Engineering
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BOREHOLE RADAR DETERMINES SOLID COAL AND MINED-OUT AREAS

MEA was asked to determine the effects of mining beneath a proposed roadway structure. In order to determine the subsidence potential and the magnitude of the mine stabilization costs, it is important to know whether underground mining is present, and if so, to what extent. The site investigated had the potential to have mining in three different coal seams. The Illinois Coal seams in question were the No. 7, No. 6, and the Seelyville ranging in depth from 70 to 300 ft.

Because of inaccuracies which exist in old abandoned mine maps and since up to 10 years of mining occurred after the date of the available No. 7 Coal mine map, cross-hole radar surveys were performed in order to determine the actual extent of mining. The borehole radar was also used to determine whether the No. 6 and Seelyville seams were mined below the site.

Borehole Radar System:

MEA's borehole radar system which was used on this project is shown in Figure 1. A borehole radar works particularly well for detecting solid coal and void areas because a coal seam is bounded above and below by materials with different electrical properties than that of the coal. Because of this, it is possible to use electromagnetic (radio) waves to detect anomalies in the coal seam. Materials such as shale, claystone, and mudstone generally have low resistivities on the order of 50 to 10,000 ohm-cm. Coal generally has a much high resistivity on the order of 20,000 to 80,000 ohm-cm. The dielectric constant of coal is generally lower than that of roof and floor materials, in the range of 5 or 6 as compared to 10 or greater for the roof and floor. These differences in electrical properties of the materials produce boundary conditions at the interfaces of coal-roof and coal-floor that allow a radio signal to be "trapped" in the coal seam and to propagate through the coal as in a waveguide. Therefore, a radio signal in solid coal will travel with less attenuation than in free space.

If two antennas are lowered down boreholes to the coal seam, a radio signal transmitted form one antenna will transmit through the coal to the receiving antenna with a certain attenuation rate (see Figure 2a)/ In a homogeneous coal seam this rate will be determined by the characteristics of the coal such as resistivity, moisture content, and coal seam thickness. In this case, the attenuation will be a function only of the distance between the antennas—the greater the distance, the weaker the signal.

FIGURE 1 MEA BOREHOLE RADAR SYSTEM: ANTENNAS BEING LOWERED INTO BORINGS IN ORDER TO CONDUCT A CROSS-HOLE SURVEY

The presence of a mined-out area (void) in a coal seam is an anomaly and will produce a greater attenuation for a ray path through or in the vicinity of the void (see Figure 2b). If the void is close to but not directly in the ray path, there will be a small increase in attenuation of the signal.

By measuring the strengths of many signals through various ray paths between pairs of boreholes drilled through a coal seam, the attenuation rate of solid coal for the area can be established and compared with the other measured attenuations to determine which ray paths pass through solid coal and which pass through or near mine voids. By this methods, the likelihood of the presence of a void in a ray path can be determined.

Results:

In about 8 days of field work, a total of 51 ray paths were performed. The travel distances between boreholes were up to 240 ft. which is

