United States Department of Agriculture

NRCS

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Subject: SOI – Geophysical Field Assistance **Date:** 07 October, 2009

To: Allen Green
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Purpose: To provide site assessment in areas containing high salinity in Alamosa County, CO (Ancient Lake Alamosa lake bed) while utilizing EMI technology. To provide site assessment assistance using noninvasive geophysical techniques at a registered archaeological site (5MT 2320), located in Montezuma County near Cortez, CO.

Participants:
Rob Mendez, Soil Scientist, USDA-NRCS, Alamosa, CO
Alan Stuebe, MLRA Project Leader, USDA-NRCS, Alamosa, CO
Steve Park, MLRA Office Leader/State Soil Scientist, USDA-NRCS, Lakewood, CO
Ann Tuttle, Earth Team Volunteer, Wilkesboro, NC
Wes Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, Wilkesboro, NC
Bill Volf, Archaeologist, USDA-NRCS, Cortez, CO

Activities:
All field activities were completed on 05, 06, and 11, 12, 13, August 2009.

Summary of Results:

1. In Alamosa County (within the lake bed area of **Ancient Lake Alamosa**), changes in apparent conductivity were associated with changes in soil properties and changes in landforms in both the deeper sensing HCP geometry and the shallower sensing PRP geometry (Dualem-2 meter). Depressional areas and "flats" contained the highest apparent conductivity. These areas contained high concentrations of salts. Apparent conductivity in excess of 1300 mS/m was observed in the depressional/flat areas (San Luis soils and a very poorly drained soil (unnamed)) in the shallower sensing PRP geometry. A thin white salt crust was often visible on the surface in the "flats". The dunal areas (Corlett soils - typically sandy in texture) exhibited the lowest conductivity. Apparent conductivity ranged to as low as 11 mS/m in the shallower sensing PRP geometry. Transitional areas between the dunal areas and the depressions/flats were usually associated with Hooper soils. Apparent conductivity measurements observed in areas of Hooper soils were typically between apparent conductivity measurements observed in dunal areas (lower conductivity) and apparent conductivity observed in depressional/flat areas (higher conductivity).

2. In Alamosa County (within the lake bed area of **Ancient Lake Alamosa**), San Luis soils appear to exhibit a broad range of apparent conductivity throughout the map unit in both HCP and PRP geometries (Dualem-2 meter). The unit may need to be divided into separate map units as suggested by the state soil scientist. An assessment of changing apparent conductivity across areas of San Luis soils may help in separating the map unit into at least two separate units based on changing salt content as inferred from apparent conductivity measurements. Additional studies need to be completed in areas containing San Luis soils to more accurately capture within map unit variability and to better define map unit composition.

3. At the House Creek Village site (5MT 2320), a resistivity survey was completed in May, 2009 by archaeologist Bill Volf (Geoscan Research RM-15 meter). An EMI survey was completed with the Geonics EM38 meter and the Dualem-2 meter across the same survey area on August 11, 12, and 13 for comparison purposes. Anomalous

features were very evident in the resistivity survey (Geoscan Research RM-15 meter), suggesting the location of several architectural structures thought to be pit structures and roomblock structures. A magnetic survey was conducted at the site in 1979 during archaeological investigations. Anomalies identified during that survey are in agreement with locations identified during the survey conducted by Volf (May, 2009). When comparing the apparent conductivity surveys to the resistivity survey (Geonics EM38 meter and Dualem-2 meter versus Geoscan Research RM-15 meter), a striking difference is revealed. Anomalous features thought to be associated with prehistoric archaeological structures at the site are very apparent in the resistivity survey and are either absent or very subtle in the conductivity surveys, comparatively speaking. It is not known if the Geoscan Research RM-15 meter may have been more sensitive to certain changes in soil properties associated with archaeological features at this particular survey site. Soil conditions were relatively wetter while conducting the resistivity survey in May, 2009 and more moisture may have enhanced the contrast between the surrounding soils and anomalous features observed in the resistivity survey as compared to the EMI (apparent conductivity) surveys conducted in August, 2009. Comparative geophysical surveys completed on the same day (under the same soil/weather conditions) would help greatly while assessing advantages and limitations (pros and cons) using different geophysical tools. Further comparative studies need to be completed to help identify limitations and advantages of these geophysical tools.

4. GPR surveys conducted with the 200 MHz antenna at the House Creek Village site (Montezuma, County) were of marginal to satisfactory interpretative quality. Observation depths ranged to approximately 1.5 m. A potential pit structure with a characteristic concave feature was identified within the 40 m x 20 m grid area, at the same location suggested from the resistivity survey. The pit structure was observed with the bottom floor of the structure being located at approximately 1 m. This is consistent with observations from nearby excavations of pit structures (at similar sites). The pit structure has filled in with surrounding soil material and the location of the structure was not evident on the surface.

5. Geophysical techniques can yield ancillary information during soils investigations and archaeological investigations and direct placement of more intense investigations including soil borings and excavations. Geophysical techniques, as demonstrated in Alamosa and Montezuma Counties, provide a noninvasive exploratory method for investigations.

It was my pleasure to work again in Colorado and with members of your fine staff.

Sincerely,

Wes Tuttle
Soil Scientist (Geophysical)
National Soil Survey Center
Lincoln, Nebraska

cc:
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Equipment:
Geonics Limited manufactures the EM38 meter.[1] This meter is portable and requires only one person to operate. No ground contact is required with this meter. McNeill (1980) and Geonics Limited (1998) have described principles of operation for the EM38 meter. Lateral resolution is approximately equal to its intercoil spacing. The EM38 meter has a 1 m intercoil spacing and operates at a frequency of 14,600 Hz. When placed on the soil surface, this instrument has a theoretical penetration depth of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively (Geonics Limited, 1998). Values of apparent conductivity are expressed in millisiemens per meter (mS/m).

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

Dualem Inc. manufactures the Dualem-2/4 meters.[1] Taylor (2003) describes the principles of operation for these meters. The meters consist of one transmitter and two receiver coils. One receiver coil and the transmitter coil provide perpendicular (PRP) geometry. The other receiver coil provides a horizontal co-planar (HCP) geometry with the transmitter coil. This dual system permits two depths to be simultaneously measured without rotating the coils. The depth of penetration is "geometry limited" and is dependent upon the intercoil spacing and coil geometry. The Dualem-2/4 meters operate at a frequency of about 9 kHz. The Dualem-2 meter has a 2-m intercoil spacing and provides penetration depths of 1.3 and 3.0 m in the PRP and HCP geometries, respectively. The Dualem-4 meter has a 4-m intercoil spacing and provides penetration depths of 2.5 and 6.0 m in the PRP and HCP geometries, respectively. The meter is keypad operated and measurements can either be automatically or manually triggered.

The Allegro field computer was used in combination with the Dualem-2/4 meter and the EM38 meter to record and store EMI data. The field computer is keypad operated and measurements can either be automatically or manually triggered. EMI data was geo-referenced with a Trimble AG114 GPS receiver with backpack and frame and a GR-213 GPS receiver manufactured by HOLUX Technology, Inc. [1]

To help summarize the results of this study, SURFER for Windows (version 8.0) program, developed by Golden Software, Inc., [1] was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search.

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the system. The SIR System-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. A 200 MHz antenna was used in this study.

The RADAN for Windows (version 6.6) software program was used to process the radar records (Geophysical Survey Systems, Inc, 2008).[1] Processing included color transformation, surface normalization, time-zero adjustment and range gain adjustments.

Electromagnetic Induction:
Electromagnetic induction is a noninvasive geophysical tool that can be used for soil and site investigations. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Results of EMI surveys are interpretable in the field. This geophysical method can provide in a relatively short time the large number of observations that are needed to comprehensively cover sites. Maps prepared from correctly interpreted EMI data provide the basis for assessing site conditions, planning further investigations, and locating sampling or monitoring sites.

Electromagnetic induction uses electromagnetic energy to measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity are caused by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the type and concentration of ions in solution, volumetric water content, temperature and phase of the soil water, and amount and type of clays in the soil matrix (McNeill, 1980). The apparent conductivity of soils increases with increases in soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

Electromagnetic induction measures vertical and lateral variations in apparent electrical conductivity. Values of apparent conductivity are seldom diagnostic in themselves. However, relative values and lateral and vertical variations in apparent conductivity can be used to infer changes in soils and soil properties.

Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, computer simulations of EMI data are normally used. To verify interpretations, ground-truth measurements are required.

