ISGS CONTRACT/GRANT REPORT 1985-1

GEOPHYSICAL STUDIES AT THE SHEFFIELD LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY TO EVALUATE POTENTIAL PATHWAYS FOR THE ESCAPE OF CONTAMINANTS

Paul C. Heigold
Timothy H. Larson

Illinois Department of Energy and Natural Resources
STATE GEOLOGICAL SURVEY DIVISION

Heigold, Paul C.

Geophysical studies at the Sheffield low-level radioactive waste disposal facility to evaluate potential pathways for the escape of contaminants / Paul C. Heigold, Timothy H. Larson. -- Champaign, Ill. : Illinois State Geological Survey, 1985

23 p. ; 28 cm. -- (Illinois--Geological Survey. Contract/Grant report ; 1985-1)

"... funds provided by the Illinois Department of Nuclear Safety."

1. Radioactive waste disposal--Illinois--Bureau County. 2. Water, Underground--Pollution. 3. Geophysical exploration. I. Larson, Timothy H. II. Illinois Department of Nuclear Safety. III. Series.

Printed by authority of the State of Illinois/1985/200

ISGS CONTRACT/GRANT REPORT 1985-1

GEOPHYSICAL STUDIES AT THE SHEFFIELD LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY TO EVALUATE POTENTIAL PATHWAYS FOR THE ESCAPE OF CONTAMINANTS

Paul C. Heigold
Timothy H. Larson

1985

The study upon which this report is based was partly supported by funds provided by the Illinois Department of Nuclear Safety.

ILLINOIS STATE GEOLOGICAL SURVEY
Morris W. Leighton, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, Illinois 61820

ABSTRACT 1

INTRODUCTION 1

GEOLOGY 2

GEOPHYSICAL METHODS 2

RESULTS OF SURVEYS
WESTERN SIDE 3
EASTERN SIDE 4
NORTHERN SIDE 5

CONCLUSIONS 7

REFERENCES 23

FIGURES

Figure 1 Location of the Sheffield area of Bureau County, Illinois, Section 26, T. 16 N., R. 6 E. 1
Figure 2 Topographic map of Sheffield low-level radioactive waste (LLRW) disposal site 8
Figure 3 Quaternary classification system in relation to rock stratigraphic classification system 9
Figure 4 Bedrock topography of the Sheffield LLRW disposal site and adjacent area 10
Figure 5a Elevation of water table surface at the Sheffield LLRW disposal site 11
Figure 5b Elevation of water tables at the Sheffield LLRW disposal site 12
Figure 6 Location of vertical electric sounding (VES) profiles around the Sheffield LLRW disposal site 13
Figure 7 Location of the shallow geothermic surveys around the Sheffield LLRW disposal site 14
Figure 8 Location of wells, borings, trenches, and tunnel at the Sheffield LLRW disposal site 15
Figure 9 Geoelectric section obtained by automatic inversion of VES profile 10 16
Figure 10 Soil temperatures along northern portion of the western side of the Sheffield LLRW disposal site 17
Figure 11 Soil temperatures along the southern portion of the western side of the Sheffield LLRW disposal site 17
Figure 12 Geoelectric sections obtained by automatic inversion of VES curves associated with VES profiles 1, 2, and 3 18
Figure 13 Soil temperatures along the southern side of the Sheffield LLRW disposal site 19
Figure 14 Geoelectric sections obtained on automatic inversion of VES curves associated with VES profiles 4, 5, 6, and 7 20
Figure 15 Geoelectric sections obtained by automatic inversion of VES profiles 8 and 13 21
Figure 16 Soil temperatures along the northern side of the Sheffield LLRW disposal site 22

ABSTRACT

Surficial electrical resistivity and shallow geothermic surveys were conducted along the western, southern, and northern sides of the Sheffield low-level radioactive waste-disposal site in Bureau County, Illinois. The purpose of these surveys was to find and delineate the boundaries of water-bearing, coarse-grained glacial deposits that could be conduits for contaminated groundwater leaving the waste-disposal site. These surveys did not indicate the presence of any previously unknown coarse-grained deposits capable of serving as pathways for contaminants; however, they did confirm the existence of a buried bedrock channel containing sands of the Toulon Member of the Glasford Formation. Located near the eastern end of the northern boundary of the LLRW disposal site, this channel may be related to a previously discovered pathway for contaminants moving eastward from the disposal site.

INTRODUCTION

The Sheffield low-level radioactive waste (LLRW) disposal site was closed in April 1978. The site was located in southwestern Bureau County, Illinois (Sec. 26, T. 16 N., R. 6 E.) (figs. 1 and 2). Detailed monitoring has indicated the presence of small amounts of tritium in a few observation wells bordering the site.

In earlier efforts to find and delineate pathways for tritiated groundwater leaving the disposal site (Larson, 1981; Larson, Gilkeson, and Heigold, 1983; Heigold, Gilkeson, and Larson, 1983), geophysicists at the Illinois State Geological Survey conducted surficial electrical resistivity and shallow geothermic surveys to the east of the disposal site. In one area, tritiated groundwater was being transported away from the disposal site through a shallow, coarse-grained deposit; its boundaries were delineated. In another area, a shallow geothermic survey indicated that a well in which small amounts of tritium had been detected was located with a narrow reentrant on the sloping shale bedrock surface--a pathway for tritiated groundwater to leave the disposal site.

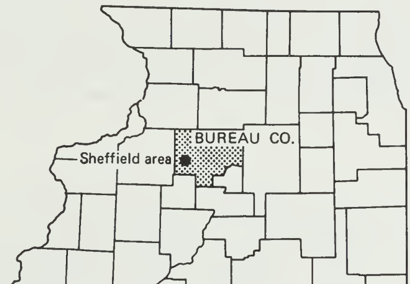


Figure 1. Location of the Sheffield area of Bureau County, Illinois, Section 26, T. 16 N., R. 6 E.

In a further effort to find and delineate the pathways taken by contaminated groundwater leaving the LLRW disposal site, more reconnaissance surficial electrical resistivity and shallow geothermic surveys have been conducted along the western, southern, and northern sides of the LLRW disposal site. The results of these surveys are the subject of this report.

GEOLOGY

In the study area unconsolidated Wisconsinan and Illinoian glacial sediments rest unconformably on Pennsylvanian bedrock. The Pleistocene stratigraphy of the Sheffield LLRW disposal site described by Foster and Erickson (1980) is summarized in figure 3. Essentially, the Pleistocene units consist of variable amounts of Peoria Loess overlying one to three members of the Glasford Formation.

The Toulon Member of the Glasford Formation is a unit of particular interest. It is an outwash deposit that varies considerably in thickness and consists generally of poorly sorted, pebbly sand that in places grades into either clean sand or clean gravel. Earlier exploratory work found that the Toulon Member formed a conduit for contaminants leaving the eastern side of the LLRW disposal site.

The bedrock surface consists of shale of the Carbondale Formation (Willman et al., 1975). The bedrock topography of the Sheffield site and adjacent areas is shown in figure 4. Both this map and the map (fig. 5a) showing the elevation of the water-table surface at the Sheffield site indicate that two buried bedrock channels control the direction of groundwater flow away from the site. One channel directs flow toward the northeast, the other to the southeast.

