Designing Seismic Surveys for Reduced Environmental Impact

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SUMMARY

Exploration and production projects, whether for oil and gas, mining, or clean tech applications such as carbon capture and storage, typically begin with the acquisition of seismic data. Generally, these surveys involve optimizing the geometry for surface constraints and operational efficiencies. However, an equally important aspect is to optimize the geometries for reducing environmental impact. Finding the balance between reducing the environmental impact, optimizing costs, and maximizing data quality can be challenging.

Sensitive animal habitats can be drastically affected by seismic survey, and the data quality can be negatively impacted by avoiding these areas. In this paper, a variety of data sets were used to understand ecosites, sensitive animal habitats, calving grounds and vegetation to rank the sensitivity of each area. Unique linear geometries were created to reduce the environmental footprint while still maintaining data quality. Results demonstrated that data quality could be maintained with up to a 55% reduction in linear km of seismic cutlines and equivalent reductions in greenhouse gas emissions. These geometries also resulted in cost savings from fewer linear km of cutlines and lower personnel requirements. Implementing linear geometries changes the way that seismic surveys are designed and depending on the scenario, these novel geometries can be applied to a whole survey area, or they can just be used in more sensitive areas to reduce the environmental impact.

Key words: Seismic Acquisition, Survey Design, Reduce Environmental footprint, Reduce Greenhouse Gases

INTRODUCTION

Seismic exploration requires clearing of trees and shrubs along seismic lines to ensure safe access for equipment deployment. (Crook et. al, 2019) These cutlines can result in the disturbance of animal habitats in environmentally sensitive areas. These surveys are typically conducted in an orthogonal pattern which results in a footprint that disturbs 10-25% of the total program area. In a forested area, the cutlines fragment the forest which creates an imbalance in the predator and prey dynamics. These cutlines, and the equipment used for seismic acquisition activities, create emissions that can also result in the loss of canopy, soil compaction and a higher water table, leading to elevated methane emissions (Strack et al., 2019) and increased greenhouse gas emissions. These emissions are in addition to those associated equipment used for deployment of sources and receivers.

Some proposed solutions to reduce seismic acquisition land footprints are flying equipment in with a helicopter, utilizing alternative sampling theorems to reduce the amount of equipment needed, and miniaturizing seismic equipment (energy sources and/or receivers). Individually, these solutions can provide benefits, such as reduced line widths and less overall cutting of the boreal forest, but forest fragmentation due to interconnected seismic lines remains a problem. (Vermeulen et al., 2022) Additionally, in areas without forest cover, other environmental restrictions such as sensitive species and habitats may require a geometry with a lower land footprint. By moving to linear type geometries, the land footprint associated with seismic can be reduced, but specific source and receiver distributions and additional processing will be required to maintain sufficient subsurface resolution.

Seismic surveys need to be customized to meet the needs of the study area. Environmentally sensitive areas can be identified as animal habitats, or specific ecosites that are home to vegetation that is slow to regrow. By incorporating linear geometries, seismic surveys can be modified such that there is a reduced environmental impact on specific ecosites while still optimizing data quality.

METHOD

In this study, a very densely acquired (grid) seismic dataset (Figure 1.a) was decimated to create 20 different orthogonal and linear geometries. The decimation involves processing the grid dataset up to migration and then removing sources and receivers to create a new geometry. The remaining data is then interpolated and migrated to create the new volume which can then be interpreted and compared back to both the grid and conventional orthogonal geometries. The focus of changing the survey design was to reduce the overall environmental footprint of the survey by decreasing the number of linear kilometres covered which, in turn, will decrease costs. The traditional orthogonal survey (Figure 1.b) with 60m line spacing and 20m station spacing was used as a reference to compare data quality.

Preliminary processing of the decimated geometries included AVO-compliant pre-stack time migrations. From the 20 decimated volumes, 12 geometries provided positive results. This paper will focus on two linear geometries that had the best imaging results. The first linear geometry survey (Figure 1.c) is a sinusoidal survey with 80m line spacing. The second linear geometry survey (Figure 1d) consists of zigzag lines where each adjacent line is spaced 60m apart.

