Temporal Changes in the Terrain Conductivity of the Falls Run Refuse Pile: Preston Co., WV

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Abstract:

This study is designed to monitor the temporal changes in terrain conductivity of the Falls Run Refuse Pile in Preston County, WV. The refuse site is currently owned and operated by the Preston County Coke and Coal Association. The refuse pile consists of four layers of material piled on top of near-surface bedrock; coal refuse, alkaline yellow boy sledge, limestone, and a thin layer of topsoil. Geophysical analysis of the current conductivity will be compared to previous studies done by Shogren (2002), Tang (2001), and Anderson (2002) who also applied geophysical techniques to delineate anomalous regions in the refuse area for the purpose of detecting and mapping acid water source areas. The survey area consists of a 600 ft. x 140 ft. grid within where terrain conductivity observations were made at 20 ft. intervals. A Geonics EM-31 conductivity meter was used to measure the varying degrees of terrain conductivity; both vertical and horizontal dipole measurements were made. Surfer was used to map the data and to compute and map the differences between the observations made in this study to the ones made by the Geology 454 class of 2000. Preliminary analysis of conductivity contours over the Falls Run Refuse Pile with observations made in 2000 indicates similar anomalous regions within the area.

Introduction:

Acid mine drainage from high sulfur coal mine refuse, mine spoil, as well as near surface mines contaminates streams through the Appalachian region. Mine contamination from coal containing high amounts of pyrite seeping into waterways is
threatening to the environment. Mainly, the lowered pH of contaminated streams and rivers leads to elevated total dissolved solids, many of which are toxic to the surrounding flora and fauna. The Surface Mining Province Number 2, which includes Monongalia and Preston counties, is characterized by high pyrite, high sulfur content and low neutralizing potential (Bennett, 2002 / Skouseen, 2001, v.1 pp.91). Refuse present from the Falls Run Refuse Area comes from this high sulfur region. The coal beds from which the refuse was extracted include: The Pittsburgh coal, Kittanning coal, and the Upper Freeport coal. These coal beds are known to produce acid mine drainage when exposed to water and oxygen (Bennett, spring 2002 / Dean, spring 2002).

Deposition of refuse at the Falls Run site began in 1983 for the purpose of disposing unusable coal from the Greer Mansion site, and from the Greer coal-processing facility. Greer continued to transport refuse to the site until 1988 when the facility was closed. Following the closure of the processing facility alkaline sludge from the Greer Mansion surface-mine sedimentation pond was dumped on the site to reduce acid seeps (Bennett, 2002). A layer of limestone was then deposited over the sludge in hopes of further reducing acid seeps and neutralizing the acidity of the refuse area. Finally a layer of topsoil was placed on top of the limestone to sustain vegetation.

Falls Run Refuse Disposal Area is located in Masontown, WV approximately 12 miles east of Morgantown along Route 7, approximately 1 mile past the entrance to the Greer Limestone quarries. The southwest corner of the study area’s UTM coordinates are: 17 601153 E, 4380480 N.

Previous studies performed by WVU students Shrogen (2001), Tang (2001), and Anderson (2002) modeled terrain conductivity, sounding and resurveyed part of the
refuse area following the initial surveys of the area conducted by the geophysics class during the fall of 2000. In addition to the terrain conductivity measurements taken by the EM-31/34, various other geophysical methods were employed to delineate anomalous regions within the refuse pile. The Geophysics class of 2000 provided magnetic data taken by a Geometrics proton precession magnetometer. Shrogen (2001) used a Phoenix very low frequency (VLF) electromagnetic survey to supplement terrain conductivity data collected. Three anomalous regions were identified within the Falls Run Coal Refuse Pile. The comparison of very low frequency surveys to terrain conductivity surveys show similarity in anomalous regions according to Shrogen (2001). For an explanation of very low frequency (VLF) surveys and study results see Shrogen (2001). A major zone of high conductivity can be identified in the data collected by the geophysics class of 2000. (Figure 1)

Figure 1. shows the observed terrain conductivity of the Falls Run Refuse Area measured by the 2000 geophysics class in millimohs per meter. Notice the high areas of conductivity located at point A) between the 50 ft. and 100 ft. range, in the central region at point B) between the 200 ft. and 350 ft. range, and at point C) between the 500 and 600 ft. range.

