Channel-count requirements for 3D land seismic acquisition in Kuwait

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Outline:

- **Introduction**
- **Relevant concepts and definitions**
- **Channel-count requirements**
- **Conclusions**

Introduction

Land seismic data acquisition in Kuwait has to address a number of issues among which are:

- **Coherent-noise wavelengths in the order of 8m**
- **Image a shallow horizon for statics determination**
- **Image deep reservoirs requiring offsets > 6,000m**
- **Achieve high vertical resolution for reservoir characterization**
- **Minimize geometry footprint to enable successful attribute analysis, AVO, inversion, etc.**

- **The signal to random noise ratio (S/N) is a function of the trace density seen by the migration operator. By increasing the acquisition trace density, the S/N in the final volume would be improved. [1]**

- **Trace multiplicity needs to build consistently with sources to receivers offset and azimuth. [2]**

[1] *Krey, Th C. 1987, Attenuation of Random Noise by 2-D and 3-D CDP Stacking and Kirchhoff Migration, Geophysical Prospecting 35, 135-147.*

[2] *Robinson Don K. and Al-Hussaini, Moujahed, 1982, Techniques for reflection prospecting in Rub" Al-Khali, Geophysics, Vol 47 No 8. .*

Adequate sampling is the use of a sampling distance that prevents the noise wavefield from aliasing into the signal passband. [1]

Thus, it is possible to adequately spatially sample with sensor spacing a little more than half of the ground roll wavelength.

[1] *Baeten, G.J.M, Belougne, V., Combee, L., Kragh, E., Laake, A., Martin, J., Orban, J., Özbek, A., and Vermeer, P.L, 2000, Acquisition and processing of point receiver measurements in land seismic, 70th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, p 41-44.*

Uncommitted Acquisition (Universal)

In "uncommitted acquisition" we are not committed to a processing and/or interpretation sampling grid during the acquisition process. [1]

i.e., in the field no irreversible step should be carried out such as group forming by conventional arrays.

[1] *Ongkiehong, L. and Askin, H. J., 1998, Towards the universal seismic acquisition technique, First Break, Vol. 6, No.02, p 46-63.*

Acquisition footprint

The number of different bin configurations, which are repeated periodically over the area of a survey is called “BSC”. For a 3D full fold scheme the total number of different bin configurations is 2.

Design changes caused by cost and equipment availability considerations usually result in a BSC which is much larger than 2.

Seismic amplitudes vary with offset, if we have changes in the offset distribution from one bin to the next, we will end up with a bias pattern in the amplitudes of the stacked traces, which is called acquisition footprint (geometry imprint).

Marschall, R. [1997] 3-D Acquisition of seismic data. Proc. of the 17th Mintrop-Seminar, Münster. DGMK Deutsche Wiss. Ges. für Erdöl, Erdgas und Kohle e.V.

Data acquisition

Noise tests conducted in Kuwait have shown that the shortest wavelength of ground roll is in the order of 8m, which would require receiver and shot spacing in the order of 4m or less.

The concept of adequate sampling could allow relaxing this anti-alias requirement to let us say 5m.

Baeten, G.J.M, Belougne, V., Combee, L., Kragh, E., Laake, A., Martin, J., Orban, J., Özbek, A., and Vermeer, P.L, 2000, Acquisition and processing of point receiver measurements in land seismic, 70th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, p 41-44.

