United States Department of Agriculture
Soil Conservation Service
Northeast NTC
160 East 7th Street
Chester, PA 19013-6092
215-499-3960

Subject: GPR Technical Assistance, Iowa, 18-22 September 1989

Date:October 27, 1989

To: J. Michael Nethery
State Conservationist
USDA-Soil Conservation Service
693 Federal Bldg.
210 Walnut Street
Des Moines, Iowa 50309

Purpose:
To provide ground-penetrating radar (GPR) and electromagnetic induction (EM) assistance for archaeological and soil studies in Union and Humboldt Counties.

Principal Participants:
Jim Doolittle, Res. Soil Scientist, SCS, Chester, PA
Ronald Kuehl, State Soil Scientist, SCS, Des Moines, IA
Richard Lersch, Soil Party Leader, SCS, Humboldt, IA
John Nixon, Assistant State Soil Scientist, SCS, Des Moines, IA
Richard Rogers, Archaeologist, SCS, Des Moines, IA

Activities:
I arrived in Creston on the evening of 18 September 1989. Field studies were conducted at selected archaeological sites along Three Mile Creek in Union County on September 19 and 20. Soil-bedrock investigations were carried out near Humboldt in Humboldt County on September 21 and 22. On the morning of 23 September, I departed Fort Dodge for field work in St. Louis County, Minnesota.

Discussion and Results:

Archaeological Investigation along Three Mile Creek

Sites selected for GPR and EM investigations were in areas of Colo (fine-silty, mixed, mesic, Cumulic Haplaquolls), Vesser (fine-silty, mixed, mesic Argiaquic Argialbolls), and Nodaway (fine-silty, mixed, nonacid, mesic Mollic Udifluvents) soils. The high silt and clay contents of these soils severely limited the resolution and depth of radar profiling. In most areas, the radar's 120 MHz antenna was restricted to profiling depths of less than 50 cm and provided limited archaeological information. Its uses was discontinued in favor of the EM-38 electromagnetic ground conductivity meter.

The operation of the EM-38 meter is described in detail by McNeill [1]. Electromagnetic (EM) methods measure the electrical conductivity between the receiver and transmitter coils. For surveying, the EM-38 meter is placed on the ground surface or suspended at a specified distance. An oscillating dipolar magnetic field is produced by the transmitter coil. This primary magnetic field induces an electrical current in the ground which generates a secondary magnetic field in a manner that the amplitude of the induced current is proportional to the electrical conductivity of the scanned earthen materials. The magnitude of this current is measured at the receiver coil and is a function of the apparent electrical conductivity of the soil.

Electromagnetic methods measure the apparent electrical conductivity of earthen materials. Factors influencing the conductivity of earthen materials include (i) the volumetric water content, (ii) amount and type of salts in solution, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. The apparent conductivity (ECa) of the soil has been related to the paste extract conductivity (ECe) by the relationship ECa $\sim$5ECa [2]. Measurements are expressed in millisiemens/meter (mS/m).

As discussed by Benson and others (1984) [3], the absolute values are not necessarily diagnostic in themselves, but lateral and vertical variations in conductivity are significant. Interpretations of the EM data are based on the identification of spatial patterns in the data set.

On 19 September, nine transects were completed along Three Mile Creek in Sec. 25, T. 73 N., R. 30 W. Four transects were completed the following day in Sec. 23, T. 73 N. R. 30 W.

The Em performance was exceptional. On mounds suspected of containing Indian artifacts, lower readings were recorded on the conductivity meter than adjoining "background" areas or on mounds believed to been caused be natural processes of pedoturbation. In Figure 1, which represents EM and elevation data collected along transect 2A in Sec. 25, T. 73 N., R. 30 W., mounds are evident between horizontal distance markers 13 to 19 and 46 to 53. Though the apparent electrical conductivity values declined on each mound, the exceptionally low values between markers 15 and 17 were considered representative of intense artificial manipulation. It

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1. McNeill, J. D. 1986. GEONICS EM38 ground conductivity meter operating instruction and survey interpretation techniques. Geonics Ltd., Mississauga, Ontario. Tech. Note TN-21. pp. 1

2. McNeill, J. D. 1986. Rapid, accurate mapping of soil salinity using electromagnetic ground conductivity meters. Geonics Ltd., Mississauga, Ontario. Tech. Note TN-18. pp. 15.

