Acquisition instrument performance from the Blackfoot broadband survey

Malcolm B. Bertram

ABSTRACT

An investigation of some shots from the Blackfoot broadband survey shows good signal resolution, and readily extractable data beneath the shot generated noise. A bit usage algorithm is demonstrated as an excellent quality control method for checking survey parameters.

INTRODUCTION

This study is to determine the ability of the 24 bit system to accurately record geophone output over a wide dynamic range, and whether there is substantial data loss on the near offset traces due to clipping and shot generated noise. The survey also provides a good opportunity to make some comparisons between different geophones and preamp gains.

The data used is from the Blackfoot broadband survey acquired by CREWES in July 1995. This survey was designed to record geophone signals to 0Hz (DC) and compare different type of geophones. The recording instruments were GEO-X Systems Ltd. ARAM-24 with a software switch used to remove all low frequency filtering from the system. Details of the survey are presented elsewhere in this volume.

Only a few of the records from the survey are used. Some of the first few records from the test shots are briefly examined, and the records from shot point 198 are analysed and compared. To date, only the 2Hz vertical component, the 10Hz strings and the 10Hz vertical component have been investigated in any depth. The records used are from the raw data set; this is the actual analog to digital converter output, sampled at 1.667 msec. This raw data set was recorded simultaneously with the resampled 1 msec output used for other processing.

PERFORMANCE

Bit usage

This first section involves an investigation of the analog to digital converter in the acquisition system. As a start the 2Hz vertical component records from the test shots were examined for clipping. These records were chosen because they exhibit the highest amplitudes of all the geophones. The record to be examined in detail here is file 5. The shot specifications are 6Kg at 18m; the same as the production shots for the rest of the survey. This shot was recorded at a high preamp gain, and shows clipping on the near offset traces. As can be seen in the wiggle trace display of the near offset traces for this shot (Figure 1) several traces exhibit "flat topping". A closer look at these clipped regions shows that the sample values are not constant, but do vary slightly, around a value of 5,700,000. The difference between the absolute values of the positive and negative clipped regions can be as much as 100,000.

To facilitate analysis of these records, a "bit count" algorithm was developed. The number of bits of the analog to digital converter occupied by the signal for each sample is determined, and the output plotted in colour with the following changes made to the colour map to highlight the areas of interest:

- where the preamp in the acquisition system is clipping the signal, the colour of the sample is white.
- when the analog to digital converter is running at just below this clipped level, the colour of the sample is black. This indicates where the preamps may be starting to exhibit non-linearity.

The clipping level value was determined from both the original manufacturers data sheet for the analog to digital converter and from analysing sample values on several of the records.

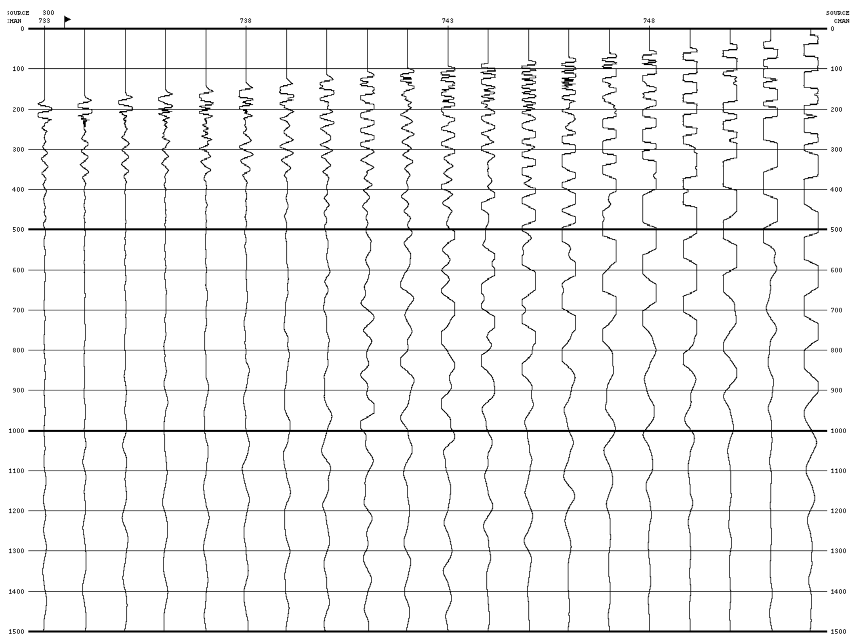

Figure 1. File 5 near traces showing the clipping on the traces closest to the shot. (2Hz vertical)

