Near-surface Geophysics at Sewanee: Field Report 2

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INTRODUCTION

As part of a collaborative research and teaching project between the University of the South (Sewanee) and the University of Texas at Austin, Bureau of Economic Geology (BEG), BEG researchers J. Paine and L. Costard have conducted the first two phases of field investigations at Sewanee on September 11-13, 2018 and November 13-15, 2018. Activities include discussions with Sewanee faculty and staff, guest lectures for two classes, and field deployments of geophysical instruments at six sites on the Sewanee and St. Andrew's-Sewanee (SAS) campus chosen by collaborating Sewanee faculty (the Sewanee Farm, a borrow pit, a wetland along Breakfield Road, along a small stream in Lost Cove, near the campus gas station, and rock shelters at SAS, fig. 1).

METHODS AND INSTRUMENTS

Geophysical instruments deployed during the first two of four planned visits included ground-penetrating radar (GPR), time-domain electromagnetic induction (TDEM), and frequency-domain electromagnetic induction (FDEM). These types of instruments are relatively easy to deploy and use, and commonly measure or respond to electrical properties that are useful in many shallow geological, hydrological, and environmental investigations. Sewanee and SAS faculty, students, and staff participate in all aspects of field work.

GPR

GPR instruments transmit radio-frequency EM pulses into the ground and record pulse returns from electrical interfaces in the shallow subsurface. As the instrument is moved along the ground, a profile of the shallow subsurface (to a few meters depth) is recorded. Exploration depth of the instrument depends on the electrical properties of the subsurface and the frequency of the transmitter (lower frequencies achieve deeper exploration depths). We used a GSSI SIR-3000 instrument with either a 200- or 400-MHz antenna (fig. 2). GPR data were acquired at six field sites.

TDEM

TDEM instruments consist of a transmitter (in this case a wire loop 25 m in radius) and one or more receivers (generally smaller coil or wire loops). A small, constant electrical current in the transmitter loop creates a static magnetic field (the primary field). When the transmitter current is shut off, the primary magnetic field collapses, which induces currents to flow in

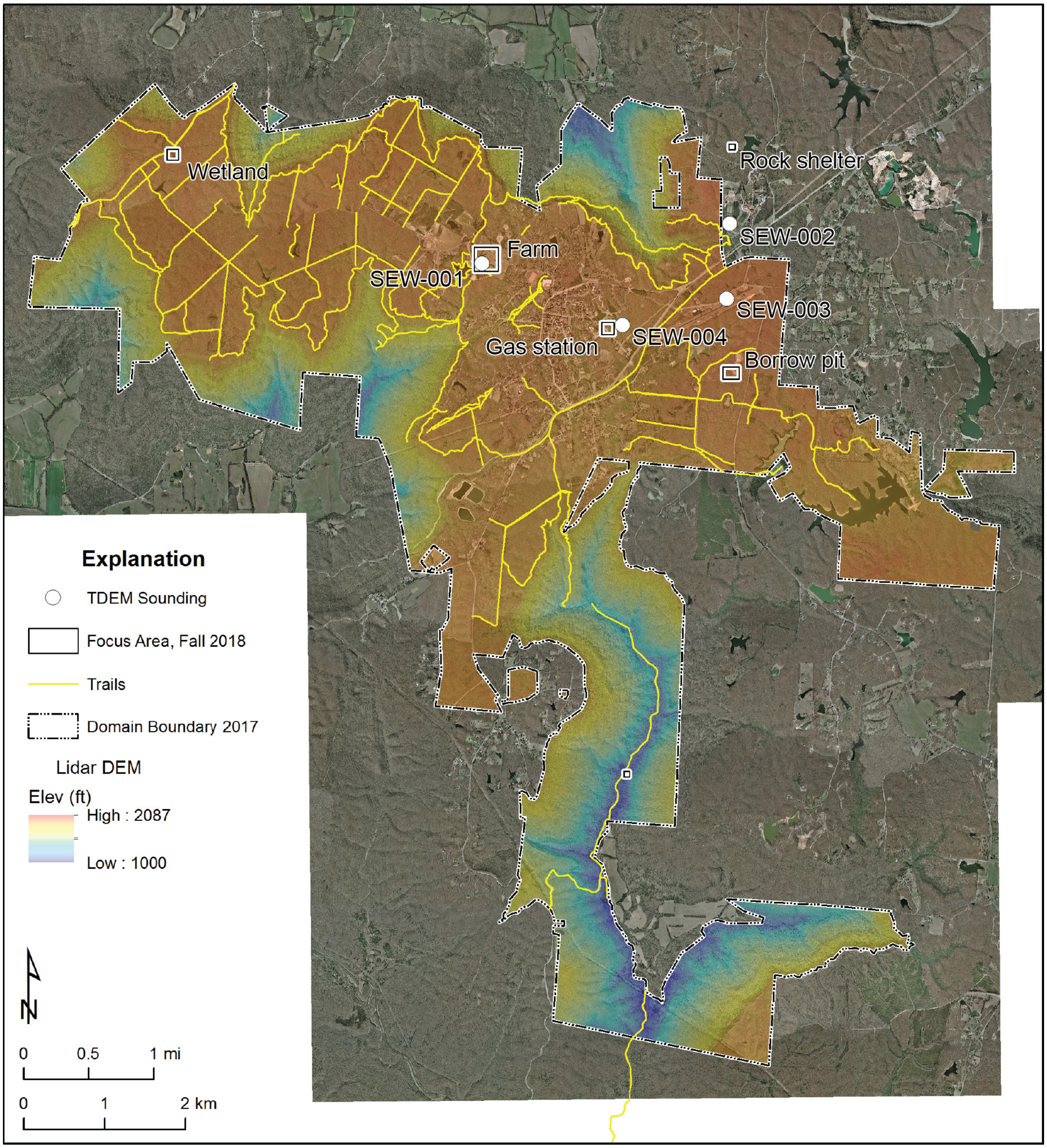

Figure 1. Map of the Domain area showing geophysical focus areas and TDEM sites visited during September and November 2018. Aerial imagery, trails, Domain boundary, and lidar-based digital elevation model (DEM) from C. Van de Ven.

Figure 2. Sewanee students operating GPR instrument along a proposed fence line at the Sewanee Farm, September 11, 2018.

nearby materials that are electrically conductive. Air is poorly conductive, but the subsurface is typically conductive. The collapsing primary magnetic field induces currents to flow in the subsurface, which in turn create a small secondary magnetic field whose strength is recorded by the receiver coils in the few milliseconds before those transient induced currents decay after the transmitter current is shut off. These induced secondary currents propagate downward in the subsurface; thus the early part of the transient decay yields information on the conductivity of the shallow part of the subsurface, and later parts of the transient decay yield information on the conductivity of the deeper subsurface. At Sewanee, we used an ABEM WalkTEM system (fig. 3) to achieve exploration depths ranging from a few meters to 200 to 300 m. Data generated by the WalkTEM includes the transient itself (the decay of the induced, secondary magnetic field over time expressed as receiver voltages) and a multilayered model of subsurface conductivity that would yield a transient that matches the observed measurements as closely as possible. These models can be used to interpret subsurface geological and hydrogeological characteristics within the upper few hundred meters of the subsurface. Four TDEM soundings were acquired during the September and November visits (SEW-001 at the Sewanee Farm, SEW-002 at the SAS

Figure 3. Sewanee students acquiring TDEM sounding data at the Sewanee Farm using a WalkTEM, September 11, 2018.

practice field, SEW-003 at the Franklin County Airport, and SEW-004 at the soccer field near the Sewanee campus gas station, fig. 1).

FDEM

FDEM instruments consist of a small transmitter coil and one or more receiver coils. The transmitter current is continuously varied following a sinusoidal pattern at a fixed frequency. A continuously varying magnetic field (the primary field) is created by the transmitter coil, which induces currents to flow in the shallow subsurface. The receiver coils measure the strength of the secondary magnetic fields generated by the small currents induced to flow in the subsurface. The more conductive the subsurface, the larger the induced currents and the secondary magnetic field strength. These instruments typically record the apparent electrical conductivity of the ground, which is proportional to the strength of the induced, secondary magnetic field. These "ground conductivity meters" have limited exploration depth and are commonly used to examine soil and other near-surface geological properties including moisture content, salinity, and clay content. We used a CMD Explorer (by GF Instruments) that consists of a transmitter coil operating at 10 kHz primary frequency and three receiver coils at three different distances (1.2 m, 2.8 m, and 4.5 m) from the transmitter coil (fig. 4). Exploration depth for this instrument increases with the distance between the transmitter and receiver coil. Maximum exploration depth at the shortest coil separation is about 2 m. Maximum exploration depth increases to about 4 m at the

Figure 4. Sewanee students acquiring FDEM data at the Sewanee Farm using the CMD Explorer ground conductivity meter, September 11, 2018.

intermediate coil separation and to about 6 m at the longest coil separation. Data were acquired with the CMD Explorer at all focus areas except the SAS rock shelters.

FIELD SITES

Site 1: Sewanee Farm

Data were acquired at the Sewanee Farm on September 11, 2018 (figs. 1 and 5) to demonstrate operation of each instrument to students, faculty, and staff and to acquire reconnaissance geophysical data to establish basic geophysical properties at the site. GPR data were acquired along three lines west of the farmhouse using the 400 MHz antenna. Two of the lines are along proposed fence lines where knowledge of the soil thickness would be useful before emplacement of fence posts. These data (as well as GPR data acquired at other sites), acquired by Sewanee students under the guidance of L. Costard, are currently being processed by L. Costard at the BEG to produce cross sections depicting strata in the upper few meters of the subsurface. GPR data along line AAA_002 (fig. 5), acquired using a 400 MHz antenna, show a reasonably strong reflector at a depth of about 1 m along the line (fig. 6), possibly indicating the top of bedrock.