3. Benson, R. C., R. A. Glaccum, and M. R. Noel. 1984. Geophysical techniques for sensing buried wastes and waste migration: an application review. IN: D. M. Nielsen and M. Curl (eds.) Surface and Borehole Geophysical Methods in Ground Water Investigations. NWWA/EPA Conference, San Antonio, Texas, p. 533-566.

is believed that Indians constructed mounds with coarser textured and less electromagnetically conductive soil materials from lower-lying flood plain positions. In addition, buried artifacts are suspected of having lower conductivities than the natural soil materials.

Figure 2 is from transect 4C which was completed in Sec. 23, T. 73 N. R. 30 W. The mound is a minor flexure in the landscape and is hardly evident in the lower cross-sectional profile of surface elevations. However, a noticeably "dip" in the apparent electrical conductivity values occurs on this mound. This particular mound was earlier confirmed by archaeologists to contain Indian artifacts.

The EM-38 appears to be a most efficient non-destructive technique for investigating suspected Indian burial sites and for differentiating natural from artificial mounds.

Soil-bedrock investigation

The purpose of this investigation was to determine whether the GPR could detect the soil/bedrock interface and be used as a quality control tool in Humboldt County to document soil variability. On alluvial terraces to the Des Moines River where the depths to bedrock are less than 1.5 meters and the clay content of the soil is relatively low (less than about 25 percent), the GPR provided continuous, high resolution profiles charting the depth to bedrock. In areas where the clay content of the soil is higher or the depth to bedrock deeper, the performance of the GPR was unsatisfactory.

Radar profiles from several transects conducted in areas of higher clay content or deeper (>1.5 m) depths to bedrock were discarded because of poor interpretability or depth restrictiveness. Generally, in the areas suitable for investigation, the GPR discerned two interfaces. The first interface discerned by the GPR was the highly fractured or fragmental C horizon. This horizon occurred at depths ranging from 22 to 34 inches. Below this interface was the image of the R horizon which (compared with the C horizon) is more weakly fractured and fragmented.

Results of the GPR survey are listed in Table 1 and 2.

TABLE 1

DEPTH TO C HORIZON AND BEDROCK
ON TERRACES OF DES MOINES RIVER, HUMBOLDT CO., IOWA

	DEPTH TO C HORIZON				DEPTH TO BEDROCK			
TRANSECT	MEAN	SD	MIN.	MAX.	MEAN	SD	MIN.	MAX.
1	25	2.1	22	28	44	4.2	39	52
2	28	2.9	23	34	45	4.1	39	55
3	25	3.9	22	31	45	3.8	41	53