Ground-Penetrating Radar (GPR):
Ground-penetrating radar is a time scaled system. The system measures the time it takes electromagnetic energy to travel from an antenna to an interface (i.e., soil horizon, stratigraphic layer) and back. To convert travel time into a depth scale requires knowledge of the velocity of pulse propagation. Several methods are available to determine the velocity of propagation. These methods include use of table values, common midpoint calibration, and calibration over a target of known depth. The last method is considered the most direct and accurate method to estimate propagation velocity (Conyers and Goodman, 1997).

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

The procedure involves measuring the two-way travel time to a known reflector that appears on a radar record and calculating the propagation velocity by using the following equation (after Morey, 1974):

$$V = 2D/T \qquad [1]$$

Equation [1] describes the relationship between the propagation velocity (V), depth (D), and two-way pulse travel time (T) to a subsurface reflector. During this study, the two-way radar pulse travel time was compared with measured depths to known subsurface interfaces within each study site. Computed propagation velocities were used to scale the radar records.

Alamosa County

The study site is located approximately 12 miles northeast of Alamosa, CO. Apparent conductivity surveys were completed in an area of Corlett sand, hilly, Corlett-Hooper complex, Hooper clay loam, Hooper loamy sand, Hooper soils, occasionally flooded, San Luis sandy loam, and a very poorly drained soil located on flats that is highly saline influenced (tentatively unnamed) (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx and update soil survey (USDA/NRCS)). The deep somewhat excessively drained Corlett soils over a fluctuating water table and moderately well drained material, formed in wind modified alluvium from basalt and similar volcanic roots on low dune-like topography on broad valley floors. The deep, well to moderately well drained Hooper soils formed in alluvium derived from igneous and metamorphic rock on flood plains, alluvial fans and alluvial flats. The somewhat poorly drained San Luis soils formed in alluvium from basalt on floodplains or valley floors. Corlett is a member of the mixed, frigid Typic Torripsamments family. Hooper is a member of the fine-loamy over sandy or sandy-skeletal, mixed, superactive, frigid Typic Natrargids family. San Luis is a member of the fine-loamy over sandy or sandy-skeletal, mixed, superactive, frigid Aquic Natrargids family.

Discussion: Study site was located within the lake bed area of **Ancient Lake Alamosa** (Excerpts below are from “Ancient Lake Alamosa and the Pliocene to Middle Pleistocene Evolution of the Rio Grande”, Machette (2007)).

From Pliocene to middle Pleistocene time, a large, high-altitude lake occupied most of the San Luis Valley of southern Colorado. This ancient lake accumulated sediments that Siebenthal (1910) designated as the Alamosa Formation, for which it is herein named. The existence of this lake was first postulated in 1822 and proven in 1910 from well logs. At its full extent, Lake Alamosa extended almost 105 km north-south and 48 km east-west. It was one of the largest high-altitude lakes in North America, comparable only to historic Lake Texcoco in the Valley of Mexico. Lake Alamosa persisted for about 3 m.y., expanding and contracting and filling the valley with sediment until about 440 ka, when it overtopped a low sill on Oligocene volcanic rocks of the San Luis Hills. The resulting overflow cut a deep gorge, coursed southward, and flowed into the Rio Grande, entering at what is now the mouth of the Red River.

EMI Line Transects

Survey Design:

Multiple line transects were conducted with the Dualem-2 meter across low lying depressional areas, long and narrow dunal ridges, and intermediate depression/dune areas while trying to assess changes in apparent conductivity and changes in soil characteristics. The Dualem-2 meter was carried at a height of approximately 4 inches (10 cm) above the surface and was operated in the continuous mode with measurements recorded at a 1-sec interval. Measurements of apparent conductivity were geo-referenced and were collected in the HCP (deeper sensing (0 - 3.0 m)) and PRP (shallower sensing (0 - 1.3 m)) geometries.

Results: Dualem-2meter (refer to Transects 1 - 7)

A total of 2110 measurements were recorded with the Dualem-2 meter in the deeper sensing HCP geometry. Apparent conductivity averaged about 251.3 mS/m with a range of 31.3 to 990.0 mS/m. One-half the observations had values of apparent conductivity between about 116.7 and 355.5 mS/m.

A total of 2110 measurements were recorded with the Dualem-2 meter in the shallower sensing PRP geometry. Apparent conductivity averaged about 295.5 mS/m with a range of 11.4 to 1374.9 mS/m. One-half the observations had values of apparent conductivity between about 96.5 and 466.0 mS/m.

Changes in apparent conductivity were associated with changes in soil properties and changes in landforms in both the deeper sensing HCP geometry and the shallower sensing PRP geometry. Depressional areas and “flats” contained the highest apparent conductivity. These areas contained high concentrations of salts. Apparent conductivity in excess of 1300 mS/m was observed in the depressional/flat areas (San Luis soils and a very poorly drained soil (unnamed)) in the shallower sensing PRP geometry. A thin white salt crust was often visible on the surface in the “flats”. The “flats” often contain water but aerial photos have shown a tendency for water levels to periodically fluctuate and even completely evaporate, depending on time of year and precipitation.

Photo 1. Alan Stuebe, MLRA Project Leader, USDA-NRCS, Alamosa, CO conducts an EMI survey with the Dualem-2 meter in an area of Corlett-Hooper complex within the lake bed area of ***Ancient Lake Alamosa****. The Corlett soils component (observed in the background) is associated with sandier textures and dune-like topography.*

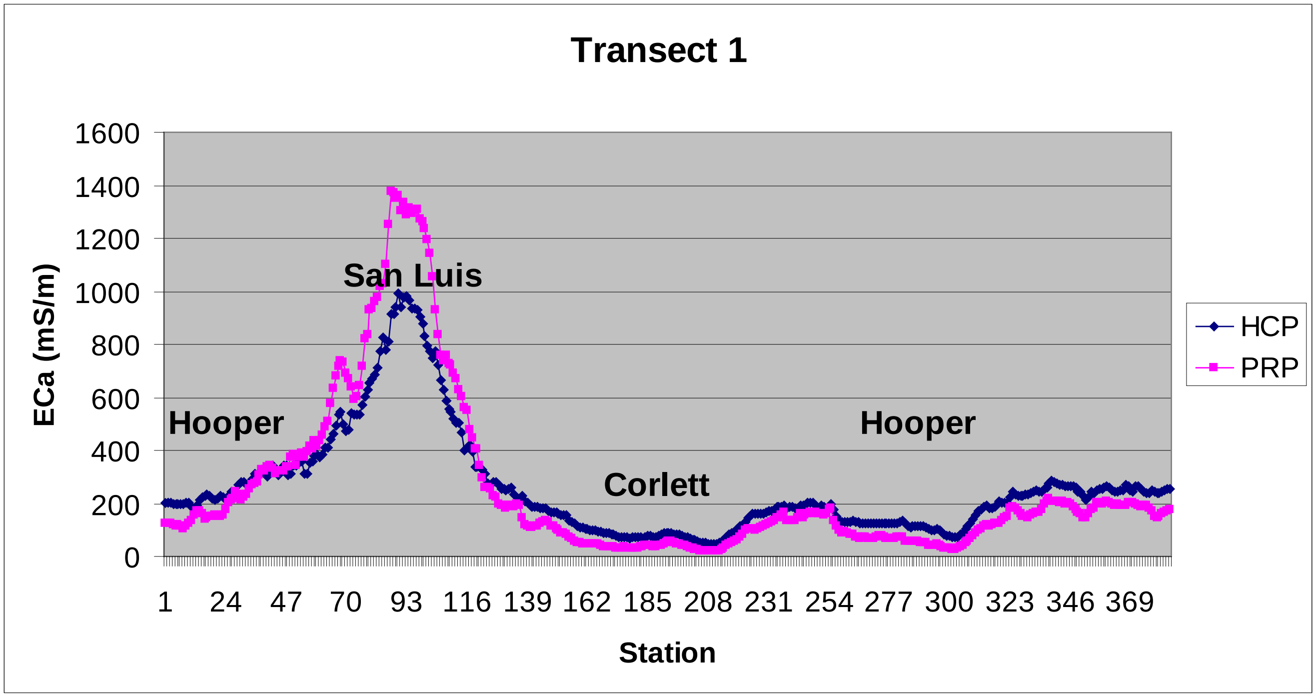
The dunal areas (Corlett soils - typically sandy in texture) exhibited the lowest conductivity. Apparent conductivity ranged to as low as 11 mS/m in the shallower sensing PRP geometry.

Transitional areas between the dunal areas and the depressions/flats were usually associated with Hooper soils. Apparent conductivity measurements observed in these areas were typically between apparent conductivity measurements observed in dunal areas (lower conductivity) and apparent conductivity observed in depressional/flat areas (higher conductivity).

