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ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--Final Report

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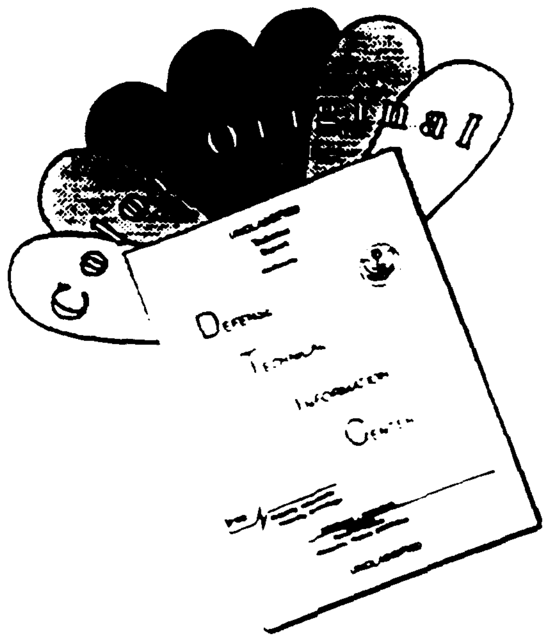

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The ELF Communications System enables the U.S. Navy to communicate with submarines worldwide at operational depth and speed. The system consists of transmitting facilities in Wisconsin and Michigan that synchronously broadcast messages. Transmitters became fully operational in Wisconsin in 1985 and in Michigan in 1989.

In situ studies to monitor for possible bioelectromagnetic effects from operation of both transmitters were initiated in 1982. The studies use a split-plot or blocked strategy to examine differences in space (treatment/control sites) or time (preoperational/operational). Physiological, developmental, behavioral, and ecological variables for dominant biota in upland, wetland, and riverine habitats near the ELF system have been examined in these studies. In Wisconsin, data collection for all studies was completed by the end of 1989; in Michigan, data collection continued through 1993.

In support of this research, IIT Research Institute has annually documented the ambient ELF electromagnetic (EM) environment, including EM fields produced by both the ELF system and electric power distribution (60 Hz). This report documents ELF EM field intensities at all study sites active in 1993, and is comprehensive for the period 1983-1993. Other engineering activities performed during 1993 in support of the ecological studies are also described.

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FOREWORD

An Ecological Monitoring Program has been conducted to test for possible electromagnetic (EM) effects from operation of the U.S. Navy's ELF Communications System. The ELF Communications System consists of two transmitting facilities: one in Clam Lake, Wisconsin, and the other in Republic, Michigan. Monitoring studies near the Wisconsin transmitter were initiated in 1982 and completed by the end of 1989. Studies near the Michigan transmitter were initiated in 1983, and field data collection was completed in 1993. This report documents measurements of extremely low frequency (ELF) electromagnetic fields, as well as other engineering activities, performed in support of the Ecological Monitoring Program. This report is comprehensive for the Michigan-based studies (1983-1993) but also makes comparative references to the Wisconsin-based studies. A full report of the Wisconsin studies was issued in 1990 (IITRI Technical Report E06620-5, ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support—1989). All work was funded by the Space and Naval Warfare Systems Command, Submarine Communications Project Office, under Contracts N00039-81-C-0357, N00039-84-C-0070, N00039-88-C-0065, and N00039-93-C-0001 to IIT Research Institute (IITRI).

Respectfully submitted,
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CONTENTS

CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLES

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: ELECTROMAGNETIC FIELD MEASUREMENTS AND ENGINEERING SUPPORT--FINAL REPORT

1. INTRODUCTION

1.1 Ecological Monitoring Program

In 1981, concurrent with its decision to complete construction of an Extremely Low Frequency (ELF) Communications System, the Department of the Navy established an Ecological Monitoring Program. The purpose of the program is to determine whether long-term exposure to electromagnetic (EM) fields produced by the communications system result in adverse effects to resident biota or their interrelationships. Ecological studies were performed by university investigators, and their efforts were supported by IIT Research Institute (IITRI).

IITRI supported the ecological investigators by making EM field measurements and providing other engineering support. EM field measurements are needed to ensure that there are significant differences in EM exposure between paired study sites and to provide data that may be needed for further examination of possible cause-and-effect relationships. Engineering support provided by IITRI included design, fabrication, and installation of EM control and recording equipment; mitigation of EM exposures in laboratories; and EM mitigation of on-site ambient monitoring equipment with respect to safety, interference, and damage from nearby lightning strikes. IITRI also summarized data on the operational characteristics of the ELF transmitters, and reviewed the use of EM data in reports by investigators. All of these support activities are documented annually in IITRI technical reports.

This report documents engineering support activities during 1993 and provides a comprehensive summary (1983-1993) of EM exposures at study sites and laboratories that were still active in 1993. Documentation of EM field measurements and engineering support for completed work--namely, the wetlands, slime mold, and bird species and communities studies performed in Wisconsin--appears in previous annual reports.[1-7] Final reports for the Wisconsin studies have also been published.[8-10] Previous documentation of EM field measurements and engineering support for Michigan studies may be found in references 1-7, as well as references 11-13.

1.2 ELF Communications System

The ELF Communications System includes two transmitting facilities, one located in the Chequamegon National Forest in Wisconsin and the other in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists of a transmitter connected to long overhead wires (antennas) with buried ground terminals at their ends. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The Naval Radio Transmitting Facility-Clam Lake, Wisconsin

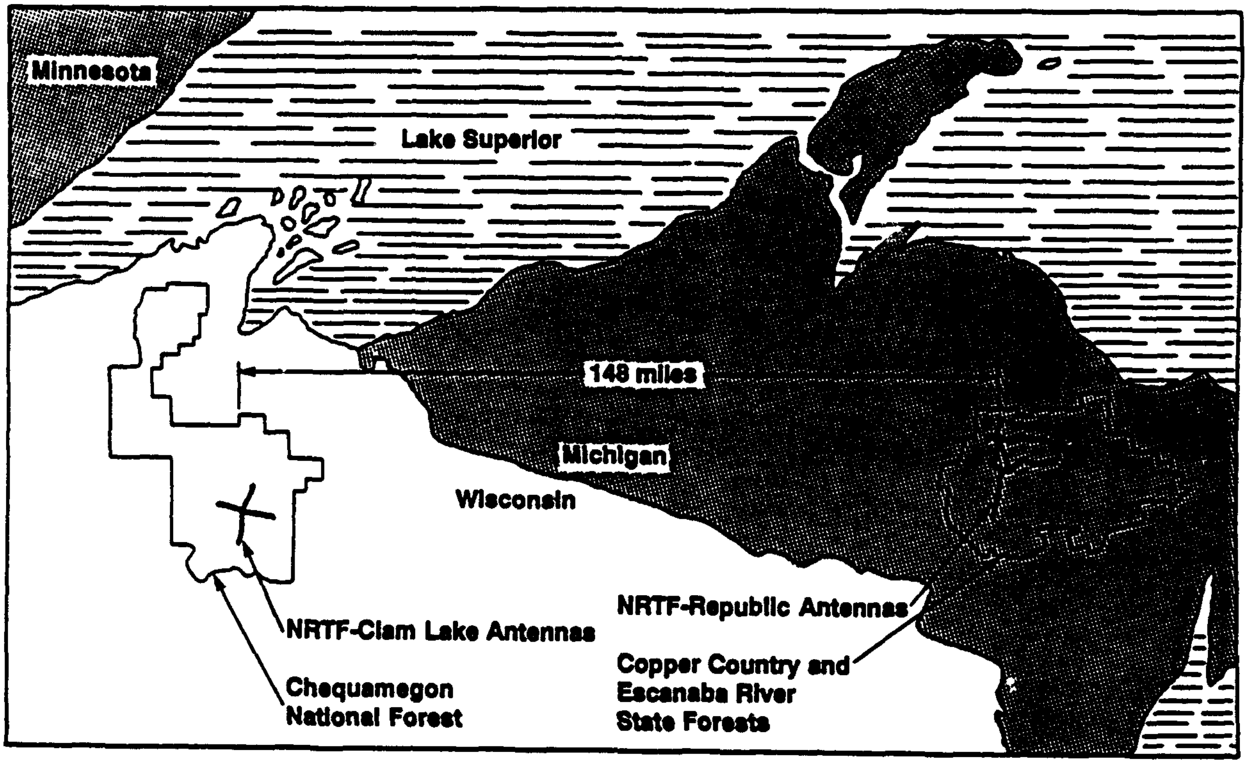


FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

(NRTF-Clam Lake) has a north-south (NS) and an east-west (EW) antenna, each 14 miles long. The Naval Radio Transmitting Facility-Republic, Michigan (NRTF-Republic) has a 28-mile-long NS antenna and an EW antenna composed of a northern east-west (NEW) and a southern east-west (SEW) element, each of which is approximately 14 miles long. The end of each antenna or antenna element terminates in one to three miles of buried horizontal ground wire and one or more arrays of vertical electrodes 100 to 300 feet deep.

The transmitters broadcast messages using ELF EM fields; these fields are the operational component to be evaluated by the Ecological Monitoring Program. The EM fields produced by the ELF Communications System are:

- a magnetic field, essentially the same in the air and the earth, that is generated by the electrical current in the antenna elements and ground terminals
- an electric field in the earth that is the sum of the fields induced by the magnetic field and the current flowing from the buried ground terminals
- an electric field in the air that is produced as a result of the difference in potential between the antenna element and the earth or created as a by-product of the earth electric field

The frequency produced by the operational ELF Communications System is modulated between 72 and 80 Hz using minimum shift keying (MSK), a special form of frequency shift keying. An important aspect of MSK modulation is that minimal energy is generated outside the signal bandwidth. The transmitted message is binary-coded: If a zero is to be transmitted, the frequency of the current is 72 Hz; for a one, the frequency is 80 Hz. The center frequency is therefore 76 Hz, and is the frequency with the greatest power spectral density (see Figure 2). The ELF Commuincations System can also transmit at frequencies between 40 and 48 Hz, but has done so only during its testing phases.

Exposure of resident biota to EM fields has gradually increased in intensity and duration throughout the development of the ELF Communications System. The NRTF-Republic antenna elements were first energized in 1986 for low-current testing. Operation was for short, sporadic periods using one antenna at a time. Current levels were increased to 10 percent of their full operational level in 1987, and to 50 percent in 1988. During the 10 percent and half-current testing, a cyclic pattern was employed by which each antenna (i.e., NS, EW) was on individually for five minutes and then off for ten. Half current testing continued through April 1989 after which full-current (150 A) testing began. During full-current testing the two antennas were operated simultaneously. By October 1989 testing was completed and 150 A operations continued on a full-time basis. The NRTF-Republic operating parameters and EM field

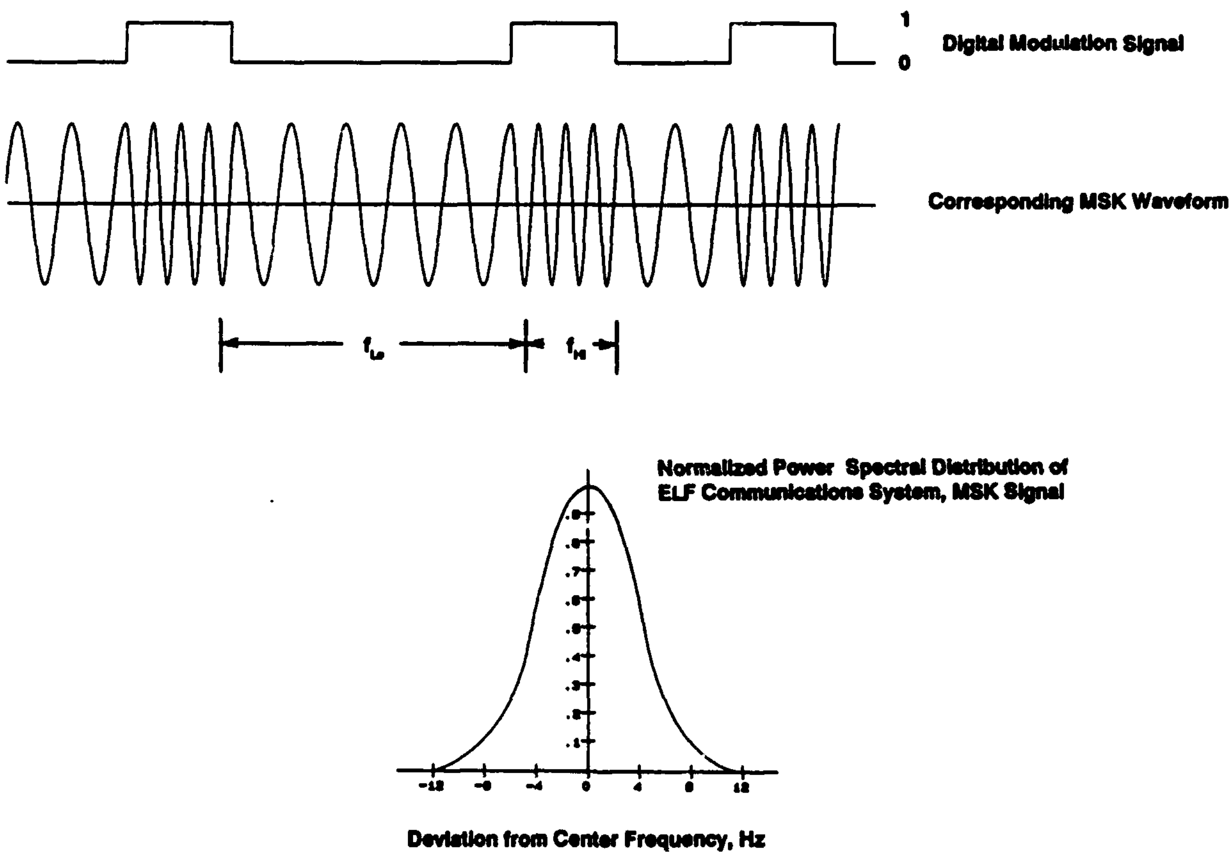


FIGURE 2. MSK WAVEFORM AND POWER SPECTRAL DISTRIBUTION.

measurements taken under each operating condition are presented in detail throughout this report. Graphs depicting normalized EM exposures based on the NRTF-Republic operations development are presented in Section 4.5 of this report. The NRTF-Clam Lake was first energized in 1969 and became fully operational during the last quarter of 1985. Additional details on the operating parameters and EM field measurements taken near this facility are presented in other reports.[1-7]

1.3 Paired-Site Concept

In order to examine for possible effects, the monitoring program uses a split-plot design that compares data collected at a control site with data collected at a treatment site. The paired sites have matched environmental factors, but have purposely dissimilar 76 Hz EM exposures. The control site is used to measure the effects of environmental factors on study variables. Variables at the treatment site reflect the effects of environmental factors as well as possible effects from exposure to higher intensity 76 Hz EM fields.

Maximal 76 Hz EM exposures were easily attained by locating treatment sites near or often within the ELF antenna ROWs. Control sites, on the other hand, had to be distant enough from the ELF Communications System to be considered nonexposed, yet close enough to have environmental factors similar to that of their paired treatment sites. In addition, possible confounding by exposure to 60 Hz EM fields needed to be minimized. In recognition of the fact that exact EM exposures cannot be dictated in an *in situ* field study of this type, the following criteria were established to address EM concerns in the site selection processes:

$$T_{(76\,Hz)}/C_{(76\,Hz)} > 10 \qquad (1)$$

$$T_{(76\,Hz)}/T_{(60\,Hz)} > 10 \qquad (2)$$

$$T_{(76\,Hz)}/C_{(60\,Hz)} > 10 \qquad (3)$$

$$0.1 < T_{(60\,Hz)}/C_{(60\,Hz)} < 10 \qquad (4)$$

where $T_{(76\,Hz)}$ = treatment site exposure due to ELF Communications System
$T_{(60\,Hz)}$ = treatment site exposure due to power lines
$C_{(76\,Hz)}$ = control site exposure due to ELF Communications System
$C_{(60\,Hz)}$ = control site exposure due to power lines

By means of these criteria, the monitoring program sought to ensure that the intensities of the 76 Hz EM fields at treatment sites were significantly greater than those at control sites (Equation 1); that the 76 Hz EM field intensities at treatment sites were significantly greater than the 60 Hz EM field intensities at both treatment sites (Equation 2) and control sites (Equation 3); and that there was minimal difference in 60 Hz EM fields between treatment and control sites (Equation 4).

Although biological and ecological data are generally analyzed as site averages, the ratio approach compares extremes of site-pair EM values (high to low) to generate a worst-case scenario. This approach has been used to examine measured intensity data as a coarse estimate of the relative exposure status of each study site pair during and at the end of data collection. At various times throughout the program, all four intensity ratios for each EM field were estimated for the paired sites. Initial calculations of the intensity ratios were based on measured 60 Hz exposures and projected values of 76 Hz exposures, because sites were selected prior to construction of the NRTF-Republic antennas. All intensity ratios were recalculated as antenna currents increased during the testing phases, to verify the original 76 Hz projections. Selected ratios for full power were verified in 1989, the first year of such operation; and in 1993, the last year of the monitoring program field work, all ratios were again recalculated. The 1993 exposure ratios appear in the corresponding appendix of this report for each study.

The primary criteria governing the relationship between the 76 Hz EM field intensities at treatment and control sites (Equation 1) have been met for each field type for all studies except for the earth electric field at the aquatic study sites. This has been the situation since initiation of aquatic studies in 1983. In these cases, site-pair ratios came close, but failed to meet estimated exposure criteria for longitudinal electric fields in water. Due to habitat limitations within the Ford River, the sites could not be relocated without adversely affecting matched environmental factors. For these reasons the sites were used as initially selected throughout the term of the program. Initial sites were, however, supplemented in 1990 when additional sites were located close to the overhead antenna. The new sites improved ratios, but ecological results have been mixed, apparently due to habitat differences. Further discussion and presentation of EM field ratios for this study appear in Section 2.

About 10 percent of the study site pairs did not meet the condition of Equation 4 concerning matched 60 Hz exposures between treatment and control sites. Although not meeting the criteria, the absolute value of 60 Hz EM field intensities have remained quite low over the period of the studies at all sites and, based on the literature, would not be expected to produce EM effects. As such, these pairs meet the underlying basis for establishing exposure criteria for 60 Hz fields. In all cases, site-averaged intensities met selection criteria, and all site pairs satisfied Equations 2 and 3.

At the NRTF-Republic, temporal comparisons between the preoperational and operational phases of the ELF Communications System are possible, in addition to the spatial comparisons of treatment and control sites. Study investigators have collected their preoperational data and are now in the operational phase of their studies. Only spatial comparisons were made at the NRTF-Clam Lake, because the transmitter has been operating since 1969 and no preoperational data base existed.

1.4 Annual Measurements of EM Fields

IITRI performs an annual survey to measure the EM fields at each study site. Annual measurements of 60 and 76 Hz EM fields are required in order to document changes in EM exposure at study sites from year to year. Ambient 60 Hz EM fields have changed due to the construction of new power lines, variations in the local use of electric power, and the presence of the ELF antennas themselves, which have been shown to couple and reradiate 60 Hz EM fields. The 76 Hz EM field intensities produced by the ELF Communications System have changed because of reconfiguration of antenna elements and because of operation at different antenna currents. In 1989 and thereafter, 76 Hz EM exposures were also influenced by the simultaneous operation of both antennas, a system configuration not present in prior years.

Other EM aspects that have been examined during the annual surveys include:

- 60 Hz and 76 Hz harmonics
- EM field levels produced at Michigan study sites due to the operation of the NRTF-Clam Lake
- EM field values as a function of the phase angle between antennas
- Geomagnetic field intensities

The first two aspects were examined and found to be either below detection levels or so low that they are not considered to be a confounder in treatment-versus-control comparisons. The third aspect--the effect of the antenna phase angle on EM exposures--was examined in Wisconsin only. This aspect is of concern for sites close to multiple antenna elements, and usually affects only the earth electric field. Phase measurements at the NRTF-Clam Lake are treated in previous annual reports.[3-7] Results showed that the effect of antenna phase angle on the earth electric fields was typically less than 5 percent. In Michigan, the effect of the antenna phase angle on EM exposure is of concern at only one site (site 10T3, bird species and communities studies). Phase angle effects could not be measured here because of schedule constraints and the full-time NRTF-Republic operating schedule, but they are expected to be similar to those in Wisconsin.

Geomagnetic field intensities were measured in Michigan initially during 1992 and again in 1993. Geomagnetic fields were not measured in Wisconsin because the Wisconsin studies were already completed at that time and they indicated no bioelectromagnetic effects. Measurements of geomagnetic fields near the NRTF-Clam Lake, can be measured after the fact should the need arise.

1.5 1993 Engineering Support

IITRI has provided a variety of engineering support in response to specific needs of individual researchers. These support activities are summarized here; details appear in Section 4.

As part of the annual EM field survey in 1993, measurement of geomagnetic field intensity and inclination was included for a second year. Geomagnetic fields were measured at all historic measurement points and at several new points along bird displacement transects. A commercially available fluxgate magnetometer was used for these measurements.

In 1991, the principal investigator for the soil arthropods and earthworms study proposed the use of buried containers to isolate earthworms for controlled reproduction studies. IITRI assisted in the design of the container--a fiber glass bag (incubation bag), which allows current flow across the interface while prohibiting the movement of worms into or out of the bag. EM field intensities within the incubation bags have been characterized annually since 1991. Electric fields were continuously monitored using data logger systems designed and fabricated by IITRI. These loggers monitored the 76 Hz earth electric field intensity in the upper soil layer both within and next to the incubation bags, as well as in three soil horizons (layers) outside the bags. Soil temperature, air temperature, and rainfall were also recorded.

Researchers for the upland flora and soil microflora studies requested a more detailed characterization of the EM field variation across their treatment sites in order to test for a correlation between EM field exposures and tree growth rates. Measurement points were added at the antenna and ground study sites in 1989 to define EM field profiles, which could then be used to estimate EM field intensities across the study sites. In 1990, still more detailed characterization of these sites was performed by setting up a grid of electric field measurements that was used to rigorously define electric field contours at the sites. In addition, fixed earth electric field probes were installed in 1990 in order to determine temporal variations of this field at these sites. Measurements have been made about twice each month at the fixed probes since then.

In 1991, temporal variability of the earth electric field at the upland flora study sites was more accurately quantified with data logger monitoring systems. Data loggers were installed in the antenna and ground site pine plantations and in the antenna site hardwood stand. Each logger was configured to monitor the earth electric field at several fixed probes along transects that are perpendicular to the antenna or ground wire, and the air and soil temperature at a single location. This monitoring continued throughout 1992 and 1993.

A data logger monitoring system was also installed in 1991 at the aquatic ecosystems treatment study site for continual monitoring of earth electric fields. Since then, earth electric fields at several points in the riverbed, as well as the air and riverbed temperatures, have been monitored by this logger.

In total, six data logger monitoring systems were used in 1993 to monitor earth electric fields and weather parameters. Three other systems at the soil amoeba study sites were used to monitor weather parameters only. The data logger measurements have provided information on earth electric field temporal variability. Seasonal and diurnal variations have been examined, as well as special cases of field variability in study chambers, in the riverbed, and in multiple soil horizons. Statistical analyses of the upland flora logger measurements were made, and measurement averages were used to construct plots of electric field profiles.

In the past, the NRTF-Clam Lake and the NRTF-Republic have operated at numerous frequency, modulation, and power conditions in order to accommodate naval fleet operations, the testing of new hardware, and the testing of utility interference mitigation. IITRI has established and maintains a computer data base of these past preoperational data as well as data on the fully operational periods. Both operational summaries and annually measured EM field values at the study sites are provided to investigators, to enable them to construct EM exposure regimes.

2. ECOLOGICAL MONITORING STUDY SITES

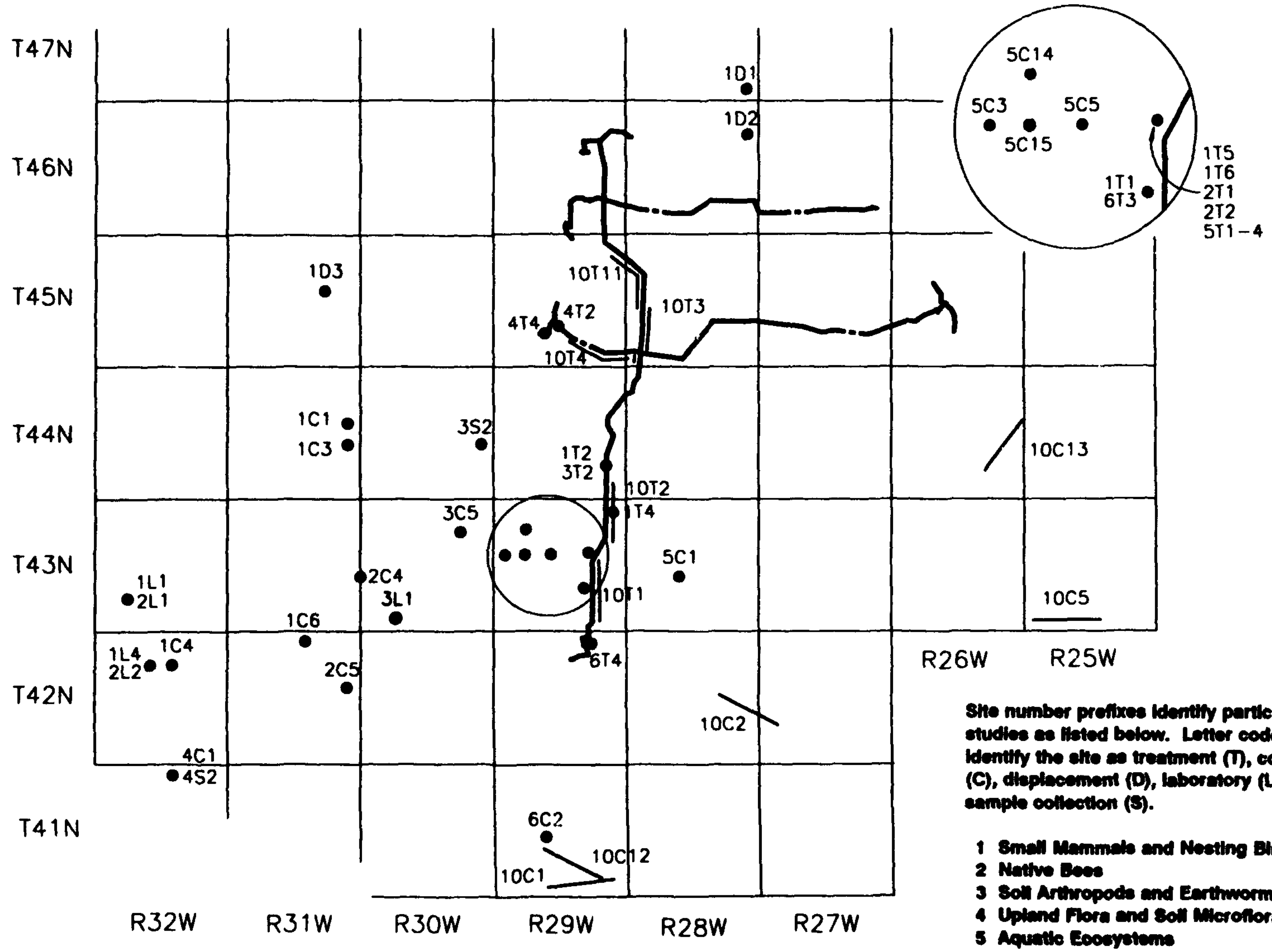
The selection of treatment and control sites began in 1983 based on the criteria described in Section 1.3. The sites selected for the Michigan studies are shown in Figure 3. The seven studies are identified in the lower right-hand corner of this figure. Collection sites for red maple leaves and pine needles do not appear in the figure, because they are beyond the range of the map shown.

The study sites in Michigan include those for treatment and control as well as special locations such as laboratories, a holding facility, displacement points, and remote collection sites. The small mammals and nesting birds studies and the native bees studies share a holding facility that is used to house animals in a low-EM-field environment near the study laboratories prior to laboratory testing. The small mammals and nesting birds studies also use sites from which displaced animals are released for timed returns to their capture location. The soil microflora studies and the soil arthropods and earthworms studies make use of remote locations to collect foliage and worms, which are brought back to the study sites. EM field exposures at all of these special locations are important because they could confound interpretation of data collection at the treatment and control sites. They have been included, therefore, in the annual measurement program for Michigan.

Because sites in Michigan were chosen prior to the construction of the NRTF-Republic antennas, their selection was based on measurements of 60 Hz EM fields and preoperational estimates of the 76 Hz EM fields that were prepared using engineering models of the proposed Michigan ELF antennas. The Michigan ELF system was completed in 1986, and 76 Hz measurements were then possible for the first time. Measurements made in 1986 verified the acceptability of the Michigan treatment and control sites: all sites were confirmed to be either acceptable or conditionally acceptable (Appendix H).

The 76 Hz earth electric field intensity ratio R1 (shown in Equation 1) has been low since the start of the site selection process for several aquatic ecosystems site pairs. Nonetheless, the sites were labeled conditionally acceptable because of limitations in the length of the Ford River over which matched habitats could be found and some uncertainty about the 76 Hz field intensities under a fully operational ELF system. In 1989, EM exposure ratios were recalculated using field intensity measurement data from the fully operational ELF system. The 76 Hz earth electric field ratio was less than the recommended order of magnitude difference. IITRI made suggestions for site relocations that would improve the intersite exposure ratios. In early 1990, study researchers and IITRI personnel visited the aquatic ecosystems study sites to discuss the site relocations, measure the EM fields at the new locations, and quantify the new EM exposure ratios.

Site changes for the aquatics study and their effects on exposure ratios are detailed in a previous report.[11] Figure 4 gives an overview of all current aquatic ecosystem study sites and activities. Although new study locations were established to improve treatment/control exposure ratios, study activities were



Site number prefixes identify particular studies as listed below. Letter codes identify the site as treatment (T), control (C), displacement (D), laboratory (L), or sample collection (S).

1 Small Mammals and Nesting Birds
2 Native Bees
3 Soil Arthropods and Earthworms
4 Upland Flora and Soil Microflora
5 Aquatic Ecosystems
6 Soil Amoeba
10 Bird Species and Communities

FIGURE 3. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

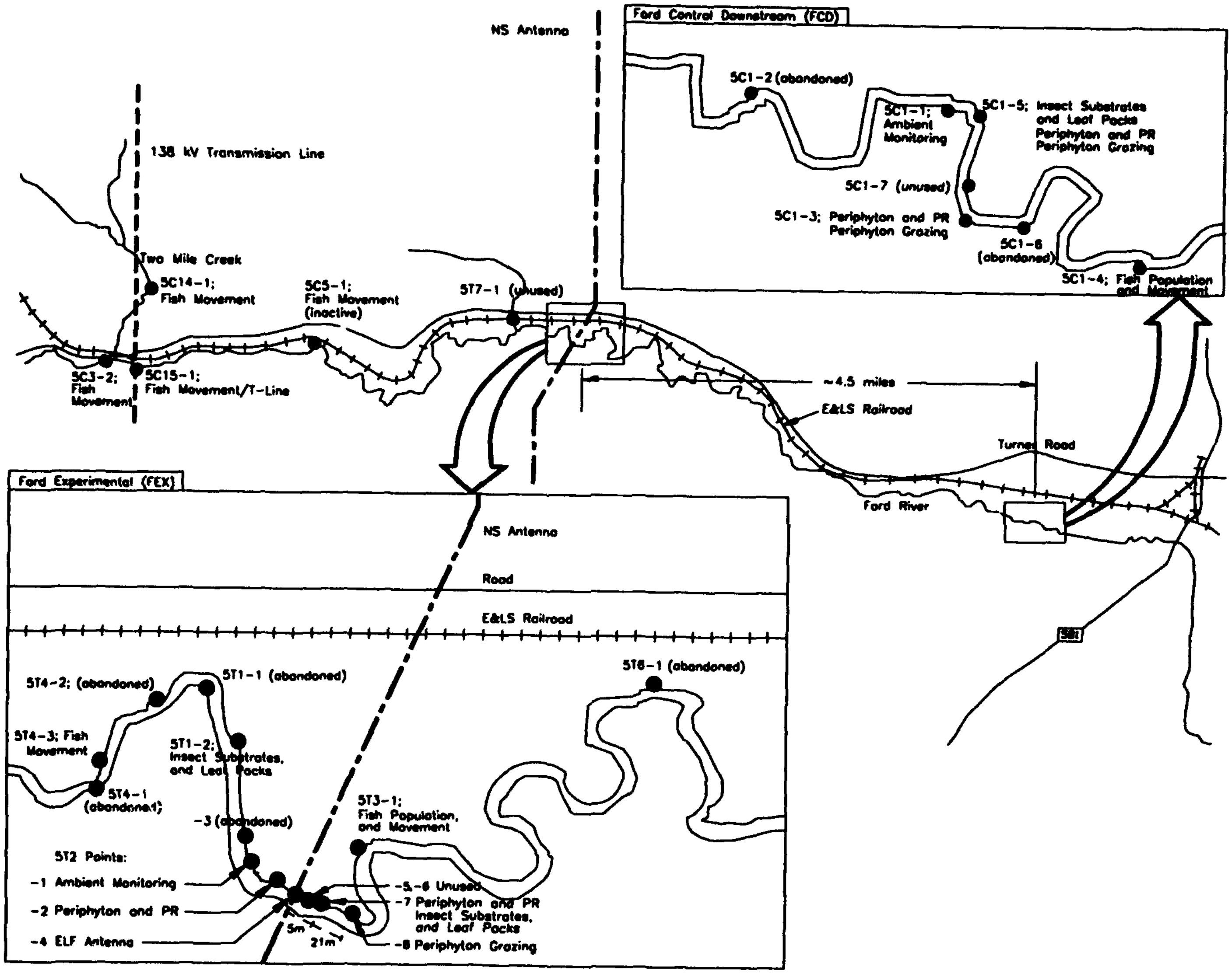


FIGURE 4. AQUATIC ECOSYSTEMS STUDY SITE LOCATIONS.

also continued at original locations to maintain continuity with historical data. EM field ratios were recalculated for the earth electric field and magnetic field using 1993 measurement data; these ratios are presented in Table 1, together with corresponding values from 1990 through 1993. Similar ratio data are not presented for the air electric field because it is shielded at the water surface and therefore not expected to affect this study's water-dwelling species. Original and new site pairings are included in this table for easy comparison of EM ratios before and after the establishment of the new study locations. The locations added in 1990 are designated with an asterisk. *In all cases, the R1 ratio for new site pairings remained* improved over the original pairings.

TABLE 1. R1 EM FIELD INTENSITY RATIOS ($T_{(76\ Hz)}/C_{(76\ Hz)}$)
Aquatic Ecosystems Studies

Compared Sites (Treatment/Control)	Activity	E_E 1990	E_E 1991	E_E 1992	E_E 1993	B 1990	B 1991	B 1992	B 1993
5T1-2/5C1-5	Insect Substrates and Leaf Packs	2.6	2.6	2.7	3.0	66	49	62	58
5T2-7*/5C1-5	Insect Substrates and Leaf Packs	6.9	6.2	7.7	7.6	600	440	570	530
5T2-2/5C1-5	Periphyton and P/R	5.0	4.8	6.4	6.5	300	300	300	320
5T2-7*/5C1-5	Periphyton and P/R	6.9	6.2	7.7	7.6	600	440	570	530
5T2-2/5C1-3*	Periphyton and P/R	7.6	7.9	9.3	8.2	300	310	290	310
5T2-7*/5C1-3*	Periphyton and P/R	10.6	10.1	11.1	9.6	600	460	550	520
5T2-8/5C1-5	Periphyton Grazing	7.7	6.7	10.1	8.8	340	310	330	310
5T2-8/5C1-3*	Periphyton Grazing	11.9	11.0	14.6	11.1	340	330	320	310

E_E = earth electric field.
B = magnetic field.
P/R = photosynthesis/respiration.

*Locations added in 1990 to improve the R1 ratio for E_E.

3. EM FIELD MEASUREMENTS

3.1 Description of EM Fields of Interest

The three EM fields under investigation in this program are the magnetic field, the earth electric field, and the air electric field.

Magnetic fields of primary interest are those generated by current passing through a conductor, as occurs with the ELF antennas and power lines. These fields alternate polarity with a frequency equal to that of their source current. Also of interest is the earth's static (non-alternating) magnetic field, which has been reported both to be used by animals for navigation and to have possible effects through interaction with other magnetic field sources. Magnetic fields are generally unaffected by environmental factors such as weather, vegetation, soil, and nonferrous structures. They behave predictably and are generally unchanged at such boundaries as air/earth or air/water. Thus, measurement techniques need not consider shielding, enhancements, or perturbations of the magnetic field by these factors. This local uniformity of the magnetic field allows precise measurements over time, provided that the field sources--particularly the ELF antenna and power line currents--remain constant. Marked variations in the earth's magnetic field occur only over geological periods.

The electric field in the earth is measured as a difference in longitudinal potential in the upper 20 cm of the earth. The two sources of 76 Hz earth electric field associated with the ELF Communications System are (1) that induced by the magnetic field and (2) that generated by the ground terminal currents. The 60 Hz earth electric field is induced by power line magnetic fields and is also generated by unbalanced 60 Hz earth return currents associated with power distribution systems. The uniformity of earth electric fields is affected by the conductivity of soil and by conductivity anomalies such as large rocks, tree roots, and pools of water. The intensity of earth electric fields is fairly uniform, and measurements are repeatable when anomalies are avoided. Some year-to-year variations in this field may occur because of temporal changes in soil moisture content, which affect soil conductivity.

The 76 Hz electric field in the air is generated as a result of the voltage differences between the ELF antenna wire and the ground, and also as a by-product of the magnetically induced earth electric field. Power lines also generate a transverse or vertical air electric field in a manner similar to that of the overhead antenna wire. The vertical fields are limited to the ROW and other nearby cleared areas. In forested areas and locations more distant to the ROW, a predominantly horizontal air electric field is set up as a by-product of the earth electric field and is consequently of similar magnitude to the earth electric field. Both the horizontal and vertical air electric fields are perturbed by vegetation, people, and instrumentation. The perturbations of the field may take the form of an enhancing of the ambient field near objects or as a shielding effect on the surroundings. This results in a high variability of the air electric field over a small area. Efforts were made to measure the air electric field in open areas in order to determine the magnitude of the unperturbed field.

Annual or historic EM field measurements consist of a survey of 60 Hz and 76 Hz air electric fields, earth electric fields, and magnetic flux densities at defined locations within study sites, laboratories, and other special-use areas. Annual EM field measurement equipment, protocols, and summaries are described in Sections 3.2, 3.3, and 3.4. Section 3.5 describes supplemental EM field measurement equipment, including a dc magnetic field meter, a magnetic field monitoring system, and an earth electric field monitoring system.

3.2 Annual EM Field Measurement Equipment

3.2.1 Field Probes and Meters

The magnetic flux density, air electric field intensity, and earth electric field intensity are measured using directional field probes designed, fabricated, and calibrated by IITRI. Each of these probes, when placed in the existing electric or magnetic field, outputs an ac voltage proportional to the field intensity. The meter used to measure the output voltages of the probes is a Hewlett-Packard 3581A signal wave analyzer. The HP 3581A functions as a frequency-selective, rms-calibrated voltmeter with factory modifications for battery and 1 Hz bandwidth operation. A 3 Hz bandwidth is used to measure 60 Hz and unmodulated ELF signals, but a wider bandwidth is needed to measure modulated ELF signals. Because the wider bandwidth includes 60 Hz signals produced by power lines, an IITRI-fabricated active notch filter is placed in series with the wave analyzer when the 60 Hz and ELF signals are of similar magnitudes, in order to remove the 60 Hz signals and their harmonics. The output voltage of a probe is multiplied by the probe's calibration factor at the frequency of interest to obtain the magnitude of the applied field.

The earth electric field probe consists of three 20-cm-long electrodes mounted on a fiber glass frame so as to form two orthogonal 1-m spaced electrode pairs (Figure 5). The electrodes are pushed into the earth, and a switch connects a voltmeter across one pair of electrodes at a time. The voltage measured across each pair of electrodes is thus equal to the earth electric field in volts per meter (V/m) in the given direction. Note that a compass and a cradle are mounted atop a 1-m vertical stalk that is hinged at the juncture of the probe legs. The compass aids in alignment of the probe legs prior to raising the stalk. The cradle is designed to hold the magnetic field probe at a 1-m height in three orthogonal positions oriented precisely with the legs of the probe.

The magnetic field probe basically consists of wire wound on a ferrite core and shunted by appropriately chosen resistors to obtain a flat frequency response. The probe generates an output voltage that is proportional to the magnetic flux density parallel to the axis of the core. This voltage is converted to the magnetic flux density by means of a calibration factor determined prior to each field outing. This probe is shown in Figure 6 mounted in the cradle atop the earth electric field probe.

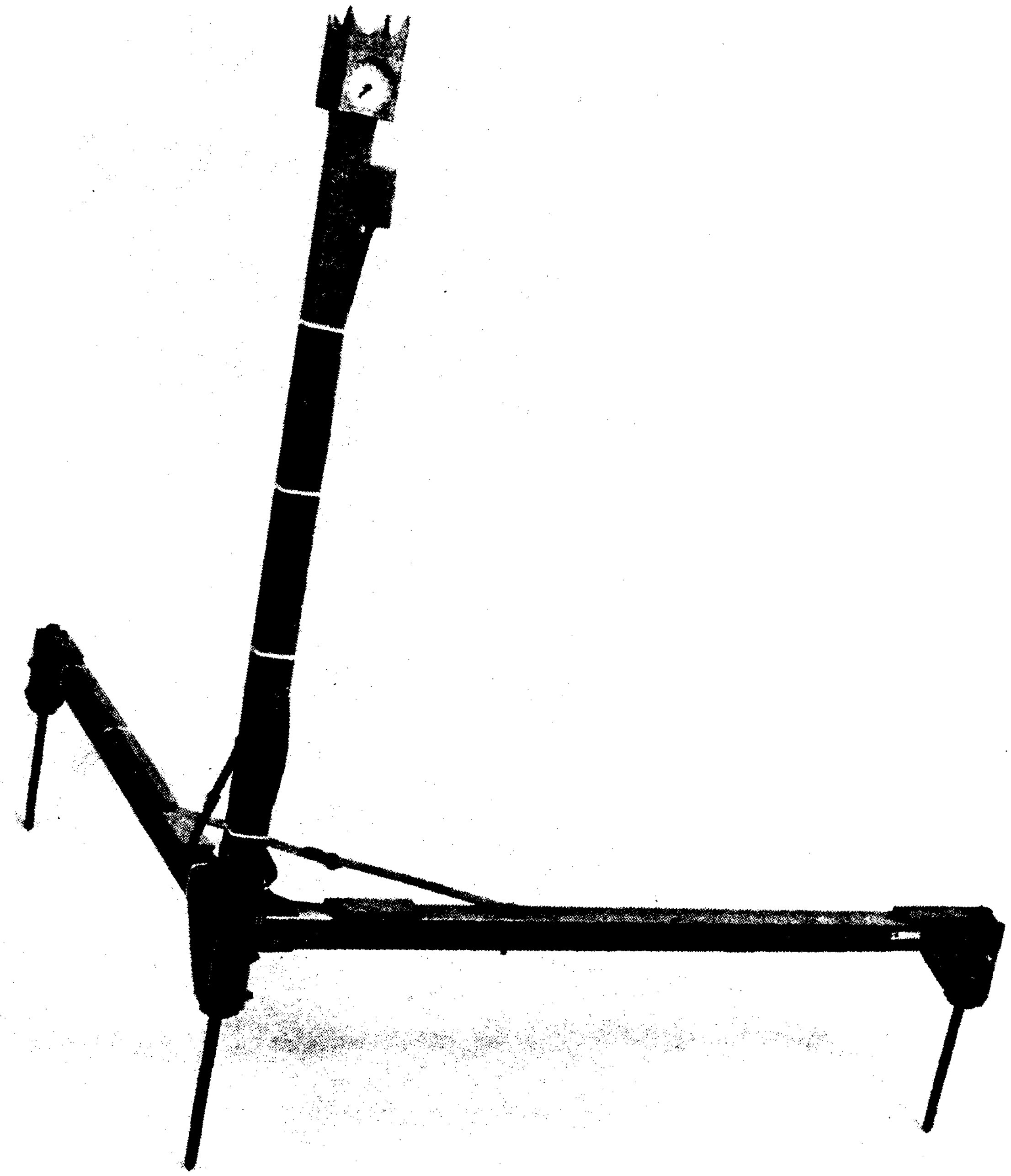


FIGURE 5. EARTH ELECTRIC FIELD PROBE.

