Innovative Uses of LIDAR Technology to assist in the Remediation of former Coal Mine Sites

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Abstract The Sydney Coalfield has been mined for more than 300 years and the legacy of this mining activity is a series of abandoned underground mines. DEMs constructed from Lidar data have assisted with the remediation at the former mines sites by revealing mining induced subsidence features that were not readily apparent through traditional methods. Typical features that can be observed on the DEMs include areas of subsidence over shallow mine workings, depressions over former shafts and bootleg mining near the coal seam outcrops. In addition, from the Lidar data, very precise topographic maps can be constructed which when used with the DEMs and mine water elevation information can help identify potential mine water discharges sites.

Key Words Lidar, remediation

Introduction

The Sydney Coalfield has been mined for more than 300 years and over 100 underground mines have extracted in excess of 350,000,000 tonnes of coal. The legacy of this mining activity is a series of abandoned underground mines. Public Works Government Services Canada (PWGSC) on behalf of Enterprise Cape Breton Corporation (ECBC) is in the process of remediating the former mine sites. Early in the remediation process several important issues were identified that could pose health and safety and environmental concerns. Two of the concerns are: 1) The identification of unstable ground and mine openings that could potentially fail during and after site remediation; and 2) The identification of potential locations where acid mine water might discharge and enter the environment in an uncontrolled manner. Lidar technology was utilized to assist in addressing these concerns.

Methodology

Lidar is an acronym for “light detection and ranging.” In the mapping industry, this term is used to describe an airborne laser profiling system that produces location and elevation data to define the surface of the earth and the heights of above-ground features.

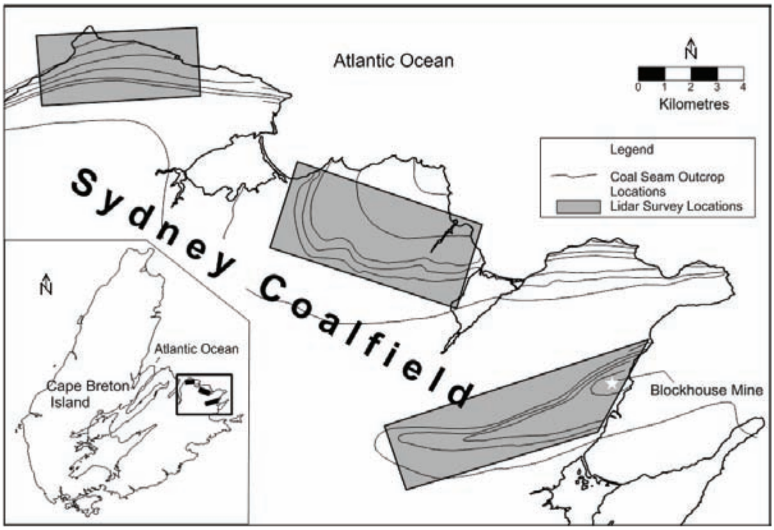

***Figure 1** Location map showing the Sydney Coalfield and Lidar Survey Areas*

On June 16, 2008 a Lidar survey was flown over Sydney Coalfield on three designated study areas (see Figure 1). This survey was conducted by Terrapoint Canada Inc. for the Applied Geomatics Research Group (AGRG), under contract to Conestoga-Rovers & Associates (CRA). After Terrapoint performed basic processing, all Lidar point data was sent to AGRG to be processed, classified and validated.

The data processing procedure included tiling the three large Lidar data sets into smaller (approximately 1 square kilometre) "tiles" thus making the data more manageable. Each tile has approximately 1,000,000 data point locations or essentially one data point every metre on an X and Y grid. The processing also classified each data point as either "ground" or "non-ground". In addition, AGRG conducted a data validation procedure to determine the accuracy of the Lidar point data. A high precision field GPS survey was conducted and the Lidar data was statistically compared to the field survey results. The comparison showed a mean difference in height of approximately 0.02 metres with a standard deviation of 0.04 metres (Webster & Roik 2009). Of interest to this study is the "ground data points" where trees, vegetation, and manmade structures have been edited out. The tiled "ground" data sets were provided to CRA as "text files" in XYZ format.

