Wide-aperture 3D acquisition over the Mangahewa Field, PPL 38705 Taranaki Basin

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Abstract

Wide-aperture 3D acquisition was undertaken in northern Taranaki in the summer of 1997/1998 over the Mangahewa Field in PPL 38705 Taranaki Basin. The technique has provided significantly improved temporal and spatial resolution of the prospective Mangahewa Formation. In addition, significant productivity per square kilometre of data was achieved.

Wide-aperture 3D acquisition produces an offset distribution bias towards long offsets which is necessary for proper 3D pre-stack time migration and ultimately greatly improves the quality of sub-surface images. Other image enhancements include velocity for NMO and multiple recognition.

Introduction

The Mangahewa Field is a large north-trending inversion anticline located within PPL 38705 (Figure 1). Mangahewa-2, drilled in 1997, intersected sand, coal and shale of the Kapuni Group (Figure 2). The Kapuni Group has been more deeply buried than the present depth of approximately 3500 m, which has resulted in overpressure and increased interval velocities.

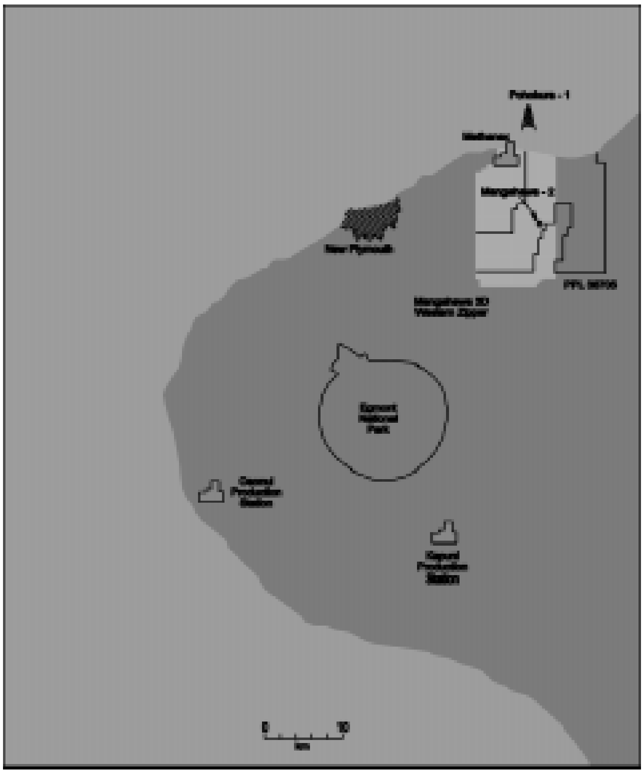


Figure 1: Location map of the Mangahewa area.

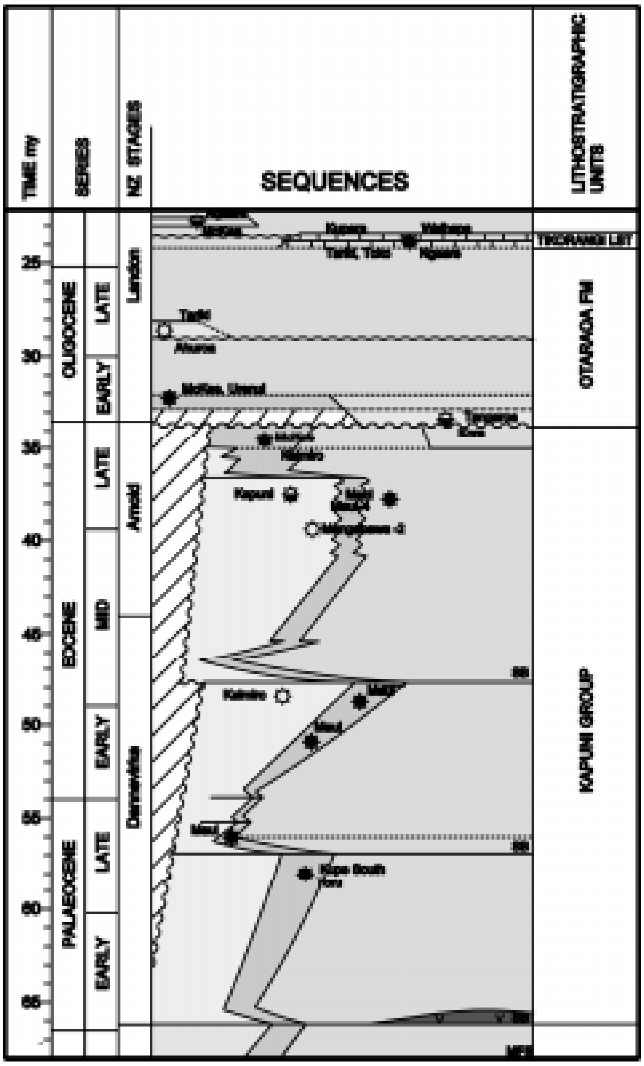


Figure 2: Generalised stratigraphy of the Mangahewa area.

Encouraging results from the exploration well Mangahewa-2 led to the need to understand the structural and stratigraphic configuration of the discovery and 3D seismic was one of the first steps taken towards field appraisal.

Seismic data quality has long been considered good inland from New Plymouth and Waitara. Undulating topography and near-surface geology generally devoid of lava flows make both dynamite and Vibroseis acquisition capable of good vertical and lateral resolution. Nevertheless significant improvements could be made with 3D acquisition rather than conventional 2D acquisition.