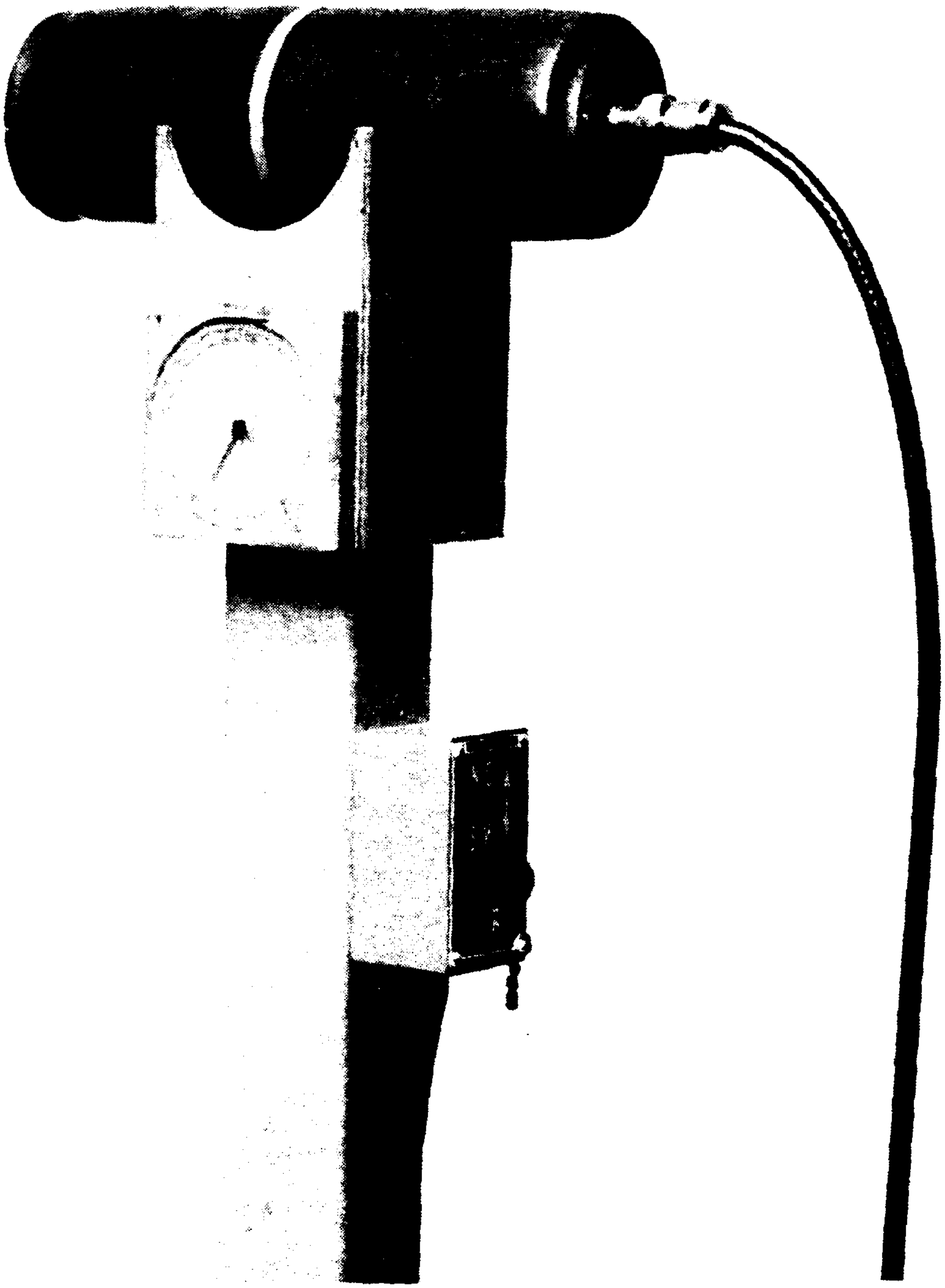


FIGURE 6. MAGNETIC FIELD PROBE.

The air electric field probe consists of a spherical sensor/transmitter, an analog fiber-optic data link, and a receiver (Figure 7). The probe produces an output voltage proportional to the air electric field along the primary axis of the spherical sensor/transmitter. This voltage is converted to the electric field intensity by means of a calibration factor determined prior to each field outing. The calibration factor and probe operation are checked periodically using a portable electric field probe calibrator. For protection and insulation, a styrofoam-and-plastic shell is placed over the probe during measurements in very cold weather.

3.2.2 Field Probe Calibrations

IITRI has developed a computer-driven system for calibrating electric and magnetic field probes over their usable frequency range (see Figure 8). At the heart of the system are:

- a Hewlett-Packard 86B computer equipped with an IEEE 488 instrument interface bus
- a Hewlett-Packard 3421A data acquisition unit
- a Valhalla 2703 precision ac calibrator

The calibration system generates a uniform electric field between a pair of 1-m-square, 1/3-m-spaced parallel plates with guard rings. A uniform magnetic field is generated over a large volume by a set of 1-m-radius Helmholtz coils.

The calibration system produces both a table of each probe's calibration factor at various frequencies and a plot of the probe's transfer function versus frequency. The magnetic field probe and air electric field probe are calibrated before and after each use, and a record is kept of all calibrations.

The magnetic field probe calibration fluctuates by no more than ±1 percent over a one-year period. This probe is constructed entirely of passive components, making routine calibration checks during field measurements unnecessary. The earth electric field probe, which consists solely of 1-m spaced electrodes, requires no calibration, and its mechanical stability is excellent. The air electric field probe calibration fluctuates by no more than ±5 percent over a one-year period. There is little difference in the calibration of this probe with or without its insulating styrofoam-and plastic shell. Portable electric field calibration plates are used during field measurements to periodically verify the probe operation.

3.3 Annual EM Field Measurement Techniques and Protocols

3.3.1 Determining EM Field Magnitudes

The magnitude of an EM field vector is determined by measuring its orthogonal components. This requires measurements with the field probe oriented along three orthogonal axes. For simplicity and repeatability, the axes chosen are aligned in the NS, the EW, and the vertical directions. The earth electric field intensity has no vertical component; therefore, only the NS and EW components are measured. In

FIGURE 7. AIR ELECTRIC FIELD PROBE.

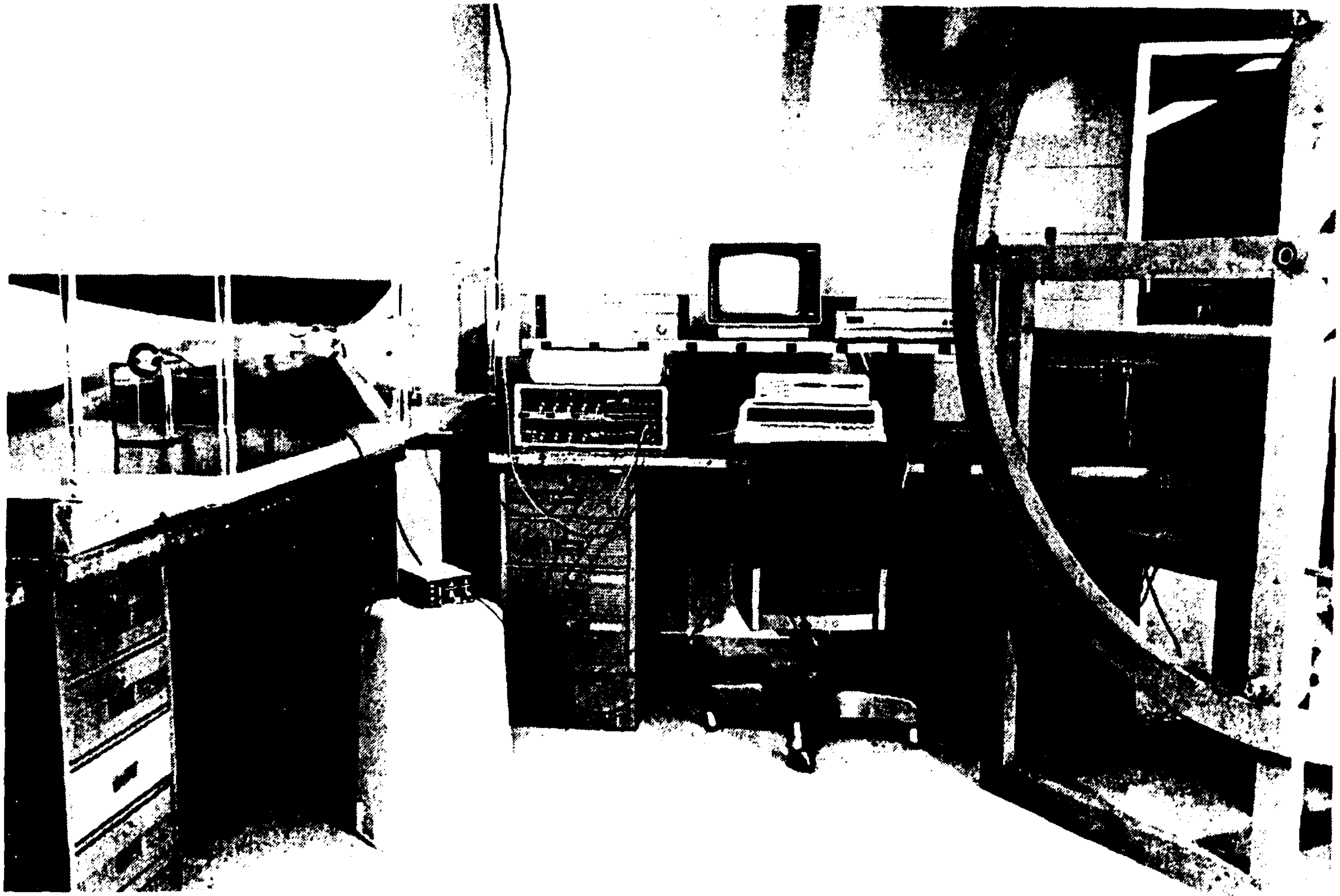


FIGURE 8. COMPUTER-DRIVEN ELECTRIC AND MAGNETIC FIELD PROBE CALIBRATION SYSTEM.

the case of the air electric field and magnetic flux density, all three orthogonal field components are measured. The orthogonal measurements are then used to compute a vector sum or maximum.

One disadvantage of the orthogonal components method is that it yields the correct field maximum only when a single field source is present or is dominant. Fortunately, this is generally the case for the ecological monitoring sites in the ELF system areas. When more than one field source is present, the computed vector sum will be conservative; that is, it will be greater than or equal to the actual maximum. Measurements were made in Wisconsin at those sites where a single antenna did not dominate, and site-specific correction factors (typically less than 5 percent) were determined for calculating actual field magnitudes from the vector sum magnitudes. Similar measurements have not been possible in Michigan; however, only one Michigan migrating bird population transect site falls in this category. Furthermore, correction factors are generally only necessary for the earth electric field, which is considered of secondary importance for this study.

3.3.2 Measurement Conditions--Michigan

Construction of the NRTF-Republic began in 1984, and was completed in early 1986. Intermittent operation began in early 1986 at power levels of 4 to 10 A of antenna current. Only one antenna or antenna element was operated at any one time during 1986: the NS antenna, the NEW element, or the SEW element. From 1987 onward, the NEW and SEW antenna elements were connected in parallel and operated as one antenna, hereafter referred to as the EW antenna. The NRTF-Republic operated intermittently with a 15 A antenna current in 1987, and intermittently with 75 A antenna currents during 1988 and early 1989. During 15 and 75 A operation, only one antenna was operated at any one time. From May 1989 onward, the NRTF-Republic operated both antennas (NS and EW) simultaneously, at a full-power current level of 150 A. Both modulated and unmodulated signals were used.

Table 2 summarizes the predominant operating conditions under which measurements have been made in Michigan. In all cases, the orthogonal components of the magnetic flux density and of the air and earth electric fields were measured, and a vector sum magnitude was computed for each EM field. Unless otherwise stated, this vector sum magnitude is the value reported in all measurement documentation.

In addition to the transmitter operating conditions listed in Table 2, the predominant status of the unpowered ("off") antenna(s) is also given for each year. The status of the unpowered antennas was observed to have an impact on 60 Hz fields because of the antennas' role in coupling and reradiating 60 Hz fields at the treatment sites (Section 3.4.2). In general, the 60 Hz fields were larger when measurements were made with the antennas connected at the transmitter (CON) than when they were grounded at the transmitter (GND).

The following subsections describe the 1983-1993 measurement protocols used in Michigan.

TABLE 2. ELF TRANSMITTER CONDITIONS DURING EM FIELD MEASUREMENTS IN MICHIGAN

Year	Antenna Element(s)	Antenna Current, A	Center Frequency, Hz	MSK Modulation	"Off" Antenna Status at Transmitter
1986	NEW	6	76	No	GND
	SEW	6			
	NS	4			
1987	NS	15	76	No	CON
	EW	15			
1988	NS	75	76	No	CON
	EW	75			
1989	B	150	76	PT	NA
1990	B	150	76	Yes	NA
1991	B	150	76	Yes	GND
	NS	150			
1992	B	150	76	Yes	NA
1993	B	150	76	Yes	NA

B = both antennas simultaneously.
NS = north-south antenna only.
EW = east-west antenna only.
NEW = northern EW element only.
SEW = southern EW element only.
PT = part-time.
NA = not applicable.
GND = grounded at transmitter.
CON = connected to transmitter.

3.3.2.1 Pre-1986 Conditions. Prior to 1986, construction of the ELF antennas was not completed and, therefore, only 60 Hz EM field intensities could be measured at the study sites. All 60 Hz measurements were performed using a meter bandwidth setting of 3 Hz.

3.3.2.2 1986 Conditions. In 1986, the EM measurement protocol for Michigan was as follows:

- Ambient 60 Hz EM fields were measured with the NS antenna and both EW antenna elements off.
- 76 Hz EM fields from the NS antenna were measured with both EW antenna elements off.
- 76 Hz EM fields from the NEW antenna element were measured with the NS antenna and the SEW antenna element off.
- 76 Hz EM fields from the SEW antenna element were measured with the NS antenna and the NEW antenna element off.

All measurements were made using a meter bandwidth setting of 3 Hz to discriminate the frequency of interest.

3.3.2.3 1987, 1988 Conditions. In 1987 and 1988, the EM measurement protocol for Michigan changed from the 1986 protocol to account for the new EW antenna configuration. That revised protocol was as follows:

- Ambient 60 Hz EM fields were measured with both antennas off.
- 76 Hz EM fields from the NS antenna were measured with the EW antenna off.
- 76 Hz EM fields from the EW antenna were measured with the NS antenna off.

All measurements were made using a meter bandwidth setting of 3 Hz to discriminate the frequency of interest.

3.3.2.4 1989-1993 Conditions. In 1989, the EM measurement protocol for Michigan changed again, because simultaneous operation of the NS and EW antennas began. Modulated signal operation also necessitated protocol modifications. The 1989-1993 protocol was as follows:

- Ambient 60 Hz EM fields at control sites were typically measured while the transmitter was on.
- Ambient 60 Hz fields at treatment sites were typically measured while the transmitter was off (MSK modulation prohibited 60 Hz field measurements at the treatment sites while the transmitter was on).
- 76 Hz EM fields were measured at both treatment and control sites while the transmitter was on (typically both antennas were operated simultaneously).

Unmodulated ELF and 60 Hz EM field measurements were taken using a meter bandwidth setting of either 1 Hz or 3 Hz to discriminate the frequency of interest. Modulated ELF signals were measured using a meter bandwidth setting of 30 Hz. A 60 Hz notch filter was employed at some control sites to allow measurement of modulated ELF signals.

3.3.3 Selection of Measurement Points

Measurement points at study sites were selected to define the spatial variation of the 76 Hz EM fields over each site. This was done on the basis of the size and shape of a site and its location relative to the antenna elements, as described below.

Control sites, all of which are several miles from the nearest antenna element, are expected to have minimal 76 Hz EM field gradients. At small control sites, a single measurement point was deemed sufficient to characterize the EM fields. At intermediate-size control sites, measurements were made at the points nearest to and farthest from the antenna grid. At large control sites, measurements were made at several additional points in order to accurately define the EM field gradients across them.

EM field gradients across treatment sites are larger than gradients at control sites. Multiple measurements were generally necessary at all treatment sites. The selection of measurement points for the treatment sites was based on one of four strategies dictated by the nature of the site. For sites comprising long, narrow transects parallel to the antenna (namely, the bird species and communities studies), measurements typically were taken at the ends of the transect and at intermediate points along the transect. For sites of very restricted area (e.g., the aquatic ecosystems studies), only one measurement was made at each experiment location. Two other measurement strategies were applied at treatment sites covering a large area. For those sites arranged with well-defined borders, measurements were made at the borders or corners of the plots such that the measurements encompassed the study area and bounded the field levels. For those sites with irregular borders, such as those for the nesting birds study, measurements were made along a transect perpendicular to the antenna, typically at 25-m intervals, to provide a profile of the field gradients.

These measurement point selection techniques allow the investigators to estimate the EM field intensity at any point of interest within a study plot. Such estimates can be made based on the fact that the EM fields decrease with distance from the antenna but show little change along a path parallel to it. Therefore, given the distance of a point of interest from the antenna, the EM fields can be estimated by linear interpolation between measured values. Because the EM fields vary little along a path parallel to the antenna, the point of interest and measured points do not need to be at the same lateral position along the length of the antenna. The accuracy of field estimations for any point can be improved by plotting the EM field gradients as a function of distance from the antenna and using graphical rather than linear interpolation between measured points. This technique can be applied to the field profiles for the nesting birds study sites and the upland flora and soil microflora study sites, which appear in Appendixes A and D, respectively.

3.4 Summary of 1993 Annual Measurement Data

In 1993, annual measurements in Michigan were conducted on 28 and 29 April; 12-16, 19-23, and 26-29 July; and 9 and 17 September. All active sites were measured during these periods. Measurements were not made at any native bee study sites in 1993 because their field activities were concluded with laboratory examinations of nest blocks in the spring of 1993.

Table 3 presents a summary of the number of sites and measurement points examined during 1992 and 1993. As shown, a total of 157 measurement points were used to characterize 36 sites, compared with 180 points at 49 sites in 1992. The number of measurement locations per site was determined by plot size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analyses.

Several sites and associated measurement points were dropped from the 1993 annual survey since they were not used in 1993 field activities. These include the Michigamme South control site (1C3) for the small mammals and nesting birds study, all native bees study sites (as mentioned), the three foliage collection sites (451, 452, 453) for the litter decomposition study, and the five upstream control sites used for the fish movement study.

TABLE 3. SUMMARY OF EM FIELD MEASUREMENTS, 1992-1993

Study	Number of Measurement Sites 1992	Number of Measurement Sites 1993	Number of Measurement Points 1992	Number of Measurement Points 1993
Small Mammals and Nesting Birds	13	12	55	53
Native Bees	5	0	15	0
Soil Arthropods and Earthworms	3	3	12	12
Upland Flora and Soil Microflora	6	3	50	47
Aquatic Ecosystems	9	5	16	12
Soil Amoeba	3	3	9	9
Bird Species and Communities, Michigan	10	10	23	24
Total	**49**	**36**	**180**	**157**

Table does not include laboratory sites.

3.4.1 Michigan Measurement Data

The data taken during the 1993 EM measurements in Michigan appear in Appendixes A, and C through G. EM data taken through 1992 at the native bees study sites appear in Appendix B. Six tables in each appendix document 60 and 76 Hz values for air electric field, earth electric field, and magnetic flux density. Following these tables in each appendix is a table of paired-site EM field ratios, which were calculated using 1993 EM field measurements. In addition, separate tables document measurements taken at various study laboratories, at fixed probes for the upland flora and soil microflora studies, and at regular intervals along treatment transects of the bird species and communities studies. Details of these measurement activities are discussed in Section 4.

In each appendix, the tables of 60 Hz data appear first. Each table contains a separate column of data for each year from 1983 through 1993. A footnote for each column describes the operational status of the ELF antenna during the 60 Hz measurements for that year. The operational status of the ELF antenna has a significant impact on the measurement of 60 Hz EM field intensities at treatment sites, because it affects the degree of coupling to the antenna of 60 Hz EM fields generated by nearby power lines. This phenomenon is explained in Section 3.4.2.

Following the 60 Hz data tables are tables containing 76 Hz EM field intensities measured in 1986 through 1993. The 76 Hz EM field intensity data have been taken at several different antenna operating currents (4 to 150 A). Specific operating currents are given in the column headings of the data tables.

EM field intensity values at ecology sites increased in proportion to the antenna operating current from 1986 through 1989.

3.4.2 Coupling of 60 Hz Fields

Yearly fluctuations can be seen in the 60 Hz EM fields from 1983 through 1993. The primary factors in these fluctuations were:

- completion of antenna installations in 1986
- parallel connection of the two EW antenna elements in 1987
- differences in antenna-to-power amplifier connections in the antenna "off" mode
- changes in power line loads
- changes in earth conductivity

The first three factors are of importance only at treatment sites; the last two are relevant at both treatment and control sites.

The 60 Hz EM intensities at the treatment sites are strongly influenced by the presence of the ELF antenna elements. This is because EM fields generated by 60 Hz power lines couple to the conducting loop formed by the ELF antenna, its ground terminals, and the earth. This coupling results in a 60 Hz current flow on the antenna wires that reradiates 60 Hz EM fields. The 60 Hz EM fields radiated by the two sources (power lines and antenna) interact at treatment study sites and elsewhere. The general observation has been that the electric fields in the earth from power lines and the antenna partially cancel each other. The relative magnitude of the resulting EM field is dependent on the intensities of the EM fields generated by the two sources. The magnetic fields from power lines fall off more rapidly than the longitudinal electric fields, and do not appear to significantly interact with the magnetic fields generated by 60 Hz current flow on the antenna. The result is that 60 Hz magnetic fields near the antenna are greater in magnitude than those measured prior to antenna construction.

The coupling of ambient 60 Hz fields to the ELF antenna was first observed in 1986, coincident with the completion of antenna construction in Michigan. This coupling will continue as long as the ELF antenna and power lines are present. Year-to-year differences in the treatment site 60 Hz EM fields are likely caused by (1) changes in coupling to the antenna elements resulting from changes in antenna configuration and (2) changes in 60 Hz power line loads. The antenna configuration changes have been the parallel connection of the two EW antenna elements beginning in 1987 and differences in the antenna connection to the power amplifiers in the antenna "off" mode--the antenna condition under which most 60 Hz measurements are made.

Variations in the 60 Hz EM fields at control sites are not related to the location of the ELF antenna or its configuration. Variations here are most likely caused by varying power line currents and temporal changes in earth conductivity. These same factors also influence the 60 Hz EM fields at treatment sites, but not necessarily to the same extent.

3.4.3 EW Antenna Shutdown

The EW antenna was off for special repairs from 8 May through 12 July, 1991, and again from 23 December 1991 through 28 March 1992. During these periods, operation of the NS antenna alone, with a 150 A, 76 Hz MSK signal, continued. EM field intensities were reduced at all treatment study sites during this solo operation of the NS antenna. The amount of reduction, however, varied widely depending on the location of the site relative to the NS and EW antennas. For sites along the NS antenna ROW, EM fields were typically reduced by less than 5 percent after the EW antenna was taken out of service. However, at sites 3T2 and 1T2, field reductions were about 10 percent. The greater reduction at these two sites is due to their proximity to the SEW antenna element. The field intensity at any given site along the NS antenna during EW antenna shutdown may be estimated by extrapolating the 1988 data measured during 75 A solo operation of the NS antenna, to the 150 A condition.

The impact of the EW antenna shutdown was most marked at sites near the EW antenna or its ground--namely, the upland flora and soil microflora sites (4T2 and 4T4) and three transects for the bird species and community studies (10T3, 10T4, 10T11). Measurements were taken in 1991 at the upland flora and soil microflora sites both while the EW antenna was out of service and during normal simultaneous operation of both antennas. During shutdown of the EW antenna the fields were reduced to about one-third the intensity level present when both antennas were operating (Appendix D). At the bird species and community study sites all measurements were taken in 1991 and 1992 during operation of both antennas. Predictions of EM field intensity reductions during shutdown of the EW antenna for various transects are presented in Appendix G.

EM field reductions at control study sites during shutdown of the EW antenna are expected to differ greatly depending on the relative position of each study site to the NS and EW antennas. Actual reduction levels are of less concern for these sites, however, since low 76 Hz EM field intensities are desirable there. Any reduction of the fields at control sites, therefore, will only serve to improve treatment/control site exposure ratios.

3.5 Supplemental EM Field Measurement Equipment

A Walker Scientific model FGM-3D1 single-axis fluxgate magnetometer was first used in 1992 for measurement of earth magnetic fields. It is shown in Figure 9 attached to a fiber glass platform and mounted on a standard nonferrous camera tripod. The pivoting tripod head has a bubble level and position lock. These are used to adjust and lock the platform in the horizontal plane. Guide rails on the platform allow for orientation of the probe sensor along three orthogonal axes. With the sensor oriented approximately east-west in the horizontal plane, the platform is rotated until the magnetometer reads zero field. The platform is then locked in that position and the probe sensor is turned 90 degrees in the horizontal plane (magnetic north) and the field maximum in this plane is recorded. Keeping the platform

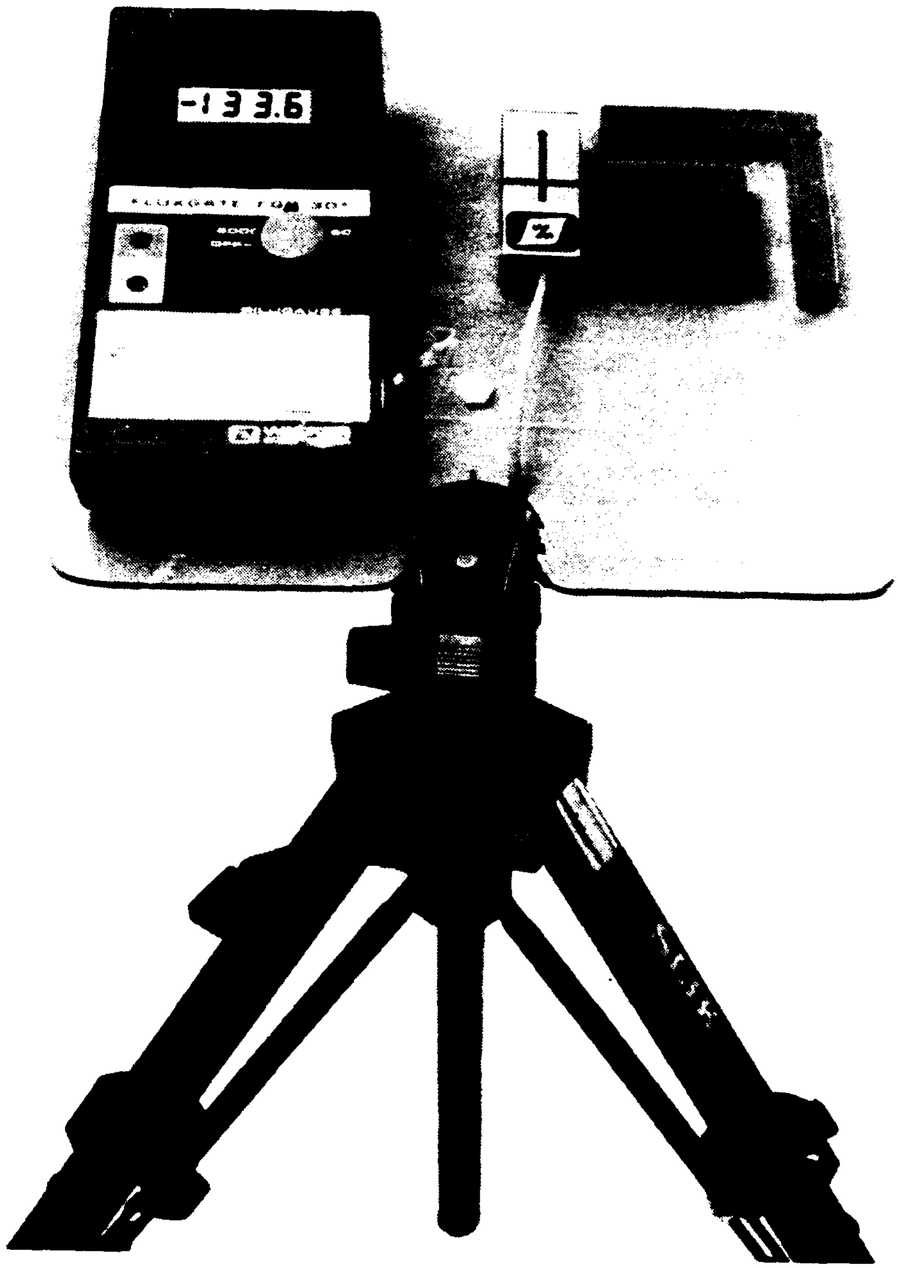


FIGURE 9. FLUXGATE MAGNETOMETER.

locked, the sensor is rotated to the vertical plane and the field intensity is again recorded. Magnetic field intensities are read directly from the digital display of the meter. The two field components are vectorally summed and reported together with the calculated angle of inclination.

The EMDEX II™ magnetic field meter, manufactured by Enertech Consultants for the Electric Power Research Institute, was used for measuring 60 Hz magnetic fields at single locations over extended periods of time. This meter, shown in Figure 10, is less sensitive than the magnetic field probe designed by IITRI,* but has the advantage of being able to monitor fields over time. The EMDEX II™, designed primarily for monitoring power frequency magnetic fields, measures in broadband (40 Hz to 800 Hz) and harmonic (100 Hz to 800 Hz) modes. The 60 Hz fundamental frequency is calculated by the EMDEX II™ from the broadband and harmonic measurements. It uses three coil sensors to measure field intensities in orthogonal directions and records both the three field components and vector sum resultants. Because of the sensitivity and frequency selectivity limitations, the EMDEX II™ is not suitable for the historic field characterization performed at treatment and control study sites. It was used in 1992, however, to monitor 60 Hz fields and harmonics at study laboratories over a 24-hour period.

In 1987-1988, IITRI developed a monitoring system based on a Tattletale™ single-board computer data logger manufactured by ONSET Computer Corporation. The data logger has multiple software-controlled digital and analog input/output channels, which give the system great flexibility in its measurement capabilities. Front-end signal-conditioning hardware such as a signal multiplexer, rms-to-dc voltage converter, and programmable amplifier were designed by IITRI to meet various monitoring needs. Variables monitored have included earth electric fields, culture chamber electric fields and current densities, rainfall, and temperatures. A data logger monitoring system is shown in Figure 11. Included in this photograph are the data logger and associated hardware mounted in a protective enclosure, a portable computer used to communicate with and download the monitoring system, and a rainfall gauge. Measurement protocols may be tailored for each monitoring system. They are written in TTBasic, a specialized version of BASIC used by the Tattletale data logger, and burned into an EPROM. On-board memory and battery capacity allow for several weeks of unattended monitoring in a typical application. A conservative approach of offloading data biweekly during the summer field season and monthly during the winter months, however, has been followed.

In addition to algorithms used to control measurement protocols, much specialized software was developed by IITRI for the presentation and analysis of data collected by the monitoring systems. Data files, written in a hexadecimal format for storage efficiency, are processed by a conversion program that produces hardcopy outputs, ASCII-formatted tables, and specially formatted files that can be operated on by plotting and statistical routines. The plotting routine provides many options, including discrete point

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* EMDEX II™ sensitivity 100 μG; IITRI magnetic field probe sensitivity 0.2 μG.

FIGURE 10. EMDEX II™ MAGNETIC FIELD METER.

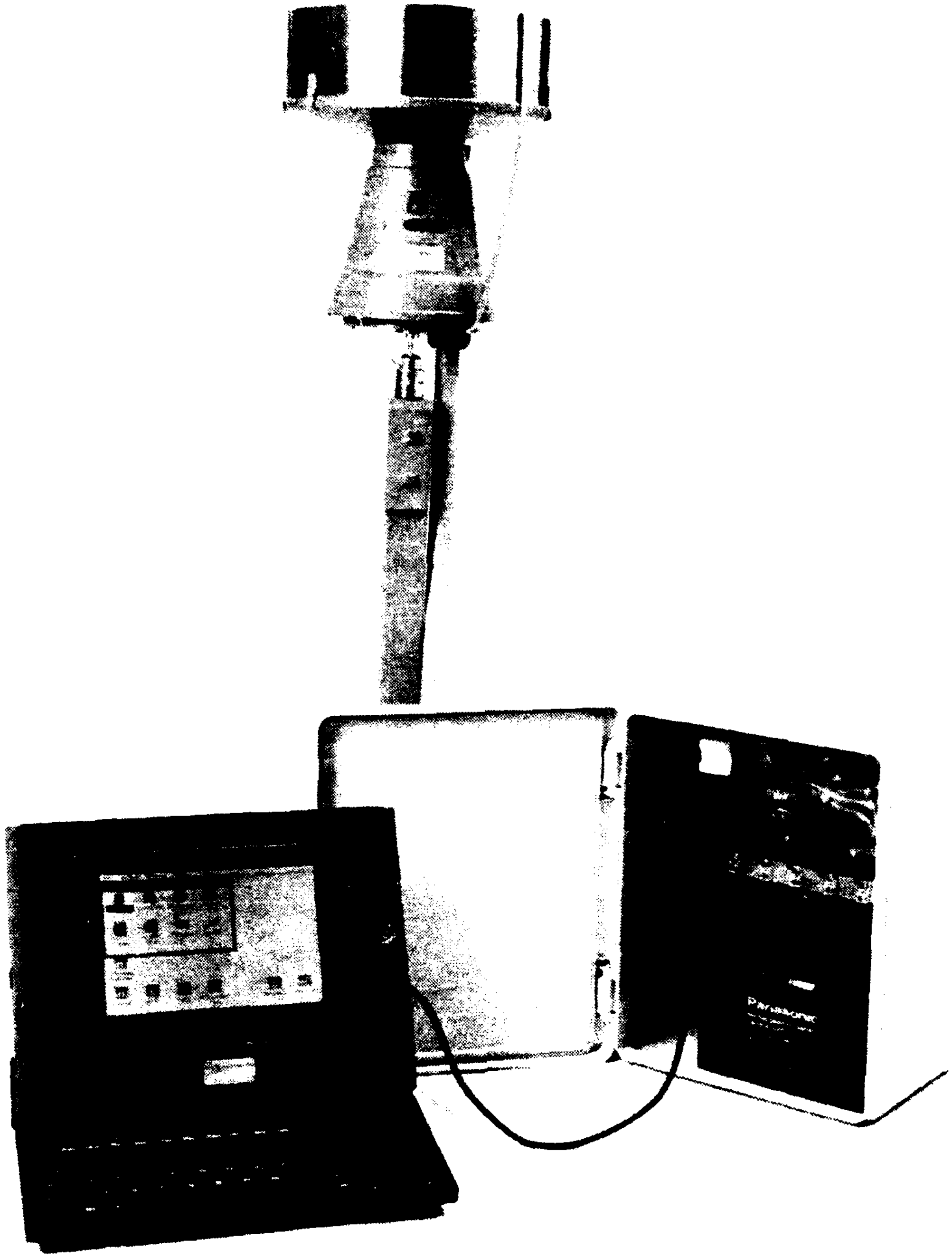


FIGURE 11. DATA LOGGER MONITORING SYSTEM.

or daily average data plots on linear or logarithmic scales, multiple color-curves, and superimposed weather data plots. The statistical routine calculates basic statistical parameters. It also incorporates data qualifiers that permit calculation of statistics based on rainfall events or a daily timespan. This feature has been used to test for diurnal variations. Both plotting and statistical routines can be run interactively or with input data files that allow for automated completion of numerous runs.

4. ENGINEERING SUPPORT ACTIVITIES

4.1 Geomagnetic Field Measurements

Although the geomagnetic field was not under direct study in the Ecological Monitoring Program, it is important because of its reported roles as a navigation cue for animal homing and as a possible synergist in the interaction of ELF EM fields with biological systems. In 1992, the geomagnetic field was characterized for the first time in the program study area at all historic measurement points. Measurements were also taken at several locations along the presumed return flight paths of birds displaced from their nests (nesting birds study). In 1993, geomagnetic fields were remeasured at most of the 1992 locations; also, three new locations along the displaced bird return flight path were added. All measurement points along these flight paths are keyed in Figure 12 to indicate the 1992 and 1993 activity. Historic measurement point locations can be found in the corresponding appendix for each study.

Geomagnetic field measurement results for 1992 and 1993 are grouped by location (township, range, section) in Table 4. The field intensity and angle of inclination are given for each measurement point. Field directions are, by definition, magnetic north. Averages of the magnetic field intensities were computed on a section (one square mile) basis and are shown for 1992 and 1993 as color-coded section boxes on the maps in Figures 13 and 14. The number of points representing each section average varies, and can be determined from discrete values in Table 4. These figures show the greatest field intensity levels to be near the Ford River antenna crossing and in a section south of the Michigamme Reservoir. Overall, variation of the geomagnetic field intensity was about 7 percent. Distribution of the field intensities, which appears to be random, is explained by variations in the distribution of magnetic ores throughout the ELF system area. IITRI-measured values agree with those available from the Department of the Interior U.S. Geological Survey. The 1992 and 1993 measurement sets also agree well with one another. Variations between the two sets are in the 0-2 percent range, which probably reflects sampling variability.

4.2 Soil Arthropods and Earthworms Studies

4.2.1 EM Field Characterization at Earthworm Sampling Locations

In 1992, in order to examine for possible correlations between localized electric field intensities and earthworm abundance, IITRI measured earth field intensities in study site quadrats used for population sampling. Both 10-cm and 1-m spaced electrodes were used to characterize and compare within-plot electric field variations. Measurements were made with the 1-m probe straddling sampling locations, with the axis of the probes oriented parallel to the maximum field direction. At the treatment site, multiple 10-cm probe measurements were made along the length of the 1-m probe, whereas at the control site, a single 10-cm probe measurement was made at the middle of the 1-m probe.

The results of these measurements are presented in Tables 5 and 6. Measurement points were situated in the corners of the quadrats comprising the study sites. Quadrat locations are diagrammed

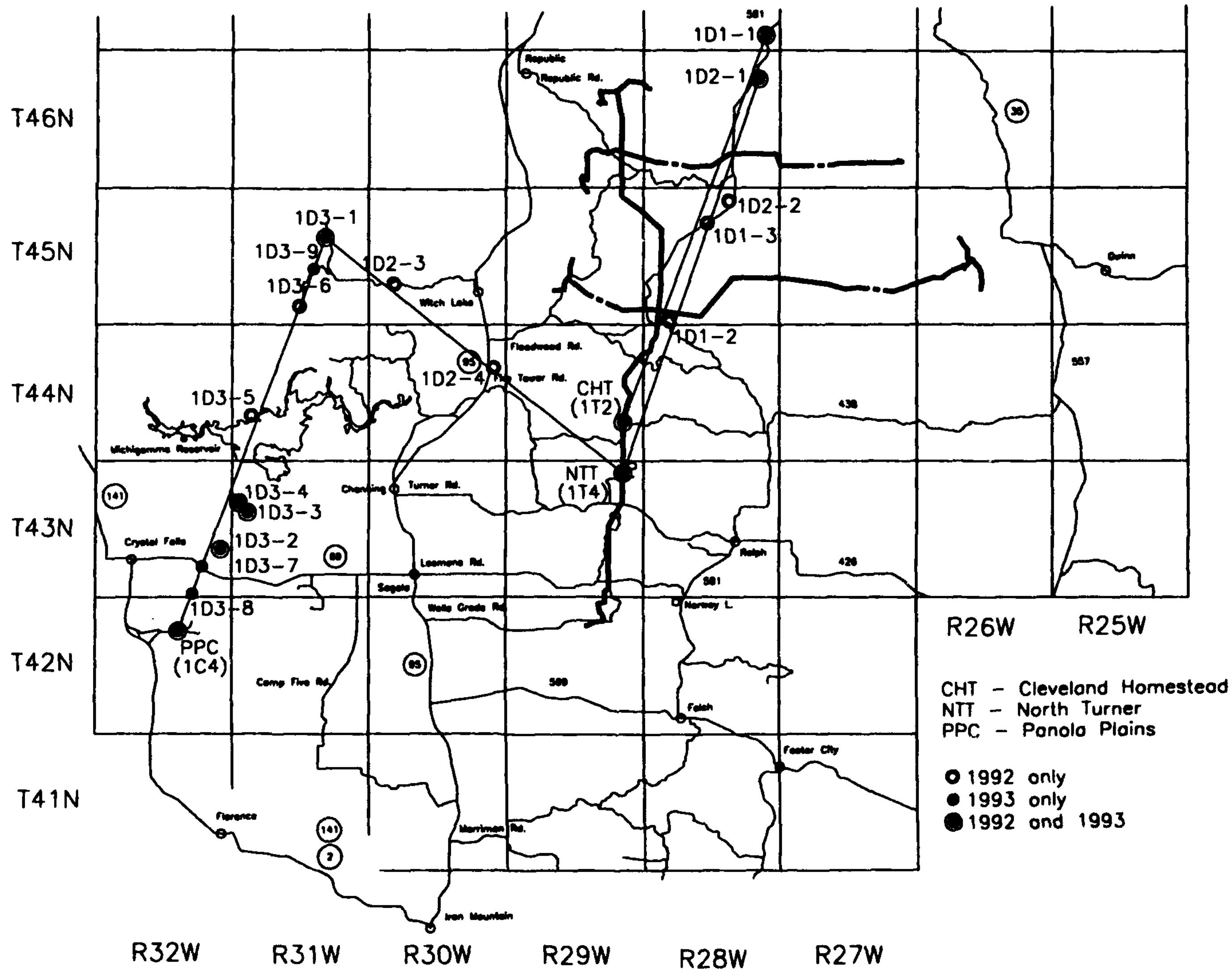


FIGURE 12. GEOMAGNETIC FIELD MEASUREMENT LOCATIONS ALONG BIRD DISPLACEMENT TRANSECTS.