Ground conductivity measurements were acquired by Sewanee students, faculty, and staff along 15 line segments at the Sewanee Farm using the CMD Explorer (fig. 5). Measurements at all three coil separations indicate the shallow subsurface exhibits very low apparent ground

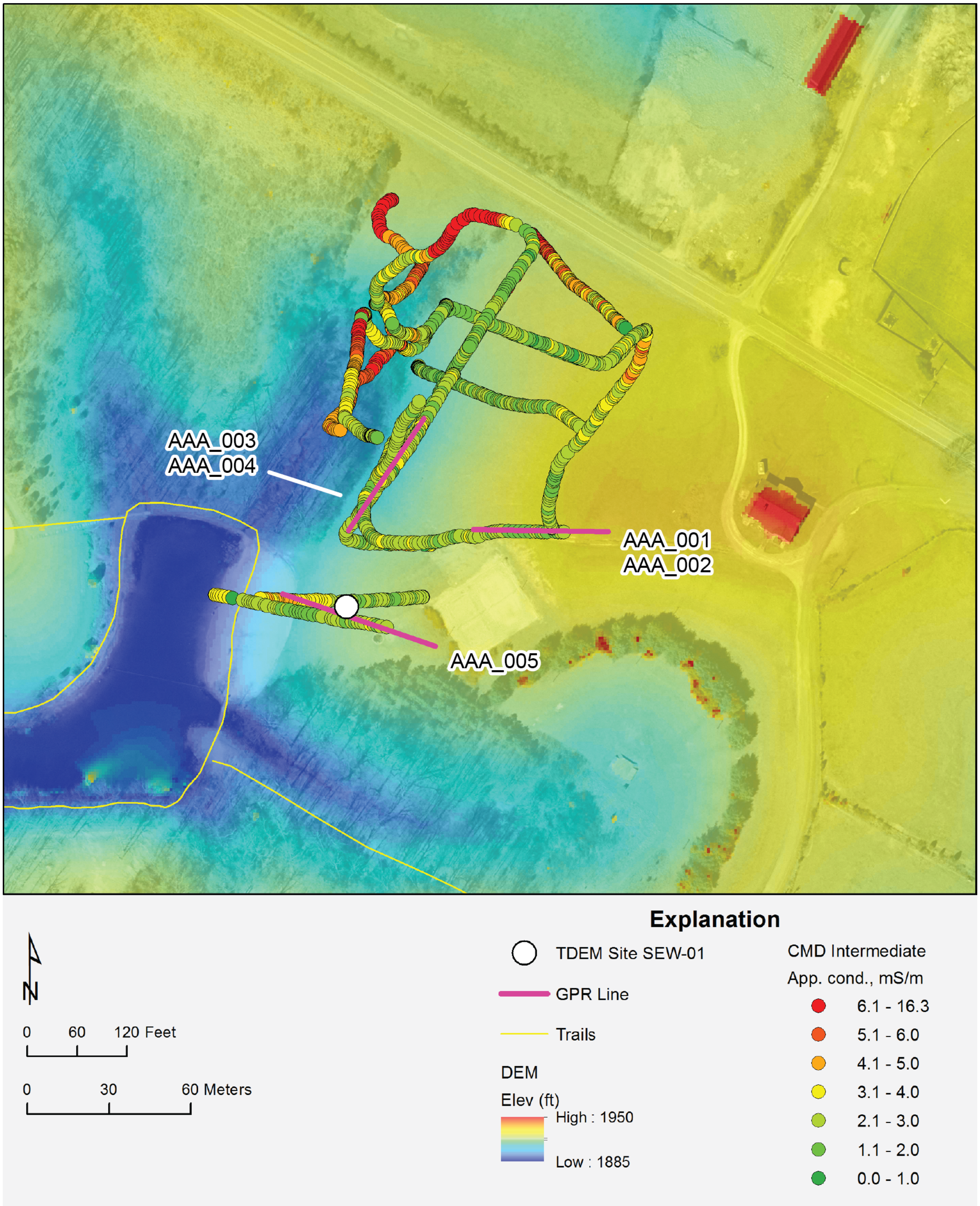

Figure 5. Map of the Sewanee Farm site (fig. 1) showing locations of GPR lines, CMD Explorer measurements (apparent conductivity for the intermediate coil separation), and TDEM sounding SEW-001 surveyed on September 11, 2018. Locations superimposed on aerial imagery and DEM from C. Van de Ven.

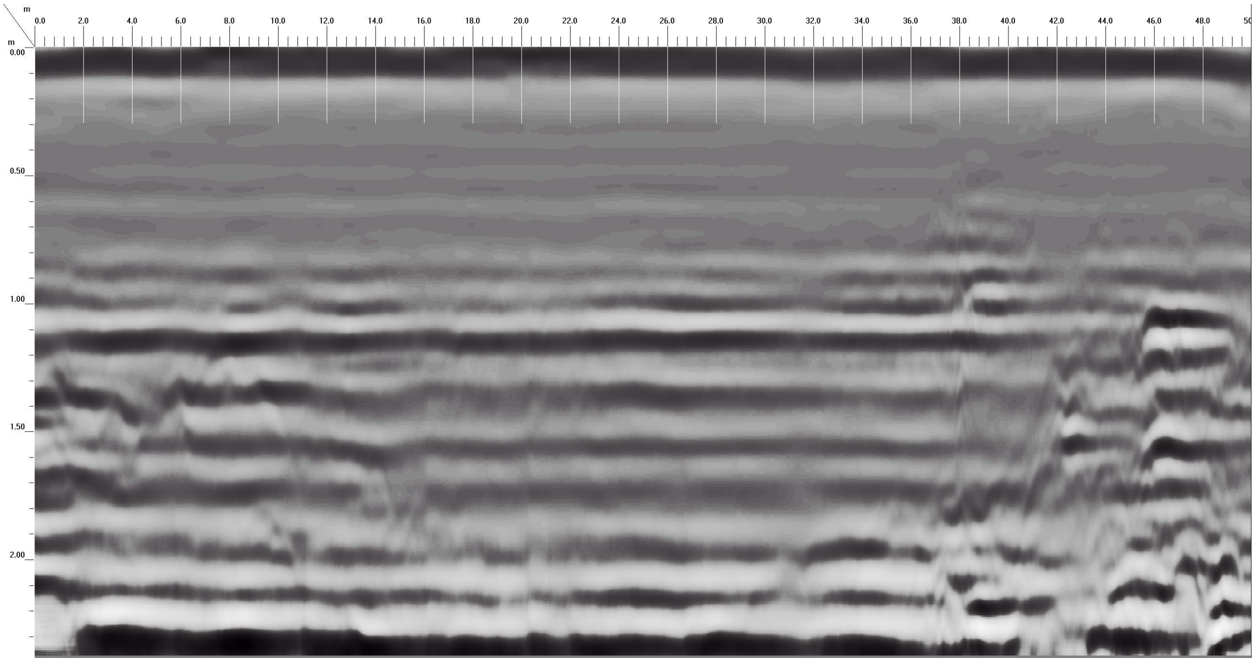

Figure 6. GPR line AAA_002 acquired at the Sewanee Farm (fig. 5) by students using a 400 MHz antenna. Data were acquired from west (0 m, at left) to east (50 m, at right) on September 11, 2018. Distance and depths are in meters.

conductivity. At the shortest coil separation (shallowest exploration depth to about 2 m), apparent conductivity averages 4.8 millisiemens per meter (mS/m). Average apparent conductivity decreases to 3.3 mS/m at the intermediate coil separation (exploration depth to about 4 m; fig. 5) and further decreases to 3.1 mS/m at the longest coil separation (exploration depth to about 6 m). These data confirm that ground conductivities in the shallow subsurface are very low, consistent with low clay content and low-salinity pore water. Conductivity is slightly higher in surficial soil than it is in underlying shallow bedrock, likely indicating either higher moisture or clay content in the surficial soil. Relatively high conductivities in the northern part of the surveyed area may indicate areas of elevated water content associated with nearby springs.

One TDEM “sounding” was acquired in an open, sloped field west of the farm house (fig. 5). This sounding, acquired by J. Paine with the assistance of Sewanee students, was intended to establish the electrical conductivity structure of the deeper subsurface (to a maximum depth of a few hundred meters) at Sewanee. Owing to the very low conductivity of geologic units in the shallow subsurface at Sewanee, signal strength is low compared to that of nearby noise sources including power lines. Nevertheless, sufficient data were acquired (fig. 7) to produce a preliminary profile of subsurface electrical conductivity at the Sewanee Farm (fig. 8). This profile, considered to be reasonably valid to a depth of about 237 m, indicates the presence of low-conductivity geologic units to a depth of about 50 m. Underlying the low-conductivity layers are higher-conductivity strata between depths of 50 to about 150 m, which are in turn underlain by units having lower electrical conductivity to the maximum depth explored. Even the more conductive zones at intermediate depths are not particularly conductive, reaching maximum

