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United States Department of Agriculture

Soil Conservation Service

Northeast NTC
160 E. 7th Street
Chester, PA 19013

Subject: SOI - GPR Field Studies in Northeastern Iowa, 27 April through 2 May 1986

Date: June 9, 1986

To: J. Michael Methery
State Conservationist
Soil Conservation Service
Des Moines, Iowa

File code: 430

## PURPOSE

To use GPR technique to investigate the variability of selected soil features including: (1) thickness of loamy sediments overlying sands and gravels, (2) depth to till underlying glacial outwash, and (3) depth to limestone bedrock.

## PARTICIPANTS

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## EQUIPMENT

The equipment used during this field trip was the SIR System-8 with the ADTEK SR-8004H graphic recorder and the Model 20 microprocessor. The 80, 120, and 300 $MH_z$ antennas were field tested under different soil conditions. The 80 and 120 $MH_z$ antennas produced the most satisfactory results. The 120 $MH_z$ with the model 705 DA2 transceiver provided slightly better balance of resolution and probing depth. However, rates of signal attenuation are high in the examined soils, and the microprocessor was required with both antennas to amplified weaker, subsurface signals and to remove unwanted background noise.

## DISCUSSION

The traditional method of obtaining soil data is very slow, labor intense, and results in post-hole observations of a three dimensional medium. Inferences must be made concerning the uniformity of soil conditions or features between observation sites. These inferences are

often inaccurate and can lead to interpretation errors. The continuous subsurface profiling of the GPR can help to fill in the large gaps which exists in our field data and provide a better understanding of the micro-variability of soil features or conditions.

The GPR was used in Iowa to study the variability in the thickness of loamy sediments overlying sands and gravel. In Iowa, two depth phases (24 to 32 inches and 32 to 40 inches to sand and gravel) are recognized in mapping Wapsie soils (coarse-loamy over sand or sandy-skeletal, mixed, mesic Mollic Hapludalfs). A graphic profile showing the variability in the thickness of loamy sediments was desired for purposes of soil correlation. The objectives of this study were: (1) to evaluate the effectiveness of GPR for charting the depth to sand and gravel, and (2) to provide a graphic profile of subsurface conditions.

The study area was located in an area along a stream terrace within Chickasaw County. Two transects (each 1,000 feet long with 10 equally spaced observation points) were completed in the study area.

The GPR was effective and provided clear and interpretable graphic profiles of the Wapsie soils. The depth to sand and gravel was easily traced and scaled on the graphic profiles. On the graphic profiles, layers of sand and gravel appear to be stratified and composed of multiple, short segments.

While the number of observations are too limited for characterization of the Wapsie soils within the survey area, statements can be made concerning the study area. The average depth to sand and gravel is 21.6 inches. Depths ranged (see Table 1) from 16.1 to 29.0 inches. In 30 percent of the observation sites, the depth to sand and gravel is less than 20 inches and is outside the range of the Wapsie series. These areas are treated as inclusions of similar soils.

The values for the depth to sand and gravel are not normally distributed (see Figures 1 and 2). However, certain statements can be made concerning this distribution. The median depth to sand and gravel is 21.35 inches, and is nearly identical to the mean (21.6 inches). The lower quartile is 18.8, the upper quartile is 24, and the interquartile interval is 5.2 inches. One-half of the observations occur between the depths of 18.8 and 24.0 inches.

In upland areas of glacial outwash, questions often arise as to the depth of the underlying till. Often, coarse fragments within the outwash restrict the penetration of mechanical probes or augers, and obstructs our efforts to define the depth to till. The second application of the GPR in Iowa was to determine the depth to till beneath glacial outwash.

At the selected sites within Chickasaw County, depth to till was believed to be variable beneath Wapsie soils but it could not be verified with conventional surveying tools. Coarse fragments, which range from 20 to 50 percent in some strata, thwarted efforts to obtain ground-truth data. To obtain ground-truth data, three auger holes were bored over a span of

approximately 1.5 hours. However, the till was never contacted or probed with the augers. Each auger hole was stopped between depths of 3 to 5 feet by coarse fragments.

Two transects were completed with the GPR using both the 80 and 120 $MH_z$ antennas with microprocessor. Both antennas provided good graphic images of the Wapsie soils and the underlying till. One transect was divided into two transects (transects A and B in Table 2) because of its exceptionally long length and for statistical purposes. Each transect has 10 referenced observation sites.

