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

Subject: EM Survey at the Gervais Farm near North Enosburg, Vermont; Trip Summary

Date: 19 November 1990

To: John C. Titchner
State Conservationist
Soil Conservation Service
69 Union Street
Winooski, Vermont

Purpose:
To evaluate the design performance of the Gervais Farm animal waste storage facility by electromagnetic (EM) induction survey.

Participants:
John S. Moore, Engineering Geologist, SCS, NENTC, Chester, PA
James A. Doolittle, Ground-Penetrating Radar Specialist, SCS, NENTC, Chester, PA
Richard J. Croft, State Conservation Engineer, SCS, Winooski, VT
Richard A. Fisher, State Design Engineer, SCS, Winooski, VT
David G. VanHouton, State Soil Scientist, SCS, Winooski, VT
James W. Monahan, District Conservationist, SCS, St. Albans, VT
Katherine Hakey, Civil Engineering Technician, SCS, St. Albans, VT
Michel LaPointe, Civil Engineer, SCS, St. Albans, VT
Penny Battison, Soil Conservation Technician, SCS, St. Albans, VT

Activities:
James Doolittle and John Moore arrived in Winooski on Monday, November 5, 1990. On November 6 and 7, we used Electromagnetic induction (EM) techniques to evaluate variations in terrain conductivity in a 28-acre area surrounding the animal waste storage facility at the Gervais Farm, North Enosburg, Vermont.

The St. Albans Field Office and the State Office staffs provided elevation and survey control of the measurement points and developed the site base map on a scale of one inch equals 40 feet with one-foot contour intervals.

David Van Houton conducted a detailed soil survey of the site at the above mapping scale.

John Moore conducted a reconnaissance geologic investigation of lineaments in the vicinity on Thursday, November 8, 1990.

Background on EM Techniques:
A GEONICS Limited EM31 ground conductivity meter was used in this survey. The meter, consisting of a 4.0 meter boom and console, weighs 11 kg. The operating frequency of the meter is 9.8 kHz. With the EM31 placed on the ground surface, measurements of the terrain conductivity were made to depths of 5.5 meters (with the meter in the vertical dipole position) and 2.75 meters (with the meter in the horizontal dipole position). THESE MEASUREMENTS REPRESENT VALUES OF TERRAIN CONDUCTIVITY WHICH HAVE BEEN AVERAGED OVER EITHER A 5.5 METER (VERTICAL POSITION) OR A 2.75 METER

(HORIZONTAL POSITION) SOIL PROFILE. Measurements obtained with the EM31 are expressed in milliSiemens/meter (mS/m). The operation of the EM-31 meter is described in detail by McNeill (1989).

Electromagnetic methods measure the apparent electrical conductivity of earthen materials. Factors influencing the conductivity of earthen materials include: (i) volumetric water content, (ii) amount and type of salts in solution, (iii) amount and type of clays in the soil matrix, and (iv) soil temperature.

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

At each grid intersect, the elevation of the ground surface and measurements with the EM 31 in both the vertical and horizontal dipole positions were obtained. The data obtained with the EM31 meter were plotted on two-dimensional contour plots using the SURFER software program. These plots were constructed using a kriging interpolation and octant search methods.

The Survey Area:
A 1500 by 750 to 800 foot grid was established across the survey area (see Figure 1). The grid interval was 50 feet. The survey area covered about 28 acres and consisted of 486, equally spaced, observation points. The survey site extended 350 feet upslope and 1050 feet down slope from the animal waste storage facility (A). The blanked area in Figure 1 represents the general location of major cultural features and the limits of the survey. The blanked area along the upper right margin of Figure 1 represents a roadway. Buildings and features associated with the Gervais farm constitute the blanked area in the upper part of this figure. The blanked area in the lower left hand corner of Figure 1 represents the limits of the survey.

Soils:
The animal waste storage facility is located in an area of Peru stony fine sandy loam, 8 to 15 percent slopes (PeC) and Westbury stony fine sandy loam, 8 to 15 percent slopes (WrC). The very deep Peru (coarse-loamy, mixed, frigid Aquic Haplorthods) and Westbury (coarse-loamy, mixed, frigid Typic Fragiaquods) soils have formed in till on backslope positions of glaciated uplands. Peru soils are moderately well drained; Westbury soils are somewhat poorly drained and have a dense, very firm substratum. Included with these soils are small areas having bedrock within depths of 60 inches.