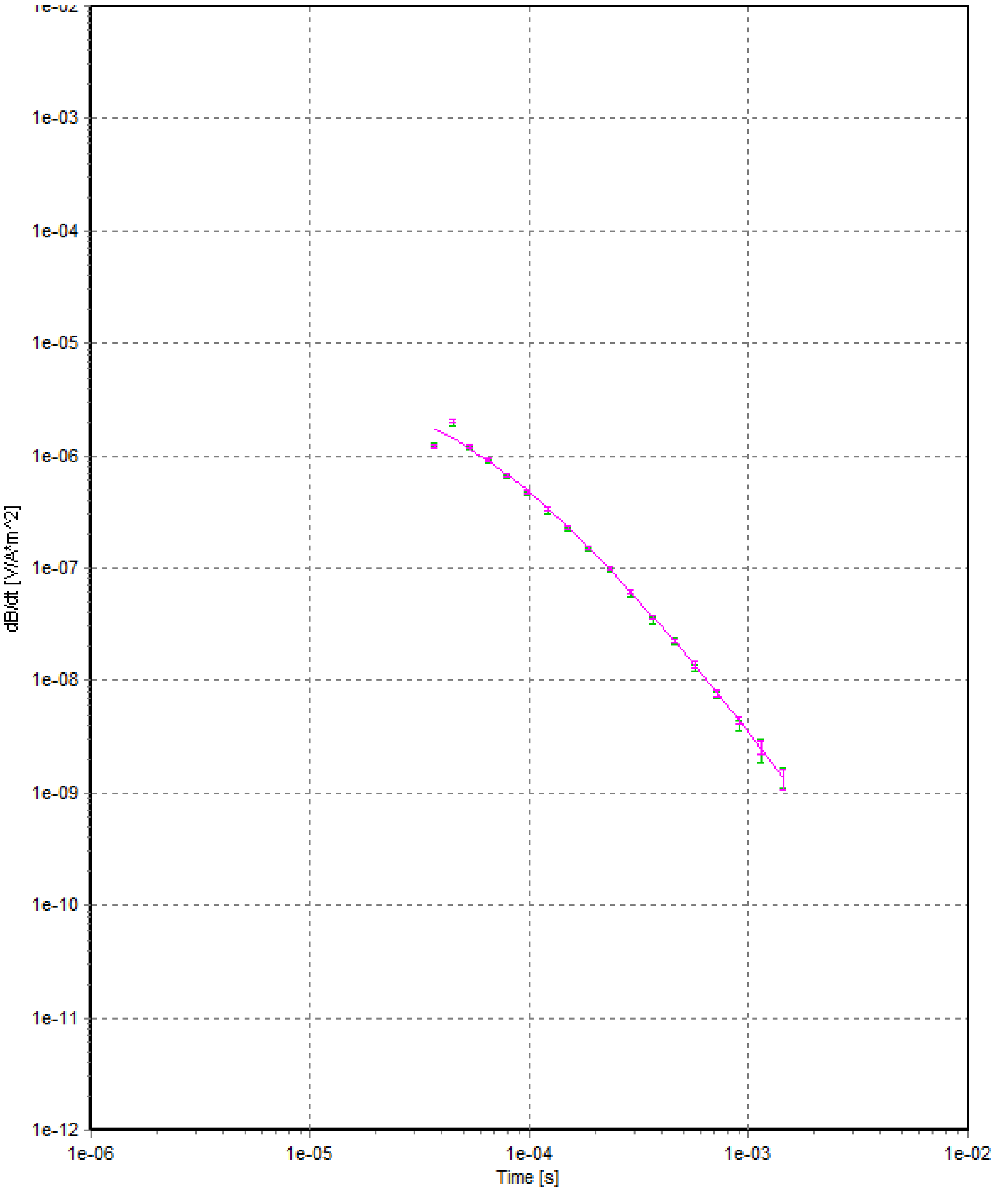

Figure 7. Decay of secondary magnetic field strength (dB/dt) at TDEM site SEW-001 at the Sewanee Farm (figs. 1 and 5), September 11, 2018. Points are measured voltages after transmitter turnoff. The curved line passing through the points is the secondary magnetic field strength that would be calculated from the best-fit conductivity model shown in fig. 8.

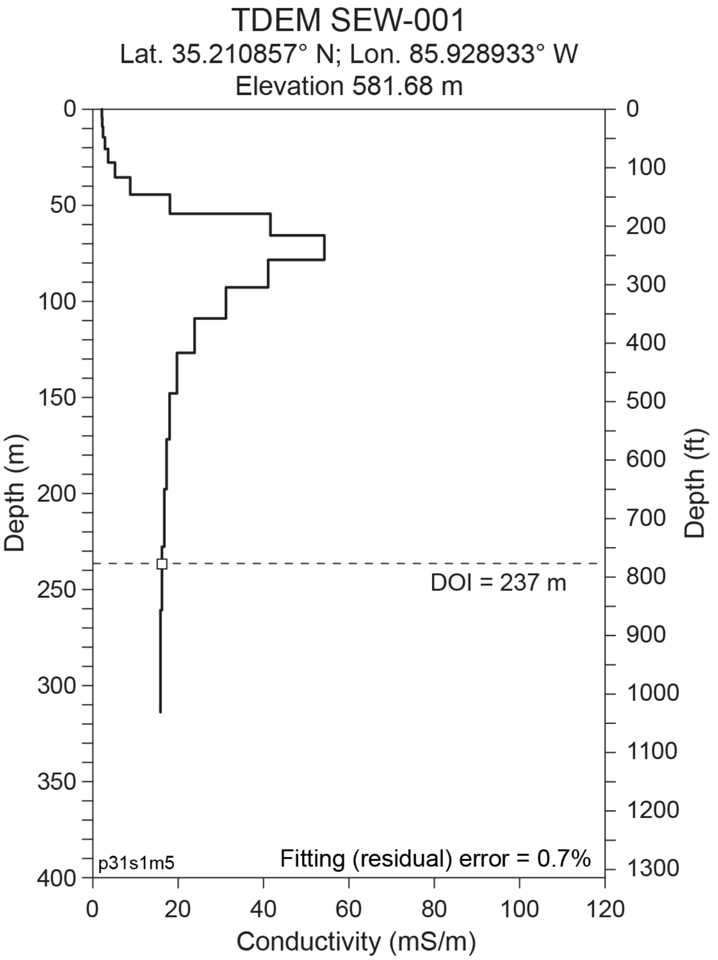

Figure 8. Best-fit model of subsurface conductivity structure at TDEM sounding site SEW-001 at the Sewanee Farm (fig. 5). DOI = depth of investigation.

conductivities near 50 mS/m. Boundaries between major layers with differing conductivity values should correspond to major lithologic or hydrologic boundaries in the subsurface.

Site 2: Borrow Pit

GPR and FDEM data were acquired during September and November 2018 at the Sewanee Borrow Pit (fig. 1), where anomalously thick (greater than 2 m) soils are being investigated by Sewanee faculty and students. GPR data were acquired on September 12 along profiles PIT_001, PIT_002, and PIT_003 atop the thick soil section by L. Costard and Sewanee faculty and staff using the 200- and 400-MHz antennas (fig. 9). Sewanee staff cleared trees and brush adjacent to the pit before the November visit, which allowed acquisition of several more lines. A total of 17 GPR profiles were collected along 9 lines at the Borrow Pit on November 13, 2018 (labeled with a BAA prefix, fig. 9). The lines are parallel to the edge of the pit on the western side in a north-

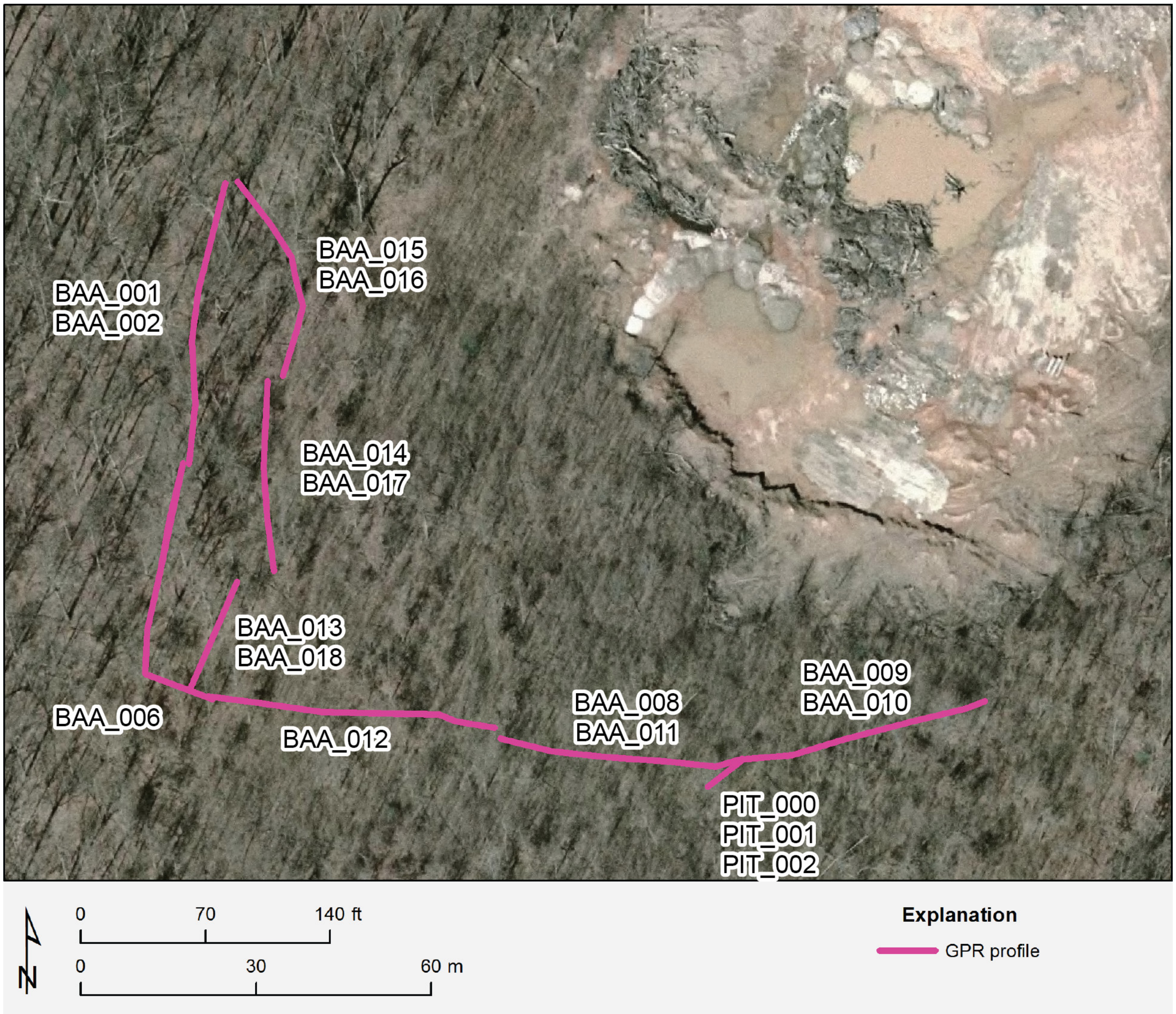

Figure 9. Map of the Sewanee Borrow Pit site (fig. 1) showing locations of 17 GPR lines surveyed on September 12 and November 13, 2018. Locations superimposed on aerial imagery provided by C. Van de Ven.

south direction and to the southern edge of the pit in west-east direction. A 400 MHz antenna was used for all lines to produce cross sections of the upper 4 m of the subsurface (fig. 10).