A depth scale was constructed for the graphic profile based on tabled values for the rate of propagation through predominantly coarse textured, upland soils. This scale and the resulting data must be viewed, in the absence of adequate ground-truth data, as only a close approximation of the actual values.

The number of observations are too small to make a detailed assessment of the variability of depth to till beneath upland area of Wapsie in Chickasaw County. However, within the study areas the average depth to till is 11.46 feet. The median depth to till is also 11.46 feet. The distribution appears to be bimodal. This is undoubtedly a consequence of the limited number of observations that was included in this study. The lower quartile is 9.8 feet, the upper quartile is 12.85 feet, and the interquartile range is 3.05 feet. One-half of the recorded observations occur between depths of 9.8 and 12.85 feet. The depth to till ranged from 8.2 to 15.1 feet.

In many upland areas it is exceedingly difficult to examine soil profiles and to determine the depth to bedrock with traditional soil surveying tools. Rock fragments limit the effectiveness of spades, augers, picks, and mechanical probes. In areas of highly variable or irregular depths to bedrock, inferences made between widely spaced observation sites are, at best, suspected of possible errors. The composition of soil map units are often based on insufficient and incomplete data, collected from a limited number of widely spaced observation sites or inferred from the landscape.

Several areas of Dubuque (fine-silty, mixed, mesic Typic Hapludalfs), Fayette (fine-silty, mixed, mesic Typic Hapludalfs), and Nordness (loamy, mixed, mesic Lithic Hapludalfs) soils were profiled with the GPR in Allamakee County. In these soils, the GPR system is exceedingly depth restricted. Depth of penetration was limited to the upper 1 meter of the soil profiles. Though deeper depths of penetration were achieved in some areas, consistent results were limited to 1 meter in all areas.

The GPR can be used effectively in many areas of shallow or moderately deep soils to chart the depth to bedrock. However, in areas of deeper or more variable depths to bedrock the present GPR system is ineffective. Table 3 contains the results of a successful radar transect in an area of Fayette and Dubuque soils.

**RESULTS**

The GPR satisfied two of the three objectives of the Iowa study. The radar successfully charted the thickness of loamy sediments and the depth to sand and gravel, and determined the depth to till beneath glacial outwash. The radar was less successful and adaptable in areas of moderately-fine textured soils for bedrock investigations.

All tools have limitations. In two of the three studies, the GPR was able to compliment traditional surveying techniques. The GPR was efficiently and effectively applied to unique surveying and correlation problems. In Iowa, as in much of the Midwest, the most effective use of the GPR will be as an investigation tool rather than as a general surveying or quality control tool (though these uses should not be ruled out in the coarser textured soils).

The Iowa study has confirmed that the GPR system can be used in some areas of the Midwest for specific applications. However, the Midwest is an areas of generally low potential for radar applications. The success of future applications will depend upon our understanding of the limitations of the present GPR systems and our knowledge of favorable soil conditions for the radar.

All graphic profiles have been returned to Ron Kuehl under a separate cover letter. My deepest thanks for the opportunity to work in your state and with members of your staff.