Interpretation requirements

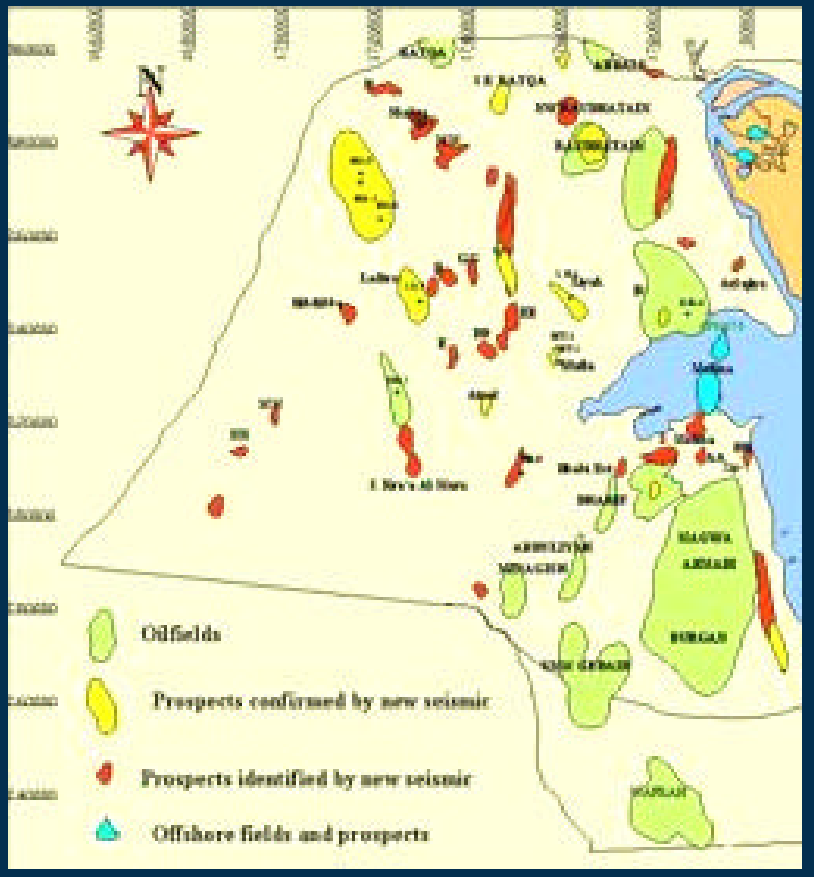
Seismic data interpretation is no more only focused on structural interpretation.

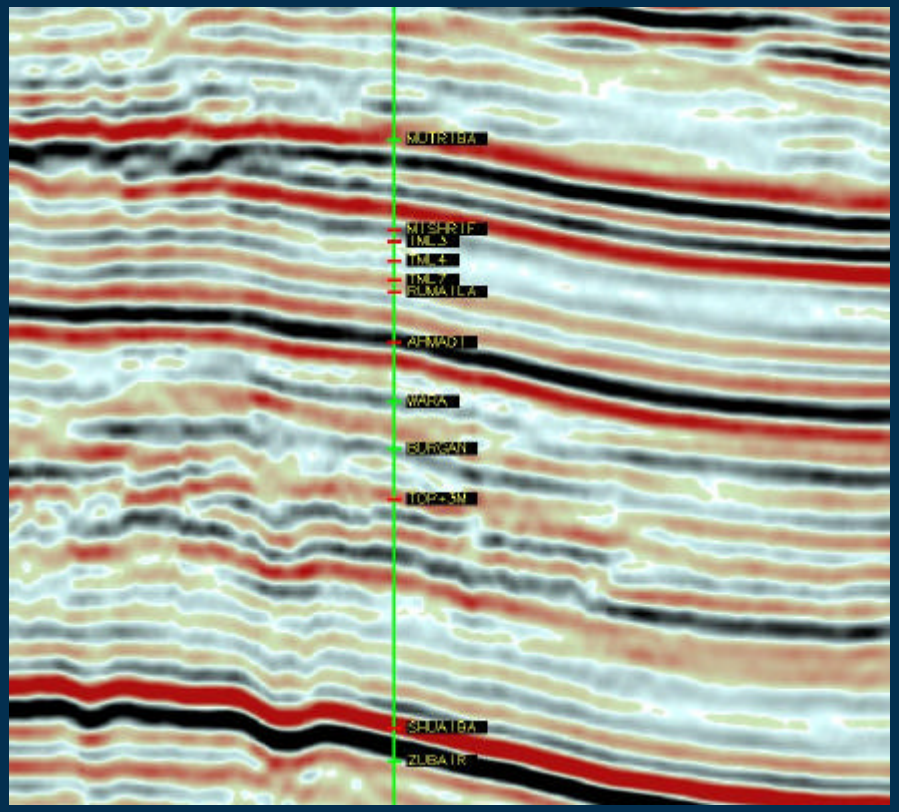
Many interpretation tools are based on amplitude analysis. Bias pattern in the amplitudes should be minimized at the acquisition stage and not left to be handled in processing with techniques that generally distort relative amplitudes.