The Mangahewa 3D was designed to meet four important objectives, namely high resolution imaging of the Mangahewa Formation, coverage over the entire structure, cost effective acquisition, and minimal environmental impact. Historically one or more of these objectives has always been compromised. However application of wide-aperture 3D acquisition meant that all four objectives could be met without compromise.

Wide-aperture 3D acquisition

The most widely accepted benefit of 3D over 2D is that 3D imaging provides information continuously through the subsurface within the bounds of the survey area whereas 2D only reveals strips of information. In Figure 3(a) an outline can be observed but drawing conclusions about the internal make up of this image requires a vivid imagination! If this image were of a field then understanding stratigraphic architecture would be nearly impossible. Figure 3(b) is the same image with complete coverage. More is revealed yet the picture is still not well imaged. This is the sort of picture a geoscientist would get of a 3D volume which suffers from poor signal to noise. Figure 3(c) is the result of optimum imaging, for a 3D survey this is attainable if the benefits of detailed resolution justify the cost. Designing a 3D survey therefore is a trade-off between resolution and cost.

Conventional 2D gathers consist of a group of traces which are one third near offsets, one third middle offsets, and one third far offsets (Figure 4). This offset distribution is illustrated on a representative gather in the Mangahewa area (Figure 5). Note that at target depths of 2000 to 2500 ms, noise trains in the near and middle offsets mask the events. With equal offset weighting this will result in a degraded signal to noise stack.

Wide-aperture 3D recording results in an offset distribution biased towards the long offsets. One ninth of recorded traces will be near offsets, one third will be medium offsets and five ninths will be far offsets (Figure 6). This weighting of offsets enhances velocity analysis for NMO, DMO and migration. Also, multiple recognition and suppression is improved (Bouska, 1998). The method therefore has the benefits of optimising signal to noise as well as saving on cost. Using Figure 3, by analogy wide-aperture 3D acquisition takes resolution of the image in Figure 3(b) to the image in Figure 3(c) without the high price tag.

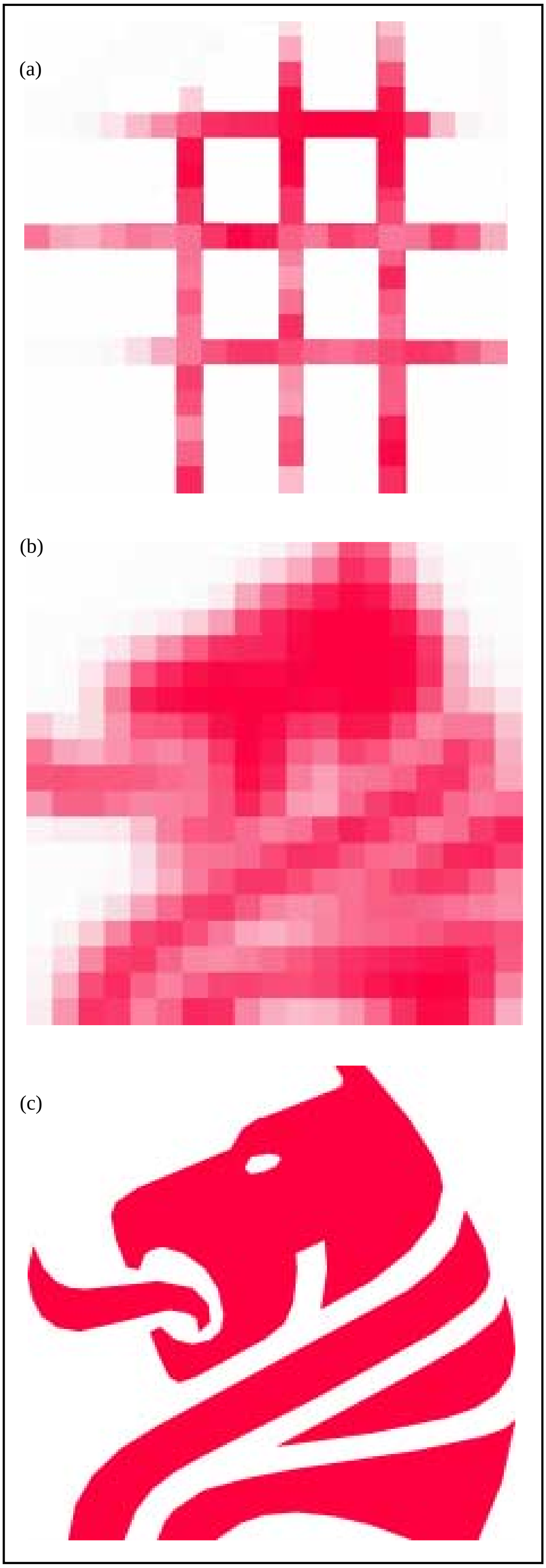


Figure 3: Comparison of 2D and 3D imaging. (a) Image as seen by 2D. (b) Image seen by a 3D grid. (c) Image focussed 3D for optimal imaging.

Figure 4: Near, mid and far offset distribution for a 2D spread.

