UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

160 East 7th Street
CHESTER, PA 19013

SUBJECT: ENG- Geophysical Investigations

DATE: 19 May 1994

To: Donald W. Lake
State Conservation Engineer
USDA-Soil Conservation Service
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Syracuse, New York 13261-7248

Purpose:
To provide training on the uses of electromagnetic induction (EM) techniques and the operation of the EM31 meter. To use ground-penetrating radar (GPR) techniques to assess the Andover Dam sites in Allegany County and bottom sediments beneath a portion of the Irondequoit stream channel in Linear Park, Monroe County.

Participants:
Joseph Albert, Sr. Public Health Sanitarian, Depth of Health, Rochester, NY
Geoffrey Benway, Project Engineer, MRB Group, Rochester, NY
Richard Crowe, Asst. State Engineer, SCS, Syracuse, NY
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Tony Esser, Water Quality Coordinator, SCS, Syracuse, NY
Matt Havens, Soil Scientist, SCS, Walton, NY
Gary Lamont, Resource Conservationist, SCS, Walton, NY
Jazelle Jusino, Biological Science Tech., SCS, Walton, NY
Lee Sepelak, Conservation Engineering Tech., SCS, Binghamton, NY
Fred Sinclair, District Manager, Allegany SWCD, Belmont, NY
Michael Simon, Assoc. Engineer, MRB Group, Rochester, NY
Paula Smith, District Manager, Monroe County SWCD, Rochester, NY
Dave Sullivan, Geologist, SCS, Syracuse, NY
Michael Townsend, Water Quality Specialist, SCS, NY

Activities:
A slide presentation on the uses of EM techniques was given at the Binghamton Field Office on the morning of 4 May. During the afternoon of 4 May, an animal waste holding facility in Broome County was surveyed as part of the EM field demonstration and training exercise. Dave Sullivan and I travelled to Allegany County in the late afternoon of 4 May. The Andover Dam site was surveyed on the morning of 5 May. During the afternoon of 5 May, Dave Sullivan and I travelled to Monroe County and viewed the proposed survey site in Penfield. On the morning of 6 May a GPR survey was conducted at the streambank erosion and stabilization project at Linear Park in Penfield. I returned to Chester, Pennsylvania, on the afternoon of 6 May.

Equipment:
The electromagnetic induction meter used was the EM31 manufactured by GEONICS Limited. [1.] Measurements of conductivity are expressed as milliSiemens per meter (mS/m). Two-dimensional plots of the EM data from the waste holding facility in Broome County were prepared using SURFER software developed by Golden Software, Inc.[1.]

The radar unit used in this study was the Subsurface Interface Radar (SIR) System-8 manufactured by Geophysical Survey Systems, Inc. The system was powered by a 12-volt marine battery. The model 3110 (120 mHz) antenna with a model 705DA transceiver were used in this study.

Discussion:
Broome County - Animal Waste-Holding Facility
An irregularly-shaped, 500 by 300 foot grid was established along the east and south sides of a waste-holding pond and farm structures. The grid interval was 50 feet. Survey flags were inserted in the ground at each of the 37 grid intersections. At each grid intersection, measurements were obtained with the EM31 meter in both the horizontal and vertical dipole orientations. Each participant was given the opportunity to operate the EM31 meter and to conduct an EM survey. Interpretations of the EM data were discussed in the field.

The study site was in an area of Unadilla silt loam, 0 to 5 percent slopes. Unadilla is member of the coarse-silty, mixed, mesic Typic Dystrochrepts family. This well drained soil form in outwash deposits.

Figures 1 and 2 are two-dimensional plots of apparent conductivity measurements of the study area. In each plot, the interval is 1 mS/m. These plots represent computer simulations of data obtained with the EM31 in the horizontal and vertical dipole modes, respectively. The EM31 meter scans depths of 0 to 2.75 meters in the horizontal and 0 to 6.0 meters in the vertical dipole mode.

In Figures 1 and 2, values of apparent conductivity are noticeably higher near the waste facility and farm structures and in a small depression (located about 100 feet north of the southeast corner of the study area). Runoff from the farm structures appears to have been channeled along a roadway into the small depression. Higher values of conductivity were attributed to elevated levels of nitrates and chlorides from animal wastes.

Allegany County - Andover Dam Site

Survey flags were placed at five foot intervals along the upstream edge of the existing dam structure. Three additional range lines were established across the water. These range lines were upstream and parallel with the dam structure. These ranges were established at distances of 5, 10 and 15 feet away from the structure.