Modulator Input Signal	Output Hex	Output Decimal
Approx +16V	7FEFFF	+8384511
approx +11V	57FFFF	**+5767167**
approx +10V	4FFFFF	+5242879
0V	000000	0
approx −10V	B00000	−5242880
approx −11V	A00000	**−5767168**
approx −16V	800000	−8388608

Table 1. Analog to digital converter values

From Table 1 the value at about 11 volts input can be compared to the sample values on a record. Since the preamps are operating with plus and minus 12 volt supplies, clipping can be expected at about the 11 volt level. The maximum input of 16 volts to the analog to digital converter can never be reached. The value chosen to represent a clipped signal was 5,600,000, slightly lower than the figure in the table, but necessary to allow for the differences between the positive and negative clipping. File 5 is shown in this colour format in Figure 2. More detail is shown in an expanded view of the near offset traces in figure 3. This is representative of the shots recorded at high preamp gain (48db). For the production shots on the rest of the line, the preamps were operated at low gain (24db), considerably reducing the amount of clipping. An example of a low preamp gain record (file 7, shot location 298) is shown in Figure 4, with the near offset detail in Figure 5.

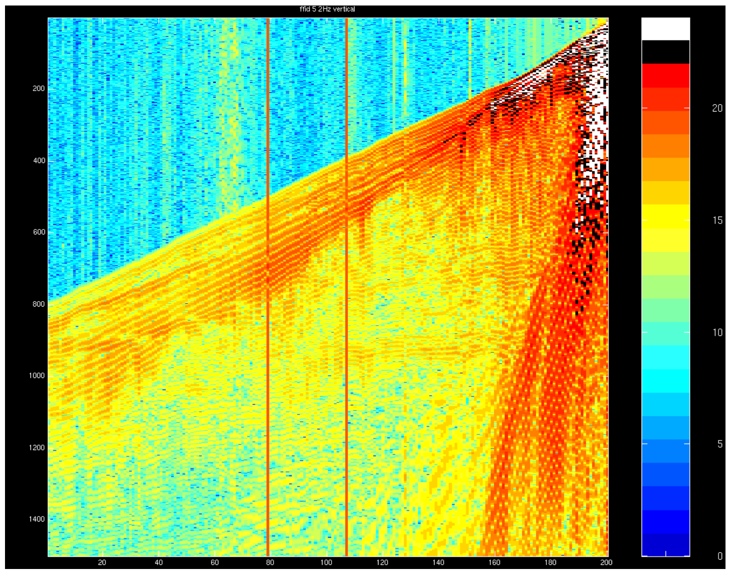

Figure 2. File 5 shown in bit usage colour format (2Hz vertical)

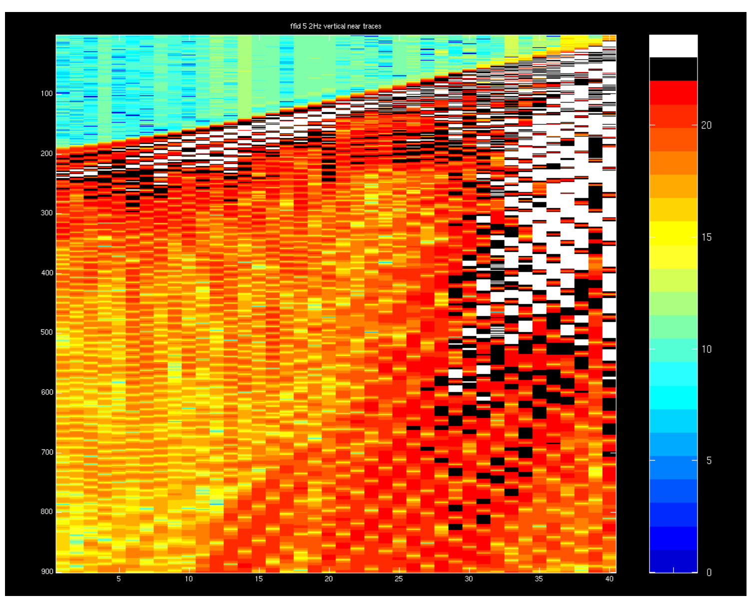

Figure 3. Plot of near traces of file 5 (2Hz vertical)

