GeoConvention
Calgary • Canada • March 7-11 2016
OPTIMIZING RESOURCES

Testing, Testing – A case study of a successful seismic acquisition startup test program in the oilsands.

Sylvestre Charles, Suncor Energy Inc, Anna Leslie, Milka Cotra, Olivier Winter, Forest Lin, Christophe Caille, CGG, C. Jason Criss, INOVA Geophysical, Rod Kellaway, Geokinetics.

Summary

Vibrator Testing is often included as a normal part of the seismic acquisition process. Often the outcome of this testing is not reflected in the acquisition parameters. This case history provides information and examples on how vibrator testing was successfully planned, acquired and processed during an acquisition project in 2015. It will also highlight how the testing provided benefits during the selection of final acquisition parameters for the survey.

Introduction

A 24km^2 vibroseis 3D seismic survey was acquired during the winter of 2015 as the baseline for a future commercial SAGD scheme in the Athabasca oil sands, Alberta. In this area, the McMurray reservoir is at a very shallow depth (around 150m) and has a very complex stratigraphic architecture. To capture all of this complexity, one needs to record a high-resolution survey with an upper frequency of at least 200Hz. To be able to extract accurate rock properties of the reservoir, one needs to record low frequencies that are below 10Hz. A charge of 1/8 kg is often used in the oilsands as it provides the required high frequencies (200Hz and beyond). A vibroseis survey is not only significantly cheaper than a dynamite survey, but new vibroseis technologies provide viable alternatives as a broadband source. Because we required such a large bandwidth, the testing included verification of the frequency range and energy output of the INOVA PLS-326 UniVib which is a 26000lbs peak force vibrator, chosen for this project. The challenging low end of the frequency spectrum was under particular scrutiny. We also needed to assess how much attenuation would affect the upper end of the frequency spectrum and whether we could achieve the desired resolution after the ground response was taken into account. Lastly, vibrators as a surface source have two well-known drawbacks: first, they generate a stronger ground roll than with buried dynamite and secondly, they are unavoidably contaminated by distortion. We therefore needed to assess whether we could attenuate the effects of this distortion in the field.

Test Planning

Initial planning for the tests commenced a few months prior to the acquisition, and required a number of meetings with everyone involved to ensure a smooth execution. Those involved in the field test planning and acquisition included Client Geophysicist, Geokinetics technical & field support, CGG R&D, INOVA Geophysicist and vibrator specialists.

Prior knowledge and data already acquired in similar areas in the past few years meant that some parameters were less likely to change during the testing. This included the number of sweeps per VP and the approximate length of the sweep, as these both would have affected the duration of the survey and budget. However, the testing did allow for these tests to be conducted with a view to how they might influence future acquisition in the area.

The test plan included:

- The vibrator low frequency response with start frequencies of 1.5, 2, 3, 4, 5, 6, 8, 10Hz
- The vibrator high frequency response with frequencies of 200, 300, 400Hz
- Different sweep length: 10, 20, 30, 40 seconds,
- Different drive levels: 30, 40, 50, 60, 70%
- Tapers to minimize the Gibbs effects that can produce side lobes on the data especially at high frequencies when the sweep does not have a long enough taper. The taper lengths were tested with the linear sweeps.
- CGG's custom non-linear low-dwell sweep, "Emphaseis™" sweep on the low and high frequency ends. These sweeps are tailored to stay within the mechanical and hydraulic limitations of the chosen vibrators while maximizing the energy output at both low and high frequencies.
- CGG's custom "CleanSweep™" with Sercel VE464 electronics to minimize the harmonic noise contaminations at the source.
- Interference tests with two vibrators running toward each other along the high resolution 2D line or running with a constant distance separation.

After completing the standing tests, linear and non-linear sweeps were to be compared during multiple acquisition of a high-resolution 2D line. The optimum sweep would be selected and used in production for the 3D survey.

Field Tests

After initial mandatory testing of the equipment, the standing tests were conducted in three separate locations. Making tests in more than one location allows for differences in ground conditions to be ruled out from the test results. Real time analyses of the tests were performed in the field to obtain a basic overview of the ground response. Small adjustments were made to the test program following the response of the vibrators and the data quality observed on the records. A more thorough analysis was conducted overnight every day and summarized in small reports that showed raw shot records, frequency analysis, FK spectrum, RMS plots, etc. to assist with comparing different test results.

Figure 1: 2D test line layout.

The response of the vibrators to different drive levels and for different sweep length were as expected (Figure 2). The vibrator is capable of sweeps from 1Hz to 400 Hz. The test that we performed with a start frequency of 1.5Hz required a very long sweep as well as a very long taper when used with a standard linear sweep. We did not identify any usable signal around that low a frequency however. For a reasonable sweep length (20 seconds), we found difficulty in getting any usable frequencies below 4Hz (Figure 3). We chose therefore to start our production sweep at 3Hz, as this did not require any significant extra time for the sweep. The test with the 200Hz, 300Hz and 400Hz sweeps showed that although the vibrator was able to generate these frequencies, the Earth very quickly attenuated frequencies beyond 250Hz. By design, the survey was limited to 220Hz.

For the linear sweep, although theoretically a 300ms taper should be adequate for a 20sec sweep length, side lobes and some ringing were observed on some records. In order to minimize the Gibbs effect, sometimes caused by not enough taper at the end of the sweep, we decided to increase the taper to 800ms on the low end, and 500ms at the high end of the sweep.