FDEM data acquired using the CMD Explorer along one short line and at selected points within the borrow pit in September and along the cleared lines in November (fig. 11) indicate that the electrical conductivity of both the thick soil and the underlying bedrock is quite low. Average apparent conductivities measured along the Borrow Pit lines increase slightly with exploration depth, from about 1.3 mS/m for the shallowest exploration depth (to about 2 m) to about 2.0 mS/m for the deepest exploration depth (to about 6 m). Measured apparent conductivities are higher on the floor of the pit where bedrock is exposed than they are on the soil surface surrounding the pit, suggesting there may be a small conductivity contrast between the thick soil sequence and the upper part of the underlying bedrock that could be used to determine soil

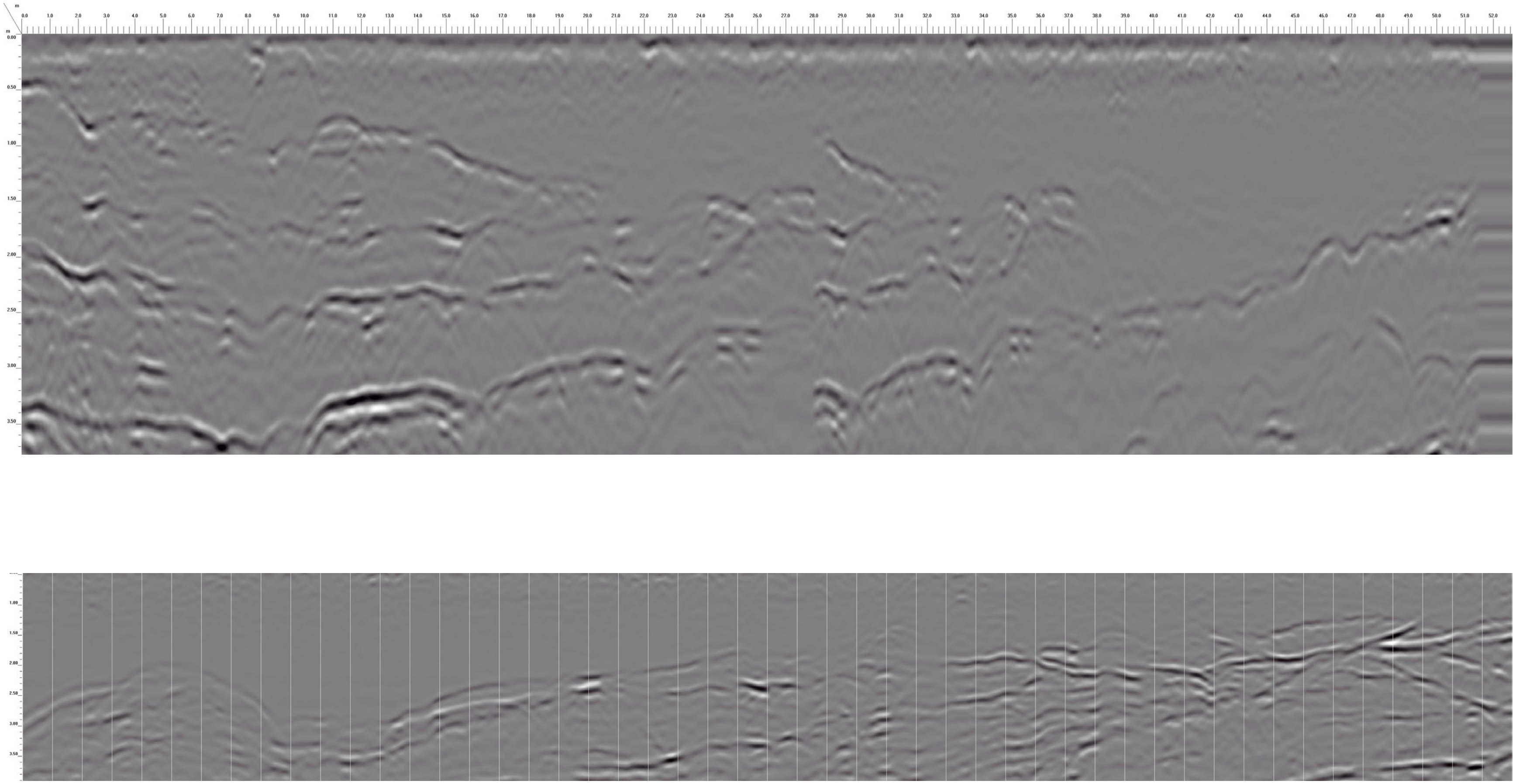

Figure 10. GPR profiles BAA_002 (upper panel) and BAA_012 (lower panel) acquired at the Borrow Pit (fig. 9) using a 400 MHz antenna. Data were acquired from south (0 m, at left) to north (52 m, at right) along BAA_002 and from east (0 m, at left) to west (50 m, at right) on November 13, 2018. Distance and depths are in meters.

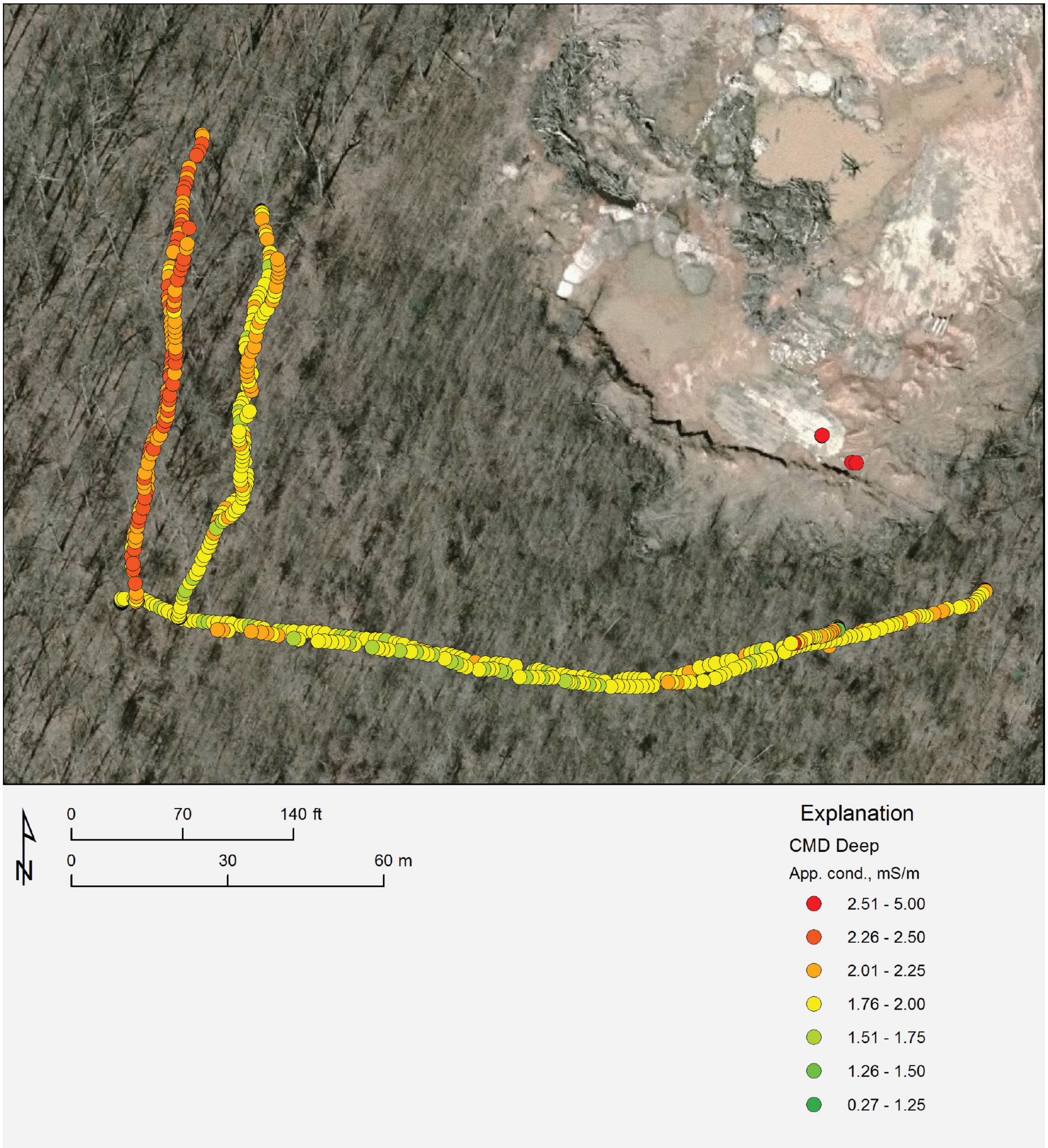

Figure 11. Map of the Sewanee Borrow Pit site (fig. 1) showing locations of CMD Explorer measurements (apparent conductivity for the longest coil separation) surveyed on September 12 and November 13, 2018. Locations superimposed on aerial imagery provided by C. Van de Ven.

thickness if two-layer inversions successfully detect the boundary. Those inversions have been completed but not yet evaluated.

Site 3: Wetland Near Breakfield Road

GPR and FDEM data were acquired at a wetland along Breakfield Road (figs. 1 and 12) on September 13, 2018 with Sewanee staff to investigate shallow subsurface stratigraphy (soil thickness and bedrock surface) on and adjacent to the wetland. GPR data were acquired in both directions along three lines using the 400 MHz antenna. Two lines crossed the topographic low on the northern side of the pond, and one line was acquired along the axis of the low in the same area (fig. 12). These data are being processed by L. Costard at BEG to produce shallow subsurface images of bedrock and overlying soil. Profile DRIFT_002 crosses the axis of the wetland and shows a prominent reflector at about 1.5 m depth that deepens to about 2 m near the axis of the wetland (fig. 13).

