Seismic Data Processing Report

By ***Velseis Processing***

For: ***ORIGIN ENERGY Resources Ltd***

Project: ***Spring Gully***
2D Land Processing and Reprocessing

Area: ***Surat Basin AUSTRALIA***

Date Processed: ***February–July 2006***
Date Compiled: ***August 2006***
Report Number: ***VP06-178***
Compiled By: ***Tatiana Gerus***

Velseis Processing Pty Ltd
ABN 30 058 427 204

Integrated Seismic Technologies

CONTENTS

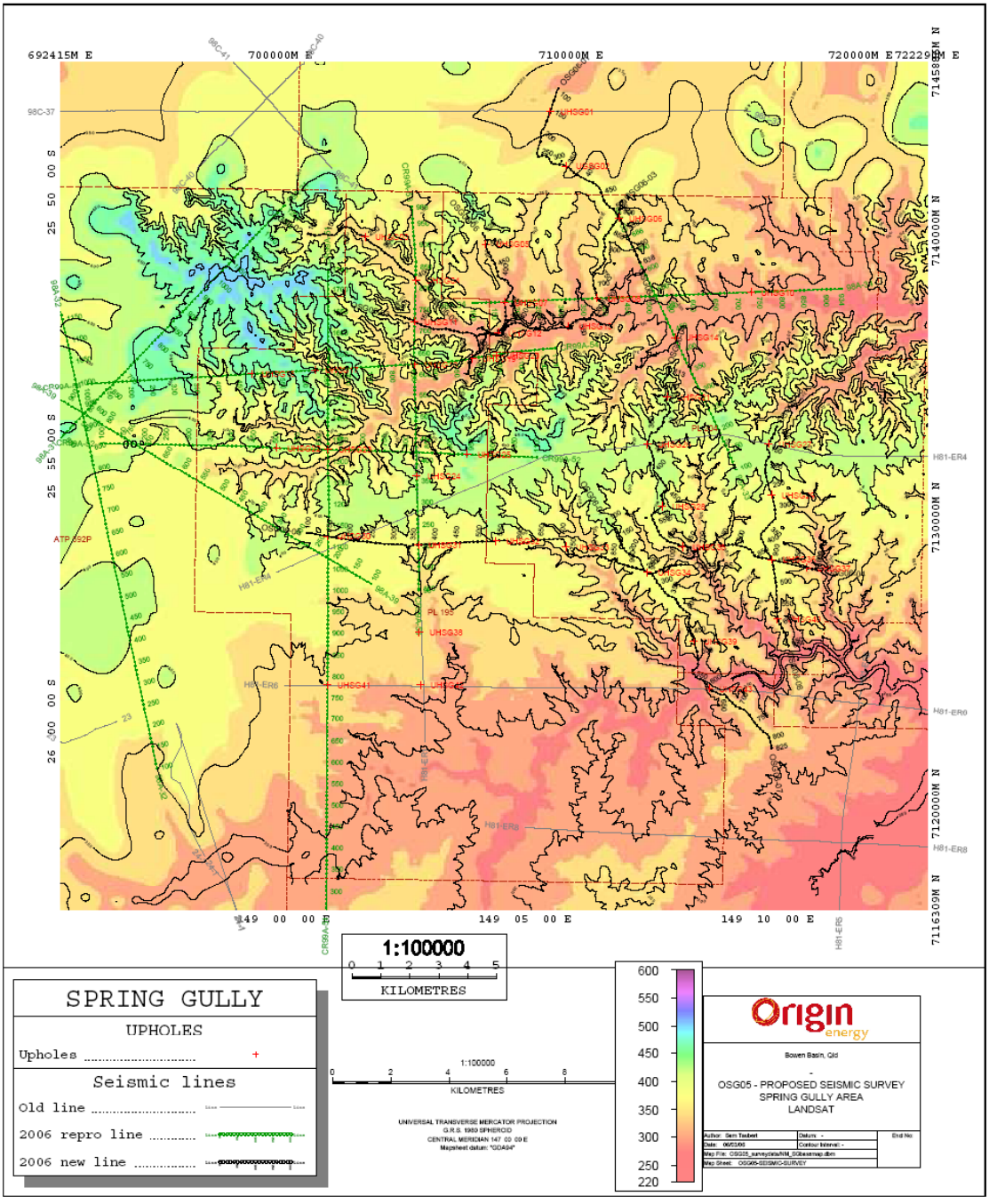
1. Introduction

This report describes the processing and reprocessing of seismic data for Origin Energy Resources Ltd. The project is situated in Surat basin, Queensland, Australia.