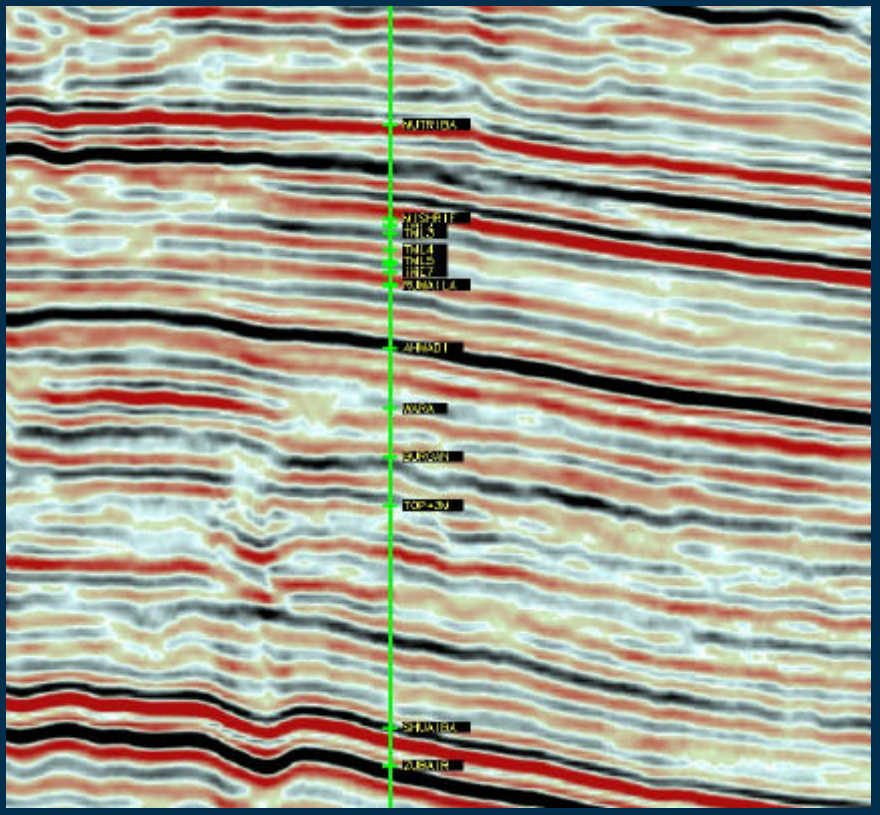
One of the major techniques to minimize bias pattern in amplitudes and improve areal resolution is to reduce the source and receiver line intervals.

Acquisition considerations for Kuwait

Because of the relatively small land area of Kuwait (17,820 sq kms) and the large number of structurally similar fields and prospects, it makes sense to consider one land 3D acquisition template that addresses all the challenges and enables future seamless merging of all individual surveys to produce a single 3D volume covering the whole of Kuwait.