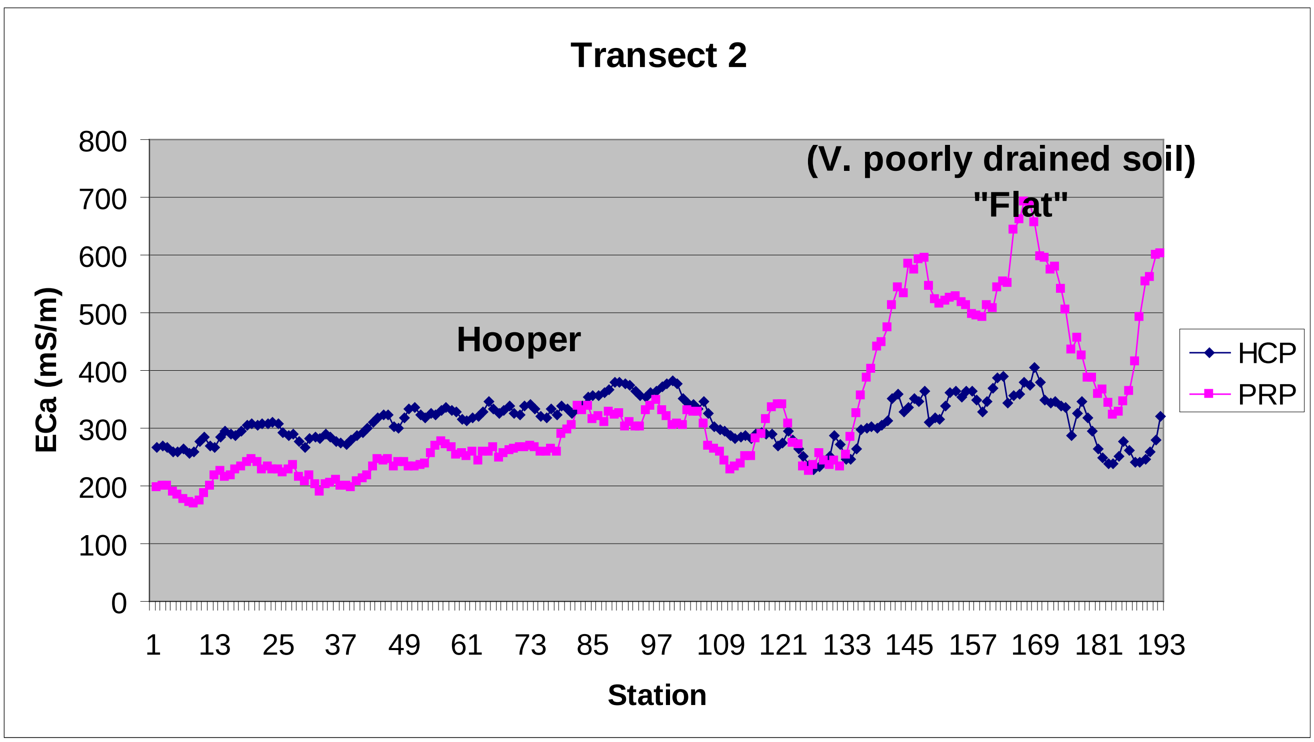
Apparent conductivity data for all seven line transects, including geo-referenced point data, has been forwarded to the Alamosa soils office.

Differentiating Recharge/ Discharge Areas:
Hydrology plays an important role in the development of soils and is a critical factor in the classification of wetlands and associated soils. The depth and movement of water through the subsurface has a direct effect on the physical and chemical properties and the morphology of soils (Richardson et al., 1992). Recharge processes remove soluble chemical constituents and translocates suspended colloids, while discharge processes add materials to soils (Richardson et al., 1992).

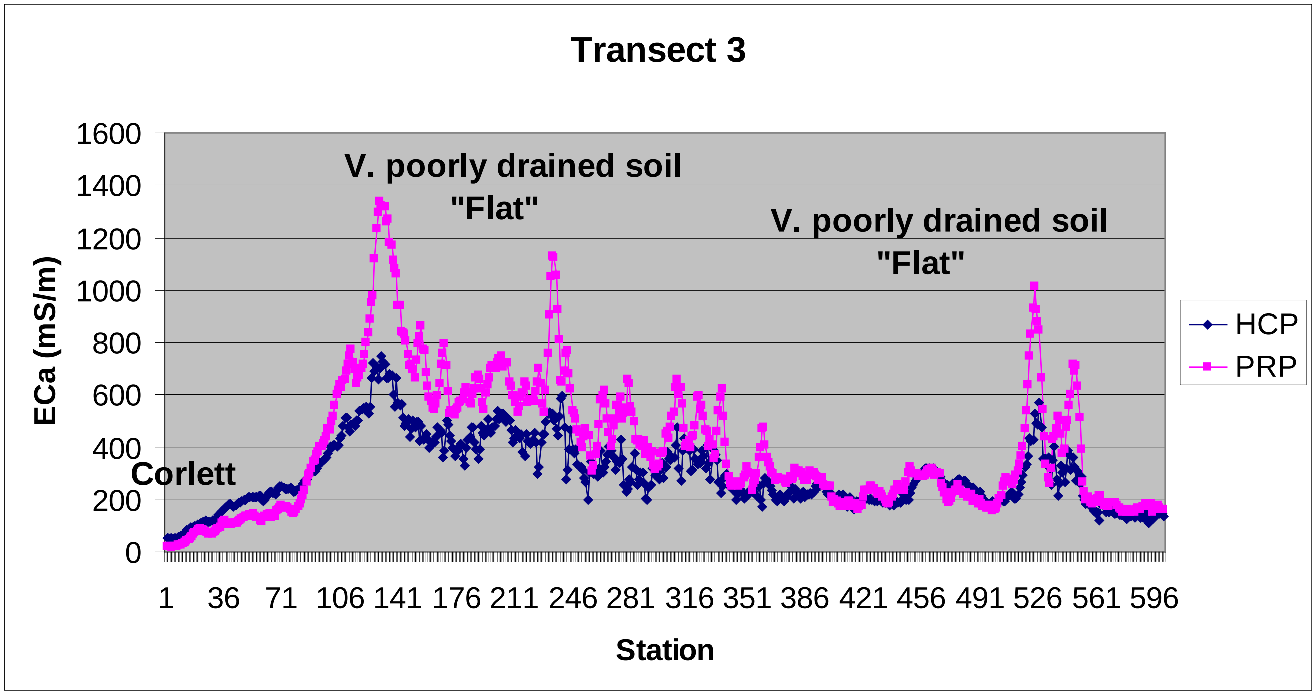
EMI techniques are useful for detecting groundwater recharge and discharge areas and the distribution of soluble salts within landscapes. EMI provides a relatively rapid means for estimating recharge on a regional basis and analyzing spatial variability (Cook et al., 1989). Cook and Williams (1998) noted “discharge areas frequently have higher soluble salt concentrations in the near surface portion of the soil profile because of evaporative processes.” “In recharge areas, soluble salts tend to be leached downwards.” Williams and Arunin (1990) found that varying the dipole orientation (geometry) could be used to determine whether the salt concentration increases or decreases with depth. These authors used a “salt ratio” to classify recharge and discharge areas. The salt ratio is the ratio of EMI measurements taken in the vertical to horizontal dipole orientation (V/H) (HCP/PRP geometry). A recharge area has increasing salt concentrations with depth and a salt ratio greater than 1 (also referred to as a *normal* salt profile). A discharge area has decreasing salt concentrations with depth and a salt ratio less than 1 (also referred to as an *inverted* salt profile).



