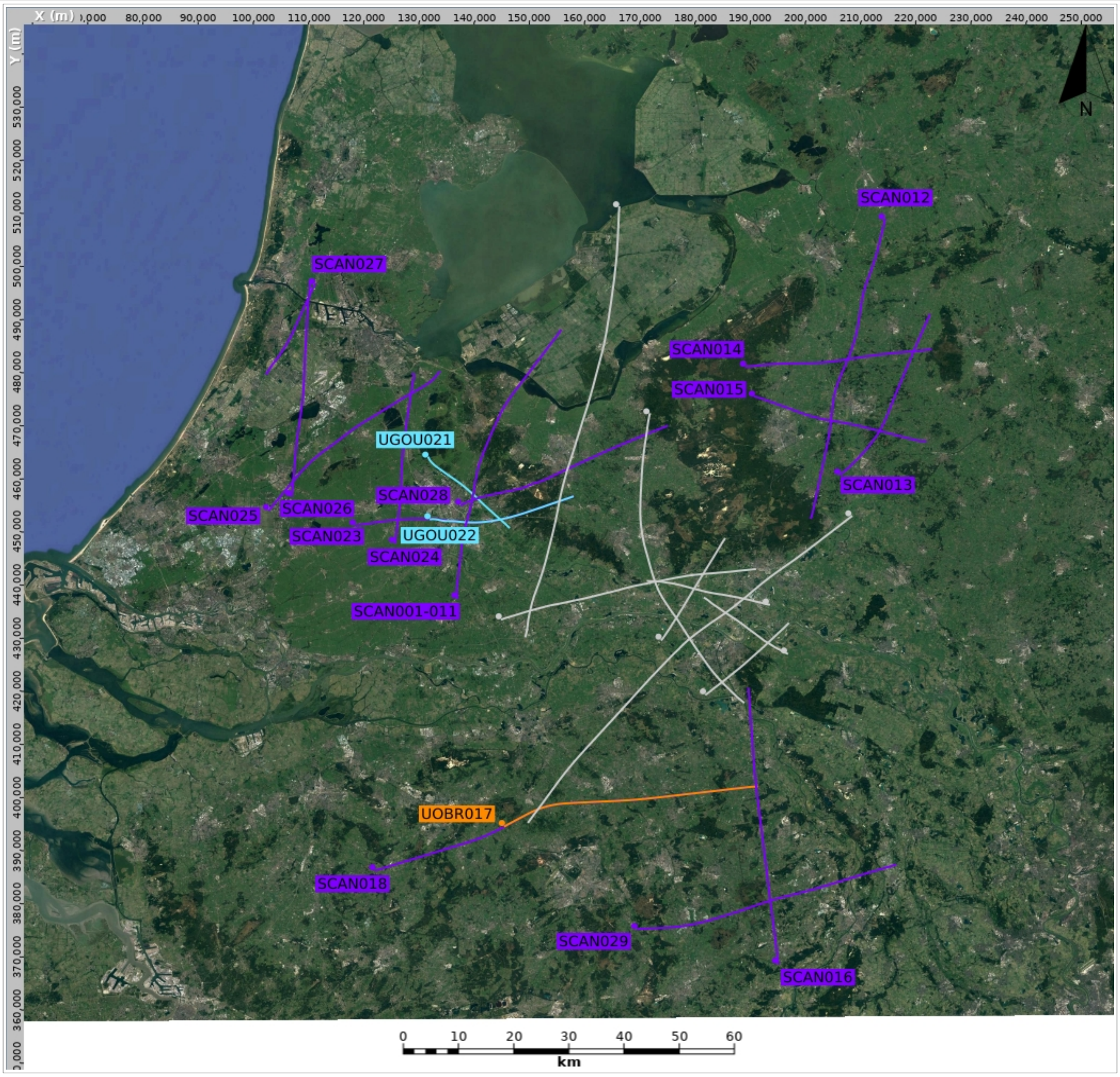

Figure 1: Line location map of the 2D seismic survey lines with aerial photograph overlain. The lines in grey are from the previous project GTO-19-C031-01/sCAnPr_005.

4. KEY PERSONNEL

The main personnel involved in the project were:

Energie Beheer Nederland (EBN) B.V.:

Johannes Rehling	Senior Geophysicist
Audrey Roustiau	Geoscientist

TNO:

Stefan Carpentier	Senior Geophysicist

DownUnder GeoSolutions:

Ian Twyford	Land Processing Team Leader
Peter Hall	Senior Geophysicist

5. DATA ACQUISITION PARAMETERS

Country of survey:	The Netherlands
Area of survey:	SCAN areas, The Netherlands
Survey crew:	Rossingh Drilling & Geophysics
Data type:	SEGY provided to DUG, recorded as SEGD
Survey name:	GTO-19-C031-02 SCAN Acquisition Seismic Processing Order #2
Acquisition record length:	10 s
Acquisition sample interval:	2 ms
Anti-alias filter applied:	208 Hz corner frequency high cut filter (minimum phase)
Low cut filter:	Disabled
Source type:	Explosive (Seismophex dynamite)
Source size:	Variable (0.22-1.54 kg)
Source depth:	Nominally 20 m (single hole)
Geophone type:	Geospace GS-One LF 5 Hz
Geophone model:	GCL-1 SEG
Geophone array:	Single geophone per station
Shot interval:	60 m (station increment of 12)
Channel interval:	5 m (station increment of 1)
Number of channels:	2800
Spread:	Symmetrical split spread (roll on/roll off)
Nominal near offset:	2.5 m
Nominal far offset:	6997.5 m
Nominal fold:	116
Recording system:	GeoRes XTC Seismic data manager
Field tape format:	3592 (provided to DUG via ftp site as SEGY records)

6. PROCESSING GRID INFORMATION

The dataset was processed on crooked line geometry with CDP spacing of 2.5 m.

The migration was output to the same crooked line geometry.

7. FINAL PROCESSING SEQUENCE

- Data reformat from SEGY to internal format
- Applied crooked line geometry
- Edits: Only keep traces with offset < 500 m for weak shots
- Spherical divergence correction
- Geophone response correction
- Refraction static computation and application using delay-time solution
    - V0=1000 m/s
    - VR=1700 m/s
    - SRD=NAP
- Noise attenuation: +/-1250 m/s Weiner dip filter
- Noise attenuation: Despike
- Noise attenuation: Wavelet (D20) transform filter
- 1st pass surface consistent amplitude compensation: Source and receiver components
- Noise attenuation: TFDN
- Inverse Q: Q=100 phase and amplitude using 40 Hz reference frequency and 12 dB gain stabilisation
- Surface consistent deconvolution: source and receiver
    - 160 ms operator length
    - 16 ms predictive gap
    - 0.1% white noise stabilisation
    - Design window: 200-3000 ms
- 1st pass velocity analysis: 1 km interval manual picks
- Noise attenuation: 1.75 ms/tr (2857 m/s) dip filter and wavelet transform filter on shots
- 1st pass residual statics pass 1: Surface consistent MASTT algorithm applying source and receiver terms
- 2nd pass velocity analysis: 1 km interval picked velocities
- 2nd pass residual statics pass 2: Surface consistent MASTT algorithm applying source and receiver terms
- 2nd pass surface consistent amplitude compensation: Source and receiver components
- Additional noise attenuation: TFDN on CDPs.
- Spherical divergence removed: T
- Low cut filter: 2.5 Hz with 18 dB/Octave slope
- *SEGY: Migration input CDPs (on floating datum with conversion to zero phase applied)*
- *SEGY: Migration input stacks (on floating datum with conversion to zero phase, stacked using 1/N stack normalisation)*