A more recent map showing the elevation of the water-table surface at the Sheffield site (fig. 5b) presents a different configuration of the water-table surface. Figure 5b does not indicate any influence of the buried bedrock channel on the elevation of the water-table surface on the eastern end of the northern boundary of the LLRW disposal site. This map incorporates recently acquired water-table data east of the LLRW disposal site. In our opinion, however, these newly acquired data do not provide sufficient information to preclude previous interpretations of the water-table configuration on the eastern end of the northern boundary of the LLRW disposal site.

GEOPHYSICAL METHODS

Surficial electrical resistivity surveying on the western, southern, and northern sides of the LLRW disposal site consisted of 13 vertical electrical sounding (VES) profiles (fig. 6). The Wenner electrode configuration was employed in all VES profiles. This electrode configuration permits more near-surface earth materials to be sampled at each resistivity station than with the more focused Schlumberger electrode configuration. This was desirable because the number and location of VES profiles were limited by dense vegetation, steeply sloping terrain, and engineered structures. Efforts were made to locate VES profiles in places where the electrodes could be kept at approximately the same elevation. The VES data were collected with a Bison 2350B resistivity meter and interpreted with the aid of the automatic inversion program of Zohdy and Bisdorf (1975).

Shallow geothermic surveying on the western, southern, and northern sides of the LLRW disposal site consisted of a network of soil temperature measurements made 1 meter below land surface (fig. 7), below the depth affected by diurnal temperature variations. Two separate surveys covered essentially the same areas. One survey was conducted during the winter (March 13, 1984) and the second during the summer (July 11, 1984). Shallow aquifers often form heat sources in the winter and heat sinks in the summer, thus influencing the temperature of the soil beyond the effects of heat originating at the earth's surface or from the earth's interior (Cartwright, 1968). Unfortunately, field conditions during the winter survey were unfavorable and the data were unreliable. Subsequent discussion of the shallow geothermic data will deal only with the summer survey.

Just as with the electrical resistivity surveying, the extent of the geothermic surveying was severely restricted by the dense vegetation and engineered structures around the LLRW disposal site.

All soil temperatures were measured with a Cole-Palmer digital thermometer (Model K-8506-40) and Cole-Palmer general thermistor probes (Model K-8415-21).

RESULTS OF SURVEYS: WESTERN SIDE

The western side of the LLRW disposal site provided little opportunity to conduct a meaningful electrical resistivity survey. In the narrow area between the LLRW disposal site and a chemical waste disposal site located immediately west of the LLRW site, steep terrain and dense vegetation allowed only two VES profiles to be run (fig. 6). The VES curve associated with VES profile 9, centered near test boring 150 (fig. 8), correlated well with the results of sampling at this test boring. Low apparent resistivities in this profile corresponded to a thin section of silty glacial deposits resting on shale bedrock. VES profile 10 was located in a topographic low near the southwestern corner of the LLRW disposal site between test borings 126 and 127 (figs. 6 and 8). The geoelectric section obtained by the inversion of the VES curve from VES profile 10 (fig. 9) indicates that a layer of fine-grained glacial sediments (with a resistivity of 70 to 85 ohm-feet) overlies slightly coarser-grained glacial deposits (185 ohm-feet) above shale bedrock. Although 185 ohm-feet is a relatively high resistivity value, it is not normally associated with deposits having significantly large hydraulic con--ductivities. This result confirmed the findings of test borings 126 and 127: in this area there is a thin, discontinuous layer (0 to 6 feet thick) of sand and gravel within the glacial deposits.

The summer geothermic survey on the western side of the LLRW site consisted of a single line of soil temperature measurements along the northern portion of the west boundary fence, and two parallel lines of soil temperature measurements along the southern end of the west boundary fence (fig. 7). The southern geothermic lines were separated from this boundary fence by a strip of dense vegetation. The soil temperatures along all the lines (figs. 10 and 11) do not show abrupt lateral changes that could be related to lithologic changes in the near-surface glacial sediments. On the contrary, the soil temperatures correlate positively with surface elevation. This phenomenon is probably due to the fact that the water table is deeper at higher topographic elevations and that areas of higher topographic elevation generally receive more solar radiation. Although contributions to soil temperatures of geothermal heat from the earth's interior are negatively correlated with surface elevation, this factor is negligible in comparison to the other factors mentioned.

In the southern portion of this survey along the western boundary of the site, soil temperatures along the line closer to the fence were generally cooler than those along the line farther from the fence. This does not indicate an underlying change in lithology, but the effect of vegetation on soil temperatures. The dense vegetation growing along the fence provides partial shade to adjacent area; root structures hold moisture in the soil.

In summary, although the logs of test borings 126, 102, 511, and 122 along the western side of the LLRW disposal site (fig. 8) all show the presence of sand deposits, these deposits do not appear to be large enough or to have sufficient great hydraulic conductivity to serve as conduits for contaminants leaving the LLRW disposal site. Moreover, water-table elevations in and around the LLRW disposal site (fig. 5) suggest that groundwater moves toward the LLRW disposal site from the west.

RESULTS OF SURVEYS: SOUTHERN SIDE

On the southern side of the LLRW disposal site (fig. 6), three VES profiles were arranged in a line just outside of and parallel to the boundary fence, on a hillside slopeing steeply to the south. The bedrock topography map (fig. 4) shows that the three VES profiles are located on an east-west trending bedrock high. In test boring 128 near the center stake of VES profile 1, the unconsolidated glacial deposits are 31 feet thick (fig. 8); samples indicate that the glacial sediments are well-drained, fine-grained loess and till resting on shale bedrock.

The geoelectric sections obtained from the inversions of the VES curves associated with VES profiles 1, 2, and 3 (figs. 6 and 12) are very similar. A thin, low-resistivity layer at the surface is underlain by a higher resistivity layer, which in turn is underlain by another low resistivity layer. The two uppermost resistivity layers correspond to two layers of unsaturated, fine-grained deposits; the lower of these two layers is slightly coarser grained.

The shallow geothermic survey in July 1984 consisted of two lines of soil temperature measurements made just outside of and parallel to the boundary fence on the southern side of the LLRW disposal site (fig. 7). The temperature data along these lines (fig. 13) probably reflect lithologic changes in unconsolidated glacial deposits. Shallow, coarse, well drained sediments are typically associated with higher soil temperatures during the summer months; thus the higher temperature values observed near the western end of the survey lines strongly suggest the presence of such deposits. Samples from test boring 120 (fig. 8) west of the line of tempeature measurements indicate that the glacial till contains sand and gravel.

The southeast corner of the LLRW disposal site is particularly interesting: both the surface topography and a buried bedrock channel (figs. 2 and 4), provide drainage away from the site. A pebbly, well sorted sand unit over 7 feet thick was encountered in test boring 525 (fig. 8) and attributed to the Wisconsinan Henry Formation. However, test borings indicate that sand of the Toulon Member of the Glasford Formation, which forms a conduit for contaminants leaving the eastern side of the LLRW disposal site (Larson, Gilkeson, and Heigold, 1983), is absent in this area. Although the sand of the Henry Formation near the southeast corner of the LLRW disposal site is similar in texture to sand of the Toulon Member of the Glasford Formation east of the disposal site, the Henry Formation is younger and is unrelated to the Toulon Member (fig. 3). Unfortunately, rough terrain and dense vegetation did not allow VES profiles and soil temperature measurements to be located along the eastern end of the southern boundary of the LLRW disposal site.