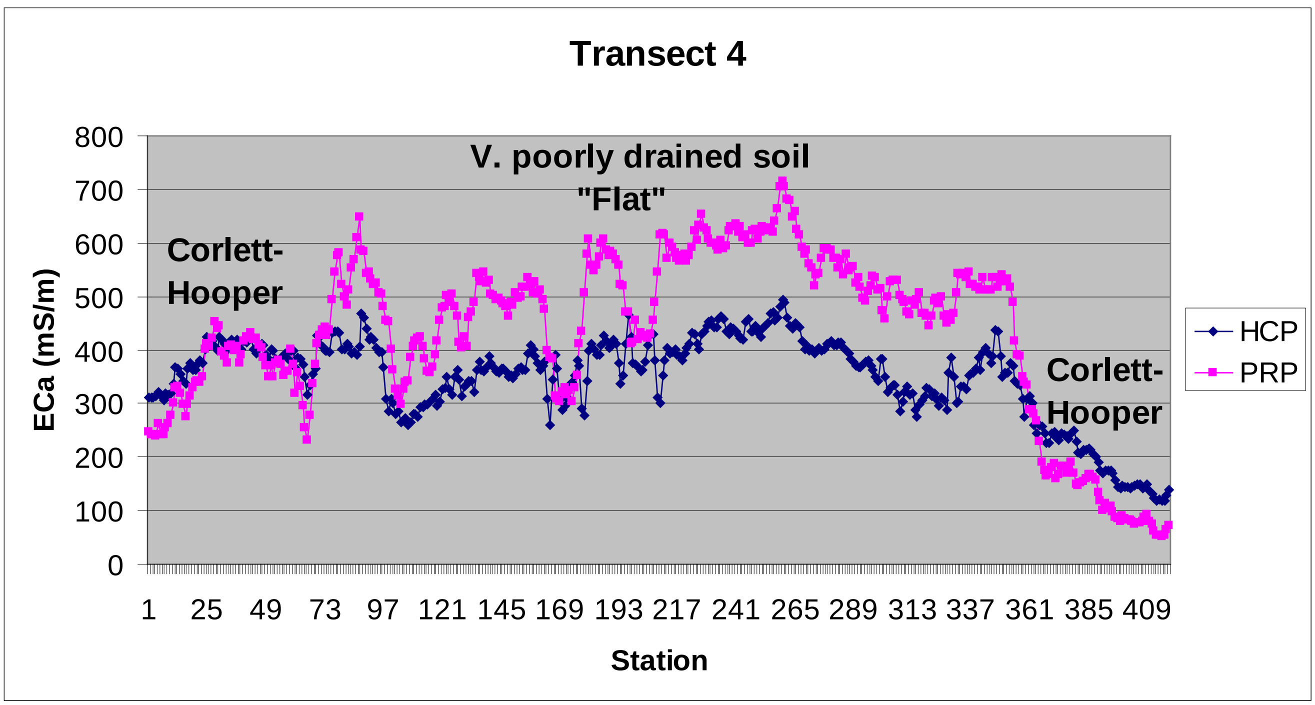
Transect 1. Starting location (northeastward direction) - N 37.554163, W -105.722392



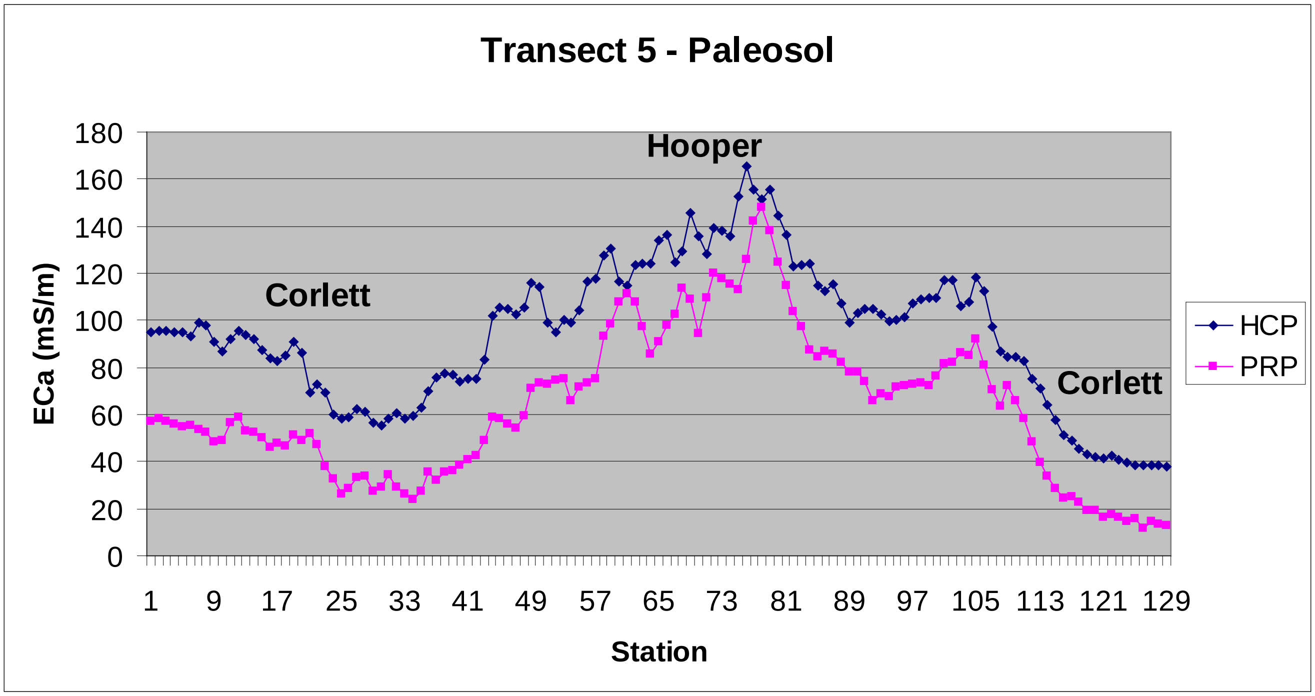
Transect 2. Starting location (eastward direction) - N 37.557033, W -105.719836



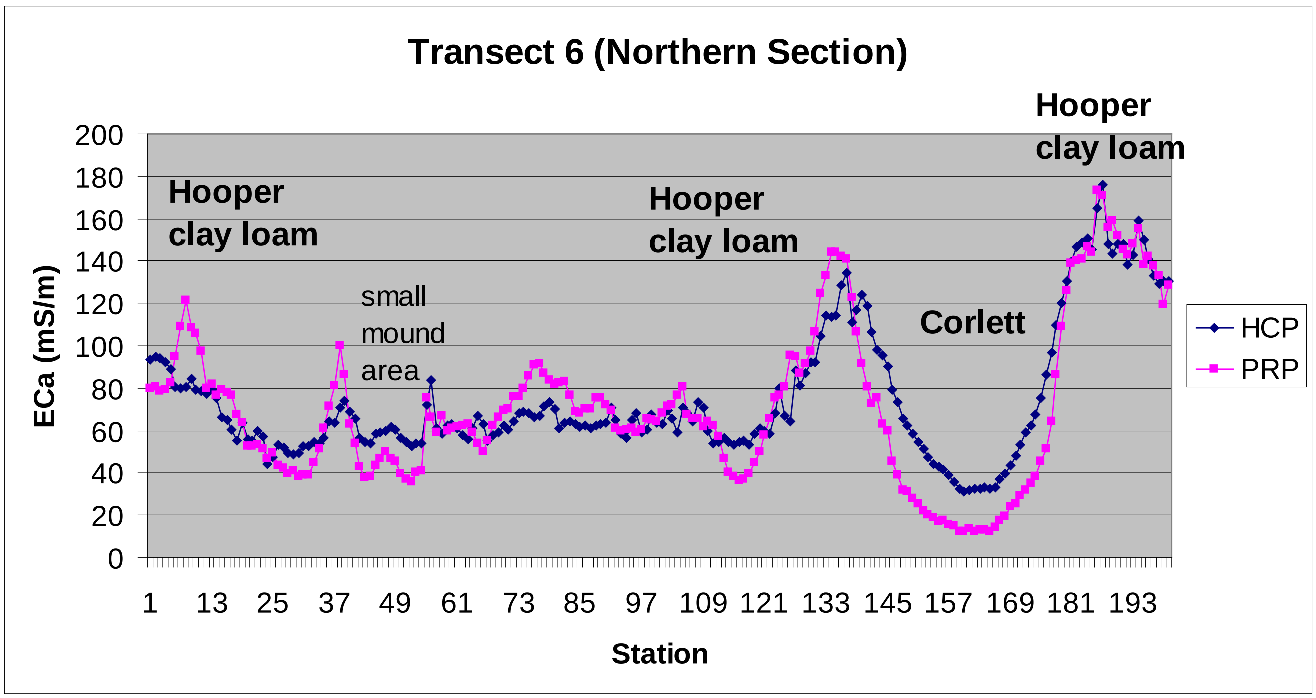
Transect 3. Starting location (southwestward direction) - N 37.555345, W -105.717952