TABLE 2
COMPOSITION BASED ON DEPTH TO BEDROCK

TRANSECT	SHALLOW (<20")	MODERATELY DEEP (20-40")	DEEP (40-60")
1	0%	57%	43%
2	0%	9%	91%
3	0%	0%	100%

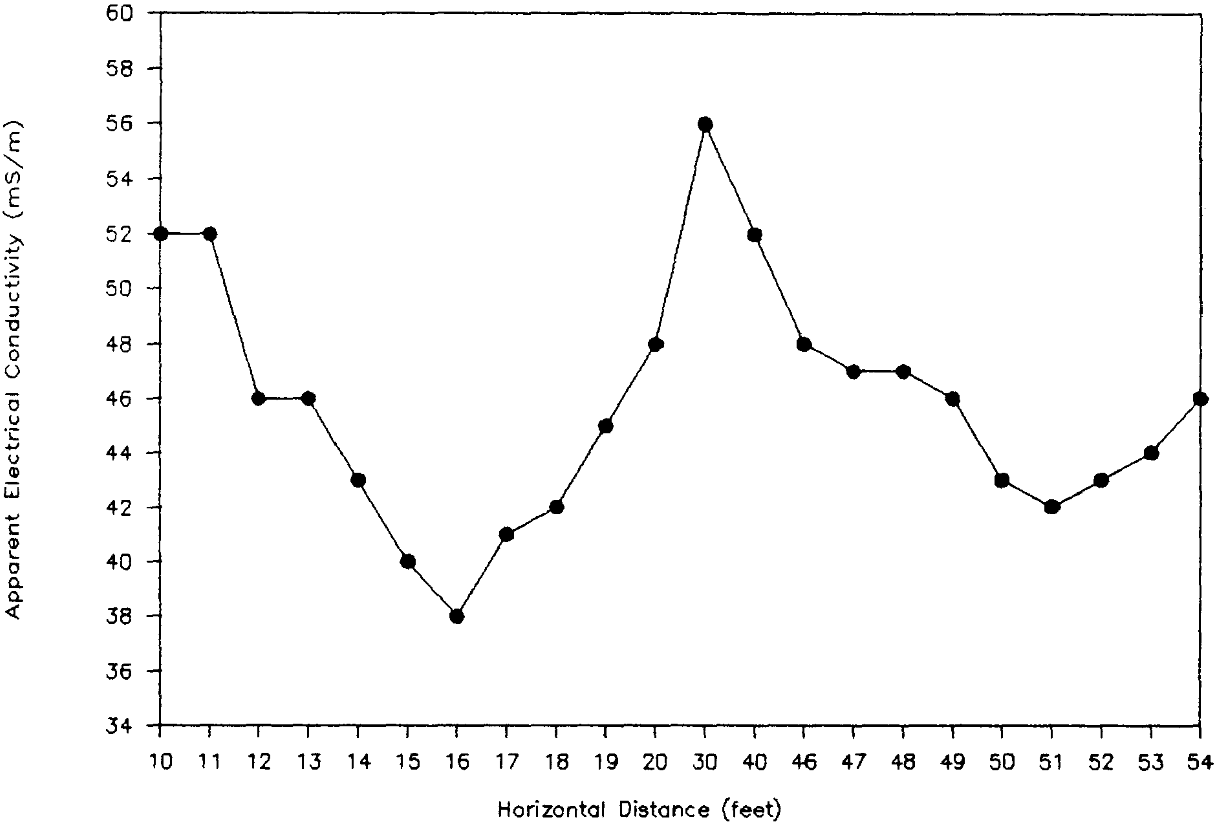
Though site specific the GPR provided valuable insight into the within map unit variability of the depth to bedrock.

All radar profiles will be returned to Ron Kuehl under a separate cover letter. Additional graphs will be prepared based on the EM survey of the archaeological sites all Tree Mile Creek. These graphs along with additional references will be forwarded to Richard Rogers for possible publication.

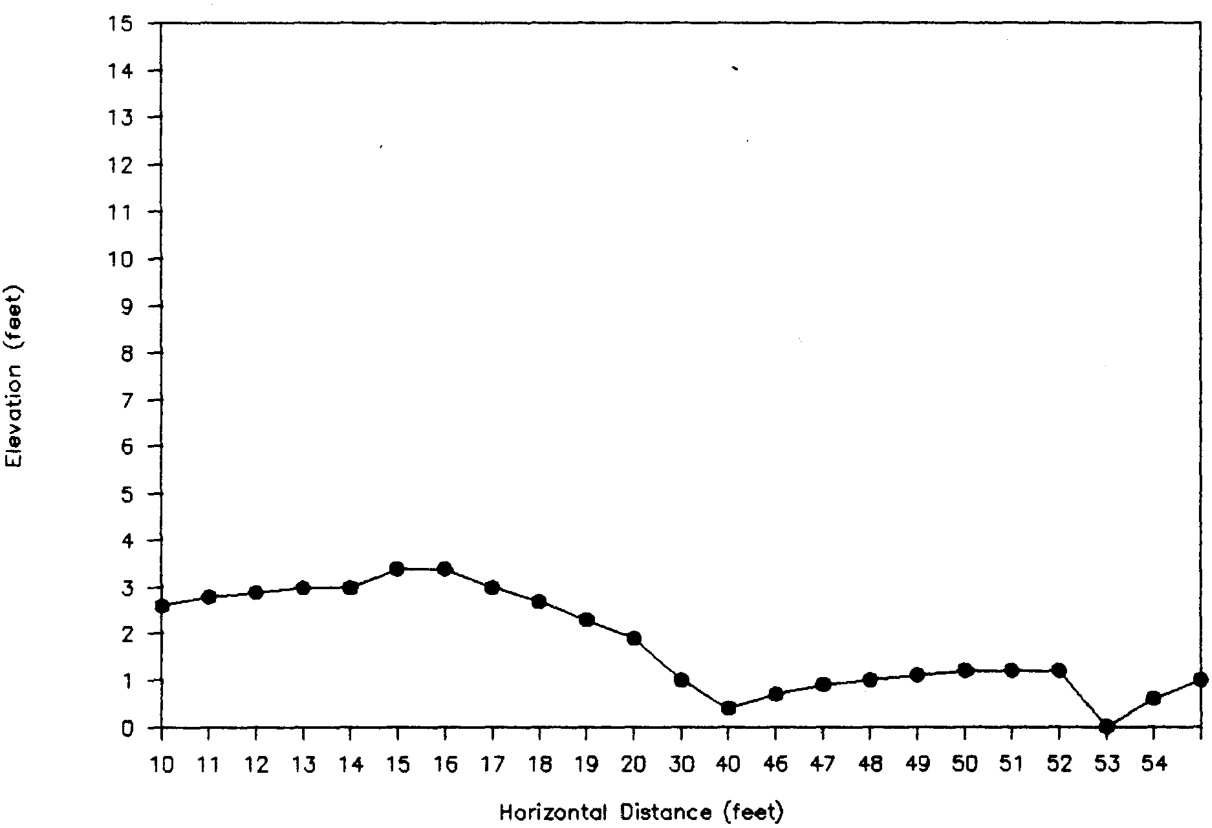
This has been for me a most enjoyable and rewarding field experience. With kind regards.