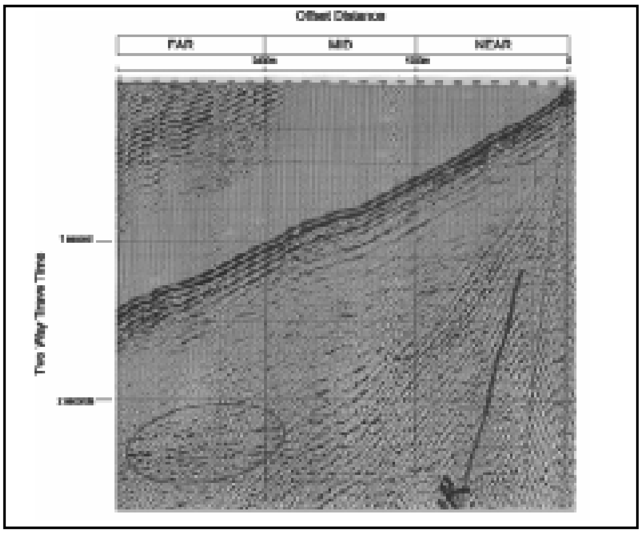


Figure 5: Representative gather in the Mangahewa area.

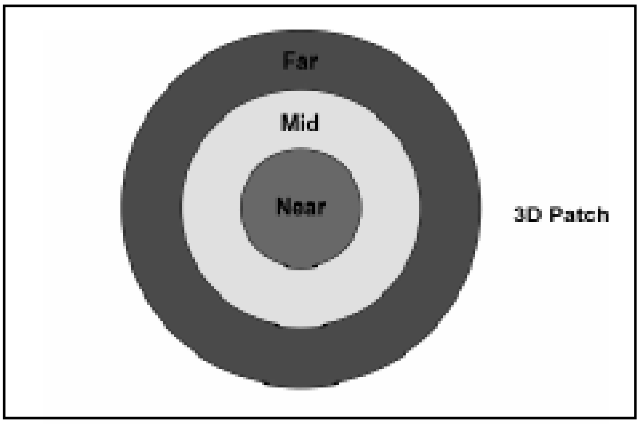


Figure 6: Near, mid and far offset distribution for a 3D patch.

Wide-aperture 3D acquisition requires large, square patches and a large supply of field equipment. With modern acquisition systems this requirement is easily met.

The Mangahewa 3D design considerations

The primary reservoir objective of the Mangahewa appraisal is the Kapuni Group. The target depth is approximately 3500 m (2100 ms and average velocity of 3300 m/s). Synthetic modelling suggested a dominant frequency of 50-60 Hz would adequately image sand bed thickness. The existing 2D dominant frequency was approximately 30 Hz although recent Vibroseis lines obtain 40 Hz.

Previous vintages of 2D data were used to establish the desired fold. Dynamite data at 18-24 fold provided good signal to noise, sometimes even better than the 120 fold vibroseis data. Desired fold for the Mangahewa 3D was set at 24 as the entire survey was acquired with a dynamite source.

Analysis of field records from the area revealed that the best signal recovery was at offsets from 150 to 3500 m and possibly longer.

From analysis of field records and geological considerations a 300 km^2 full fold survey was designed with the parameters outlined in Table 1.

Execution of the Mangahewa 3D acquisition programme

Design of the survey was completed within 10 days in late September by Mustagh Resources.

Summer months are optimal for seismic acquisition in Taranaki, as the season provides a combination of good weather, safe working conditions and minimal interference to the majority of land users. The land is predominately undulating farmland and many small lifestyle blocks. The McKee oil production facility, Methanex Motonui methanol plant, national gas distribution network, and some DoC land are also located within the survey area. The area is also rich in tangata whenua. All these types of land use require detailed planning and careful execution of a 3D seismic survey. Planning commenced immediately after financial approval was granted. It became obvious at an early stage that the entire 360 km^2 could not be acquired in a single summer season. Accordingly, the decision was made to acquire the Western and Eastern Zippers over consecutive summer seasons. The Eastern Zipper has not been acquired to date.

For the Western zipper, over 700 landowners were to be affected by the survey. Some 11,000 shot and receiver pegs were surveyed, 3700 shot holes drilled, 177 km^2 recorded and the entire area restored by Autumn. Tenders were awarded on the basis of performance record, ability to meet stringent safety requirements, and cost effectiveness.

Permitting commenced in late November 1997 and was largely executed by BTW and Associates on behalf of Fletcher Challenge Energy. BTW provided a team of seven experienced personnel all of whom were well known within the community, had depth of knowledge of the area and strong interpersonal skills. The exemplary work by this team meant that a considerable amount of overlap of surveying, drilling and acquisition activity could be undertaken with minimal disruption to landowners while maximising productivity (Figure 7a).