The project consists of processing 2D Land seismic lines which comprises the newly acquired "Spring Gully" survey and associated reprocessing of two "Comet Ridge" surveys. A total of 221 km over 17 onshore lines have been processed in the period from February till July 2006.

The objectives of the processing and reprocessing were to delineate the Bandanna coal horizon for coal bed methane drilling.

Below is Spring Gully area map showing topography and seismic lines.



2. Data Acquisition

2.1. Data Acquisition Parameters

The following table is the summary of acquisition parameters of the three seismic surveys:

Survey -->	**Spring Gully**	**Comet Ridge 99A**	**Comet Ridge 98A**
Line Prefix	**OSG06**	**CR99A**	**98A**
Energy Source	Vibroseis	Vibroseis	Vibroseis
No. channels	160	160	240
Group interval	15m	15m	15.24m
SP interval nominal	15m	15m	30.48m
Spread	Split-spread	Split-spread	Split-spread
Acquisition fold	80	80	60
Record length	2s	3s	3s
Sample rate	1 msec	1 msec	2 msec
No. of lines	8	4	5
2D Km total	79 km	69 km	73 km

The following details the acquisition parameters for each of the surveys:

2.1.1. Spring Gully OSG06 survey

The newly acquired OSG06 data was recorded by Terrex Seismic at 19th to 30th January 2006.

INSTRUMENTS:

Type:	SERCEL-Société d'Etudes
Record Length:	2 seconds correlated
Sample Rate:	1 msec
Tape Format:	SEGD 8058, 3490 cartridge
Recording Filter:	Low cut out 0.5 Nyquist Min Phase: 250Hz 120dB/oct

SOURCE:

Energy Source:	Vibroseis, 3 x Mertz M26 in line
Source Array:	30.48 m pad-to-pad
Sweep Length:	5000 msec
Sweep Frequencies:	8-90, 50-120, 30-100 Hz linear, 3 sweeps
Source Location:	Centred between stations
Source Interval:	15 m

RECEIVERS:

Type:	N/A					
No. of Channels:	160					
Array:	12 phones over 15 m.					
Array location:	Centred on stations					
Group Interval:	15 m					
Spread Diagram:	Chan	1	80	SP	81	160
	Offset,m	-1192.5	-7.5	0	7.5	1192.5

2.1.2. CR99A Comet Ridge survey

The data were acquired by GECO during March 1999

INSTRUMENTS:

Type:	I/O System II
Record Length:	3 seconds correlated
Sample Rate:	1 msec
Tape Format:	SEGD 8058, 3490 cartridge
Recording Filter:	Low Cut Out
	Antialias: 270Hz 188dB/Oct

SOURCE:

Energy Source:	Vibroseis, 3 x Mertz M26 in line
Source Array:	30.48 m pad-to-pad
Sweep Length:	7000 msec, 300 msec taper
Sweep Frequencies:	10 – 90 Hz linear, 4 sweeps
Source Location:	Centred between stations
Source Interval:	15 m

RECEIVERS:

Type:	Sensor SM4U 10 Hz					
No. of Channels:	160					
Array:	6 phones over 12.5 m.					
Array location:	Centred on stations					
Group Interval:	15 m					
Spread Diagram:	Chan	1	80	SP	81	160
	Offset,m	-1192.5	-7.5	0	7.5	1192.5

2.1.3. 98A Comet Ridge survey

The data were acquired by GECO during March and April 1998

INSTRUMENTS:

Type:	I/O System II
Record Length:	3 seconds correlated
Sample Rate:	2 msec
Tape Format:	SEGD 8058, 3490 cartridge
Recording Filter:	Low Cut Out
	Antialias: 135Hz 190dB/Oct

SOURCE:

Energy Source:	Vibroseis, 3 x Mertz M26 in line
Source Array:	30.48 m pad-to-pad, 7.62 move-up
Sweep Length:	8000 msec, 300 msec taper
Sweep Frequencies:	10 – 90 Hz linear, 4 sweeps
Source Location:	Centred between stations
Source Interval:	30.48 m (nominal)

RECEIVERS:

Type:	Sensor SM4U 10 Hz					
No. of Channels:	240					
Array:	12 phones over 15.24 m.					
Array location:	Centred on stations					
Group Interval:	15.24 m					
Spread Diagram:	Chan	1	120	SP	121	240
	Offset,m	-1821	-7.62	0	7.6	1821

2.2. List of Lines Processed

There are 17 lines from 3 surveys totalling of **220.7** km 2D data.

	Spring Gully 2006								
	Line NAME	First SP	Last SP	Km	FCDP	LCDP	SOURCE INTERVAL (M)	GROUP INTERVAL (M)	NO. OF CHANs
1	OSG06-01	100.5	638.5	8.09	200	1276	15	15	160
2	OSG06-02	103.5	441.5	5.09	206	882	15	15	160
3	OSG06-03	87.5	922.5	12.54	174	1844	15	15	160
4	OSG06-04	113.5	1008.5	13.44	228	2017	15	15	160
5	OSG06-05	100.5	1037.5	14.07	200	2074	15	15	160
6	OSG06-06	104.5	528.5	6.38	208	1056	15	15	160
7	OSG06-07	100.5	825.5	10.89	200	1650	15	15	160
8	OSG06-08	654.5	102.5	8.30	204	1308	15	15	160
			Total km:	78.78					
	Spring Gully (Comet Ridge)				REPROCESSING				
	Line NAME	First SP	Last SP	Km	FCDP	LCDP	SOURCE INTERVAL (M)	GROUP INTERVAL (M)	NO. OF CHANs
1	98A-31	100	1224	17.13	200	2426	15.24-30.48	15.24	240
2	98A-32	100	1443	20.47	200	2885	15.24-30.48	15.24	240
3	98A-33	100	686	8.93	200	1372	15.24-30.48	15.24	240
4	98A-34	100	934	12.71	200	1868	15.24-30.48	15.24	240
5	98A-39	100	1019	14.01	200	2037	30.48	15.24	240
6	CR99A-51	88	1745	24.86	176	3482	15	15	160
7	CR99A-52	118	1075	14.36	236	2150	15	15	160
8	CR99A-53	100	984	13.26	200	1968	15	15	160
9	CR99A-54	100	1178	16.17	200	2355	15	15	160
			Total km:	141.88					
		TOTAL KM		**220.66**					