- Migration (PreSTM 1): Isotropic 4th order curved-ray Kirchhoff using smoothed stacking velocities
- Velocity analysis: 500 m manually picked 2nd order velocities with automatic Eta picking every 250 m
- Migration (PreSTM 2): Anisotropic VTI Kirchhoff using re-picked 2nd order velocities and auto-picked Eta
- Time-tomography: Automatic non-parabolic RMO picking every 250 m followed by time-tomography to update velocity and Eta - Time-tomography velocity and Eta were smoothed using a 2 km along line smoother
- AGC products only: 2000 ms AGC
- Migration (PreSTM 3): Anisotropic VTI Kirchhoff using re-picked 2nd order velocities
    - Auto-picked Eta
    - 60 m offset bins to 6990 m
    - 3 km aperture length
    - Time-variant dip: 45° dip at 0 ms, 45° dip at 1250 ms, 30° dip at 2500 ms
    - Anti-alias constant = 2
- *SEGY: Migration output CDPs (with conversion to zero phase and shifted to final datum)*
- *SEGY: Raw stacks (with conversion to zero phase and shifted to final datum, stacked using 1/N stack normalisation)*
- Demultiple: Radon domain (801 P-traces from -1000 – 7000) with subtraction using a polygon
- Noise attenuation: Weiner dip filter with signal protection
- Trim statics: 12 ms maximum shift, smoothed field
- Noise attenuation: CDP offset Cadzow rank-reduction random noise attenuation
- Noise attenuation: Common offset dip filter
- Drop offsets not input to migration
- Mute: Offset domain manually picked inside and outside trace mutes
- Conversion to zero phase: Statistically derived filter operator (an increase in acoustic impedance is a negative number)
- *SEGY: Final CDPs (on final datum with conversion to zero phase applied)*
- AGC products only: 2000 ms AGC
- Stack: 1/N for true amplitude stacks (1/√N for AGC stacks)
- *SEGY: Processed stacks (output shifted to final datum)*
- Spectral broadening
- Noise attenuation: Weiner post-stack dip filter
- Noise attenuation: Cadzow rank-reduction noise attenuation
- Noise attenuation: Structurally Oriented Filter (SOF)
- Time-variant frequency domain filter
    - Time (ms): 0-750 1250-2500 3500-10000
    - Frequency (Hz): 6-8-100-190 4-8-100-120 4-8-35-55

- AGC products only: Dual gate 500/2000 ms AGC
- True amplitude products only: Bulk line scalar
- Final datum shift
- *SEGY: Final stack (true amplitude and AGC products supplied)*

8. PROCESSING

8.1 Introduction

The SEGY field data were received from EBN as and when they were made available from the field. The first set of the data was received on Tuesday 8 September 2020, but full processing was put on hold until a new copy of the data was received on Monday 14 December along with data for SCAN018. This meant that the combined line UOBR017-SCAN018 could be processed seamlessly. Data were processed by DownUnder GeoSolutions from December 2020 to March 2021.

8.2 Data Reformat

Data were read from SEGY files and reformatted to internal format for processing.

8.3 Geometry

Crooked line geometries were designed based on the SPS format navigation files. Information assigned to each trace included CDP locations, offsets and CDP fold.

Source and receiver indexing had been used during acquisition – this is where a given station is assigned two or more coordinates, either because there are several occurrences of that station, or the station was relocated at some stage during acquisition. A station can then be assigned its own unique coordinate via the index. For UOBR017-SCAN018 the receiver stations that had been relaid for the later phase of acquisition had the same station number but new index numbers.

Lines UOBR017-SCAN018 were shot as a continuous line (although the data were provided as if they were isolated lines) so no merging was required. They were also processed as a continuous line in order to improve the CDP and migration fold at the ends of each individual line and the final deliverables were kept as full continuous lines.

8.4 Trace Edit

Weak shots were identified manually during first break picking and they were restricted to 0-500 m offsets.

Line	Weak shots	Killed Shots	Total shots	Percentage Weak Shots from Total
UOBR017-SCAN018	64	0	1150	5.5 %

The traces with receivers killed in the SPS were also dropped from the sequence (these traces had been zeroed in the data provided from the field).

8.5 Spherical Divergence Correction

A spherical divergence correction was applied using a factor of T^1 (time).

8.6 Geophone Response Correction

The geophone response filter had previously been generated for the lines in the previous project (GTO-19-C031-01/sCAnPr_005) and the same filter also used for this project. This filter was designed to compensate for amplitude and shifted phase response at low frequencies.

8.7 Refraction Static Computation and Application

The same procedure was used as for the previous project (GTO-19-C031-01/sCAnPr_005). First arrivals for a single refraction layer were picked using an auto-picker and then each shot was reviewed manually in order to ensure all the first break picks were accurate and reliable for the refractor range modelled, which was approximately offsets 500-1000 m. This range was chosen as it encompassed the energy from the first main refractor with good S/N consistently along both lines with minimal interference from other refractors. Shot and receiver delay-times were calculated using a least squares delay-time algorithm. Shot and receiver static corrections were then calculated using a single refractor layer model with a weathering velocity of 1000 m/s, a replacement velocity of 1700 m/s and datum of 0 m MSL (=NAP).

The shot and receiver statics were used to produce a smooth floating datum, and the data were shifted to this floating datum for most of the processing sequence, with correction to final datum taking place after final stack.

The results of the refraction statics are presented in the following report:

- sCAnPr_007_UOBR017-SCAN018_RefractionStaticsUpdate_201224.pdf

8.8 Noise Attenuation: Dip filter

A Weiner dip filter was applied on shots within a 500 ms wraparound AGC to remove coherent energy with a velocity of +/- 1250 m/s.

Parameter	Value
Number of traces in the filter	1001
Length of filter (in samples)	501
Dip filter	±0-4 ms/trace
Conditioning	500 ms wraparound AGC

8.9 Noise Attenuation: Despike

A despike routine was applied to identify RMS amplitude spikes within the window 3-5 s. These extremely high amplitude traces were dropped from the processing.

8.10 Noise Attenuation: Wavelet Transform Filter

The data were transformed to wavelet domain using the Daubechies wavelet with 20 coefficients (10 vanishing moments), also referred to as a D20 wavelet. The largest 10% of amplitude coefficients were muted to 90 % in scales 6-10.

8.11 Surface Consistent Amplitude Correction: Pass 1

Source and receiver amplitude scalars were calculated from RMS values of NMO corrected gathers using an analysis window of 200-2200 ms. A 16 ms gapped operator with an operator length of 160 ms was used and 0.1% white noise was added to stabilise the solutions. The operator design window used was 200-3000 ms.

8.12 Noise Attenuation: TFDN

Time-Frequency DeNoise (TFDN) is used to suppress anomalous noise in traces when compared to the neighbouring traces. The data are transformed to frequency domain using a short window Fourier transform. The magnitude of the individual frequencies are compared to the neighbouring traces in a particular window using a selected statistical method. If the amplitude of the trace exceeds a specified statistical threshold, the amplitude is replaced by a statistic.

TFDN is used in different domains to ensure that the noise is isolated and can then be removed.

Parameter	Value
Frequency range (Hz)	0-250
Threshold at start of trace	7
Threshold at end of trace	2
Trace window (traces)	101
Window length (ms)	500
Statistical threshold calculation	Lower quartile

8.13 Inverse Q

Frequencies are attenuated in time at different rates. Higher frequencies are absorbed more rapidly than lower frequencies, which also travel more slowly. This second phenomenon causes a phase change in the embedded wavelet. Both of these effects can be corrected by applying an inverse filter generated from a Q model.

The inverse Q phase and amplitude correction used a constant Q=100 model, with a 40 Hz reference frequency and 12 dB gain stabilisation. This also matched with the approach taken for previous lines processed by EBN in the area.

8.14 Surface Consistent Deconvolution

Surface consistent deconvolution was used to deconvolve and remove the source and receiver signature effects from the earth filter. Using averaged operators for each source and receiver helps to stabilise the operators.

A 16 ms gapped operator with an operator length of 160 ms was used and 0.1% white noise was added to stabilise the solutions. The operator design window used was 200-3000 ms.

8.15 Velocity Analysis

Initial velocities were picked every 1 km. The interactive velocity analysis used velocity spectra, moved out gathers and stacked panels to assist in careful interpretation of stacking velocities. Whole line CVS panels were also used.