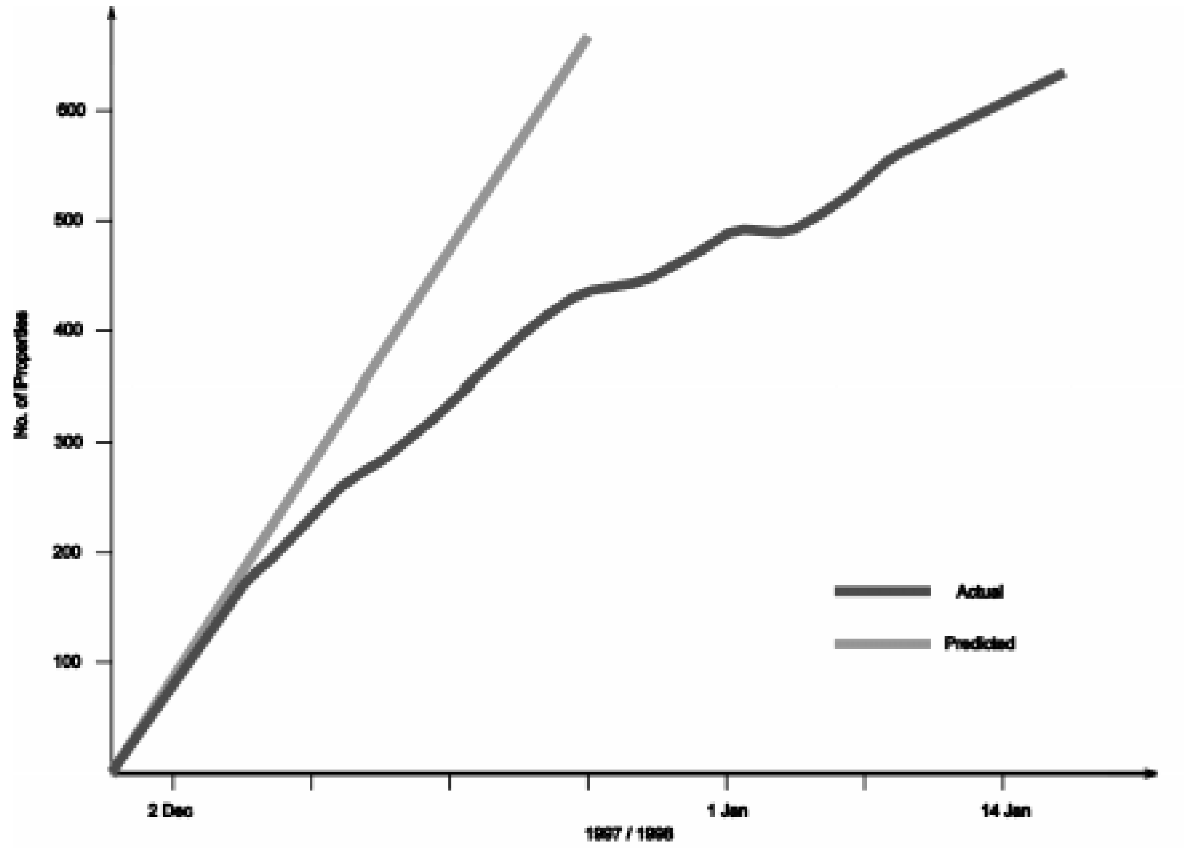
Surveying was carried out by a variety of crew configurations depending primarily on the terrain. Global Positioning System (GPS) work was undertaken by four two-man crews in gentle undulating terrain and this system provided approximately 85% coverage of the shot and receiver peg locations. Four-man thodolite crews were used for pegging in steep and highly vegetated terrain. The difficulty of the steep and highly vegetated terrain is noticeable by the significant drop in production rate toward the end of the survey activity (Figure 7b).

Survey	17280 m east-west	
	21120 m north-south	
	actual area	= 363.77 sq km
		= 140.51 sq mi
	approx. full fuld area	= 299.8 sq km
		= 113.5 sq mi
Sour ce	source interval	= 60 m
	line spacing	= 720 m (12.0 receiver intervals)
	line direction	= north-south
	number of lines	= 25
	source points per line	= 352 (on full lines)
	total number of SP's	= 8800 (24 per km^2; 63 per mi^2)
	total source line	= 526.50 km
	source	= 1 x 2.00 kg at 18 m
Receiver	receiver interval	= 60 m
	line spacing	= 480 m (8.0 source intervals)
	line direction	= east-west
	number of lines	= 45
	receivers per line	= 288 (on full lines)
	total number of receivers	= 12960 (36 per km^2; 92 per mi^2)
	total receiver line	= 774.90 km
	geophones	= 14 Hz, 6 or 9 over 20 m (follow contour line in steep topography)
Instruments	system	= I/O System Two or equivalent
	data format	= IEEE
	sample rate	= 2 ms
	record length to tape	= 5.120 seconds
	record length to paper	= 3.000 seconds
	high filter	= 1/2 Ny Min
	low filter	= to be determined by testing
	SSF filter	= to be determined by testing
Patch	10 lines x 120 receivers per line shoot in two zippers or 204 and 192 channels can roll on and off with 6 lines (all receivers) 1200 channel 7140 x 4320 m require 3456 channels to lay out entire receiver lines with two line roll capacity.	
Average fold with 30 m x 30 m bins is about 22.24 (assuming offsets to 3500 m)		