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Enclosures

cc:
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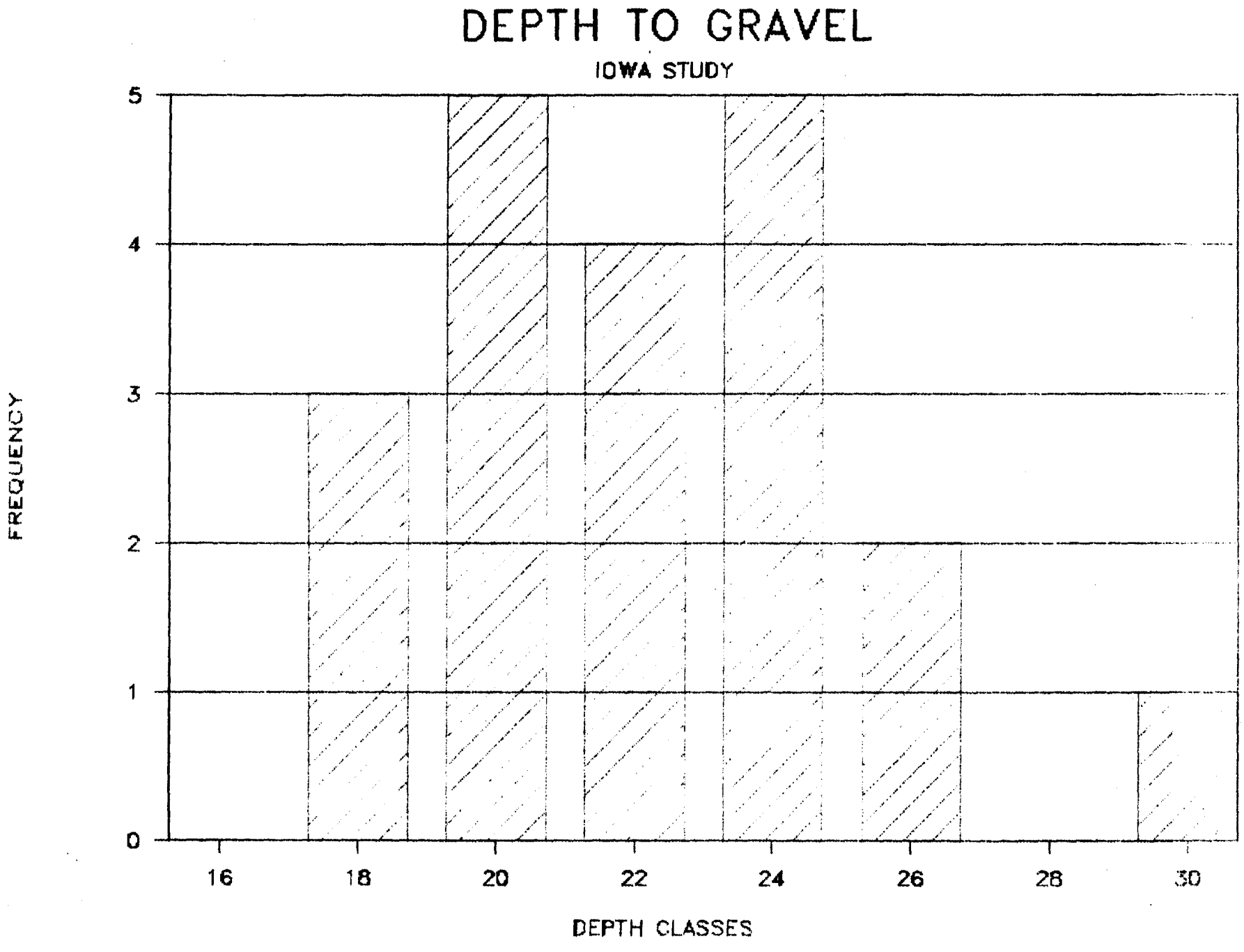
TABLE 1

DEPTH TO SAND AND GRAVEL
WAPSIE SOIL

| TRANSECT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | $\bar{X}$ | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 24.0 | 23.2 | 18.0 | 18.8 | 24.0 | 16.1 | 20.2 | 25.5 | 19.5 | 24 | 21.3 | 3.19 |
| B | 17.2 | 20.0 | 26.0 | 29.0 | 20.0 | 21.7 | 23.2 | 21.8 | 21.0 | 18.8 | 21.9 | 3.5 |