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 1 of 6)

				1992		1993	
Township	Range	Section	Site No.-Meas. Pt.	Intensity, mG	Inclination, deg	Intensity, mG	Inclination, deg
T41N	R29W	21	6C2-1	567	72.9	568	72.7
T41N	R29W	21	10C12-1	567	72.9	568	72.7
T41N	R29W	33	10C1-3	576	74.3	562	73.8
T41N	R29W	35	10C1-2	575	73.1	567	73.3
T41N	R29W	35	10C12-2	575	73.1	567	73.3
T41N	R32W	3	4C1-6	573	74.0	582	74.1
T41N	R32W	3	4C1-7	580	74.1	583	73.2
T41N	R32W	3	4C1-8	579	73.9	584	73.1
T41N	R32W	3	4C1-9	579	74.3	583	73.9
T41N	R32W	3	4C1-10	583	72.9	581	74.0
T41N	R32W	3	4C1-11	580	74.0	583	72.6
T41N	R32W	3	4C1-12	580	74.0	584	72.7
T41N	R32W	3	4C1-13	581	73.0	582	73.4
T41N	R32W	3	4S2-1	578	73.9	/	/
T42N	R27W	14	10C2-1	580	75.3	577	75.0
T42N	R27W	24	10C2-2	575	74.2	575	73.1
T42N	R29W	2	6T4-1	577	74.8	577	74.0
T42N	R29W	2	6T4-2	577	73.5	578	73.9
T42N	R29W	2	6T4-3	576	73.3	577	73.6
T42N	R29W	2	6T4-4	577	72.9	579	74.2
T42N	R29W	2	6T4-5	576	74.8	577	73.7
T42N	R29W	2	6T4-6	577	73.2	576	74.0
T42N	R31W	3	1C6-1	575	74.2	579	73.2
T42N	R31W	3	1C6-3	579	73.8	579	72.9
T42N	R31W	3	1C6-4	575	73.5	581	73.2
T42N	R31W	13	2C5-1	574	74.7	/	/
T42N	R31W	13	2C5-2	574	74.7	/	/
T42N	R31W	13	2C5-4N	576	73.8	/	/
T42N	R31W	13	2C5-4S	576	73.7	/	/
T42N	R32W	10	1C4-1	577	73.6	568	73.0
T42N	R32W	10	1C4-4	573	74.4	584	72.7
T42N	R32W	10	1C4-5	570	74.4	580	72.8
T42N	R32W	9	1L4-1/2L2-1	584	74.4	584	74.5
T43N	R25W	34	10C5-3	580	73.4	574	74.1
T43N	R25W	31	10C5-2	580	74.0	574	73.9
T43N	R28W	23	1T1-15	578	74.5	579	73.5

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 2 of 6)

				1992		1993	
Township	Range	Section	Site No.-Meas. Pt.	Intensity, mG	Inclination, deg	Intensity, mG	Inclination, deg
T43N	R28W	21	5C1-1	570	72.9	573	73.3
T43N	R28W	21	5C1-3	576	72.8	580	73.3
T43N	R28W	21	5C1-4	575	73.4	578	73.0
T43N	R28W	21	5C1-5	574	73.5	577	74.0
T43N	R29W	23	1T1-14	578	74.1	577	74.4
T43N	R29W	23	1T1-16	577	73.8	576	74.7
T43N	R29W	23	1T1-17	577	74.0	/	/
T43N	R29W	23	1T1-18	577	74.0	/	/
T43N	R29W	23	1T1-19	576	73.9	/	/
T43N	R29W	23	1T1-20	578	73.9	/	/
T43N	R29W	23	1T1-21	577	74.3	579	73.2
T43N	R29W	23	1T1-22	581	74.1	595	74.0
T43N	R29W	23	1T1-23	579	74.8	570	76.3
T43N	R29W	23	1T1-24	580	74.2	581	72.6
T43N	R29W	23	1T1-25	579	74.7	577	74.3
T43N	R29W	23	1T1-26	577	74.8	571	74.3
T43N	R29W	23	1T1-27	578	74.9	578	73.7
T43N	R29W	23	1T1-28	577	74.5	/	/
T43N	R29W	23	1T1-29	579	73.5	/	/
T43N	R29W	23	1T1-30	577	74.0	/	/
T43N	R29W	23	1T1-31	575	74.7	/	/
T43N	R29W	1	1T4-5	578	73.7	577	74.7
T43N	R29W	1	1T4-6	577	74.4	579	73.9
T43N	R29W	1	1T4-7	577	74.5	578	74.4
T43N	R29W	1	1T4-8	578	74.2	579	74.2
T43N	R29W	1	1T4-9	577	74.4	580	74.0
T43N	R29W	1	1T4-10	576	74.4	565	73.6
T43N	R29W	1	1T4-11	577	73.6	578	74.6
T43N	R29W	1	1T4-12	577	74.1	580	74.0
T43N	R29W	1	1T4-13	577	73.9	582	74.3
T43N	R29W	1	1T4-14	577	74.5	579	73.8
T43N	R29W	14	1T5-1	580	74.9	580	74.0
T43N	R29W	14	1T5-2	581	73.7	577	74.6
T43N	R29W	14	1T5-4	578	73.3	578	73.8
T43N	R29W	14	1T5-5	581	73.3	577	73.8
T43N	R29W	14	1T5-6	588	73.4	588	72.1
T43N	R29W	14	1T5-7	580	74.1	579	73.9
T43N	R29W	14	1T5-8	579	73.9	578	73.9
T43N	R29W	14	1T5-9	583	73.6	576	73.1
T43N	R29W	14	1T5-10	591	74.2	585	72.8
T43N	R29W	14	1T6-1	578	74.0	561	72.4

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 3 of 6)

				1992		1993	
Township	Range	Section	Site No.-Meas. Pt.	Intensity, mG	Inclination, deg	Intensity, mG	Inclination, deg
T43N	R29W	14	1T6-2	577	72.3	568	73.6
T43N	R29W	14	1T6-3	578	73.9	579	73.1
T43N	R29W	14	1T6-4	578	73.9	579	72.9
T43N	R29W	14	1T6-5	580	73.5	578	73.3
T43N	R29W	14	1T6-6	578	73.2	579	73.1
T43N	R29W	14	1T6-7	578	72.8	579	73.0
T43N	R29W	14	2T1-1	581	73.7	/	/
T43N	R29W	14	2T1-2	588	73.4	/	/
T43N	R29W	14	2T1-3	581	73.3	/	/
T43N	R29W	14	2T1-4	585	70.2	/	/
T43N	R29W	14	2T1-5	582	73.9	/	/
T43N	R29W	14	2T2-1	578	74.0	/	/
T43N	R29W	14	2T2-2	578	72.8	/	/
T43N	R29W	18	5C3-2	580	74.8	/	/
T43N	R29W	16	5C5-1	575	74.2	/	/
T43N	R29W	8	5C14-1	577	73.2	/	/
T43N	R29W	17	5C15-1	581	74.0	/	/
T43N	R29W	14	5T1-2	584	72.8	591	71.4
T43N	R29W	14	5T2-1	577	73.6	585	73.6
T43N	R29W	14	5T2-2	578	72.9	585	73.9
T43N	R29W	14	5T2-4	577	73.9	584	73.3
T43N	R29W	14	5T2-7	575	74.0	585	72.8
T43N	R29W	14	5T2-8	578	73.1	584	72.8
T43N	R29W	14	5T3-1	574	74.4	578	72.7
T43N	R29W	11	5T4-3	593	73.0	592	73.0
T43N	R29W	23	6T3-2	577	73.4	579	73.8
T43N	R29W	23	6T3-3	578	73.4	574	74.4
T43N	R29W	35	10T1-1	576	74.2	578	73.5
T43N	R29W	23	10T1-3	573	74.9	578	73.5
T43N	R29W	23	10T1-4	579	73.9	576	74.5
T43N	R29W	26	10T1-5	577	73.7	563	74.7
T43N	R29W	12	10T2-1	591	74.4	592	74.3
T43N	R29W	1	10T2-2	559	74.9	565	74.6
T43N	R30W	19	2C4-1	583	74.5	/	/
T43N	R30W	19	2C4-2	582	75.0	/	/
T43N	R30W	11	3C5-1	580	74.7	580	73.3
T43N	R30W	11	3C5-2	580	74.8	580	74.0
T43N	R30W	11	3C5-3	580	75.3	579	73.7
T43N	R31W	18	1D3-3	579	74.7	575	73.7
T43N	R31W	7	1D3-4	577	73.1	576	73.5

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 4 of 6)

				1992		1993	
Township	Range	Section	Site No.-Meas. Pt.	Intensity, mG	Inclination, deg	Intensity, mG	Inclination, deg
T43N	R32W	24	1D3-2	609	73.1	607	72.3
T43N	R32W	26	1D3-7	/	/	583	73.1
T43N	R32W	35	1D3-8	/	/	579	74.1
T44N	R26W	18	10C13-1	583	73.2	581	73.9
T44N	R29W	25	1T2-5	579	73.3	580	74.2
T44N	R29W	25	1T2-6	577	74.5	581	73.9
T44N	R29W	25	1T2-7	576	74.6	582	73.6
T44N	R29W	25	1T2-8	578	73.9	580	74.6
T44N	R29W	25	1T2-9	578	73.4	581	73.9
T44N	R29W	25	3T2-1	577	73.6	579	74.2
T44N	R29W	25	3T2-2	579	74.6	579	74.6
T44N	R29W	25	3T2-3	574	75.3	579	73.4
T44N	R29W	25	3T2-4	576	75.0	578	74.6
T44N	R29W	25	3T2-5	577	74.4	578	73.4
T44N	R29W	25	3T2-6	575	74.2	578	73.5
T44N	R29W	25	3T2-7	/	/	579	74.4
T44N	R29W	25	3T2-13	/	/	579	73.9
T44N	R29W	36	10T2-4	569	72.4	567	73.7
T44N	R30W	12	1D2-4	579	73.9	/	/
T44N	R30W	24	3S2-1	579	73.5	580	72.8
T44N	R31W	13	1C1-3	568	74.5	575	74.0
T44N	R31W	13	1C1-4	579	74.3	579	73.7
T44N	R31W	24	1C3-1	574	74.2	/	/
T44N	R31W	24	1C3-3	578	74.4	/	/
T44N	R31W	30	1D3-5	576	73.1	/	/
T45N	R28W	32	1D1-2	579	73.4	/	/
T45N	R28W	10	1D1-3	579	74.4	/	/
T45N	R28W	3	1D2-2	578	74.4	/	/
T45N	R28W	19	10T3-1	579	73.3	581	74.4
T45N	R28W	31	10T3-2	580	73.8	582	74.3
T45N	R28W	31	10T3-3	577	74.7	580	74.3
T45N	R28W	31	10T4-1	576	74.9	579	73.9
T45N	R28W	19	10T11-1	579	74.2	581	73.9
T45N	R29W	28	4T2-2	577	74.2		
T45N	R29W	28	4T2-3	577	73.6	578	74.1
T45N	R29W	28	4T2-4	577	74.2	586	74.7
T45N	R29W	28	4T2-5	578	74.2	580	73.0

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 5 of 6)

				1992		1993	
Township	Range	Section	Site No.-Meas. Pt.	Intensity, mG	Inclination, deg	Intensity, mG	Inclination, deg
T45N	R29W	28	4T2-6	577	74.1	579	73.4
T45N	R29W	28	4T2-7	577	73.9	579	72.6
T45N	R29W	28	4T2-8	576	74.0	578	74.8
T45N	R29W	28	4T2-9	577	74.3	578	73.8
T45N	R29W	28	4T2-10	577	74.1	579	73.1
T45N	R29W	28	4T2-11	577	74.0	579	72.9
T45N	R29W	28	4T2-12	576	74.0	578	74.1
T45N	R29W	28	4T2-13	577	73.9	575	74.9
T45N	R29W	28	4T2-14	576	74.2	577	72.7
T45N	R29W	28	4T2-15	576	74.0	580	74.6
T45N	R29W	28	4T2-16	577	74.0	578	73.3
T45N	R29W	28	4T2-17	577	74.2	579	73.4
T45N	R29W	28	4T2-18	577	73.7	577	73.6
T45N	R29W	28	4T2-19	577	73.9	579	73.9
T45N	R29W	28	4T2-26	577	74.2	576	73.5
T45N	R29W	28	4T2-33	578	74.1	578	74.6
T45N	R29W	28	4T2-34	577	74.1	578	74.4
T45N	R29W	28	4T2-35	576	74.1	578	73.6
T45N	R29W	28	4T2-36	577	74.2	579	74.1
T45N	R29W	28	4T4-4	578	73.5	579	74.8
T45N	R29W	28	4T4-5	577	74.4	577	74.4
T45N	R29W	28	4T4-6	575	74.7	580	75.3
T45N	R29W	28	4T4-7	576	74.7	573	74.1
T45N	R29W	28	4T4-8	571	74.6	580	73.2
T45N	R29W	28	4T4-9	577	73.6	580	72.3
T45N	R29W	28	4T4-10	577	74.0	581	72.9
T45N	R29W	28	4T4-11	576	74.1	582	73.5
T45N	R29W	28	4T4-12	579	73.9	579	73.7
T45N	R29W	28	4T4-13	577	74.1	581	72.9
T45N	R29W	28	4T4-14	577	73.7	581	73.4
T45N	R29W	28	4T4-15	578	74.2	580	73.0
T45N	R29W	28	4T4-16	574	73.6	578	74.4
T45N	R29W	28	4T4-17	577	73.7	/	/
T45N	R29W	28	4T4-18	576	74.1	581	74.7
T45N	R29W	28	4T4-19	578	73.4	581	74.0
T45N	R29W	28	4T4-20	576	73.4	581	74.4
T45N	R29W	35	10T4-3	/	/	580	73.0
T45N	R29W	1	10T11-2	577	74.1	572	74.6
T45N	R30W	29	1D2-3	585	73.7	/	/
T45N	R31W	14	1D3-1	577	73.6	573	73.0
T45N	R31W	33	1D3-6	586	73.8	/	/

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 6 of 6)

				1992		1993	
Township	Range	Section	Site No.-Meas. Pt.	Intensity, mG	Inclination, deg	Intensity, mG	Inclination, deg
T45N	R31W	22	1D3-9	/	/	577	73.6
T47N	R28W	36	1D1-1	570	72.4	572	72.9
T46N	R28W	12	1D2-1	571	73.9	571	73.2
T54N	R34W	5	4S3-1	582	73.5	/	/
T55N	R35W	21	4S1-1	583	74.6	/	/

/ = data not taken.

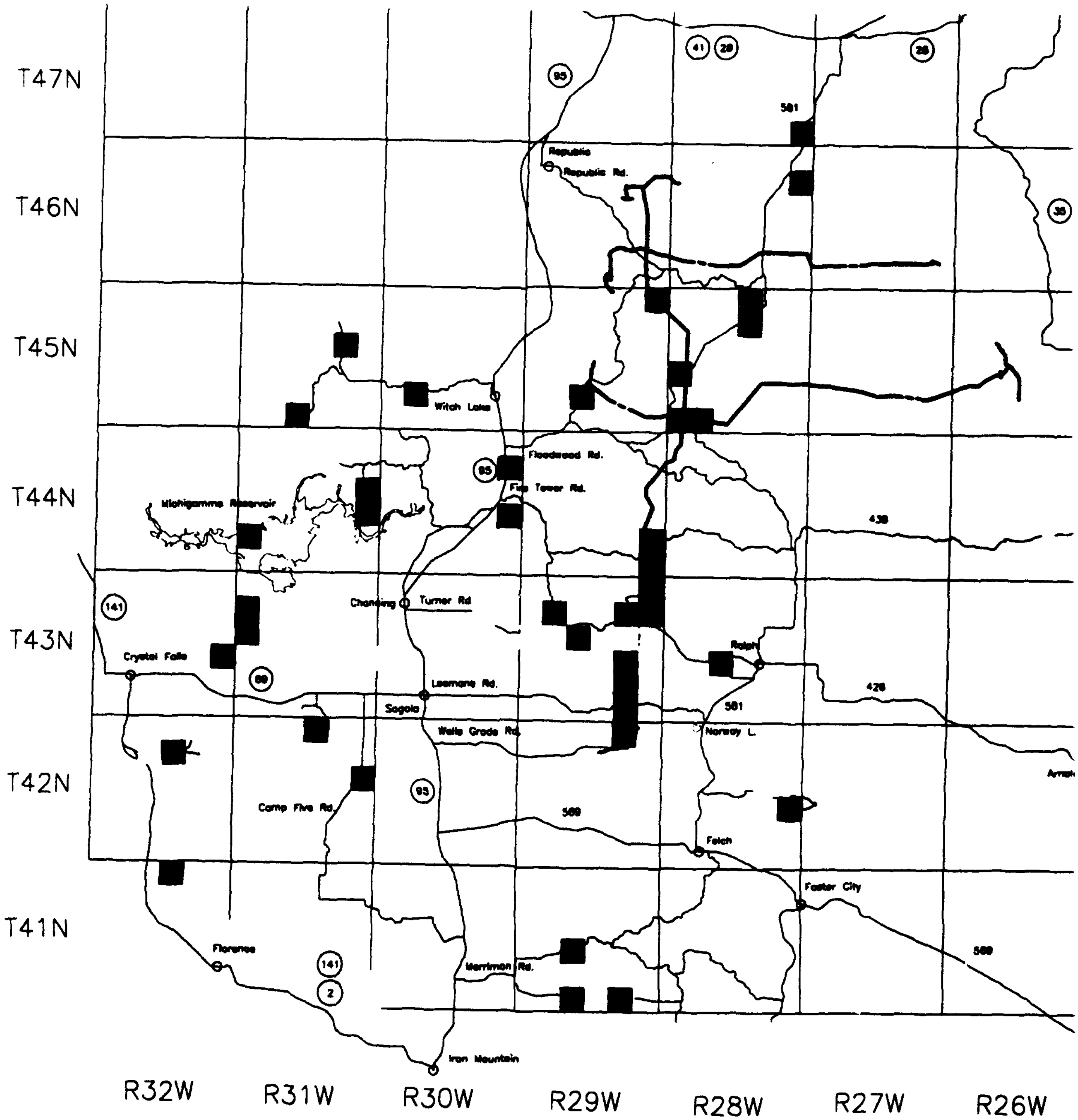
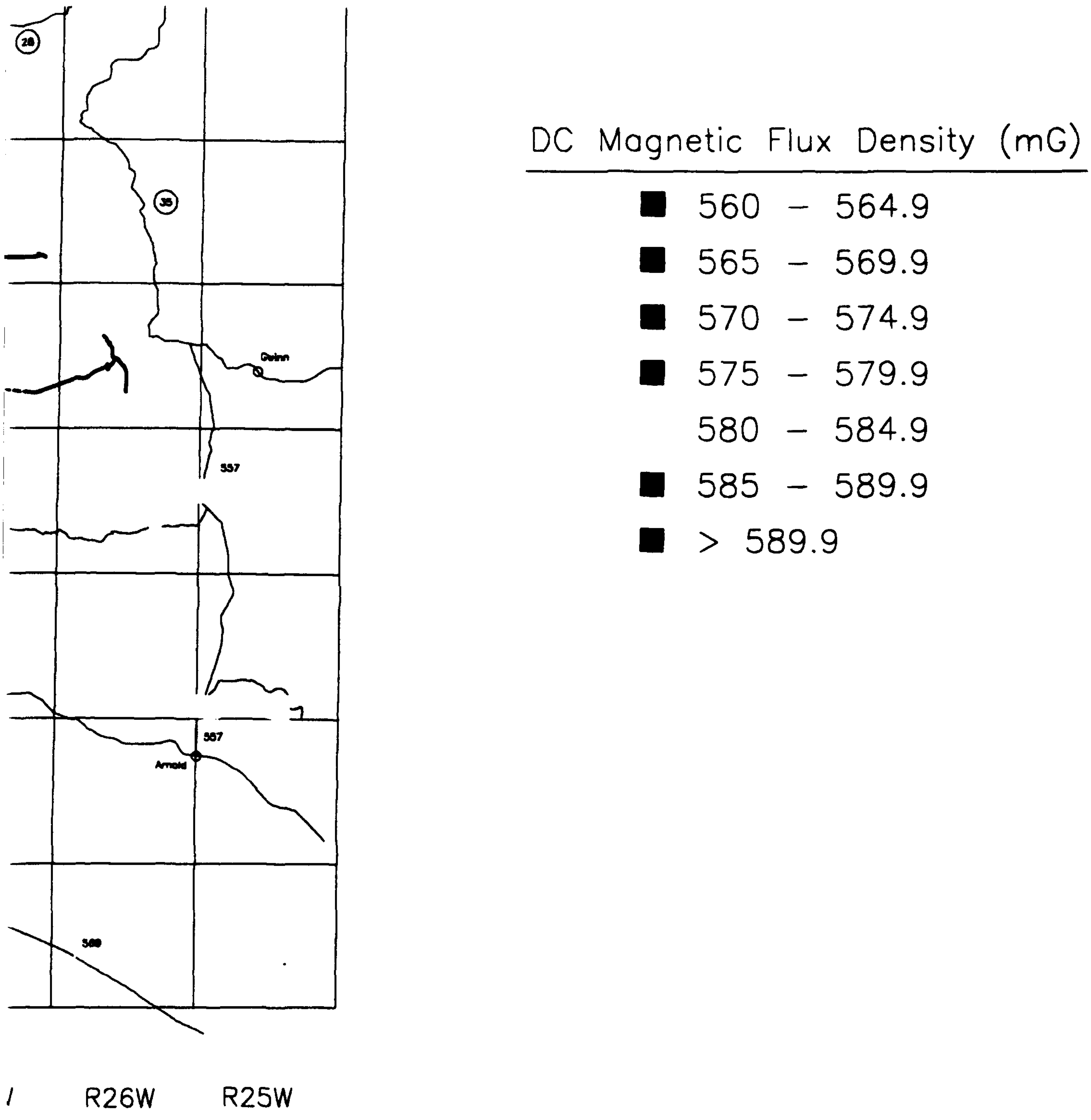


FIGURE 13. 1992 GEOMAGNETIC FIELD INTENSITY LEVELS NEAR ECO

(2)



.EVELS NEAR ECOLOGICAL MONITORING PROGRAM STUDY SITES.

1

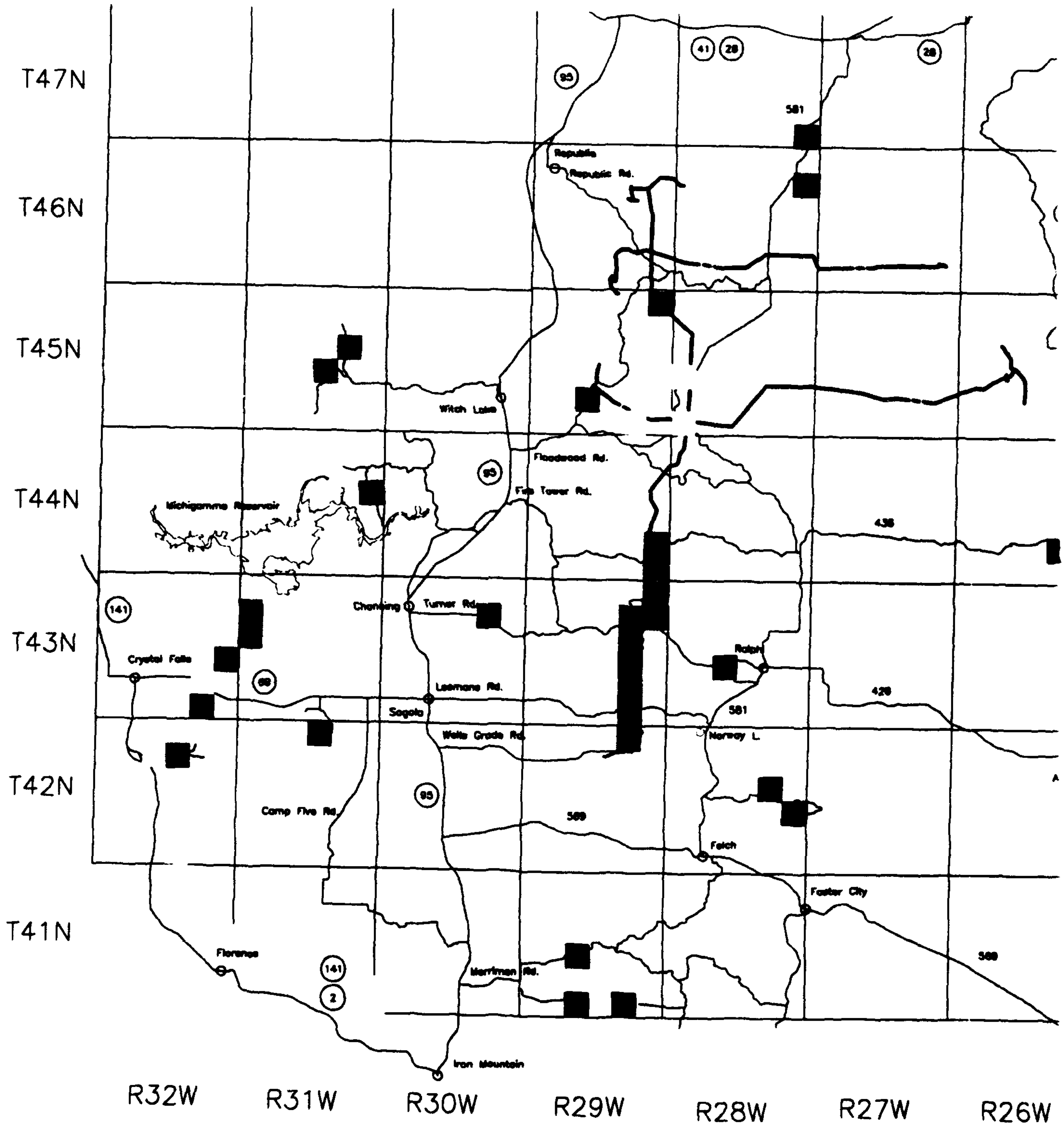
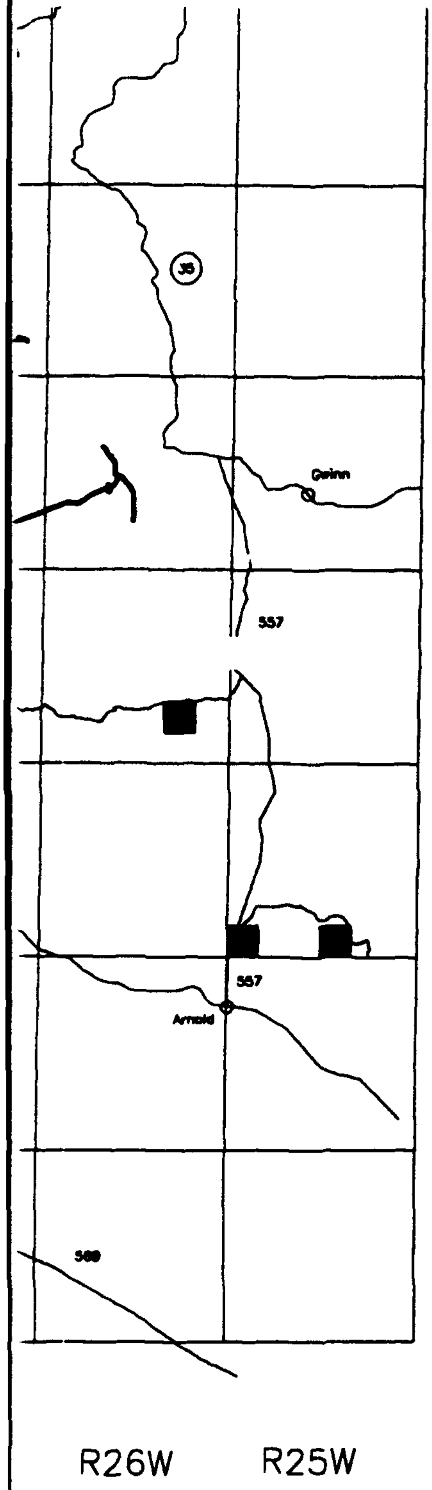


FIGURE 14. 1993 GEOMAGNETIC FIELD INTENSITY LEVELS NEAR EC

2



DC Magnetic Flux Density (mG)

- 560 – 564.9
- 565 – 569.9
- 570 – 574.9
- 575 – 579.9
- 580 – 584.9
- 585 – 589.9
- > 589.9

ELS NEAR ECOLOGICAL MONITORING PROGRAM STUDY SITES.

in Figures C-2 and C-3 of Appendix C. Measurement corners are defined in Tables 5 and 6. Orientations of the maximal field intensities varied little at each site, indicating that no major anomalies were present near the sampling locations. At both sites, the standard deviation of the 1-m measurements was on the order of 10 percent of the 1-m average.

At the treatment site (Table 5), the averages of the ten 10-cm probe measurements made within each quadrat on 13 May correspond closely to the 1-m values. The standard deviations of the 10-cm probe values were nominally 10 percent of their means. On 26 May, only two 10-cm probe measurements were made at the center of the 1-m probe within each quadrat. Averages of the smaller sample set of

TABLE 5. 76 Hz EARTH ELECTRIC FIELD INTENSITIES
1992 Treatment Site Earthworm Sampling Locations

	Southeast Corner (13 May)			Northwest Corner (26 May)		
		E-Field, mV/m			E-Field, mV/m	
Quadrat[a]	Direction of Maximum	Avg. ± S.D. 10-cm[b]	1-m	Direction of Maximum	Avg. 10-cm[c]	1-m
2	0°	62 ± 6.3	64	340°	47	56
4	15°	66 ± 10.0	66	16°	60	58
6	15°	58 ± 6.3	58	14°	50	56
8	10°	72 ± 7.6	73	4°	51	61
10	5°	54 ± 5.8	54	4°	49	55
12	25°	62 ± 11.3	65	2°	61	63
14	1°	53 ± 8.9	54	2°	47	52
16	16°	63 ± 4.7	67	6°	44	47
18	20°	55 ± 5.7	57	11°	55	63
20	12°	67 ± 5.1	69	10°	52	60
Site Average		61	63		52	57
S.D.		5.9	6.2		5.3	4.8

S.D. = standard deviation.
[a]For locations, see Figure C-2 in Appendix C.
[b]N = 10, taken along length of 1-m probe.
[c]N = 2, taken at middle of 1-m probe (i.e., at 40 to 50-cm and 50 to 60-cm positions).

TABLE 6. 76 Hz EARTH ELECTRIC FIELD INTENSITIES
1992 Control Site Earthworm Sampling Locations

	East Corner (11 May)			West Corner (27 May)		
	Direction of	E-Field, mV/m		Direction of	E-Field, mV/m	
Quadrat[a]	Maximum	10-cm[b]	1-m	Maximum	10-cm[b]	1-m
2	64°	0.25	0.28	78°	0.193	0.25
4	70°	0.23	0.24	85°	0.26	0.23
6	68°	0.23	0.24	76°	0.29	0.27
8	52°	0.28	0.31	70°	0.27	0.29
10	52°	0.25	0.26	85°	0.24	0.23
12	60°	0.22	0.22	78°	0.26	0.26
14	64°	0.25	0.27	60°	0.29	0.27
16	75°	0.25	0.26	103°	0.173	0.27
18	80°	0.24	0.24	82°	0.26	0.23
20	67°	0.28	0.26	74°	0.29	0.29
Mean		0.25	0.26		0.25	0.26
S.D.		0.019	0.024		0.038	0.022

S.D. = standard deviation.
[a]For locations, see Figure C-3 in Appendix C.
[b]Taken at middle of 1-m probe.

10-cm probe measurement made on 26 May did not match the 1-m values as closely as those measured on 13 May, probably because of variations in the earth electric field over the 1-m span. At the control site, only one 10-cm probe measurement was made along the 1-m probe span. Measurements made with the 10-cm probe were similar in value to the 1-cm probe values (Table 6). This would tend to indicate that the earth electric fields are less variable over a 1-m span at the control site than at the treatment site.

4.2.2 Earthworm Incubation Experiments

The soil arthropods and earthworms studies monitored treatment and control sites for potential effects of ELF EM fields from 1983 through 1993 (Appendix C). Data collected through 1990 suggested possible EM effects on the reproductive behavior of one species of earthworm. In order to examine this possibility more closely, investigators needed to confine and periodically retrieve earthworms for observation and population census. A container was needed that would confine the worms and yet allow exposure to natural environmental conditions as well as exposure to the 76 Hz electric fields present in the soil.

A fiber glass mesh bag design was developed and tested which met these conflicting requirements with only a moderate reduction in electric field intensity. The 1991 study season (April through October) was used to find appropriate locations for the bags and develop optimal EM exposure regimes and biological protocols. Data were subsequently collected during 1992 and 1993.

4.2.2.1 Protocol Development

A pilot study of earthworm reproduction was begun in 1991. Worms were collected at the treatment site, and at a non-historic site where ELF EM field intensities were markedly lower than that at the treatment site. Fiber glass window screening (2 mm mesh) was fashioned into flat-bottomed cylinders 20 cm in diameter and 50 cm tall. The bags were then placed in 20-cm-deep holes and carefully filled with soil. The soil within the bags was manually compressed several times and settled by adding water. After a day or so the earthworms were added and covered with leaf litter. The protruding portion of each bag was folded over and closed with clips. The mesh bags were generally retrieved on a monthly basis and the contents analyzed. The bags were then redeployed in the previously used holes, and the process was repeated. Soil in all bags was moistened when any one fell below a 20 percent water content. The incubation bags were located adjacent to the treatment (3T2) and control (3C5) grids. In this manner examination of the null hypothesis (76 Hz EM fields have no effect on earthworm reproduction) could be tested and also compared to results obtained on the study grid.

Locations for the worm incubation bags at the treatment site were selected on the basis of earth electric field intensity. Ideally, the bags at this site would be placed in an area where the electric field intensities were greater than those within the historic study plots in order to compensate for the somewhat reduced fields inside the bags. However, no electric fields of the desired magnitude could be found despite a thorough measurement survey of the study area on both sides of the antenna ROW. The maximum electric field intensities measured within areas of acceptable biological habitat were along a line 28 m east of, and parallel to, the eastern border of the existing site as shown in Figure 15. Based on electric field measurements taken for other studies located along the NS antenna, it was thought unlikely that a new site having significantly greater earth electric field intensities as well as matched habitat could be found. The bag numbering, together with nearby historic measurement points, is also shown in the figure. Note that the bag numbering used in 1993 differs from that used in 1991 and 1992.

Reduced earth electric field intensities inside the worm incubation bags were not a concern at the control site. It was decided to place the bags within unused plots at the west corner of the study site for convenience and ease of monitoring. The bag locations, together with nearby historic measurement points, are shown in Figure 16. The bag numbering for this site also differed in 1991, 1992, and 1993.

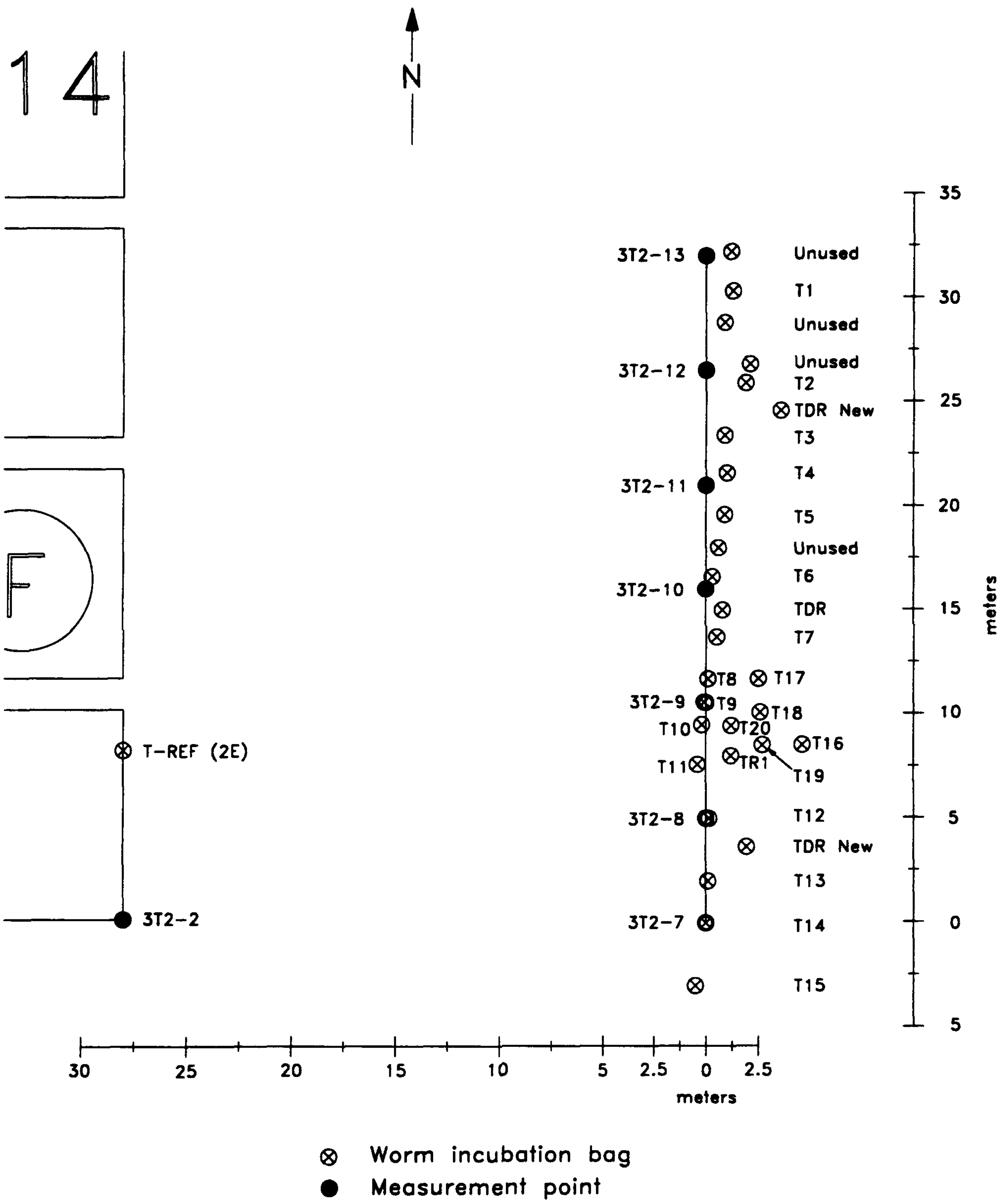


FIGURE 15. WORM INCUBATION BAG LOCATIONS AT SOUTH SILVER LAKE; 3T2.

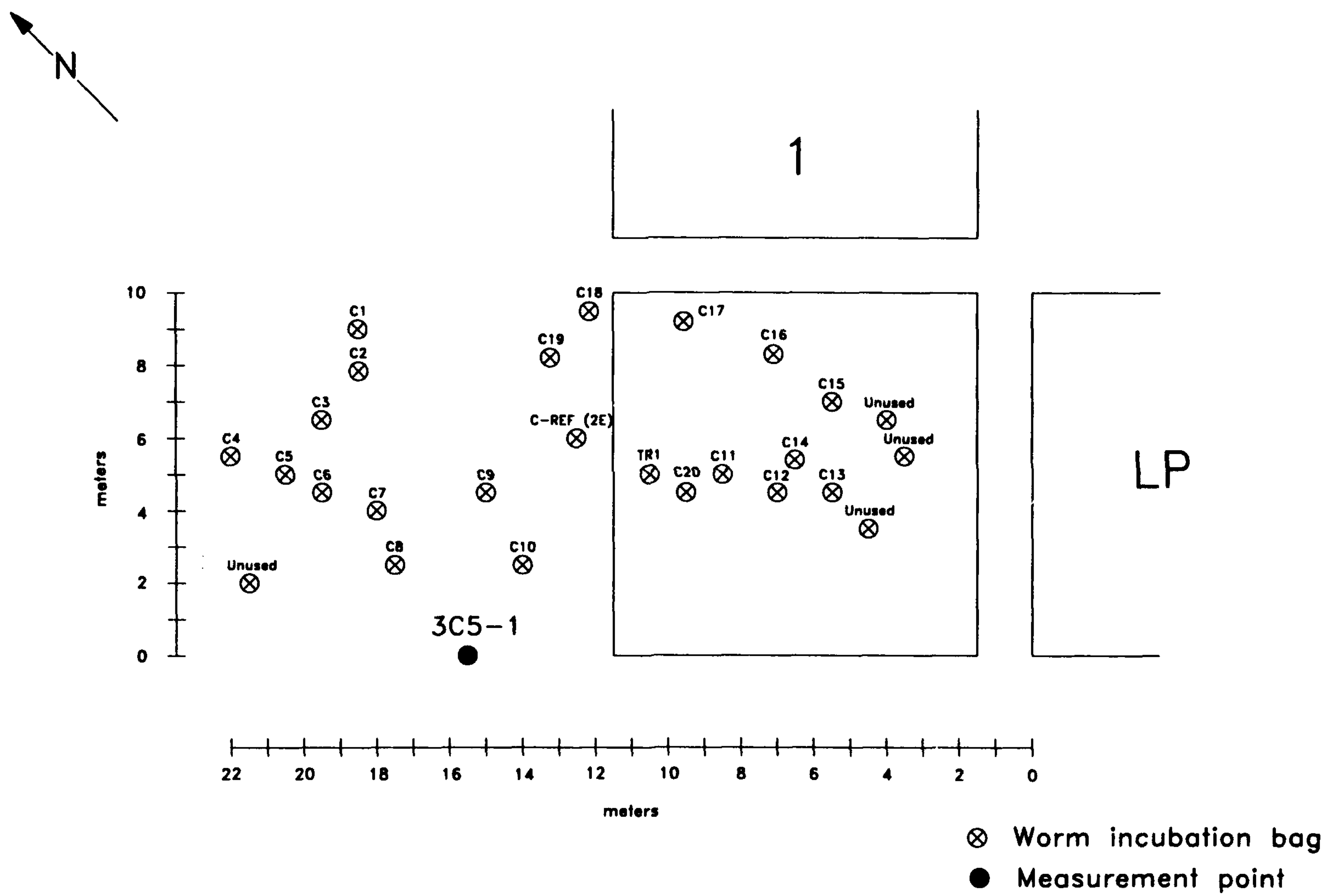


FIGURE 16. WORM INCUBATION BAG LOCATIONS AT TURNER ROAD; 3C5.

4.2.2.2 EM Monitoring

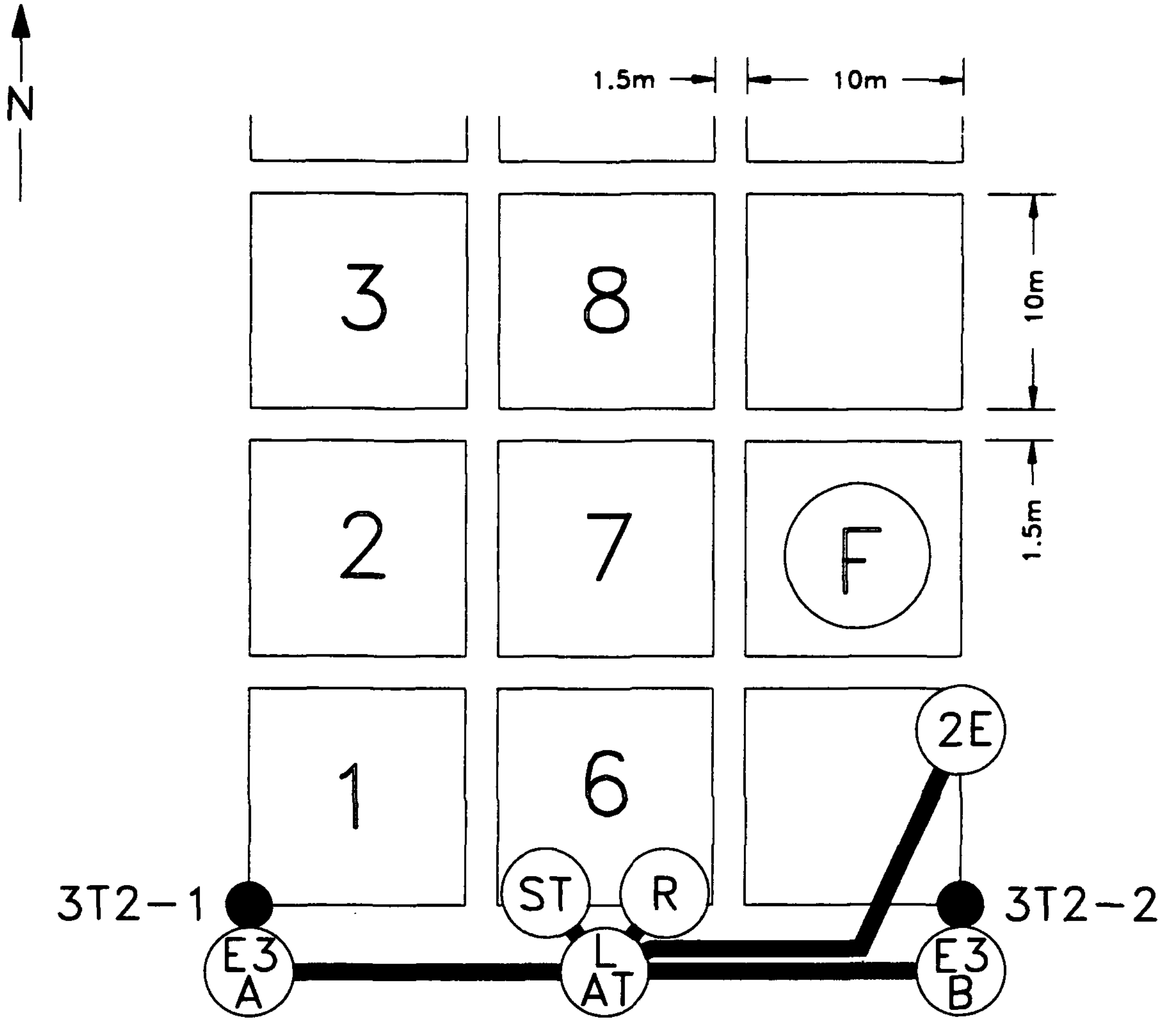
Temporal variations in the intensity of the earth electric field within and beside a reference incubation bag at each site were studied using data logger monitoring systems (Figures 17 and 18). Monitoring results are presented in a daily average plot (Figure 19) and statistical summary (Table 7). Annual measurements were made within and next to each of the study incubation bags to determine field reduction effects and spatial relationships of the 76 Hz electric field intensity in the soil (Tables 8 and 9).

Values of the electric field within the reference incubation bags (T-ref, C-ref) and in the soil adjacent to the bags were recorded hourly by the monitoring systems. Standard 1-m spaced electrodes adjacent to the bags were oriented parallel to the direction of the maximal field to record changes in the electric field due to natural conditions. Within the bags 10-cm electrodes were aligned with the 1-m electrodes, and monitored electric field variations due to the manipulations of the experiment (i.e., bag removal, soil compaction, watering). Values recorded for both probe sets at the treatment site are presented in Figure 19. Corresponding electric field values at the control site were below the level detectable by the monitoring system and are therefore not presented.

Electric field values presented in Figure 19 are daily averages of hourly measurements taken during the 1992 and 1993 field seasons, as well as during the intervening winter. Bag changeout and watering activities are labeled on this figure. The effects of these manipulations on the electric field intensities within the reference bag are evident. Effects of the fiber glass mesh on the electric field intensities within the reference bag can also be seen.