The control and recording units were placed on the dam structure. The antenna was placed in a rubber raft which was towed along each range line. Along each range line, the radar operator electronically affixed a dashed, vertical line on the radar profile as the antenna passed each of the survey flags on the dam structure.

Two traverses were made along each range line. These traverses were conducted in an west to east direction. For each range line, two time windows or observation depths were used: a 170 and a 70 nanosecond (ns) time interval.

Radar profiles revealed three distinct subsurface interfaces. These boundaries were believed to represent the: (i) water/sediment, (ii) sediment/original bottom, and (iii) sub-bottom interfaces. Point anomalies are common within 5 feet of the dam structure. Anomalies were less common at distances of 10 and 15 feet from the dam structure. Anomalies were assumed to represent randomly occurring rocks, buried logs, or other debris. However, a repeating pattern along each range line between observation flags 55 and 60 feet, suggest a possible structural feature related to the dam.

Monroe County - Linear Park, Penfield

The purpose of this survey was to use GPR techniques to assess the nature and thickness of bottom sediments beneath the Irondequoit stream channel in Linear Park, Penfield, New York.

The control and recording units were carried to a small point bar in the channel. The antenna was placed in a rubber raft which was pulled across the stream channel. After several non-productive traverses across and along the center-line of the channel, the GPR survey was terminated.

The point bar and the bottom of the channel was covered with a thin veneer of sands, gravels, and cobbles. However, beneath this relatively thin deposits, a layer of highly conductive clayey sediments. These sediments rapidly attenuated the radar signal and restricted the depth of observation. Because of the fine textured and depth restricting sediments, GPR provided little sub-bottom information and its use at this site was considered inappropriate.

Results:

1. Results from these surveys are interpretative. As no auger or drill observations were obtained to verify conclusions, results are interpretative. The enclosed plots provide understanding into the conditions existing with the Broome County survey area. These plots can be used to guide the selection of sampling sites.

2. Results from this study support the use of the EM31 meter to assess the dissemination of contaminants from animal-waste holding areas by seepage and surface runoff. If desired, an EM34 and/or an EM31 meter can be loaned to your staff in late August 1994. Your staff would

have the opportunity to become more familiar with and to more fully assess the potentials of using this technique to support SCS programs in the New York.

3. The ground-penetrating radar survey at the Andover Dam site helped to characterize the site. Generally, numerous subsurface anomalies occur within 7.5 feet of the existing up-stream edge of the structure. Ground truth verification is needed to confirm the nature of the discerned anomalies.

It is my pleasure to work in New York, with Dave Sullivan and members of your fine SCS staff.