8.16 Noise Attenuation: Dip Filter

A Weiner dip filter was applied on shots within a 400 ms wraparound AGC to remove coherent energy with a velocity of 0-1.75 ms/tr (2857 m/s)

Parameter	Value
Number of traces in the filter	1001
Length of filter (in samples)	751
Dip filter	±0-1.75 ms/trace
Conditioning	400 ms wraparound AGC Weak shots did not have this noise attenuation applied
Noise model conditioning	Dip filter to remove energy with ±0-1 ms/trace dips ('flat' energy)

The results from processing up to this stage were presented in the following report:

- sCAnPr_007_UOBR017-SCAN018_InitialProcessing_201230.pdf

8.17 Noise Attenuation: Wavelet Transform Filter

The data were transformed to wavelet domain using the Daubechies wavelet with 20 coefficients (10 vanishing moments), also referred to as a D20 wavelet. The largest 10% of amplitude coefficients were muted to 90% in scales 6-10. This is similar to the noise attenuation applied previously in 8.10, and needed to be reapplied after SCAC and DBS.

The noise model output from the wavelet transform had a 15 degree inside trace mute applied before the noise model was subtracted from the data.

8.18 First Pass Surface Consistent Residual Statics

Surface consistent residual statics were calculated and applied using Techco MASTT residual statics. This is an industry leading semi-intelligent picking algorithm that derives time picks for each input trace with sub-algorithms for different qualities of data. The MASTT solution uses a median value criterion to obtain statics from the picks rather than the more common least squared error solution.

In this case, analysis was conducted for the 0-1500 ms window using an 8 ms correlation length, cross-correlating up to 99 traces. Two iterations were performed in order to generate residual static shifts for each shot and receiver.

8.19 Surface Consistent Amplitude Correction: Pass 2

Source and receiver amplitude scalars were derived from RMS values calculated from NMO corrected gathers over 200-2200 ms. This second pass of SCAC was used to resolve residual variations in amplitude not resolved in the first pass of SCAC.

8.20 Velocity Re-picking

Velocities were re-picked every 1 km. The interactive velocity analysis used velocity spectra, moved out gathers and stacked panels to assist in careful interpretation of stacking velocities.

Interpreted horizons were supplied by EBN and every effort was made to ensure the RMS velocities were picked consistently with these horizons whilst maintaining a smooth velocity field (even when converted to an interval velocity), flat gathers and improved stack response.

8.21 Second Pass Surface Consistent Residual Statics

Surface consistent residual statics were calculated again using the same parameters as the initial residual statics pass and applied to the data.

The pre-migration velocities, amplitude correction and residual statics are presented in the following report:

- sCAnPr_007_UOBR017-SCAN018_VelsAmplitudesResidualStatics_210112.pdf

8.22 Additional Noise Attenuation: TFDN on CDPs

Line UOBR017-SCAN018 was one of the lines in the project that contained residual noise so additional passes of TFDN in CDP domain were applied as described in the velocities and residual statics report:

- sCAnPr_007_UOBR017-SCAN018_VelsAmplitudesResidualStatics_210112.pdf

8.23 Spherical Divergence Correction Removed

Spherical divergence correction factor of T (time) was removed. The spherical divergence is more accurately compensated within the migration algorithm.

It is known that the migration restrictions with 2D data can cause data to mis-tie between lines. Before migration, checks were made to ensure all the pre-migration stacks had minimal mis-ties between all lines in the project.

8.24 Migration (PreSTM 1)

The picked velocities were smoothed with a 2 km smoother, chosen after testing, and an initial isotropic 4th order curved-ray Kirchhoff pre-stack migration was performed.

8.25 Velocity Analysis For Eta

The gathers output from the initial migration described above were used for manual picking of the 2nd order velocities, initially at a 1 km interval. It was subsequently decided to review the function every 500 m and add additional picks at the intermediate locations where required. In common with previous velocity picking episodes semblance panels, CDPs with interactive moveout, stacks with interactive stacking velocities and constant velocity stacks were used to enable accurate picking.

The gathers were conditioned using the following sequence:

- 6-8-120-150 Hz bandpass filter
- A harsh Radon filter
- Migration velocities were removed
- The new second order picked velocity function was applied
- 500 ms AGC

An automatic Eta picker was then run on the conditioned gathers every 250 m.

8.26 Migration (PreSTM 2)

Anisotropic VTI Kirchhoff migration was performed using the re-picked 2nd order velocities and auto-picked Eta described above.

The PreSTM2 processing results are presented in the following reports:

- sCAnPr_007_UOBR017-SCAN018_PreSTM2Update_210121.pdf

8.27 Time-Tomography

The gathers output from the second pass of migration were conditioned using the following sequence:

- A harsh Radon filter
- ±6 ms/trace dip filter
- 500 ms AGC
- 6-8-120-150 Hz bandpass filter

The conditioned gathers were then used in a non-parabolic automatic RMO picking algorithm every 250 m. These RMO picks were then used in time-tomography to update both the velocity and Eta fields simultaneously. The output Eta and velocity fields were smoothed using a 2 km smoother.

8.28 Low Cut Filter

There was some low frequency energy present on the gathers prior to migration. This was considered to be noise rather than useful data, so a 2.5 Hz low cut filter with 18 dB/Octave slope was applied to the gathers prior to the final migration.

8.29 Migration (PreSTM 3)

The final migration was an anisotropic VTI Kirchhoff pre-stack migration using the velocities and Eta fields output from the time-tomography described in section 8.27.

After extensive testing, the following parameters were used for the migration:

Parameter	Value
Offset bins	30 – 6990 m (60 m bins)
Half aperture	3 km
Dip limit (time-variant)	0 ms: 45° 1250 ms: 45° 2500 ms: 30°
Spatial anti-alias	2

The results from PreSTM3 are displayed in the following report:

- sCAnPr_007_UOBR017-SCAN018_PreSTM3_210125.pdf

8.30 Radon Demultiple

In the previous project it was found to be more effective to apply demultiple post migration. The gathers were transformed to Radon domain using 801 P-traces from -1000 to 7000. The multiple was identified with a polygon in Radon space, which was then transformed back to X-T domain to be subtracted from the input gathers. The polygon used to identify the mute in the Radon domain is described by the following corner points:

P	TWT
816	10021
109	10052
130	2581
141	2041
158	1783
194	1542
212	1476
251	1448
358	1415
603	1388
812	1376

The full post migration processing included Radon is presented in the following report:

- sCAnPr_007_UOBR017-SCAN018_PostMigProcessing_210204.pdf

8.31 Noise Attenuation: Dip Filter

Weiner dip filters were used to remove residual dipping noise present on the CDP gathers. A ±4 ms/trace dip filter was selected for production.

8.32 Trim Statics

In the previous project non-parabolic RMO and CDP consistent trim static approaches were tested with the aim of generating flatter gathers and improving the resolution of stacks.

The RMO approach relates all shifts back to the near offsets, whereas CDP consistent trim statics attempt to align all traces within a CDP gather by cross-correlating with a 'pilot' trace generated from an enhanced version of the full offset stack. Both methods are very similar in that they produce a volume of statics shifts which require a degree of smoothing in three dimensions (offset, time and along the CDP line) to avoid sharp discontinuities being introduced on adjacent traces in any dimension.

Despite the extensive testing, it was not possible to produce an acceptable RMO solution. However, even after smoothing, the CDP trim was very effective.

To guide the CDP trim statics a pilot stack was produced by stacking the gathers with a 400 ms AGC and a mild (4-6-90-120 Hz) bandpass filter. Trim statics were then calculated with an allowed maximum shift of 12 ms. These raw trim statics were smoothed using a 100 m along line smoother, and 300 m within gathers in order to keep them spatially consistent before being applied to the gathers.

8.33 Conversion to Zero Phase

The same statistically derived zero phase filter was used for all lines in the previous project and this project in order to maintain consistency. The zero phase filter is included in the appendix of this report (section 10.6). Polarity: An increase in acoustic impedance is a negative number.