3. Processing Sequence

3.1. Parameters

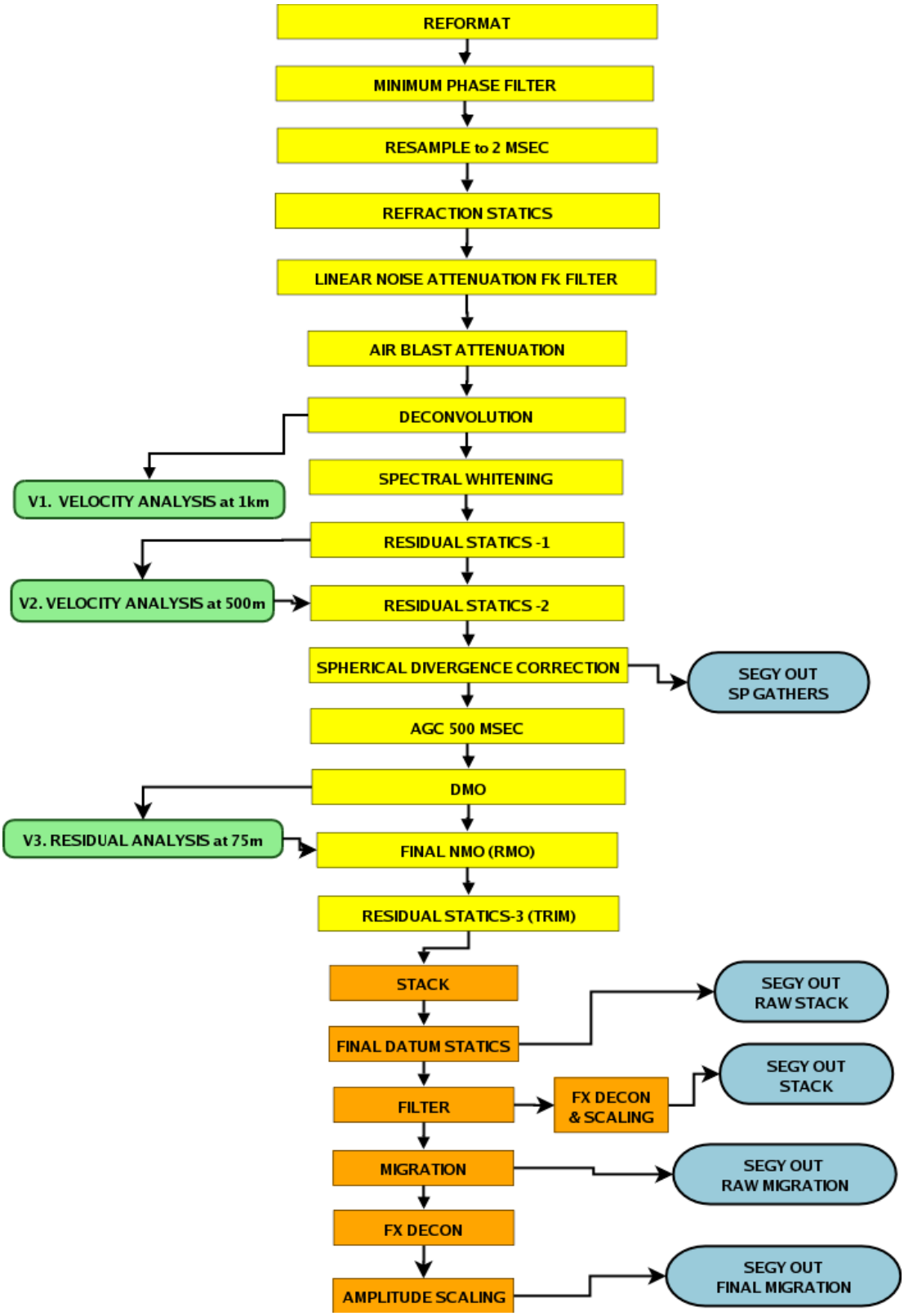
The 17 lines of 2D land seismic data of 3 surveys totalling 221 kms have been processed with the following parameters:

Processing length	:	2 seconds for OSG06 3 seconds for reprocessing CR99A & 98A
Processing sample rate	:	2 milliseconds
Resampling	:	To 2msec for OSG06 and CR99A
Maximum stacking fold	:	80 (OSG06 & CR99A series lines) 60 (98A serie lines)
Final Datum plane	:	244m

3.2. Final Processing Sequence

3.2.1. Flow chart

The newly acquired data and two reprocessing surveys have been processed with similar processing sequences: The processing parameters were tested basically using test line OSG06-05 and have been verified and adjusted for each survey.



3.2.2. Details

3.2.2.1. Pre Stack Data Processing

- **Transcription** to ProMAX internal data format
  - Record length /OSG06 lines/: 2000 ms
  - Record length /CR99A & 98A lines/ : 3000 ms
- **Geometry**.

  Information assigned to each trace includes source, receiver and CDP locations, along with offsets, elevations, and CDP fold. The observer's logs were used to assign geometry
- **Bad Trace and Shots Edit**.

  Bad trace edits was performed statistically using average trace energy for offsets greater that 200m.
- **Minimum phase filter**

  Using a zero phase correlated sweep signal, a filter was designed to shift the seismic data from zero to minimum phase.
- **Resample**

  Resample from 1 msec to 2 msec was applied for *OSG06* and *CR99A* lines.

  High- Fidelity antialias filter was applied before resampling.
- **Amplitude recovery**

  Initial (reversible) Time/Power constant of 2 was applied for gain recovery.
- **Air Blast Attenuation**.