The XYZ files for areas of interest were imported into Surfer software where the data was gridded to create Digital Elevation Models (DEMs) or in this case they are also known as "bare-earth" shaded relief maps. For orientation the DEMs were digitally superimposed over geographic maps and mine plans.

To highlight subtle topographic features in the DEMs, the orientation of the artificial light source was adjusted horizontally and vertically. The vertical scale of the topography was also exaggerated which has the affect of enhancing the shading from the artificial light.

Figure 2 *Traditional aerial photograph of Lidar survey area*

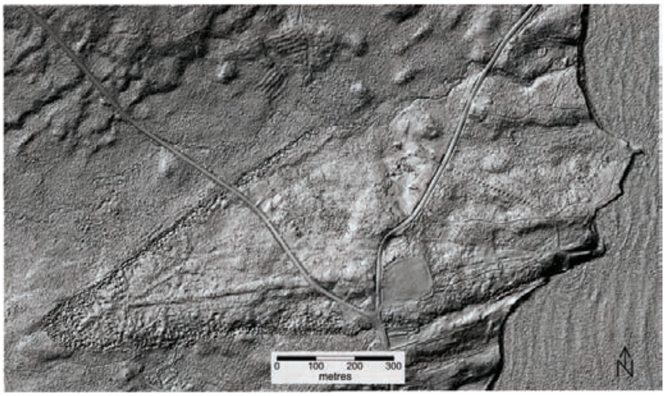

Figure 3 *Digital Elevation Model (DEM) created from Lidar survey data*

Results

The DEMs showed mining induced subsidence features that were not readily apparent through traditional methods such as air photography. Typical features include areas of subsidence over shallow mine workings, depressions over former shafts and bootleg mining near the seam outcrops. The following sections describe these features in more detail.

Are as of subsidence over shallow mine workings

Figures 2—5 provide representative examples of where DEMs created from Lidar data show mining induced subsidence features. The area shown is underlain by the Blockhouse Mine which operated between 1859 and 1888, although some coal was extracted as early as 1720 (Hennick & Weaver 2003). The colliery mined the 2.9 metre thick Harbour Seam by room and pillar method with extensive pillar extraction. It was this combination of mining methods and the relatively shallow depth of cover (maximum 50 metres) that formed the subtle subsidence features now detectable by the DEMs.

On the DEMs, the linear, approximately east- west trending, subsidence features are actually remnant topographically high areas (up to approximately 0.5 metres higher than the surrounding topography). When superimposed with the mine plan (see Figures 3 and 4) they coincide with the main Levels (mine tunnels) and are in a sense a projection of the mine geometry to surface. The mine geometry shows up so clearly in fact that the DEM was used to help geo-referencing the mine plan.

It is postulated that the ground above the main Levels incurred minimal subsidence (creating the remnant topographically high areas) because the large coal pillars supporting the Levels were

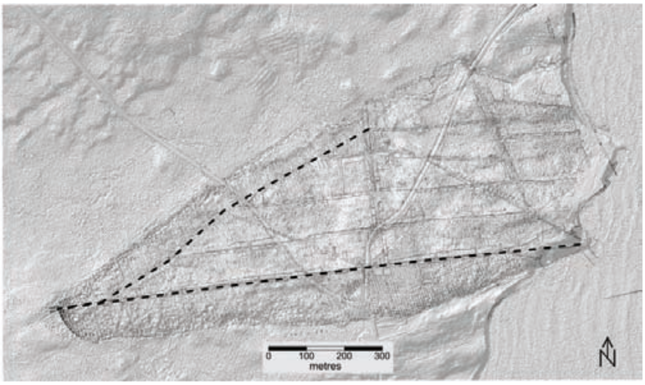

Figure 4 *Blockhouse Mine Plan superimposed over DEM. Dashed lines highlight main Levels in the mine*