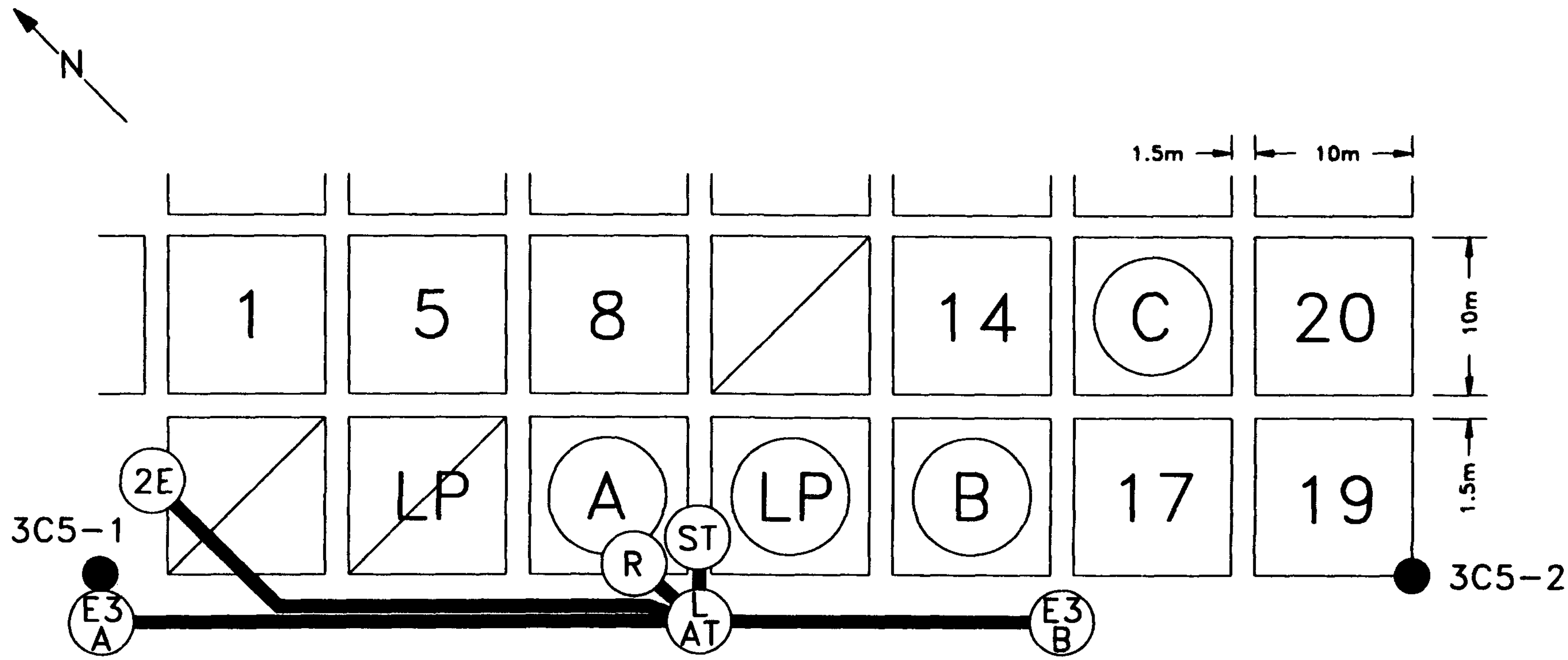
A statistical summary of the data presented in Figure 19 is given in Table 7. Data recorded by the 1-m probes at the treatment site showed that the variability of ambient 76 Hz electric fields was low within sample periods (1-3 percent) and that changes across sample periods were small (5-6 percent). Within incubation bags the differences between sample periods were larger (32-42 percent) and more variable (3-14 percent). The dissimilarity between the electric fields inside and outside of the bags appears to be due primarily to the physical manipulations of the bags necessary to obtain earthworm data.

Tables 8 and 9 present measurements taken at each incubation bag at the onset of both the 1992 and 1993 field seasons. These data, along with those in Table C-7, show that the electric fields within the treatment incubation bags averaged about 22 percent less than the electric fields on the treatment study grid. Combining the spatial data from Table 8 with the temporal data collected within the single reference bag, indicates that the average incubation bag electric field intensities were 5-50 percent more variable than those experienced on the study grid. However, the average electric field within incubation bags at the treatment site was always two orders of magnitude greater than the corresponding average experienced in bags at the control site.



KEY
- L/AT Data Logger with Air Temperature Sensor
- ST Soil Temperature Sensor
- R Rain Gauge
- E3 Three-depth Earth Electric Field Probe
- 2E Pair of Electric Field Probes at Worm Incubation Bag T-Reference, 10 cm probe inside incubation bag, 1 m probe outside bag

FIGURE 17. DATA LOGGER MONITORING SYSTEM AT SOUTH SILVER LAKE; 3T2.



KEY
- (L/AT) Data Logger with Air Temperature Sensor
- (ST) Soil Temperature Sensor
- (R) Rain Gauge
- (E3) Three-depth Earth Electric Field Probe
- (2E) Pair of Electric Field Probes at Worm Incubation Bag C-Ref, 10 cm probe inside incubation bag, 1 m probe outside bag

FIGURE 18. DATA LOGGER MONITORING SYSTEM AT TURNER ROAD; 3C5.

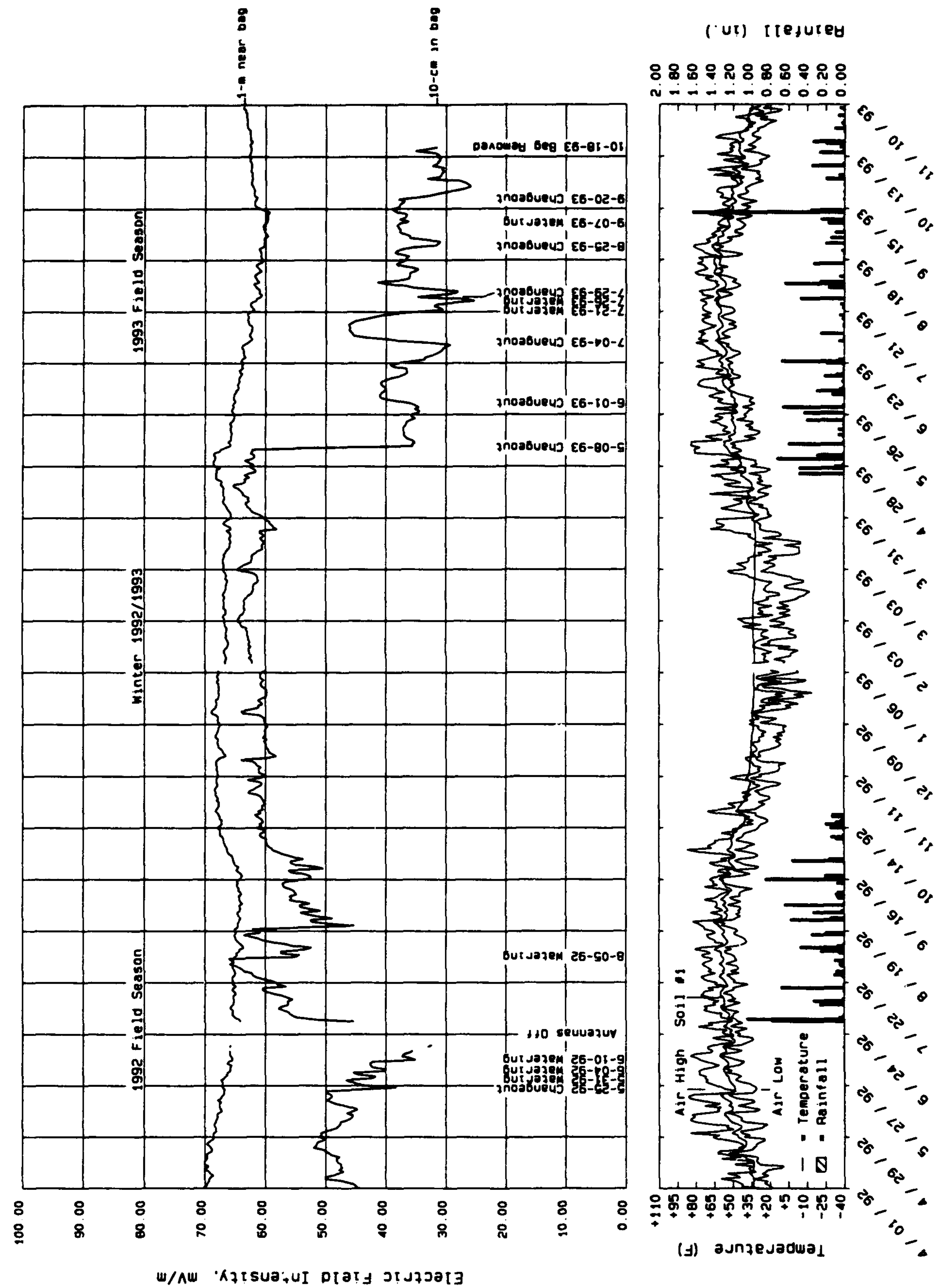


FIGURE 19. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES IN AND NEAR REFERENCE BAG AT THE EARTHWORM TREATMENT SITE; 3T2.

TABLE 7. TREATMENT SITE WORM INCUBATION BAG MEASUREMENTS: STATISTICAL SUMMARY OF MONITORING SYSTEM DATA

Period	E-Field Outside Bag		E-Field Inside Bag	
	Avgerage, mV/m	Coefficient of Variation	Average, mV/m	Coefficient of Variation
1992 Field Season	66	0.03	53	0.13
Winter 1992/1993	67	0.01	62	0.03
1993 Field Season	63	0.03	36	0.14

4.3 Laboratory Measurements

Experimental protocols for some study species require that they be removed from the study sites to undergo laboratory measurements. In these cases, "non-76 Hz" EM exposures in the laboratory should be minimized in order to prevent possible confounding of results.

In past years, measurements made at the laboratories of the small mammals and nesting birds studies and the native bees studies showed that the 60 Hz EM fields there were of the same order of magnitude as 76 Hz EM fields at the test sites. Efforts were made to reduce these exposures by asking investigators to (1) limit the amount of time biota spend at the laboratory and (2) reduce the EM field intensities at the laboratory.

In 1992, spot EM measurements were made at a new laboratory location for the native bees studies, and, for the first time, at the earthworm and soil arthropod laboratory. Magnetic field intensities were monitored nominally for a 24-hour period at each of these laboratories using the EMDEX II™ magnetic field meter described in Section 3.5. Discussion and presentation of all data in support of the laboratory measurements appear in the appendixes.

4.4 Characterization of EM Variability

EM field intensity levels are dependent on several factors that make them subject to both spatial and temporal variability. A simplified mathematical description of the three fields of interest is given to help explain the factors on which each EM field is dependent. This is followed by separate discussion and examples of spatial and temporal EM field variability based on engineering support efforts for various studies.

The top diagram in Figure 20 illustrates the orientation of the magnetic flux and earth electric field near an ELF antenna. The earth electric field near a buried ground wire and the air electric field near an ELF antenna are shown in the middle and bottom diagrams of the figure. Equations 5 through 8 provide mathematical representations for the magnitude of each of these fields. The equations assume that the

TABLE 8. TREATMENT SITE WORM INCUBATION BAG MEASUREMENTS
Soil Arthropods and Earthworms Studies

Incubation Bag No.			Earth Electric Field, mV/m									Field Reduction Ratio		
			Next to Bag						Within Bag					
			East Side			West Side								
1991	1992	1993	1991	1992	1993	1991	1992	1993	1991	1992	1993	1991	1992	1993
T1			45			47			22			0.48		
T2	T1	T1	52	67	54	53	61	60	16.5	23	37	0.31	0.36	0.65
T3			60			52			19.5			0.35		
T4			60			55			22			0.37		
T5	T2	T2	52	56	53	43	50	50	16.0	32	35	0.34	0.60	0.68
T6	T3	T3	54	51	50	64	69	63	33	40	50	0.56	0.67	0.89
T7	T4	T4	53	51	52	57	52	50	30	39	47	0.55	0.76	0.92
T8	T5	T5	42	38	43	49	55	45	24	29	25	0.66	0.62	0.57
T9			67			64			17.0			0.26		
T10	T6	T6	43	57	56	40	44	46	19.5	38	27	0.47	0.75	0.53
T11			52			53			17.0			0.32		
T12	T7	T7	67	80	87	70	80	86	31	62	63	0.45	0.78	0.73
T13	T8	T8	55	60	63	56	57	59	21	43	37	0.56	0.74	0.61
T14	T9	T9	52	66	59	58	75	72	21	48	39	0.37	0.68	0.60
T15	T10	T10	49	60	67	54	57	70	20	47	42	0.39	0.80	0.61
T16	T11	T11	52	58	58	46	54	54	22	45	40	0.45	0.80	0.71
T17	T12	T12	52	66	71	53	59	66	37	55	65	0.70	0.88	0.95
T18	T13	T13	50	58	58	50	66	59	25	47	40	0.50	0.76	0.68
T19	T14	T14	51	63	72	68	75	72	36	59	64	0.61	0.86	0.89
T20	T15	T15	53	73	73	63	81	78	34	48	62	0.59	0.62	0.82
		T16			85			79			52			0.91
		T17			67			60			39			0.61
T-ref	T-ref		51		64	58		64	26		58	0.48		0.91
	FTR1	T20		85	69		70	69		61	37		0.79	0.88
	FTR2	T18		80	72		80	68		55	39		0.69	0.56
	TR1			63			76			55			0.79	
	TR2	T19		74	68		72	65		54	46		0.74	0.69
Mean			53	63	64	55	65	64	24	46	45	0.47	0.72	0.73
S.D.			6.4	11.2	10.8	7.9	11.1	10.6	6.7	10.6	11.6	0.12	0.114	0.138

S.D. = standard deviation.

TABLE 9. CONTROL SITE WORM INCUBATION BAG MEASUREMENTS
Soil Arthropods and Earthworms Studies

Incubation Bag No.			Earth Electric Field, mV/m						Field Reduction Ratio		
			Next to Bag			Within Bag					
1991	1992	1993	1991	1992	1993	1991	1992	1993	1991	1992	1993
C1			0.110			0.039			0.35		
C2	C5	C5	0.185	0.188	0.20	0.078	0.132	0.143	0.42	0.70	0.72
C3	C4	C4	0.130	0.153	0.165	0.048	0.106	0.120	0.37	0.69	0.73
C4	C3	C3	0.100	0.163	0.180	0.056	0.109	0.105	0.56	0.67	0.58
C5	C1	C1	0.23	0.21	0.25	0.086	0.133	0.195	0.37	0.63	0.80
C6	C6	C6	0.21	0.183	0.21	0.115	0.173	0.115	0.55	0.95	0.56
C7	C7	C7	0.170	0.158	0.175	0.058	0.123	0.130	0.34	0.78	0.74
C8	C8	C8	0.22	0.168	0.165	0.086	0.140	0.095	0.39	0.83	0.58
C9	C9	C9	0.21	0.135	0.135	0.078	0.113	0.085	0.38	0.84	0.63
C10	C10	C10	0.22	0.148	0.160	0.095	0.109	0.070	0.44	0.74	0.44
C11	TR1		0.155	0.27		0.095	0.22		0.61	0.81	
C12	TR2	C20	0.26	0.26	0.28	0.125	0.23	0.140	0.49	0.88	0.50
C13	C11	C11	0.190	0.188	0.21	0.110	0.148	0.145	0.58	0.79	0.69
C14	C12	C12	0.160	0.178	0.175	0.095	0.153	0.105	0.59	0.86	0.60
C15	C14	C14	0.120	0.188	0.21	0.062	0.143	0.140	0.52	0.76	0.68
C16	C15	C15	0.095	0.195	0.198	0.049	0.125	0.113	0.52	0.64	0.57
C17			0.26			0.135			0.53		
C18	C13	C13	0.36	0.21	0.22	0.150	0.148	0.180	0.42	0.70	0.84
C19			0.68			0.23			0.34		
C20			0.22			0.120			0.55		
C-ref			0.115		0.173	0.067		0.163	0.58		0.94
	C2	C2		0.163	0.145		0.098	0.105		0.60	0.72
		C16			0.22			0.140			0.64
		C17			0.195			0.098			0.50
	FTR1	C19		0.173	0.21		0.158	0.095		0.91	0.4[illegible]
	FTR2	C18		0.23	0.21		0.195	0.120		0.85	0.57
Mean			0.21	0.186	0.195	0.094	0.144	0.124	0.47	0.77	0.64
S.D.			0.13	0.035	0.033	0.044	0.036	0.030	0.094	0.096	0.126

S.D. = standard deviation.

distance of the measurement point from the antenna or ground wire is small relative to the length of the antenna or ground wire. This assumption is valid for all treatment site measurement points. Although EM fields at the much more distant control sites are also dependent on the same variables, Equations 5 through 8 are not accurate predictors of the EM field intensities at control sites.

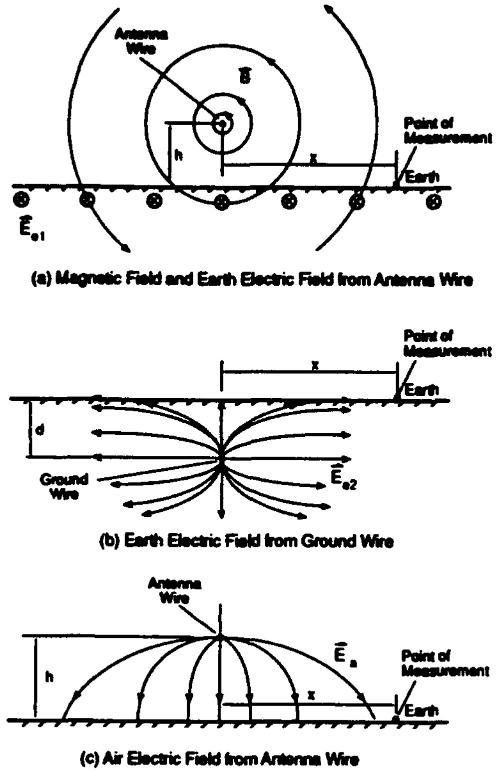


FIGURE 20. EM FIELD ORIENTATIONS.

$$|B| = \frac{\mu_0 I}{2\pi\sqrt{x^2 + h^2}} \tag{5}$$

$$|E_{e1}| = -jf\, I\mu_0 \ln\left(\frac{1.85}{x\sqrt{2\pi f \mu_0 \sigma_b}}\right) - \frac{\pi f\, I\mu_0}{4} \tag{6}$$

$$|E_{e2}| = \left(\frac{I}{\pi l \sigma_s}\right)\left(\frac{x}{x^2 + d^2}\right) \tag{7}$$

$$|E_a| = \left(\frac{2V}{\ln\left(\frac{2h}{a}\right)}\right)\left(\frac{h}{h^2 + x^2}\right) \tag{8}$$

where B = magnetic flux density
E_{e1} = induced earth electric field
E_{e2} = conducted earth electric field
E_a = air electric field
I = antenna or ground wire current
μ_0 = magnetic permeability in free space
h = height of antenna wire
x = horizontal distance to antenna wire
V = voltage on antenna wire
a = radius of antenna wire
l = ground wire length
d = depth of buried ground wire
σ_b = bulk earth conductivity
σ_s = surface earth conductivity
j = $\sqrt{-1}$
f = frequency of antenna current

4.4.1 Spatial Field Variability

4.4.1.1 Predicted Sources of Spatial Variation. Of the four field components indicated, magnetic flux density is dependent on the fewest variables. It is described by Equation 5, which is valid for the magnetic flux density in both the air and the earth. This equation may also be used to predict the magnetic flux density resulting from ground wire currents by replacing "h" with "d." The magnetic flux density at any point is dependent only on antenna current and distance from the current element. Its magnitude is inversely proportional to the separation distance from the antenna or ground wire.

The total electric field in the earth at any point is the sum of that induced by the magnetic field and that generated by current conducted from the buried ground terminals. Equations 6 and 7 illustrate the difference in the earth electric field near antenna ROWs and ground terminals, respectively. Spatially, the earth electric field near an antenna ROW decreases logarithmically with separation from the antenna, assuming homogeneous earth conductivity. The spatial variability near a buried ground wire is somewhat more complicated. Directly above the ground wire is a null in the earth electric field explained by a change in polarity as currents bleed off the wire in opposite directions. Field intensities then rise sharply, reaching a peak at a lateral distance roughly equal to the wire burial depth (nominally 8 feet), after which the field decreases in inverse proportion to the distance from the wire. Such a pattern also assumes a homogeneous earth conductivity. Deviations from the earth electric field intensity levels modeled by Equations 6 and 7 are expected because of anomalies in the earth conductivity caused primarily by large rocks, roots, elevation changes, or variations in soil moisture.

In an ROW or a clearing near the antenna, the air electric field is well modeled by Equation 8. It decreases with the square of the distance from the antenna. Deviations from this pattern are not expected, provided that surrounding vegetation is low enough so as not to shield the field. At other locations where vegetation and trees shield the air electric field described by Equation 8, a secondary electric field may be set up in the air as a by-product of the electric field in the earth. In these cases, potential differences associated with the earth electric field are translated to the air through objects such as trees and other vegetation. Spatial variability of this secondary air electric field is expected to be subject to the same factors as the earth electric field that establishes it.

4.4.1.2 Measured Spatial Variability--EM Field Profiles. Profiles were first used in 1987 at nesting bird sites to characterize the EM fields across large areas. The profiles are generated from a series of measurements taken at regularly spaced distances along a line perpendicular to the antenna wire. These measurements have been made annually since 1987. Profiles for 60 Hz magnetic flux density and earth electric fields are presented in Figures A-17 to A-23; corresponding 76 Hz profiles for antenna operation at 150 A are presented in Figures A-24 to A-37. Similar profiles for 1987 and 1988, when the antennas were operating with a 15 and 75 A current, can be found in a previous report.[11] All profiles demonstrate the decreases in the magnetic, earth, and air electric fields with increasing distance from an antenna ROW. The magnetic flux density and air electric field intensity in cleared areas display a uniform decrease with distance from the antenna. Site anomalies affecting the earth conductivity cause unpredictable patterns in the earth electric fields.

Similar annual profile characterizations for the upland flora and soil microflora (also abbreviated as "MTU" for the investigator's university affiliation or "upland flora" for short) treatment sites have been constructed since 1989. Profiles of the earth electric field intensities have also been constructed from temporal averages of fixed probe and data logger measurements. Selected profiles from these years are presented and discussed in the following text.

Profiles of the 76 Hz air electric field and magnetic flux density along two transects perpendicular to the upland flora antenna and ground ROWs appear in Figures 21 to 24. Each figure has multiple profiles relating to normal operation with both antennas for the years 1989-1993 and one profile for the period of NS antenna operation only in 1991. The historic measurement points that comprise each profile are shown above the horizontal axis. Measurement points 4T2-26 and -33 through -36 were not established in 1989, and this profile is therefore missing for that year. Discontinuities at zero distance shown in the curves in Figure 21 and less apparent in Figure 23 are due to elevation differences in the laterally separated transects (see Figure D-3). Air electric field profiles are missing for 1992 because of a malfunctioning probe.

The air electric fields in the pine plantations at both the antenna and ground sites decrease in a uniform fashion with increasing distance from the antenna or ground feed wire. At the ground site there is a dip in the field profiles near the plot center, which occurs in all years. This is caused by an interaction between, and partial cancellation of, the fields produced by the overhead and buried ground wires. The profiles for both sites may be used to provide good estimates of the air electric field intensity at any point in the pine plantations by graphical interpolation, given the distance of the point from the antenna or ground wires. Air electric fields at the pine plantations show a marked decrease in 1993 from 1991 levels. This reflects the shielding effect of substantial tree growth (~3 feet) between the two years.

The air electric field profile for the pole stand and herbaceous reserve plots is not as uniform as that for the pine plantations. The air electric field, normally set up by the difference in potential between the antenna wire and the earth, is shielded by the tall trees at these plots. The air electric fields that do appear at these plots are the by-product of the earth electric field and are subject to the same variables as the earth electric field. Because these fields vary unpredictably across the pole stand and herbaceous reserve plots, the historic profile data can only be used to bound expected values at these plots. The data cannot be used to accurately predict field intensity levels at other points within the plots.

The magnetic flux density for a given current is dependent only on the distance of the measurement point from the source. The profiles for this field are therefore the most predictable and stable of those measured. As shown in Figures 23 and 24, the fields decrease uniformly with increasing distance from their sources. At the ground site, a dip in the magnetic flux density profile near the plot center, similar to that seen for the air electric field, occurs in all years. This, again, is caused by a partial cancellation of the fields generated by the overhead and buried ground wires. These profiles may be used to estimate the magnetic flux density at any point within the treatment sites with very good accuracy.

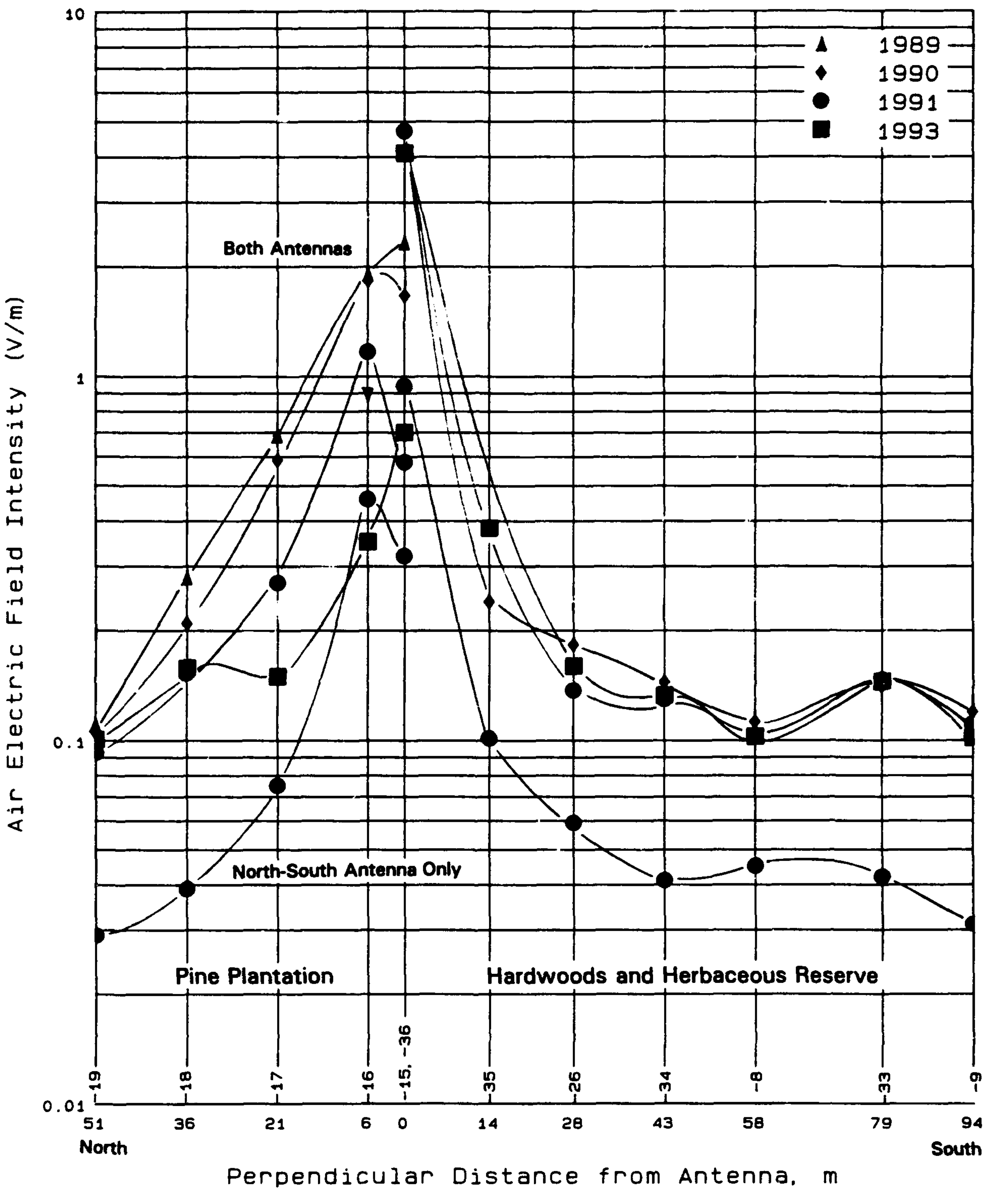


FIGURE 21. 76 HZ AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (OVERHEAD) ML; 4T2-8, 9, 15-18, 26, 33-36.

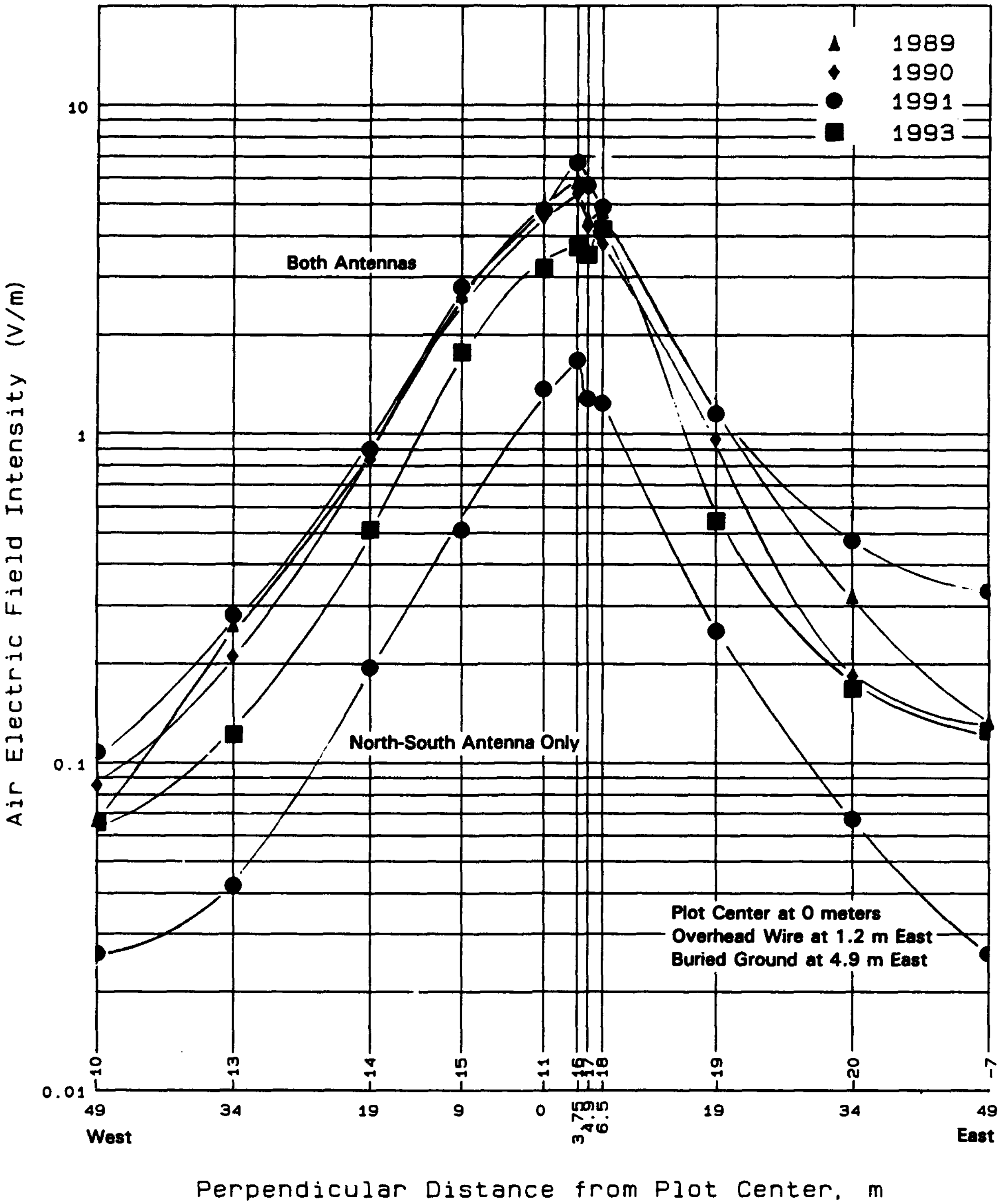


FIGURE 22. 76 HZ AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (BURIED) EP; 4T4-7, 10, 11, 13-20.

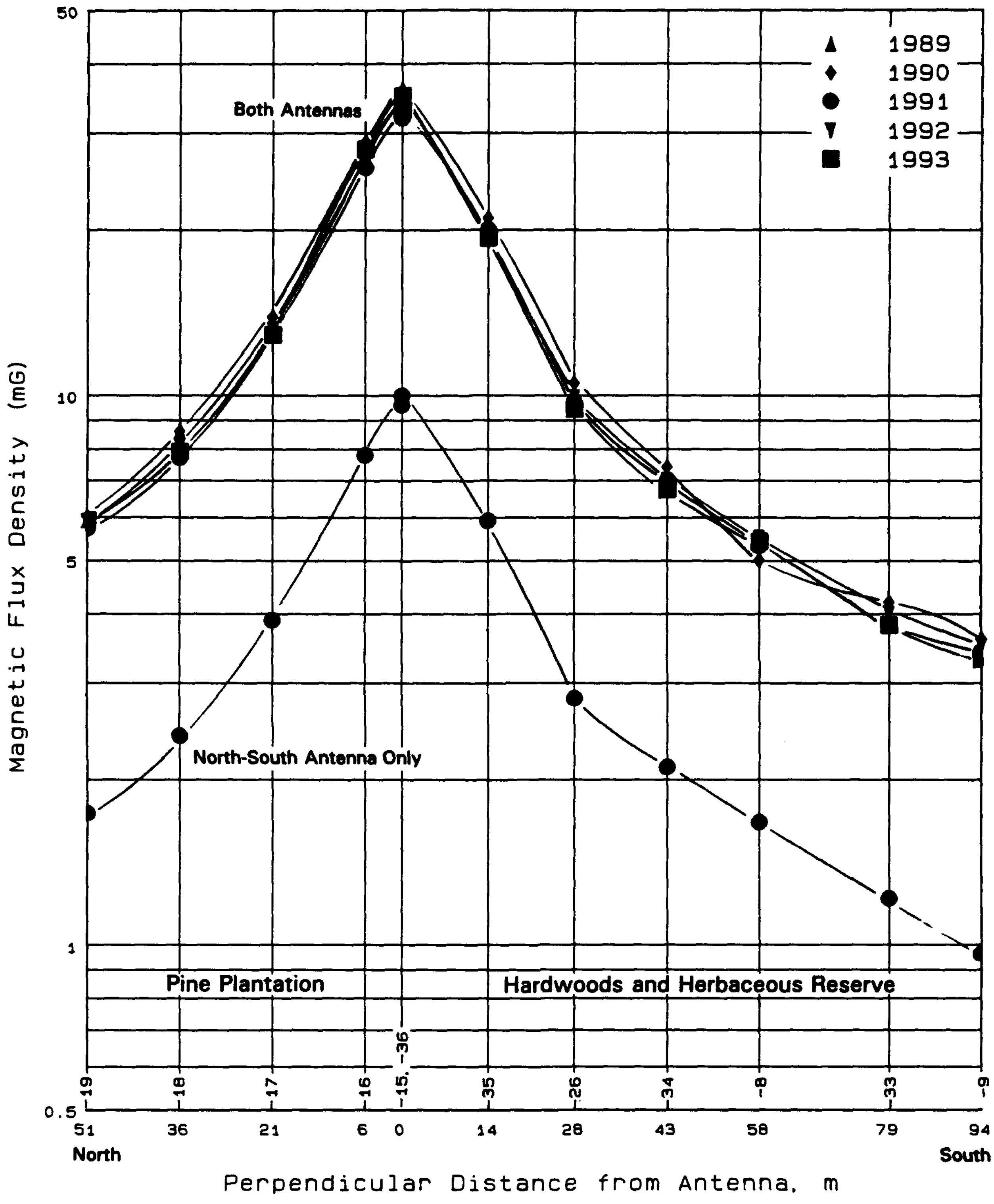


FIGURE 23. 76 HZ MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (OVERHEAD) ML; 4T2-8, 9, 15-19, 26, 33-36.

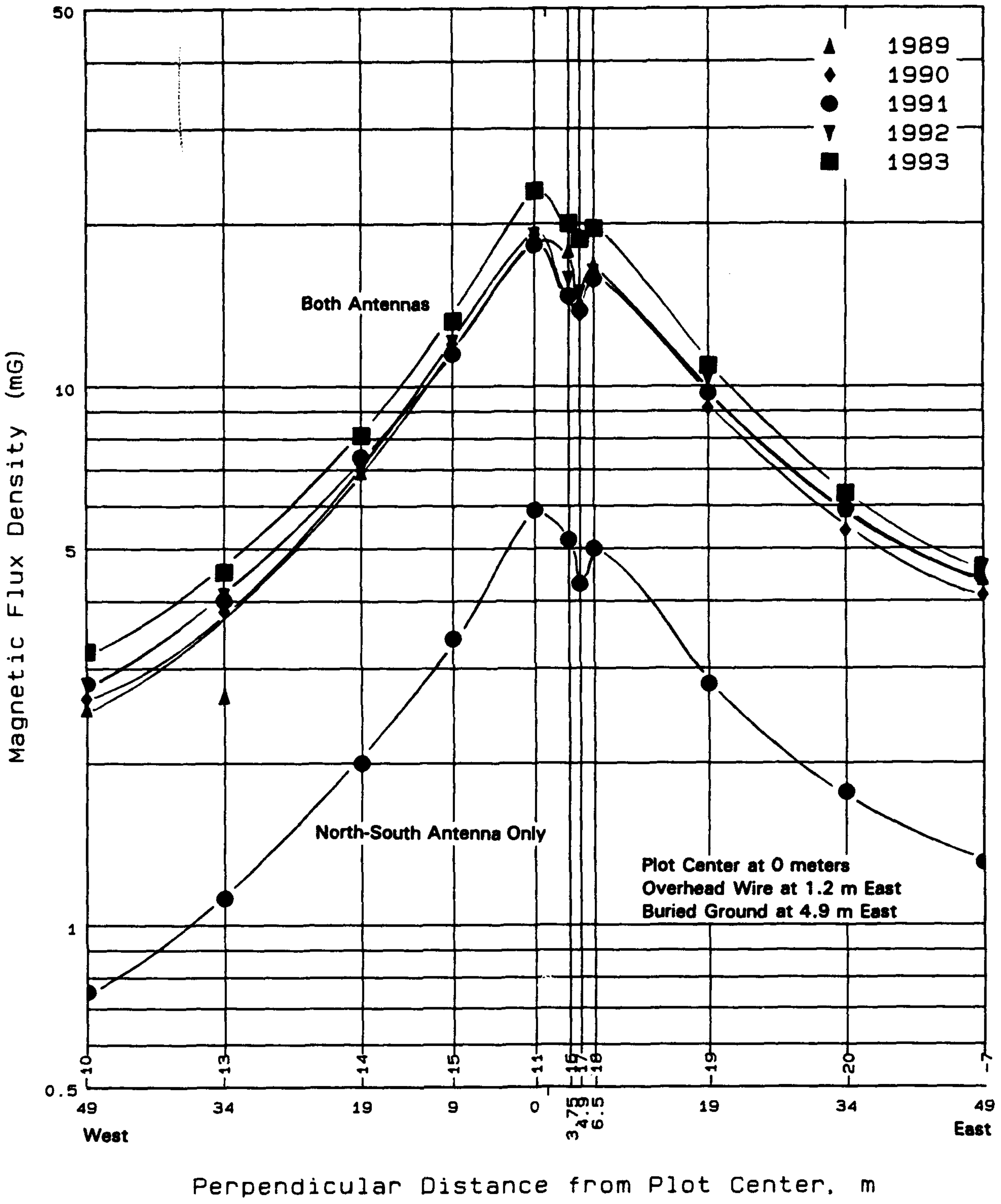


FIGURE 24. 76 HZ MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (BURIED) EP; 4T4-7, 10, 11, 13-20.

In 1993, earth electric field values for the upland flora and soil microflora treatment sites were obtained from three measurement sources:

- annual survey (once)
- fixed probes (biweekly)
- data logger monitors (hourly)

For comparative purposes, values used to construct profiles across the treatment and control sites (for locations see Figures D-3 and D-4) are summarized in Table 10 and plotted in Figures 25 and 26. Average values determined by fixed probe measurements closely agree with those recorded by the data loggers. Annual survey values, however, were just as likely to fall within as outside one standard deviation of the values recorded by the loggers.

The data also show that the earth electric fields at the antenna site (4T2) do not consistently decrease with distance from the antenna as might be expected from Equation 6. This inconsistency may be due to subterranean rock or grounding structures associated with meteorological monitoring equipment (see Section 4.4.2.4 for further discussion). At the ground site (4T4), the electric fields were distributed as predicted by Equation 7, with a null directly over the buried grounding wire and relatively high peaks on either side of the wire.

Because the earth electric field behaves unpredictably across these treatment sites, the annual historic, data logger, and fixed probe data will not provide very accurate estimates of the earth fields at other points at these sites. To improve on these estimates, an extensive set of earth electric field measurements was made at these sites in 1990. These measurements, made at locations on a uniformly spaced grid, were used to create contour maps of the field.[11] Results of this effort are presented in Appendix D.

4.4.1.3 Measured Earth Electric Field vs. Soil Depth. The effects of soil depth on earth electric field intensities may be of importance for ecological studies investigating plants or ground-dwelling organisms. In 1991, the principal investigator for the earthworms and soil arthropods study requested such information to examine possible correlations between earth electric field intensities and earthworm distributions among soil layers. In response, IITRI designed and fabricated special coaxial electrodes to measure the earth electric field in the three soil horizons specified by the principal investigator. The depths specified were 5 cm, 25 cm, and 60 cm. In actuality, the electrode measurement spans were 0 to 5 cm, 25 ± 4 cm, and 60 ± 6 cm in order to provide enough electrode surface area for good soil contact. Pairs of these 1-m-spaced, coaxial electrodes were installed at two locations within each study site (labeled E3 in Figures 17 and 18) and connected to data loggers for continual monitoring.

Monitoring of coaxial electrodes has continued since 1991. Graphs of the multidepth electric field measurements from 1993 are provided in Figures 27 and 28. The electric fields and soil temperatures presented in these graphs are daily averages of hourly measurements. Air temperatures are the daily

TABLE 10. 1993 EARTH ELECTRIC FIELD STATISTICAL SUMMARY FOR THE PERIOD 1 JANUARY-10 NOVEMBER
Upland Flora and Soil Microflora Studies

	Data Logger				Fixed Probe				
	No. of Data Points	E-Field, mV/m		Coefficient of Variation	No. of Data Points	E-Field, mV/m		Coefficient of Variation	Annual Survey, mV/m
Location		Mean	S.D.			Mean	S.D.		
Antenna Site, Hardwood Stand									
4T2-36	7045	128	22	0.172	16	128	11.3	0.088	120
4T2-35	7054	133	7.2	0.054	16	138	4.3	0.031	142
4T2-26	7051	200	17.7	0.089	16	204	11.9	0.058	163
4T2-34	7053	102	15.4	0.151	16	105	11.0	0.105	100
4T2-8	7051	133	8.4	0.063	16	133	11.8	0.089	107
4T2-33	7053	94	12.1	0.129	16	96	5.4	0.056	128
4T2-9	7052	135	23	0.170	16	133	6.4	0.048	114
Antenna Site, Pine Plantation									
4T2-15	6588	57	9.8	0.172	16	57	1.69	0.030	72
4T2-16	6465	95	10.5	0.111	16	90	3.3	0.037	71
4T2-17	6577	89	9.1	0.102	16	96	5.9	0.061	91
4T2-18	6598	98	9.5	0.097	16	102	6.1	0.060	91
4T2-19	6597	98	12.0	0.122	16	97	3.9	0.040	85
Ground Site, Pine Plantation									
4T4-7	4798	133	13.6	0.102	16	133	5.6	0.042	161
4T4-20	4361	196	22	0.112	16	181	18.0	0.099	152
4T4-19	6248	670	39	0.058	16	670	30	0.045	430
4T4-18	5945	3500	730	0.210	16	3900	1060	0.270	2800
4T4-16	6248	2900	410	0.141	16	3200	570	0.178	2700
4T4-15	6247	690	108	0.157	16	740	102	0.138	720
4T4-14	6248	220	31	0.141	16	230	25	0.109	210
4T4-13	5255	44	12.2	0.280	16	36	3.8	0.106	52
4T4-10	-	-	-	-	16	16.0	1.56	0.098	38

S.D. = standard deviation.
\- = not a data logger measurement point.

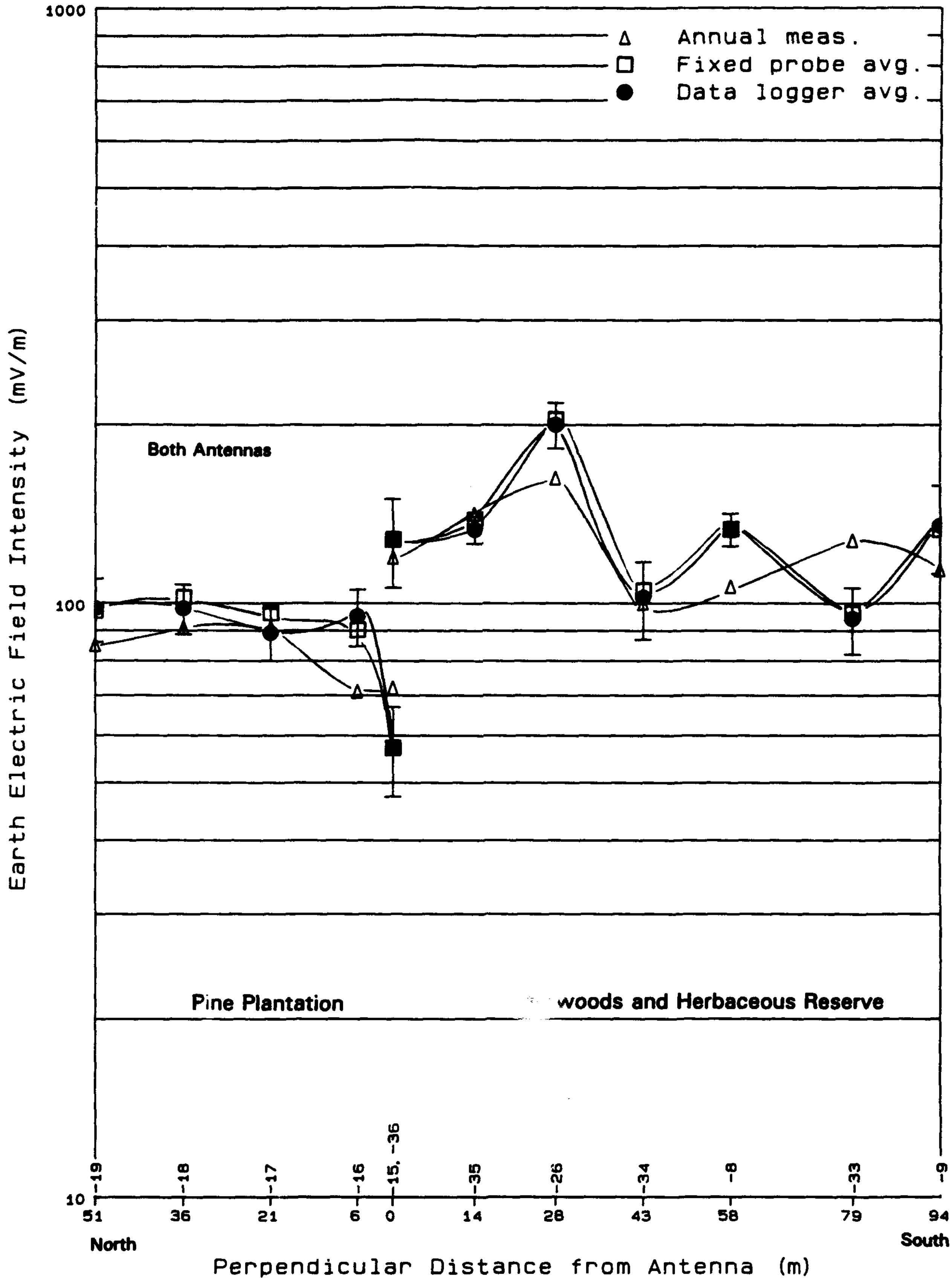


FIGURE 25. COMPARISON OF 1993 76 HZ EARTH ELECTRIC FIELD MEASUREMENTS AT SITE 4T2.