Yen Tang, in her analysis of the Falls Run Refuse Pile, employed a Sting and Swift resistivity imaging system. The resistivity survey was conducted to supplement the
findings of the EM-31 terrain conductivity survey. For further explanations of resistivity theories and detailed results of the study refer to Tang (2001).

Erin Anderson, in her 2002 survey of the refuse site repeated magnetic surveys over part of the refuse area. The magnetic survey revealed what are believed to be metallic objects at the pile. For an explanation of the principals of the Geometrics proton procession magnetometer see: Anderson (2002). Anderson also collected four 580 ft. EM-31 profiles over the area surveyed earlier in the fall of 2000. Her survey confirmed that the area of high conductivity observed in 2000 still remained at the site.

Methods:
The Geonics EM-31 conductivity meter was used to measure the terrain conductivity of the coal refuse site. The EM-31 conductivity meter utilizes a transmitter coil, which sends out an alternating electromagnetic field. This “primary” field induces a current flow in the sub-surface, which is measured, by secondary current flow measured in the meter’s receiver coil.

Figure 2.

![Figure 2.a displays the electric model for vertical dipoles. Figure 2.b shows the electrical circuit for vertical dipoles.](image)
The time varying magnetic field arising from the alternating current in the transmitting coil induces very small currents in the earth. These currents generate a secondary magnetic field $H_s$, which sensed together with the primary field, $H_p$, by the receiver coil (McNeill, 1980). Three factors influence the secondary magnetic field; inter-coil spacing $s$, operating frequency $f$, and ground conductivity $\sigma$. The secondary magnetic field is a function of the following constraints which are incorporated in the EM-31 design (McNeill, 1980).

Here McNeill defines the equation that describes the constraints of the secondary magnetic field, calculated by the EM-31 conductivity meter.

$$H_s \sim \frac{io\mu_0\sigma(s \text{ squared})}{Hp}$$

where:  
$H_s$ = secondary magnetic field at receiver coil  
$H_p$ = primary magnetic field at the receiver coil  
$f$ = frequency (Hz)  
$\omega = 2\pi f$  
$\mu_0$ = permeability of free space  
$\sigma$ = ground conductivity (mho/m)  
$s$ = inter-coil spacing (m)  
i = the square root of -1

This allows the ratio of the secondary to the primary magnetic field to be linearly proportional to the terrain conductivity of the sub-surface.

The Geonics EM-31 assumes a low induction number, which measures the ratio of the secondary magnetic field $H_s$ at the receiver. This occurs when both coils are lying on the surface of a half-space of conductivity $\sigma$ to the primary magnetic field $H_p$ in the absence of half-space (McNeil, 1980). The induction number, $B$ is a function of inter-coil spacing over skin depth.
\[ B = \frac{s}{\delta} \]

S is the intercoil spacing and \( \delta \) is the skin depth. The electrical skin depth is described as the depth at which the amplitude of the electromagnetic field drops to 1/e of the source amplitude and is a function of the operating frequency and the ground conductivity (Shrogen, 2001). Electrical skin depth \( \delta \) is a known characteristic of a homogeneous half-space and is defined by

\[ \delta = 500\left(\frac{1}{\sigma f}\right)^{-1} \]

The amplitude \( A_r \) of an electromagnetic field generated by a transmitter having source amplitude \( A_s \) is given by equation 4.

\[ A_r = A_s e^{-\alpha r} \]

Where \( A_r \) is the measured amplitude at distance \( r \)
\( A_s \) is the amplitude of the electromagnetic field at the source
\( \alpha \) is the attenuation coefficient
\( r \) is the distance from the source

The attenuation coefficient varies in proportion to the frequency of the electromagnetic wave such that higher frequencies are attenuated more than lower frequencies over the same distance. Therefore to obtain a greater exploration depth a lower frequency must be used (Shrogen, 2001).

The EM-31 conductivity meter has an inter-coil spacing of 3.7 meters, which yields an effective exploration depth of about 6 meters using a vertical dipole orientation and 3 meters when the horizontal dipole is used. The operating frequency of the Geonics EM-31 is 6500 Hz. The conductivity meter constantly evaluates the electrical conductivity so the conductivity readings displayed continuously. Output of the conductivity meter is
displayed on a mmhos/m scale. The secondary field intensity measured by the meter is automatically scaled according to the relationship given by equation 1). The EM-31 carried in front of the operator with a shoulder strap for convenience.