8.34 Noise Attenuation: CDP-Offset Cadzow

Cadzow matrix rank-reduction is an algorithm used for attenuating random noise. It can be applied in 2D (shots, receivers, CDPs, offset planes) but DUG's implementation of Cadzow rank-reduction can also be applied in 3D, to CDPs and offsets simultaneously. Using a 3D application helps to attenuate random noise more surgically with less leakage.

It was decided to use a time-variant application of the CDP-Offset Cadzow, using a 13x13 matrix above 100 ms and 7x7 matrix below 500 ms with a linear taper as presented in the report.

8.35 Noise Attenuation: Common Offset Dip Filter

The gathers output from migration have a regular offset distribution, which means that the traces can be sorted into offset planes i.e. a volume of traces that consists of the same offset trace from every CDP. A dip filter that limits dips to +/-3333 m/s was applied in this common offset domain and the noise model filtered to only pass frequencies above a low cut filter of 40-50 Hz to remove residual high frequency dipping noise that could be observed on the stack.

8.36 Post Migration Trace Drop

After migration, the range of offsets in each gather were limited to the range of offsets input to the migration with a spatial smoother. The far offsets were smoothed over a half window of 500 CDPs and initially a similar methodology was applied for the near offsets. After further testing it was decided to calculate the minimum offset over a half window of 50 CDPs and then smooth the value over a half window of 10 CDPs.

Note that the full output from migration was retained until post Radon and dip filter processing in order to improve the efficacy of the transforms.

8.37 Mute

A 55° mute had been favoured for the fast-track data and a 45° mute for the intermediate processing stacks, however a manually picked offset domain mute was preferred for the final stacks. The initial mute function is described in the table below:

Time (ms)	Offset
0	0
370	767
655	1004
860	1004
1260	1320
1566	2012
2146	3138
2891	4996
3939	8632

Due to the complexity of the shallow structures, the mutes were made spatially variable in order to follow the geological trends, but following closely to the mute described above. These picked mutes are provided in text files apart of the final deliverables.

Inside trace mutes were also tested and the selected inside trace mute used for the full and near stacks is defined in the table below. Note that the inside trace mute is not spatially variable:

Time (ms)	Offset
0	0
1000	0
1250	60
1500	180
1750	240
2000	300
2500	360
10000	360

Near, mid and far offset mutes were derived by dividing the full stack mute, including inside trace mute, into three equal portions.

8.38 Stack

Traces within a common midpoint bin were summed.

The true amplitude stacks (no AGC in the processing sequence) were normalised using 1/N standard normalisation.

The stacks with AGC scaling were produced by scaling the amplitude of the traces by the square root of the fold for each sample in the trace (1/√N)

8.39 Spectral Balancing

The frequency spectra of the data had been carefully monitored throughout the processing. Spectral balancing was applied post-stack as frequency dB gain pairs in order to broaden the spectrum and improve the resolution of the seismic data. However using this method was found over boost some frequencies, resulting in an anomalous frequency spectrum. Several methodologies were investigated and it was agreed to apply a frequency matching filter instead, as this preserved amplitudes whilst resulting in a flatter frequency spectrum. The filter was designed by generating frequency matching filters for each trace on line SCAN001-011 to shape the spectra to 2-8-100-140 Hz. The filters were then averaged to give a single filter that was applied to the whole line, and the results are presented in the following report:

- sCAnPr_007_UOBR017-SCAN018_PostStackProcessing_210303.pdf

8.40 Noise Attenuation: Dip Filter

In the previous project dipping noise was removed using a ±3 ms/trace dip filter. More aggressive dip filters had been tested but they were found to damage steeply dipping events and fault plane imaging. The client highlighted that there was some residual dipping noise on line SCAN016 so a harsher post-stack dip filter was developed:

- ±3 ms/trace dip filter in the shallow (with a taper in the shallow 300 ms)
- ±1 ms/trace in the deep (below the Base North Sea)

This filter was applied to the UOBR017.

8.41 Noise Attenuation: Cadzow

The stacks contained a small amount of random noise, particularly in the shallow part of the section. Cadzow rank-reduction was applied to attenuate this random noise. A 30 trace matrix with a rank of 3 was used for production.

8.42 Noise Attenuation: Structurally Oriented Filter

A Structurally Oriented Filter (SOF) was derived from a dip field generated from the stack. After testing, it was decided to apply a dual gate SOF to allow steeper dips to be attenuated in the shallow part of the section. The transition between the shallow 5 CDP half smoother and the deeper 3 CDP half smoother took place at 600 ms with a centred 200 ms taper.

8.43 Time-Variant Bandpass Filter

In some parts of the section, the earlier spectral broadening was deemed to have over boosted the higher frequencies, plus there was remnant low frequency energy present with no useful signal. During an interactive meeting with the client, the following parameters were approved:

Window (s)	Frequency
0 - 750	6-8-100-190
1250 - 2500	4-8-100-120
3500 - 10000	4-8-35-55

8.44 Trace Amplitude Balance

AGC (Automatic Gain Control) varies the gain applied to trace samples within a specified time window. The AGC scalar is based on the mean of the absolute values of the samples in the sliding time gate and was applied to the AGC products only.

Although an AGC can help improve imaging and reduce the influence of noise, using an AGC means that the stack is no longer true amplitude. Some areas were found to benefit from AGC, in particular the lines that traversed the areas with shallow glacial deposits, so a separate product was generated using pre-migration, pre-stack and post-stack AGCs. This product had the same processing sequence applied as the true amplitude product, apart from using 1/√N normalisation in the stacking process (refer to section 8.38).

A scaling window of 2000 ms was applied both pre-migration and pre-stack. A 500 ms AGC window was proposed for the post-stack scaling and subsequently refined to be a 500 ms window above 1 s and a 2000 ms AGC window below 2 s, with a linear taper between the windows.

8.45 Post-Stack Scalar

There were mild amplitude variations between the different stacks. Although shot and receiver amplitudes had been successfully balanced within lines and the overall amplitude maintained, there were variable levels of noise and signal amplitudes, which meant that there were bulk variations in amplitude between lines in the full SCAN project.

A scalar was calculated from RMS analysis of the stack in a window of 200-3200 ms and the value compared to the other lines in the full SCAN project. The following scalar was applied to the final true amplitude stacks:

Line	Scalar
017-018	0.60

8.46 Final Datum Shift

Stacks were shifted from the processing datum to the final datum of 0 m MSL (=NAP).

8.47 Post-Stack Mute

Primarily as a result of obstacles and access restrictions, there were numerous omitted and offset shots, plus deviated receiver station positioning during acquisition. This results in a loss of near offset traces in these areas, plus irregular offset distribution and lower fold. These areas, which appear on the stack as notches, become partially infilled with migration noise.

To limit the introduction of migration artefacts a post-stack mute was applied to constrain the start time of the live samples to match that of a pre-migration stack. A pre-migration stack with a harsh mute results in deeper notches in the stack.

A range of pre-migration stacking mutes were applied to generate stacks as a template for a cosmetic post-stack mute for the final PreSTM stack products. After discussion with the interpreters, a 65° mute was selected as the pre-migration stacking mute, and used as a template for the post-stack cosmetic mute applied to the post migration data.

8.48 Output to SEGY

The required products were transformed into SEGY revision 1 format for delivery to the client.

9. CONCLUSIONS AND RECOMMENDATIONS

These conclusions are based on the work from the full SCAN processing, and are not line specific.

This project benefited considerably from the work performed in project GTO-19-C031-01/sCAnPr_005. This meant that the processing sequence had been established and only needed to be refined where necessary. This project followed on immediately from the previous work with the same experienced team that had developed a good working relationship despite the COVID-19 restrictions. Face to face meetings at key stages of the project would have been a more efficient way to conduct and conclude processing stages such as velocity picking and post-stack testing, but this was not a significant issue due to the web conferencing facilities available.

The deep shot holes and dynamite source gave a good broad frequency signal across the area whilst also reducing the impact of the shot generated noise. The 5 m geophone spacing resulted in a high-resolution CDP interval. Some areas had shallow glacial till/moraine deposits which reduced signal penetration and increased shot generated noise, but fortunately these areas were limited to just a few locations.