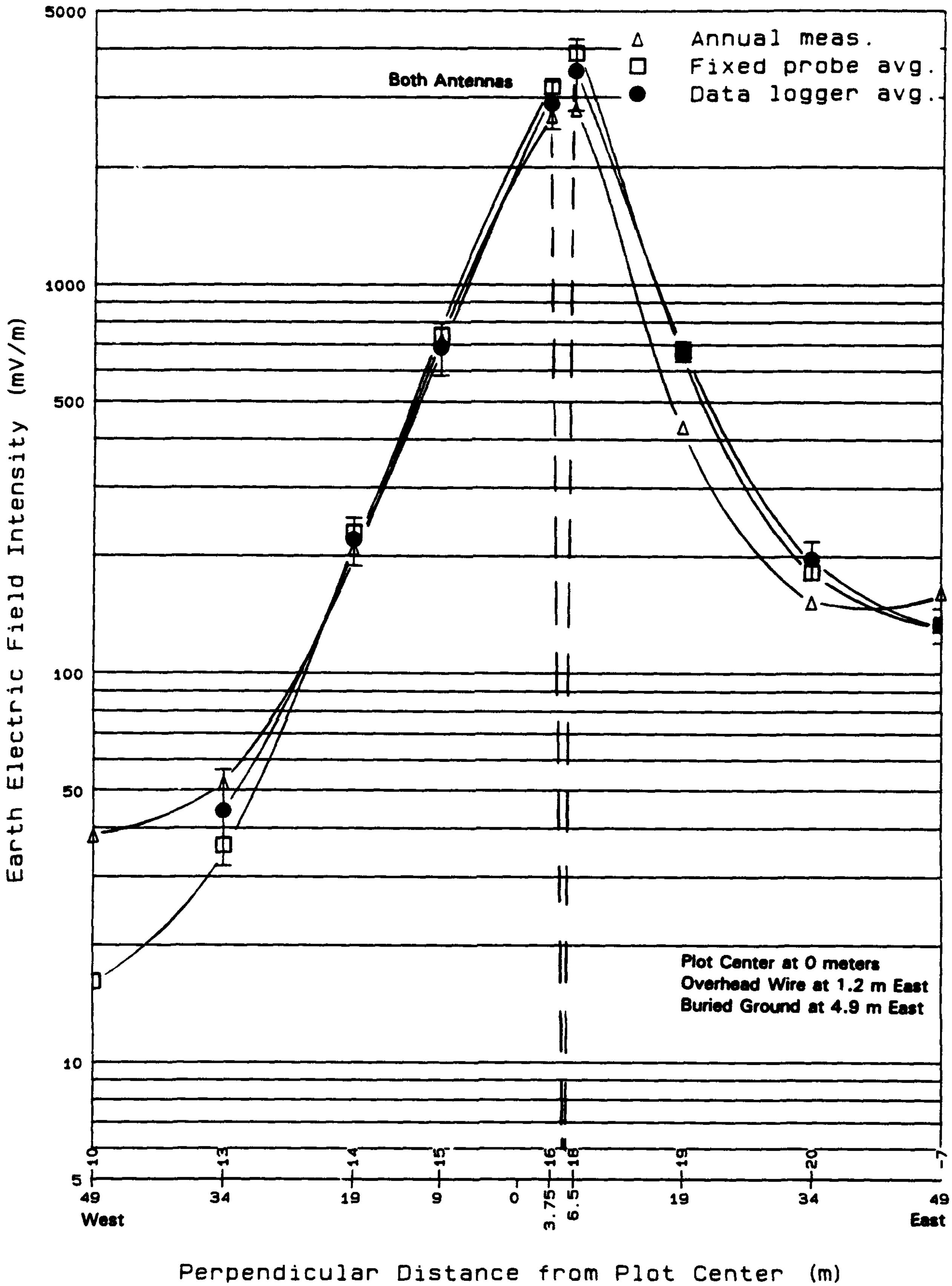


FIGURE 26. COMPARISON OF 1993 76 HZ EARTH ELECTRIC FIELD MEASUREMENTS AT SITE 4T4.

maximum and minimum, and rainfall is the daily total. Valid electric field data were not obtained for the 5 cm depth probe E3-A at the control site and, therefore, do not appear in Figure 28. A statistical summary of the multidepth electric field measurements, based on the discrete hourly data, appears in Table 11. The table shows that the overall variation for each probe, measured as the ratio of the standard deviation to the mean, was small—less than 5 percent at the treatment site and less than 7 percent at the control site. In 1993, as in previous years, no consistent intensity versus depth pattern was observed across either site. The order of intensity with depth was fairly consistent for each probe location but differed from location to location. The amount of variation with depth that was measured for each probe was very small. At the treatment site, field intensity averages differed by 1.1 and 2.6 percent (maximum) at each probe. This difference was greater at the control site, 6 and 10 percent, but probably still not of concern for spatial comparisons because the control site field intensities are about 200 times less than those at the treatment site. In summary, these data show that the earth electric field may be dependent upon soil depth, but this dependence is location specific. Also, the amount of variation at the depths examined is small relative to variations across the sites. For example, the maximum variation with depth at the treatment site was 2.6 percent, while the variation between the two probe locations was 11.4 percent.

TABLE 11. 1993 MULTIDEPTH EARTH ELECTRIC FIELD STATISTICAL SUMMARY
Soil Arthropods and Earthworms Studies

Site	Probe	Depth, cm	No. of Data Points	E-Field, mV/m		Coefficient of Variation, %
				Mean	S.D.	
Treatment (3T2)	E3-A	5	6957	60.5	2.6	4
		25	6957	61.0	1.6	3
		60	6957	61.2	2.0	3
	E3-B	5	6957	55.7	1.1	2
		25	6957	54.5	1.0	2
		60	6957	54.2	1.1	2
Control (3C5)	E3-A	25	6320	0.212	0.014	6
		60	6304	0.198	0.013	7
	E3-B	5	6316	0.277	0.013	5
		25	6311	0.313	0.018	6
		60	6315	0.276	0.013	5

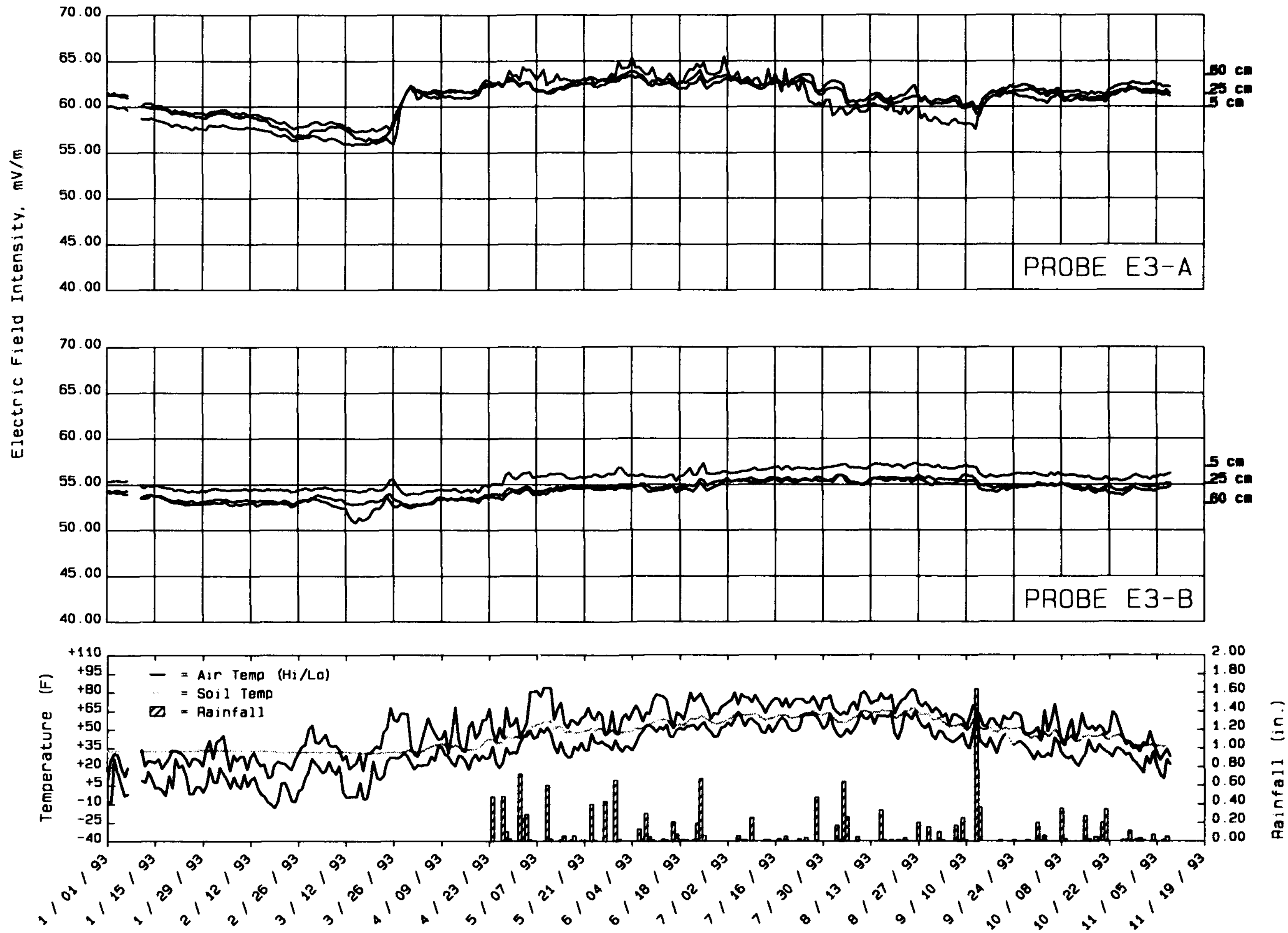


FIGURE 27. DAILY AVERAGE 76 Hz ELECTRIC FIELD INTENSITIES VS. SOIL DEPTH AT EARTHWORM TREATMENT SITE.

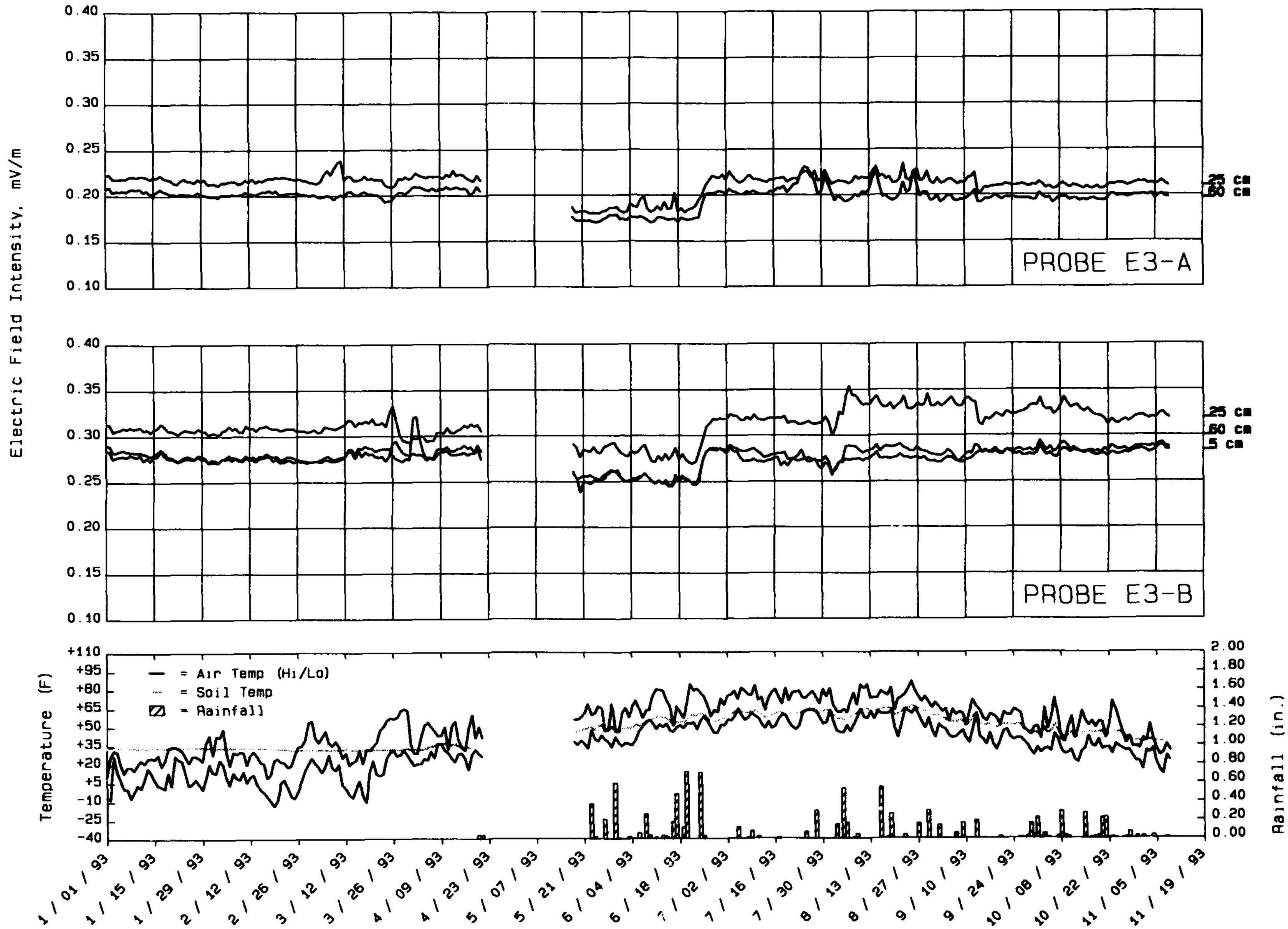


FIGURE 28. DAILY AVERAGE 76 Hz ELECTRIC FIELD INTENSITIES VS. SOIL DEPTH AT EARTHWORM CONTROL SITE.

4.4.2 Temporal Field Variability

4.4.2.1 Predicted Sources of Temporal Variation. Annual EM field measurements generally have been made in late summer and early fall. Since most biota remain on the study sites throughout the year, EM field variations over the course of a year are important. Temporal EM variations are related to differences in the operating parameters of the ELF transmitters and to climatic variables such as temperature, rainfall, and soil moisture levels. The mathematical descriptions of the fields given at the beginning of Section 4.4 show the functional relationships of the EM field variables and provide a basis for understanding and predicting temporal variations. Measurements of temporal EM field variations are presented in Subsections 4.4.2.2 through 4.4.2.5.

The magnetic flux density is the least variable of EM fields. It is described by Equation 5, which is valid for the magnetic flux density in both the air and the earth. This equation may also be used to predict the magnetic flux density resulting from ground wire currents by replacing "h" with "d." The magnetic flux density at any point is dependent only on antenna current and distance from the antenna. It is not expected to show seasonal variation, because it is not affected by the conductivity of surrounding vegetation and soil and it does not vary with the antenna frequency.

The total earth electric field at any point is the sum of that induced by the magnetic field and that generated by current conducted from the buried ground terminals. Equations 6 and 7 describe the distribution of the earth electric field near antenna ROWs and ground terminals as a function of current, frequency, and soil conductivity. Note that the conducted electric field is dependent on the ground wire current only, while the magnetically induced electric field is dependent on both the antenna current and the frequency. Thus, significant variations in the induced earth electric field are expected with changes in the antenna operating frequency. If used, electric field intensities during possible 44 Hz operation would be a little more than half the intensity levels induced during normal 76 Hz operation. Smaller and less obvious changes in field intensity are also expected because of the MSK signal used by the ELF antennas (see Section 1.2). Although this report generally refers to the MSK signal by its center frequency, the antenna frequency actually shifts between two frequencies 8 Hz apart. This changing frequency will also result in a changing induced electric field intensity.

In Equations 6 and 7, earth conductivity is the only variable that is expected to show a seasonal variation. In both cases, the field intensities are dependent on soil conductivity, which in turn varies with changes in soil moisture and temperature. The two conductivity terms (bulk and surface) are not equivalent, and have different functional relationships within the corresponding electric field equations. The earth electric field near ground terminals is dependent primarily on surface earth conductivity, while bulk earth conductivity determines the electric field near antenna ROWs. The bulk earth conductivity is a weighted average of the surface and deep earth conductivities. Because the deep earth conductivity remains stable throughout the year, the bulk earth conductivity shows less seasonal variation than does the surface earth conductivity. Therefore, the earth electric field is almost twice as sensitive to changes in conductivity near ground terminals as it is to changes in conductivity along antenna ROWs. This fact, in conjunction with the expected higher variation in surface conductivity, indicates that the greatest seasonal variations in earth electric fields will occur along ground terminal ROWs. Additional earth electric field variability can result if either conductivity term is itself frequency-dependent.

The air electric field in an ROW or a clearing near the antenna is essentially dependent only on the antenna voltage, and the distance to and height of the antenna wire. It should be noted that the antenna voltage is constant for a given antenna current, and there is no frequency-dependent term in Equation 8. The air electric field is also independent of soil conductivities and humidity. Therefore, it is not expected to show climate-induced variation at unshielded locations throughout the year. However, at other locations where the air electric field is shielded by vegetation and trees, or generated as a by-product of the earth electric field, more seasonal variation is expected as plants grow or lose foliage or as the earth electric field varies. Such variations in the air electric field would be difficult to quantify to any useful degree.

4.4.2.2 Measured Frequency-Related Electric Field Variations. The expected variations in the induced earth electric field caused by antenna frequency changes have, in fact, been observed in measurements made during periods of 44 and 76 Hz antenna operations. Also detectable are the less dramatic electric field variations that are associated with the MSK modulation. The amount of field variation measured during MSK operation (9 to 10 percent at 76 Hz, 16 to 17 percent at 44 Hz) is consistent with the percent frequency shift of the MSK signal. Similarly, the 44 and 76 Hz field intensity levels are proportional to the signal center frequency. Throughout 1993, essentially all antenna operations were with a 76 Hz MSK signal. The best examples of measured frequency-related electric field variations, therefore, come from earlier years, when multiple frequencies and signal types were used, and are well documented in previous reports.[7,11] Frequency variations of concern in 1993 are limited to those associated with MSK signal operation.

4.4.2.3 Fixed Probe Seasonal Measurements. The 1990 contour drawings presented in Appendix D provide for the most accurate earth electric field spatial estimates at the MTU treatment study sites. They do not, however, provide precise information on the temporal variation of these field intensities. For this reason, fixed earth electric field probes were installed in 1990 at 40 measurement points at the antenna and ground treatment sites for these studies. This measurement set was expanded in 1991 to include the electrode pairs monitored by data loggers. The fixed probe locations are shown, together with the historic and data logger measurement points, in Figures D-3 and D-4. Fixed probe measurements have been made twice a month, with the expectation of identifying long-term or seasonal variations at these points. Fixed probe measurements and summary statistics for June 1990 to mid-November 1993 are listed in Tables D-10 through D-13. The fields at the fixed probes have displayed a wide range of coefficients of variation. Reasons for this variation are discussed in the next section.

4.4.2.4 Data Logger Seasonal Measurements. Data logger monitoring systems were installed at soil amoeba study sites in 1988 and have been in operation since then. In 1991, six additional data logger systems were installed at the earthworm, upland flora, and aquatic ecosystems study sites for long-term monitoring of earth electric field variability. Measurement parameters for each of the new logger systems are presented in Table 12. The 1993 data for the earthworm study sites as well as the monitoring system layouts have already been presented in Sections 4.2.2.2 and 4.4.1.3. Summary plots of 1993 logger data for the upland flora and aquatics study sites are presented here. The aquatic ecosystems logger monitoring system also is diagrammed in this section. Layout drawings of the three data logger monitoring systems at the upland flora treatment study sites are shown in Figures D-3 and D-4 in Appendix D. Comprehensive plots of the soil amoeba test chamber data logger measurements for the 1988 through 1991 field seasons appear in Appendix F. Soil amoeba test chambers were not used in 1992 and 1993, although some data logger weather monitoring continued at study sites. These data are also presented in Appendix F.

TABLE 12. 1991-1993 DATA LOGGER MEASUREMENT PARAMETERS
Earthworms, Upland Flora, and Aquatics Studies

	Data Logger Site Identification*					
Measurement Parameter	3C5	3T2	4T2H	4T2P	4T4	5T2
Earth Electric Field (Surface)	•	•	•	•	•	•
Earth Electric Field (3-Depth)	•	•				
Incubation Bag Electric Field	•	•				
Data Logger Case Temperature	•	•	•	•	•	•
Air Temperature	•	•	•	•	•	•
Soil Temperature (5 cm)	•	•				
Soil Temperature (10 cm)	•	•	•	•	•	•
Rainfall	•	•				

*3C5 = earthworms control site.
3T2 = earthworms treatment site.
4T2H = upland flora antenna site, hardwood stand.
4T2P = upland flora antenna site, pine plantation.
4T4 = upland flora ground site, pine plantation.
5T2 = aquatic ecosystems treatment site.

Daily averages of the hourly earth electric field intensity measurements at the upland flora logger sites for 1993 are plotted in Figures 29 through 31. Weather-related parameters that might be expected to affect the electric field intensity levels are on a separate grid below the main plot. The soil temperatures presented were taken by the IITRI data loggers, while the air temperature and rainfall data are from the study researchers' ambient monitoring system (referred to by their affiliation--Michigan Technological University, MTU). The source of the MTU weather data is noted parenthetically in the legend. An "A" or "G" is used to designate the antenna or ground site, and a "P" or "H" is used to designate pine plantation or hardwood stand.

The spatial variability of the data logger earth electric field measurements at the upland flora sites was discussed in Section 4.4.1.2. Table 10, in that section, listed statistical summaries for these data, which are useful in discussion of temporal variations. Overall, variations at the upland flora treatment sites are the greatest of those monitored. Coefficients of variation for probes at these sites, which are included in Table 10, range from 5 to 17 percent for the antenna site and 6 to 28 percent for the ground site. Variations based on less frequent fixed probe measurements at the same locations are somewhat less—3 to 10 percent at the antenna site and 3 to 27 percent at the ground site. By comparison, the coefficient of variation for the earthworm treatment site three-depth probes was 2 to 4 percent; and in the riverbed for the aquatic ecosystems study, it was 5 to 9 percent.

Three factors, which are believed to have contributed to greater electric field variation at the MTU study sties, are considered here. First, for reasons discussed in Section 4.4.2.1, seasonal variation is expected to be greater near ground terminal ROWs than near antenna ROWs. As the coefficients of variation show, the MTU ground site has greater variation than other study sites located in antenna ROWs, including the nearby MTU antenna site.

The second factor, which is related in principle to the first, was observed in 1990 after performing extensive measurements for development of electric field contours. The contours (see Figures D-7 and D-8) identify areas of abnormally high electric field intensity. These elevated electric fields resulted from currents induced on cable sheaths that run from environmental sensors to an on-site communications station. As part of a lightning protection plan, these cable sheaths were grounded at both the station and sensors ends, creating a current loop through the sheath and returning through the earth between the two grounding points. Electric fields generated by this ground current flow are subject to the same variables as described for an electric field near a ground terminal. Variations in earth electric fields at the antenna site, as a result, are difficult to predict because the variation associated with the cable sheath injection-current electric field just described is tempered by the less variable electric field set up by the antenna. Understanding the earth electric field variation at the ground site is no less of a task because sources of the fields there include injection currents from cable sheaths, current bleeding from the buried

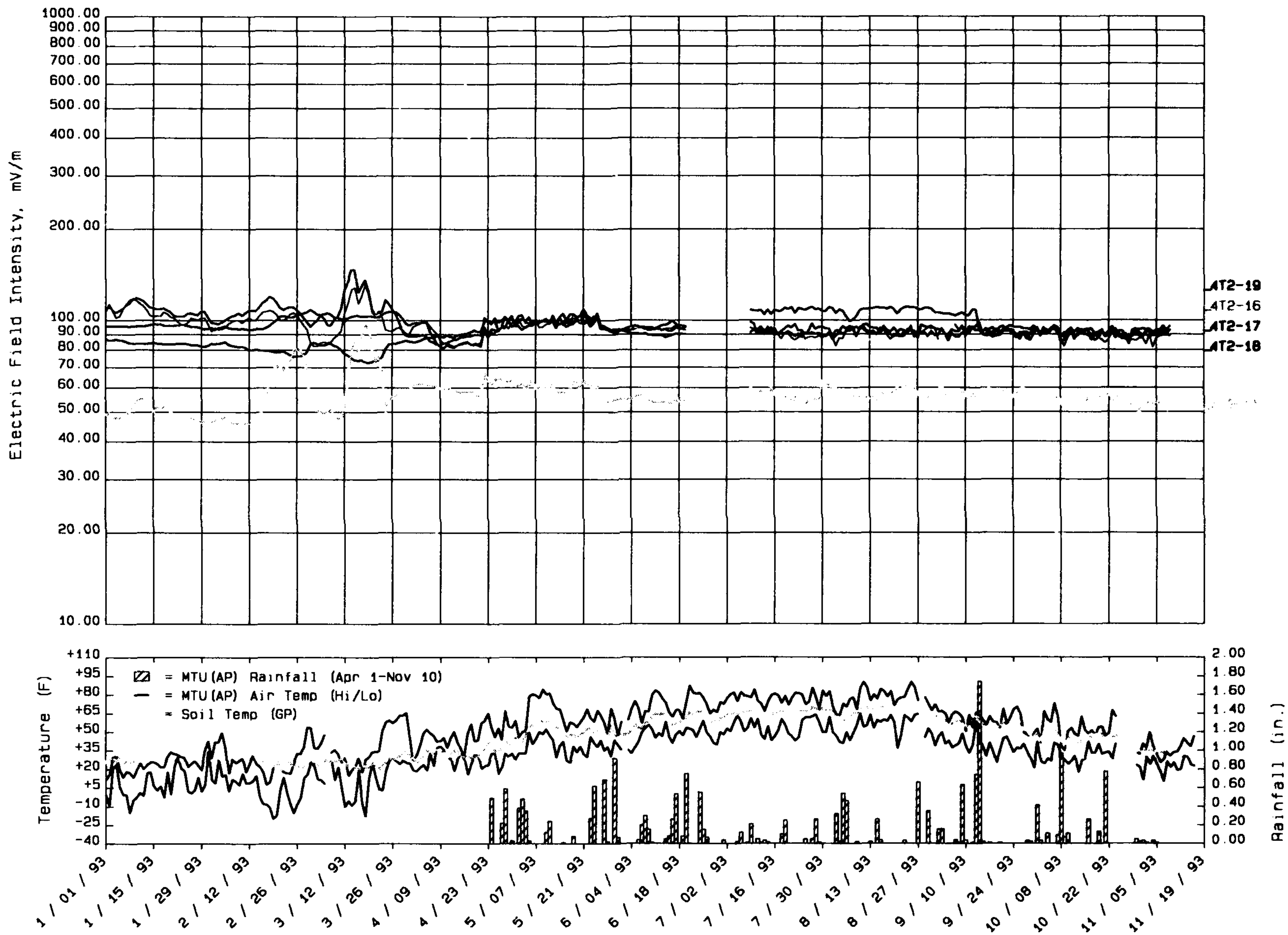


FIGURE 29. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT ANTENNA SITE PINE PLANTATION: 4T2–19, 18, 17, 16, 15.

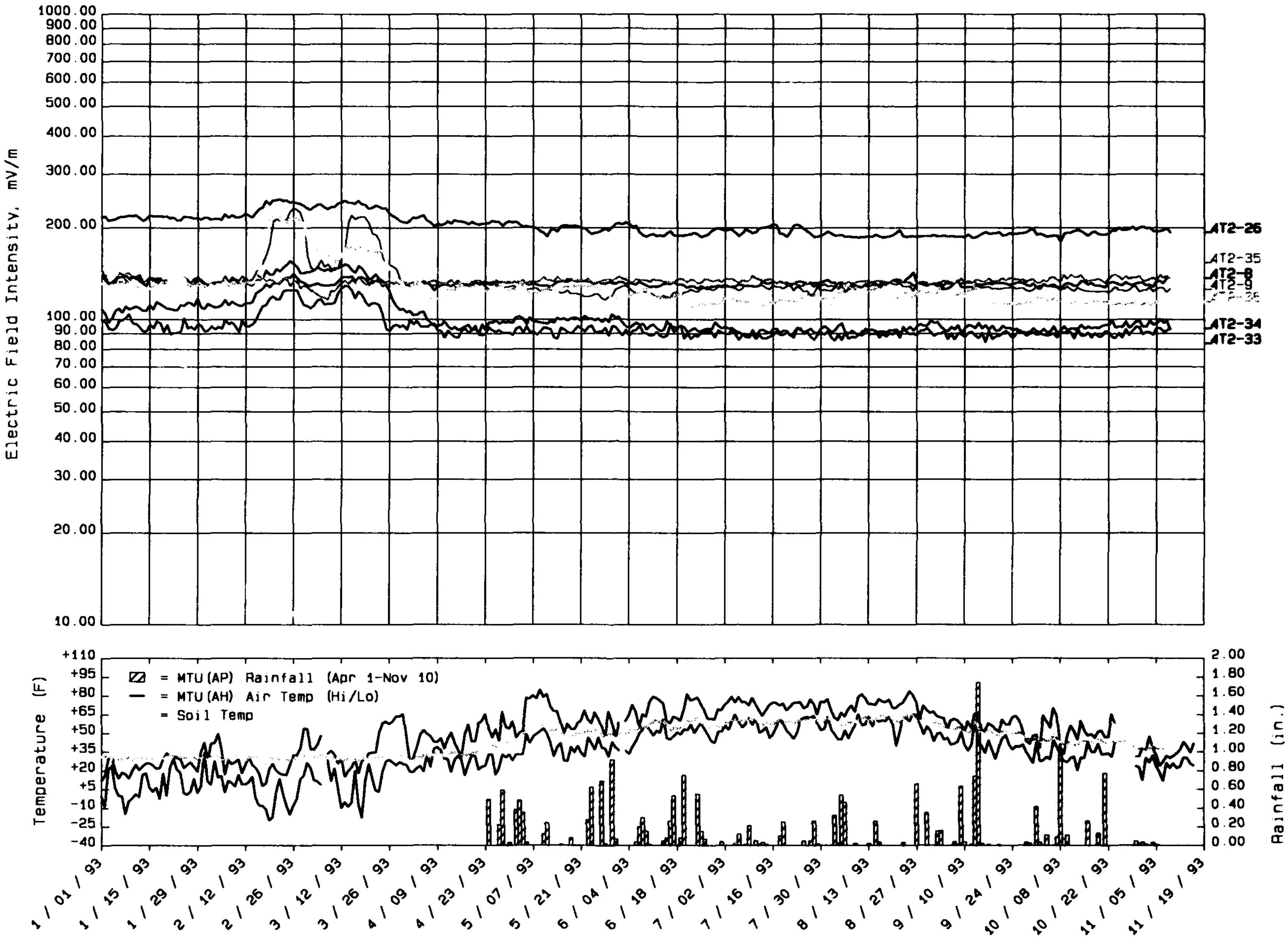


FIGURE 30. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT ANTENNA SITE HARDWOOD STAND; 4T2–9, 33, 8, 34, 26, 35, 36.

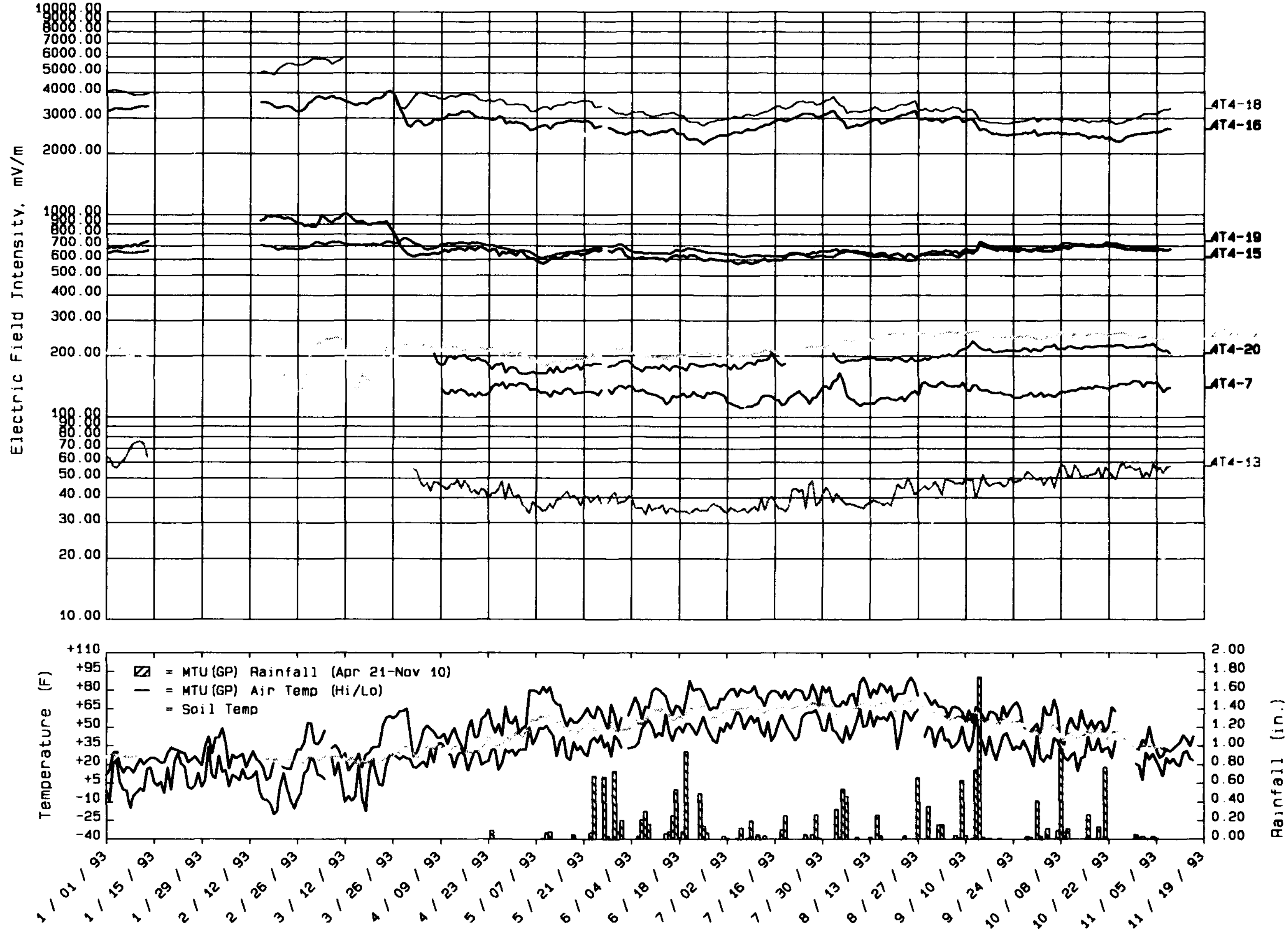


FIGURE 31. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT GROUND SITE PINE PLANTATION; 4T4-7, 20, 19, 18, 16, 15, 14, 13.

ground wire, and an overhead ground feed wire, which may be analyzed like an antenna wire, although current levels are lower.

The third factor of concern in discussion of earth electric field temporal variability is conductivity. Although this factor is applicable to all study sites, differences between sites may cause it to have a greater impact at one site than another. A wetland, for example, may experience less field variability with rainfall than a sandy pine plantation. Probably more important than differences between sites, however, is the role that conductivity plays at each site. Seasonal variation in the earth electric fields near a ground wire, as stated, is expected to be greater than near an antenna ROW. This is because of different conductivity terms (surface and bulk) and different functional relationships in the describing equations for each area (Section 4.4.2.1). These differences are applicable in discussion of the MTU study sites because of the presence of overhead wires, buried uninsulated ground wires, and long grounded cables. Field sources notwithstanding, differences between electric field variations at the MTU treatment sites and other sites may also exist solely because of differences in conductivity variations. The relative significance of such differences would be difficult to determine because of the large number of other variables involved there. At other sites, where field sources are similar, these differences can be better examined.

Figure 32 shows the layout of the data logger monitoring system at the aquatic ecosystems treatment study site. Daily averages of the earth electric field intensities measured at the four riverbed probe locations, the daily high and low air temperatures, and the hourly riverbed temperature measured by the data logger in 1993 are plotted in Figure 33. Mean, standard deviation, and coefficient of variation values are listed in Table 13. The coefficients of variation at this aquatic site are, in range, comparable to, but slightly larger than, those measured at earthworm and amoeba terrestrial sites. Because the aquatics, earthworm, and soil amoeba antenna sites have a similar mechanism of earth electric field generation (induction from antenna wire described by Equation 6), temporal variation differences between

TABLE 13. 1993 EARTH ELECTRIC FIELD STATISTICAL SUMMARY
Aquatic Ecosystems Studies

Location in River Relative to Antenna	No. of Data Points	E-Field, mV/m		Coefficient of Variation, %
		Mean	S.D.	
20 m upstream	4577	53	5	9
1 m upstream	4577	64	6	9
10 m downstream	4577	73	4	5
14 m downstream	4576	81	4	5

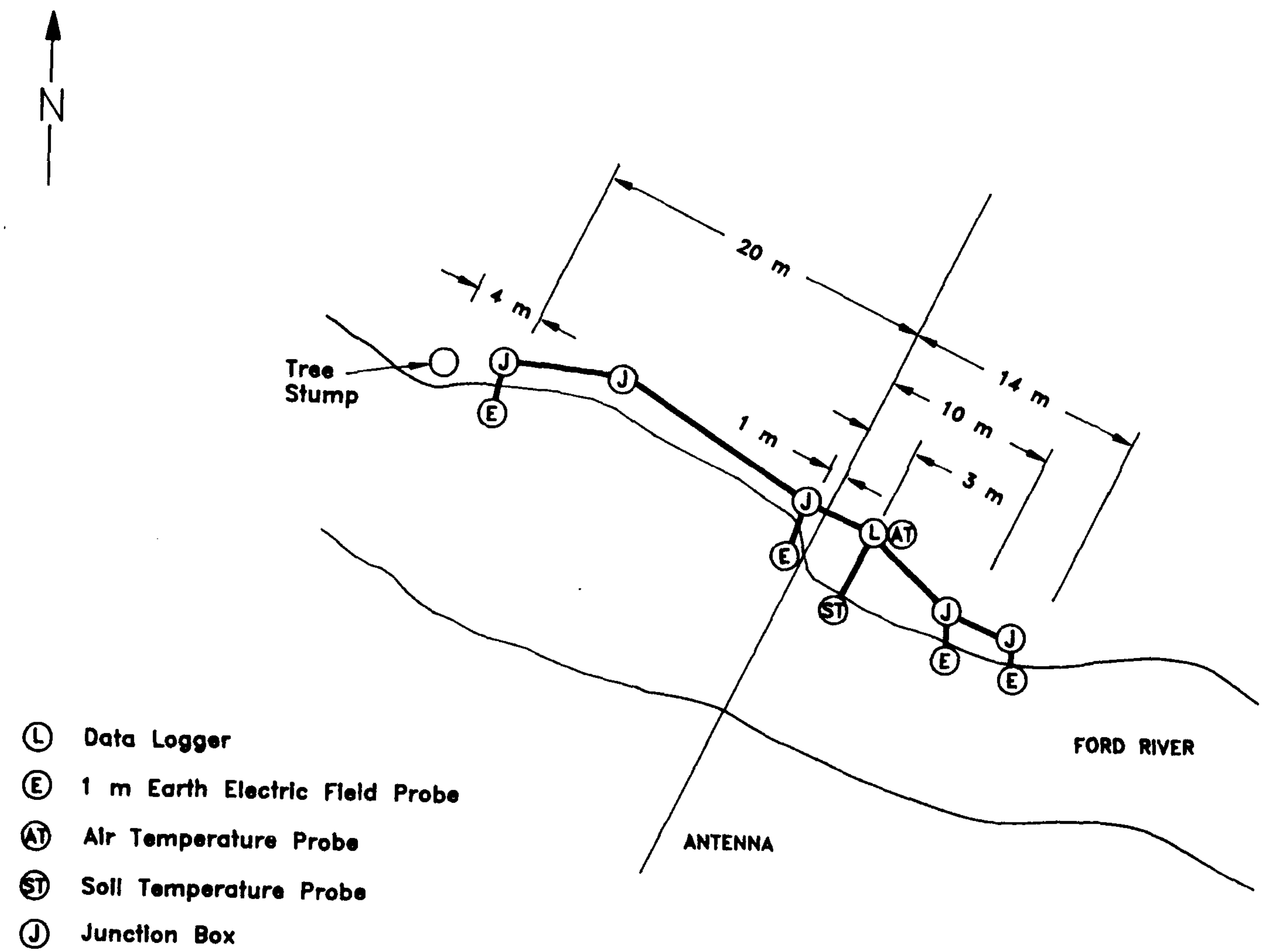


FIGURE 32. DAILY LOGGER MONITORING SYSTEM AT FORD RIVER EXPERIMENTAL SITE; 5T2.

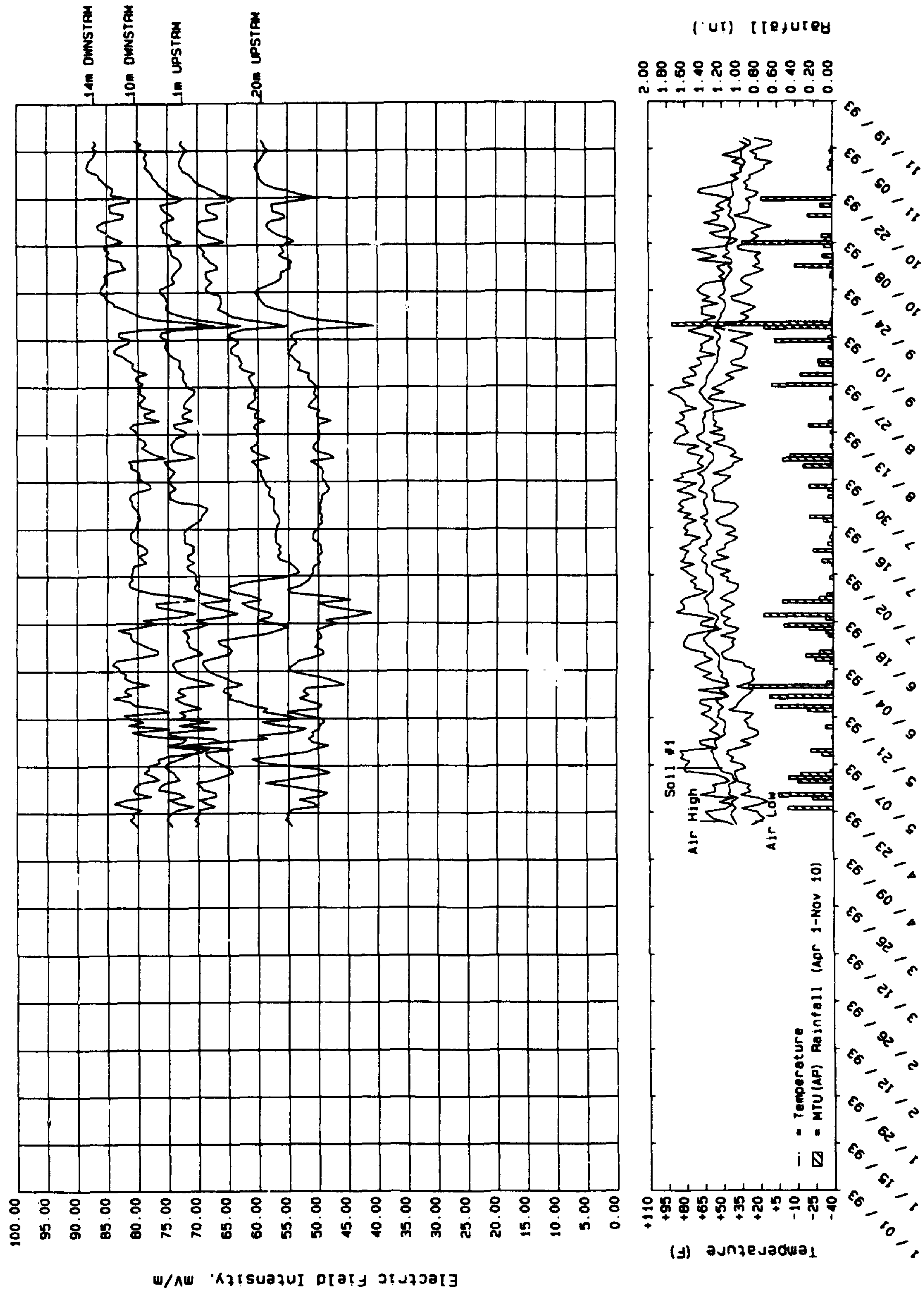


FIGURE 33. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT FORD RIVER EXPERIMENTAL SITE; 5T2.

these can be expected to be primarily related to differences in conductivity between the sites. Table 14 summarizes the coefficients of variation calculated for selected study sites. In review, the coefficient of variation at the aquatics site ranged from 5 to 9 percent in 1993. Variation at the earthworm site (three-depth probes) was 2 to 4 percent in 1993 and at the similarly forested soil amoeba antenna site, 3 to 4 percent in 1991 when data logger electric field measurements were last performed there. Soil amoeba data logger measurements are presented in Appendix F. These data indicate that the bulk conductivity associated with the river environment was more variable than that in a forest floor.