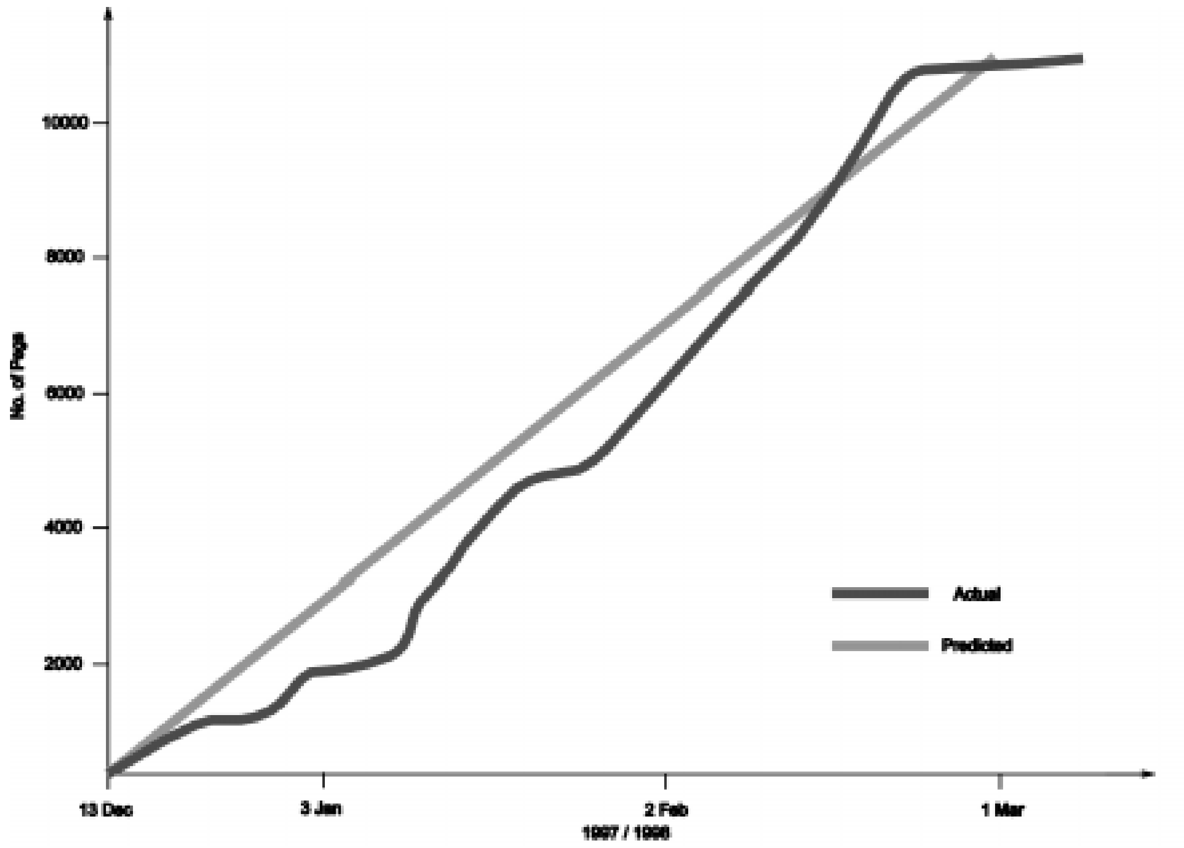
Table 1: Parameter summary.

Drilling was undertaken entirely by tractor and truck mounted drilling rigs. A good summer season and flexibility in shot hole placement enabled significant cost savings as helicopter support was not required. Weathered sediment thickness varies over the survey area and creates significant statics problems. Based on an extensive database of shot hole profiles and acquisition tests the decision to use a single charge loaded between 15 and 30m was made. This realised significant savings in charge placement, minimal environmental impact, reduced drill hours and the seismic benefit of a single point source (Figure 7c).

Acquisition involved a significantly larger amount of equipment than has been traditionally required in the onshore Taranaki. Some 3456 channels were required to lay out entire receiver lines with two line roll capacity (which enabled efficiency ahead of troubleshooters). The I/O System II was used as this provided greater reliability, and better dynamic range. The dynamic range, in particular, was important in the rejection of noise. The crew performed beyond expectation with regard to the demands of the design, and the extra effort of planning and co-ordination with surveyors greatly assisted productivity. Unfortunately the production Figures do not directly demonstrate this because they also include the misfortunes of weather and vandalism on daily production. Vandalism caused significant delays because it required firstly identifying damaged cable over a large spread area and then mobilising crews away from production to rectify the damage (Figure 7d).