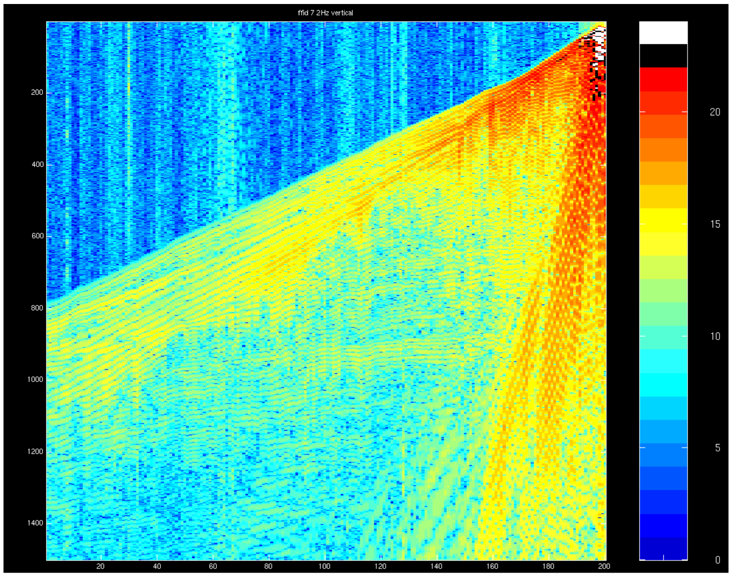

Figure 4. Bit usage plot of file 7 (2Hz vertical)

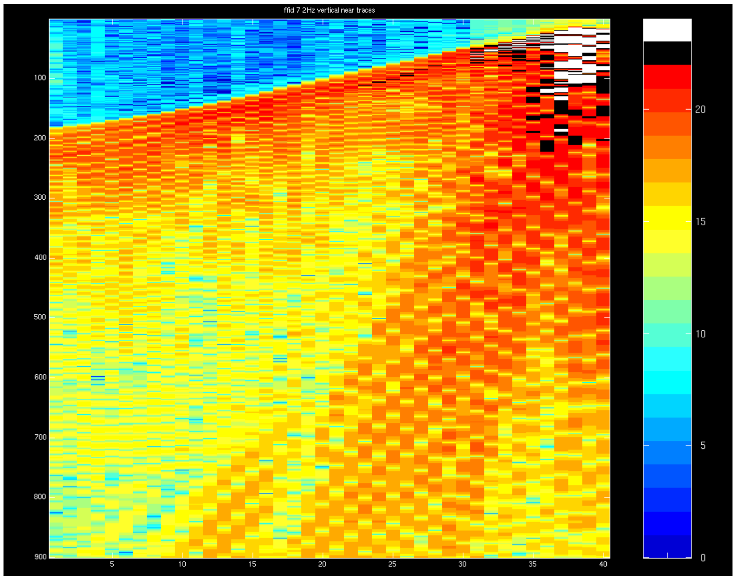

Figure 5. Near traces of file 7 (2Hz vertical)

Moving to the record from shot location 198 (File 101) it is apparent that the clipping is similar to the level shown on File 7 (Figure 6 with detail in Figure 7). This shot is the one used for further analysis in the following section.

A few records from the 2Hz radial spread were also checked, and these show considerably less clipping than the vertical component. The 10Hz records show only a few samples clipped on the 2 or 3 nearest traces.

From these colour displays, it is apparent that all the clipping occurs in an area of the record that is normally muted. Outside this section the available resolution of the instruments should be fully available for processing.