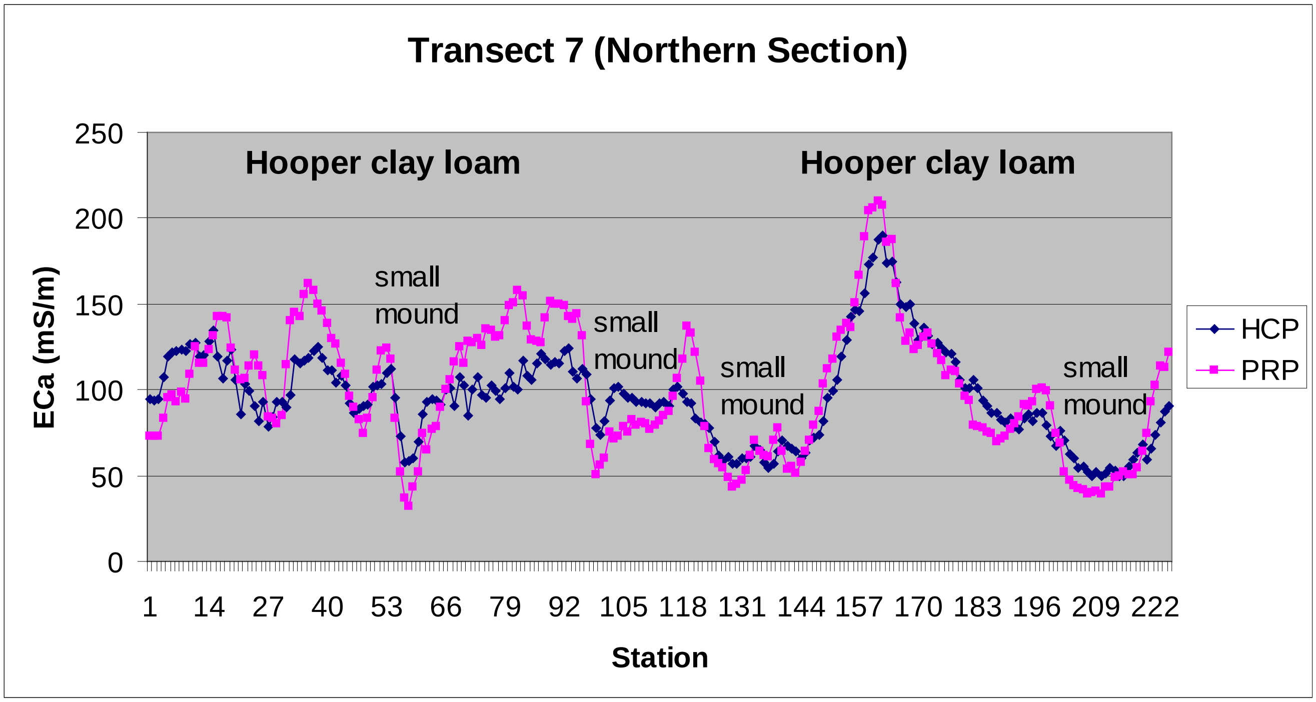
Transect 4. Starting location (eastward direction) - N 37.572887, W -105.703128



Transect 5. Starting location (northeastward direction) - N 37.557283, W -105.712573



Transect 6. Starting location (southwestward direction) - N 37.593755, W -105.759953



Transect 7. Starting location (northward/eastward direction) - N 37.593417, W -105.762188

Figures 1(Transects 1 – 7). EMI line transect surveys measuring apparent conductivity collected with the Dualem-2 meter in both the shallower sensing perpendicular (PRP) geometry (0 - 1.3 m) and the deeper sensing horizontal coplanar (HCP) geometry(0 - 3.0 m). Changes in apparent conductivity were associated with changes in topography and soil characteristics. Apparent conductivity was measured in mS/m (millisiemens/meter).

Photo 2. Highly saline influenced soils can be observed in the photo. These soils are currently unnamed. The soils are very poorly drained and typically occur on "flats". A thin white surface crust (accumulation of salts) is a common occurrence in these areas.

Survey Design: Grid Survey - Dualem-2 meter

A semi-rectangular grid was established across the site. Survey procedures were simplified to expedite fieldwork. Two parallel lines defined the eastern and western boundaries of the survey site. Each line was approximately 260 m long. The lines were spaced approximately 300 m apart. An EMI survey was completed by walking at a fairly uniform pace between similarly numbered traverse lines on the opposing set of parallel lines in a back and forth pattern. Each survey traverse line (east to west/west to east direction) had a 20 m interval spacing. The Dualem-2 meter was carried at a height of approximately 4 inches above the surface and was operated in the continuous mode with measurements recorded at a 1sec interval. Measurements of apparent were collected in the HCP (deeper sensing (0 - 3.0 m) and PRP (shallower sensing (0 - 1.3 m) geometries.

Results:

A total of 3067 measurements were recorded with the Dualem-2 meter in the deeper sensing HCP geometry. Apparent conductivity averaged about 212.3 mS/m with a range of 57.9 to 437.3 mS/m. One-half the observations had values of apparent conductivity between about 146.3 and 267.8 mS/m.

A total of 3067 measurements were recorded with the Dualem-2 meter in the shallower sensing PRP geometry. Apparent conductivity averaged about 195.8 mS/m with a range of 22.1 to 555.6 mS/m. One-half the observations had values of apparent conductivity between about 104.8 and 277.4 mS/m.

Changes in apparent conductivity were associated with changes in soil properties and changes in landforms in both the deeper sensing HCP geometry and the shallower sensing PRP geometry. Soils containing higher apparent conductivity were thought to be associated with higher concentrations of salts. Tentative soil lines (dashed blues lines) observed in *Figure 2*, are thought to more accurately represent soils occurring within the survey grid area, especially with respects to San Luis soils. Areas of San Luis soils observed in *Figure 2* were previously mapped Hooper soils in the prior soil survey of the area. San Luis soils are of particular interest within the update survey area. San Luis soils appear to exhibit a broad range of apparent conductivity throughout the map unit as observed in *Figure 2* in both HCP and PRP geometries, and as observed in line transect surveys collected in adjacent areas. San Luis soils may need to be divided into separate map units (interpretative units) as suggested by the state soil scientist. An assessment of changing apparent conductivity across the map unit may help in separating the map unit into at least two separate units based on changing salt content as inferred from apparent conductivity measurements. Additional studies need to be completed in areas containing San Luis soils to more accurately capture within map unit variability and to better define map unit composition.

A comparison of the deeper sensing HCP geometry and the shallower sensing PRP geometry revealed higher apparent conductivity measurements in the PRP geometry in more saline influenced areas (depressions and “flats). These areas were usually associated with inverted salt profiles (PRP>HCP). *Inverted* salt profiles are those where EMI(PRP)/EMI(HCP) > 1.05 (Corwin and Rhoades, 1990).