**Results:**

EM-31 conductivity results of the falls Run Refuse Area taken in the fall of 2002 reveal anomalous regions in both vertical and horizontal orientations. The terrain conductivity of the refuse area ranges from 0 to 38 mmhos/m in the vertical dipole survey, and from 0 to 25 mmhos/m in the horizontal dipole survey (figure 3.). The location of the anomalies is consistent between the horizontal and vertical orientations, showing an increase in extent of the anomalous region with increased depth. Three areas with conductivity higher than 25 mmhos/m are observed from the measurements of the terrain conductivity in the vertical dipole orientation. These areas are located on the x–axis between 50 and 100 ft., between 150 and 375 ft., and between 525 and 600 ft. possibly extending beyond 600 ft (figure 3.). The data taken in the horizontal dipole orientation, which has a shallower penetration depth, reveal areas of conductivity greater than 16 mmhos/m in approximately the same location along the x–axis as the vertical data.

**Figure 3.**
Figure 3 demonstrates the terrain conductivity of the falls Run Refuse Area. Three anomalous regions, A, B, & C, are present and consistent between the horizontal and vertical measurements.

Universal Transverse Mercator (UTM) coordinates were recorded for the purpose of geo-referencing the refuse site (figure 4.). Global Positioning Satellites (GPS) were used to determine the UTM coordinate. A hand-held GPS unit; constructed by Navistar, up-linked to three or more satellites orbiting the planet triangulates its location with and accuracy of about 10 m. Although this degree of precision may not be useful in referencing the location of anomalous regions within the refuse area, it will help co-reference the survey area with digital ortho-photo quadrangle images.

Figure 4.
UTM Coordinates

A.  17 601011E  4380588N
B.  17 601040E  4380615N
C.  17 601090E  4380535N
D.  17 601181E  4380501N
E.  17 601153E  4380480N

The strike along the x-axis from 0 to 600 is N28W.

Comparison:

The EM terrain conductivity data collected in fall, 2002 has been rotated to fit the
spacing intervals collected by the geophysics class of 2000. The results of the data
measured with the vertical dipole orientation in fall, 2002 show anomalous regions to be
located in the same areas as the data of the 2000 geophysics class measured in the vertical
orientation. (Figure 5.) Using the same contour interval of 5 mmhos/m, it is clear that
the apparent electromagnetic terrain conductivity within the anomalous regions has
dropped. Areas of high terrain conductivity, measured at a depth of about 6 meters, in
the 2002 data are not as laterally extensive as those measured in 2000. (Figure 5.) It is
also apparent that the values of the terrain conductivity for the 2002 data are not as
elevated as those in the measured data from 2000. The maximum value illustrated below
(Figure 5), recorded in fall of 2002 tops out at 35 mmhos/m, while the data collected in
2000 shows a maximum value of 45 mmhos/m. This 22% reduction in the maximum
conductivity values marks an overall reduction in conductivity in this region of the refuse
pile (Figure 6).
Figure 5. shows the reduction in overall conductivity of the observed zone of the Falls Run Refuse Area from the years 2000 to 2002. This reduction is obvious through the diminished extension of anomalous areas and lower maximum conductivity values.

Figure 6 displays the difference in conductivity measured by the geophysics class of 2000 and the data collected in the fall of 2002. In the zones labeled A, B, C, the map shows a reduction in the conductivity. In zone D there is a significant increase in a small area.
Conclusions:

Geophysical methods are not only useful in determining the extent and location of AMD sources in the shallow sub-surface, but are also useful for documenting how conductivity changes over time. In this particular study, the Geonics EM-31 demonstrated an efficient and cost effective solution to determining shallow sub-surface conditions in the Falls Run Refuse Area.

Three anomalous regions have been identified within the Falls Run Refuse Area. These regions show elevated conductivity levels that are interpreted to correlate with increasingly acidic waters filling the pore spaces with the refuse.

In comparing data collected during the fall semester of 2000 to the data collected during the fall semester of 2002, the results reveal that a 22% reduction in the maximum values of the overall terrain conductivity has occurred during that two year time period. This reduction is complemented by a reduction of the aerial extent of the contaminated zones from two years ago.

Action to remedy the acid seep sources is presently underway and has been in the past. The analysis of the geophysical information gathered at the Falls Run Refuse Area can be helpful in pinpointing the location of AMD trouble areas, thus reducing excavation costs. The time lapse comparison also indicates that treatment of the refuse area has been successful in reducing the overall acidity of the pile.

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References:


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