The low-dwell and the harmonic reduced sweep with the vibrator electronics to provide a tailored and customized sweep based on the local ground conditions. The harmonic reduced sweep was of particular interest because of the broadband nature of harmonic noise that contaminates the entire frequency bandwidth. In theory, by canceling the harmonic distortion during the sweep generation, that custom sweep will not only provide a signal-to-noise ratio enhancement over the full bandwidth but it will also minimize the harmonic interference when using slip sweep acquisition. This is of high importance for such a shallow play. Looking at individual shot records to select the optimum sweeps can be misleading: the linear sweep at first glance looked “cleaner” than the low-dwell sweep due to the lack of low frequencies, and less ground roll on the record. We selected five sweeps from the standing test analysis that would be used on the high resolution 2D line.

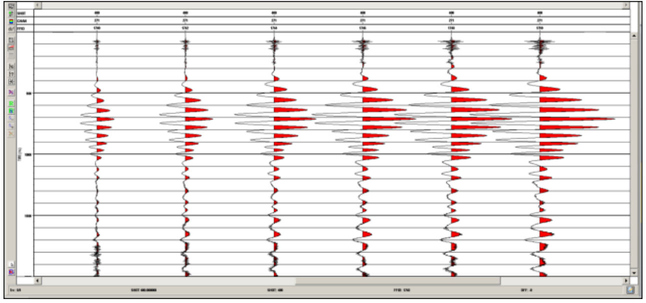

Figure 2: From left to right, 6, 8, 12, 16, 20, 24 seconds sweep length responses.

2D lines

The 2D line was oversampled in both the source (2.5m) and receiver domains (2.5m). This provided almost perfect sampling of the noise and signal produced during the acquisition. As the bin size was so small, spatial aliasing was not a problem. The line was shot “live”, seven times to assess linear and nonlinear sweeps as well as standing and interference tests. We used analog geophones with a 10Hz dominant frequency. The seismic records were all compensated for the inherent -12dB/Octave roll-off of the geophones below 10Hz by inverse filtering. To match the 3D response, the line was decimated at processing. The results of this line do show considerable benefits in quality when compared with the decimation of the 3D acquisition parameters that had a 10m source and receiver spacing. This better quality observed from this line can be directly attributed to a combination of increased trace density/fold and stacking results. The advantages in acquiring an oversampled test dataset allow for decimation during processing to clearly discern how the acquisition parameter selection would affect the final results of processing. Although this is more relevant in 3D tests, the same concept can be used for a 2D test program.

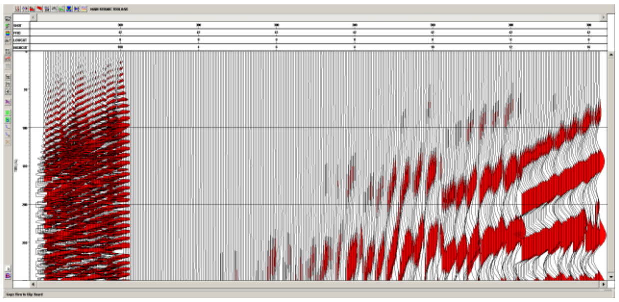

Figure 3: From left to right, reference shot, then 2-4Hz, 4-6Hz, 8-10Hz, 10-12Hz, 12-16Hz frequency panels.

The line was shot with a linear sweep; a linear sweep with harmonic reduction, a custom sweep that emphasizes the low and high frequencies, a custom sweep that combines the harmonic reduction with the frequency content enhancement, a short linear sweep (8s), an interference test with two vibrators separated by 600m and an interference test with two vibrators driving toward each other, The parameters for all the sweeps but one are: 3-240Hz, 20s, low end taper: 800ms, high end taper: 500ms and a drive level of 70%. The reduced harmonic custom sweep was tuned up using the linear sweep. The 8 seconds linear sweep was acquired to observe the effects of half the energy on the final stack.

The differences between the images derived by these sweeps were small but systematic. The custom sweep that emphasized the frequencies on each end of the bandwidth had better frequency content than the linear sweep. Combining the reduced harmonic sweep with the frequency enhancements would have been ideal for production. Unfortunately, we found out through a detailed analysis that the reduction of the harmonics while good in the low and mid frequencies was limited above 150Hz by the electronics of the vibrator controller. Ultimately, we selected a custom sweep (3-220Hz, 20s, 0.8, 0.3) that enhanced the frequency content on both ends of the spectrum for production.

Processing

Fast track processing of the 2D line in a dedicated processing center provided results ready one week after the test was finished. This allowed the client to make a decision based on the final results of both acquisition field processing results, and the more advanced processing conducted in the processing center. When processing test lines such as these, it must be noted that it is important to only change the input parameters. Even if the processing is not perfect, the main aim is to observe the differences caused by the acquisition parameters.

Conclusions

Carrying out a test program at the start of a seismic acquisition survey has been commonplace in many seismic surveys over the past few years. Trying to optimise the parameters for the acquisition is part of the seismic survey design process. However, it is not often that these results are so available and clearly enacted as observed in this case study. The production parameters changed from the planned parameters, but more importantly, the results of the testing indicated that these were the best for the survey area. As a result, this test program was not only essential for improving the acquisition that followed, but also future seismic surveys in the same area.

With careful planning, a seismic acquisition start-up test dataset can be a valuable tool for any seismic program, which can be used for many years to assist with the optimization and planning of parameters and operational aspects of the seismic acquisition process.

Acknowledgements

We would like to thank the following people and organizations: Suncor Energy Inc. for the permission to publish these results, all of those at Geokinetics, CGG, INOVA, Lorrnel, who helped with this project, Peter Maxwell for fruitful discussions.

Disclaimer

Suncor Energy Inc. and its affiliates (collectively "Suncor") do not make any express or implied representations or warranties as to the accuracy, timeliness or completeness of the statements, information, data and content contained in this presentation and any materials or information (written or otherwise) provided in conjunction with this presentation (collectively, the "Information"). The Information has been prepared solely for informational purposes only and should not be relied upon.