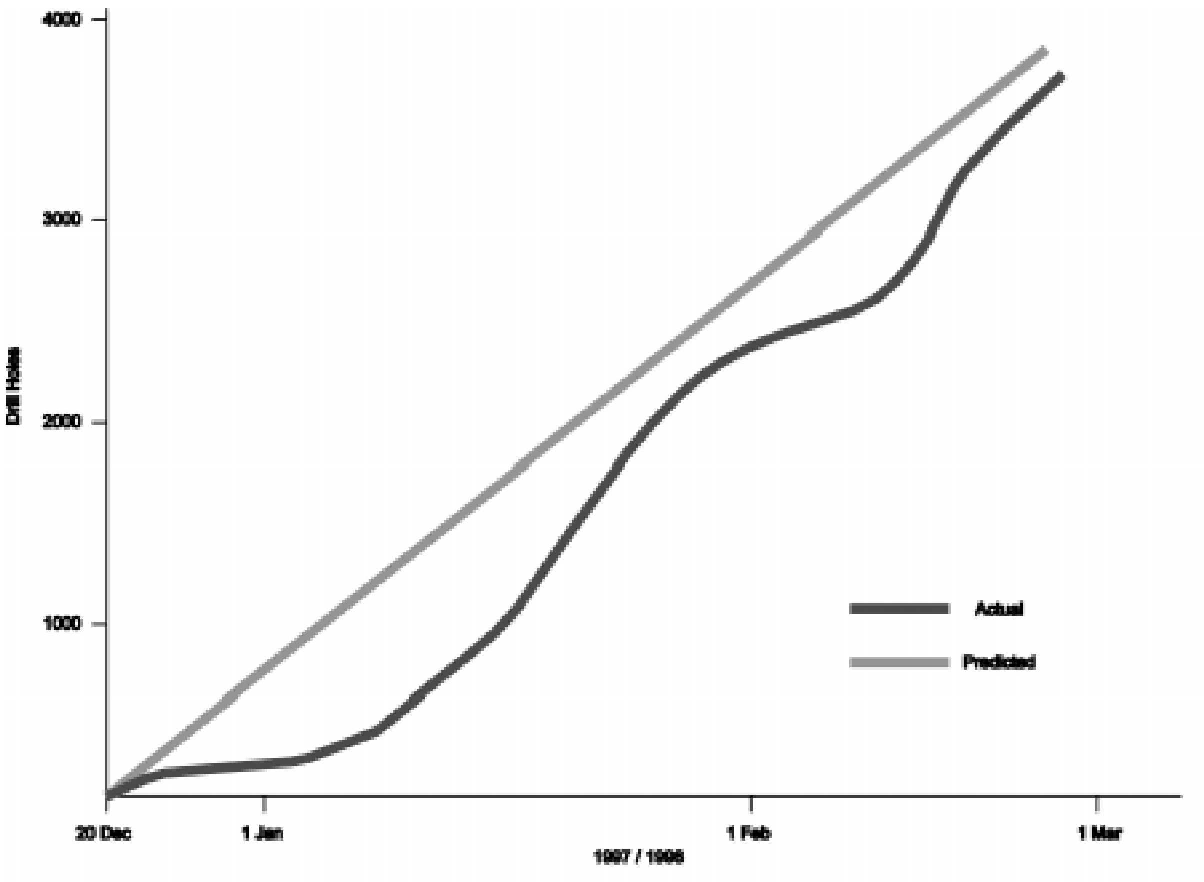


(a) Permitting Production

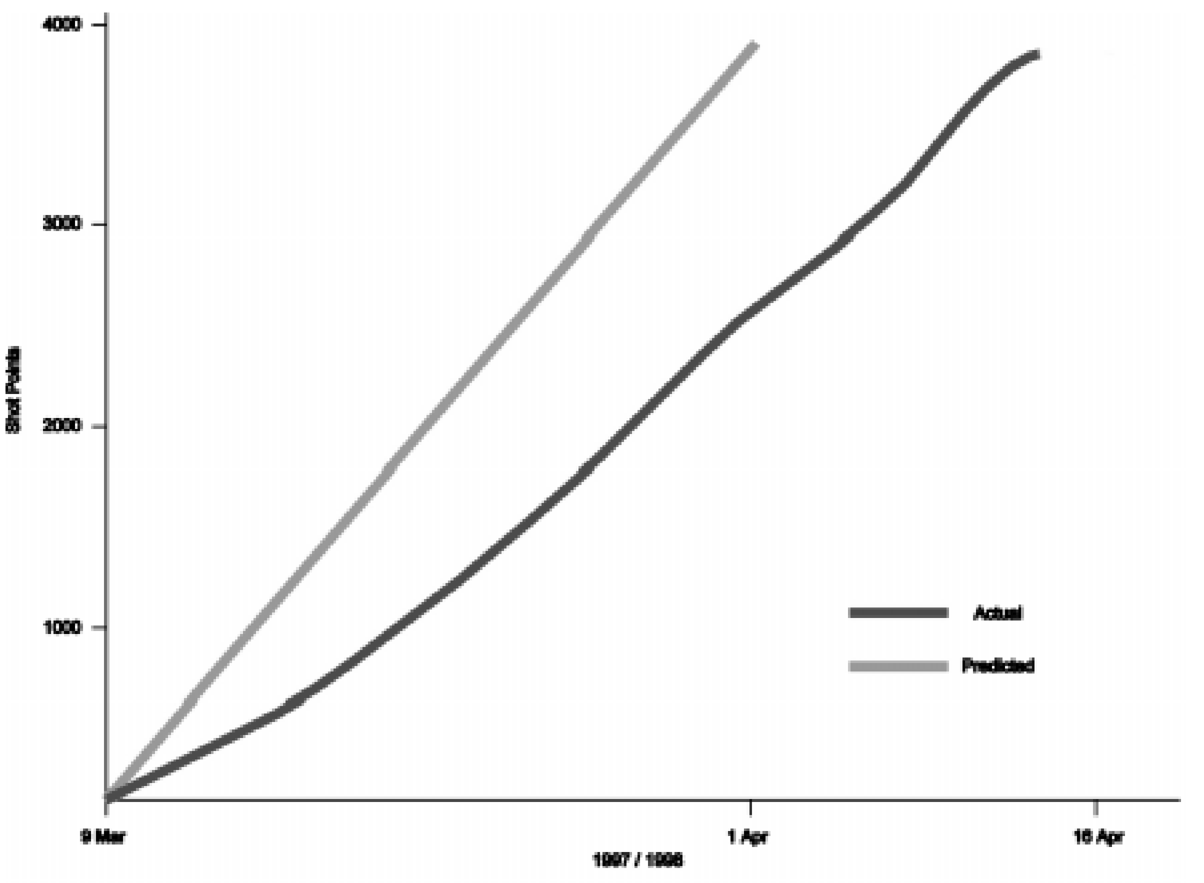


(b) Surveyors Production

Figure 7: Daily production statistics.



(c) Drilling Production



(d) Acquisition Production

Figure 7: Daily production statistics (continued).

Restoration commenced as soon as possible and was completed two weeks after recording was completed. Additional effort was required as a result of earlier vandalism and extra care and consideration was given to Department of Conservation reserves and wahi tapu.

Safety is given equal importance in all Fletcher Challenge Energy's activity and for the Mangahewa 3D survey the score card was excellent. Overall, production although hampered by vandalism, met expectations (Figure 8).