In summary, geophysical data gathered in accessible areas on the southern side of the LLRW disposal site did not indicate the presence of shallow glacial deposits capable of serving as significant pathways for contaminant transport in those areas.

RESULTS OF SURVEYS: NORTHERN SIDE

Four VES profiles were located in a line just outside of, and parallel to, the fence on the northern side of the LLRW disposal site (fig. 6). Inversion of the VES curves associated with these VES profiles yielded geoelectric sections (fig. 14) whose resistivities and thicknesses are consistent with the results of sampling in test borings 513, 515, and 514 (fig. 8) along the northern boundary fence. Within the geoelectric sections, a thin, low-resistivity surface layer appears to correspond to a thin layer of clayey silt. A second, higher-resistivity layer below corresponds to a slightly coarser, but still fine-grained, layer of glacial deposits above the bedrock. A third layer with low resistivities corresponds to shale bedrock. The relatively higher resistivity middle layer assumes its highest value (179 ohm-feet) at VES profile 4. This could mean that the sediments corresponding to this resistivity value are either coarser grained or better drained than those to the east.

Dense vegetation and culture (structures and equipment) did not allow this line of VES profiles to be extended far enough to the east to intersect the area where borings 516, 517, and 518 indicate the presence of a buried bedrock channel (fig. 4 and 8). According to Foster and Erickson (1980), this channel is partially filled by sand of the Toulon Member.

VES profiles 8, 12, and 13 were located in the limited surveying space outside the northeast corner of the LLRW disposal site in an attempt to map and evaluate the coarse-grained deposits filling the bedrock channel there (fig. 4 and 6). VES profile 12 was restricted by a small stream running perpendicular to the profile and by heavy equipment parked nearby, but VES profiles 8 and 13 were expanded to a considerable length. Inversion of the VES curves associated with profiles 8 and 13 (fig. 15) resulted in geoelectric sections consisting of a low-resistivity layer at the surface, a thick higher resistivity middle layer, and a low-resistivity layer at the base. Resistivities of the middle layer determined in VES profiles 8 and 13 were 195 and 169 ohm-feet, respectively. These values are not very different from the higher resistivities determined at VES profiles 4, 5, 6, and 7. We conclude that VES profiles 8 and 13 are both located to the northwest of the deepest part of the bedrock channel. Very little of the coarse-grained material indicated in test borings 516, 517, and 518 was detected by the VES profiling.

Shallow geothermic surveying conducted in July 1984 on the northern side of the LLRW disposal site (fig. 7) covered a considerably larger area than the summer surveys of the western and southern sides of the LLRW disposal site; but it also was restricted by areas of dense vegetation and engineered structures. Soil temperatures on the northern side of the site (fig. 16) appear to be controlled by two factors: the moisture content of the sediments above the water table, and the grain size of sediments below the water table. The higher soil temperature values observed in figure 16 are probably the result of well-drained, near-surface glacial deposits. These temperatures occur in an area where surface elevations are higher and test borings did not penetrate coarse-grained materials below the water table. Lower soil temperatures are prevalent on the eastern side of the surveyed areas. Here, surface elevations are lower and coarse-grained glacial deposits were found below the water table. This latter situation is the classic case of a shallow aquifer acting as a heat sink during the summer.

On the northern side of the LLRW disposal site, surficial electrical resistivity surveying could not be conducted where test borings had definitely located coarse-grained glacial deposits below the water table; however, resistivity surveying could be used to indicate areas of well-drained, fine-grained glacial deposits. Shallow geothermic surveys not only corroborated the findings of the resistivity surveys, but more importantly, also confirmed the presence of coarser grained deposits below the water table near the northeast corner of the LLRW disposal site.

From the limited test boring and geophysical data gathered on the northeastern side of the LLRW disposal site, it is not possible to accurately delineate the buried bedrock channel (fig. 4) in the northeast area of the disposal site. Similarly, the data are insufficient to describe the relationship between this bedrock channel and the previously determined pathway for tritiated groundwater leaving the disposal site to the east (Larson, Gilkeson, and Heigold, 1983). The relationship is important because the buried bedrock channel on the northeast side of the LLRW disposal site is known to contain sand deposits of the Toulon Member of the Glasford Formation similar to those that form the conduit for contaminants leaving the eastern side of the LLRW disposal site.

CONCLUSIONS

Electrical resistivity and shallow geothermic surveys were conducted on the western, southern, and northern sides of the Sheffield LLRW disposal site. Although limited in areal coverage, these surficial geophysical surveys confirmed existing geological information. They did not indicate the presence of any previously unknown coarse-grained deposits capable of serving as pathways for contaminants leaving the LLRW disposal site. Data on bedrock topography, water table configuration, and lithologies of the glacial deposits, together with measurements of soil temperature confirm the existence of a buried bedrock channel containing deposits of sand belonging to the Toulon Member. Located near the eastern end of the northern boundary of the LLRW disposal site, this channel may be a possible pathway for contaminants leaving the disposal site. Its relationship to the previously discovered pathway for contaminants leaving the disposal site to the east is unknown at this time.

ACKNOWLEDGMENTS

This study was supported under contract through the University of Illinois with the Illinois Department of Nuclear Safety, Terry Lash, Director. This study was conducted in support of the activities of the Steering Committee for the Tritium Migration Investigation. The committee consists of a representative of the Illinois State Geological Survey, U. S. Geological Survey, Illinois Department of Nuclear Safety, Illinois Attorney General, and U. S. Ecology, Inc.