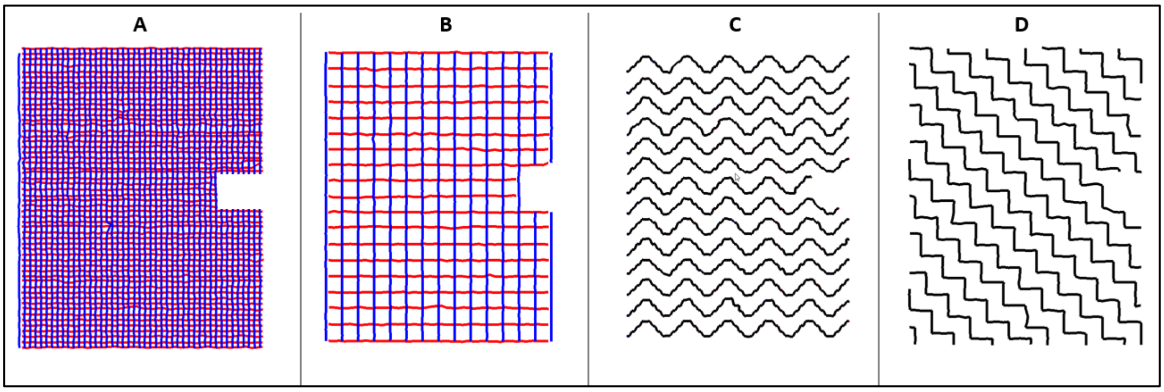

Figure 1: A: Densely acquired seismic data that is decimated into B: orthogonal, C: sinusoidal, and D: zigzag geometries, respectively. The red lines indicate source lines, blue lines indicate receiver lines and black lines indicate both sources and receivers on the lines.

RESULTS

By using linear geometries, the number of linear kilometres of cutline is reduced which reduces the land footprint and provides cost savings. Depending on the terrain, this can mean fewer trees cut and the reduction of soil compaction. This leads to decreased equipment costs, less operational time, and a reduction in greenhouse gas emissions. According to table 1, both the sinusoidal and zigzag geometries reduce the linear km of cutlines required by about 50%.

Percent Reduction Relative to Orthogonal B	C Sinusoidal	D Zigzag
Seismic Trace Density	45%	0%
Linear km of Source Lines	50%	51%

Table 1: Reduction of land footprint of linear geometries verses orthogonal. The letters refer to the geometries shown in Figure 1.

Time slices, frequency slices and acoustic impedance results were compared between the different geometries as seen in figure 2. The results of the well sampled geometry (figure 2a, 2e and 2i) and of the traditional orthogonal survey (figure 2b, 2f and 2j) were compared to the sinusoidal geometry (figure 2c, 2g and 2k) and zigzag geometry (figure 2d, 2h and 2l). These results showed that there were some variations in resolution, but the alternative linear geometries have comparable results to that of the orthogonal geometry.