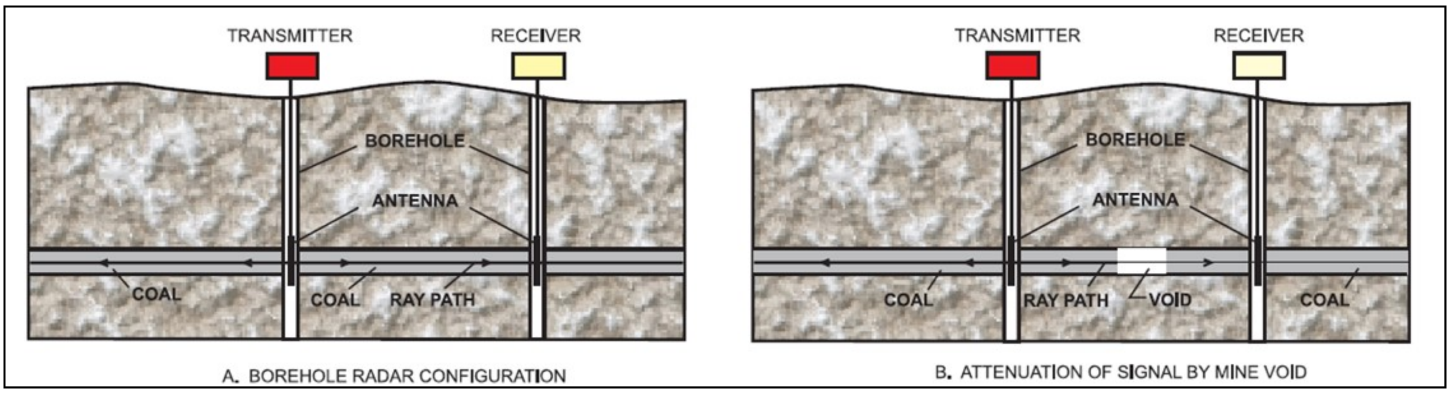

FIGURE 2 BOREHOLE RADAR SYSTEM SHOWING RAY PATHS AND ATTENUATION BY A VOID IN THE COAL SEAM

significantly greater than that achieved with surface ground penetrating radar (GPR). The cross-hole surveys found solid coal as well as flooded mine voids with and without rubble.

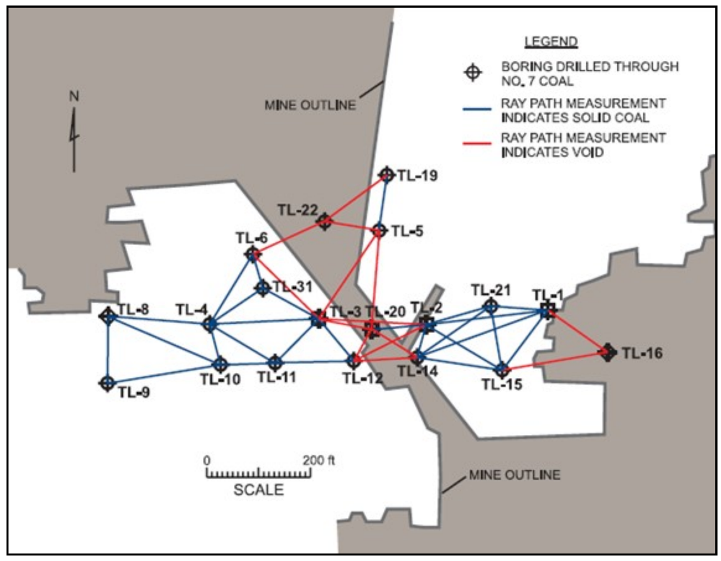

FIGURE 3 RAY PATHS BETWEEN BORINGS MEASURED WITH BOREHOLE RADAR IN THE NO. 7 COAL AT THE PROJECT SITE

The results obtained in the No. 7 Coal seam are summarized in Figure 3. There were 41 ray paths taken in this coal seam. All the measurements except two (TL-2/TL-6 and TL-2/ TL-20) confirm the mine outline. In order to assess the indication of mining between TL-3 and TL-6, a supplement boring was drilled (TL-31). Measurements from this hole showed solid coal. Consequently, it was concluded that mining was in the vicinity of TL-3/TL-6 ray path but it did not proceed southwest (see Figure 3). The other anomalous ray path measurement indicated no mining where it clearly existed based on the mine map and a number of other ray path readings. This anomalous reading was attributed to electrical resonance form the relative orientation of steel roof support (probably left in the main rooms in this section of the mine) and the ray path.

In summary, the borehole radar subsurface investigation:

- Validated that the mine map in the No. 7 Coal was fairly accurate despite its age (1888),
- Found no mining in the No. 6 Coal, and
- Found an area of unknown mining at a depth of about 300 ft. in the Seelyville Coal Seam which was verified by subsequent drilling.

Other Engineering UPDATES of Interest:

UPDATE 19: Cross-Hole Radar Used to Locate Mined-Out Areas

UPDATE 27: Borehole Radar Used to Identify Deep Coal Pillars

UPDATE 1: Successful Deep Mine Backfilling to Mitigate Mine Subsidence

ABOUT MEA: Marino Engineering Associates, Inc. focuses on engineering research, practice and expert evaluations and is licensed in 24 states in the U.S. Our projects primarily have an emphasis on Geotechnical Engineering, however, we also have significant experience in projects involving transportation, subsidence engineering, laboratory testing, training, and geophysical exploration. Gennaro G. Marino, Ph.D., P.E., D.GE is president and principal engineer of Marino Engineering Associates, Inc., and has been a licensed professional engineer since 1984. To obtain additional information on MEA, one can also visit our website at www.meacorporation.com.

FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact Dr. Marino at the address listed below.

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