James A. Doolittle
Research Soil Scientist (GPR)

cc:
A. J. Dornbusch, Jr., Director, Midwest NTC, SCS, Lincoln, NE
C. S. Holzhey, Assistant Dir., Soil Survey Division, NSSC, SCS, Lincoln, NE
E. G. Knox, Head, NSSL, NSSC, SCS, Lincoln, NE
C. G. Olson, Staff Leader, FIS, NSSL, NSSC, SCS, Lincoln, NE
R. J. Kuehl, State Soil Scientist, SCS, Des Moines, IA
R. A. Rogers, Archaeologist, SCS, Des Moines, IA

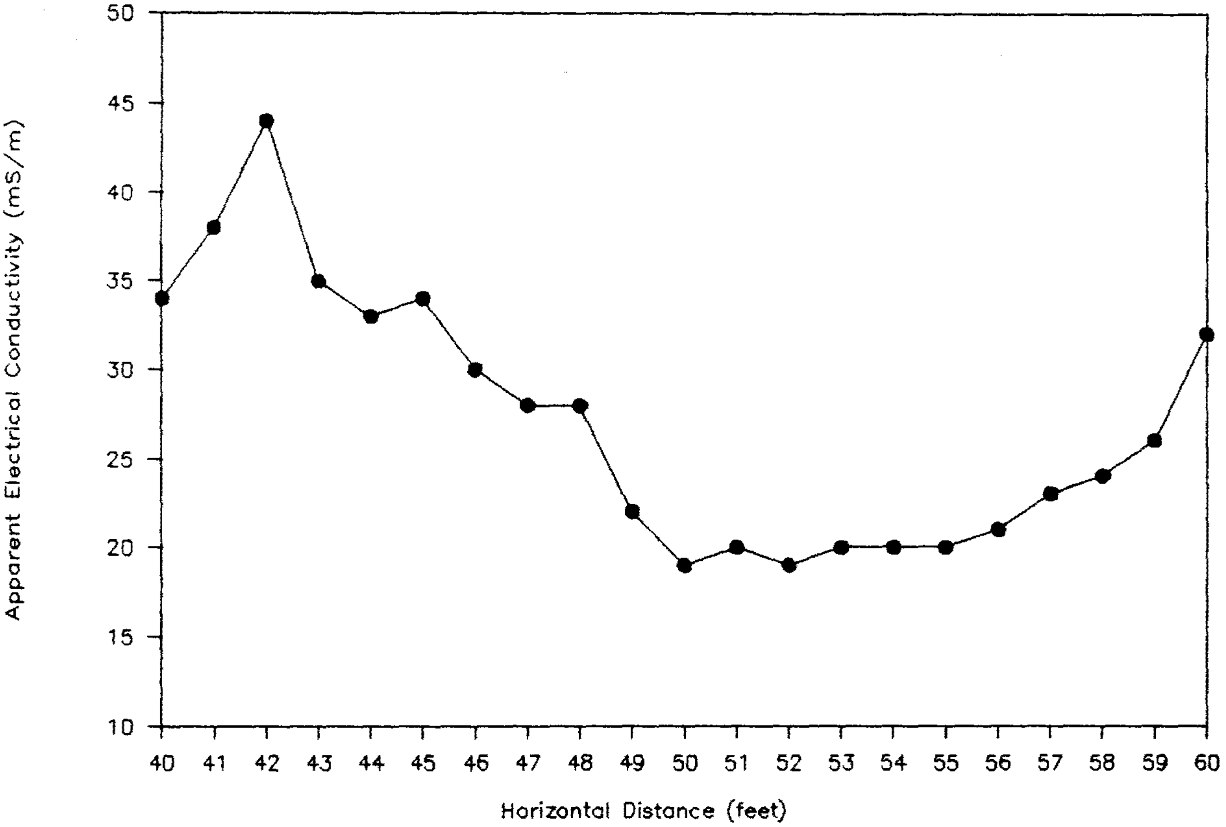


Apparent Electrical Conductivity (mS/m)
60
58
56
54
52
50
48
46
44
42
40
38
36
34