  Anomalous energy, such as shot -generated air blast, was removed from the data using the following parameters:
  - Approximate velocity of energy to be attenuated: 330m/s
  - Filter to help detect air blast energy:
    - 70, 80,120,140 Hz. >>>> surveys OSG06 and CR99A
    - 50, 60,120,140 Hz. >>>> survey 98A
- **FK filter**.

  The velocity FK filter in Shot point domain was used to remove Linear Noise.
  - Filter parameters: accept +/- 3000 m/s velocity at frequency of 4-250Hz.
  - AGC 300ms wrap was applied

❖ **Refraction Statics**

Statics were calculated using a refraction static delay time algorithm. First breaks for a single refraction layer were picked. The following was used and calculated:

- Weathering velocity: 800m/s
- Compute Refractor velocities and refractor depth model using a least squares algorithm.
- Scale the Refractor velocities by 90%
- Compute Source and Receiver Statics:
  - Replacement method: 90% of refractor velocities
  - Final Datum Elevation: 320m

This method was used for most OSG06 lines and for 98A lines.

For CR99A survey, however, refraction statics were calculated using a constant 3000m/s replacement velocity with limiting the absolute offsets of first breaks to 750m. Weathering velocity was set at 1000 m/s for this survey.

The refraction statics were then tied to uphole data where available. This data was provided by Origin Energy. Holes ID: UHSG01 to UHSG43. Total 41 upholes were used in the area.

Lines 31, 32 and 39 of 98A Comet Ridge survey do not have upholes and refraction statics for these lines have been tied to intersected lines.

Refer also to Specific Problem

❖ **Deconvolution**

Multiple Surface Consistent Spiking Deconvolution with a 160 ms operator was chosen from the testing and applied. The power spectrum was decomposed into shot, receiver, and offset components, however only the shot and receiver portions were applied within the deconvolution with 0.1% white noise added. The gate design was as follows:

Offset (m)	Window start (ms)	Window end (ms)
7.5	120	1300
1150	500	1465
1850	700	1580

❖ **Spectral Whitening**

Data was transferred to frequency domain. 8 gates were designed to cover 8-140 Hz in amplitude spectral with an edge overlap. The amplitude in a gate was scaled by a scalar calculated from the gate. After spectral whitening, the spectrum was more balanced or "flatter".

❖ **Velocity Analysis 1st pass**

Velocities were picked using the ProMAX interactive velocity picking package (IVA). IVA uses velocity spectra, moved out gathers and stacked panels to assist in a careful interpretation of stacking velocities. As the velocity function is altered, revised gathers and stacks are produced until optimised stacking velocities are achieved.

Velocities were picked at locations of 1.0 km (for OSG06) or 500m (for 98A and CR99A lines) apart. Each panel consisted of 15 CDPs stacked using 15 velocity functions centred around the regional velocity function. 11 CDPs of 15 were used to sum into common offset stacked supergather at each location.

❖ **Normal Moveout Correction** using 1st pass velocities (V1).

❖ **Residual Static Calculation and Application**

Surface consistent residual statics were calculated and applied using Maximum Power Autostatics.

Pilot or reference traces were formed for a 800ms time gate following structure by flattening all traces along the picked autostatics horizon over 11 CDP's.

These traces are summed to form a single pilot trace. Each trace from the active CDP is time shifted relative to the pilot trace and summed with it. The power of the stack is measured for each time shift. This shift-power trace is then summed with other traces having the same shot and receiver in their respective domains.

After the shift spectra has been calculated for the entire line and summed in the Receiver/Shot domains, time shifts are picked at the maximum of the power shift spectra and stored as Static Values. The pilot stack is updated and the process repeated for a number of iterations.
In this case, calculations were conducted for at least 5 iterations.
The maximum allowable statics was up to 24msec in magnitude although the actual residuals were generally less than 5msec, maximum 10msec for some lines.

❖ **Velocity Analysis 2nd pass (V2).**

Velocities were picked at locations of about 500m apart. Velocities 1st pass were used as a guide function.

❖ **Residual Static Calculation and Application, 2nd pass**

An additional pass of surface consistent residual statics was undertaken to further optimise shot and receiver statics.