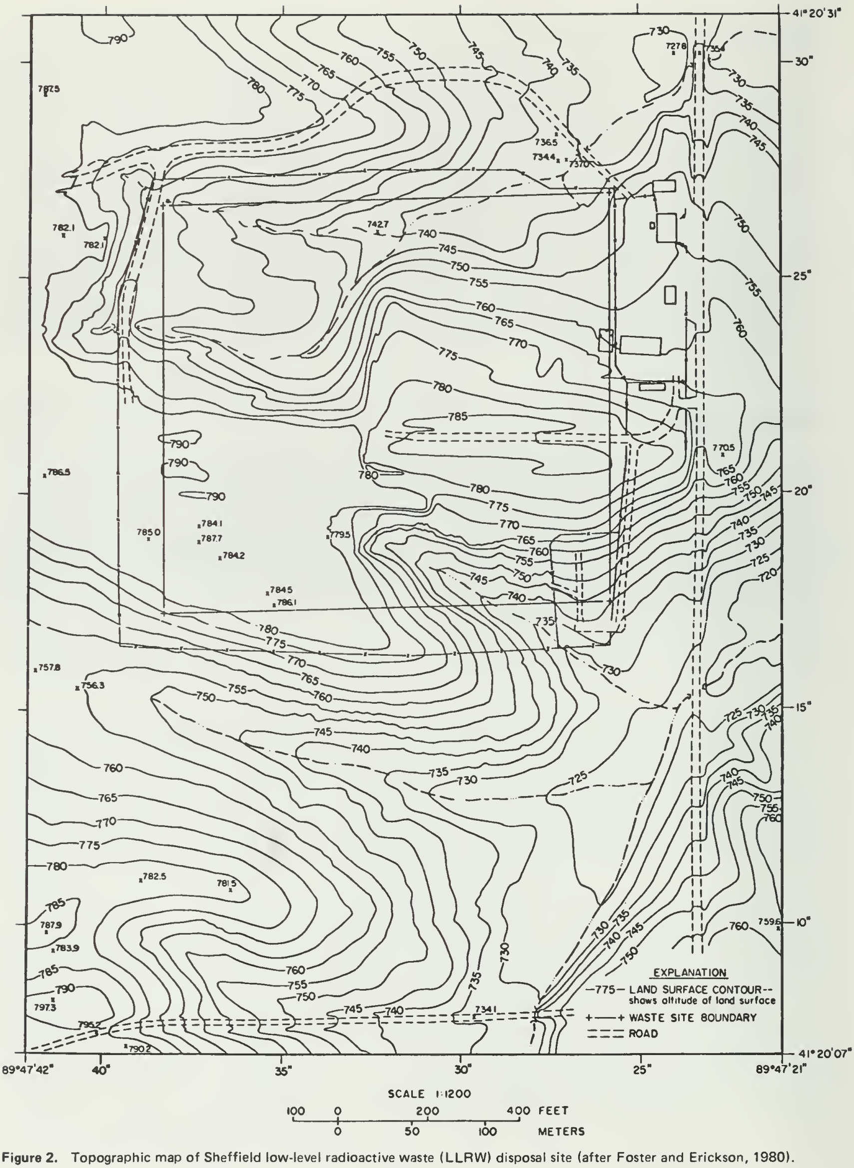


Figure 2. Topographic map of Sheffield low-level radioactive waste (LLRW) disposal site (after Foster and Erickson, 1980).

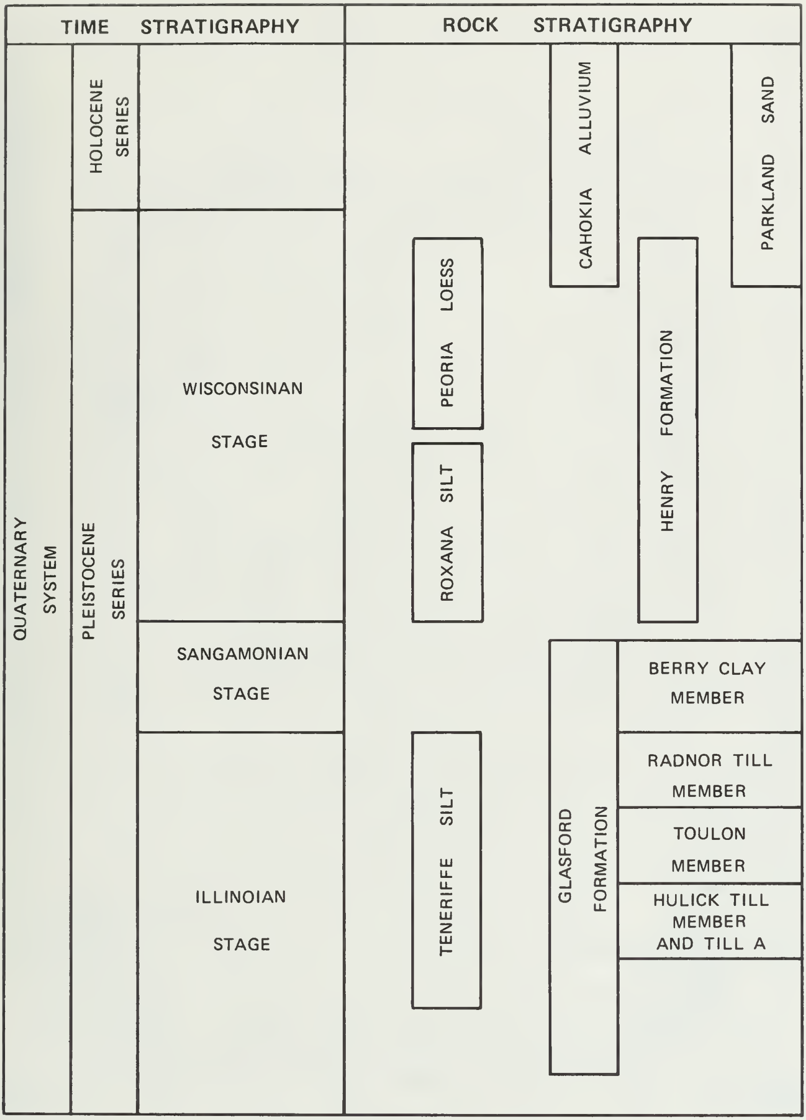


Figure 3. Quaternary classification system in relation to rock stratigraphic classification system (after Foster and Erickson, 1980).

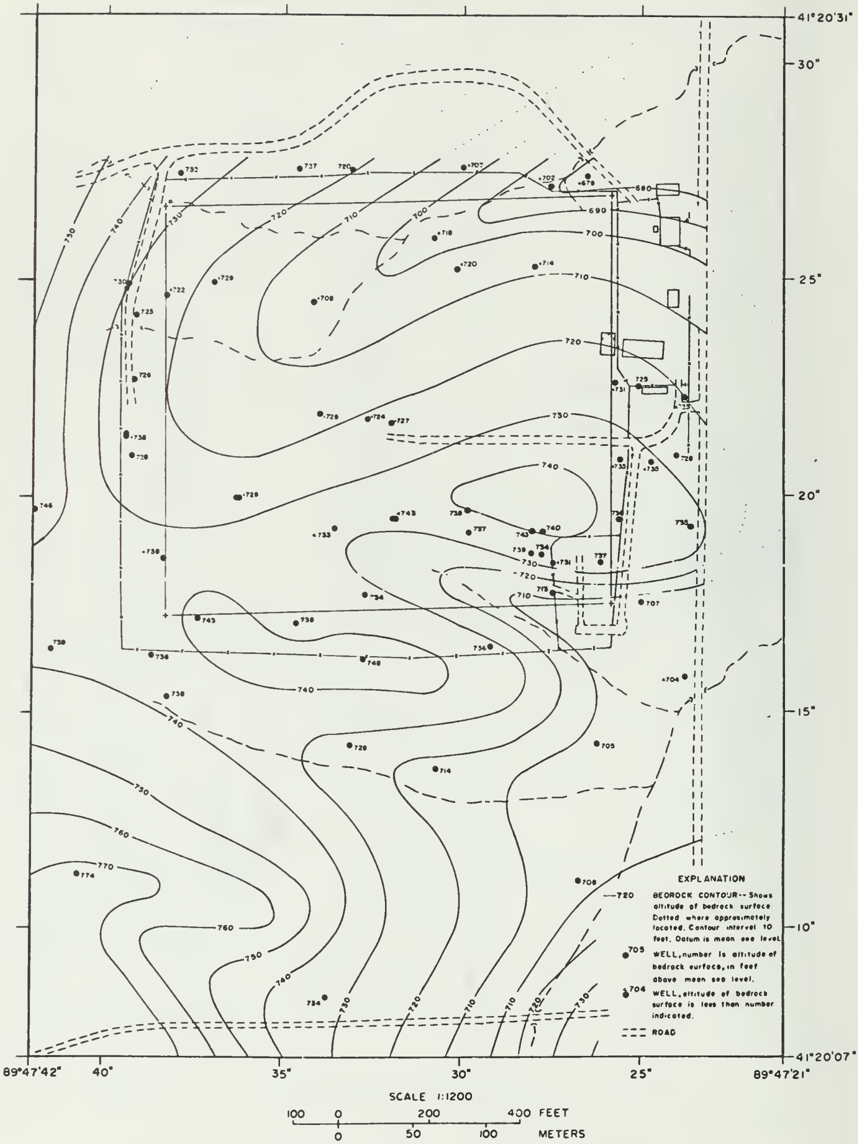


Figure 4. Bedrock topography of the Sheffield LLRW disposal site and adjacent area (after Foster and Erickson, 1980).