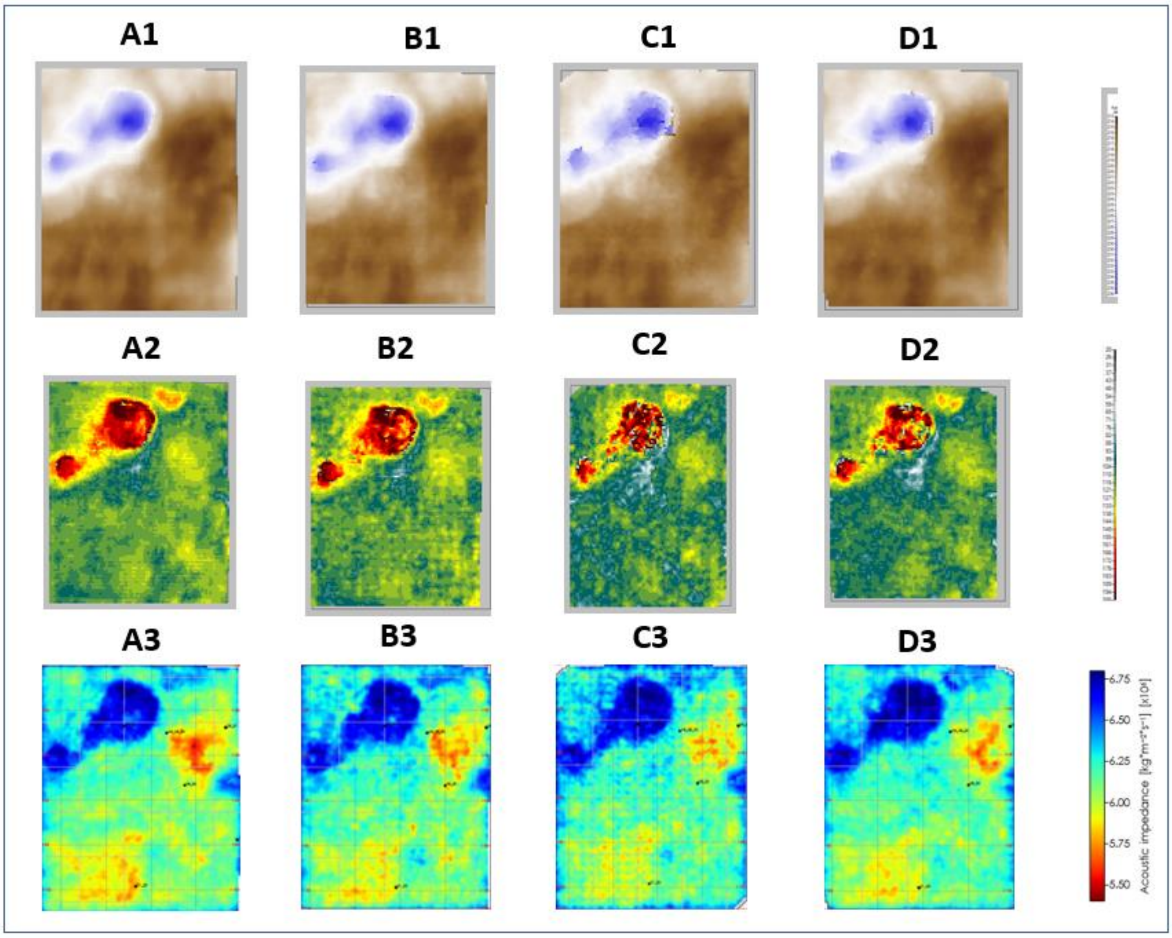

Figure 2: The A column refers to the densely sampled grid, B refers to the orthogonal survey, C refers to the sinusoidal geometry, and D for zigzag geometry. The first row are AVO-compliant processing results of time slices, the second row relates to instantaneous frequency slices and the third row are acoustic impedance results.

DISCUSSION

As linear geometries have a reduced environmental footprint, they can be used in conjunction with traditional orthogonal geometries to optimize data quality while reducing impact on sensitive areas. These sensitive areas can include endangered animals, sensitive animal habitats and endangered or sensitive vegetation. Another factor to consider is that in areas with specific types of vegetation, it can take much longer to regrow (van Rensen et. al., 2015). Ecosites classify land based on soil type and site conditions that represent certain ecosystems and can differentiate areas with different regrowth rates. Figure 3a below is a map with different ecosites represented by different colours. Figure 2B shows the concentration of sensitive animal habitats in the different areas. With these two sets of data, areas were ranked based on the sensitivity of the area to produce final map in figure 3c. Green symbolizes areas with ecosites with fewer sensitive animal habitats and a faster regrowth rate of vegetation. Red symbolizes area with sensitive animal habitats and vegetation that can take more time to regrow. This information can provide insight into areas where the unique linear geometries could be utilized to reduce the impact of surveys in the specific area.

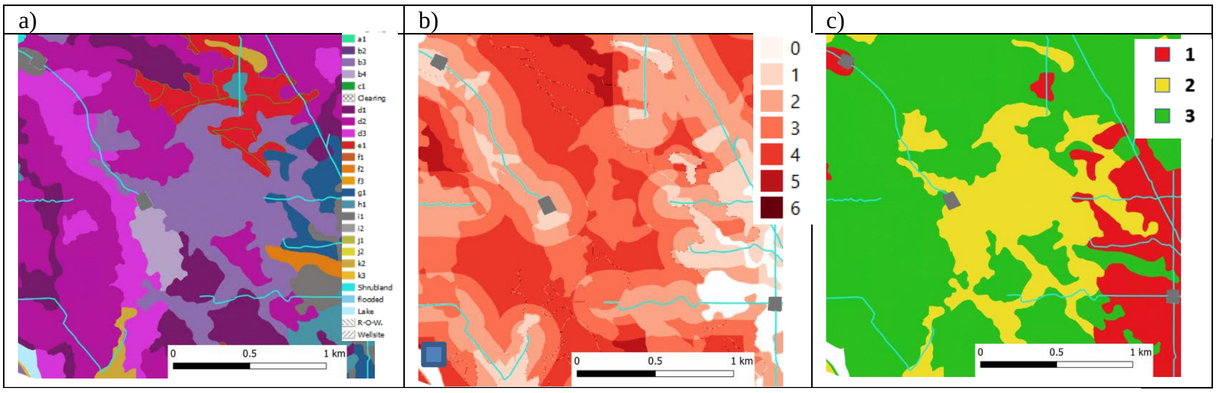

Figure 3: a) map depicts ecosite data, each ecosite is symbolized by a different colour. b) map depicts the number of animal habitats in the area. The darker red indicates more animal habitats. c) map depicts the rank of area based on sensitive animal habitat locations and types of ecosites. The colour represents a rank of sensitivity. One being the most sensitive area and 3 being the least.

One approach to utilize the map created in figure 3 is to utilize a combination of different geometries. Figure 4 illustrates the zigzag geometries in the sensitive areas in purple. These lines are designed to seamlessly merge with the traditional orthogonal geometry that is designed over the rest of the survey area.