❖ Update of **Spherical Divergence Correction**:

- Remove initial gain recovery
- Apply spherical divergence correction using 2nd pass velocity analysis
- Additional 1dB/sec correction

❖ **Dip Move Out**

Common Offset FK DMO was applied to all datasets. 4000M/s RMS velocity was used for DMO. All Negative and positive offsets were used for binning:

Bin Size:

- 30 m for CR99A and OSG06 data.
- 30.48 m for 98A.

It was decided to apply 500msec AGC prior to DMO in order to balance the amplitudes.

❖ **Residual Moveout correction 75m interval**

In order to improve the final stacking velocity and final stack image, a high density Residual Moveout correction (100m interval) was applied after Residual velocity Auto picker.

Residual Moveout Correction flattens events on migrated gathers in a procedure analogous to Normal Moveout Correction. The Residual Moveout Correction assumes that the residual moveout is hyperbolic function of offset, just like normal moveout.

$$t = \sqrt{t_0^2 + R_T x^2}$$

The equations for Residual Normal Moveout use the Residual Parameter **R** in place of inverse velocity squared. Residual moveouts can be positive or negative, reflected in the sign of R.

The residual velocity analysis is carried out on NMO corrected cdp gathers (with V2).

Min and Max squared reciprocal velocity (slowness) are used to define the corridor for maximum in minimum residual correction.

- R scan -50 to +20 and time smoothing operator 200ms was used for Residual velocity Auto picker.

❖ **CDP Consistent Residual Statics and Application**

External Model Correlation was used to calculate CDP Trim Statics. Final RMO was applied prior to calculation.

❖ **Outer trace muting**

Hand picked mute was applied to Final NMO (RMO) corrected CDP gathers.

❖ **Stack**

Traces are summed within a common midpoint (cmp) gather. The post stack trace is scaled by the square root of the sum of fold for each sample in the trace.

3.2.2.2. Post Stack Data Processing

❖ **Statics.**

Data was shifted from floating datum to a Final Datum of 320 meters. Then bulk shift -56msec was applied to set final datum to 244 meters. Then the data was shifted down by 200 msec in order to see more of the near surface data above the final datum. Thus final datum of 244m appears on 200msec at the final stack data.

❖ **Frequency Filtering**.

- *OSG06 lines:* *Frequency (Hz)* : 20-28-120-140 *Time (ms)* 0-2000
- *CR99A lines:* *Frequency (Hz) :* 20-28-120-140 *Time (ms)* 0-3000
- *98A lines:*

Frequency (Hz)	*Time (ms)*
20-28-70-80	0- 600
15-20-70-80	800
15-20-40-50	2000-3000

Note: Frequency filter for reprocessing data (CR99A and 98A lines) was applied after Migration

❖ **Migration**

Finite Difference Migration was performed to post stack data**.** Smoothed interval velocities were used. Maximum dip was set to 50 degrees.

❖ **FX Deconvolution**

Randon Noise was attenuated using FX Deconvolution which applies a Fourier transform to each trace and Wiener levinson prediction filter. A 9 trace operator was applied over frequency range 10-140 Hz.

❖ **Scaling**.

AGC 500msec window length was applied with 50% addback of original unscaled data.

3.2.3. Navigation

Origin Energy provided UTM XY stations coordinates for all surveys.
Some missing coordinates for reprocessing data were interpolated. The coordinates were used for the geometry assign. They have been loaded to the Segy trace headers. CDP XY coordinates have been also archived as ascii file.

- ✓ GDA94 Geodetic Datum, MGA Zone 55 and central meridian 147 were used

3.2.4. Specific Problem

The calculation of refraction statics was an issue for the project.
It is caused by following factors:

- The area, known as Durham Ranch, has very rough topography. The elevation varies by 150m along the lines with numerous steep slopes.
- The newly acquired Spring Gully lines have a crooked geometry spread.
- It was almost impossible to pick consistent refractor along any of the lines.
- The uphole data that has been provided show large variations with sub weathering velocities.

For these reasons the refraction solutions were problematic. The refraction statics approach and calculation were re-assessed a few times during processing.