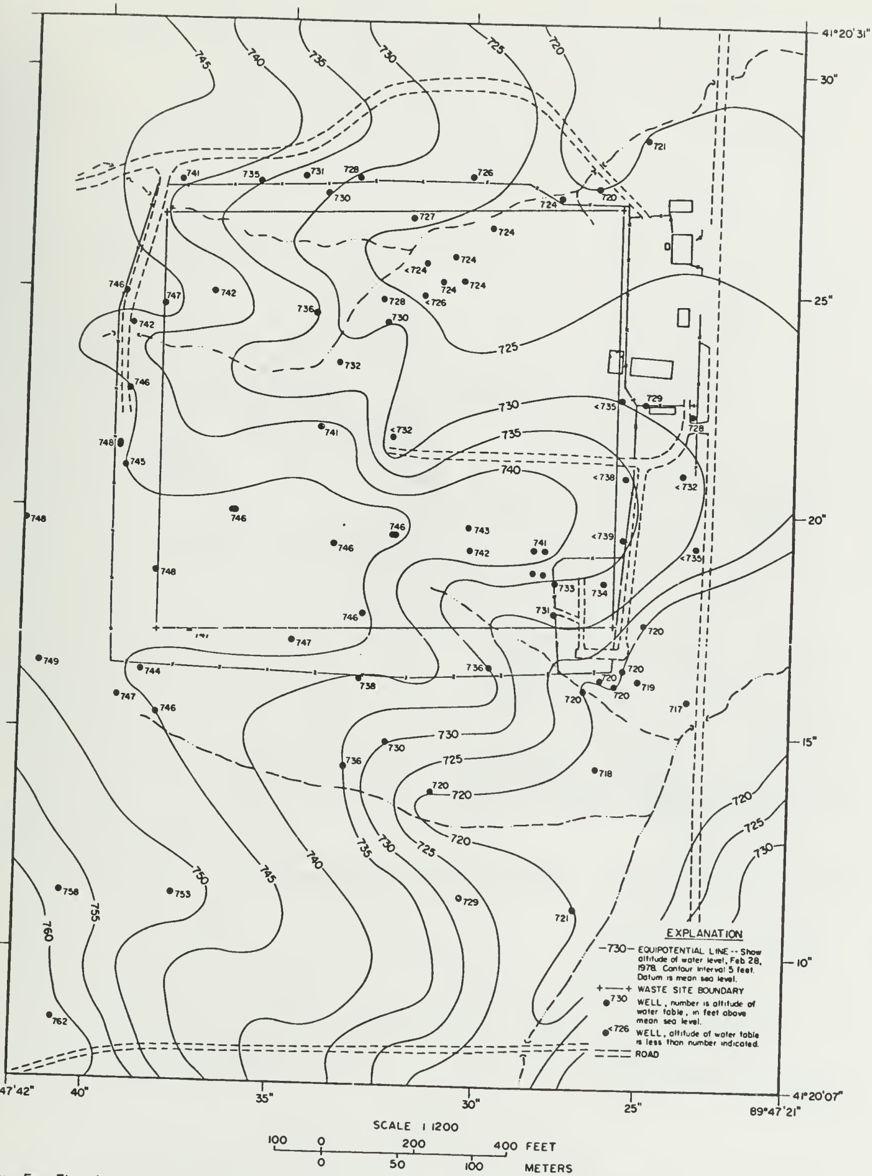


Figure 5a. Elevation of water table surface at the Sheffield LLRW disposal site (after Foster and Erickson, 1980).

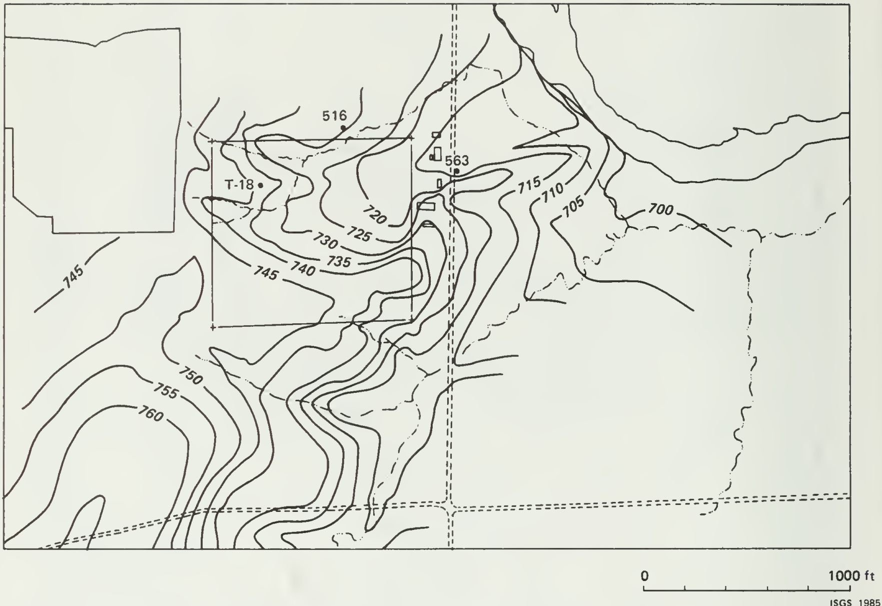


Figure 5b. Elevation of water tables at the Sheffield LLRW disposal site (February, 1983).