Within the survey area on lower backslope and foot slope positions are areas of Munson silt loam, 3 to 8 percent slopes. The very deep, somewhat poorly drained Munson (coarse-silty over clayey, mixed, nonacid, mesic Aeric Haplaquepts) soils formed in glaciolacustrine sediments comprised of coarse silts over clay.

Surficial Geology:
During deglaciation of this region in late Pleistocene time, the margin of the continental ice sheet retreated both northward and away from the Green Mountain front. Large, proglacial lakes formed at the margin of the ice sheet in the Champlain Valley with arms of the lakes extending well up into major valleys, including the Missisquoi River valley and its tributaries. According to Parrott and Stone (1972), the highest stage of Lake Vermont was at an elevation of between 720 and 740 feet above mean sea level (MSL) in the Missisquoi valley. The Gervais Farm headquarters, barn, and manure holding facility are located between 700 and 720 feet above MSL, in what had been a near-shore, high-energy environment of Glacial Lake Vermont. This area to approximately 500 feet north and down slope of the holding facility is underlain by a zone of wave-washed till, corresponding to the Peru and Westbury soils described above. The general lack of fines in these soils and the abundance of prominent, sub-rounded stones and cobbles reflect the winnowing effect of wave-action. Above elevation 740, stones and cobbles exhibit the angular features that are more typical of coarse fraction of ground moraine. Below (north of) the east-west stone wall located 500 feet north of the holding

facility the finer textured Munson soils reflect quiet water deposition in the deeper waters of Glacial Lake Vermont. The increase in clay content is reflected in the EM data discussed below (illustrated in Figures 2 and 3) and has been field-verified by David Van Houton, State Soil Scientist.

Lineaments:
The alleged east-west lineament extending from the Longe Spring to 100 feet into the lower Gervais field (as drawn by the Johnson Report, 1989) coincides exactly with a low stone wall, which presumably may have been an old property line. There is no surficial geologic evidence to support the contention for a geologic fracture or lineament in the bedrock at this location. In this area, bedrock is covered with an irregular mantle of glaciolacustrine deposits over till with a combined thickness of up to 22 feet.

The east-west lineament identified by Dennis (1964) was field checked by John Moore; the lineament followed a fence line for the most part. However, this lineament closely corresponds to a strandline (between approx. elevations 520 - 540 ft) that marks the contact between marine sedimentary deposits of the Champlain Sea and till on the south side of the Missisquoi River valley. The strandline was also identified by Parrott and Stone (1972) on their Surficial Geologic Map of the Enosburg Falls 15-minute Quadrangle. The lineament has no structural bedrock fracture implications, being entirely a surficial geologic phenomenon.

Survey Results:
Figure 1 is a topographic base map of the survey area. Figures 2 and 3 are two-dimensional contour plots illustrating the spatial distribution of EM measurements within the survey area. Figure 2 represents values obtained with the EM31 meter in the vertical dipole position (5.5 meters); Figure 3 represents values obtained with the EM31 meter in the horizontal dipole position (2.75 meters).

Interpretations:
Two major spatial patterns are evident in each of these figures: one produced by variations in electromagnetic properties associated with changes in soil parent material (till versus glaciolacustrine deposits); the other produced by variations in electromagnetic properties associated with the Gervais's farm.

Variations in the electromagnetic properties exist between the predominantly coarse-loamy till and the finer glaciolacustrine deposits. Soils formed in till occupy higher-lying slope positions (Figure 1, 550 to 1500 Y). A value of 0.1 mS/m was selected as the average terrain conductivity for this area of Peru and Westbury soils. The lower clay content and cation exchange capacities of these soils are reflected in the very low terrain conductivity values obtained in areas of till (see Figures 2 and 3).

Within the survey area, soils formed in glaciolacustrine sediments occupy the lower-lying slope positions (Figures 1, 0 to 550 Y). These soils have higher clay contents, higher cation exchange capacities, and higher terrain conductivity values (see Figures 2 and 3). In areas of Munson soils, values of 4.3 mS/m and 4.0 mS/m were selected as the average terrain conductivity for the 5.5 and the 2.75 meter profiles, respectively. The slightly higher vertical dipole measurements (5.5 meters) are believed to reflect the increasing clay content of Munson soils with depth. In areas of Munson soils, terrain conductivity values appear to reflect variations in the thickness, depth to and amount of clays in the profile.

The second major spatial patterns evident in Figures 2 and 3 have been produced by variations in electromagnetic properties associated with the Gervais's farm. The blanked area in the upper part of Figures 2 and 3 represents the Gervais Farm. This area represents the general location of the farm house, access road, farm buildings, silage pits, animal holding areas, and animal waste holding pond.