3D Conventional

Array of 24 analogue geophones

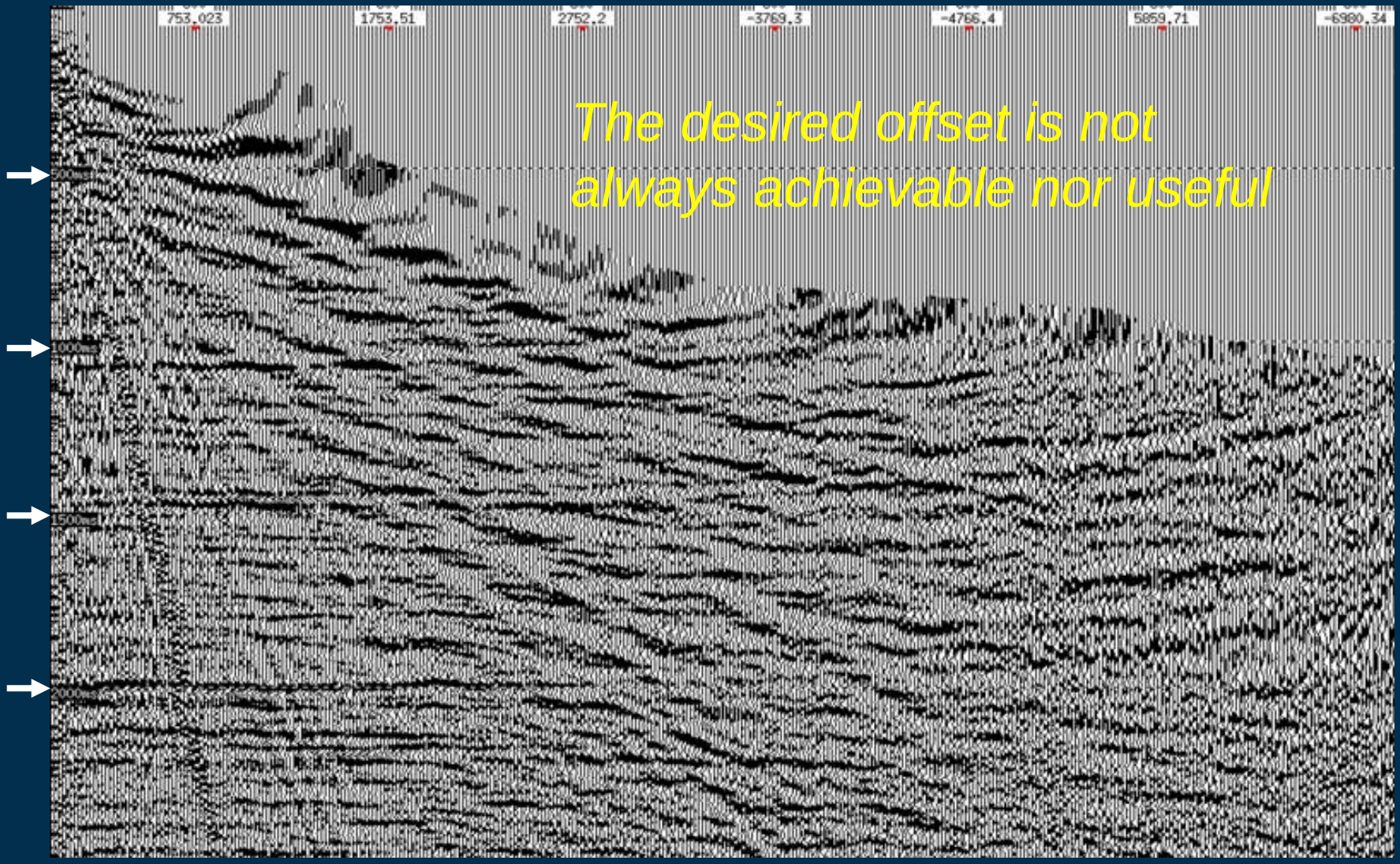
Bin 25x25

3D digital 1C single sensors

Array of 8 digital sensor formed post initial processing

Bin 10x10

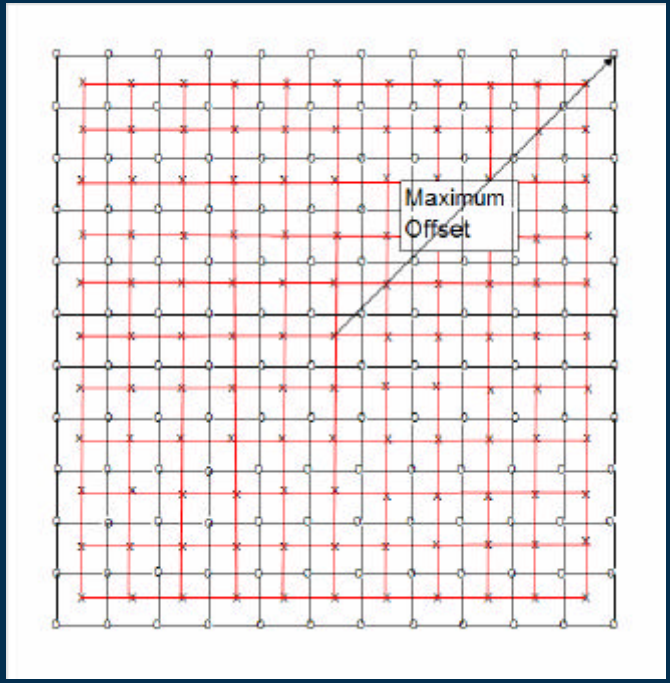
Desired offset versus useful offset



CMP Gather: offset 0 – 7,000m

Data acquisition – Universal (uncommitted)

Let us start by selecting a surface acquisition template consisting of two square grids with equal bin sizes: source-grid (red) and receiver-grid (black). An active single-sensor is located at each receiver-grid point and a source at the center. The roll-along in x- and y-directions is with increments of one grid point.