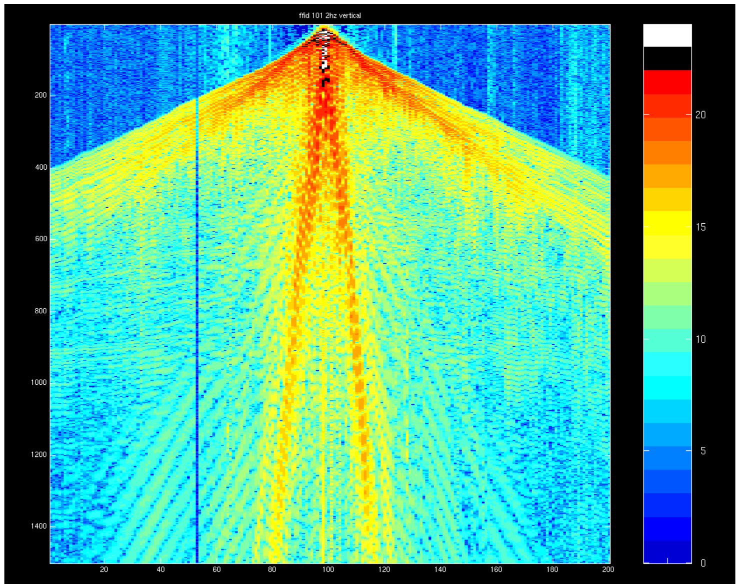

Figure 6. Bit usage plot of file 101 at shot location 198 (2Hz vertical)

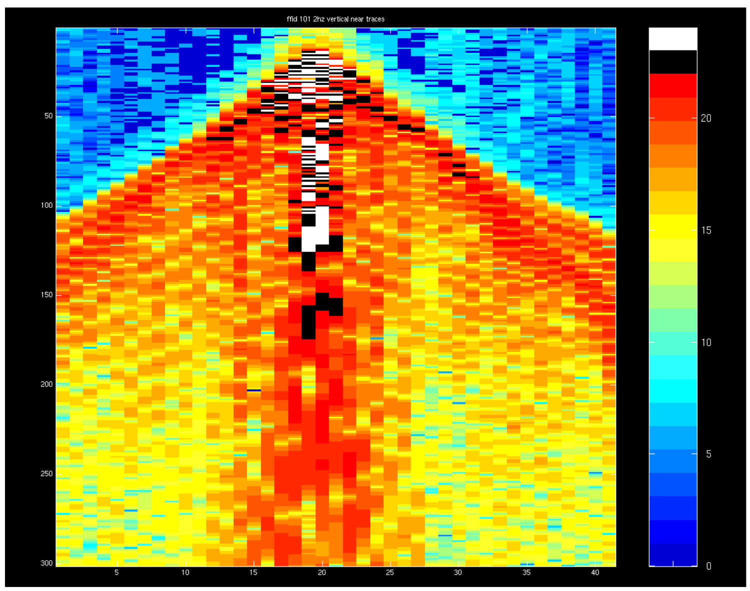

Figure 7. Near traces from file 101 (2Hz vertical)

Data recovery

As well as showing the portions of a record where data is unrecoverable, these colour plots provide a direct indication of the number of bits occupied by signals of interest i.e. the amplitude resolution of reflection energy.

For this part of the study, records from shot location 198 (file 101) were used. From a plot of the 10Hz strings at this location (Figure 8) the reflection energy between 1 and 2 seconds is clearly defined, occupying about 10 to 12 bits of the converter. This signal has excellent resolution, and should be readily extracted from beneath the shot generated noise on the near offset traces. This plot also shows that there is considerably less clipping on these geophones than was apparent on the 2Hz spread shown earlier.

In fact the clipped region occurs only on the nearest 4 traces, and for the first 50 samples only (Figure 9).

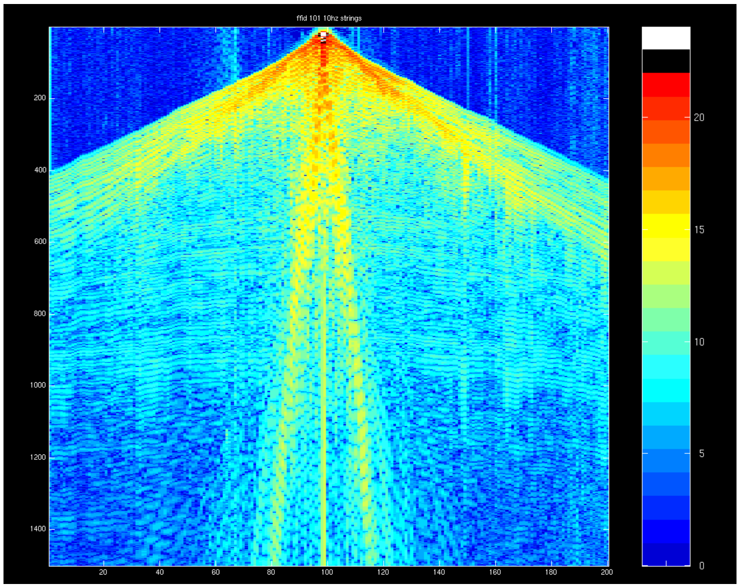

Figure 8. Bit usage plot of file 101 (10Hz strings)