DATA EXPRESSED IN INCHES


DEPTH TO GRAVEL
IOWA STUDY
FREQUENCY
0
1
2
3
4
5
16
18
20
22
24
26
28
30
DEPTH CLASSES

# DEPTH TO GRAVEL

IOWA STUDY

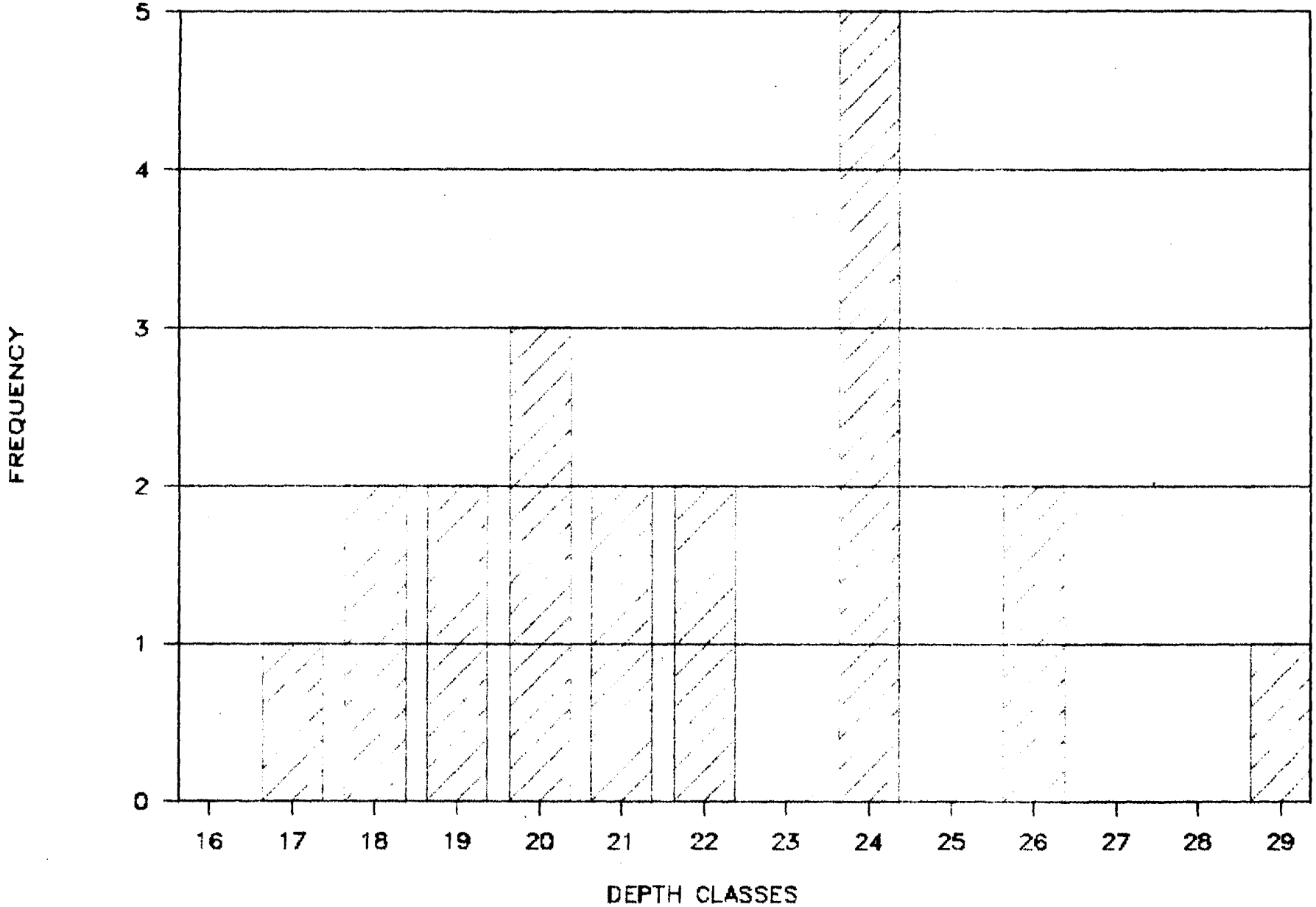


TABLE 2

DEPTH TO TILL
WAPSIE SOIL

| TRANSECT | OBSERVATION SITES 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | $\bar{X}$ | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 14.5 | 14.0 | 12.5 | 10.3 | 10.9 | 11.4 | 12.2 | 12.6 | 12.8 | 10.6 | 12.18 | 1.4 |
| B | 9.4 | 10.6 | 8.2 | 8.6 | 9.4 | 9.5 | 8.3 | 9.0 | 13.2 | 12.6 | 9.88 | 1.74 |
| C | 10.1 | 9.2 | 10.1 | 12.8 | 12.5 | 12.8 | 15.1 | 14.2 | 13.5 | 12.9 | 12.32 | 1.92 |

DATA EXPRESSED IN FEET

TABLE 3

DEPTH TO BEDROCK
FAYETTE AND DUBUQUE SOILS

| TRANSECT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 26 | 56 | 36 | 23 | 24 | 27 | 25 | 32 | 56 | 18 | 23 | 26 | 23 |

$\overline{X} = 30.3$; $a = 12.1$

DATA EXPRESSED IN INCHES