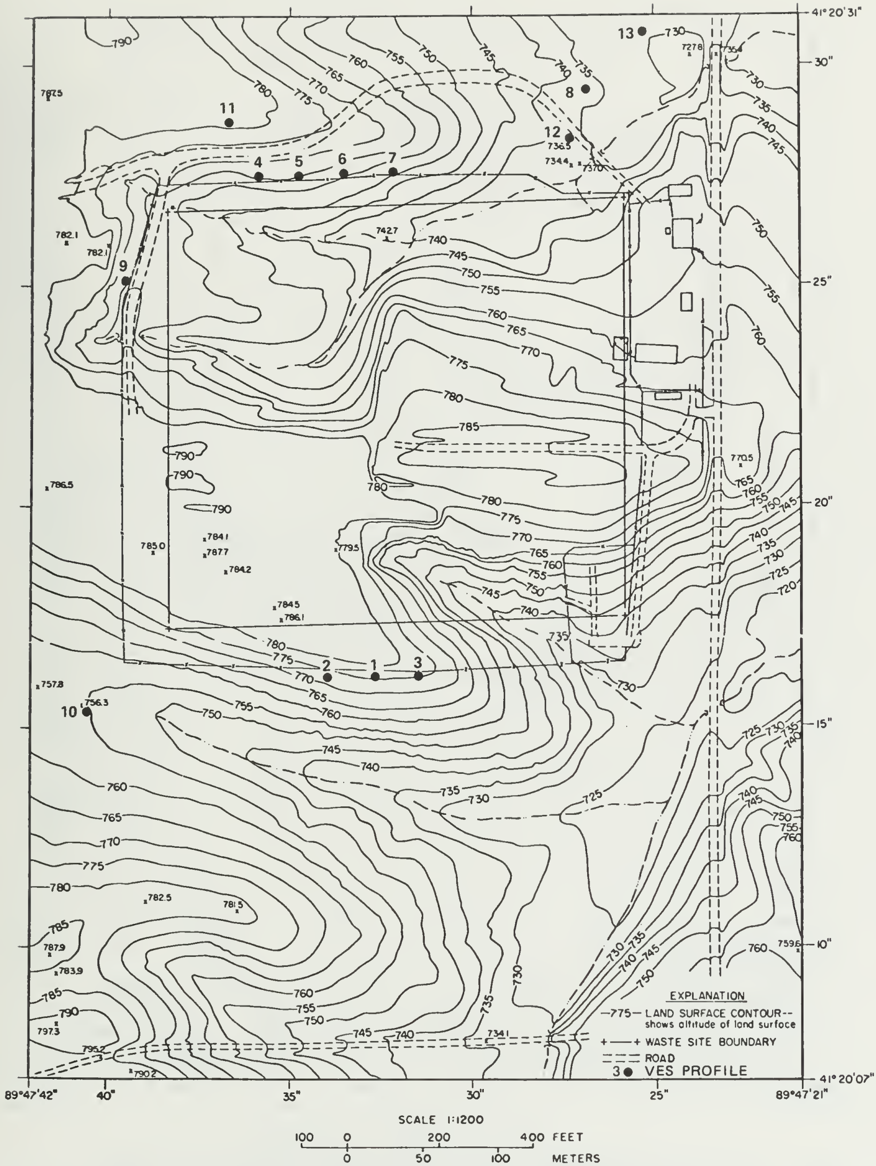


Figure 6. Location of vertical electric sounding (VES) profiles around the Sheffield LLRW disposal site.

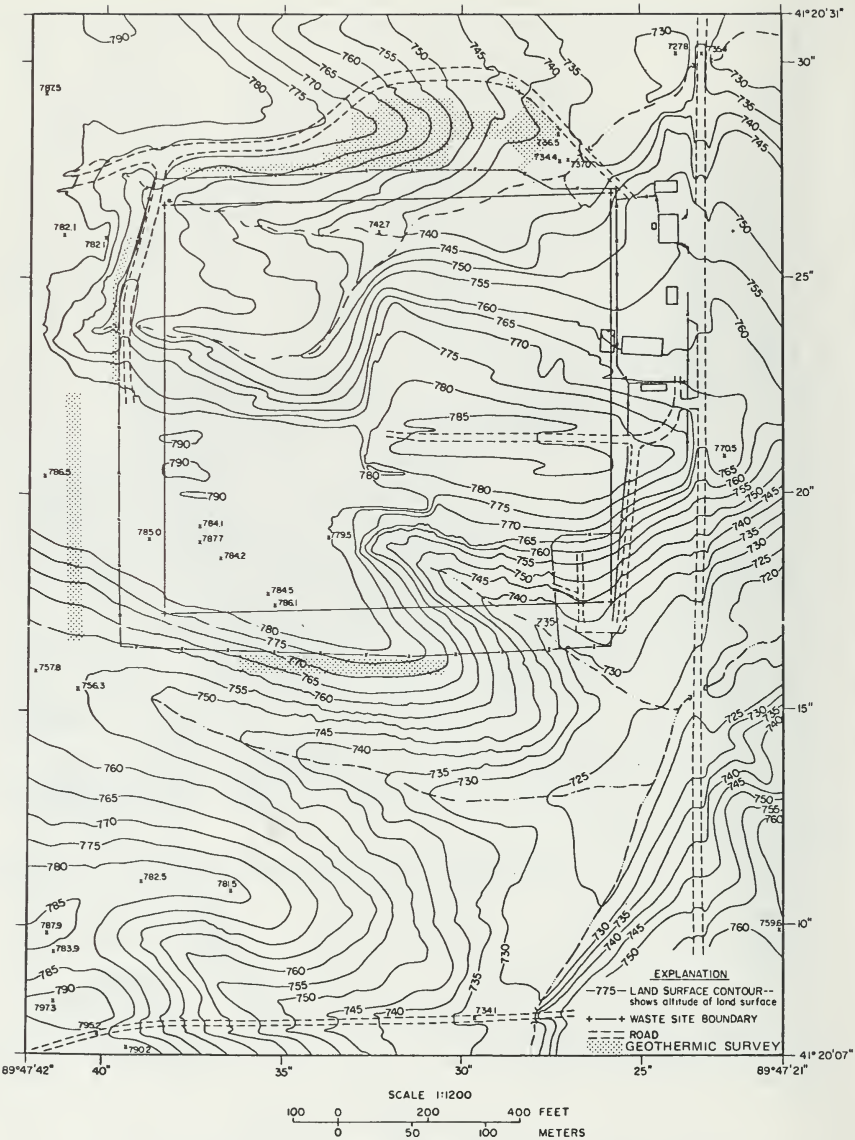


Figure 7. Location of the shallow geothermic surveys around the Sheffield LLRW disposal site (summer, 1984).