FDEM data were acquired at three coil separations along two transects across the low on the north side of the pond and along one longer line along the axis of the low extending from the northern end of the low to the southern end of the pond (fig. 12). Apparent conductivities were generally low at all coil separations, averaging about 4 mS/m for the short, intermediate, and long coil separations, suggesting that conductivities in soil and underlying bedrock may not be sufficiently different to allow discrimination using FDEM instruments. However, simple two-layer inversions of conductivity measurements along these lines generally show a low-conductivity surface layer underlain by a higher-conductivity basal layer, which may indicate the presence of detectable lithologic or hydrologic differences between the saturated wetland soil and underlying bedrock.

Site 4: Lost Cove Streambed and Alluvial Terrace

GPR and FDEM data were acquired on September 13, 2018 with Sewanee staff near a small stream in Lost Cove (figs. 1 and 14). At this site, a significant thickness of alluvium overlies carbonate bedrock. GPR and FDEM data were acquired to attempt to image strata within the alluvium as well as the contact between alluvium and bedrock adjacent to the stream. GPR data were acquired along a single line on the alluvial surface (fig. 14) using a 400-MHz antenna. These data are being processed by L. Costard at BEG to produce shallow subsurface images of the stream alluvium and underlying bedrock surface.

FDEM data were acquired along two lines using the CMD Explorer at all three coil separations (fig. 14). One of the lines coincided with the GPR line across the alluvial surface. Along this line, apparent conductivity measurements averaged near 5 mS/m for all three coil separations. Simple two-layer inversions yielded reasonable average values for alluvial thickness (about 1.5 m) and conductivity of alluvium (13 mS/m) and underlying carbonate bedrock (4 mS/m). A second line was acquired along the axis of the stream, where bedrock and boulders occur at the surface. Average measured conductivities increase with coil separation from about 5.1 mS/m for the

Figure 12. Map of the Breakfield Road wetland site (fig. 1) showing locations of GPR lines and CMD Explorer measurements (apparent conductivity for the intermediate coil separation) surveyed on September 13, 2018. Locations superimposed on aerial imagery provided by C. Van de Ven.

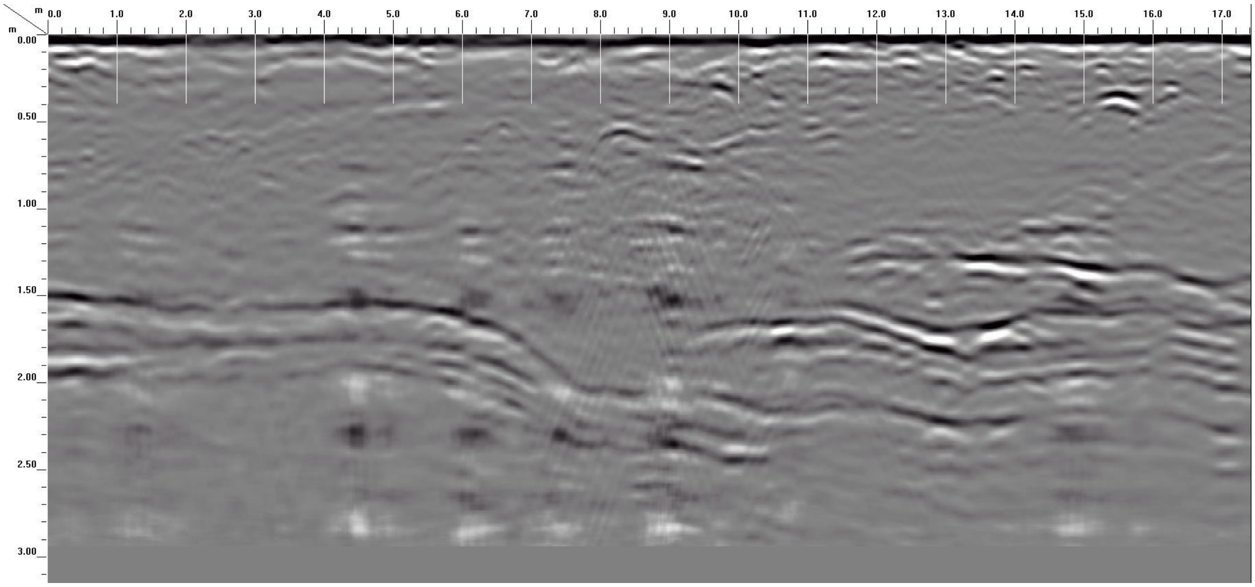

Figure 13. GPR profile DRIFT_002 acquired at the Breakfield Wetland site (fig. 12) on September 13, 2018 using a 400 MHz antenna. Data were acquired from northeast (0 m, at left) to southwest (17 m, at right). Distance and depths are in meters.

shallowest exploration depth (about 2 m) to about 7 m for the deepest exploration depth (about 6 m), possibly indicating increasing water content with depth in carbonate bedrock.

Site 5: Sewanee Gas Station

GPR and EM data were acquired in September and November 2018 with Sewanee faculty and students adjacent to an on-campus gas station (figs. 1 and 15). The purpose was to determine whether there is an electrical conductivity anomaly associated with a shallow gasoline plume migrating downgradient from a former underground storage tank location, and to better constrain the depth to bedrock that underlies the soil and is presumed to be the surface on which the gasoline migrated from the storage tank. A GPS instrument was also used to determine approximate locations of shallow boreholes installed as part of a contaminant monitoring program.

On September 13, 2018, GPR data were acquired in the plume area by Sewanee students using a 400 MHz antenna. Three lines crossed the plume area across the assumed gradient. One line was acquired parallel to the assumed gradient. Because of poor quality of GPR data, one line was repeated at the Gas Station site on November 15, 2018 using 400- and 200-MHz antennas with the help of Sewanee students. Laterally continuous reflectors are visible on 200 MHz profiles across the plume area to depths of about 5 m (fig. 16). Additional profiles are being processed by L. Costard at BEG to produce shallow subsurface images of the contact between soil and underlying bedrock.

FDEM data were acquired by Sewanee students using the CMD Explorer and all three coil separations (fig. 15). Three lines crossed the presumed plume gradient in a northwest-southeast

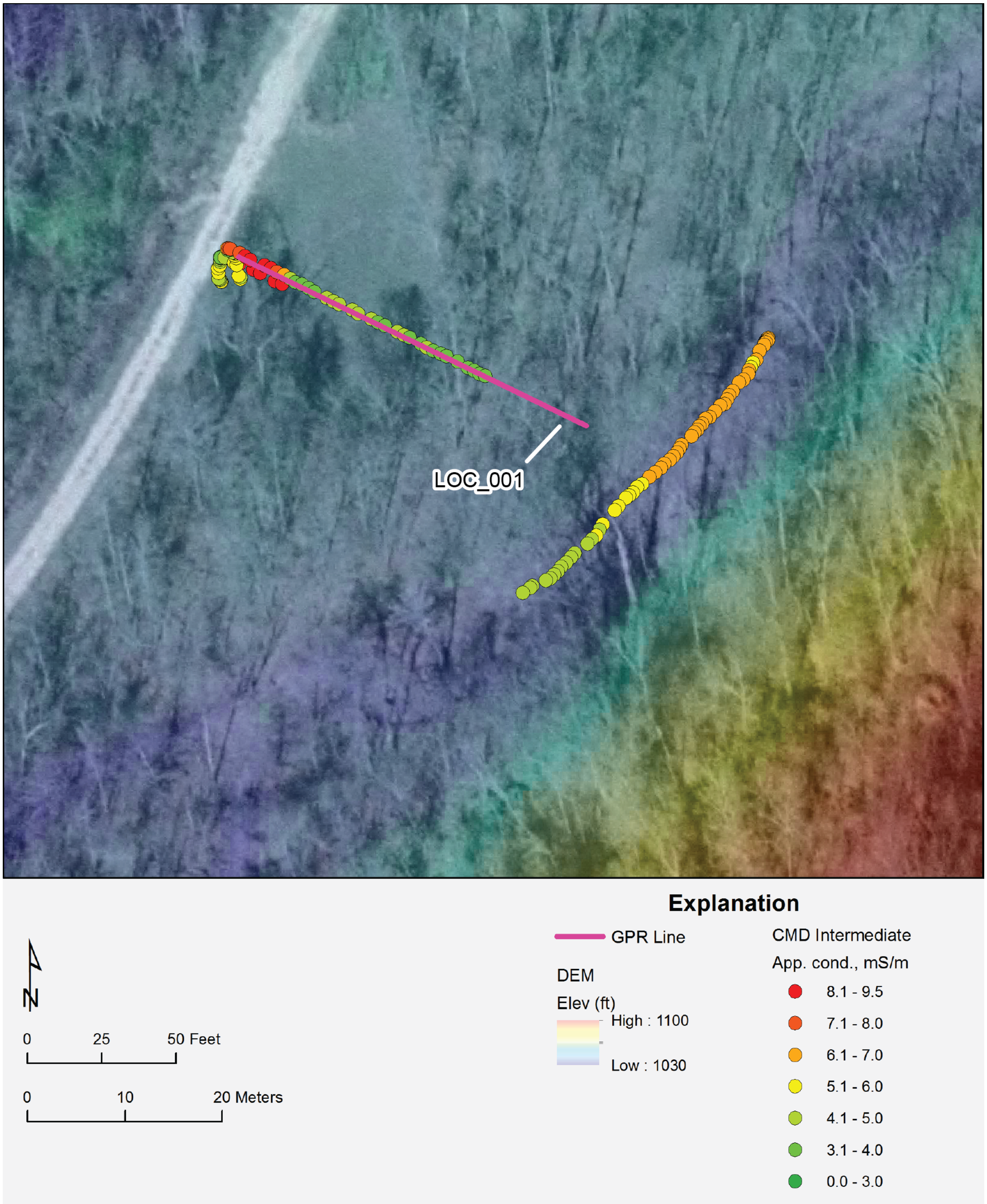

Figure 14. Map of the Lost Cove site (fig. 1) showing locations of a GPR line and CMD Explorer measurements (apparent conductivity for the intermediate coil separation) surveyed on September 13, 2018. Locations superimposed on aerial imagery and DEM provided by C. Van de Ven.