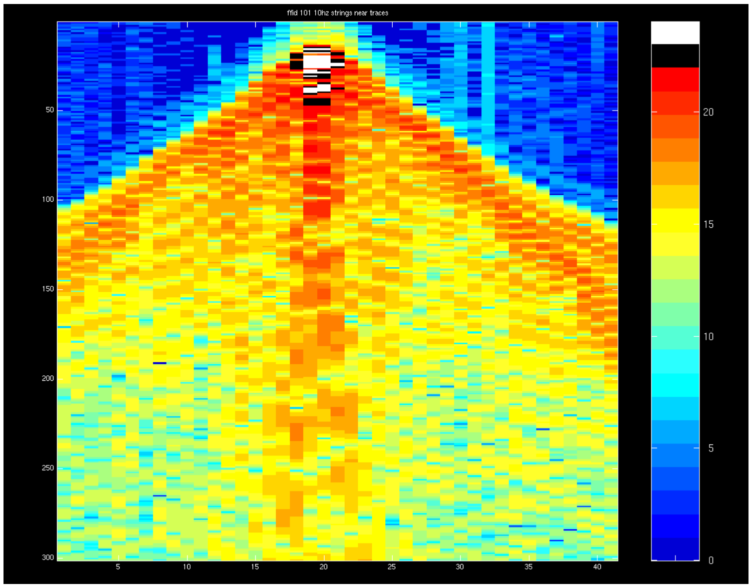

Figure 9. Near traces of file 101 (10Hz strings)

There are several methods available for data extraction from noise which preserve the full bandwidth of the signal, but for simplicity in this study a bandpass filter of 15-20-50-100 was applied.

For the 10Hz strings the output shown in Figure 10 was obtained. The reflection energy is clearly coherent across the record, with similar amplitude resolution on all traces.

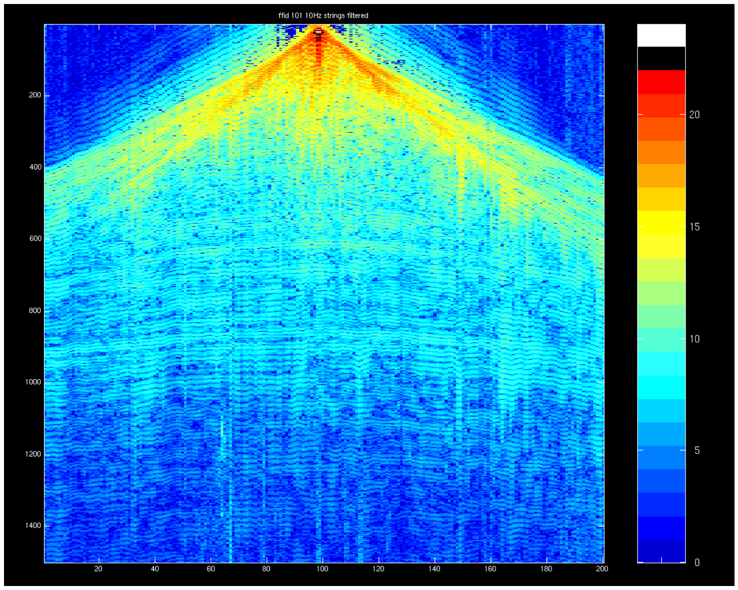

Figure 10. File 101 (10Hz strings) filtered 15-20-50-100 Hz

This same process was applied to the 2Hz vertical component and the 10Hz vertical component with the results shown in Figure 11 (2Hz) and Figure 12 (10Hz vertical single). The 2Hz vertical component has noticeably higher amplitude than the 10Hz as indicated by the shift in colour on the plots. The 10Hz vertical component is almost identical to the 10Hz strings in amplitude, although reflection coherency appears slightly reduced.