NL= 1,720
NRL=1,720
X-max=6,078m
NR=2,958,400 sensors (Channels)
F= 739,600

?R=?S=?r=?s=5m.

This is neither practical nor achievable. But the scheme is intended as the theoretical reference against which all other schemes are to be evaluated.

Data acquisition

The shallowest horizon to be imaged has to be identified and considered in relaxing the requirement of the nominal 3D full fold acquisition.

The imaging of the Rus shallow horizon is needed for static determination and as a reference for depth conversion and multiple attenuation.

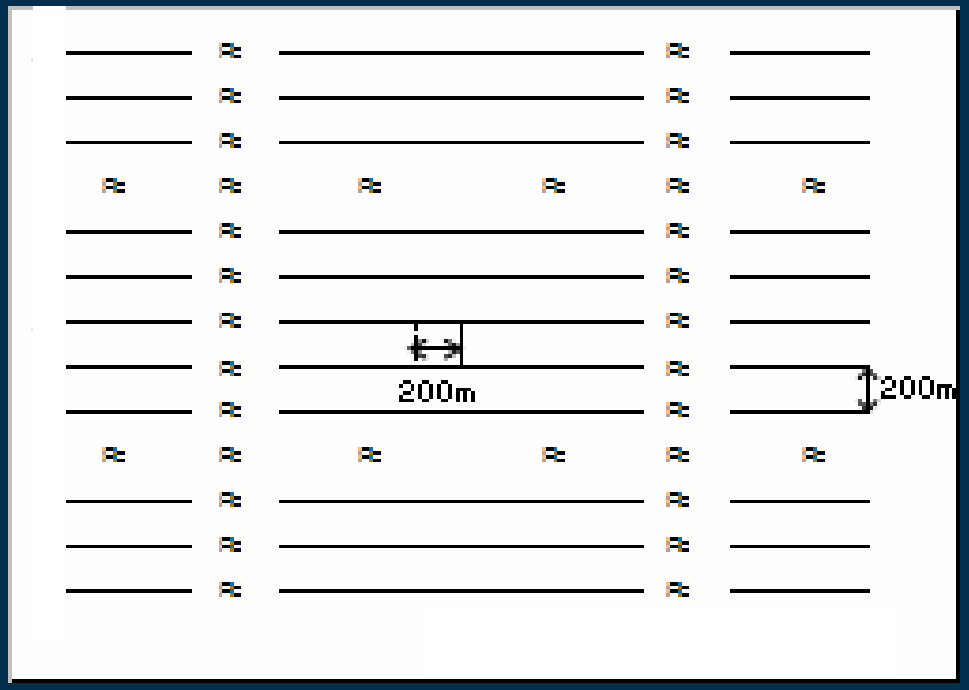
The Rus lies at depths ranging between 200m and 600m. Ideally, a fold of 4 would be desirable at this level.

Homogeneous scheme, one line roll

let us now compromise and select a less ambitious acquisition scheme using single digital 1C sensors .

?R=?S=200m.

?r=?s=5m.



NL= 44
NRL=1,760
X-max=6,150m
NR=77,440 sensors
F= 484

Data acquisition

As both the shots and receivers are inline, it is doubtful that ground roll suppression would be optimum.

The WesternGeco's Q-Land single-sensor (1C) acquisition and processing system, the only high channel-count currently commercially available, is currently only capable of recording 30,000 live channels at 4ms sample rate.

Recall that we need 77,440 sensors.

Data acquisition

Let us now compromise further but use 4 staggered sub-lines of single-sensors spaced 10m to form a receiver array of 8 digital sensors post pre-processing.

?R=?S=200m.

?r=?s=20m.

NL= 16
NRL=1,160, 4 sub-lines
X-max=5,986m
NR=74,240 sensors (channels)

Again, this humble scheme, with aspect ratio of only 0.28, is currently unachievable with the commercially available single-sensor recording instruments (Recall that Q-Land has 30,000 channels).

Data acquisition

Considering the 3C MEMS-type sensors, such as Sercel's DSU3 or Input/Output's VectorSeis and depending on using adaptive filtering for noise attenuation, we can modify the design to:

?R=?S=200m.

?r=?s=20m.

NL= 16

NRL=580 , 3C digital sensors

X-max=5,986m

NR=9,280, Channels= 27,840

Even if achievable, this approach might not be good enough to attenuate the various types of noise encountered in Kuwait.