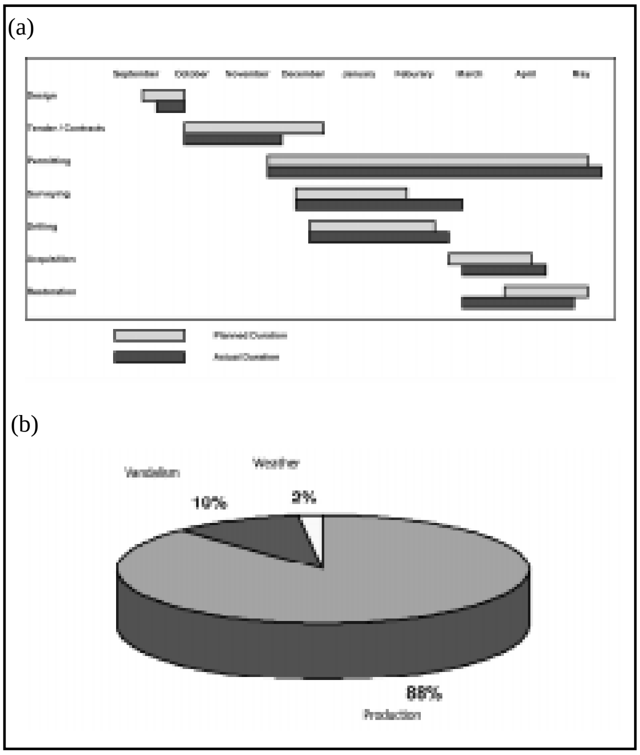


Figure 8: Production for the Mangahewa 3D. (a) Timeline of predicted versus actual production. (b) Breakdown of overall activity for surveying, drilling and acquisition.

Results

The data

3D acquisition has long been known to greatly increase the structural imaging of a field and dramatic examples of this are widely available in geoscience literature (Brown 1991), but of equal importance is the stratigraphic definition that can be gained. The Mangahewa 3D survey has surpassed expectations in the provision of structural and stratigraphic definition.

Prior to the Mangahewa 3D survey the area was covered by numerous vintages of 2D data with line spacing ranging from 2-8 km. The data suffered from severe inter-vintage misties and poorly understood statics profiles. This was most noticeable towards the coastline where the statics falsely elevated the depth structure. The Mangahewa 3D survey by virtue of close-spaced sampling provided more consistent and accurate statics solution and this, combined with horizon consistent stacking velocities, has led to a more accurate depth image of the Mangahewa structure. This finding has realised significant changes to the interpretation of the Mangahewa structure, which in turn have led to important decisions about the field-wide appraisal.

The interpretation

Hydrocarbons in the Mangahewa structure are reservoired in paralic and coastal plain sandstones of the Kapuni Group. Well logs and cores reveal a highly interdigitated vertical sequence of sands, shales and coals. Understanding the lateral distribution of these facies are vital for field appraisal. The Mangahewa 3D data has dramatically increased the understanding of reservoir distribution through enhanced temporal and spatial resolution. Individual reservoir sands are between 10 and 30 m thick and to adequately image these at depths of 3500 m requires frequencies greater than 60 Hz. The Mangahewa 3D survey achieved maximum useable frequencies up to 80 Hz at this depth, some 40-60 Hz higher than the existing 2D (Figure 9).

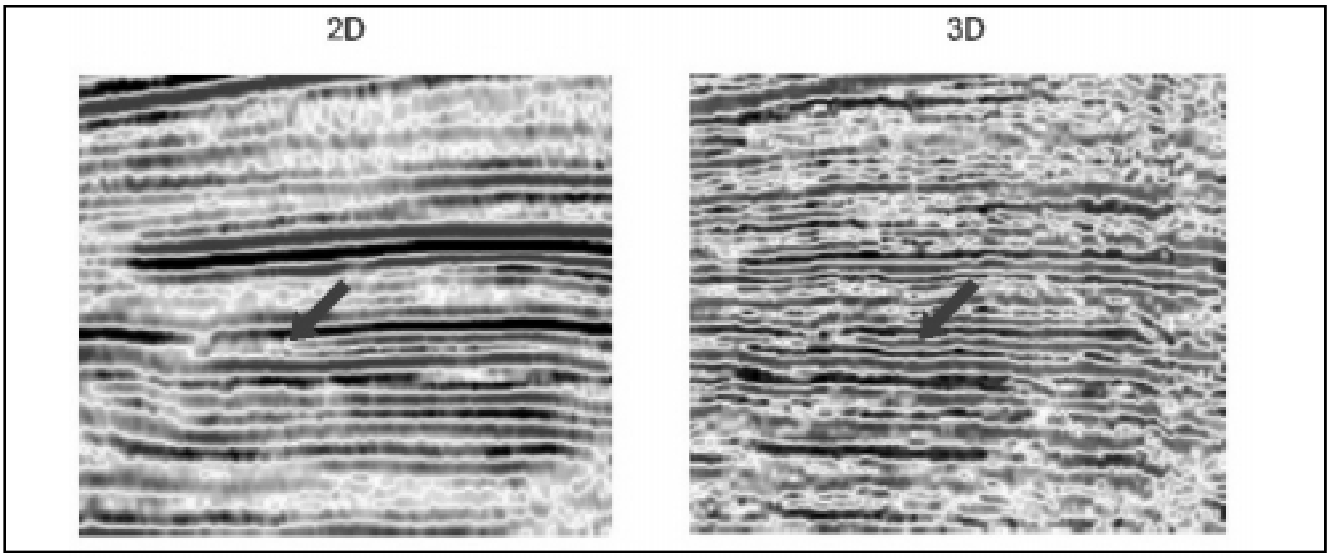


Figure 9: Comparison of 2D and 3D in the Mangahewa area. Panels are at approximately two seconds TWT. Arrows point to a sand where resolution on the 3D has greatly improved its spatial imaging.