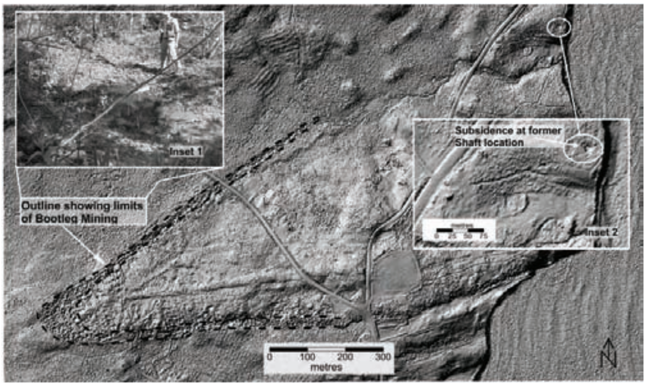

Figure 5 *Shows Bootleg Mining areas (outline with dashed line). Inset 1 shows typical site conditions near bootleg pits. Inset 2 shows subsidence detected at a former shaft location*

left intact. This was a common mining practice used to maintain the major underground transportation routes through the operational life of the mine. Maximum subsidence would have occurred over adjacent areas where full pillar extraction took place. It is this difference in vertical subsidence that creates the linear features visible on the DEM. At the Blockhouse Mine, these features can be identified to a maximum depth of approximately 25 metres, although elsewhere in the coalfield mine features can be still be identified on the DEMs at depths in excess of 70 metres.

Depressions over former shafts

Shafts are mine openings that extend vertically downward from surface to the mine workings. Abandonment procedures vary but usually the shaft was filled to surface with rock and soil and a 2 to 3 metre mound was left at surface to allow for settling. In some instances, settling has occurred to the extent that a depression may now be seen at the former shaft location.

Figure 5 provides a typical example of where a DEM revealed a depression that formed over a former shaft. Mining records indicated that a shaft was located in this vicinity but its exact location was unknown. Initial field mapping did not locate the former shaft. When the DEM was examined, a circular depression was observed near the former shaft location. Follow-up fieldwork and a review of historical aerial photographs confirmed that the depression was the location of the former shaft. In this example, the depression was approximately 13 metres in diameter and 0.7 metres deep (CRA 2009). Field observations at the depression revealed a very gradual slope towards the center of the depression. Considering its shallow surface expression, gradual slope and dense vegetation in the area, this shaft location would have been very difficult to locate without the DEM.

Bootleg mining near the seam outcrops

Bootleg mines are illegal or unregulated mines that access the coal seam through pits dug from surface, usually near the seam outcrop. The remnants of these excavations often appear as semicircular depressions at surface. Typically, the depressions are 1 to 3 metres deep and several metres in diameter, although they can be much larger. The area outlined in Figure 5 covers approximately 5 hectares and contains hundreds of depressions that are likely the result of bootleg mining. The resolution of DEMs permits detection of pits as shallow as 0.5 metres and 2.5 metres in diameter.

These features are particularly significant because they provide sites whereby surface water can enter mine workings and acquire an acidic mine water character. The impacted waters may then discharge to surface though similar pits or workings located at lower elevations. Utilizing the Lidar data, very precise topographic maps can be constructed, and when used with mine water elevations (obtained from wells) these maps can aid in the identification of potential mine water discharge sites.

Conclusions

Preferential subsidence as a result of mining methods can cause subtle topographic differences that can be detected with DEMs. Mine pillars are visible as remnant topographic highs and can be detected over mines at depths of more than 25 metres. DEMs can aid in locating former mine shafts by identifying slight ground depressions that often form due to settling over backfilled shafts. They are especially useful in densely vegetated areas. DEMs can detect pits formed from bootleg mining and the resolution allows for detection of pits as shallow as 0.5 metres and 2.5 metres in diameter. The pits provide areas for water to migrate into and out of the mine, which can potentially produce uncontrolled acid mine water discharges.

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