A comprehensive suite of noise attenuation processes were applied at all stages of processing to target the usual noise components seen on seismic data acquired onshore, including dip filters, Cadzow rank-reduction, wavelet transform filters, Radon domain demultiple and structurally oriented filters. Data integrity was monitored closely at every stage to minimise leakage of signal energy and to maintain true amplitudes.

In hindsight some of the parameters selected in the previous project were developed focusing on optimising the limited amount of data available at the time. The processing sequence was updated with improved Radon parameters, spectral broadening and a time-variant filter where required. Line UOBR017-SCAN018 required additional noise attenuation as had been observed in the previous project.

A major part of the of the project was picking the stacking velocities to honour the interpreted horizons whilst generating flat gathers and improving stack continuity but also maintaining a smooth and geologically consistent interval velocity. The processing used 2nd order velocities and Eta fields to correct for anisotropic variations across the area. There was limited evidence of anisotropy and the resulting Eta fields are low in magnitude. A fourth order curved ray migration may have been satisfactory.

Despite the use of deep shot holes and nominal 5 m receiver station increments, there were a couple of areas compromised by the acquisition, which could be addressed for future acquisition:

- CDP fold was only nominally 116 due to the 60 m source increment.
- In some lines land access issues resulted in skipped shot and receiver locations, resulting in compromised data in the very shallow.
- Offset sampling in the CDP domain was irregular, again often due to land access issues.

The data in this project were all collected as 2D lines. In the future DUG recommends using 3D acquisition which will enable data to be fully migrated (no ‘out of plane’ energy) and allow more advanced processing to be performed (e.g. cross-spread gathers, COV migrations), although this will be considerably more expensive to acquire.

A special thanks must go to Johannes Rehling for his considerable input into the processing of these data, for being available at short notice for video conference meetings and for making prompt decisions when required.

10. APPENDICES

10.1 Final Line List

Line	First SP	Last SP	Length (km)	Full fold length (km)
L2EBN2020CUOBR017-L2EBN2020ASCAN018	1001	15353	71.68	64.68
L2EBN2020CUOBR017 only	6641	15353	46.73	36.23

Line	First CDP	Last CDP	First CDP X	First CDP Y	Last CDP X	Last CDP Y
L2EBN2020CUOBR017-L2EBN2020ASCAN018	100	28769	122182.2	191275.2	386327.7	402095.0

10.2 Fast-Track Processing Sequence

- Data reformat from SEGY to internal format
- Applied crooked line geometry
- Edits: Kill invalid shots
- Edits: Only keep traces with offset < 500 m for weak shots
- Spherical divergence correction
- Geophone response correction
- Refraction static computation and application using delay-time solution
  - V0=1000 m/s
  - VR=1700 m/s
  - SRD=NAP
- Noise attenuation: +/-1250 m/s Weiner dip filter
- Noise attenuation: Despike
- Noise attenuation: Wavelet (D20) transform filter
- Surface consistent amplitude compensation: Source and receiver components
- Noise attenuation: TFDN
- Inverse Q: Q=100 phase and amplitude using 40 Hz reference frequency and 12 dB gain stabilisation
- Surface consistent deconvolution: Source and receiver
  - 160 ms operator length
  - 16 ms predictive gap
  - 0.1% white noise stabilisation
  - Design window: 200-3000 ms
- Velocity analysis: 1 km interval manual picks
- Noise attenuation: 1.75 ms/tr (2857 m/s) dip filter and wavelet transform filter on shots
- Residual statics pass 1: Surface consistent MASTT algorithm applying source and receiver terms
- Spherical divergence removed: T
- Migration (PreSTM 1): Isotropic 4th order curved-ray Kirchhoff using smoothed stacking velocities
  - 3 km aperture
  - 65° dips
  - Anti-alias constant = 2
- Conversion to zero phase: statistical. Statistically derived filter operator (an increase in acoustic impedance is a negative number)
- Mute: 55°
- Drop far offsets not input to migration
- Gain: (500 ms AGC)

- Stack: 1/N for true amplitude stacks (1/√N for AGC stacks)
- Noise attenuation: Weiner dip filter +/- 3333 m/s
- Noise attenuation: Cadzow rank-reduction rank 4, 250 ms and 101 trace half window size
- Frequency domain filter:
    - Frequency (Hz): 2-3-160-180 2-3-90-108 2-3-40-48
    - Time (ms): 0-1400 1800-2800 3200-6000
- Gain: $T^{0.75}$ (1000 ms AGC)
- Final datum shift
- Output to SEGY (0 - 6000 ms only)

10.3 Example EBCDIC

C01 CLIENT: EBN AREA: SCAN AREAS, NETHERLANDS
C02 PROCESSED BY: DOWNUNDER GEOSOLUTIONS LONDON UK
C03 DATA FORMAT: 32-BIT IBM FLOATING POINT SEG-Y REV1
C04 DATASET: 2D PRESTM FINAL STACK AT FINAL DATUM
C05 SAMPLE INTERVAL: 2 MS MIN/MAXTIME: 0/10000 MS SAMPLES PER TRACE : 5001
C06 LINE NAME: L2EBN2020CUOBR017-L2EBN2020ASCAN018 CMP:100-28769(1)
C07 -------------------------RECORDING PARAMETERS-------------------------------
C08 ACQUIRED BY: ROSSINGH DRILLING AND GEOPHYSICS; YEAR OF RECORDING: 2020;
C09 RECORDING SYSTEM: GEOSPACE; SOURCE & RECEIVER SPACING: 60x5 M;
C10 DYNAMITE SOURCE: VARIABLE CHARGE SIZE AND DEPTH; GEOPHONE: GS-One LF;
C11 RECORDING POLARITY: SEG NORMAL; TIME OF 1ST SAMPLE: 0 MS;
C12 --------------------------GEODETIC PARAMETERS-------------------------------
C13 PROJ ZONE: AMERSFOORT/RD NEW; PROJ TYPE: OBLIQUE STEREOGRAPHIC;
C14 CM_LONG:5.387638888888889E;ORIGIN Grid:155000E,463000N;SF:0.9999079; METERS;
C15 ------------------------PROCESSING INFORMATION------------------------------
C16 SEGY TRANSCRIPTION TO INTERNAL FORMAT; GEOMETRY (2.5 M CDP INTERVAL);
C17 GAIN RECOVERY: T**1; REFRACTION STATICS: DELAY-TIME V0=1000M/S VR=1700M/S
C18 SRD=MSL; SHIFT TO FLOATING DATUM; NOISE ATTENUATION: DIP FILTER; EDITS;
C19 NOISE ATTENUATION: DESPIKE, WAVELET TRANSFORM FILTER; SCAC1;
C20 NOISE ATTENUATION: TFDN; INVERSE Q; SC DECONVOLUTION; VELOCITIES: 1 KM;
C21 NOISE ATTENUATION: DIP FILTER, WAVELET TRANSFORM FILTER; RESIDUAL STATICS 1;
C22 SCAC2; VELOCITIES: 1 KM; RESIDUAL STATICS 2; NOISE ATTENUATION: TFDN ON CDP;
C23 REMOVE GAIN; 2.5 Hz LOW CUT FILTER; ANISOTROPIC VTI KIRCHHOFF PRESTM USING
C24 TOMOVEL & ETA AFTER 3 ITERATIONS OF MIGRATION VELOCITY PICKING; RADON DEMUL;
C25 DIP FILTER ON CDPS; TRIM STATICS; CDP-OFFSET CADZOW RNA; DIP FILTER ON
C26 OFFSET PLANES; CONVERSION TO ZERO PHASE; TRACE DROP TO MIG INPUT; OFFSET
C27 MUTE; STACK: 1/N; SPECTRAL BROADENING; NOISE ATTENUATION: DIP FILTER,
C28 CADZOW FILTER, STRUCTURALLY ORIENTED FILTER; TV BANDPASS FILTER;
C29 LINE SCALAR; SHIFT TO FINAL DATUM; REAPPLY POST-STACK MUTE; OUTPUT TO SEG-Y
C30
C31 FIRST SEISMIC SAMPLE IS AT FINAL DATUM (MSL = NAP);
C32 ZERO PHASE POLARITY: AN INCREASE IN ACOUSTIC IMPEDANCE IS A NEGATIVE NUMBER;
C33 SEISMIC REFERENCE DATUM: MSL = NAP; REPLACEMENT VELOCITY:1700M/S;
C34 -------------------------TRACE HEADER INFORMATION---------------------------
C35 CDP: 21-24 4 BYTE INTEGER; COORD SCALAR: 71-72 2 BYTE INTEGER;
C36 CDP ELEVATION: 53-56 4 BYTE INTEGER; CDP-X: 181-184 4 BYTE INTEGER;
C37 CDP-Y: 185-188 4 BYTE INTEGER; SHOTPOINT AT CDP: 197-200 4 BYTE INTEGER;
C38 FLOATING TO FINAL DATUM SHIFT SCALED BY 100: 237-240 4 BYTE INTEGER;
C39
C40 WRITTEN BY DUG INSIGHT; http://www.dug.com MARCH 2021;