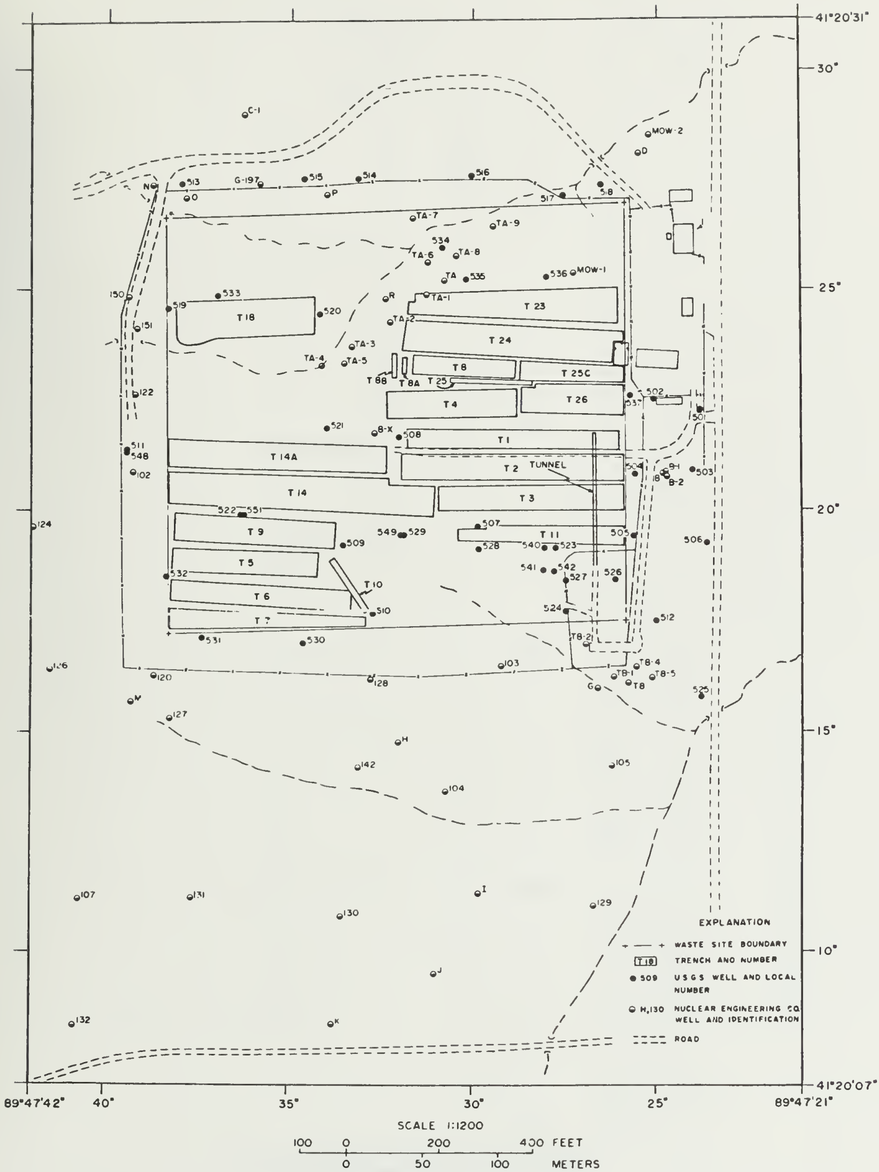


Figure 8. Location of wells, borings, trenches, and tunnel at the Sheffield LLRW disposal site (after Foster and Erickson, 1980).

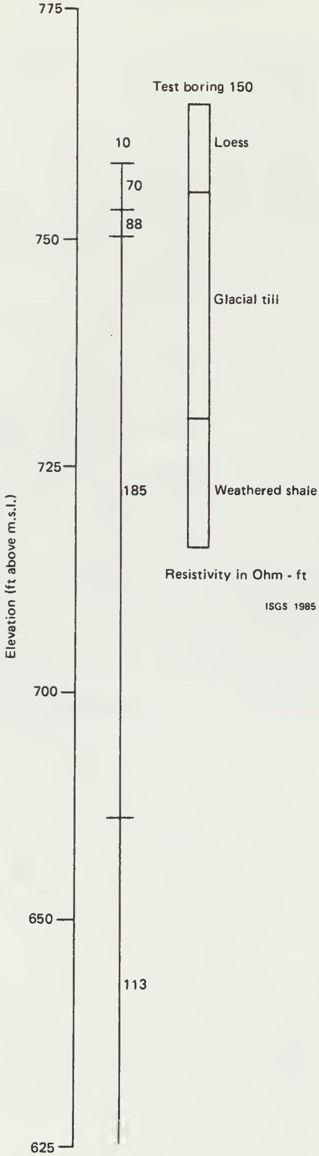


Figure 9. Geoelectric section obtained by automatic inversion of VES profile 10 (see figs. 6 and 8).

Figure 10. Soil temperatures (taken at a depth of 1 m on July 11, 1984) along northern portion of the western side of the Sheffield LLRW disposal site (see fig. 7).

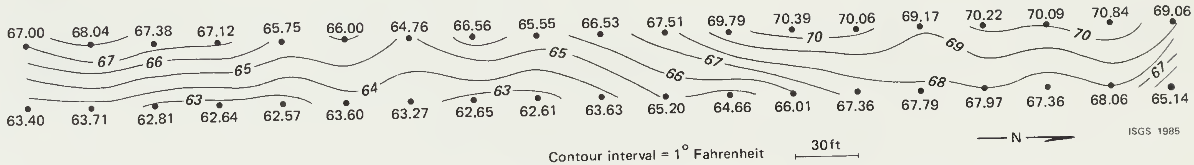


Figure 11. Soil temperatures (taken at a depth of 1 m on July 11, 1984) along the southern portion of the western side of the Sheffield LLRW disposal site (see fig. 7).

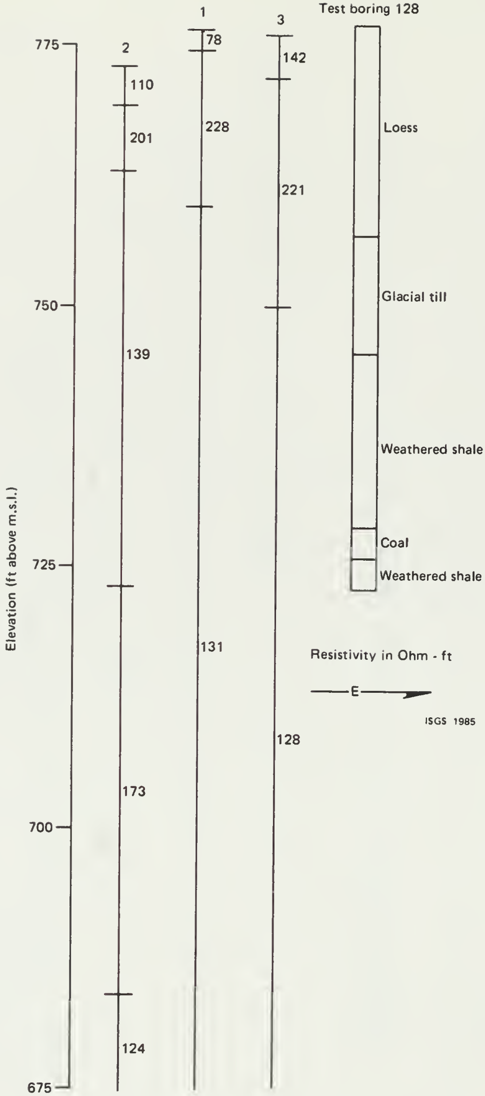


Figure 12. Geoelectric sections obtained by automatic inversion of VES curves associated with VES profiles 1, 2, and 3 (see figs. 6 and 8).

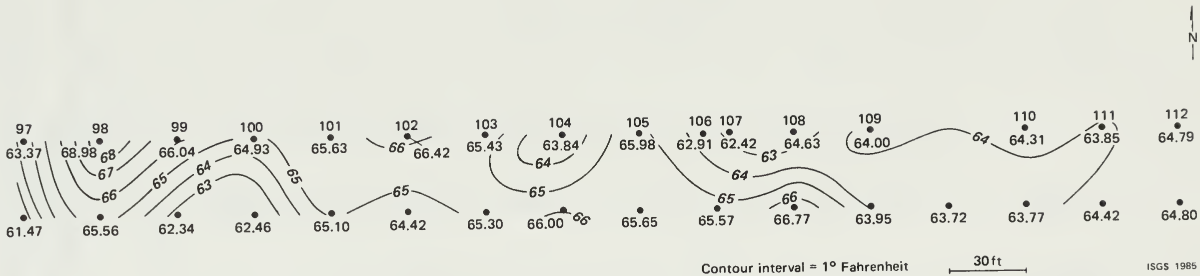


Figure 13. Soil temperatures (taken at a depth of 1 m on July 11, 1984) along the southern side of the Sheffield LLRW disposal site (see fig. 7).