In Figures 2 and 3, the blanked area representing the Gervais Farm is surrounded by high values of terrain conductivities. In areas immediately adjoining the animal waste holding pond, EM values were noticeably higher than the selected background value of 0.1 mS/m for Peru and Westbury soils. In the vertical dipole position (5.5 meters), measurements were 10 to 180 times higher than the selected background value (0.1 mS/m). In the horizontal dipole position (2.75 meters), measurements were 10 to 130 times higher than the selected background value (0.1 mS/m).

Measurements taken with the EM31 meter in the vertical dipole position (5.5 meters) indicate that the highest terrain conductivity values (greater than 3.0 mS/m) are completely confined within the footprint of the embankment materials of the storage facility (Figure 2).

A zone of moderately high conductivities (1.0 to 3.0 mS/m) extends up to 200 feet from the downstream toe of the waste storage facility with EM values decreasing away and down slope from the holding facility. This area is the former location of the manure stacking area prior to the construction of the new holding facility and also marks the location of a previous spillage (overflow) event.

In Figure 3, a zone of higher terrain conductivities extends outward and down slope from the blanked area. In this zone, horizontal EM values (2.75 meters) ranged from 1.0 to 13.0 mS/m (or 10 to 130 times greater than the background value of 0.1 mS/m). IN ADDITION, IN MANY DOWN SLOPE AREAS, TERRAIN CONDUCTIVITY VALUES DECREASE WITH DEPTH AS THE HORIZONTAL MEASUREMENTS ARE HIGHER THAN THE VERTICAL EM MEASUREMENTS (We interpret these higher near surface (<2.75 meter) terrain conductivity values to reflect the deposition of dissolved salts from the waste-laden surface runoff from livestock holding areas adjacent to the farm buildings.

A narrow zone of higher terrain conductivity values, ranging from 0.2 to 2.7 mS/m (2 to 27 times the selected background value), appears to extend approximately 400 to 700 feet down slope toward the road ditch. One may be quickly led to suspect surface runoff from the animal holding areas as a possible source for these elevated conductivity values. However, AS THIS ZONE OF HIGHER TERRAIN CONDUCTIVITY DISSIPATES TOWARDS THE MARGINS OF THE STUDY AREA AND DOES NOT APPEAR TO EXTEND DOWN SLOPE ALONG THE ROAD DITCH, THIS ZONE IS ASSUMED TO BE CONFINED. IN ADDITION, after comparing Figures 2 and 3, variations in soil type and clay content, and the possible occurrence of road salts are suspected of influencing these terrain conductivity values.

Summary:

1. The tight contours of the 5.5 meter penetration data indicate that seepage from the pit is confined to the embankment of the facility itself.

2. The 2.75-meter penetration data around the north, lower side of the facility delimits an area that was "burned" by the old stacking facility, spillage, and surface and near-surface accumulation of dissolved salts, such as nitrates, from waste-laden surface runoff from the livestock holding area adjacent to the farm buildings.

3. The holding facility is entirely surrounded by a 200-foot wide band of extremely low background values at both the 2.75 and 5.5 meter survey depths which indicate that leachate is not migrating from the vicinity of the facility.

4. The increase in background EM values in the lower north end of the field is attributed to an increase in clay content of the soils in that area based on detailed field checking and the published Franklin County Soil Survey Report.

Conclusion:

An electromagnetic induction survey conducted on a 50-foot grid over a 28-acre area using 942 readings taken at 486 points indicates that the Gervais animal waste storage facility is adequately performing according to engineering design expectations.

References Cited:

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

2. McNeill, J. D. 1989, EM31 Operating Manual: GEONICS Ltd. Mississauga, Canada, 35 pp.

3. Parrott, W.R., and Stone, B.D., 1972, Strandline features and late Pleistocene chronology of northwestern Vermont: in, Doolan, B.L., and Stanley, R.S. (Eds.), 64th Annual Meeting of the New England Intercollegiate Geological Conference Guidebook, pp. 359-376.

4. Flynn, D. J. and R. V. Joslin. 1979. Soil Survey of Franklin County, Vermont. USDA-SCS, Washington DC.

cc:
August J. Dornbusch, Jr., Director, SCS, MNTC, Lincoln, NE.
D. Bruce Champeon, State Geologist, SCS, Oorono, ME
James B. Hyland, National Engineering and Ground Water Geologist, SCS, NHQ, Washington, DC