10.4 Example Statics File Headers

10.4.1 Shots

#PROJECT: sCAnPr_007 GTO-19-C031-02 SCAN AREAS, NETHERLANDS
#LINE: L2EBN2020CUOBR017-L2EBN2020ASCAN018
#PROCESSED IN MARCH 2021 BY DUG, LONDON
#SHOT STATICS: SDEP = SHOT DEPTH (m), R_STAT = REFRACTION STATIC (ms)
#RES_STAT (ms) = RESIDUAL STATIC PASS 1 + RESIDUAL STATIC PASS 2
#MODEL VELS: REPLACEMENT VEL = 1700 m/s, WEATHERING VEL = 1000 m/s
#CO-ORDINATE PROJECTION: AMERSFOORT (EPSG: 28992)
#
#LINE FFID STN SHOT-X SHOT-Y ELEV SDEP R_STAT RES_STAT
L2EBN2020CUOBR017-L2EBN2020ASCAN018 1001 15329.5 191146.25 401981.31 17.73 14.0 -2.90 -2.73
L2EBN2020CUOBR017-L2EBN2020ASCAN018 1002 15341.5 191202.20 402035.22 17.77 11.0 -8.44 1.40

10.4.2 Receivers

#PROJECT: sCAnPr_007 GTO-19-C031-02 SCAN AREAS, NETHERLANDS
#LINE: L2EBN2020CUOBR017-L2EBN2020ASCAN018
#PROCESSED IN MARCH 2021 BY DUG, LONDON
#REC STATICS: R_STAT = REFRACTION STATIC (ms)
#RES_STAT (ms) = RESIDUAL STATIC PASS 1 + RESIDUAL STATIC PASS 2
#MODEL VELS: REPLACEMENT VEL = 1700 m/s, WEATHERING VEL = 1000 m/s
#CO-ORDINATE PROJECTION: AMERSFOORT (EPSG: 28992)
#STN PREFIXED BY INDEX FOR LINE PARTS
#
#LINE STN REC-X REC-Y ELEV R_STAT RES_STAT
L2EBN2020CUOBR017-L2EBN2020ASCAN018 105348.0 142809.09 393094.03 10.12 -14.44 0.00
L2EBN2020CUOBR017-L2EBN2020ASCAN018 105349.0 142814.76 393094.00 10.03 -14.41 0.00

10.4.3 CDPs

#PROJECT: sCAnPr_007 GTO-19-C031-02 SCAN AREAS, NETHERLANDS
#LINE: L2EBN2020CUOBR017-L2EBN2020ASCAN018
#PROCESSED IN MARCH 2021 BY DUG, LONDON
#MODEL VELS: REPLACEMENT VEL = 1700 m/s, WEATHERING VEL = 1000 m/s
#CO-ORDINATE PROJECTION: AMERSFOORT (EPSG: 28992)
#
#LINE CDP SP CDP-X CDP-Y ELEV FLOAT_DATUM
L2EBN2020CUOBR017-L2EBN2020ASCAN018 100 1001 122182.20 386327.70 19.54 -31.82
L2EBN2020CUOBR017-L2EBN2020ASCAN018 101 1002 122184.60 386328.30 19.54 -31.82

10.5 Deliverables

Post migration stacks are at zero phase polarity with an increase in acoustic impedance as a negative number.

Datasets	Type of media	Type of data	Contents	Date delivered
Raw stack before migration (on floating datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_pre_migration_stack.sgy	April 2021
Raw PreSTM stack (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_raw_nopostproc_full.sgy	April 2021
Raw PreSTM offset stacks (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file for each range with filenames: L2EBN2020CUOBR017_PreSTM_raw_nopostproc_near.sgy L2EBN2020CUOBR017_PreSTM_raw_nopostproc_mid.sgy L2EBN2020CUOBR017_PreSTM_raw_nopostproc_far.sgy	April 2021
Processed PreSTM stack (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_raw_postproc_full.sgy	April 2021
Processed PreSTM offset stacks (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file for each range with filenames: L2EBN2020CUOBR017_PreSTM_raw_postproc_near.sgy L2EBN2020CUOBR017_PreSTM_raw_postproc_mid.sgy L2EBN2020CUOBR017_PreSTM_raw_postproc_far.sgy	April 2021
Final PreSTM stack (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_final_full.sgy	April 2021
Final PreSTM offset stacks (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file for each range with filenames: L2EBN2020CUOBR017_PreSTM_final_near.sgy L2EBN2020CUOBR017_PreSTM_final_mid.sgy L2EBN2020CUOBR017_PreSTM_final_far.sgy	April 2021
Final AGC PreSTM stack (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_final_full_AGC.sgy	April 2021
Final AGC PreSTM offset stacks (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file for each range with filenames: L2EBN2020CUOBR017_PreSTM_final_near_AGC.sgy L2EBN2020CUOBR017_PreSTM_final_mid_AGC.sgy L2EBN2020CUOBR017_PreSTM_final_far_AGC.sgy	April 2021

Datasets	Type of media	Type of data	Contents	Date delivered
CDPs input to migration (on floating datum at minimum phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_CDP_gathers_pre_migration.sgy	April 2021
CDPs after final migration - no mute or further processing (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_CDP_gathers_raw.sgy	April 2021
CDPs after final imaging, with trim statics, no mute (on final datum with conversion to zero phase)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_CDP_gathers_final.sgy	April 2021
RMS stacking velocities used for first migration	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_RMS_velocities_stacking.sgy	April 2021
Final migration velocities	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_velocities_migration.sgy	April 2021
Final Eta field	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	SEGY	1 file with filename: L2EBN2020CUOBR017_PreSTM_final_eta.sgy	April 2021
RMS stacking velocities for first migration	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	ASCII	1 file with filename: L2EBN2020CUOBR017_velocities_stacking_ascii.txt	April 2021
Final migration velocities and eta	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	ASCII	1 file with filename: L2EBN2020CUOBR017_velocities_migration_ascii.txt L2EBN2020CUOBR017_final_eta_ascii.txt	April 2021
Statics corrections (elevation, refraction and residual statics with station numbering and co-ordinates)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	ASCII	1 file for each with filename: L2EBN2020CUOBR017_shot_statics_ascii.txt L2EBN2020CUOBR017_receiver_statics_ascii.txt	April 2021
CDP navigation files (XYZ and floating datum)	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	ASCII	1 file with filename: L2EBN2020CUOBR017_CDP_statics_ascii.txt	April 2021
Picked offset mutes	USB disk ID:EB0010UW 3592 tape ID:EB0009IA	ASCII	1 file with filename: inner_mute_all_lines.txt 1 file with filename: L2EBN2020CUOBR017_PreSTM_final_mute_ascii.txt	April 2021
Filter to convert from minimum to zero phase	USB disk ID:EB0010UW 3592 tape	ASCII	1 file with filename: zero_phasing_filter.txt	April 2021