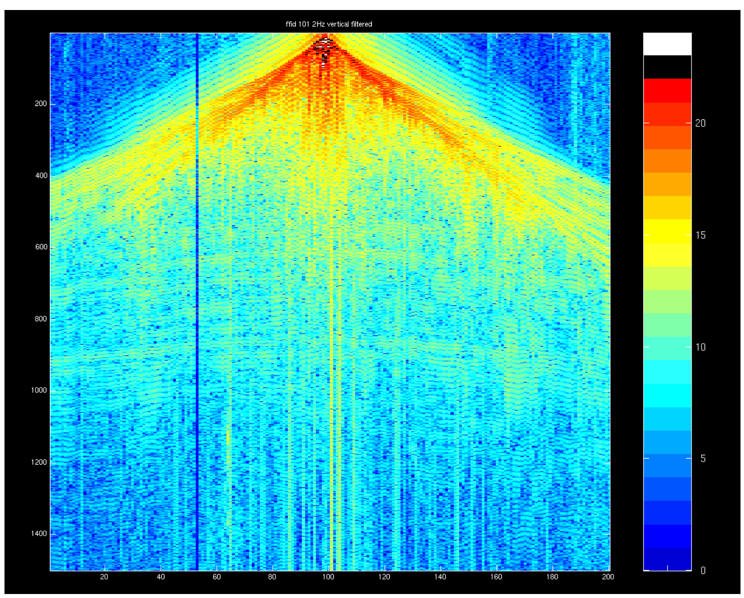

Figure 11. File 101 (2Hz vertical) filtered 15-20-50-120 Hz

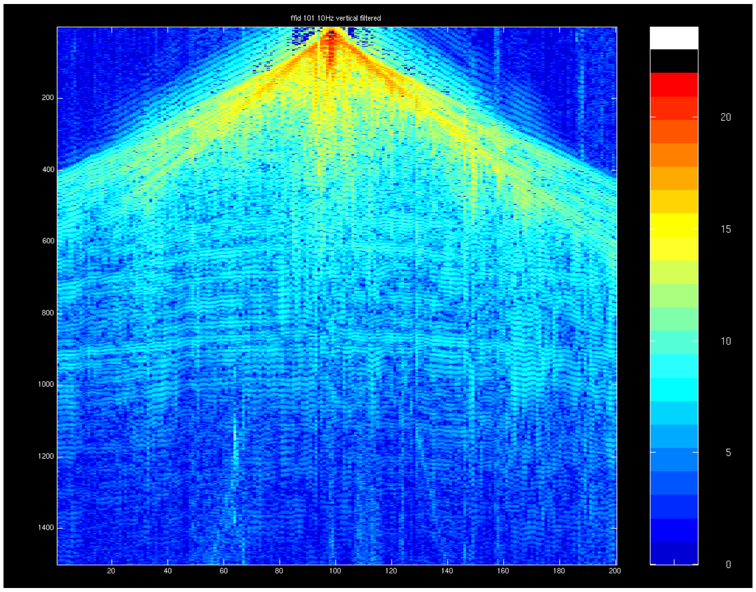

Figure 12. File 101 (10Hz vertical) filtered 15-20-50-100 Hz

CONCLUSIONS

Several decisions regarding the design of this survey had to be made with minimal information on parameters such as geophone output levels. The chosen parameters prove to be almost optimal for maximum available resolution. There is some clipping from shot energy on the nearest traces, but it does not occur in areas where data would be damaged.

The bit usage algorithm provides a direct and simple quality control output to check on instrument performance and to optimise recording signal levels.

Because there is not the "push down" effect in the 24 bit systems that existed in the previous Instantaneous Floating Point systems the desired reflection energy is recorded under the shot generated noise with no loss in resolution. Extraction of this energy is therefore possible without loss of character.

ACKNOWLEDGEMENTS

GEO-X Systems Ltd of Calgary for modifying the acquisition software used in the Blackfoot broadband survey to allow recording of all frequencies to 0Hz.

Henry Bland of the CREWES project for assistance in developing the bit usage algorithm and installing it as a module in the ProMAX processing system.