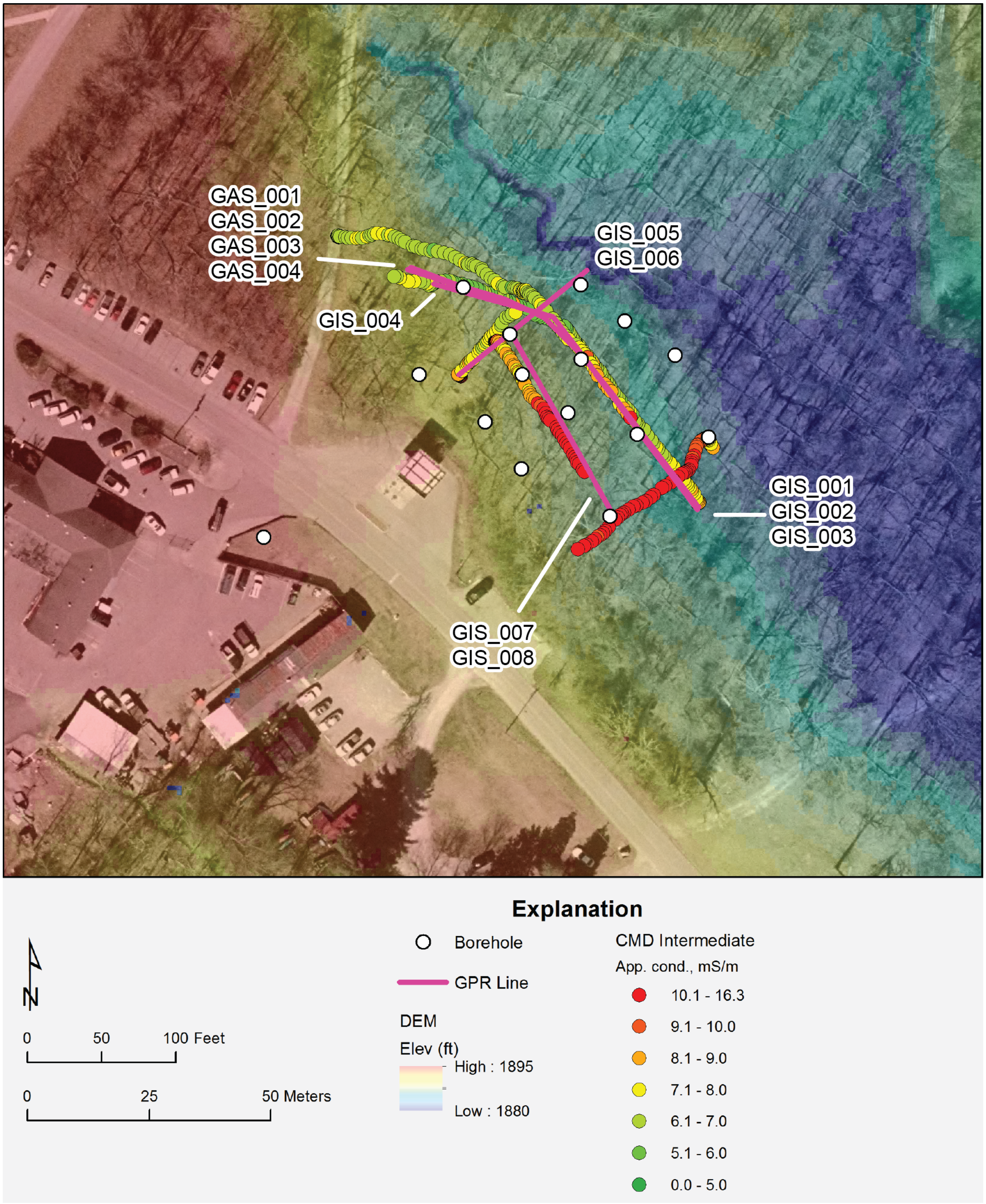

Figure 15. Map of the Sewanee Gas Station site (fig. 1) showing locations of GPR lines and CMD Explorer measurements (apparent conductivity for the intermediate coil separation) surveyed on September 13 and November 15, 2018. Locations superimposed on aerial imagery and DEM provided by C. Van de Ven.

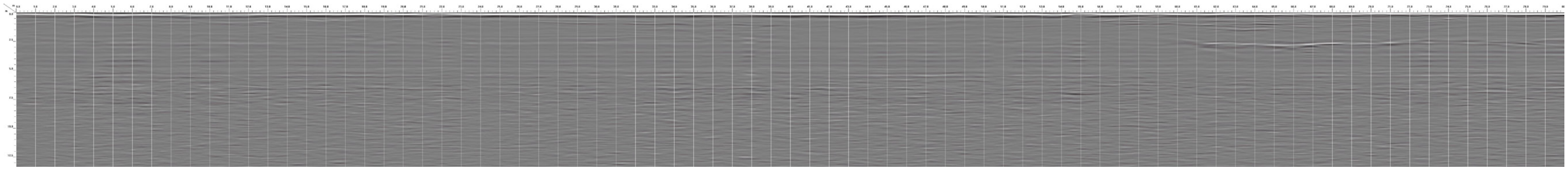

Figure 16. GPR profile GAS_004 acquired at the Gas Station site (fig. 15) on November 15, 2018 using a 200 MHz antenna. Data were acquired from southeast (0 m, at left) to northwest (80 m, at right). Distance and depths are in meters.

orientation; two more lines were parallel to the gradient in a northeast-southwest orientation. Apparent conductivity values averaged about 8 mS/m for all three coil separations. Simple two-layer inversions indicate a 2-m thick surficial layer with relatively high conductivities averaging 36 mS/m underlain by a low-conductivity layer averaging 9 mS/m. Surficial layer conductivities are significantly higher here than at other surveyed sites. Further, highest apparent conductivities appear to coincide with the presumed plume area as outlined by the borehole locations (fig. 15).

Site 6: St. Andrew's–Sewanee

GPR data were acquired at a large and small rock shelter on the St. Andrew's–Sewanee (SAS) campus on November 14, 2018 with SAS faculty and students (figs. 1, 17, and 18). The purpose was to image shallow strata at these shelters that might host archeological materials and to image a mound of unknown origin downslope from the smaller rock shelter. Fifteen GPR profiles were acquired along 12 lines adjacent to these shelters using a 400 MHz antenna along all lines and a 200 MHz antenna along one line across the mound (fig. 17).

Preliminary images from some of the GPR profiles acquired at the SAS rock shelters generally show discontinuous reflectors in the upper 3 to 4 m of the subsurface. Along profile SAS_003 extending northward from the large rock shelter, relatively weak, discontinuous reflectors in the upper 1.6 m transition to stronger discontinous reflectors between 2 and 4 m below the surface. (fig. 19). Along GPR profile SAS_015, parallel and downslope to the rock shelter overhang (fig. 17), some structure is evident on reflectors in the upper 0.5 m, particularly between 2 and 4 m along the profile (fig. 20). Discontinuous reflectors deeper than 2 m are generally stronger than those less than 2 m deep. Along GPR profile MOD_001, which crosses the mound below the smaller rock shelter (fig. 17), the depth to a reasonably continuous reflector increases from about 1 m away from the mound to about 4 m beneath the mound (fig. 21). This profile has not been corrected for topography (the mound is topographically higher than the surrounding surface). Processing of these and other GPR profiles from the rock shelter area is ongoing.

Supplemental TDEM Sites

Three TDEM soundings were acquired during the November visit at convenient sites at the SAS practice fields (SEW-002, fig. 1), adjacent to the runway at the Franklin County Airport (SEW-003, fig. 1), and at the soccer fields adjacent to the Sewanee gas station (SEW-004, fig. 1) to determine the electrical conductivity structure in the deeper subsurface. Profiles of electrical conductivity with depth at these sites are generally similar to that determined from TDEM sounding SEW-001 acquired at the Sewanee Farm during the September 2018 (fig. 8), where a low-conductivity layer tens of meters thick is underlain by a more conductive unit that is also tens of meters thick, which is underlain by increasingly less conductive layers to more than 200 m depth, the maximum exploration depth achieved by the instrument. Like at the Sewanee Farm, the conductivity changes with depth are likely to be caused by major changes in lithology (sandstone or conglomerate, shale, and limestone differ in their electrical properties), water saturation, or water salinity.