Datasets	Type of media	Type of data	Contents	Date delivered
	ID:EB0009IA			
Processing report	USB disk ID:EB0010UW 3592 tape ID:EB0009IA 2x printed hard copies	PDF	sCAnPr_007_L2EBN2020DUGOU_ProcessingReport_20426.pdf	April 2021

Hard copies were delivered in April 2021 to the following address:

EBN B.V.
Attn. Johannes Rehling
Daalsesingel 1
3511 SV Utrecht
The Netherlands

10.6 Zero Phase Filter

Time (ms)	Amplitude
-500	5.887419e-04
-498	-1.457665e-03
-496	1.544978e-03
-494	-6.765102e-04
-492	-3.384895e-04
-490	4.954507e-04
-488	-2.059296e-04
-486	-3.453626e-04
-484	1.178866e-04
-482	9.534264e-05
-480	-1.442089e-04
-478	-1.091560e-04
-476	-9.357685e-05
-474	-1.018704e-04
-472	-1.776582e-04
-470	-1.333493e-04
-468	-1.788069e-05
-466	3.270549e-05
-464	-1.633163e-04
-462	-1.756421e-04
-460	-1.125467e-04
-458	-1.875137e-05
-456	-9.366847e-05
-454	-6.649666e-05
-452	-1.296838e-04
-450	-5.563721e-05
-448	-4.129519e-05
-446	-2.923020e-04
-444	7.041614e-05
-442	2.931478e-05
-440	-2.536292e-04
-438	-1.969946e-04
-436	-3.272569e-05
-434	1.382636e-05

Time (ms)	Amplitude
-432	-3.548339e-07
-430	1.017418e-05
-428	6.905460e-05
-426	1.006725e-05
-424	-1.486694e-04
-422	-7.797725e-05
-420	8.312892e-05
-418	1.687283e-05
-416	-9.565026e-05
-414	-3.114011e-05
-412	-5.968066e-05
-410	-1.775306e-04
-408	-1.821627e-04
-406	-6.181851e-05
-404	6.167893e-05
-402	2.029386e-04
-400	1.707993e-04
-398	1.026547e-04
-396	1.928193e-04
-394	3.057343e-04
-392	1.734003e-04
-390	2.588081e-04
-388	5.634187e-04
-386	5.581809e-04
-384	9.894912e-05
-382	-7.355900e-05
-380	4.389905e-05
-378	1.674677e-04
-376	-1.100631e-04
-374	-6.040352e-04
-372	-9.207884e-04
-370	-5.410588e-04
-368	-3.471985e-04
-366	-4.394144e-04
-364	-3.988255e-04

Time (ms)	Amplitude
-362	-1.448293e-04
-360	-6.421284e-04
-358	-6.797852e-04
-356	-3.743568e-05
-354	6.016367e-04
-352	2.968758e-04
-350	2.079369e-04
-348	-6.767618e-05
-346	-1.731530e-03
-344	-6.985273e-04
-342	1.024887e-03
-340	9.823437e-04
-338	-3.502455e-04
-336	-4.477506e-04
-334	5.889887e-04
-332	3.654629e-04
-330	-6.996772e-04
-328	2.691650e-04
-326	1.135730e-03
-324	-6.694943e-04
-322	-2.138165e-03
-320	-3.912367e-04
-318	1.624348e-03
-316	1.629235e-03
-314	3.452834e-04
-312	-6.813374e-04
-310	-3.693326e-04
-308	1.107298e-03
-306	1.307137e-03
-304	7.568903e-04
-302	1.340780e-03
-300	1.439505e-03
-298	-5.803937e-04
-296	-1.160974e-03
-294	6.236949e-04

Time (ms)	Amplitude
-292	1.211446e-03
-290	-5.156547e-05
-288	-3.880006e-04
-286	-2.489223e-04
-284	-6.979622e-04
-282	-1.255838e-03
-280	-8.194833e-04
-278	2.018639e-04
-276	4.367253e-04
-274	-1.010773e-03
-272	-1.358975e-03
-270	2.192373e-04
-268	9.003805e-04
-266	2.898336e-04
-264	1.492176e-03
-262	2.500011e-03
-260	8.456872e-04
-258	-1.005442e-03
-256	-2.173930e-04
-254	9.200519e-04
-252	6.294863e-04
-250	-1.159596e-03
-248	-2.906669e-03
-246	-3.523650e-03
-244	-2.441888e-03
-242	-1.282116e-03
-240	1.508847e-04
-238	2.329998e-03
-236	3.442049e-03
-234	2.970092e-04
-232	-3.071146e-03
-230	-2.098728e-03
-228	6.774277e-05
-226	-8.677738e-04
-224	-1.158526e-04

Time (ms)	Amplitude
-222	2.593432e-03
-220	1.271363e-03
-218	-3.313510e-03
-216	-3.318180e-03
-214	-6.603748e-04
-212	-5.340674e-04
-210	-2.110118e-03
-208	-4.118602e-04
-206	3.127021e-03
-204	4.141807e-03
-202	1.497213e-03
-200	1.508602e-03
-198	3.567445e-03
-196	1.774200e-03
-194	-1.547942e-03
-192	1.053144e-03
-190	4.145224e-03
-188	2.741493e-03
-186	1.399037e-03
-184	2.066108e-03
-182	-9.979533e-04
-180	-2.353861e-03
-178	1.239372e-03
-176	1.168806e-03
-174	-4.221194e-03
-172	-2.505460e-03
-170	2.260501e-03
-168	1.096146e-03
-166	-8.175345e-04
-164	9.463402e-04
-162	-2.280902e-03
-160	-4.767491e-03
-158	-3.830693e-04
-156	1.597590e-03
-154	-3.202758e-03

Time (ms)	Amplitude
-152	-2.140665e-03
-150	3.525019e-04
-148	-4.609911e-03
-146	-8.075466e-03
-144	1.161359e-06
-142	4.326977e-03
-140	-1.979796e-03
-138	-6.164178e-03
-136	-4.144656e-04
-134	8.135792e-04
-132	-2.845139e-03
-130	-9.840913e-05
-128	7.389463e-03
-126	4.482463e-03
-124	1.262397e-03
-122	8.134902e-03
-120	1.151883e-02
-118	-2.322764e-03
-116	-9.957118e-03
-114	-6.725686e-04
-112	5.972771e-03
-110	-3.300292e-03
-108	-9.298546e-03
-106	-8.203479e-03
-104	-5.668196e-03
-102	-2.515913e-03
-100	2.806266e-03
-98	-1.173061e-03
-96	-5.262880e-03
-94	-4.100148e-04
-92	5.660988e-03
-90	-1.053818e-03
-88	-5.003061e-03
-86	-1.808275e-04
-84	5.657160e-03

Time (ms)	Amplitude
-82	4.576314e-03
-80	7.042130e-03
-78	4.888097e-03
-76	1.686970e-04
-74	2.286082e-03
-72	8.335207e-03
-70	-1.006230e-03
-68	3.093981e-03
-66	2.546464e-02
-64	2.588691e-02
-62	-1.326217e-03
-60	2.656392e-03
-58	2.218655e-02
-56	1.911522e-02
-54	4.884815e-03
-52	4.707754e-03
-50	1.695663e-03
-48	1.607868e-02
-46	3.266081e-02
-44	2.019554e-02
-42	-1.399800e-03
-40	1.147196e-02
-38	3.092289e-03
-36	-2.773736e-02
-34	-3.829531e-02
-32	-4.511161e-02
-30	-9.491013e-02
-28	-1.130140e-01
-26	-1.001839e-01
-24	-1.098247e-01
-22	-1.323789e-01
-20	-1.039777e-01
-18	-7.613927e-02
-16	-4.977044e-02
-14	-3.158325e-02