With kind regards,

James A. Doolittle
Soil Specialist

cc:
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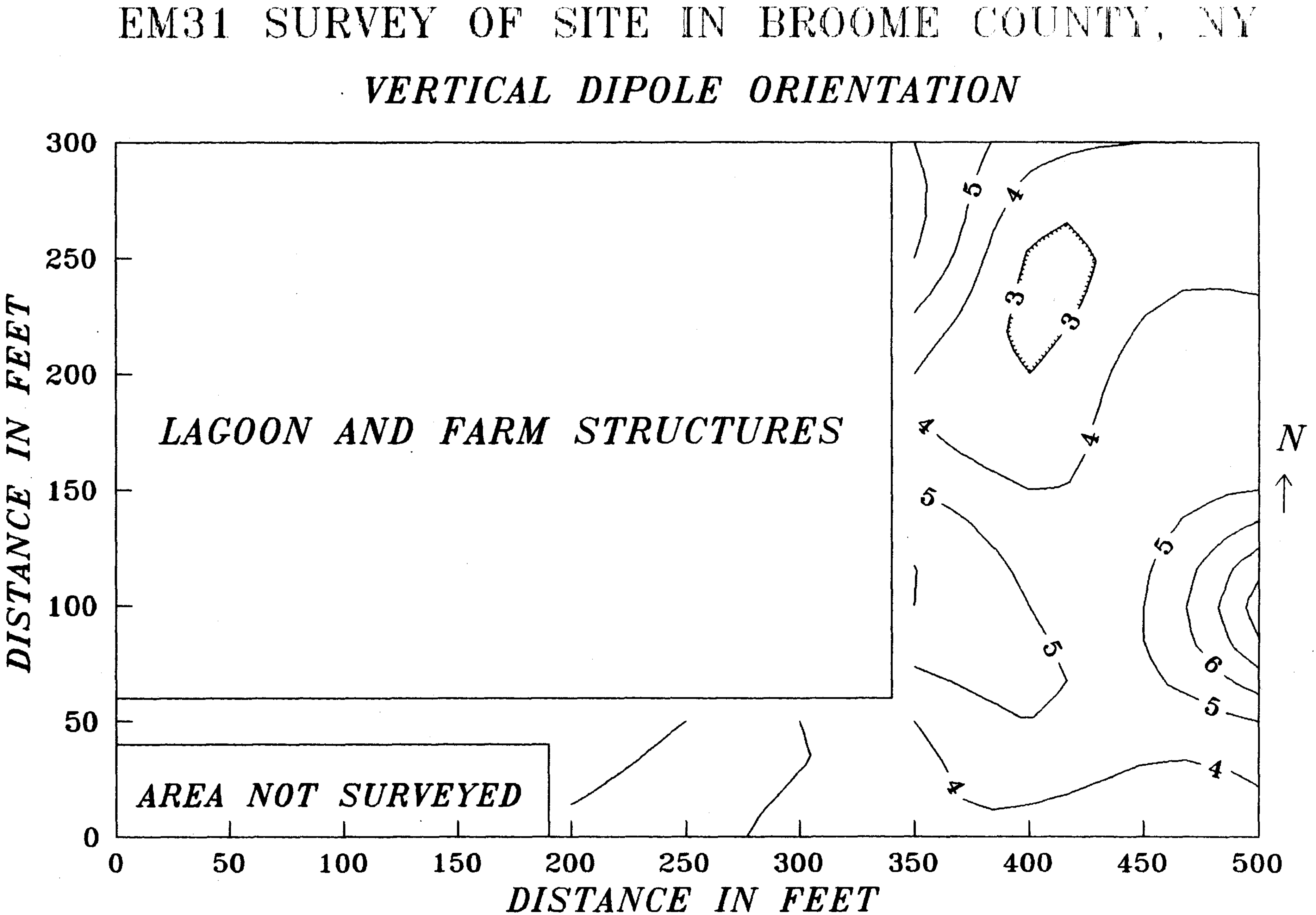
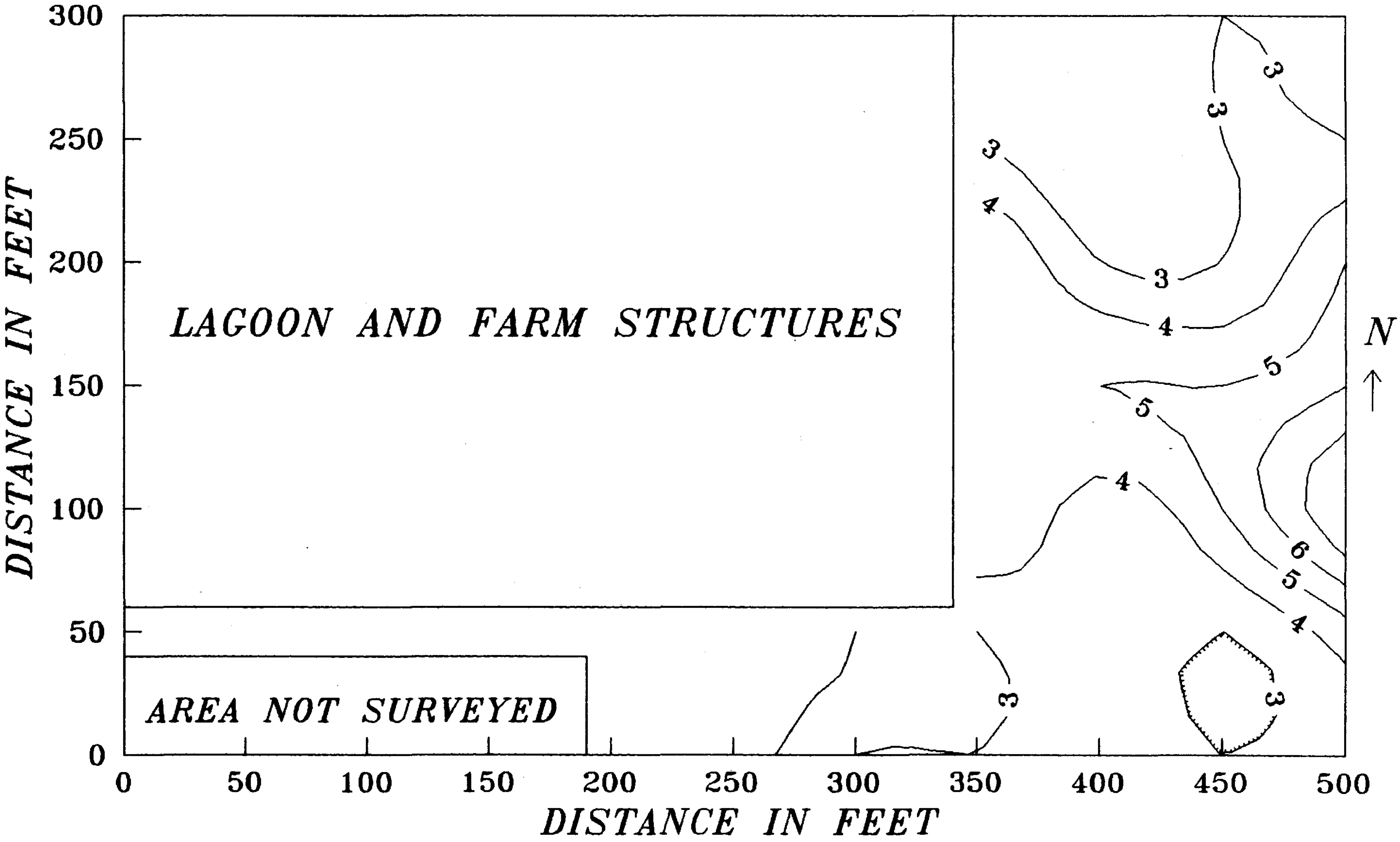