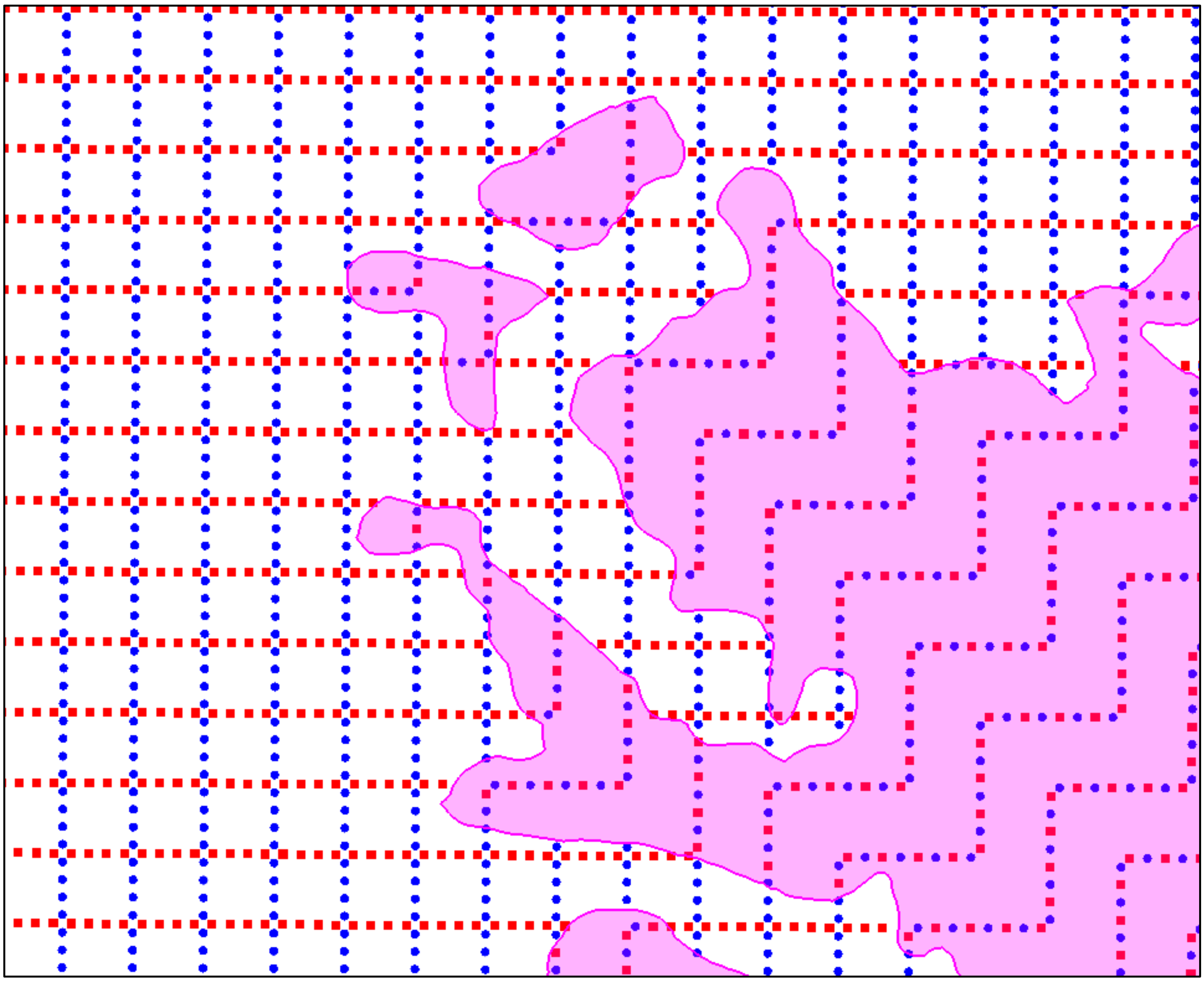

Figure 4: Sensitive areas are symbolized in light purple. The zigzag geometry with a smaller footprint is deployed in the purple areas. Source stations are red, Receiver stations are blue.

CONCLUSION

Linear geometries such as the ones showcased in this study provide a new way to acquire seismic data while reducing the environmental land footprint by up to 55%. This can significantly reduce tree cutting, reduce impact to animal habitats and costs. The quality and trace density of these geometries are comparable to that of the traditional orthogonal survey. These geometries can be applied to environmentally sensitive areas to have a reduced impact to the environment in comparison to the traditional orthogonal survey while still imaging targets clearly. The next step is to conduct a full-scale field test to evaluate the operational efficiencies, processing algorithms and resulting data quality of these linear geometries.

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