Time (ms)	Amplitude
-12	4.257259e-02
-10	2.442577e-01
-8	4.317057e-01
-6	1.906653e-01
-4	-2.448477e-01
-2	-2.512783e-01
0	1.008446e-01
2	1.458279e-01
4	-5.705574e-02
6	4.499060e-02
8	1.316951e-01
10	3.143096e-02
12	5.558610e-03
14	6.958828e-02
16	4.403857e-02
18	-1.620998e-03
20	2.510449e-02
22	4.883512e-02
24	2.920557e-02
26	2.773965e-02
28	4.045475e-02
30	3.770005e-02
32	3.335555e-02
34	4.253680e-02
36	4.245856e-02
38	2.573693e-02
40	1.188410e-02
42	2.215745e-02
44	3.816297e-02
46	3.235690e-02
48	1.441494e-02
50	1.725006e-02
52	3.377392e-02
54	3.690786e-02
56	2.361575e-02

Time (ms)	Amplitude
58	1.348585e-02
60	1.323374e-02
62	1.638616e-02
64	1.359995e-02
66	9.203292e-03
68	1.129512e-02
70	1.613731e-02
72	1.186454e-02
74	4.264390e-03
76	3.516457e-03
78	7.305406e-03
80	8.655198e-03
82	8.946401e-03
84	8.363003e-03
86	9.385522e-03
88	1.376019e-02
90	1.576982e-02
92	9.280623e-03
94	2.576335e-03
96	3.572713e-03
98	9.143956e-03
100	1.006191e-02
102	3.615401e-03
104	-3.496241e-03
106	-1.435980e-03
108	6.076396e-03
110	7.106528e-03
112	1.966463e-03
114	9.810054e-04
116	3.711696e-03
118	2.940670e-03
120	-7.751472e-04
122	-1.065358e-03
124	3.327481e-04
126	-9.379564e-04

Time (ms)	Amplitude
128	-1.091169e-03
130	3.584957e-03
132	4.913240e-03
134	-1.527642e-03
136	-5.914881e-03
138	-2.060743e-03
140	1.377446e-03
142	-3.879576e-04
144	-1.649340e-03
146	-8.014934e-04
148	-2.076759e-03
150	-3.318449e-03
152	-5.115261e-04
154	2.768403e-03
156	2.176259e-03
158	3.209608e-04
160	1.703156e-04
162	5.915312e-04
164	4.821413e-04
166	5.904480e-04
168	5.819807e-04
170	-3.728932e-04
172	-7.909581e-04
174	1.156205e-03
176	3.001756e-03
178	1.414369e-03
180	-1.551273e-03
182	-2.132291e-03
184	-9.175788e-04
186	-1.276270e-04
188	1.666725e-04
190	9.237386e-04
192	2.328579e-03
194	3.133693e-03
196	1.955510e-03

Time (ms)	Amplitude
198	3.395700e-04
200	3.572928e-04
202	2.982162e-04
204	-1.466350e-03
206	-2.154540e-03
208	7.308410e-04
210	2.711729e-03
212	8.647149e-04
214	-1.214817e-03
216	-8.793124e-04
218	-1.062412e-03
220	-2.388119e-03
222	-1.346568e-03
224	2.308081e-03
226	3.936863e-03
228	2.242737e-03
230	3.931161e-04
232	-4.489347e-05
234	-9.490001e-04
236	-1.886889e-03
238	-7.575037e-04
240	1.156206e-03
242	5.274725e-04
244	-1.469631e-03
246	-1.767493e-03
248	-4.555879e-04
250	3.421532e-04
252	4.051812e-04
254	2.923489e-04
256	2.201516e-04
258	-3.171775e-04
260	-8.705291e-04
262	-5.094463e-04
264	6.531421e-04
266	9.848827e-04

Time (ms)	Amplitude
268	4.257448e-04
270	2.093334e-05
272	1.952078e-04
274	2.678004e-04
276	1.455644e-04
278	1.785730e-04
280	5.856052e-04
282	2.640553e-04
284	-7.976166e-04
286	-9.558222e-04
288	1.723021e-04
290	7.243019e-04
292	6.129525e-04
294	7.177263e-04
296	5.127513e-04
298	-5.534494e-04
300	-1.086158e-03
302	-1.859141e-04
304	1.323071e-03
306	1.423925e-03
308	-1.827353e-04
310	-1.429699e-03
312	-5.954721e-04
314	5.788119e-04
316	4.057568e-04
318	-8.161948e-05
320	1.940755e-04
322	3.471862e-04
324	3.360549e-05
326	2.402521e-05
328	5.712784e-04
330	8.219338e-04
332	1.137046e-04
334	-7.797919e-04
336	-6.857110e-04

Time (ms)	Amplitude
338	1.679410e-04
340	4.466089e-04
342	6.543839e-05
344	-3.219456e-04
346	-1.771468e-04
348	6.394117e-05
350	1.603427e-04
352	-1.244451e-04
354	-4.930203e-04
356	2.146726e-04
358	-1.516758e-05
360	-3.199430e-04
362	-3.244908e-04
364	-4.533632e-05
366	2.240115e-04
368	1.391946e-04
370	-4.175797e-04
372	-3.598998e-04
374	8.151465e-05
376	8.024205e-05
378	-3.704925e-04
380	-3.041288e-04
382	-6.435084e-05
384	-1.546138e-04
386	-4.425644e-04
388	-2.672600e-04
390	5.832664e-05
392	2.066626e-04
394	4.376628e-05
396	-8.128823e-05
398	-1.353306e-04
400	-3.088254e-05
402	3.860776e-05
404	4.591284e-05
406	-1.292377e-04

Time (ms)	Amplitude
408	-1.909152e-04
410	-5.159189e-05
412	1.162663e-04
414	-1.700289e-06
416	-9.200785e-05
418	-2.798208e-05
420	-4.232643e-06
422	-1.693808e-04
424	-1.877863e-04
426	-2.744261e-05
428	1.143750e-04
430	1.027478e-04
432	2.847837e-05
434	-1.682455e-05
436	4.639442e-07
438	-4.594967e-05
440	-1.955102e-04
442	-1.307292e-04
444	1.274111e-04
446	2.203907e-04
448	-2.808362e-05
450	-1.193940e-04
452	2.048152e-05
454	-8.965956e-05
456	1.095451e-04
458	1.098047e-05
460	1.958606e-05
462	5.245919e-05
464	4.856766e-05
466	5.993492e-05
468	1.226430e-04
470	3.228476e-05
472	1.429499e-05
474	2.460415e-05
476	7.365772e-05

Time (ms)	Amplitude
478	-1.110218e-05
480	-5.032460e-05
482	6.751320e-05
484	5.727238e-05
486	-3.204093e-04
488	1.006213e-05
490	6.073071e-04
492	-2.062924e-04
494	-6.182125e-04
496	1.162121e-03
498	-1.074817e-03
500	4.857826e-04

10.7 Confirmation of Decisions

Date	Client Decision	Reference Presentation	By Whom
16/09/2020	Approved refraction statics for UOBR017	sCAnPr_007_SCAN017_RefractionStatics_200915.pdf	Johannes Rehling
02/10/2020	Confirmation that an AGC scaled PreSTM deliverable will required for all lines	-	Johannes Rehling
24/12/2020	Approval of the refraction statics for UOBR017-SCAN018	sCAnPr_007_UOBR017-SCAN018_RefractionStaticsUpdate_201224.pdf	Johannes Rehling
12/01/2021	Approval of additional pre-migration noise attenuation and pre-migration velocities for UOBR017-SCAN018	sCAnPr_007_UOBR017-SCAN018_VelsAmplitudesResidualStatics_210112.pdf	Johannes Rehling
22/01/2021	Approval of PreSTM 2 velocities for UOBR017-SCAN018	sCAnPr_007_UOBR017-SCAN018_PreSTM2Update_210121.pdf	Johannes Rehling
27/01/2021	Approval of the PreSTM 2 to be used as the final migration for UOBR017-SCAN018	sCAnPr_007_UOBR017-SCAN018_PreSTM3_210125.pdf	Johannes Rehling
04/03/2021	Approval of post-stack processing for line UOBR017-SCAN018	sCAnPr_007_UOBR017-SCAN018_PostStackProcessing_210303.pdf	Johannes Rehling

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