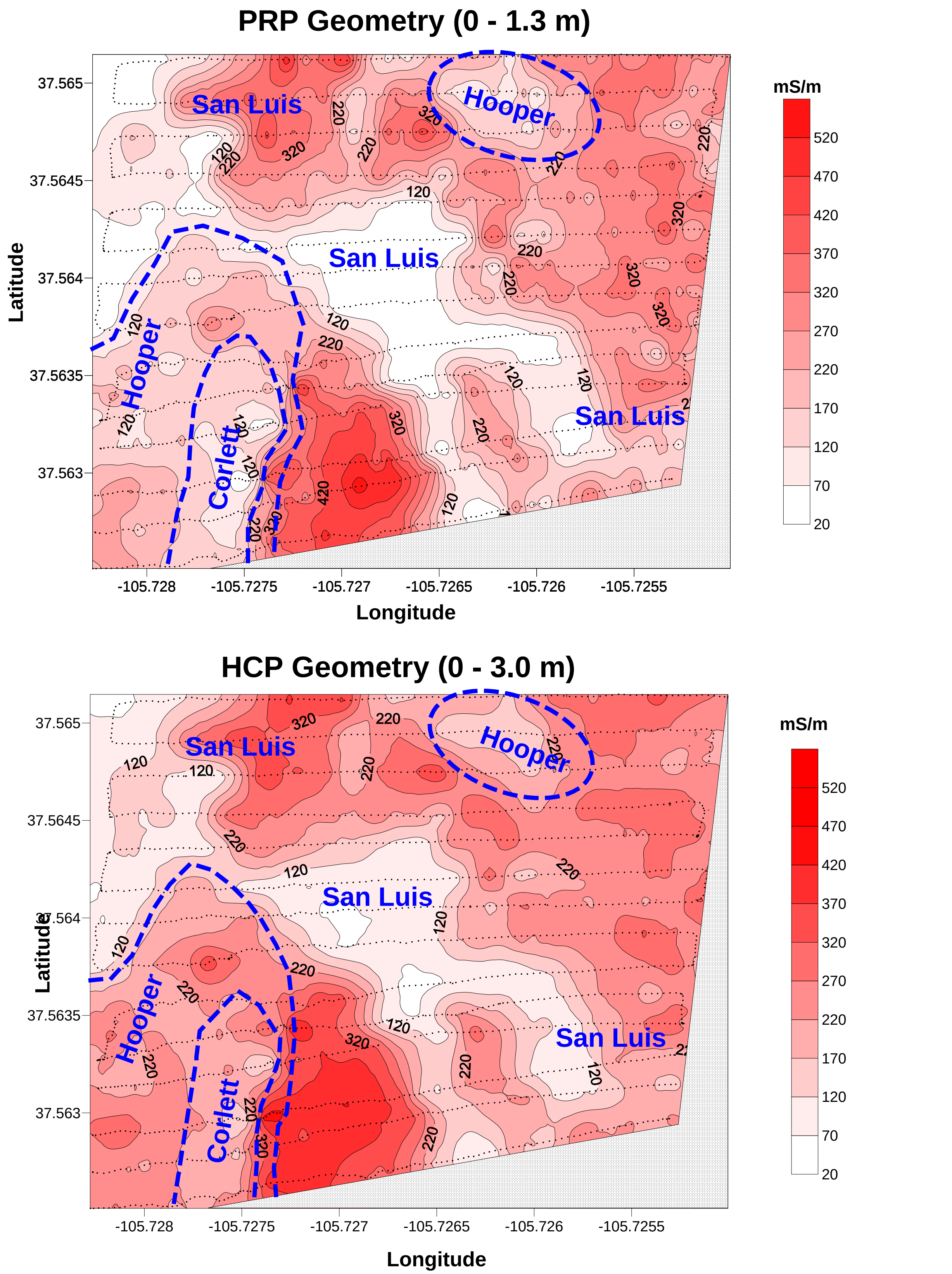


Figure 2 – Apparent conductivity measured with the Dualem-2 meter in the shallower sensing perpendicular geometry (0 – 1.3 m) and the deeper sensing horizontal coplanar geometry(0 – 3.0 m) in an area of Corlett sand, hilly, Hooper loamy sand, and San Luis sandy loam. Apparent conductivity values were measured in mS/m (millisiemens/meter).

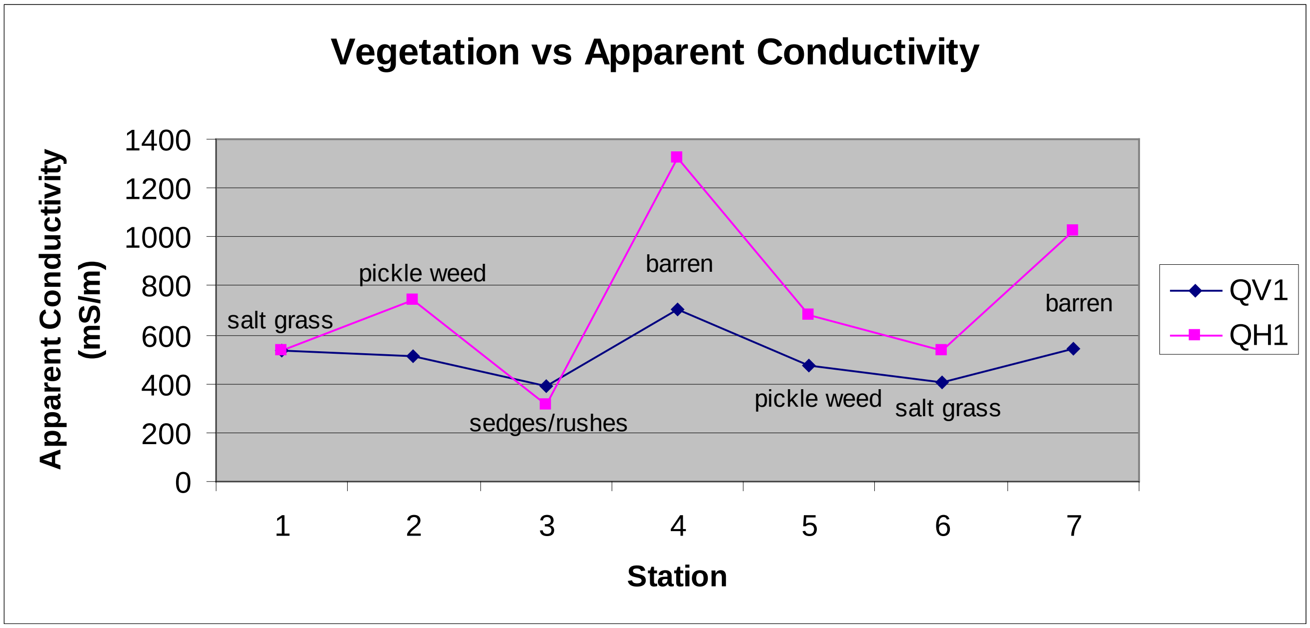


Figure 3. EMI response measured with the EM38 meter across differing plant communities as observed in a representative "flat" area. Four distinct vegetative communities were observed during the EMI survey. Soils observed in the sedges/rushes community exhibited the lowest apparent conductivity, followed by salt grass, pickle weed, and barren soil areas containing no vegetation. Barren areas exhibited extremely high apparent conductivity, especially in the shallower sensing horizontal dipole orientation (QH1). Inverted salt profiles (QH1>QV1) were observed in all plant community sites except for the sedges/rushes plant community, where normal salt profiles were observed (QV1>QH1). Both inverted salt profiles and normal salt profiles were observed in the salt grass community during data collection. Apparent conductivity was more variable in the shallower sensing horizontal dipole orientation (QH1).

Montezuma County

Overview: House Creek Village Site (Archaeological Site # 5MT.2320)
House Creek Village site is a large, aggregated Anasazi habitation located on the south rim of House Creek canyon. The primary occupation of the site is assigned to the A.D. 850-900 time period. Because it is inferred that more than 5 roomblock units are at the site, the site is classified as a village. (Robinson and Brisbin, 1984)

House creek was first surveyed in 1973 and excavations were conducted during the 1979 and 1983 field seasons. Cultural debris found at the site during investigative efforts included ceramics, flaked and nonflaked lithic tools, burnt adobe, and irregularly shaped sandstone slabs. Roomblock-pit structures were observed during excavations. (Robinson and Brisbin, 1984)

The study site is located approximately 5 miles north of Dolores, CO. Apparent conductivity surveys were completed in an area of Weatherill loam, 3 to 6 percent slopes (Ramsey, 2003). A resistivity survey and a magnetic survey were conducted in May, 2009 at the site (courtesy of Bill Volf, USDA/NRCS, Archaeologist, Cortez, CO). The deep and very deep, well drained Weatherill soils formed in eolian material derived from siltstone and sandstone on plateaus, mesas, cuestas, hills, and terraces. Weatherill is a member of the fine-silty, mixed, superactive, mesic Aridic Haplustalfs family.

Conductivity Surveys

Survey Design:
A 40 m x 20 m square grid was established across the site. Survey procedures were simplified to expedite fieldwork. Two parallel lines defined the upper and lower boundaries of the survey site. Each line was 40 m long. The lines were spaced 20 m apart. An EMI survey was completed by walking at a fairly uniform pace between similarly numbered traverse lines on the opposing set of parallel lines in a back and forth pattern. Each survey traverse line (north to south/south to north direction) had a 1 m interval spacing. The EM38 meter was carried at a height of approximately 3 inches above the surface and was operated in the continuous mode with measurements recorded at a 1/2-sec interval. The Dualem-2 meter was carried at a height of approximately 4 inches above the surface and was operated in the continuous mode with measurements recorded at a 1/2-sec interval. Measurements of apparent were collected in the HCP (deeper sensing (0 - 3.0 m)) and PRP (shallower sensing (0 - 1.3 m)) geometries.

Results:
A total of 1906 measurements were recorded with the Geonics EM38 meter in the vertical dipole orientation. Apparent conductivity averaged 8.1 mS/m and ranged from 4.3 to 12.3 mS/m. One-half of the observations had an apparent conductivity between 7.1 and 9.1 mS/m.

A resistivity survey was completed at the site in May, 2009 by archaeologist Bill Volf. An EMI survey was completed with the Geonics EM38 meter across the same survey area on August 11, 12, and 13 for comparison purposes. The comparative surveys can be observed in *Figure 4*. Changes in apparent conductivity (EM38 meter) across the survey area were thought to be associated with changes in soil characteristics. The northern portion (top) (*Figure 4*) of the survey grid was located on a ridge that was more convex in comparison to the southern portion which was down slope (receiving slope). More moisture and slightly deeper soils were thought to be associated with the down slope position and resulted in slightly higher apparent conductivity. There were no identifiable spatial patterns observed with the EM38 meter suggesting the location of architectural features even though a scatter of prehistoric ceramic and lithic artifacts was identified at the site.