Initially, on the basis of tests carried out on lines OSG06 -05 and 07, it was decided to use 90% of modelled refractors velocity for replacement velocity for the static calculation. However this method did not work for CR99A survey and it has caused a cycle skip. Thus refraction statics for this survey were calculated using 3000m/s replacement velocity. The same way refraction statics were finally calculated for lines OSG06-04 and OSG06-08.

Some severe problems, like for lines OSG06-05 and OSG06-08 were fixed by re-picking first breaks and limiting offsets to 700m. The near offset traces (< 750m) were also used for CR99A survey refraction statics calculation.

After all, the processed and reprocessed final section revealed a good quality. They are more geologically plausible, in terms of the distribution of the main coal reflector and the removal of unlikely fault-like and cycle-skip features.

4. Final Documents and Tapes

The following final products were delivered to Origin Energy:

Deliverable Products	Format	Media		Completed date
I. Gathers				
1.SP Gathers before DMO	*SegY*	**DLT**		27/07/2006
II. Stack				
2. Final Migrated Stack	*SegY*	CD		29/06/2006
3. Raw Migrated Stack	*SegY*	CD		18/07/2006
4. Raw Stack	*SegY*	CD		18/07/2006
5. Filtered Stack	*SegY*	CD		18/07/2006
III. Supporting data				
6. CDP XY Coordinates (GDA94)& elevation	ASCII	CD		27/07/2006
7. CDP final datum statics	ASCII	CD		27/07/2006
8. Source Refraction Statics	ASCII	CD		27/07/2006
9. Receiver Refraction Statics	ASCII	CD		27/07/2006
IV. Velocity				
10. Stacking RMS velocities	ASCII	CD		27/07/2006
11. Migration Interval Velocity	ASCII	CD		27/07/2006
V. Processing Report	pdf	CD		11/08/2006

5. Testing (Technical Notes Hyperlinks)

Following is the list of technical notes that have been provided to Origin Energy during the lifetime of the project. These technical notes describe testing and QC carried out, with supporting figures.

5.1. Refraction Statics

SG_TN01_RefrStat.ppt
SG_TN02_RefrStat.ppt
SG_TN03_RefrStat_ReplVel.ppt
SG_TN04_RefrStat_line07.ppt
SG_TN11_QC_line03.ppt
SG_TN12_line54_Replacement_.ppt
SG_TN13_Line39_Replacement.ppt
SG_TN14_Lines34_07_Refrstat.ppt
SG_TN15_line05_RefrStat_reassess.ppt
SG_TN11_QC_line03.ppt

5.2. Minimum Phase Filter

SG_TN02_RefrStat.ppt

5.3. Denoise

SG_TN05_Denoise.ppt

5.4. Deconvolution

SG_TN06_DBS.ppt

5.5. Residual Velocity Analysis

SG_TN08_Vel_3.ppt

5.6. Post Stack Processing

SG_TN09_PostStack.ppt

6. Annexes

6.1. Personnel involved in reprocessing

The data was processed by *Velseis Processing Pty. Ltd*., Brisbane, Australia.
Tatiana Gerus was the project leader.

The *Origin Energy Resources Limited* representative was **Neil Millar.**

6.2. Software

Velseis Processing utilizes ProMAX 3D processing software. This is a totally interactive system allowing the user to view data processing at each stage, producing a final result of the highest quality.

The software executes on a quad processor Sparc 20 Sun workstation and a 27 node, dual CPU/node Linux cluster. Data is viewed via X terminals networked to the main system, each terminal has a high definition monitor to enable accurate representation of the digital data in pixel form.

Velseis Processing is committed to offering a premium product, the software development undertaken by ProMAX resulting in processing algorithms which are state of the art.

6.3. Disclaimer

This report has been prepared in good faith and with all due care and diligence. It is based on the seismic and other geophysical data presented and referred to, in combination with the author's experience with the seismic technique, and as tempered by the geological and stratigraphic evidence presented in various forms and through discussions with client representatives.

As such, the report represents a collation of opinions, conclusions and recommendations, the majority of which remain untested at the time of preparation. In the light of these facts it must be clearly understood that Velseis Processing Pty. Ltd., its proprietors and employees cannot take responsibility for any consequences arising from this report.