Of equal importance to the vertical detection of individual reservoir sands is the understanding of palaeogeography from seismic character. This is where the power of 3D interpretation lies. The distribution of sand sheets, channels, and shorelines (to name but a few examples) can be mapped on the Mangahewa 3D in detail. Figure 10 is an example of the extent of a coal seam within the Mangahewa 3D area. By analogy, this sort of imaging would be the detail around the lions face and neck in Figure 3(c).

No 3D data volume is without its shortcomings and for the Mangahewa 3D it is a narrow focus on the Kapuni Group. The design specifically addressed targets below 3000 m and in doing so provides no significant coverage above 2000 m where the fold diminishes to 1or 2. If stratigraphy of the Mt Messenger is present within the Mangahewa area, for example, it is not adequately imaged by the 3D volume.

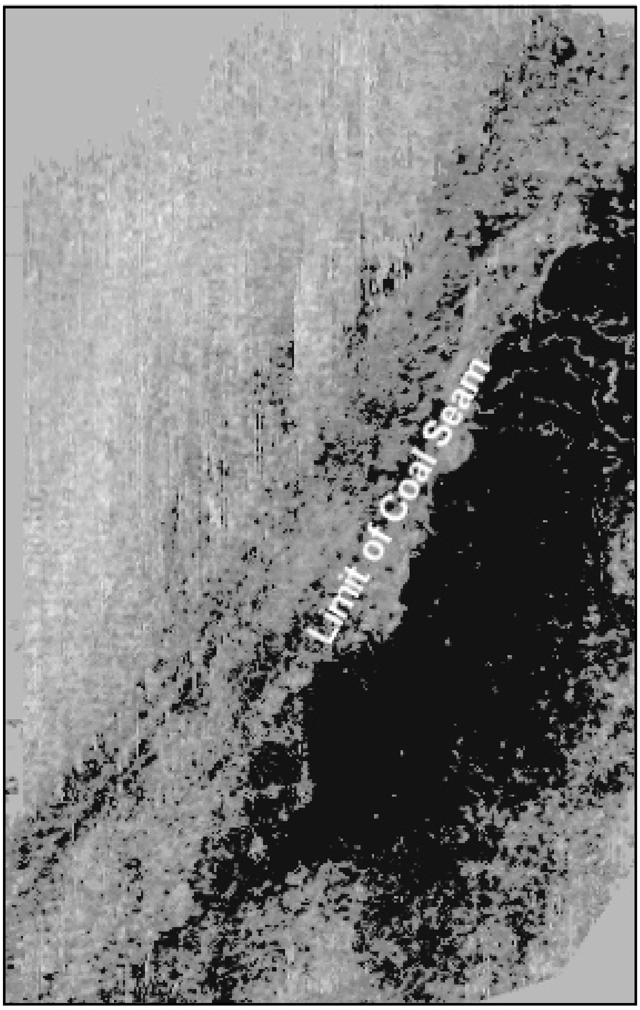


Figure 10: Seismic TWT slice showing the limit of a coal seam within the Mangahewa area.

The cost

Comparison with other Taranaki 3D seismic surveys clearly demonstrates the effectiveness of the Mangahewa 3D to meet geological goals while reducing effort (Table 2).

The Mangahewa 3D survey clearly does not have the effort per square kilometre of the McKee and Kaimiro surveys. In the case of the Kaimiro 3D this is because the Kaimiro 3D survey's objective was highest possible resolution above 2500 m. However, the Kaimiro 3D survey does provides a good comparison of the impact high effort acquisition has on production rate. The McKee 3D survey was designed to target similar depths to the Mangahewa 3D survey, but does not image the target event well because it does not have sufficient offsets or migration aperture. In other words the effort did not match the aim of good imaging. The Kapuni 3D survey provides a good comparison of target depths, surface coverage and effort. Comparison of the production between the Kapuni and Mangahewa 3D surveys demonstrates that the wide-aperture acquisition technique used in the Mangahewa 3D has greatly improved productivity. If one assumes effort and duration equate to cost then the Mangahewa 3D survey is value for money.

Wide-aperture acquisition in the Mangahewa area has been beneficial from an operational perspective because it allowed rapid acquisition and lower effort on the ground. This was positively received for the most part by the community and in particular, the ability to avoid wahi tapu was appreciated by local iwi.

Conclusion

Benefits of the Mangahewa 3D survey can be conveniently categorised under headings of reservoir, well and appraisal:

Reservoir related benefits

- enable detailed stratigraphic interpretation;
- potential to derive field wide rock properties; and
- identify natural fracture systems and orientation.

Survey	Surface coverage (km^2)	Shotpoints per km^2	Receivers per km^2	Production (km^2/day)
Kapuni 3D	380	37	67	2.7
McKee 3D	60	20	129	0.9
Kaimiro 3D	96	69	138	1.5
Mangahewa 3D	177	21	36	4.5

Table 2: Comparison of onshore Taranaki 3D seismic surveys.

Well related benefits

- maximise effectiveness of the drilling programme;
- identify sweet spot locations; and
- reduce depth prognosis error.

Field appraisal and development related benefits

- cost effective data acquisition;
- reduced impact on the environment; and
- booking reserves earlier.

Wide-aperture 3D acquisition over the Mangahewa Field has provided significantly improved temporal and spatial resolution of the field. The technique has also enabled significant cost reductions in the subsequent appraisal and development of the field without compromise to safety.

References

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Author

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