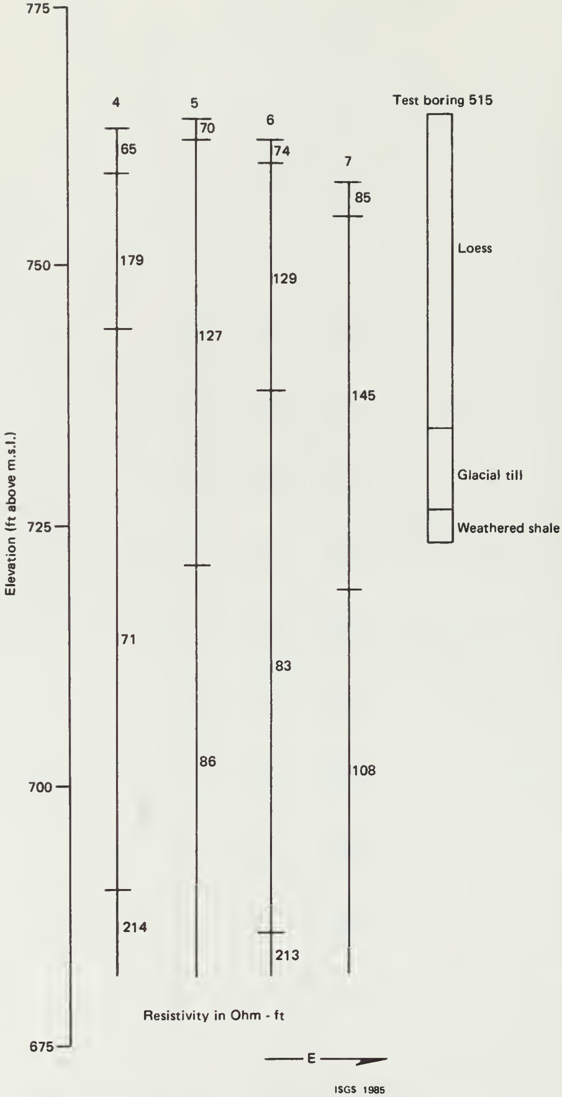


Figure 14. Geoelectric sections obtained on automatic inversion of VES curves associated with VES profiles 4, 5, 6, and 7 (see figs. 6 and 8).

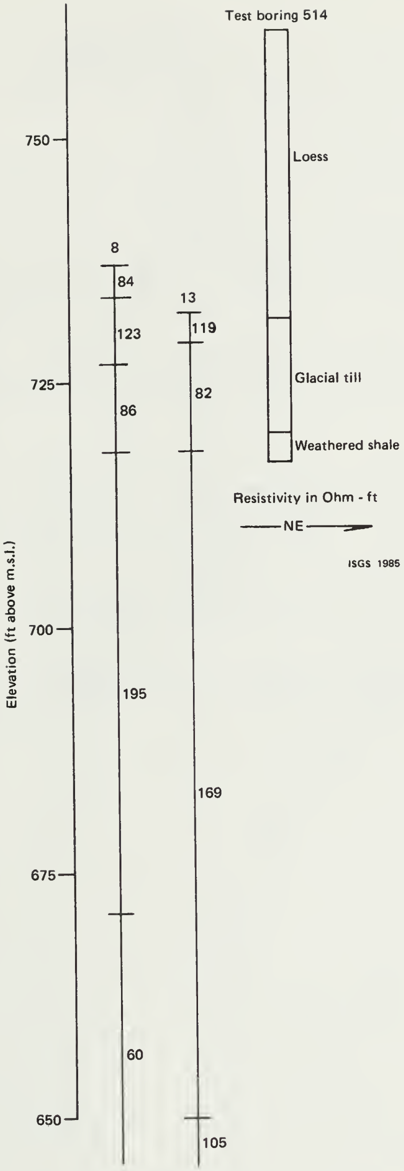
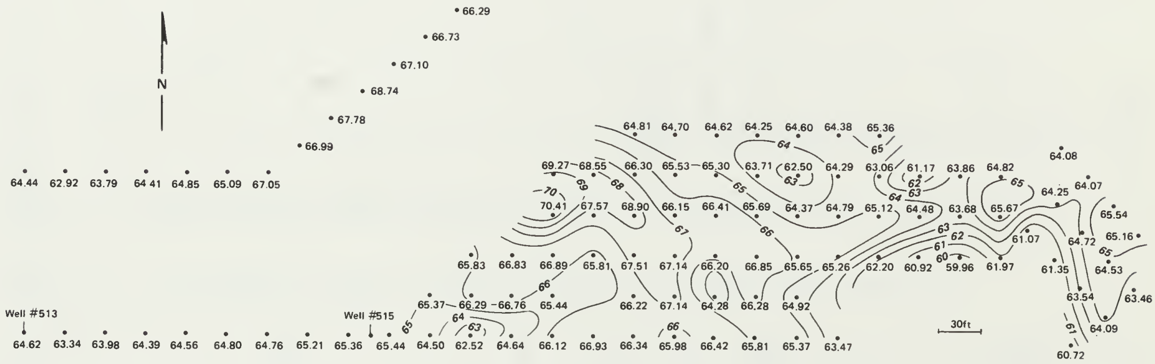


Figure 15. Geoelectric sections obtained by automatic inversion of VES profiles 8 and 13 (see figs. 6 and 8).



Contour interval = 1° Fahrenheit

Figure 16. Soil temperatures (taken at a depth of 1 m on July 11, 1984) along the northern side of the Sheffield LLRW disposal site (see fig. 7).

REFERENCES

Cartwright, K., 1968, Temperature prospecting for shallow glacial and alluvial aquifers in Illinois: Illinois State Geological Survey Circular 433, 41 p.

Foster, J. B., and J. R. Erickson, 1980, Preliminary report on the hydrogeology of the low-level radioactive waste disposal site near Sheffield, Illinois: USGS, Open File Report 79-1545, 87 p.

Heigold, P. C., R. H. Gilkeson, and T. H. Larson, 1983, Shallow geothermic survey east of Sheffield low-level radioactive waste site, Bureau County, Illinois: Illinois State Geological Survey, unpublished letter report to Illinois Department of Nuclear Safety.

Larson, T. H., 1981, A surficial electrical resistivity survey east of the Sheffield low-level radioactive waste disposal site, Bureau County, Illinois: Illinois State Geological Survey Contract/Grant Report 1981-6, 11 p.

Larson, T. H., R. H. Gilkeson, and P. C. Heigold, 1983, Surficial electrical resistivity and shallow geothermic surveys east of the Sheffield low-level radioactive waste disposal site, Bureau County, Illinois: Illinois State Geological Survey Contract/Grant Report 1983-1, 17 p.

Willman, H. B., E. Atherton, T. C. Buschbach, C. Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, and J. A. Simon, 1975, Handbook of Illinois Stratigraphy: Illinois State Geological Survey Bulletin 95, 261 p.

Zohdy, A.R.R. and R. J. Bisdorf, 1975, Computer programs for the forward calculation and automatic inversion of Wenner sounding curves: US NTIS PB-247-265, 47 p.