Rainfall is thought to be the major factor affecting riverine conductivity. Figure 33 illustrates the effects of rainfall on the earth electric field intensity in the river. Rainfall activity, as measured at the MTU antenna site (about 10 miles north of the aquatics treatment site), is closely associated with earth electric field decreases. This is believed to occur as the result of water runoff into the river carrying ions that increase the water conductivity and thereby decrease the electric field intensity (Equation 6).

4.4.2.5 Data Logger Measured Diurnal Variation. All hourly measurement data from the upland flora study sites were also examined for diurnal variations in 1991. Such variations were most apparent near the buried ground wire and are illustrated in the hourly data presented in Figure 34. To clarify the diurnal pattern, the data plotted in this figure were averaged by hour of day for the 28-day period. The hourly averages are plotted in Figure 35. A clear peak in the average field intensity is visible at 8:00 a.m. and a null at 8:00 p.m. for this probe and time period. The daily variation was about 3.5 percent.

TABLE 14. VARIABILITY OF ELF EARTH ELECTRIC FIELDS AT SELECTED STUDY SITES DURING FULL-POWER OPERATION OF NRTF-REPUBLIC

		Coefficient of Variation, %	
Study	Data Year(s)	Antenna Site	Ground Site
Earthworm Soil Mesofauna			
Single electrode	1992-1993	1-3	—
Triple electrode	1993	2-4	—
Amoeba	1990-1991	3-4	12-22
Aquatic Biota			
Single electrode	1992-1993	4-9	—
Four electrodes	1993	5-9	—
Upland Flora			
12 electrodes	1992-1993	5-17	—
9 electrodes	1992-1993	—	6-28

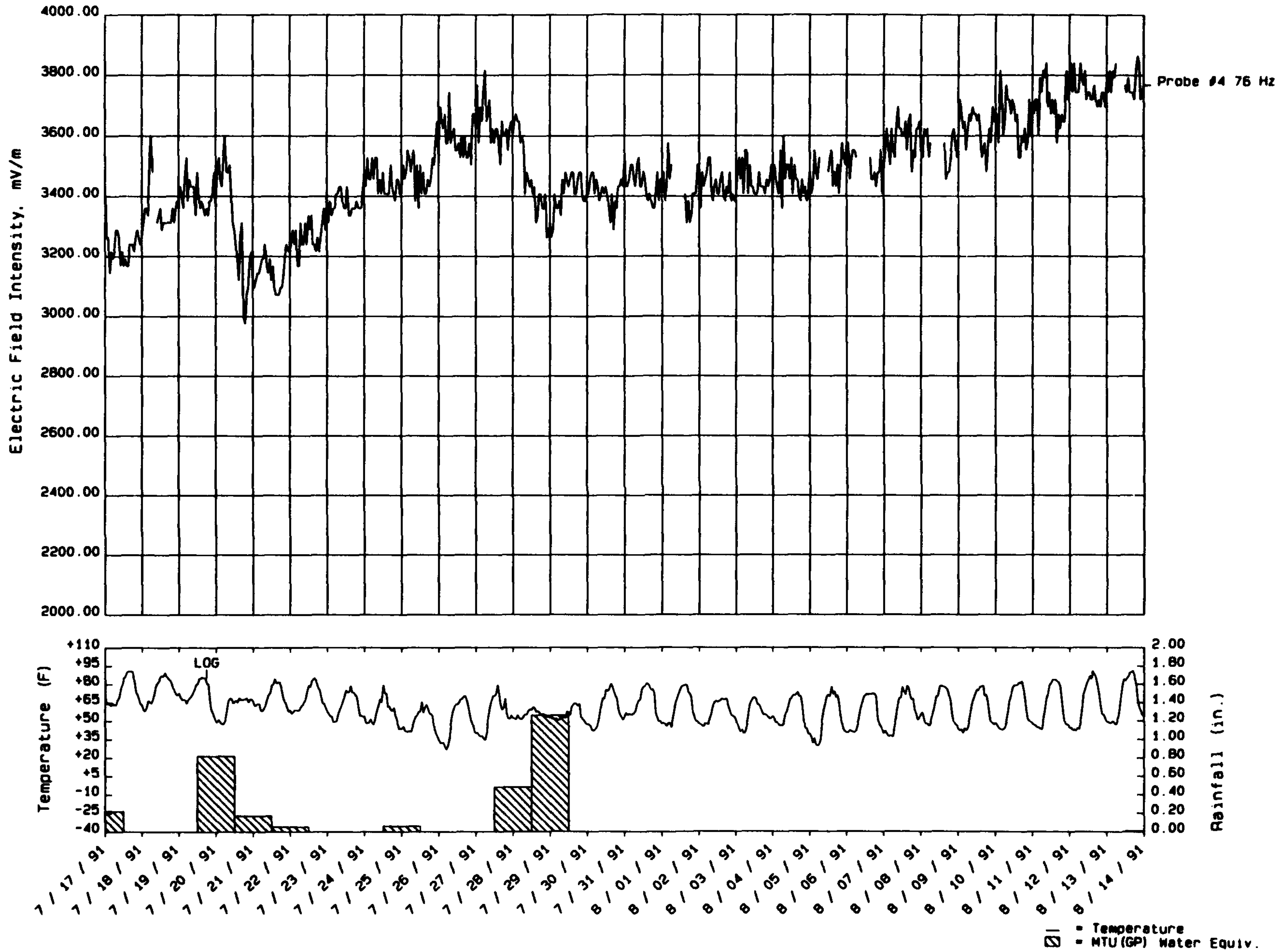


FIGURE 34. HOURLY EARTH ELECTRIC FIELD INTENSITIES AT GROUND SITE PINE PLANTATION; MEASUREMENT POINT 4T4-18.

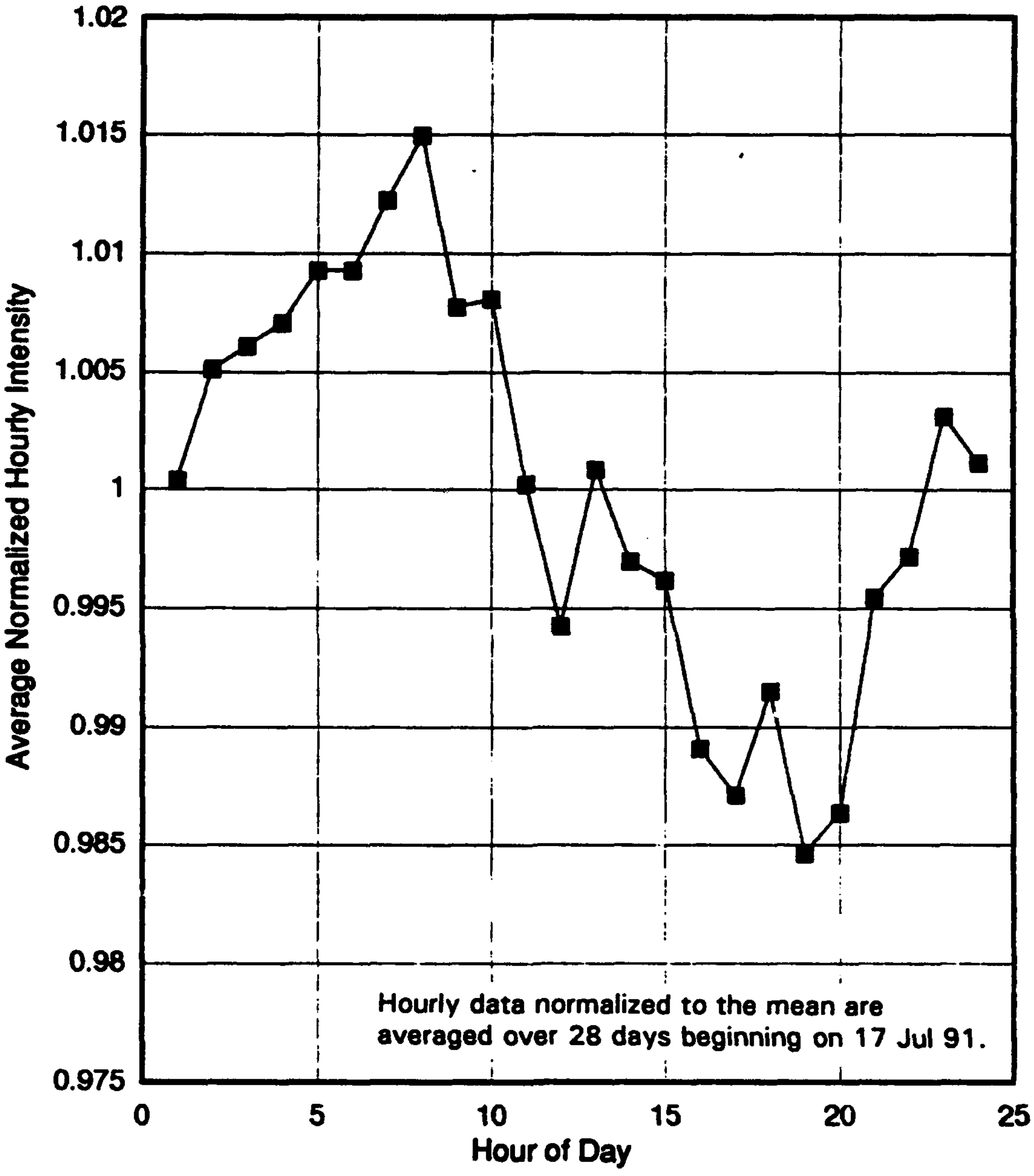


FIGURE 35. EARTH ELECTRIC FIELD DIURNAL CYCLE AT GROUND SITE PINE PLANTATION: MEASUREMENT POINT 4T4-18.

Similar analyses were done for several other probes at both the antenna and ground sites for this study. Although diurnal variations were not identified for all locations and/or time periods, they were observed at both sites. When present, diurnal changes were typically less than 5 percent.

4.5 Transmitter Operations--Analysis and Data Base

4.5.1 Operating Log Data Base

In order to calculate the EM exposure regimes, study investigators must have both field intensity values at their study sites as well as the duration of exposure. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through G. Data on the duration of antenna operations were provided to IITRI by the Navy's Submarine Communications Project Office. In addition, information on operating frequency, modulation, power, and phasing between antenna elements were provided. This information was entered into a computer data base from which both graphic and tabular operating condition summaries were formed. Graphic summaries for the NRTF-Republic are presented in this section; more detailed tabular summaries appear in Appendix J. IITRI provides the data bases to the study investigators on request.

4.5.2 Summary of NRTF-Republic Operations, 1986-1993

The NRTF-Republic has gone through several stages of development. These stages have been marked by changes in the operating times, currents, and antenna element configurations. The antenna elements at the NRTF-Republic were first energized in March 1986. Initial tests used a low-current (4, 6, or 10 A) unmodulated signal, and the antenna elements were operated individually. In 1987, antenna currents were increased to 15 A, and the NEW and SEW antenna elements were permanently connected in parallel, constituting the EW antenna. In 1988, antenna currents were increased to 75 A. In May 1989, currents were increased to full power (150 A), the NS and EW antennas were operated simultaneously, and a modulated signal was used. Operating times increased dramatically as the NRTF-Republic became an on-line Naval Communications Facility in the latter half of 1989. Normal full-power operation continued through 1993, with the exception of periods in 1991 and 1992 when the EW antenna was off for special maintenance. Operation of the NS antenna continued at full power during these special maintenance periods.

During the 15 and 75 A testing periods in 1987, 1988, and 1989, virtually all transmitter operations were conducted according to a 15-minute rotational schedule commencing on the hour. Each cycle consisted of the following:

- 5 minutes--both antennas off
- 5 minutes--NS antenna only on
- 5 minutes--EW antenna only on

NRTF-Republic operational logs supplied to IITRI list specific times at which such cycles begin and end. The actual operating times were estimated by assuming a 33 percent duty cycle for each antenna during the testing period. The rotational schedule was not used after 150 A testing began in May 1989.

Figures 36 and 37 show the hours of operation for each antenna or antenna element on a month-by-month basis. The hours of operation for 1986-1988 are shown in Figure 36. During 1986-1988, the NS and EW antennas were never operated simultaneously. Furthermore, in 1986 the NEW and SEW elements, which comprise the EW antenna, were always operated individually. From 1987 on, these elements were connected in parallel and referred to as the EW antenna. The hours of operation for 1989-1993 are shown in Figure 37. They are broken down into periods of operation with both antennas, the NS antenna only, and EW antenna only.

The pie charts in Figure 38 present NRTF-Republic annual operating summaries for 1986-1993. For each year, a pie wedge representing the total percent time of all transmissions is exploded in a second pie, which details this operating time by antenna or antenna element. This figure clearly illustrates the gradation of annual operation times from 1.5 percent in 1986 to near 90 percent in 1990 through 1993. The exploded pie wedges provide a "snapshot" history of major operating configuration changes, from solo operation of the NS antenna and EW antenna elements in 1986 to nearly exclusive simultaneous operation of both antennas in 1989 through 1993.

NRTF-Republic operations in 1986-1993 can be summarized as follows:

<u>1986</u>

- The NRTF-Republic was transmitting about 1.5 percent of the time (about 160 hours) (see Figures 36 and 38).
- About 98 percent of "on" time was with an unmodulated 76 Hz signal.
- The NS antenna and the NEW and SEW antenna elements were always operated individually.
- Primary operating currents were 4 and 6 A for the NS antenna and the NEW antenna element, respectively, and both 6 and 10 A for the SEW antenna element.

<u>1987</u>

- The NRTF-Republic was transmitting about 4.5 percent of the time (about 400 hours) (see Figures 36 and 38).
- 100 percent of "on" time was with an unmodulated 76 Hz signal.
- The NS and EW antennas were always operated individually.
- 99.6 percent of the operating time was with a 15 A current.

<u>1988</u>

- The NRTF-Republic was transmitting about 11.6 percent of the time (about 1000 hours) (see Figures 36 and 38).
- About 98 percent of "on" time was with an unmodulated 76 Hz or 44 Hz signal.

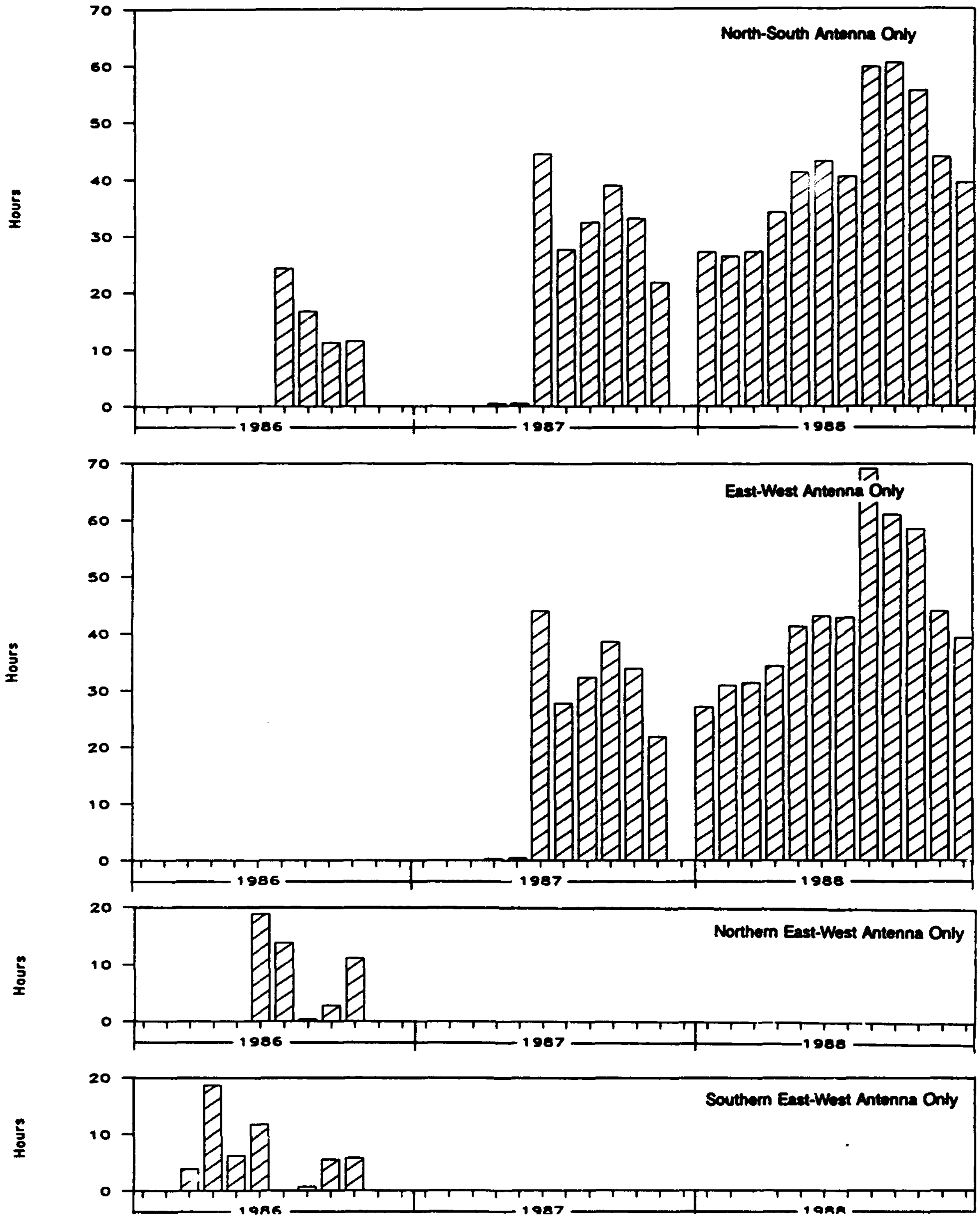


FIGURE 36. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1986-1988.

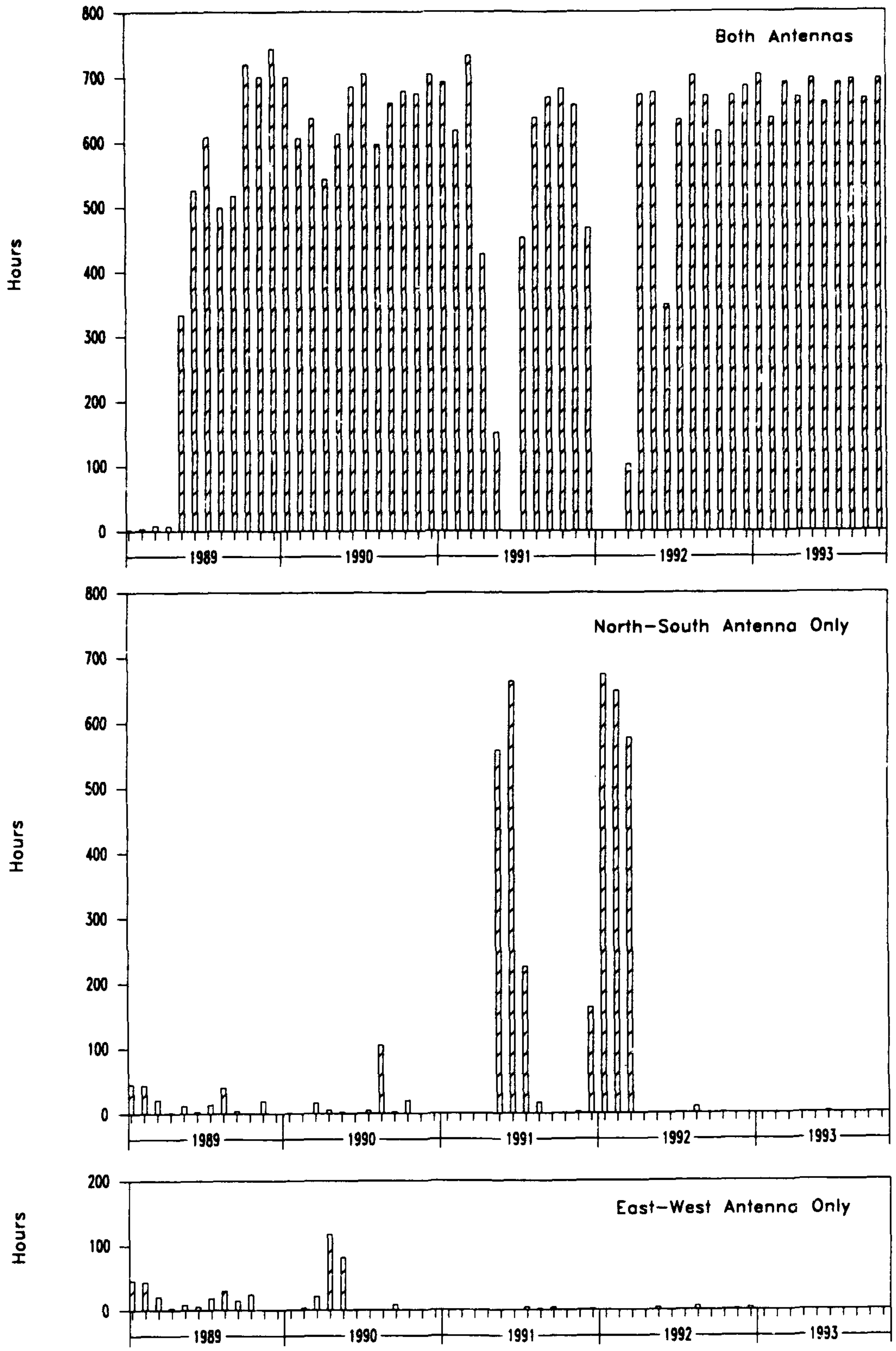


FIGURE 37. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1989-OCT. 1993.

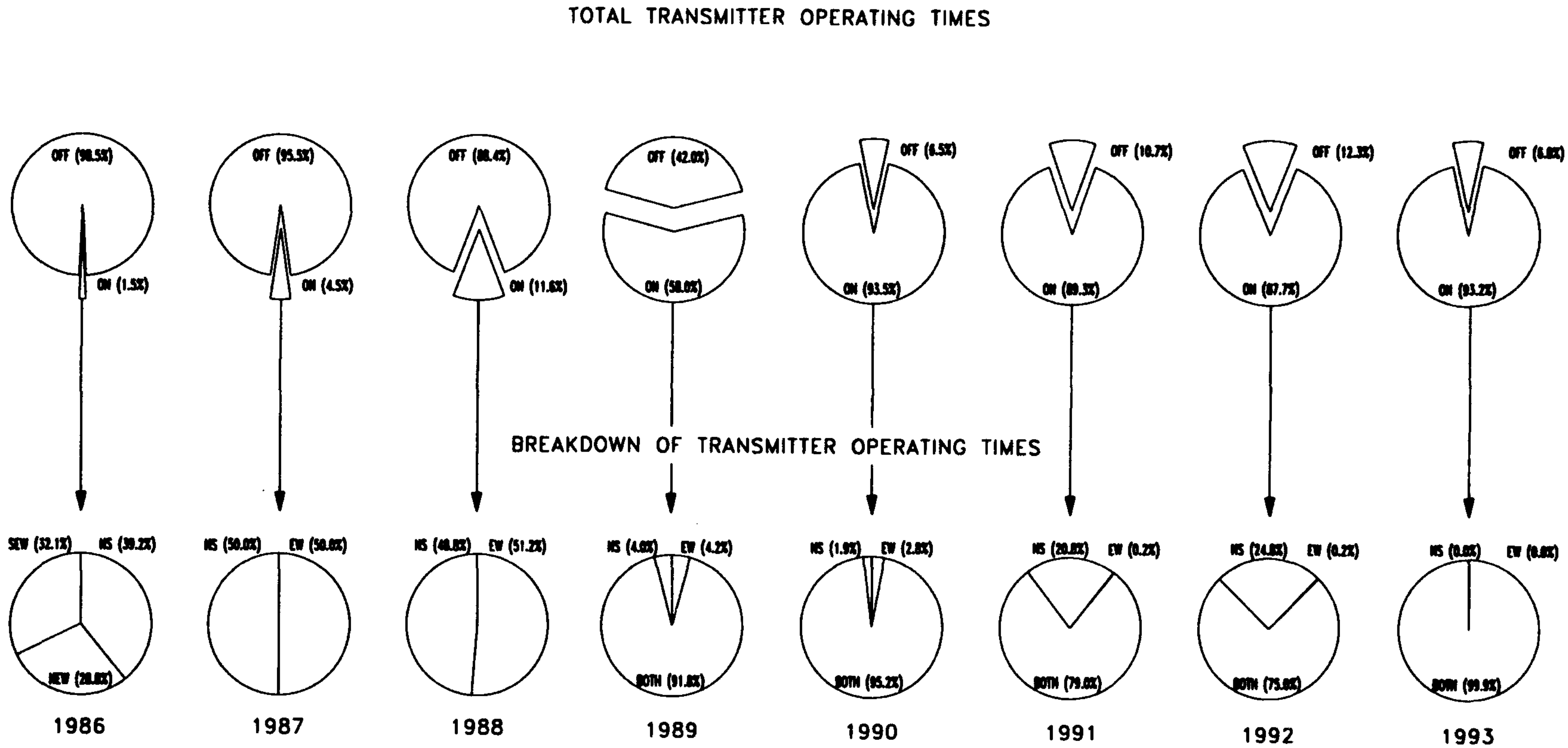


FIGURE 38. NRTF-REPUBLIC OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-OCT. 1993.

- The NS and EW antennas were always operated individually.
- Primary operating currents were 15 and 75 A. 40.6 percent of "on" time was at 15 A, and 59.2 percent of "on" time was at 75 A.

1989

- The NRTF-Republic was transmitting about 58 percent of the time (about 5100 hours) (see Figures 37 and 38).
- About 57 percent of "on" time was with a modulated 76 Hz signal, and 28 percent of "on" time was with an unmodulated 76 Hz signal.
- The NS and EW antennas were operated simultaneously for 91.8 percent of the "on" time.
- Primary operating currents were 75 and 150 A. 95 percent of "on" time was at 150 A.

1990

- The NRTF-Republic was transmitting about 93.5 percent of the time (about 8200 hours) (see Figures 37 and 38).
- About 95 percent of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- The NS and EW antennas were operated simultaneously for 95.2 percent of the "on" time.
- All operations were at 150 A.

1991

- The NRTF-Republic was transmitting about 89 percent of the time (about 7825 hours) (see Figures 37 and 38).
- About 79 percent of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- About 21 percent of "on" time was with a modulated 76 Hz signal and only the NS antenna operating.
- Essentially all operations were at 150 A with a modulated 76 Hz signal.

1992

- The NRTF-Republic was transmitting about 88 percent of the time (about 7680 hours) (see Figures 37 and 38).
- About 75 percent of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- About 25 percent of "on" time was with a modulated 76 Hz signal and only the NS antenna operating.
- Essentially all operations were at 150 A with a modulated 76 Hz signal.

Jan.-Oct. 1993

- The NRTF-Republic was transmitting about 93 percent of the time (about 8160 hours) (see Figures 37 and 38).

- Essentially all "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- All operations were at 150 A.

Finally, cumulative exposure data for the duration of the Ecological Monitoring Program are plotted on a normalized scale in Figure 39 for the NS and EW antennas. This cumulative exposure is based on antenna operating times provided to IITRI by the Navy. The operating times for each antenna were multiplied by the operating current and plotted as cumulative sums in this figure. The current parameter was chosen because intensities of the EM fields of interest are proportional to antenna current. The data in Figure 39 are normalized to the NS antenna cumulative total (5.3 million ampere-hours). Relative exposure levels for any period can be estimated as the first derivative (slope) of the exposure curve.

The exposure curve in Figure 39 may be useful in defining a preoperational/operational break-point for data analyses. The break-point chosen for most analyses was May 1989 when antenna currents increased to 150 A. Other antenna operational change points of interest include July 1986 when operations began at low currents, June 1987 when operating currents were increased to 15 A, and July 1988 when operating currents were increased again to 75 A. The large plateaus for the EW antenna in 1991 and 1992 correspond to times when this antenna was off for extended maintenance (see Section 3.4.3). Overall, cumulative operations for the EW antenna totaled 4.77 million ampere-hours, or 90 percent of the NS antenna total. The 10-percent difference appears from Figure 39 to be explained solely by the two EW antenna maintenance periods.

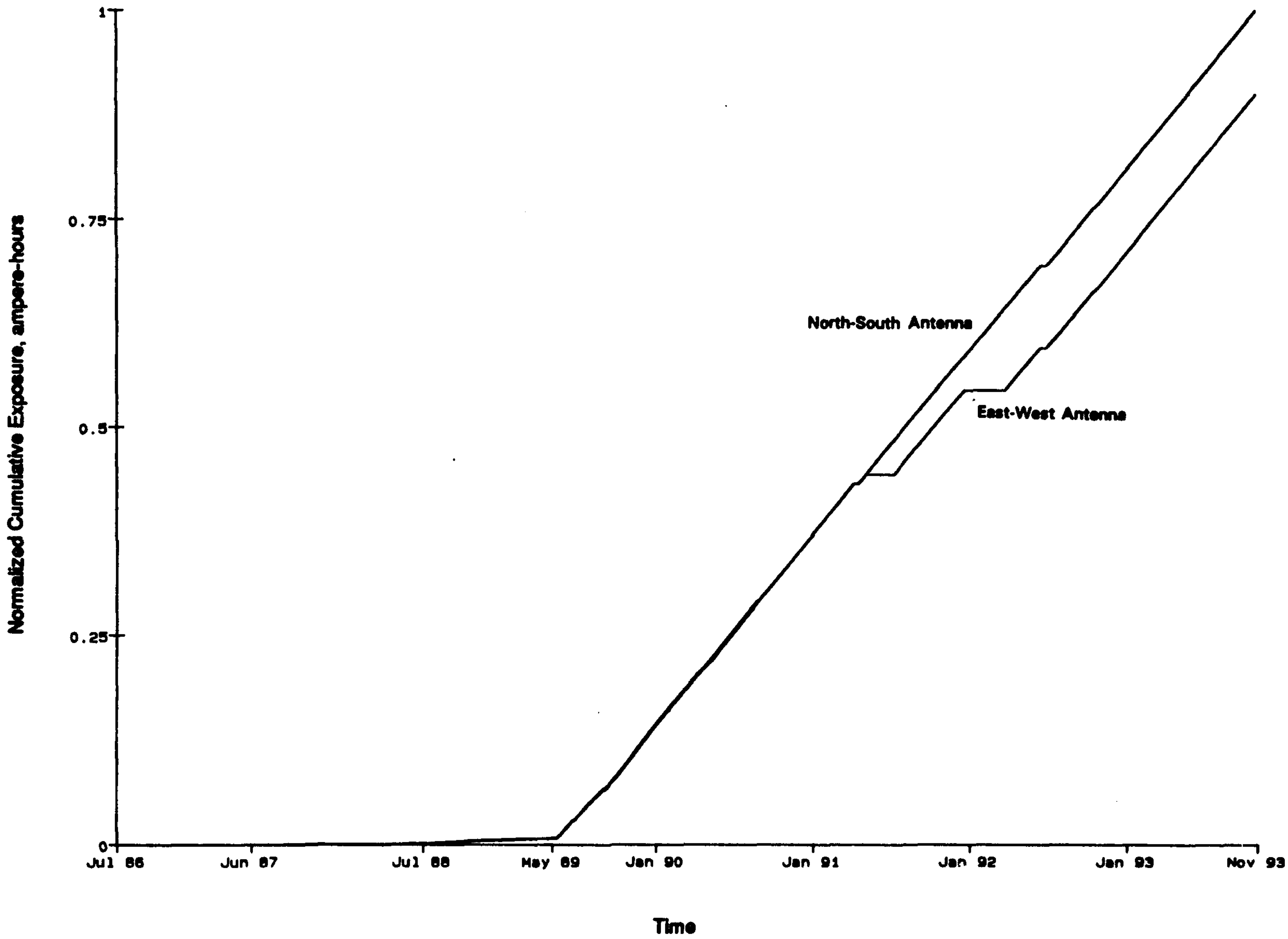


FIGURE 39. NORMALIZED CUMULATIVE EXPOSURES FOR STUDY SPECIES NEAR THE NS AND EW ANTENNAS.

5. SUMMARY

Annual EM field measurement surveys in support of the Ecological Monitoring Program were performed during April, July, and September of 1993. Measurements were made at a total of 157 points at 36 study sites, compared with 180 points at 49 sites in 1992. No new measurement points were added in 1993. The reduction in the number of sites and measurement points primarily corresponded to completion of several ecological monitoring activities.

In addition to the annual EM field measurements, data loggers were deployed at selected sites to monitor earth electric field intensities. These loggers remained on site throughout the years and performed measurements on an hourly basis. Also, at the MTU treatment sites, fixed probes were established for regular earth electric field measurements during visits to offload the data loggers at these sites. Together, the fixed probe and data logger measurements provide useful information on earth electric field temporal variability.

The NRTF-Republic continued operation with a modulated 76 Hz, 150 A antenna current during 1993, employing both antennas. Annual 76 Hz EM field measurements were made at all points during simultaneous operation of NS and EW antennas. Measurements of the ambient 60 Hz EM fields at treatment sites were made only if both antennas were off, since 60 Hz EM fields cannot be measured there during NRTF-Republic modulated signal transmission. At the control sites, 60 Hz measurements were made regardless of antenna condition. Earth electric field measurements obtained by data logger monitoring systems and at fixed probe locations supplemented the annual measurement set.

Geomagnetic field intensities at sites adjacent to the NRTF-Republic, Michigan, were characterized for a second time in 1993. Overall spatial variation of this field was about 7 percent. Measurement results agreed well with aeromagnetic measurements made by the Department of the Interior's U.S. Geological Survey.

Incubation bags used to isolate earthworms for reproduction studies were designed and used in the field in 1991 through 1993. The bags were effective in containing the earthworms while maintaining an electric field intensity level of 50 to 70 percent of that in the surrounding soil. Among the incubation bags deployed at the treatment and control sites was a single bag dedicated for electric field monitoring by data logger systems. Monitoring of the electric field in the control site reference bag did not produce usable results, because field intensities were below the logger sensitivity. At the treatment site reference bag, recorded electric fields appropriately showed the effects of changeouts and watering. Multiple-depth monitoring of the earth electric field at the earthworm sites showed some differences in field intensity levels between various soil horizons. Unfortunately, these differences were not consistent between soil layers or the probe sets.

Six data loggers monitored earth electric field temporal variations at several sites. Coefficients of variation were typically between 1 and 30 percent, with the higher values near antenna ground terminals or other direct ground current sources. At the upland flora study sites, diurnal variations in the electric field were examined in 1991. Distinct patterns could be observed at some locations, but variations were less than 5 percent. Diurnal variations were not reexamined thereafter. Variations resulting from changing antenna operating conditions could also be observed, particularly at the upland flora study sites where special maintenance on the EW antenna in 1991 and 1992 had its greatest impact.

Another year of postoperational data was collected by study investigators in 1993 as both antennas operated essentially full time and at full power. Antenna operating parameter summaries are provided for all years, 1986-1993, in Section 4.5 and Appendix J. The duration of EM field exposures can be viewed, from the standpoint of the antenna operating parameters, in monthly bar charts, time percentage pie charts, and a cumulative intensity-duration style curve. All field data collection was completed by the end of October 1993; data summaries, therefore, were made only up to this point.

6. REFERENCES

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APPENDIX A

SMALL MAMMALS AND NESTING BIRDS STUDIES

SMALL MAMMALS AND NESTING BIRDS STUDIES

These studies monitor parental care, nestling growth and maturation, fecundity, homing activity patterns, embryological development, and metabolic physiology of small mammals and nesting birds. The electric and magnetic fields in the air are considered important factors to be examined in orientation and other behavior patterns of birds. The electric and magnetic fields in the earth and near its surface are important to the small mammals studies. The air electric field and magnetic field in the laboratory where study animals undergo physiological testing, and in the holding areas used prior to these tests, are also of importance.

In 1993, IITRI field crews made ELF electromagnetic (EM) field measurements at 53 measurement points within the five treatment sites, three control sites, three (bird) displacement sites, and the remote holding facility for the small mammals and nesting birds studies. The measurement regime differed from 1992 in that measurements were not made at the Michigamme South control site, since it is no longer in use. Documentation of previous measurements at all sites as well as of 1990 EM field shielding activities at the study laboratory is included in this appendix, however, for easy reference. Measurement dates for 1993 and previous years appear in Table A-1.

TABLE A-1. EM FIELD MEASUREMENT DATES
Small Mammals and Nesting Birds Studies

Year	Measurement Dates		
1983	May 23, 24, 26	Jun 9, 14, 15	Jul 13, 14
1984	May 16, 17	Aug 6, 7, 9, 10, 14-16, 21, 22	
1985	Jul 15, 17, 18, 22-24		
1986	Oct 2, 3, 6, 8, 14-17		
1987	Sep 24, 28-30	Oct 1, 5, 6, 8	Dec 11
1988	Sep 19-22, 27, 28	Oct 3-5	Nov 11
1989	Feb 21	Sep 13-15, 18, 20-22	Oct 12
1990	Jan 9, 10, 22	Sep 24, 25, 27	Oct 2, 4, 8-10
1991	Sep 23, 24, 26, 27	Oct 1-4, 16	
1992	May 27, 28	Sep 14, 15, 17, 18, 21, 22, 25, 29, 30	Oct 2
1993	Jul 12, 13, 16, 19, 20, 21, 22, 23, 28, 29	Sep 9	

The positions of all sites relative to the NRTF-Republic are shown on the composite map in Figure A-1. The site numbers listed on the map are those used by IITRI. Table A-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures A-2 through A-16.

TABLE A-2. SITE NUMBER CROSS-REFERENCE
Small Mammals and Nesting Birds Studies

IITRI Site No.	Investigator's Site Name	Location Township	Range	Section(s)
1T1	Pirlot Road	T43N	R29W	23, 26
1T2	Cleveland Homestead	T44N	R29W	25
1T4	North Turner Road	T43N	R29W	1
1T5	Ford River North	T43N	R29W	14
1T6	Ford River South	T43N	R29W	14
1C1	Michigamme North	T44N	R31W	13
1C3	Michigamme South	T44N	R31W	24
1C4	Panola Plains	T42N	R32W	10
1C6	Tachycineta Meadow	T42N	R31W	3
1D1	Cleveland Homestead Displacement	T47N	R28W	36
1D2	North Turner Road Displacement	T46N	R28W	12
1D3	Panola Plains Displacement	T45N	R31W	14
1L1	Crystal Falls Laboratory	T43N	R32W	29
1L4	Remote Holding Facility	T42N	R32W	9

EM field measurements for 1993 and previous years are found in Tables A-3 through A-8. Tables A-3, A-4, and A-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. These tables include data for 18 measurement locations that are no longer active. This has been done in order to provide historical measurement values at study sites where new measurement locations were laid out after antenna construction in 1986. Tables A-6, A-7, and A-8 present 76 Hz data for these three fields as well as the corresponding operating currents of the NRTF-Republic for each year. Paired site EM field intensity ratios, which were recalculated using the 1993 measurement data, appear in Table A-9.

The 60 Hz data for the air electric field and magnetic flux density measured at the Crystal Falls laboratory from 1986 through 1990 appear in Tables A-9 and A-10.

Plots of the 60 Hz EM field profiles for the five nest box sites for the years 1989 through 1993 are presented in Figures A-17 through A-23. Considerable year-to-year variability in these fields is evident. The primary factors in this variability are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements made in 1986 through 1993 (excluding 1989) were typically made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were made at the treatment sites during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off. It should be noted that a significant gradient in the 60 Hz fields exists across the nest box treatment sites because of their size and the 60 Hz coupling to the nearby NS antenna.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control sites show lower spatial variation compared to those at the treatment sites because the antenna is not present to establish a field gradient.

Overall, the 60 Hz EM fields measured at all of the study sites in 1993 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites.

The 76 Hz EM field measurements in 1993 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The antenna currents at which measurements were made in each year are shown in the column headings of Tables A-6 through A-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurements are consistent with the measurements made in 1989 through 1992 at the same current, and are proportional to the 1986, 1987, and 1988 measurements made at lower currents.

Plots of the 76 Hz EM field profiles for the five nest box test sites for the years 1989 through 1993 are presented in Figures A-24 through A-37. An estimate of the EM field levels for any nest box at a treatment site can be obtained graphically from these figures given the perpendicular distance of the nest box from the antenna wire.

EM field measurements were made at the release points for the Cleveland Homestead, North Turner Road, and Panola Plains tree swallow homing transects. The EM field environment along the flight paths can be estimated using Figures A-38 and A-39, which show the locations of the bird flight paths and the

ELF antenna relative to positions of high-voltage 60 Hz transmission lines and 60 Hz power distribution lines, respectively. The EM fields generated by the distribution lines are of magnitudes similar to those that are generated by the ELF antenna when it is operating at full power. The EM fields produced by the transmission lines can be considerably higher, depending on operating conditions. The air electric field generated by a transmission line may be as much as 100 times greater than that of the ELF antenna; the magnetic flux generated by a transmission line is dependent on the load current, and may be several times greater than that of the ELF antenna.

The 60 Hz field intensities measured at the Crystal Falls laboratory in 1989 were nominally 100 times greater than those at the study sites, and were of the same order of magnitude as the 76 Hz intensities at the treatment sites. IITRI made efforts in 1989 to reduce the ambient field levels in critical laboratory work areas by recommending methods for shielding sources of electric fields and by providing magnetic field shielding for the containers used for metabolic testing. Details of these shielding efforts were discussed in a previous report.* The magnetic field shielding configuration, as well as 1989 and 1990 measurements at the laboratory, are presented in this appendix; no measurements were made at the laboratory after 1990.

Table A-10 presents 60 Hz air electric field data before and after shielding was implemented in the Crystal Falls laboratory. It can be seen from this table that the air electric field shielding reduced the fields by factors of 4.5 to 20. Figure A-40 shows the locations of magnetic shields used to reduce the 60 Hz magnetic field exposures in the cooling bath during metabolic tests. The effectiveness of the shielding is seen in Table A-11, which gives the magnetic flux densities inside the test containers under various shielding configurations. The final shielding configuration served to reduce the magnetic fields inside the test containers by factors of 30 to 68.

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* Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1990. IIT Research Institute, Technical Report E06628-3, 87 pp. plus appendixes, 1991.