At the SAS practice field, TDEM sounding SEW-002 (fig. 22) indicates the presence of a poorly conductive unit from the ground surface to a depth of about 50 m. Beneath this is a more

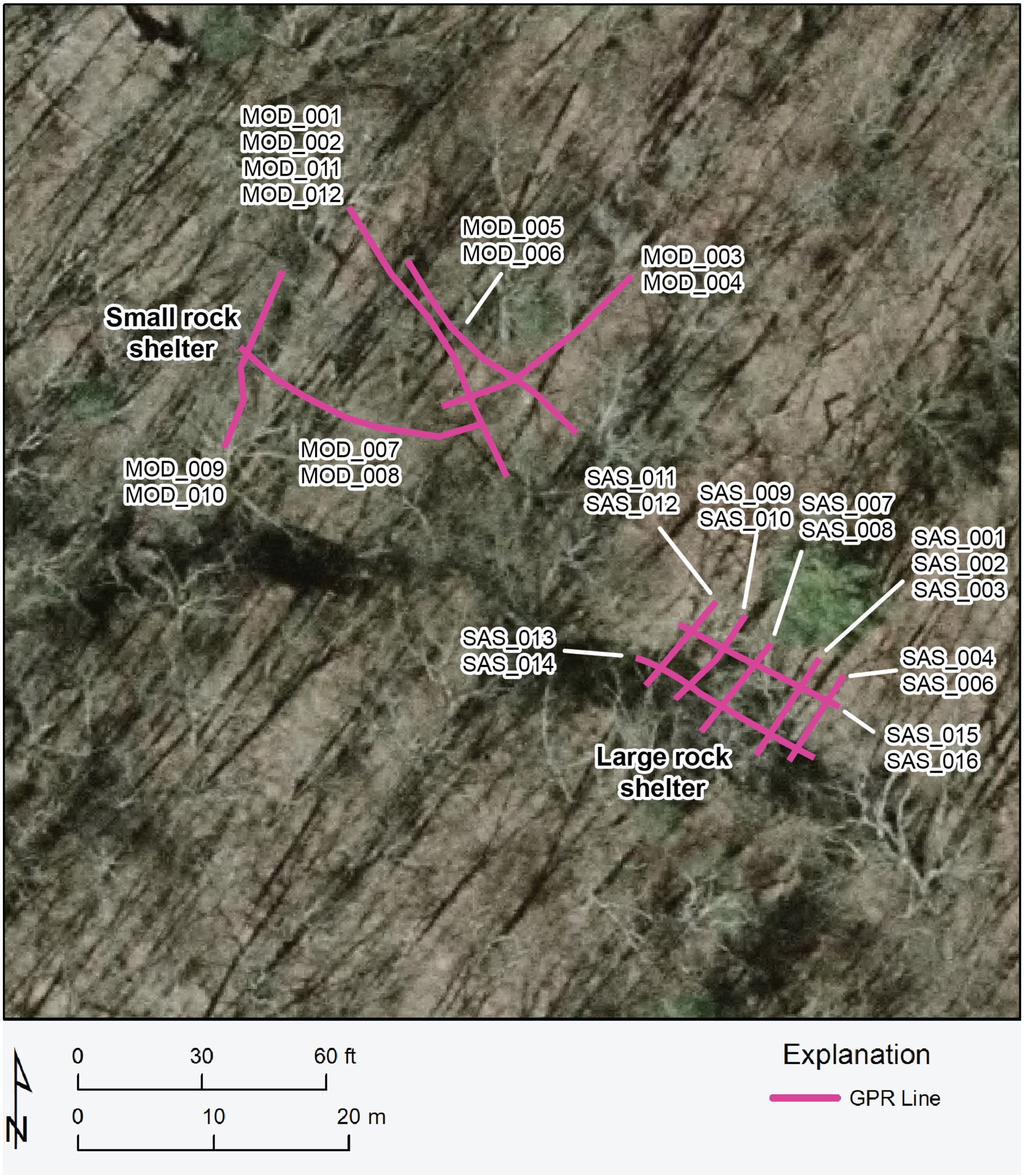

Figure 17. Map of the rock shelter site at St. Andrew's–Sewanee (fig. 1) showing locations of the small and large rock shelters and GPR lines surveyed on November 14, 2018. Locations superimposed on aerial imagery provided by C. Van de Ven.

Figure 18. SAS students and faculty member Marion Knoll assisting with GPR data acquisition at the rock shelters.

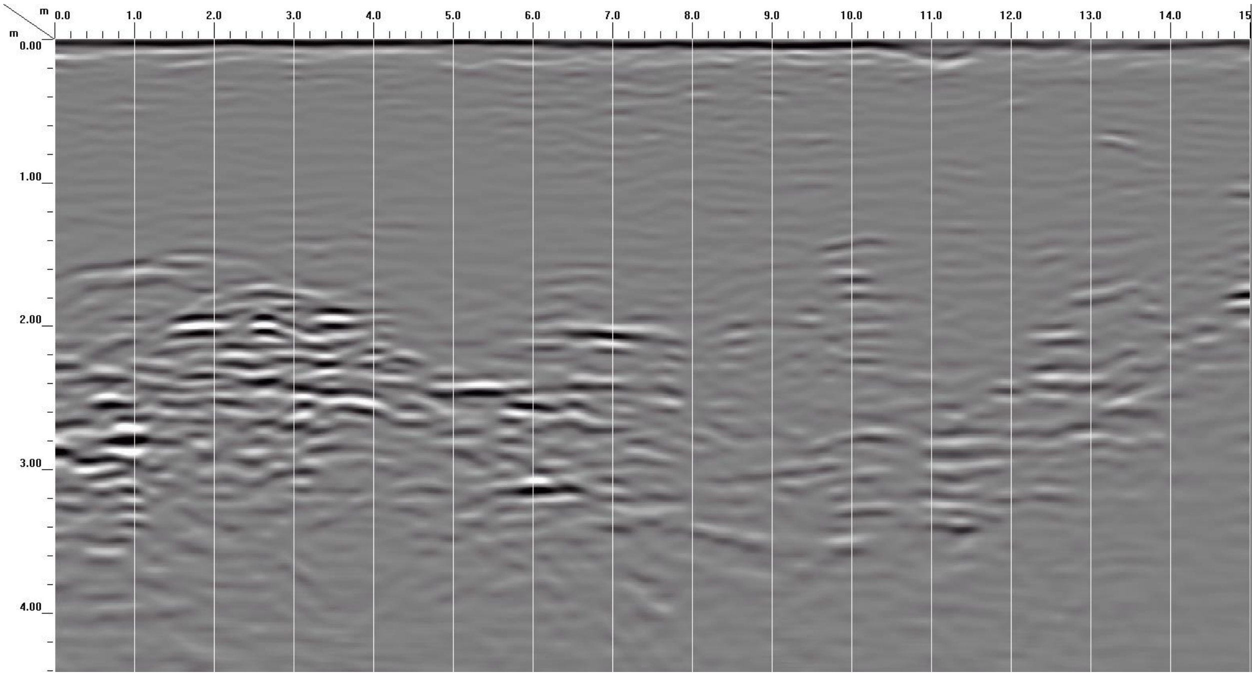

Figure 19. GPR profile SAS_003 acquired at the large rock shelter on the SAS campus (fig. 17) on November 14, 2018 using 400 MHz antennas. Data were acquired from northeast (0 m) to southwest (15 m). Distance and depths are in meters.

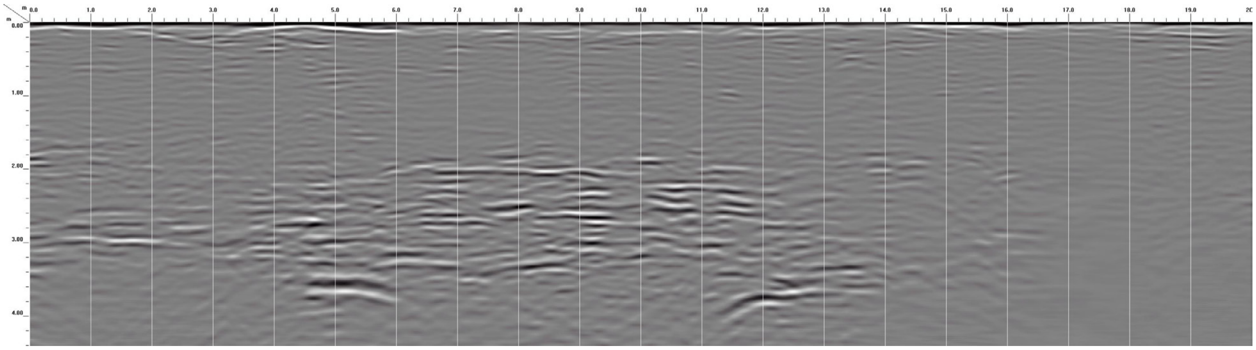

Figure 20. GPR profile SAS_015 acquired along the berm crest at the large rock shelter on the SAS campus (fig. 17) on November 14, 2018 using a 400 MHz antenna. Data were acquired from southeast (0 m) to northwest (20 m). Distance and depths are in meters.

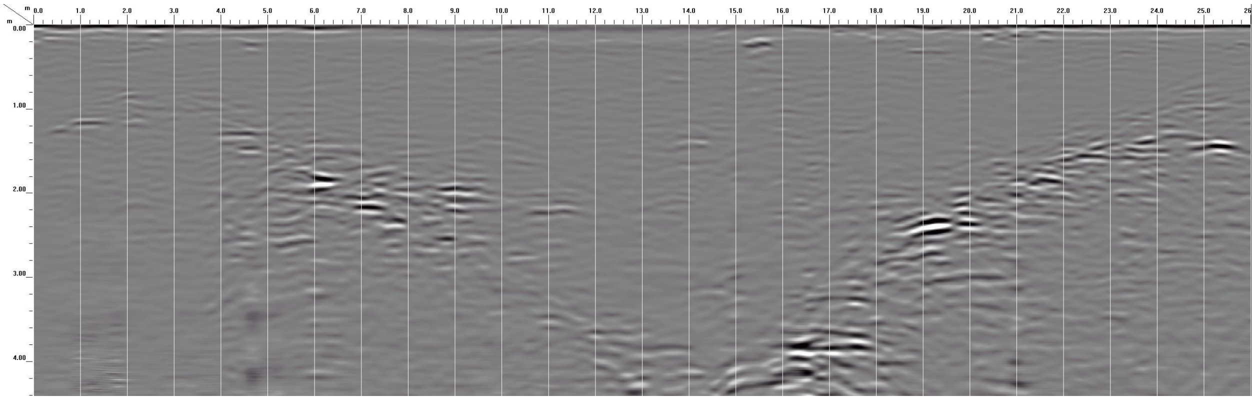

Figure 21. GPR profile MOD_001 acquired across the mound structure below the smaller rock shelter on the SAS campus (fig. 17) on November 14, 2018 using a 400 MHz antenna. Data were acquired from southeast (0 m) to northwest (26 m). Distance and depths are in meters.

conductive zone extending from about 50 m to about 150 m depth, which is underlain by poorly conductive strata to beyond 186 m, the maximum depth of investigation.