The resistivity survey by Volf in May, 2009 resulted in distinct anomalous features suggesting the location of several architectural structures thought to be pit structures and roomblock structures. A magnetic survey was conducted at the site by Volf in May, 2009. A prior magnetic survey was also conducted at the site in 1979, during archaeological investigations. Anomalies identified during the magnetic surveys conducted in May, 2009 and 1979 are in agreement with locations identified during the resistivity survey conducted by Volf (May, 2009).

When comparing the two surveys in *Figure 4* (Geonics EM38 meter versus Geoscan Research RM-15 meter), a striking difference is revealed. The anomalous features thought to be associated with structures at the site are very apparent in the resistivity survey and absent in the conductivity survey, comparatively speaking. It is not known if the Geoscan Research RM-15 meter may have been more sensitive to certain changes in soil properties associated with archaeological features at this particular survey site. Soil conditions were relatively wetter while conducting the resistivity survey in May, 2009 and more moisture may have enhanced the contrast between the surrounding soils and anomalous features observed in the resistivity survey as compared to the EMI (apparent conductivity) surveys conducted in August, 2009. Comparative geophysical surveys completed on the same day (under the same soil/weather conditions) would help greatly while assessing advantages and limitations (pros and cons) using different geophysical tools. Further comparative studies need to be completed to help identify limitations and advantages of these geophysical tools.

Photo 3. Wes Tuttle, Geophysical Soil Scientist, USDANRCS/NSSC, Wilkesboro, NC completes an apparent conductivity survey with the Geonics EM38 meter in an area of Weatherill loam, 3 to 6 percent slopes at the House Creek Village site.

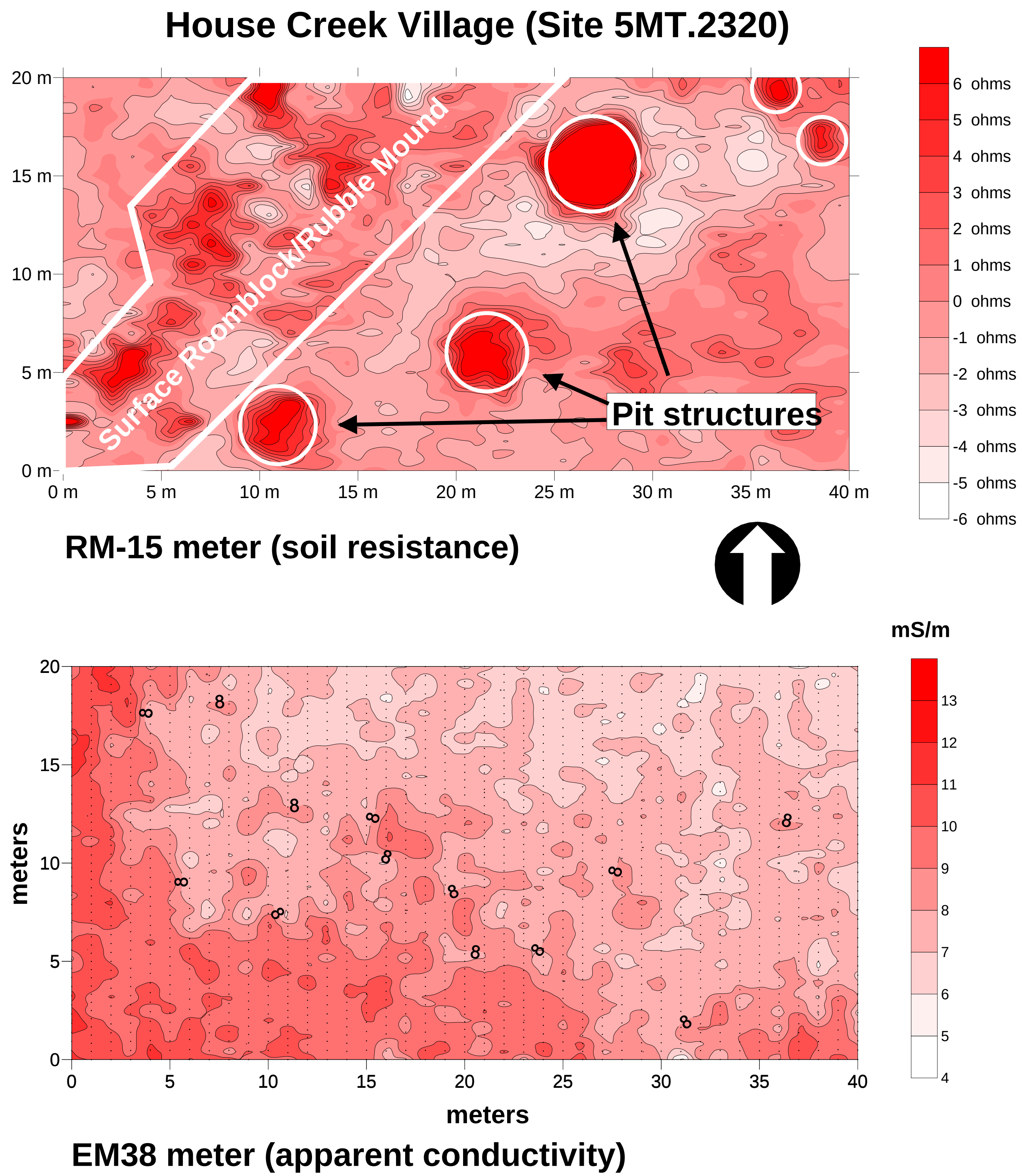


Figure 4 – Spatial pattern of resistivity measured with the RM-15 meter and the EM38 meter at the House Creek Village site. The resistivity survey (RM-15 meter) was completed by Bill Volf, USDA/NRCS Archaeologist, Cortez CO. The instrument electrode spacing was set at 0.5 m. This setting provides an effective response depth between 10 and 80 cm. Resistivity is measured in ohms. The apparent conductivity survey (EM38 meter) was completed by Wes Tuttle, USDA/NRCS/NSSC Geophysical Soil Scientist, Wilkesboro, NC. The EM38 meter was operated in the vertical dipole orientation (0 - 1.5 m observation depth). A comparison of the two geophysical methods resulted in different spatial patterns.

Photo 4. William (Bill) Volf, Archaeologist, USDA/NRCS, Cortez, CO completes a resistivity survey at the House Creek Village site. Bill is using an RM-15 resistivity meter manufactured by Geoscan Research.

Photo 5. The House Creek Village site is a registered archaeological site consisting of a scatter of prehistoric ceramic and lithic artifacts. Small sandstone cobbles and flat slabs were scattered throughout the site and suggests architectural structures were present at the site. Evidence of pot hunters (looters' pits) was observed throughout the site.