10 11 12 13 14 15 16 17 18 19 20 30 40 46 47 48 49 50 51 52 53 54
Horizontal Distance (feet)



Elevation (feet)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10 11 12 13 14 15 16 17 18 19 20 30 40 46 47 48 49 50 51 52 53 54
Horizontal Distance (feet)

Fig


Apparent Electrical Conductivity (mS/m)
50
45
40
35
30
25
20
15
10
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
Horizontal Distance (feet)

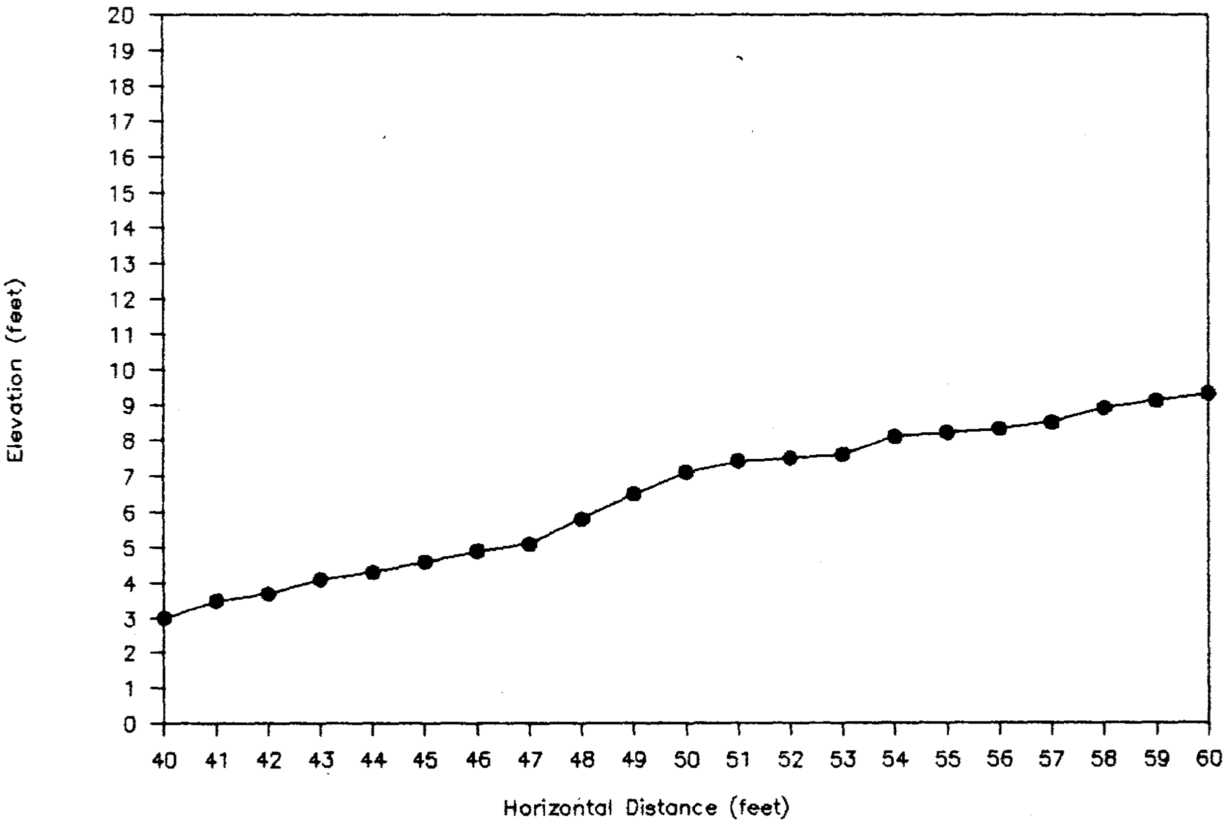

Elevation (feet)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
Horizontal Distance (feet)

Fig 2