At the Franklin County Airport, nearby sources of electromagnetic noise reduced the maximum exploration depth of TDEM sounding SEW-003 to a little greater than 100 m and increased the best-fit model error to 5.6 percent (fig. 23). Nevertheless, a conductivity profile similar to those determined elsewhere included a poorly conductive layer from the ground surface to about 40 m depth, a more conductive unit between 40 m and about 110 m depth, and a poorly conductive unit from 110 m to the maximum depth achieved.

At the soccer fields near the Sewanee Gas Station (sounding SEW-004, fig. 1), the best-fit conductivity profile includes a poorly conductive surficial layer about 30 m thick, gradually increasing electrical conductivity with depth to a maximum electrical conductivity at about 100 m depth. Below that, conductivity decreases with depth to about 150 m depth. Below 150 m, strata are poorly conductive to the maximum exploration depth achieved.

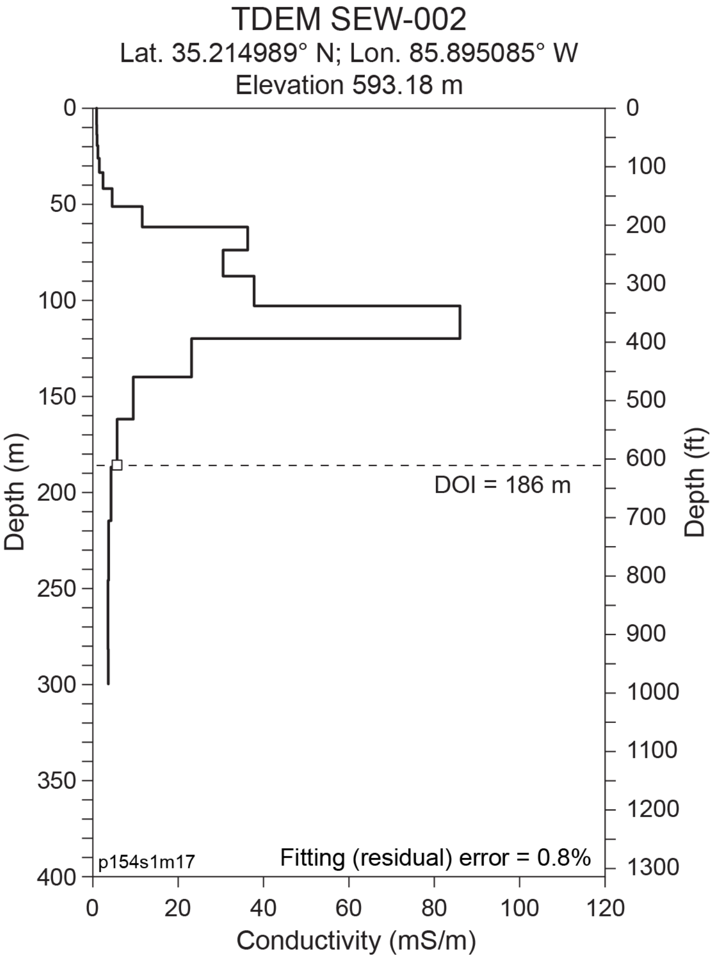

Figure 22. Best-fit model of subsurface conductivity structure at TDEM sounding site SEW-002 at the SAS practice field (fig. 1). DOI = depth of investigation.

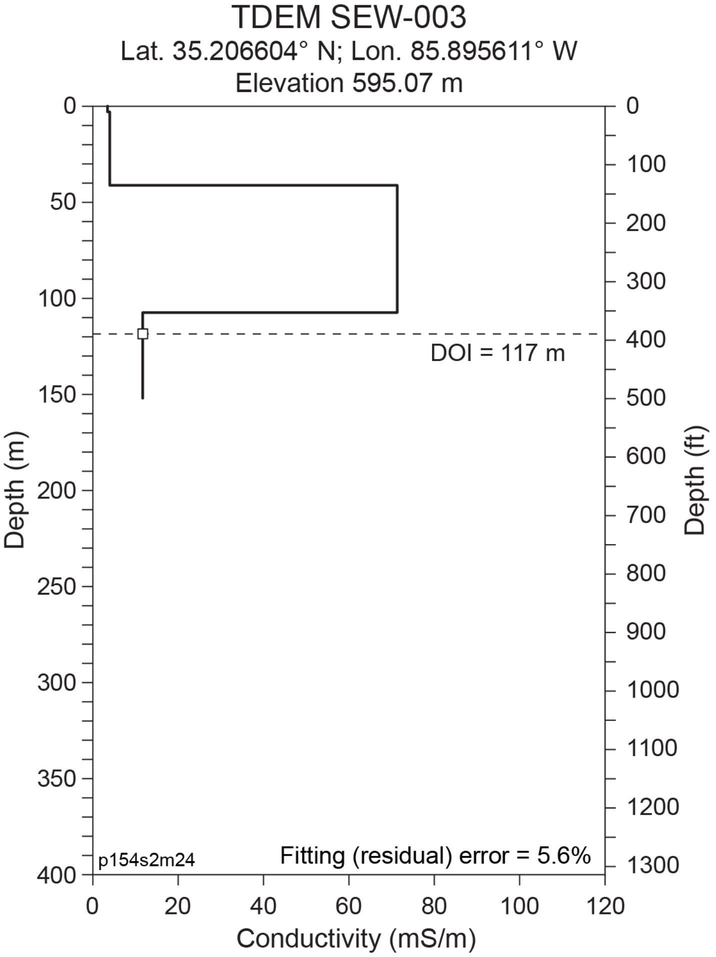

Figure 23. Best-fit model of subsurface conductivity structure at TDEM sounding site SEW-003 at the Frankin County Airport (fig. 1). DOI = depth of investigation.

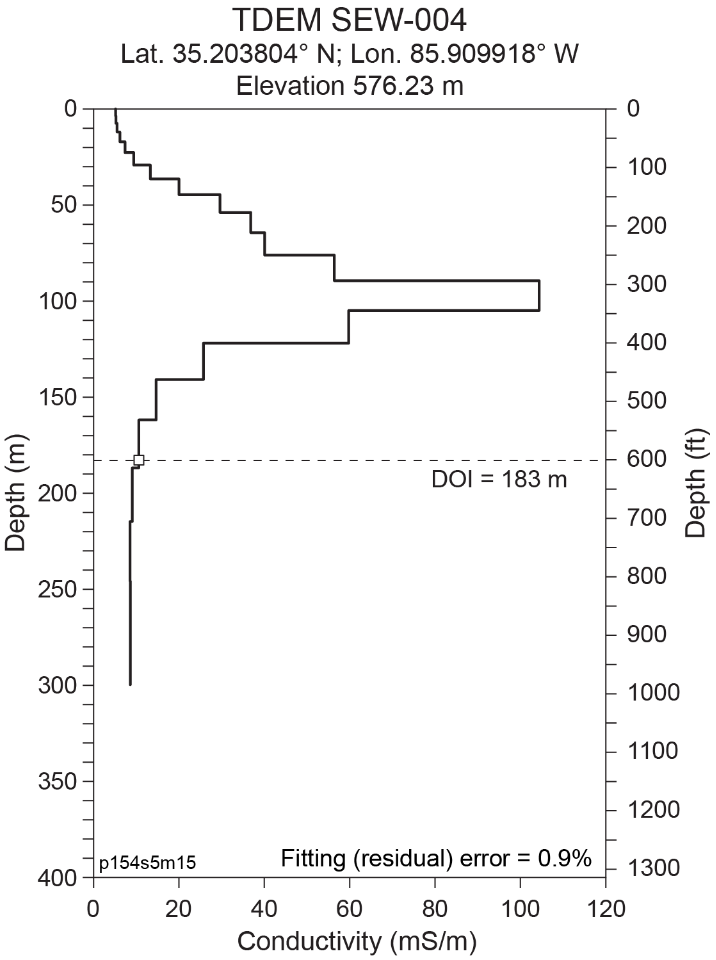

Figure 24. Best-fit model of subsurface conductivity structure at TDEM sounding site SEW-004 at the soccer fields near the Sewanee Gas Station (fig. 1). DOI = depth of investigation.

SUMMARY

Geophysical investigations at Sewanee during the first and second field visits in September and November 2018 included measurements at six focus areas on the Sewanee and SAS campuses and supplemental geophysical measurements at three additional sites. Three major types of near-surface geophysical instruments were introduced to Sewanee and SAS faculty, staff, and students, including GPR, FDEM, and TDEM. Data acquired at the six focus areas (Sewanee Farm, Borrow Pit, Breakfield Road wetland, Lost Cove, Gas Station, and SAS rock shelters) and three supplemental sites indicate that:

- Soil and bedrock strata on the Cumberland Plateau part of the Sewanee Domain are dominantly clay-poor and poorly conductive. Conductivity contrasts between soil and bedrock are typically small. Alluvium and carbonate strata off the plateau within Lost Cove are moderately more electrically conductive.
- FDEM measurements have been successful in determining alluvial thickness along a stream in Lost Cove and identifying conductivity increases possibly caused by shallow water saturation associated with springs near the Sewanee Farm, residuum from a gasoline plume, and a transition from soil to underlying bedrock near a borrow pit.
- TDEM soundings at the Sewanee Farm, SAS practice field, the Franklin County Airport, and near the Sewanee Gas Station acquired data on conductivity structure from the surface to greater than 100 m depth and indicated the presence of a general conductivity structure of poorly conductive layers from the surface to 30 to 50 m, more electrically conductive strata between 50 to as great as 190 m depth, and poorly conductive strata beneath the more conductive strata to the maximum depths explored. These distinct values and depths likely correspond to major lithological boundaries in the subsurface.
- GPR data acquired at all sites indicate relatively deep exploration owing to the low signal attenuation associated with poorly conductive soil and bedrock common at Sewanee. Data continue to be processed to produce shallow cross sections that can reveal soil thickness, bedrock depths, and internal layering in shallow strata and at archeological sites.

Field activities during future visits to Sewanee will be conducted with these instruments and possibly others that will help address near-surface geological, hydrological, and archeological issues identified by participating faculty and staff at Sewanee, SAS, and BEG.

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