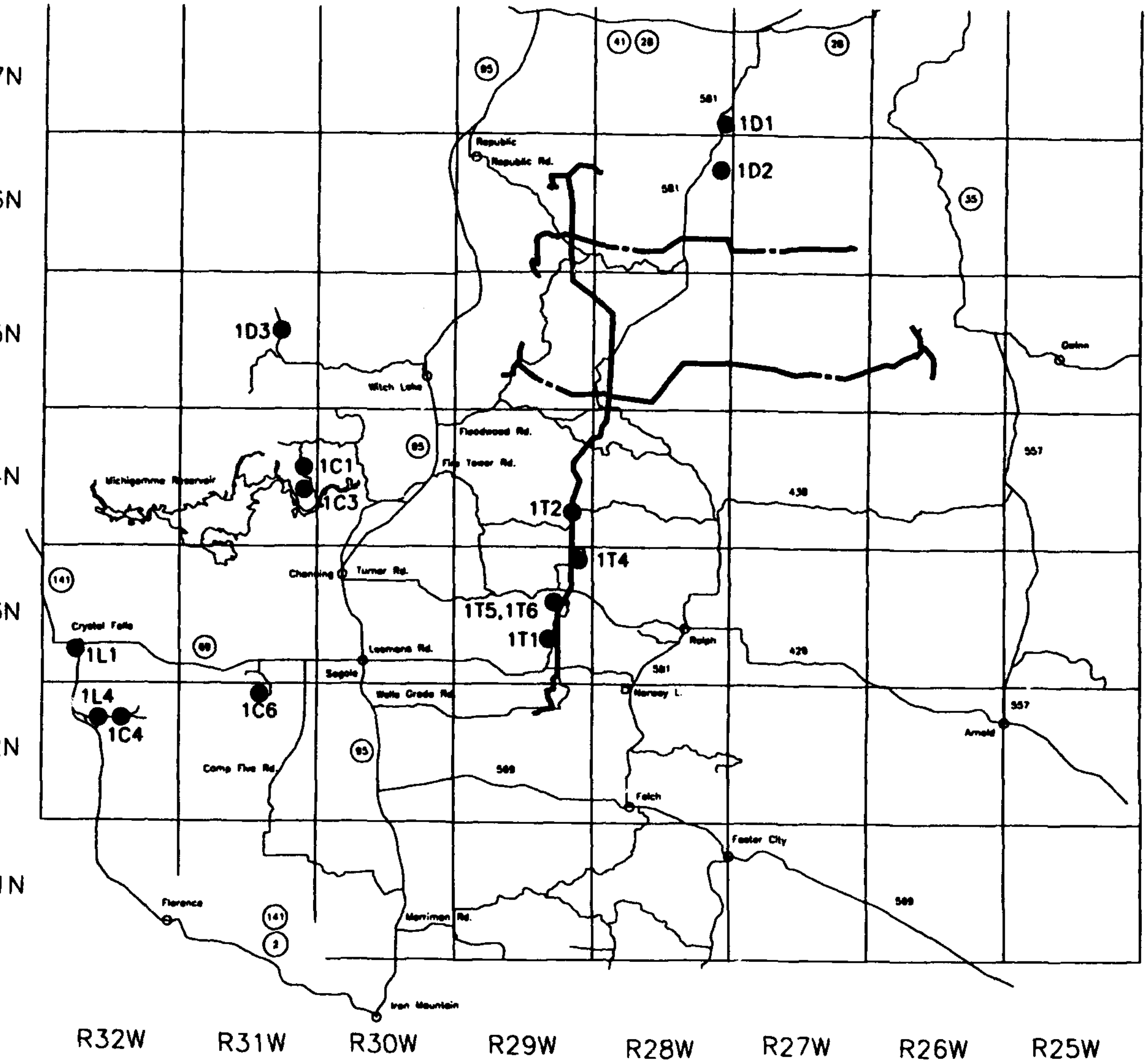


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

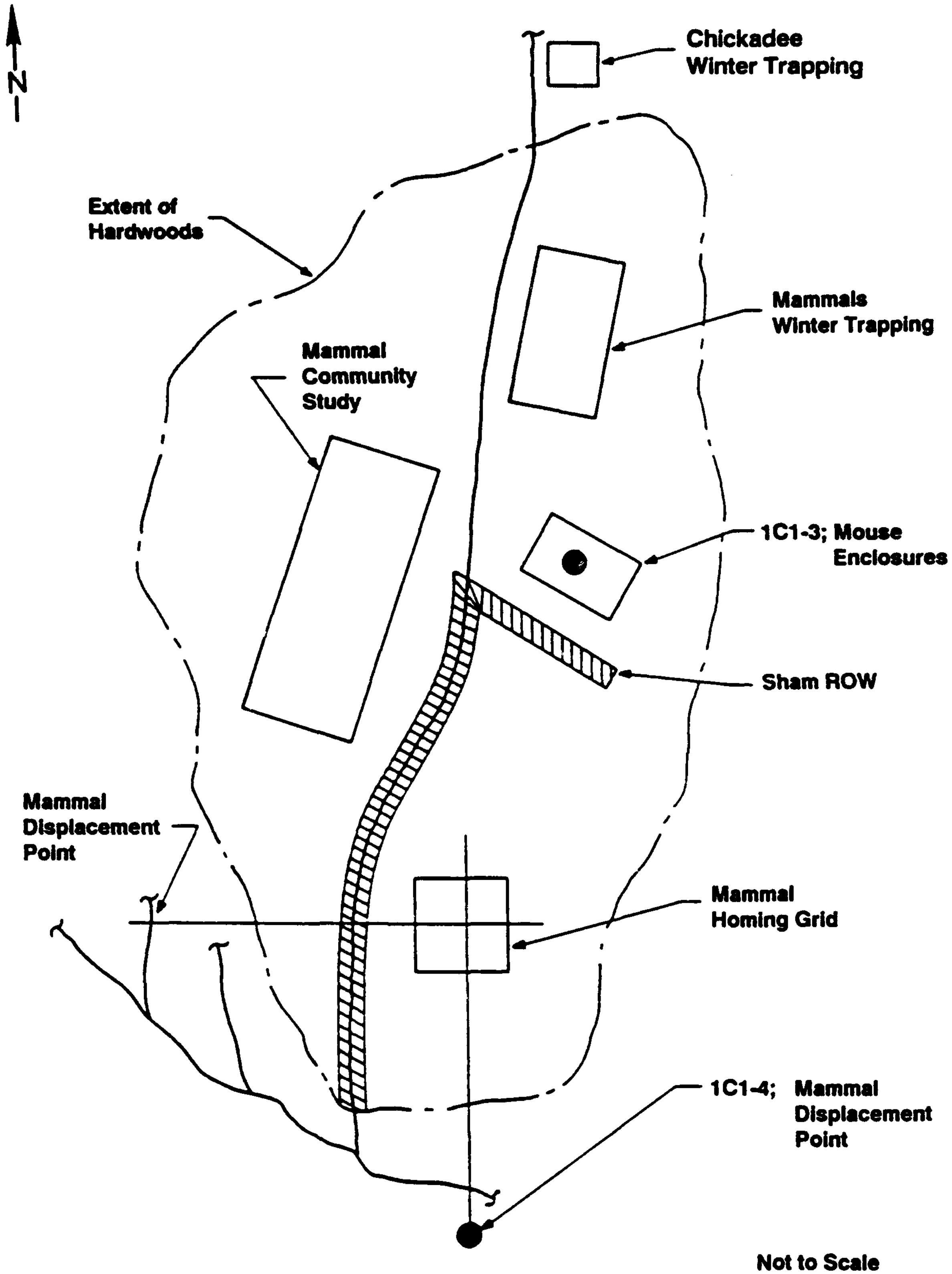


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH; 1C1-3, 4.

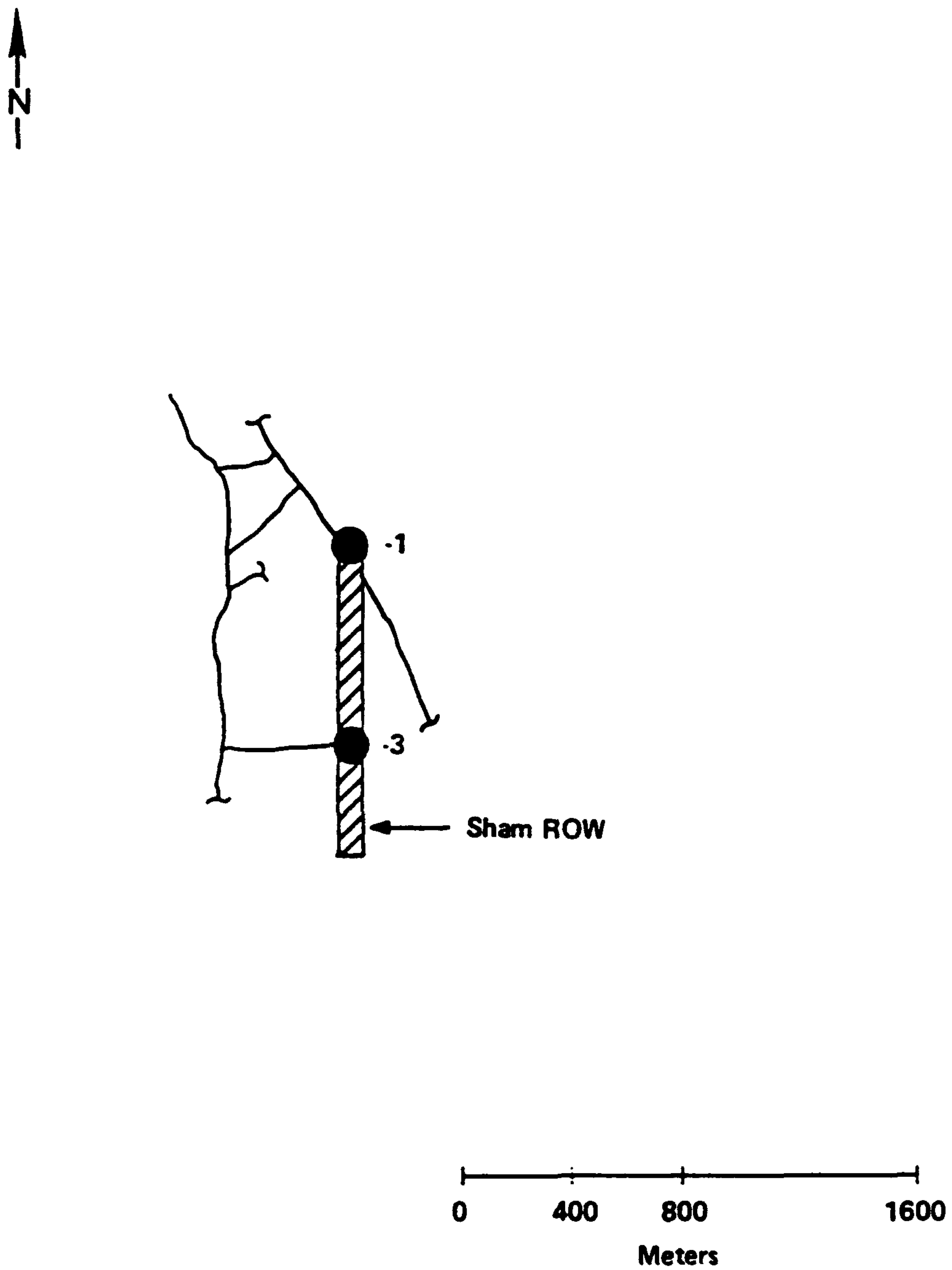


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH; 1C3-1, 3.

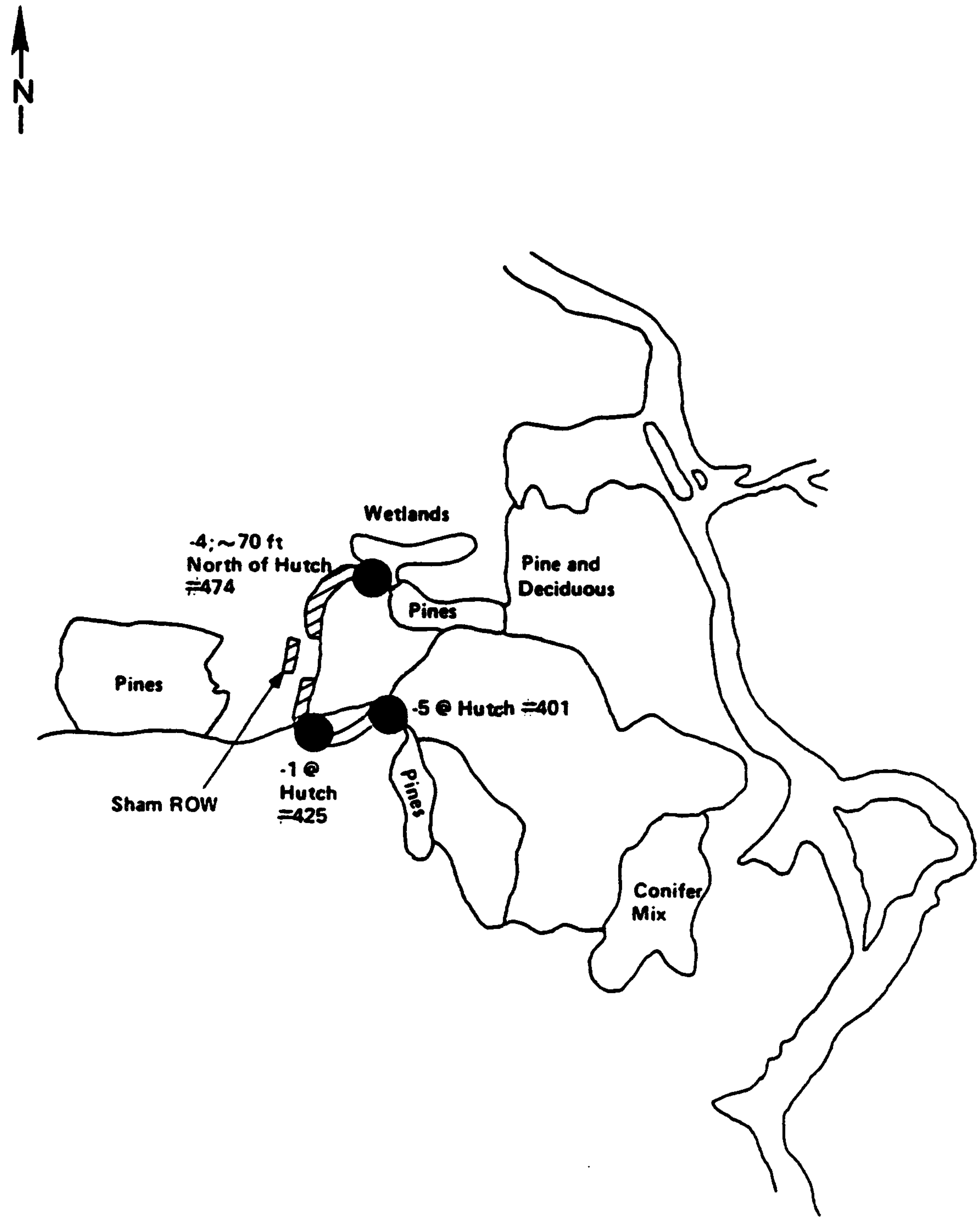


FIGURE A-4. MEASUREMENT POINTS AT PANOLA PLAINS; 1C4-1, 4, 5.

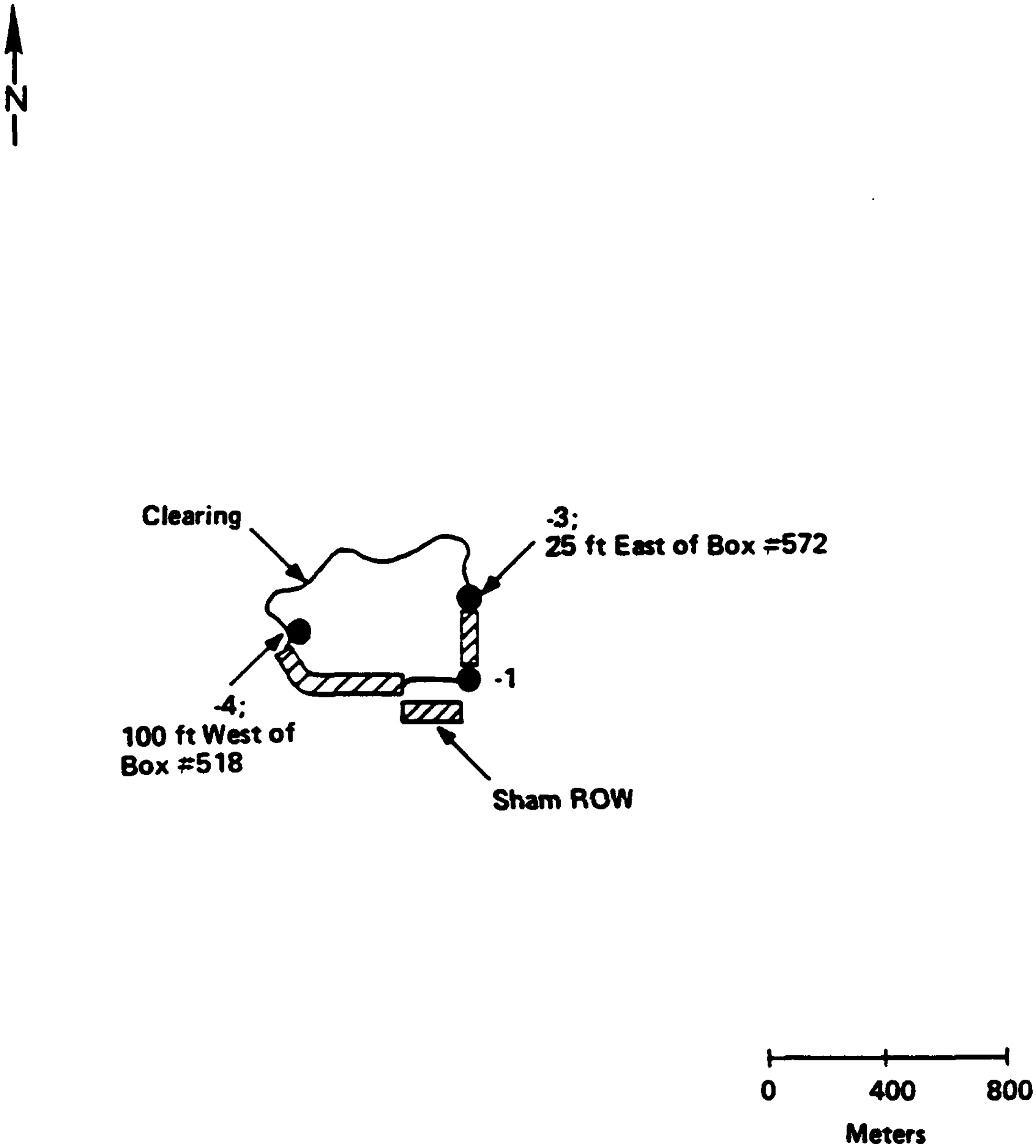


FIGURE A-5. MEASUREMENT POINTS AT TACHYCINETA MEADOW; 1C6-1, 3, 4.

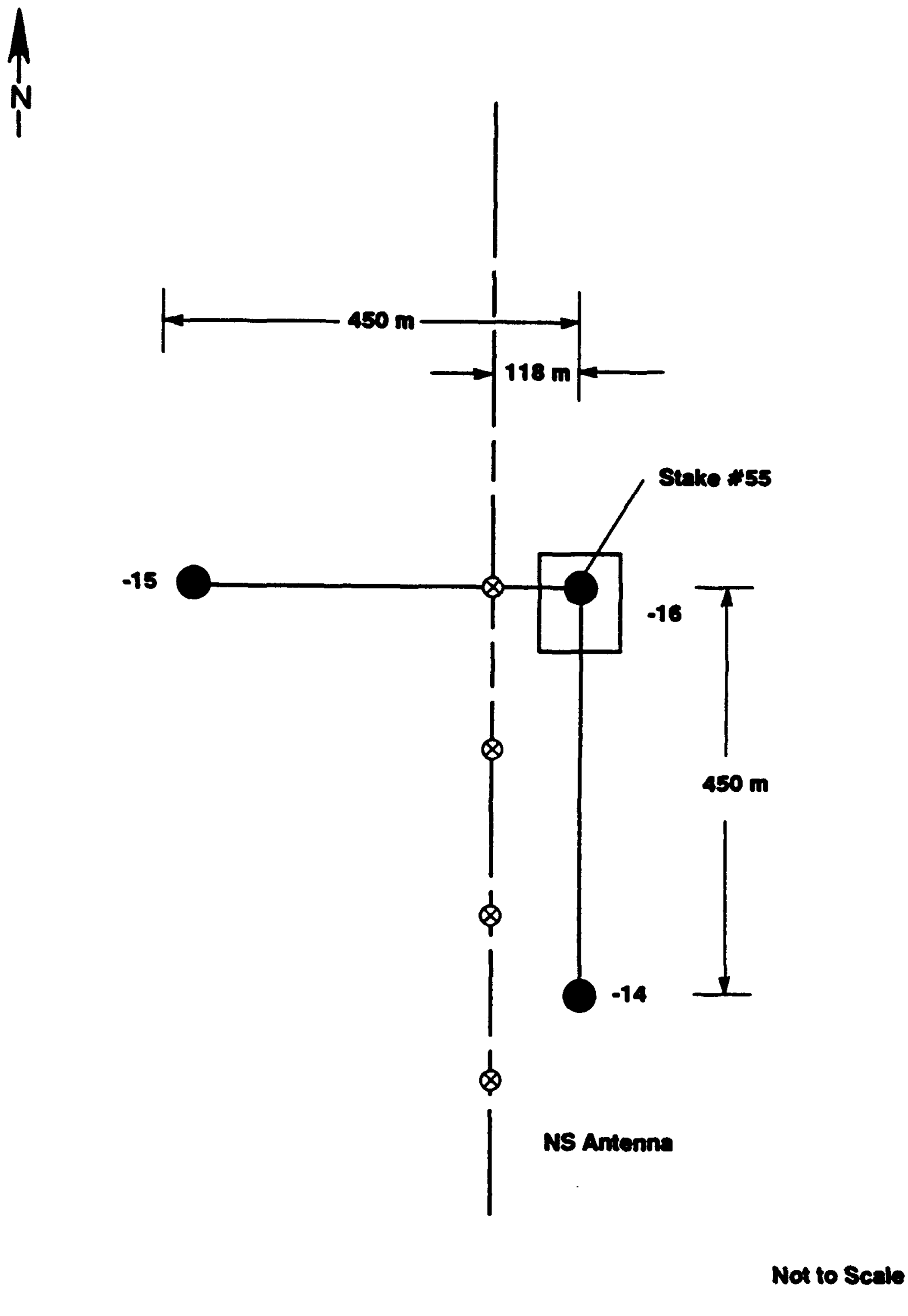


FIGURE A-6. MEASUREMENT POINTS AT PIRLOT ROAD MAMMAL DISPLACEMENT; 1T1-14, 15, 16.

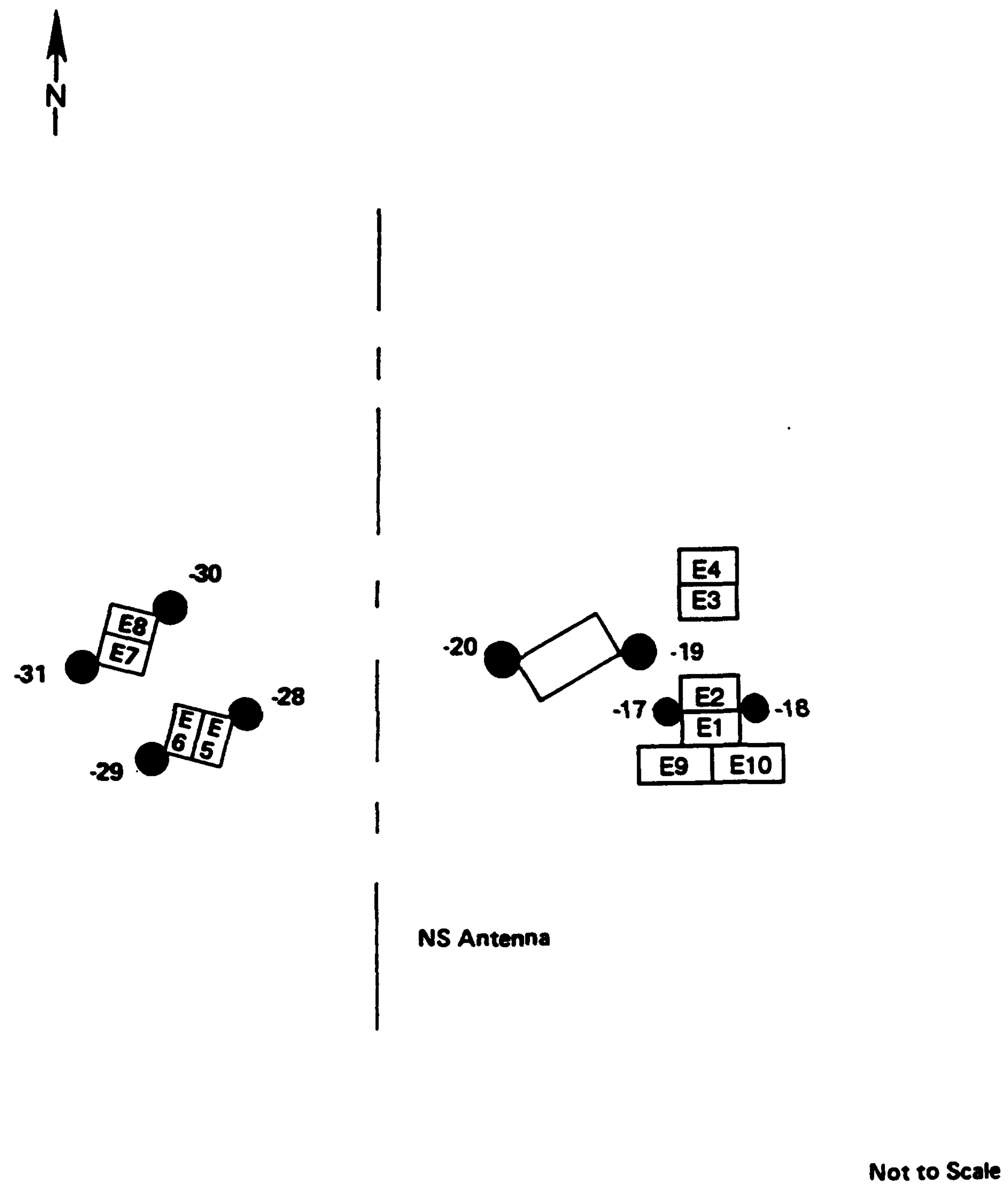


FIGURE A-7. MEASUREMENT POINTS AT PIRLOT ROAD MOUSE ENCLOSURES; 1T1-17 THROUGH 20, 28 THROUGH 31.

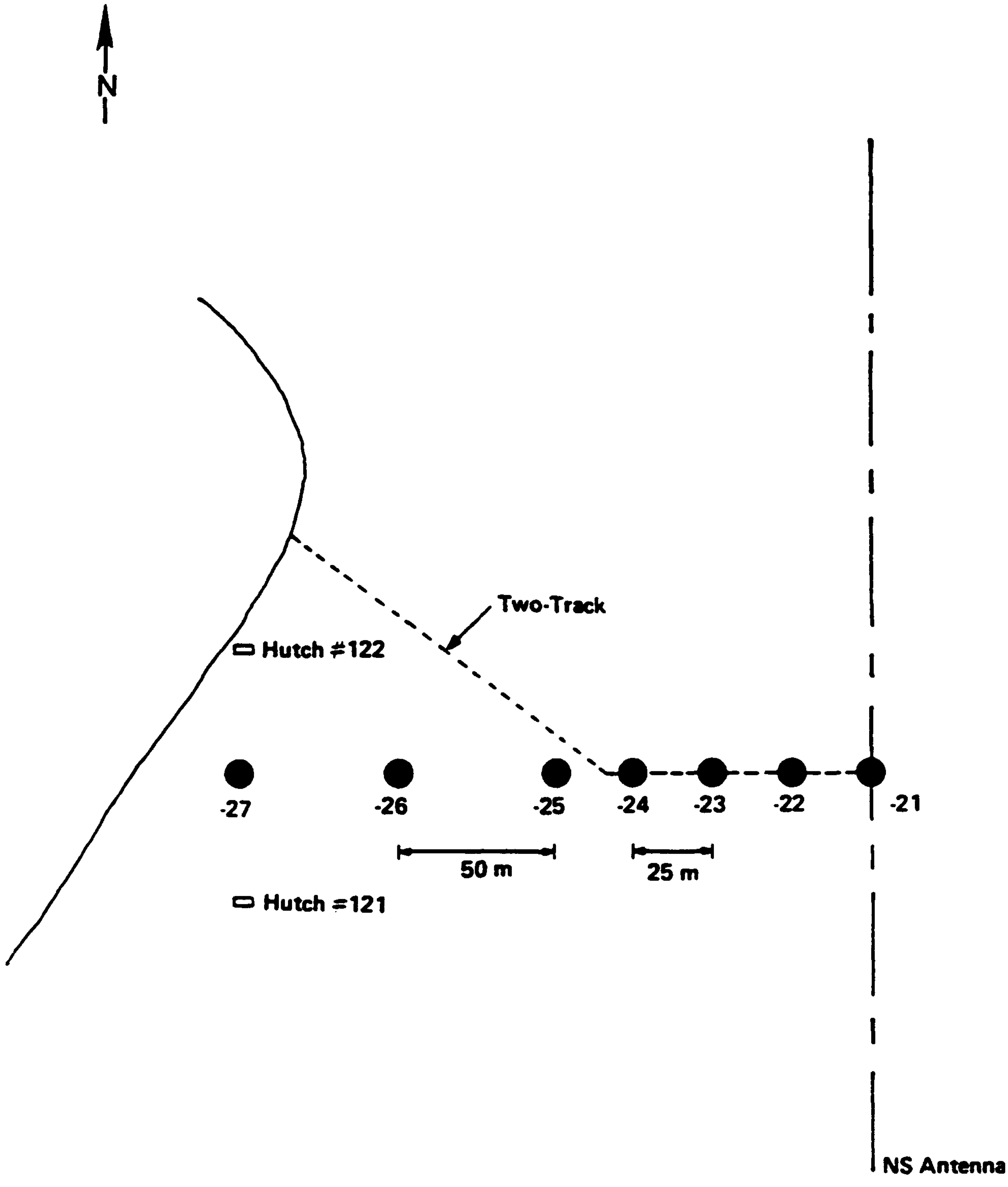


FIGURE A-8. MEASUREMENT POINTS AT PIRLOT ROAD; 1T1-21 THROUGH 27.

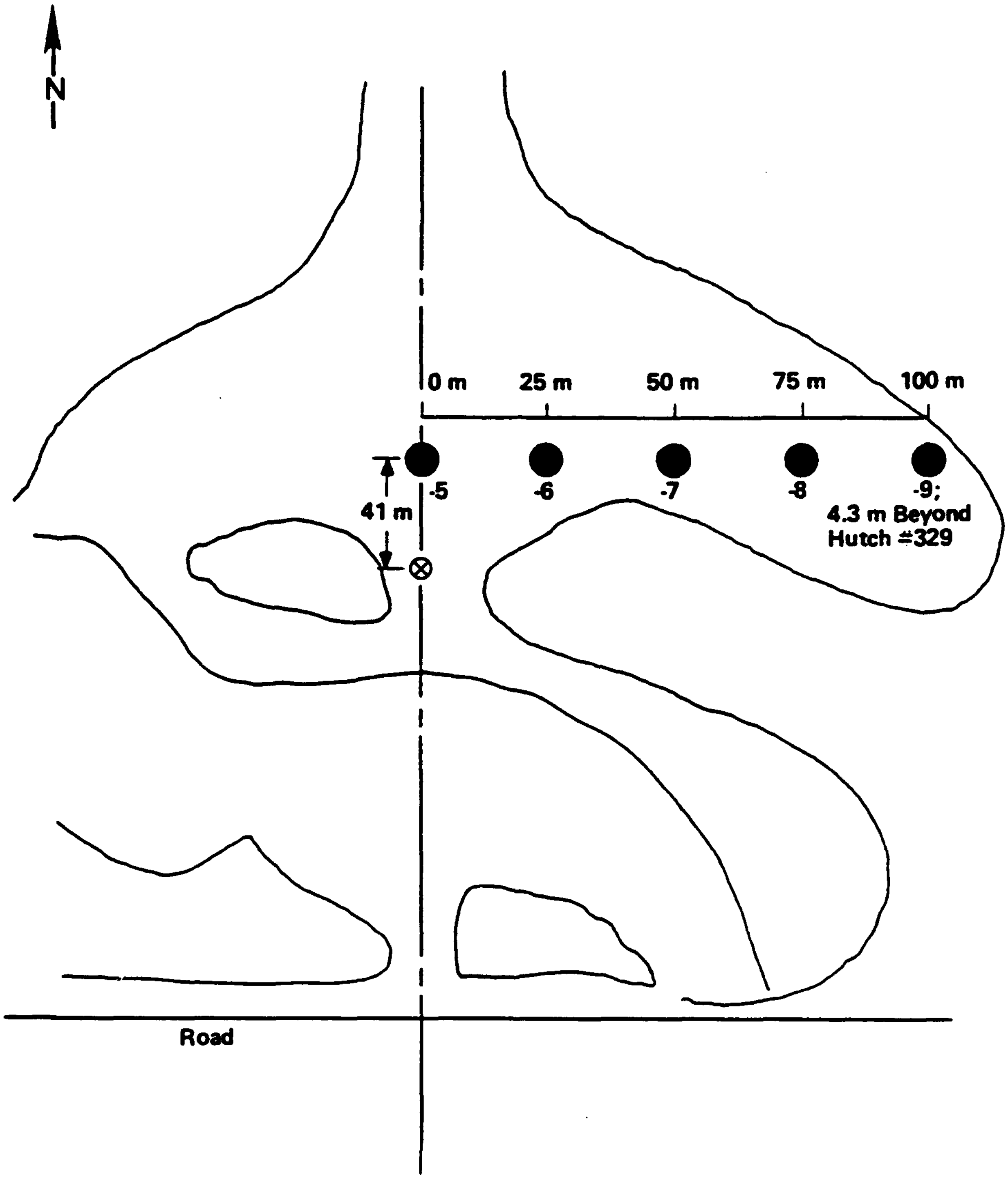


FIGURE A-9. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

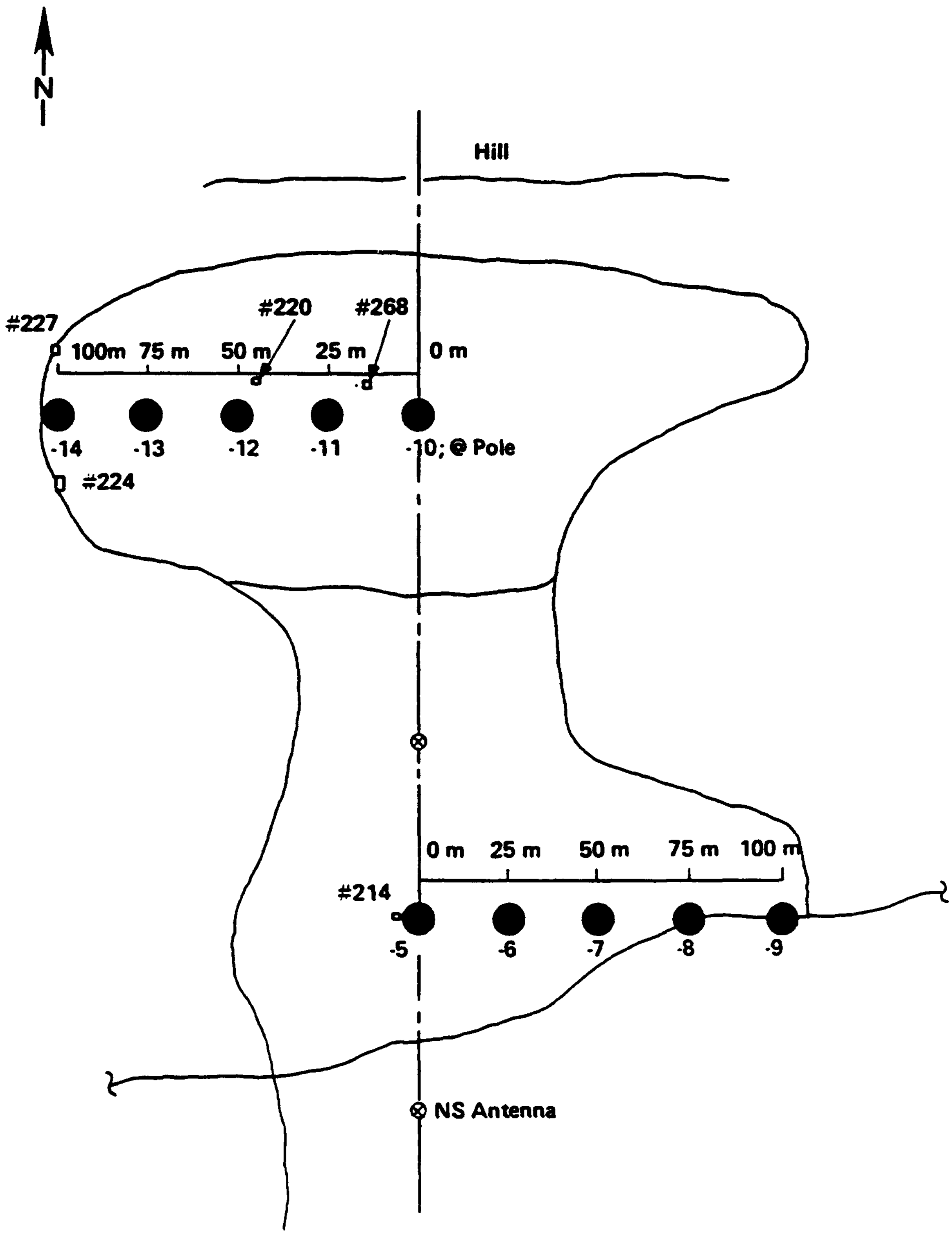


FIGURE A-10. MEASUREMENT POINTS AT NORTH TURNER ROAD; 1T4-5 THROUGH 14.

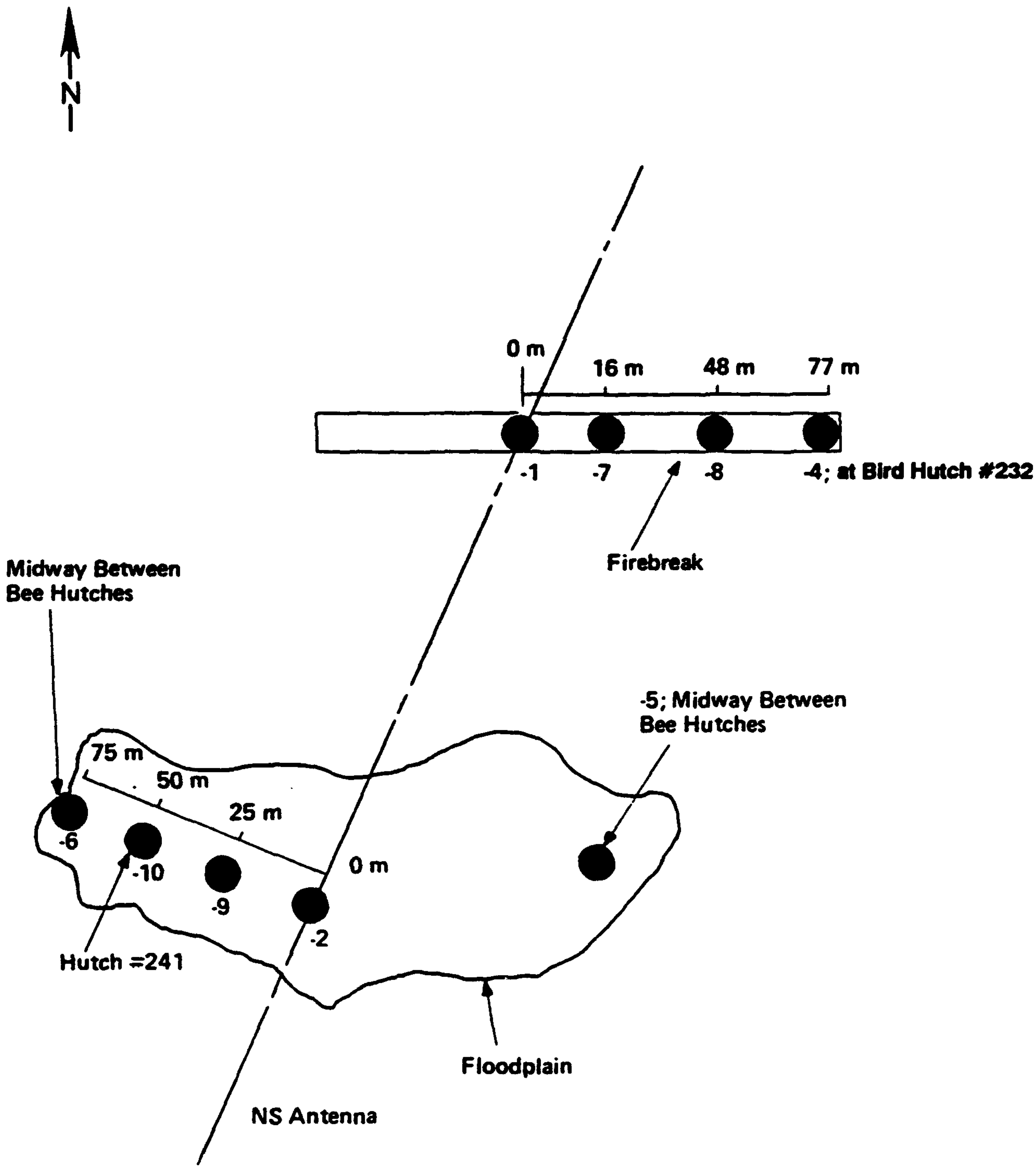


FIGURE A-11. MEASUREMENT POINTS AT FORD RIVER NORTH; 1T5-1, 2, 4, 6, 7, 8, 9, 10.

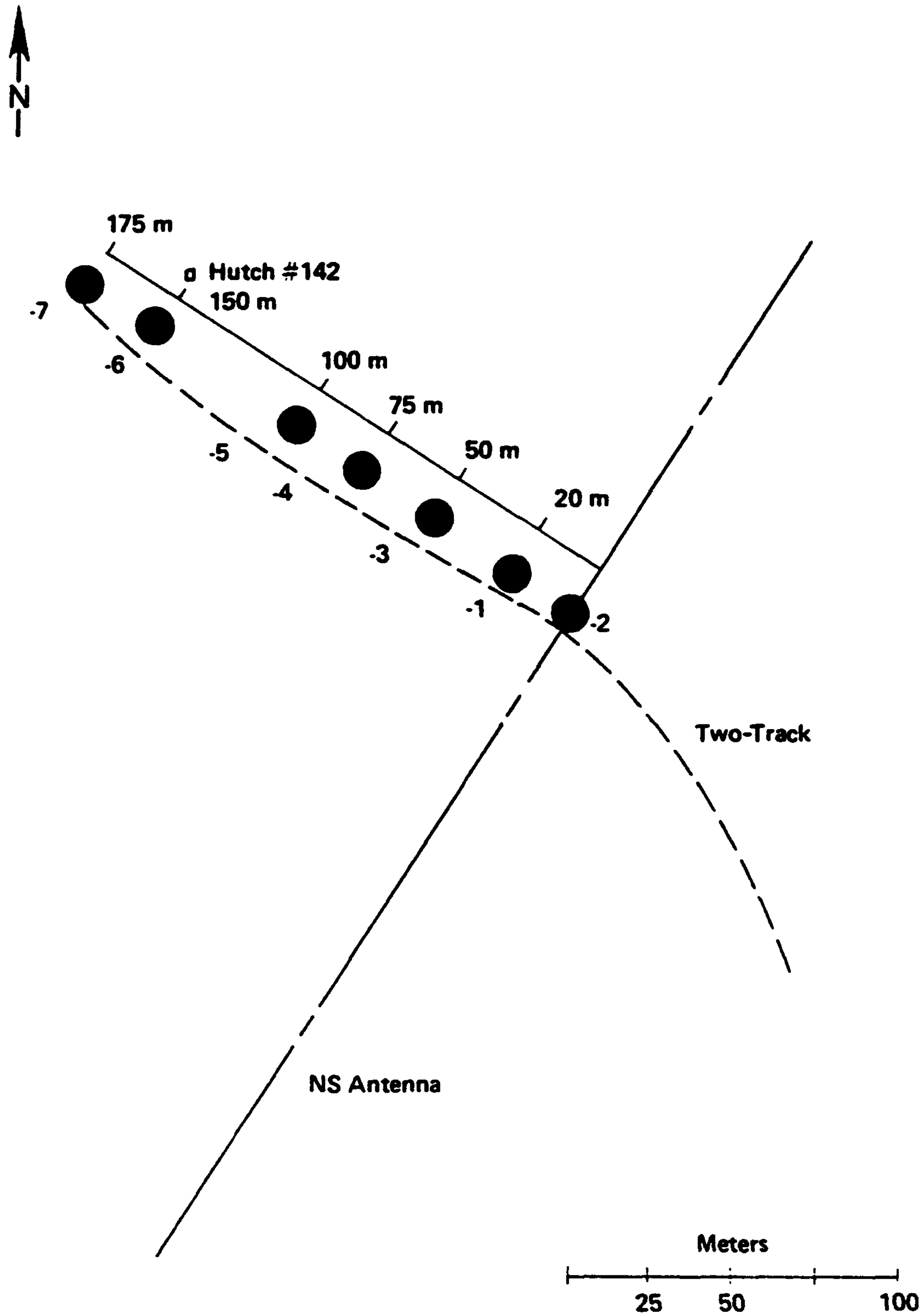


FIGURE A-12. MEASUREMENT POINTS AT FORD RIVER SOUTH; 1T6-1 THROUGH 7.

