AN EFFICIENT APPROACH TO SHALLOW HIGH-RESOLUTION SEISMIC DATA ACQUISITION: PRELIMINARY RESULTS

Michiel van der Veen, Frank Lehmann, Peter Wild and Alan Green

ETH-Swiss Federal Institute of Technology, Institute of Geophysics, ETH-Hönggerberg, CH-8093, Zürich, Switzerland, email: michiel@augias.ig.erdw.ethz.ch

INTRODUCTION

High-resolution reflection seismic techniques are powerful tools for mapping shallow geological structures (Steeple and Miller, 1990; Lanz et al., 1996). During the past decade, the quality of seismic data has improved significantly. This improvement can be ascribed to a better understanding of shallow seismic techniques and significant developments in technology. These advances not only have improved the data quality and increased the ability to record very high-fold data, but they also have increased significantly the logistical complexity of a typical shallow seismic survey; many more geophones now have to be planted and higher shot densities are required.

In light of this, the ETH-Zürich has initiated a project to increase the efficiency of high-resolution seismic profiling techniques, with the principal goal to markedly decrease the effort, field time and costs of shallow surveys. As an initial step in this direction, we report here the preliminary results of employing a new towed land streamer for high-resolution seismic applications.

TOWED LAND STREAMER

Accurate determination of geophone and shot locations and the planting of large numbers of "standard" spiked geophones are time consuming and costly aspects of seismic data acquisition. To increase efficiency, the concept of a snow streamer, which has successfully been employed in snow covered areas (Eiken, 1989), is being adapted for solid land applications. A multiple 96-channel seismic cable has been specially designed and is in the process of being manufactured for this purpose. It will consist of 96 takeouts at 1-meter intervals. The seismic cable, or land streamer (Fig. 1), is to be pulled by an all terrain vehicle. A kevlar outer casing, that increases the strength of the cable will help prevent the cable from being damaged as it is pulled across rugged ground.

For mobility reasons, the land streamer will be divided into interchangeable segments, each with 12 takeouts. The individual segments will be connected to each other via waterproof marine connectors. The takeouts can be connected to either standard spike geophones or to self-rotating gimbal geophones. Gimbal geophones, originally designed for use in swamp areas, have the advantage that they don't have to be "planted".

Figure 1: Schematic illustration of a land streamer to be pulled by an all-terrain vehicle. The land streamer comprises segments, each with 12 gimballed geophones.

TESTS OF GEOPHONE TO GROUND COUPLING

A critical issue in the innovative land streamer concept is the geophone-ground coupling. Gimbal geophones have the potential to record high-quality data only when the seismic wave field can be recorded with minimal distortion in the frequency range of interest. (up to 500 Hz). Various coupling experiments have been performed to test the quality of the recorded wave field. At a test site in Zürich (Switzerland), 30 Hz spike geophones were planted alongside 6 gimbal units with identical 30 Hz velocity sensors. Two typical results from these experiments are shown in Figures 2 and 3. In Figure 2, the response of a 30Hz standard geophone is compared with the response of a 30 Hz gimbal geophone that is poorly "planted" alongside the standard geophone. There are major phase and amplitude differences between the responses. In contrast, Figure 3 shows the results when the gimbal geophone is planted in a small ditch. Phase and amplitude changes have been significantly reduced. Note that minor differences in geophone response may be due to very local variations in near-surface conditions and differences in electro-mechanical characteristics of the individual sensors, but these are likely to be small compared to the effect of ground coupling.

Figure 2: Results of ground coupling comparisons between 30Hz spiked (dashed line) and poorly planted 30Hz gimbal geophones (solid line). (a) shows typical recorded traces. (b) displays the equivalent amplitude spectrum of the two traces. (c) shows the phase difference between the responses of the two geophones

Figure 3: Equivalent to Figure 2, but with the gimbal geophone laid in a small ditch.