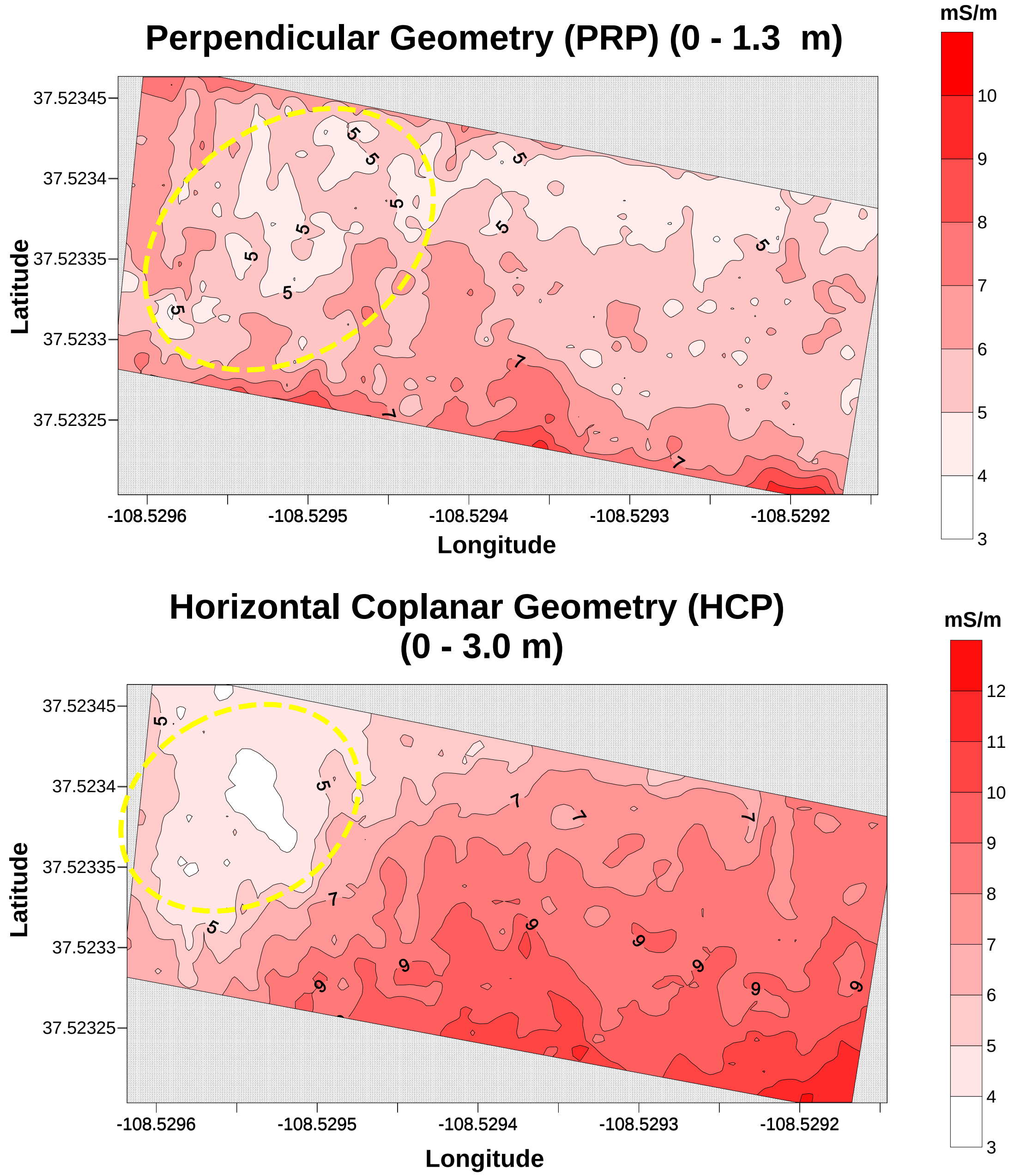


Figure 5– Spatial pattern of apparent conductivity measured with the Dualem-2 meter in the PRP and HCP geometries in an area of Weatherill loam, 3 to 6 percent slopes, located at the House Creek Village (site 5MT.2320), in Montezuma County, CO.

Results: Dualem-2meter (House Creek Village site)
A total of 1310 measurements were recorded with the Dualem-2 meter in the deeper sensing HCP geometry. Apparent conductivity averaged about 7.5 mS/m with a range of 3.2 to 12.3 mS/m. One-half the observations had values of apparent conductivity between about 6.0 and 8.9 mS/m.

A total of 1310 measurements were recorded with the Dualem-2 meter in the shallower sensing PRP geometry. Apparent conductivity averaged about 5.7 mS/m with a range of 3.2 to 9.5 mS/m. One-half the observations had values of apparent conductivity between about 5.0 and 6.3 mS/m.

An EMI survey (*Figure 5*) was completed across the same grid area as surveyed with the Geonics EM38 meter and the Geoscan Research RM-15 meter (same grid area used in *Figure 4*). Changes in apparent conductivity across the survey area were thought to be associated with changes in soil characteristics. Higher apparent conductivity was thought to be associated with and increase in clay and moisture. Although no distinct anomalous features were present suggesting the location of prehistoric archaeological structures in the surveys completed in the PRP or HCP geometries (similar to results from the conductivity survey completed with the EM38 meter), the PRP geometry did reveal a subtle spatial pattern thought to be associated with soil disturbance (area highlighted within the yellow dashed line - oblong circular feature). An anomalous feature (area) resulting in lower apparent conductivity can also be observed in the deeper sensing HCP geometry in the same area of the survey grid. Very little definitive information (in terms of subsurface structures and locations) can be postulated from the anomalous features observed in the PRP or HCP geometries. This is the same area thought to contain roomblock features/rubble mound, as suggested by Volf (May, 2009 - resistivity survey). The roomblock area (inferred from the resistivity survey - *Figure 4*)) is consistent with the positioning of roomblock areas observed at other similar investigation sites as noted by Volf. Roomblocks were identified directly adjacent to the survey grid area during investigations conducted in the late 1970's and early 1980's.

GPR Survey (House Creek Village site)
GPR records collected at the site were of poor to satisfactory interpretative quality. Surveys conducted with the 400 MHz antenna resulted in poor interpretative quality. High rates of signal attenuation resulted in limited depth of observation with the 400 MHz antenna. Surveys conducted with the 200 MHz antenna were of marginal to satisfactory interpretative quality. Observation depths ranged to approximately 1.5 m.

A GPR survey was conducted at the site using the 200 MHz antenna. A potential pit structure with a characteristic concave feature was identified (*Figure 6)* within the 40 m x 20 m grid area, at the same location suggested in the resistivity survey (*Figure 4*). The pit structure can be observed in *Figure 6* with the bottom floor of the structure being located at approximately 1 meter. This is consistent with observations from nearby excavations of pit structures (at similar sites). The pit structure has filled in with surrounding soil material and its location is not evident at the surface.

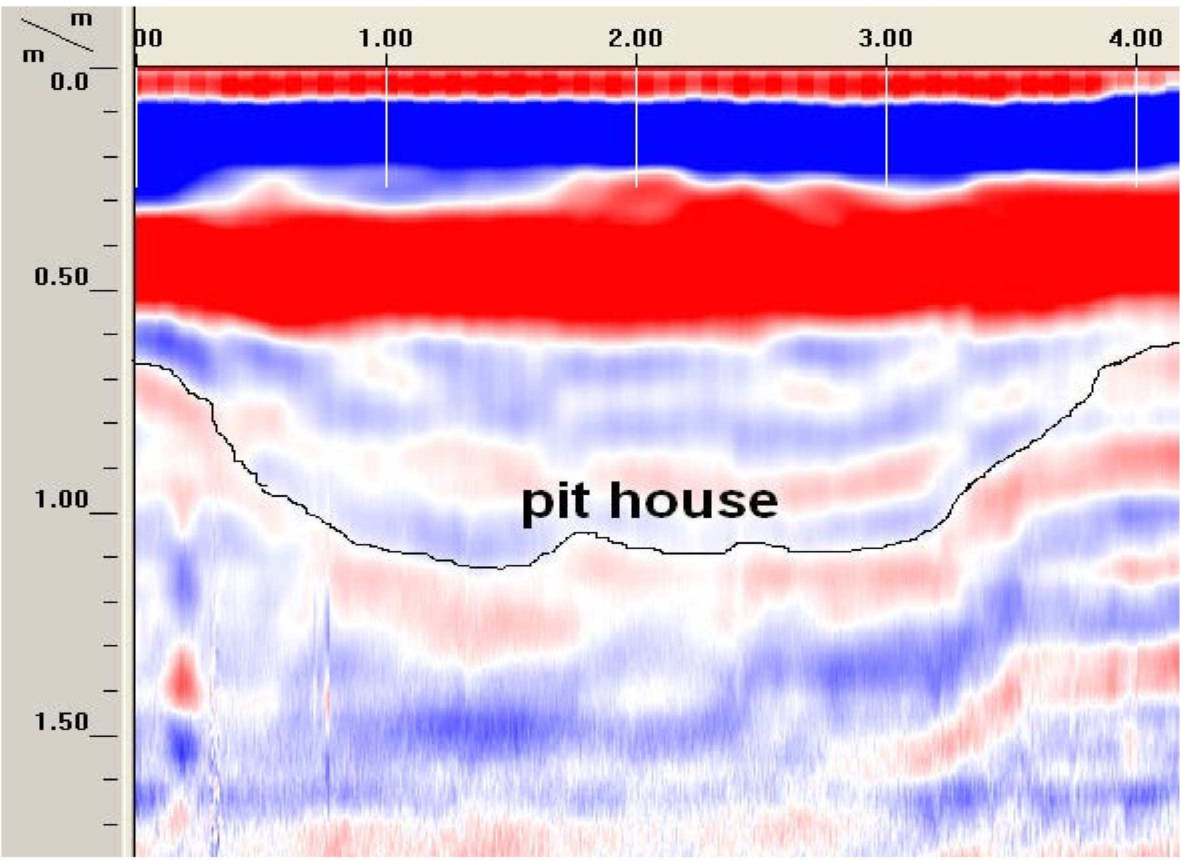


Figure 6. A representative radar record collected with the 200 MHz antenna at the House Creek Village site. Depth and distance were recorded in meters. The depth scale is a vertical exaggeration and is not to scale.

Photo 6. While conducting geophysical surveys, all types of physical and environmental hazards are encountered. A rattle snake was encountered during this field investigation. The local USDA/NRCS biologist (Cortez, CO) identified the snake potentially as a "Midget Faded Rattlesnake".... A rare type of snake that prefers high desert sagebrush areas. It has one of the most toxic venoms of all US rattlesnakes! All parties went their separate ways.

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