EM31 SURVEY OF SITE IN BROOME COUNTY, NY
VERTICAL DIPOLE ORIENTATION
LAGOON AND FARM STRUCTURES
AREA NOT SURVEYED
DISTANCE IN FEET
DISTANCE IN FEET
N
0
50
100
150
200
250
300
350
400
450
500
3
4
5
6

EM31 SURVEY OF SITE IN BROOME COUNTY, NY

HORIZONTAL DIPOLE ORIENTATION



Review of Electromagnetic Induction Methods

Electromagnetic inductive (EM) is a surface-geophysical method in which electromagnetic energy is used to measure the terrain or apparent conductivity of earthen materials. This technique has been used extensively to monitor groundwater quality and potential seepage from waste sites (Brune and Doolittle, 1990; Byrnes and Stoner, 1988; De Rose, 1986; Greenhouse and Slaine, 1983; Greenhouse et al., 1987; and Siegrist and Hargett, 1989)

For surveying, the meter is placed on the ground surface or held above the surface at a specified distance. A power source within the meter generates an alternating current in the transmitter coil. The current flow produces a primary magnetic field and induces electrical currents in the soil. The induced current flow is proportional to the electrical conductivity of the intervening medium. The electrical currents create a secondary magnetic field in the soil. The secondary magnetic field is of the same frequency as the primary field but of different phase and direction. The primary and secondary fields are measured as a change in the potential induced in the receiver coil. At low transmission frequency, the ratio of the secondary to the primary magnetic field is directly proportional to the ground conductivity. Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

Electromagnetic methods measure the apparent conductivity of earthen materials. Apparent conductivity is the weighted average conductivity measurement for a column of earthen materials to a specified penetration depth (Greenhouse and Slaine; 1983). The averages are weighted according to the depth response function of the meter (Slavich and Petterson, 1990).

Variations in the meters response are produced by changes in the ionic concentration of earthen materials which reflects changes in sediment type, degree of saturation, nature of the ions in solution, and metallic objects. Factors influencing the conductivity of earthen materials include: (i) the volumetric water content, (ii) the amount and type of ions in soil water, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. Williams and Baker (1982), and Williams (1983) observed that, in areas of salt affected soils, 65 to 70 percent of the variation in measurements could be explained by the concentration of soluble salts. However, as water provides the electrolytic solution through which the current must pass, a threshold level of moisture is required in order to obtain meaningful results (Van der Lelij, 1983).

The depth of penetration is dependent upon the intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. Table 1 list the anticipated depths of measurements for the EM31 meter. The actual depth of measurement will depend on the conductivity of the earthen material(s) scanned.

TABLE 1

Depth of Measurement

Meter	Intercoil Spacing	Depth of Measurement Horizontal	Vertical
EM31	3.7 m	2.75 m	6.0 m

The conductivity meters provide limited vertical resolution and depth information. However, as discussed by Benson and others (1984), the absolute EM values are not necessarily diagnostic in themselves, but lateral and vertical variations in these measurements are significant. The seasonal variation in soil conductivity (produced by variations in soil moisture and temperature) can be added to the statement by Benson. Interpretations of the EM data are based on the identification of spatial patterns in the data set appearing on two-dimensional contour plots.

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