The positive results of the coupling experiments show that gimbal geophones have the potential to record high-resolution seismic data if they are in good contact with the ground. This contact can be achieved by housing the sensor in a heavy robust outer shell with a smooth surface and by laying the geophone in a small ditch.

FIELD EXAMPLE

In order to compare data recorded with gimbal geophones with those recorded with "standard" geophones, two short coincident seismic reflection profiles have been recorded in the Reuss delta, central Switzerland. The geology in the Reuss delta is dominated by braided river deposits, overlying lacustrine sands and clay. The ground water table is at ~0.7 to ~3 meters. Two nominal 18-fold reflection surveys have been simulated with 6 spike and 6 gimbal test geophones. Detailed recording parameters are given in Table 1.

Figure 4a shows a typical shot gather recorded with standard 30 Hz geophones. Figure 4b shows a shot gather recorded at the same location, with the gimbal units. The shot records are practically indistinguishable.

The two data sets have been processed with the same parameters. Processing included trace editing, first break top mute, air blast attenuation, time-variant spectral whitening, CMP-sort, velocity analysis, NMO correction, stack, and display with an AGC (100 msec).

As for the shot gathers, the spike- and gimbal geophone sections match very well (Figure 5). On the basis of information from a bore hole, approximately 2 km of the seismic survey, the first strong reflector (200-250 msec) is interpreted as the boundary between outwash gravel deposits and fine sands. The basement is interpreted as the strong reflection at approximately 500-600 msec.

Table 1: Recording parameters for a high-resolution seismic reflection profile in the Reuss Delta

Source type	Shot gun
Source offset	2 m
Receiver spacing	2 m
# geophones	2 × 6
Geophone type	30 Hz, spike/gimbal
Sample rate	0.250 msec
Nominal fold	18
Total length	210 m

Figure 4: Two typical shot gathers recorded in the Reuss delta. The left record was recorded with "standard" spike geophones and the right one with gimbal geophones. The raw data have been scaled with a single individual scaling factor for each trace.

CONCLUSIONS

Preliminary results have demonstrated the potential of towed land streamers with self-rotating gimbal geophones as a means of efficient high-resolution seismic data acquisition. Housing the sensor in a heavy casing that is laid in a small ditch behind the towing vehicle seems to solve the coupling problem. This ditch was simulated in the 18-fold test reflection survey. Due to good coupling, the survey matches very well with the traditional spike geophone survey.

Success of this system may depend on the surface conditions (e.g. the presence or not of trees, slopes, railroads etc.). Despite these limitations, it is expected that in many cases the acquisition time and costs can be decreased dramatically. Over the next two years, the acquisition system will be expanded to include an automated positioning unit (GPS/theodolite) and a fast high-frequency energy source.

ACKNOWLEDGEMENTS

We gratefully acknowledge the valuable discussions with Heinrich Horstmeyer (ETH) and Pete Maxwell (SENSOR Nederland bv), and the technical support of Christoph Barlöcher (ETH). The seismic data has been recorded with a 120-channel BISON Jupiter acquisition system. This research is funded by the Jubilee Fund of the ETH-Zürich.

REFERENCES

- Eiken, O., Degutsch, M., Riste, P. and Rod, K., 1989, Snowstreamer: an efficient tool in seismic acquisition: *First Break*, 7, 374-378
- Lanz, E., Pugin, A., Green, A.G. and Horstmeyer, H., 1996, Results of 2- and 3-D high-resolution seismic reflection surveying of surficial sediments: *Geophysical Research Letters*, 23, 491-494
- Steeple, D.W., and Miller, R.D., 1990, Seismic reflection methods applied to engineering, environmental and groundwater problems: *Geotechnical and Environmental Geophysics v. I*, edited by S. Ward, Soc. Expl. Geophys., Tulsa, Oklahoma, 1-30

Figure 5: Two seismic reflection data sets, recorded simultaneously at the same location. The top section was recorded with standard spike geophones, whereas the bottom section was recorded with gimbal geophones.