Data acquisition

Replacing each 3C unit with an array of 12 conventional analog velocity geophones would result in a requirement for 9,280 active channels.

This is achievable. However, straight analog summation provides suboptimal performance in signal preservation and in antialias filtering.

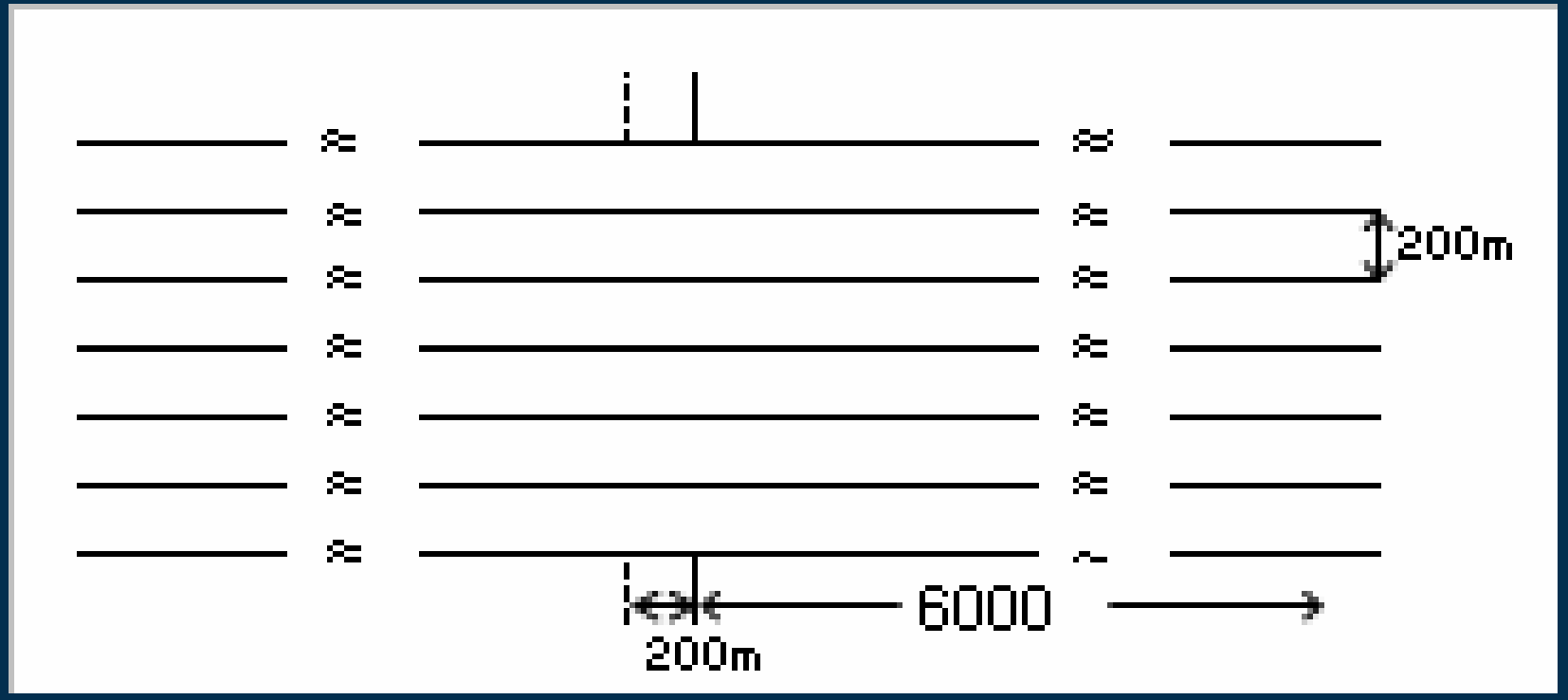
The response of the analog array is distorted by the presence of intra-array perturbations.

Recall that the aspect ratio is only 0.28

Rached G. and Al-Fares A. [2006] Single-sensor 3D land seismic acquisition in Kuwait, 76th Meeting, Society of Exploration Geophysicists, Expanded Abstract, 2.5.

Alternative techniques

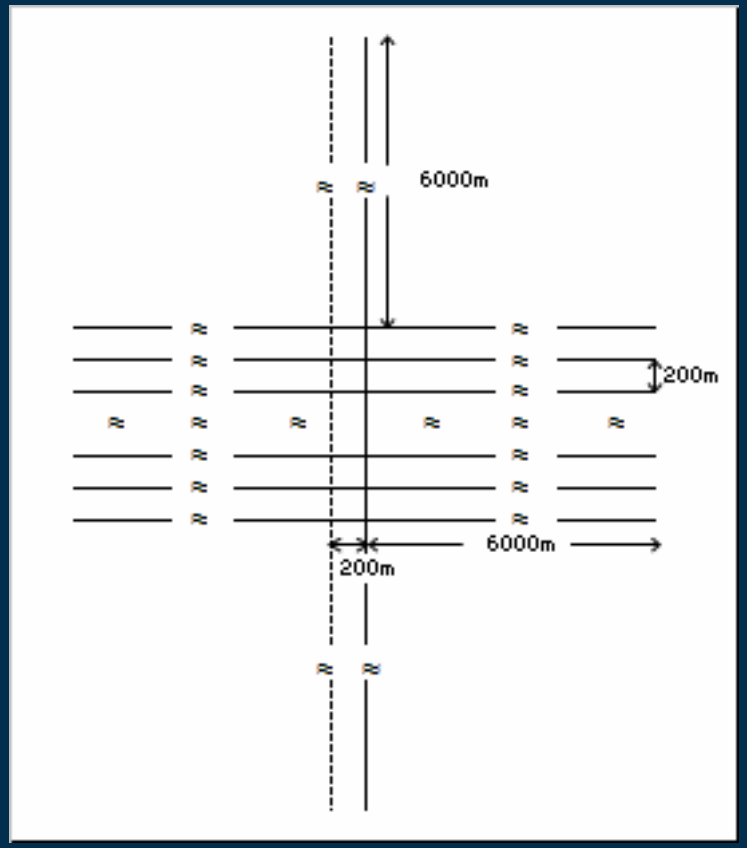
3-D wide-azimuth-swath (WAS) geometry, one line roll, two sets of shots on either side of the acquisition template



*Hastings-James, R., Green, P., Al-Saad R., and M. Al-Ali, 2000, Wide-azimuth 3-D swath acquisition: GeoArabia, **5**, 1003.*

Cross-spread, Full-swath roll

The salvos should extend far outside both sides of the acquisition template to allow recording of the required maximum crossline offset (ideally this should be equal to the required inline offset).



Vermeer, G.J.O., 2002, 3-D Seismic Survey Design: SEG.

Limitations

- Both techniques require repeated shooting of the same shotpoint into different templates resulting in that the nominal design geometry is simulated by more than one data set from one shotpoint location.
- Statics coupling and shot repeatability are issues that should be taken into consideration in acquisition and processing.

Conclusions 1/3

- **In 3D land seismic data acquisition, in spite of the recent advancements, the industry is still facing a challenge to properly sample data in the spatial domain without repeating shots.**

- **One of the major techniques to minimize bias pattern in amplitudes is to reduce the source and receiver line intervals and avoid multi-line roll schemes.**

Conclusions 2/3

- **Repeating shots results in repeatability and static decoupling implications which increase as the shot repeat factor increases.**
- **We need higher channel-count and improved methods to handle the resulting increase in operational difficulty and data volume.**
- **Survey design decisions should continue to consider cost and operational issues. But…**

Conclusions 3/3

- **We should bear in mind that seismic techniques are not only tools for structural imaging. Now they play an important role in reservoir characterization, and in tracking fluid movement and by-passed hydrocarbons.**

- **Proper design decisions with adequate channel-count availability result in much higher value added to the exploration and production companies as well as to the future generations.**

- **We should face the challenge and be prepared to spend more money.**

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THANK YOU

Thanks to:

Kuwait Ministry of Energy

Kuwait Oil Company

Summary of channel-count calculations

	lines	Channels /line post-grouping	Channel/ source spacing	Receiver /shot line spacing	Live channels
Single sensors 1C	**1,720**	**1,720**	**5**	**5**	**2,958,400**
Single sensors 1C	**44**	**1760**	**5**	**200**	**77,440**
Single sensors 1C, (array of 8 sensors)	**16**	**580**	**20**	**200**	**74,240**
Single sensors 3C	**16**	**580(x3)**	**20**	**200**	**27,840**
Conventional, array of 2x6	**16**	**580**	**20**	**200**	**9,280**