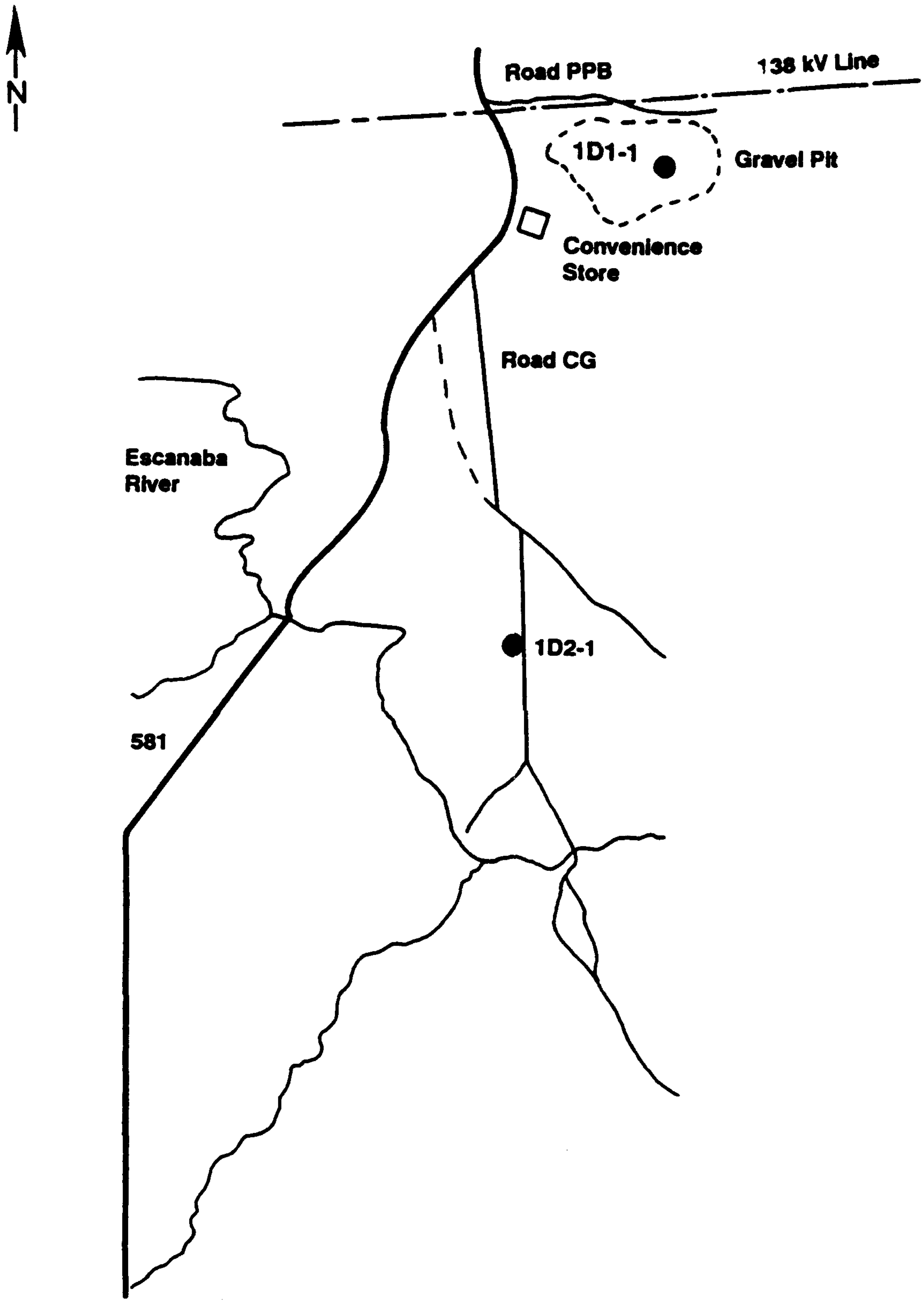


FIGURE A-13. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD AND NORTH TURNER ROAD DISPLACEMENT POINTS; 1D1-1 AND 1D2-1.

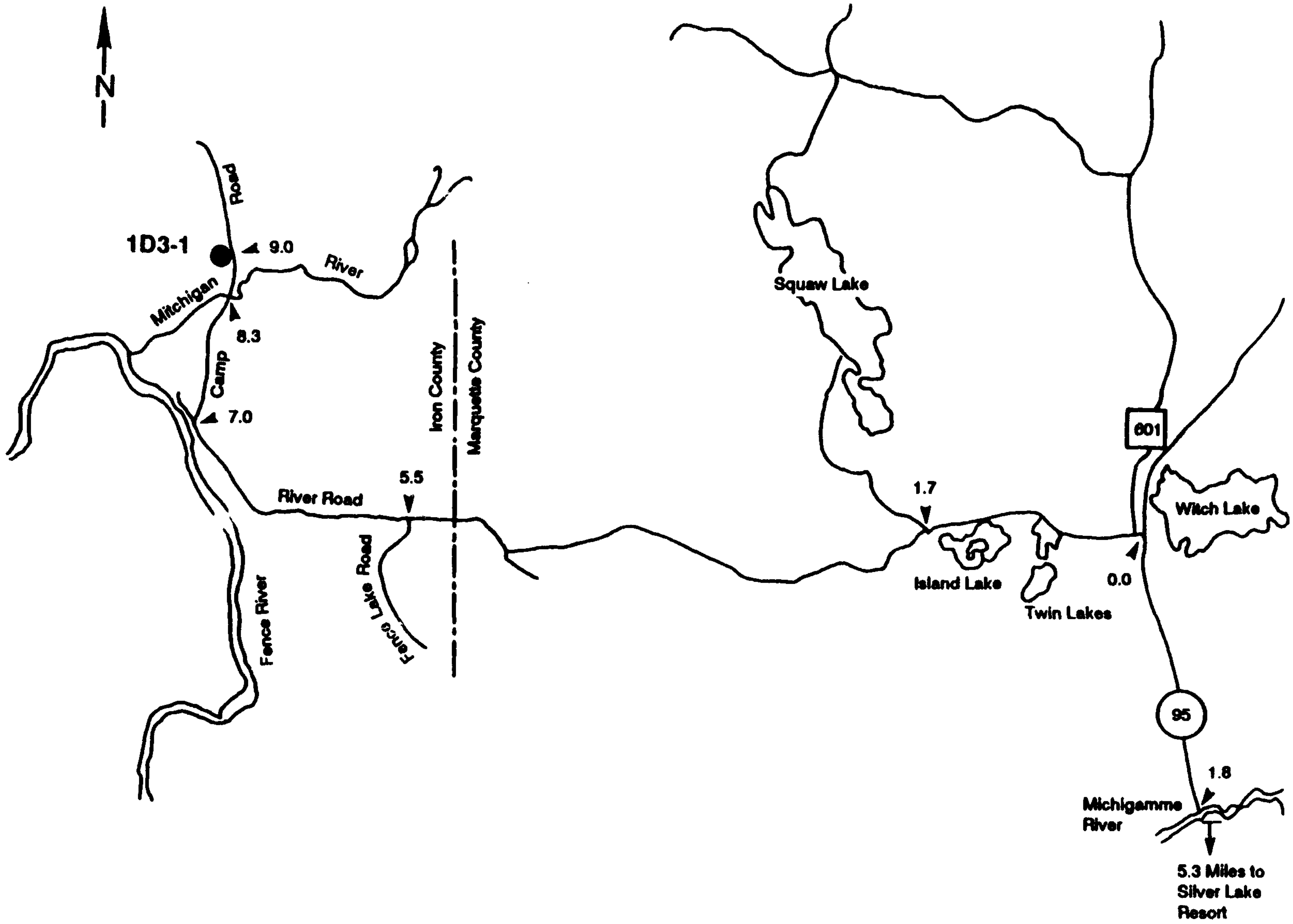


FIGURE A-14. MEASUREMENT POINT AT PANOLA PLAINS DISPLACEMENT; 1D3-1.

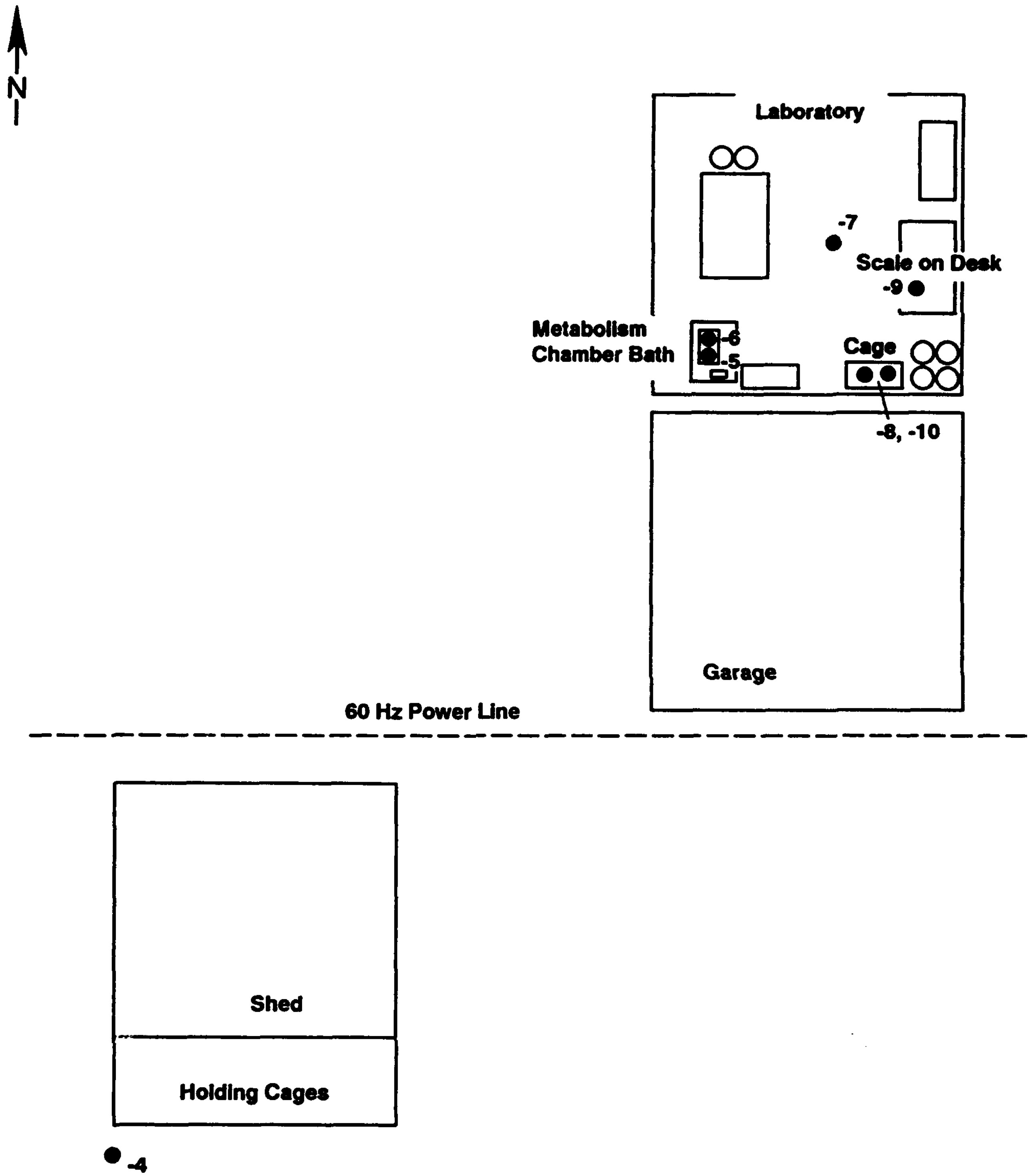


FIGURE A-15. MEASUREMENT POINTS AT MAMMAL LABORATORY; 1L1-4 THROUGH 1L1-10.

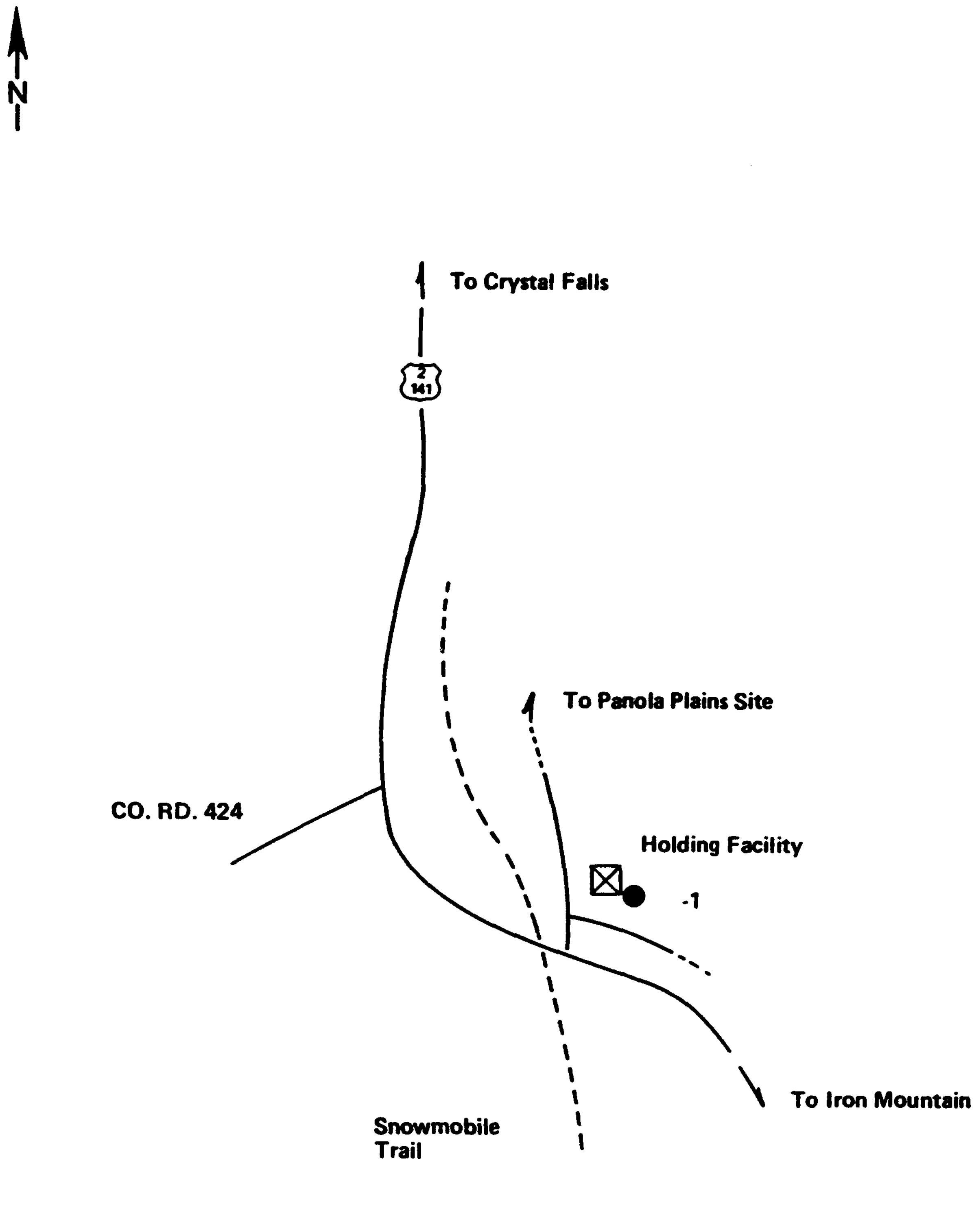


FIGURE A-16. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 1L4-1.

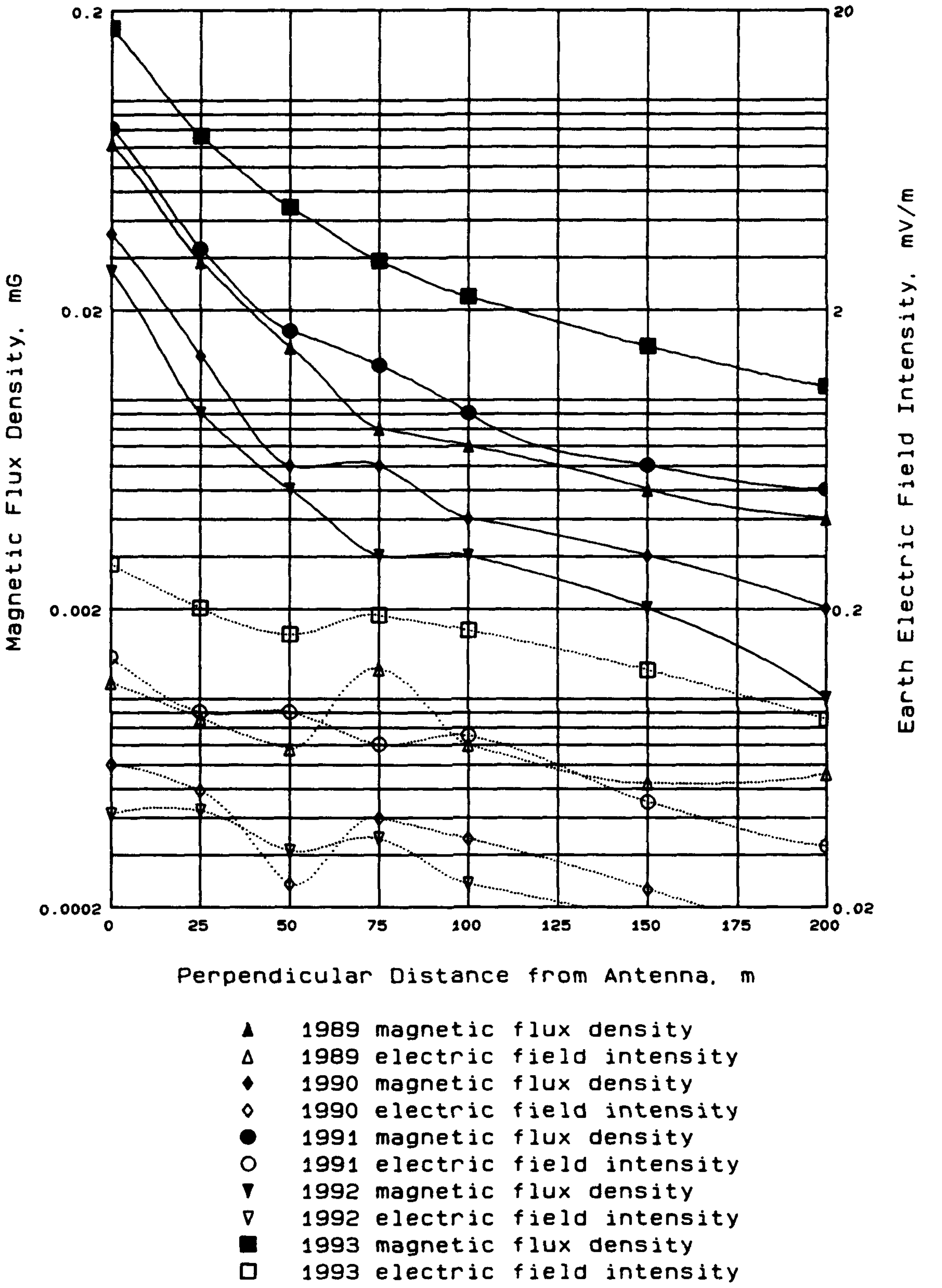


FIGURE A-17. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, PIRLOT ROAD: 1T1-21 THROUGH 27.

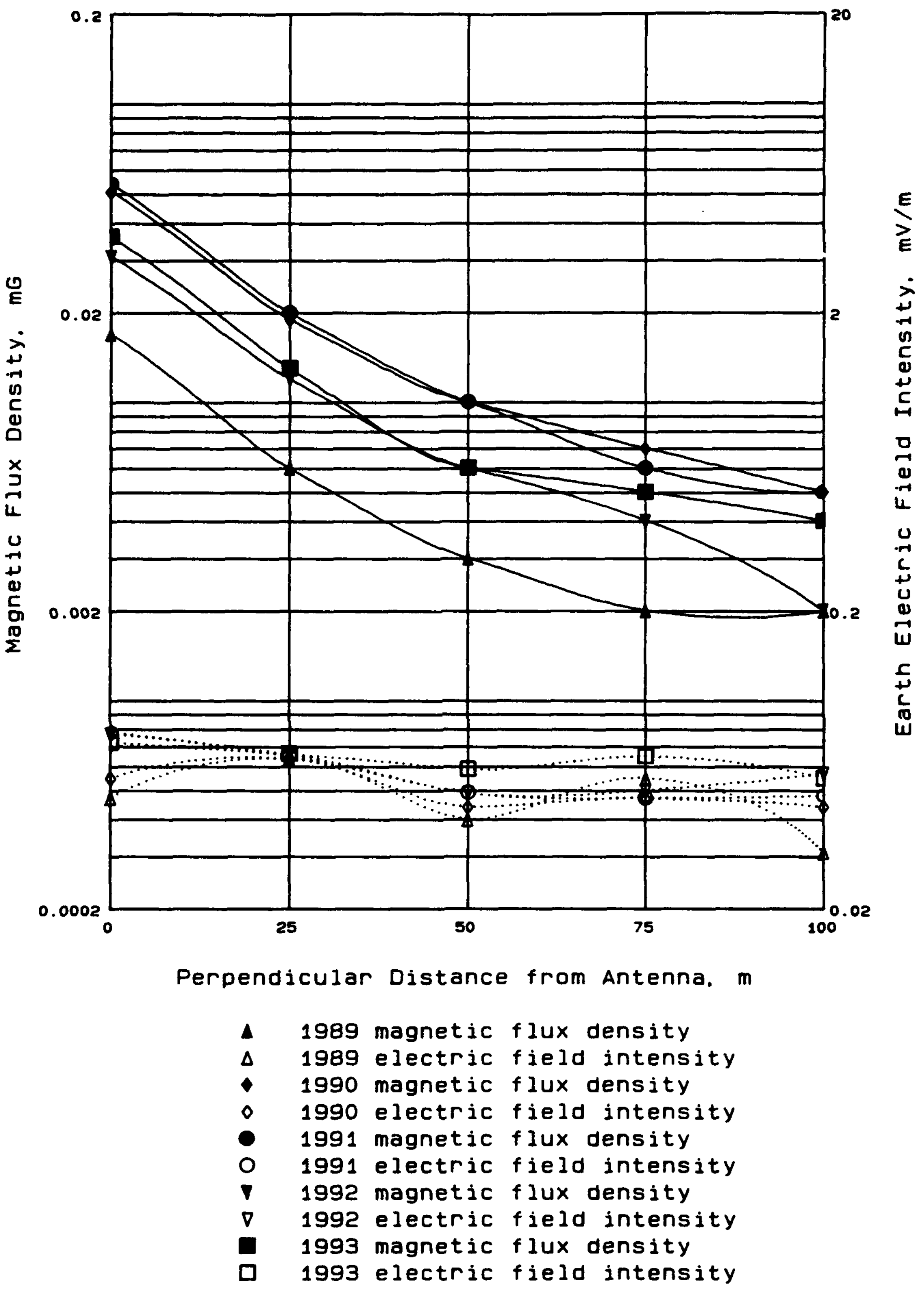


FIGURE A-18. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

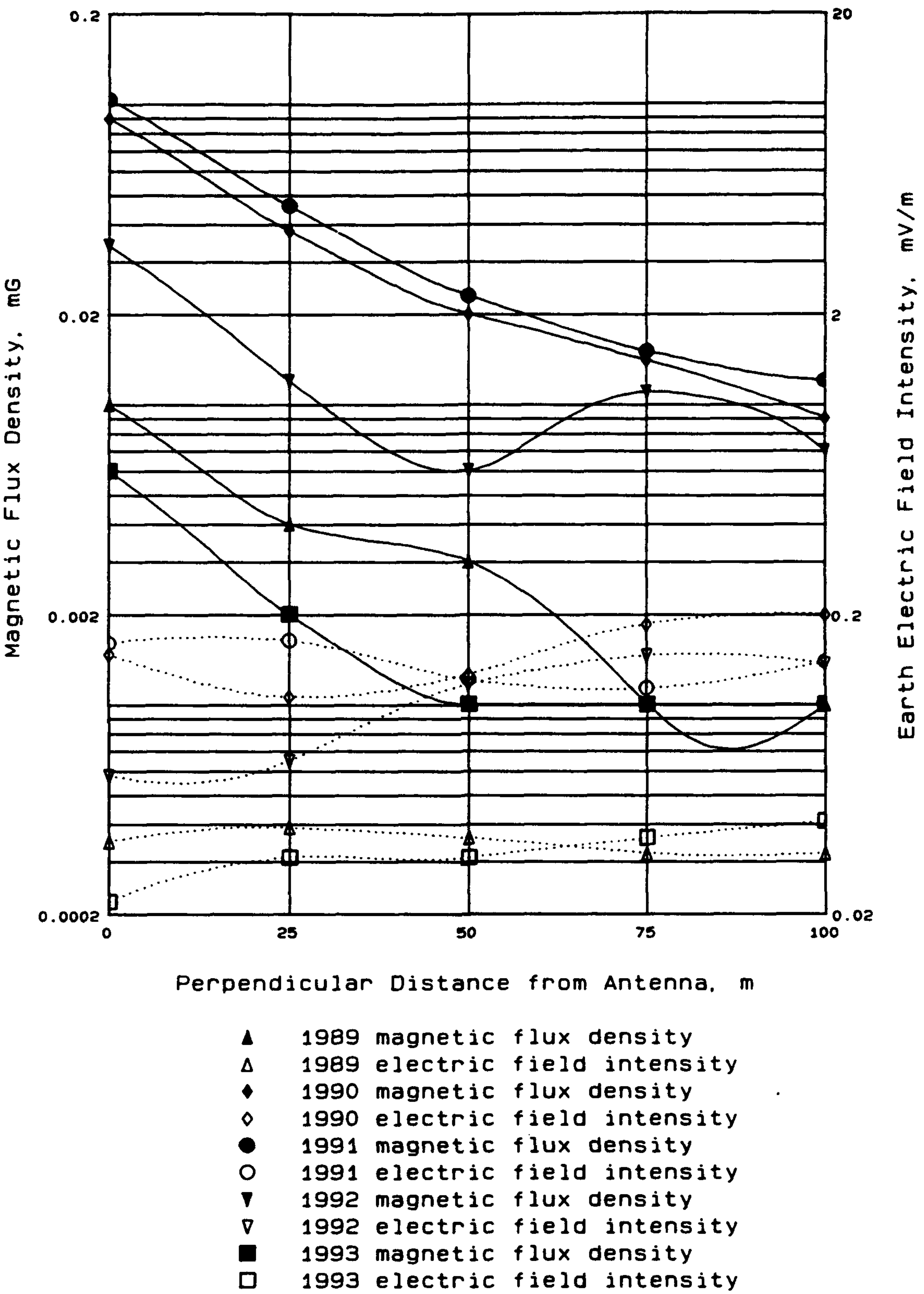


FIGURE A-19. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

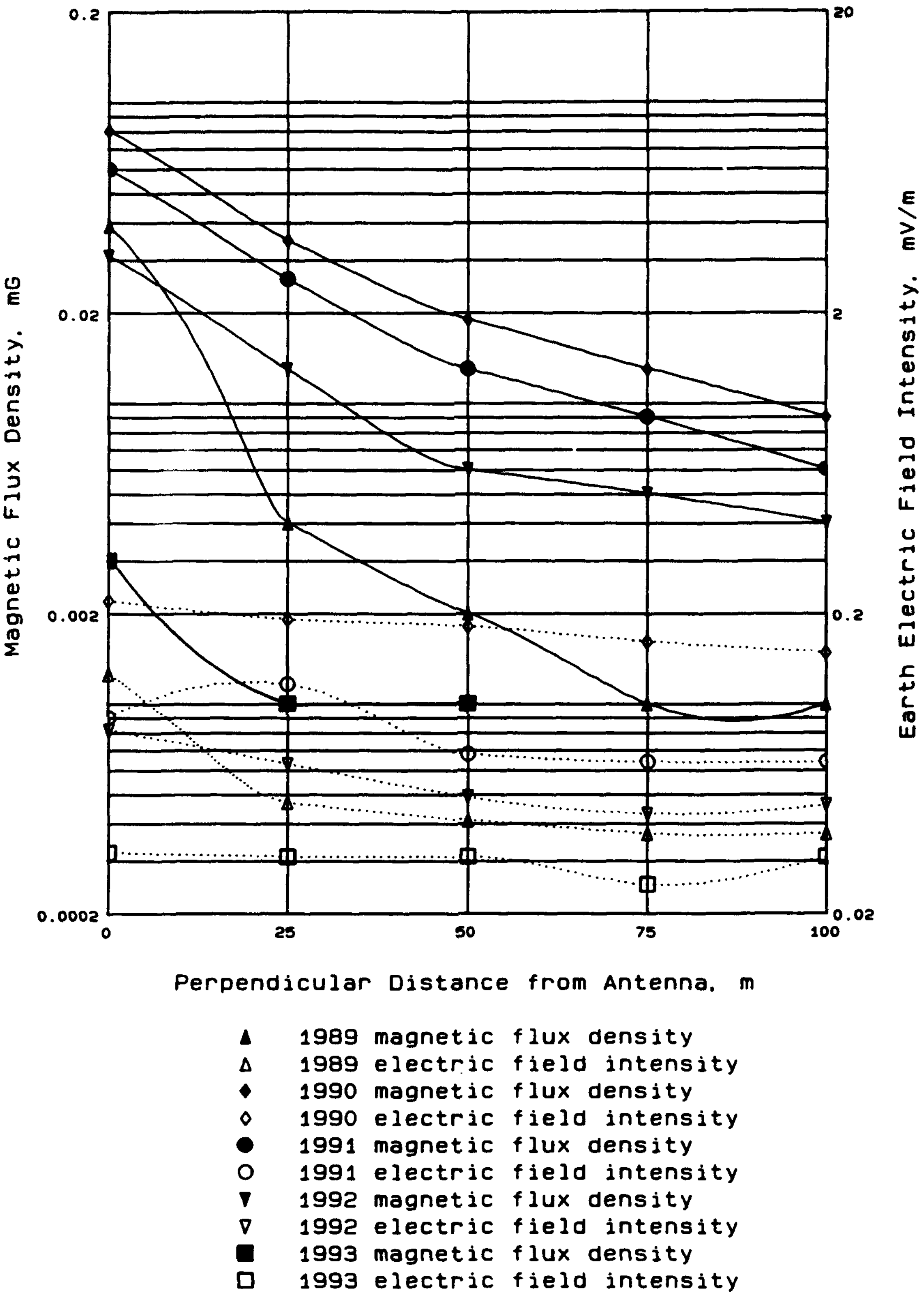


FIGURE A-20. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

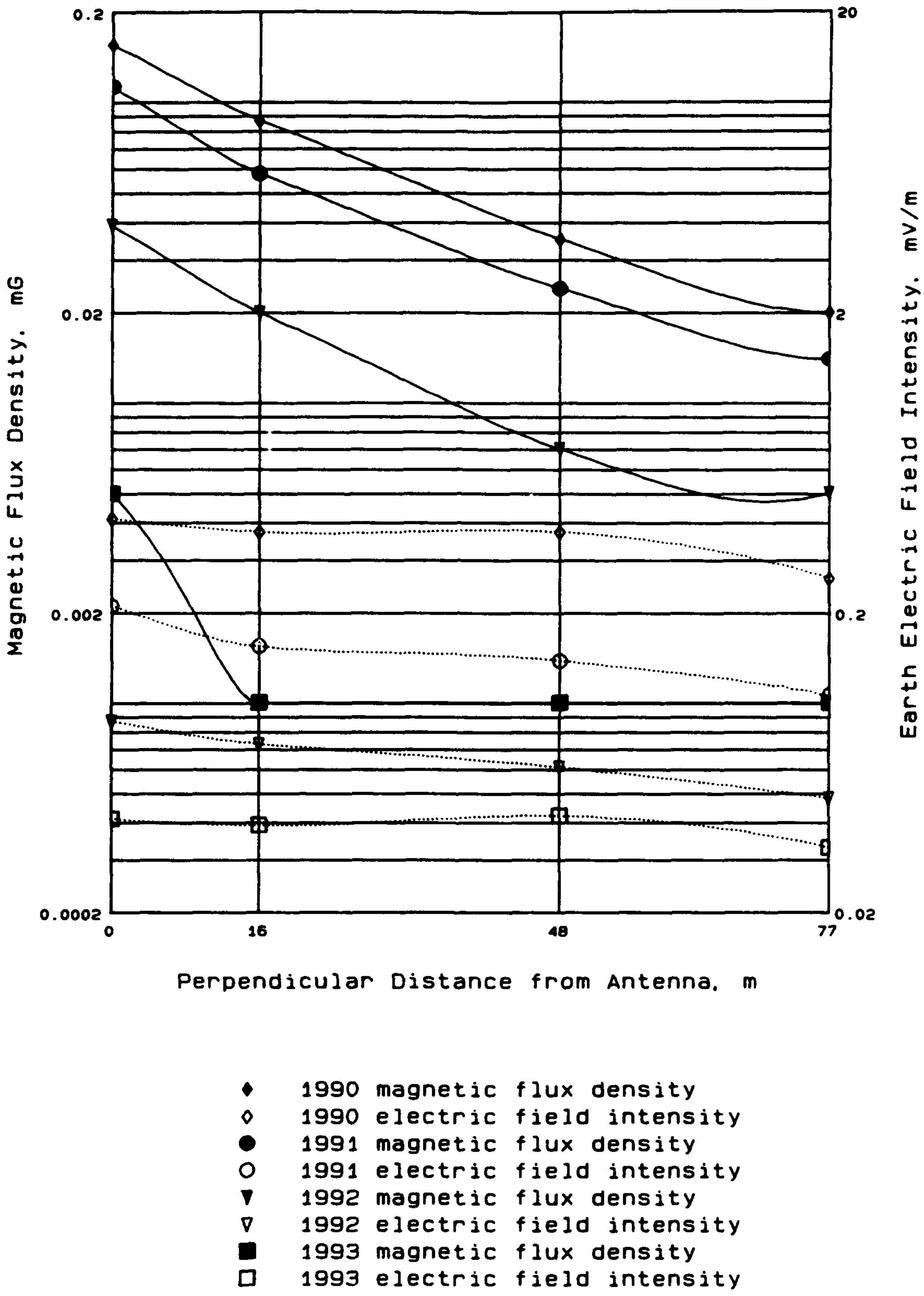
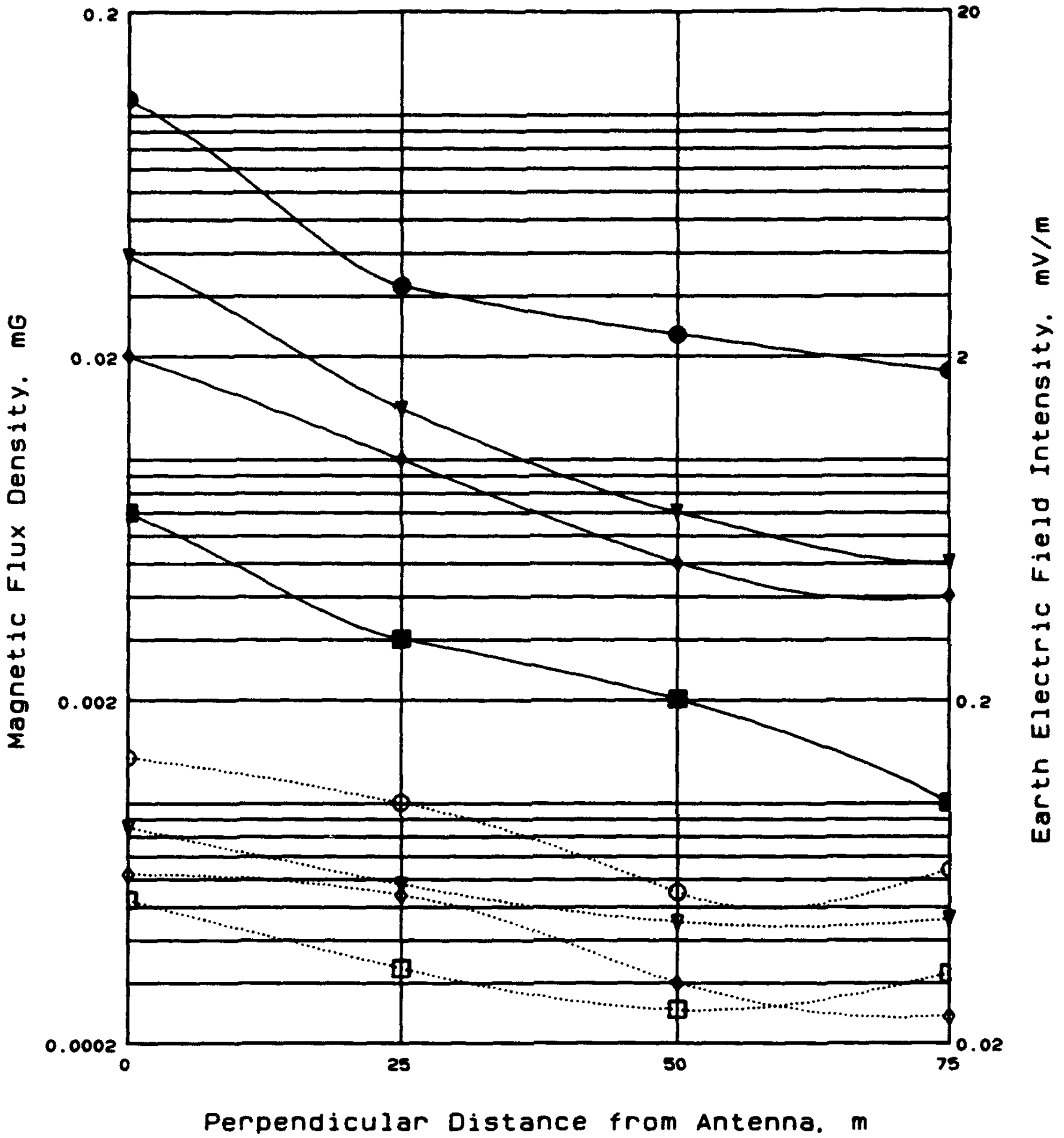


FIGURE A-21. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.



- ♦ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- ● 1991 magnetic flux density
- ○ 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity
- ■ 1993 magnetic flux density
- □ 1993 electric field intensity

FIGURE A-22. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

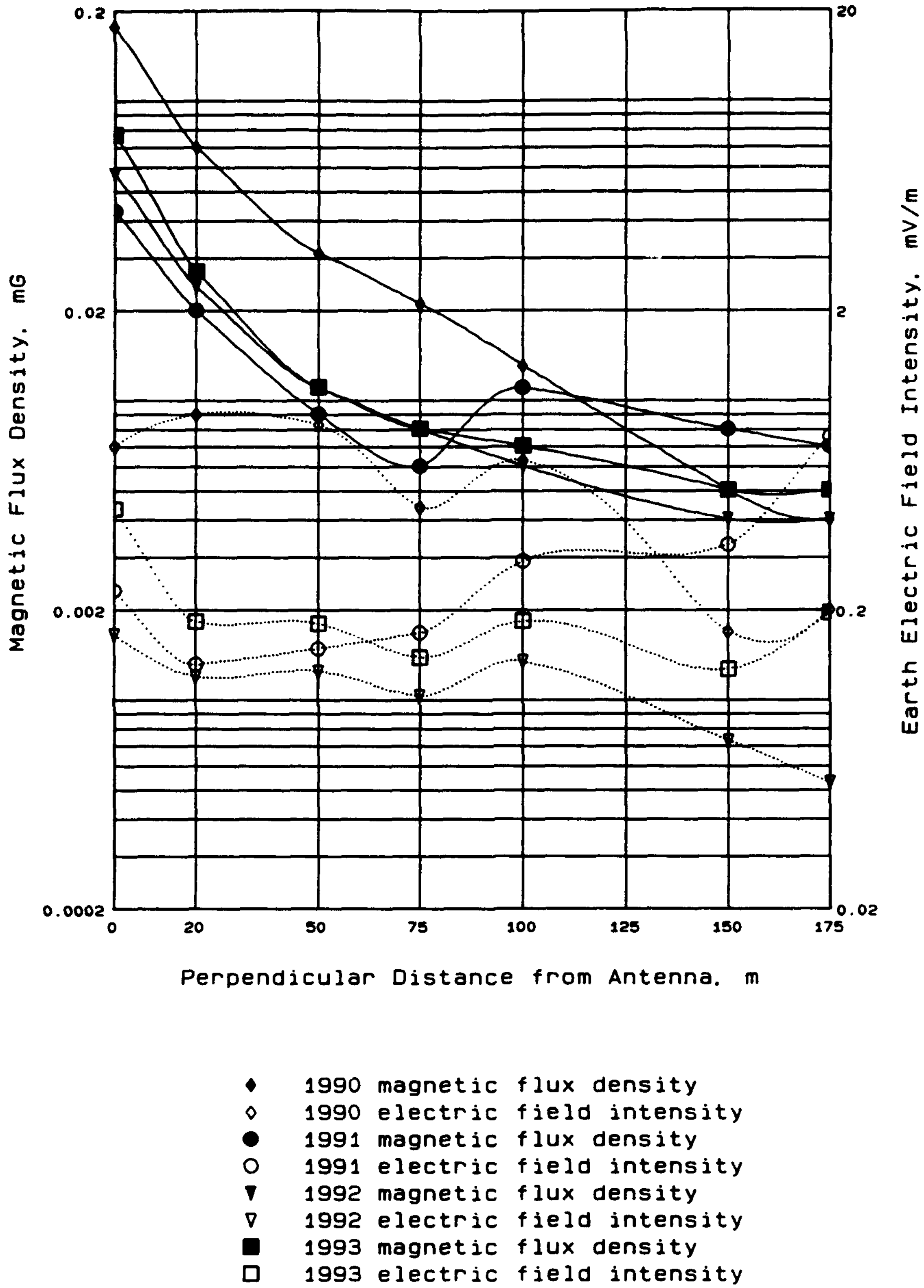


FIGURE A-23. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

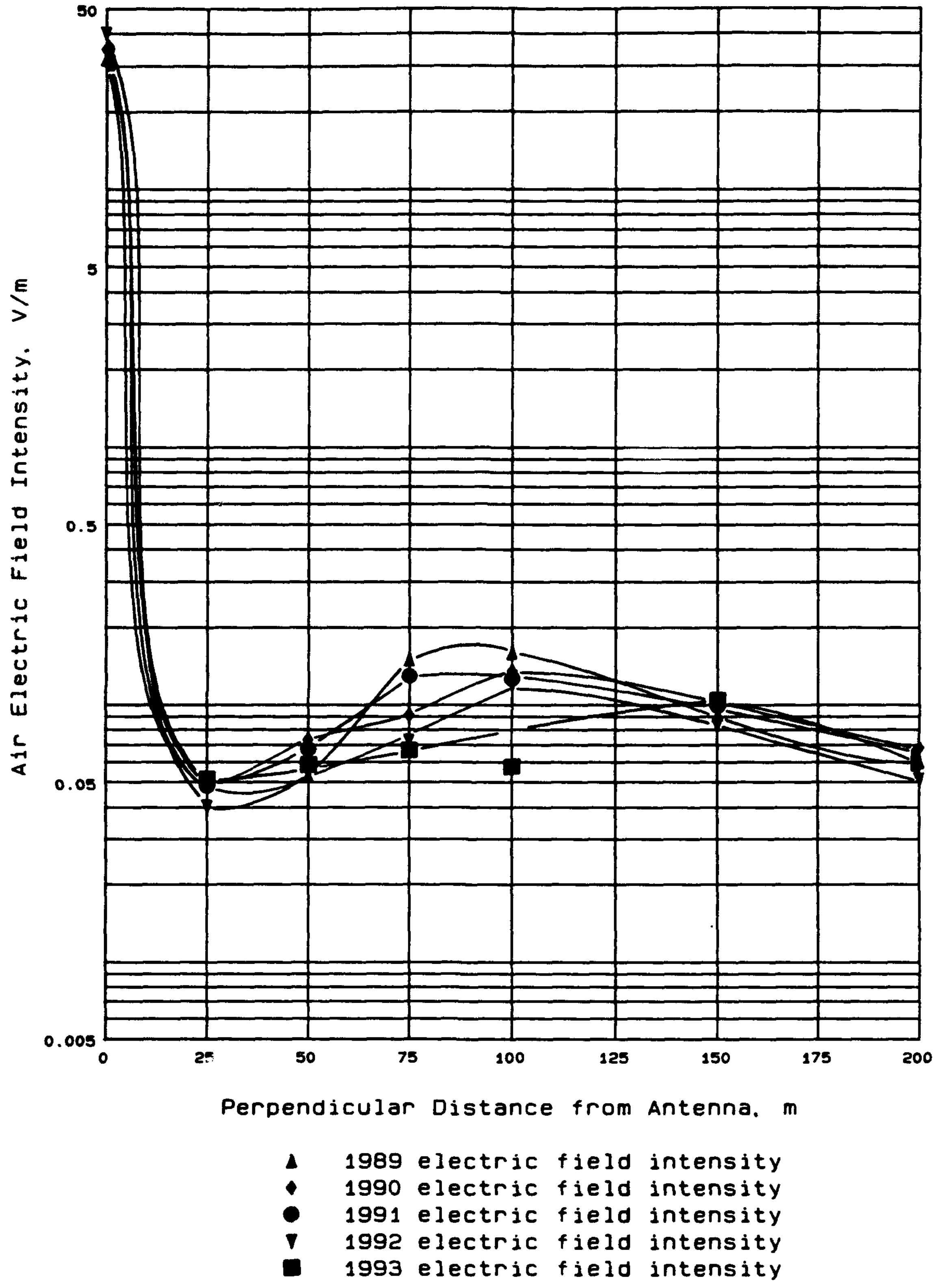


FIGURE A-24. 76 Hz AIR ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

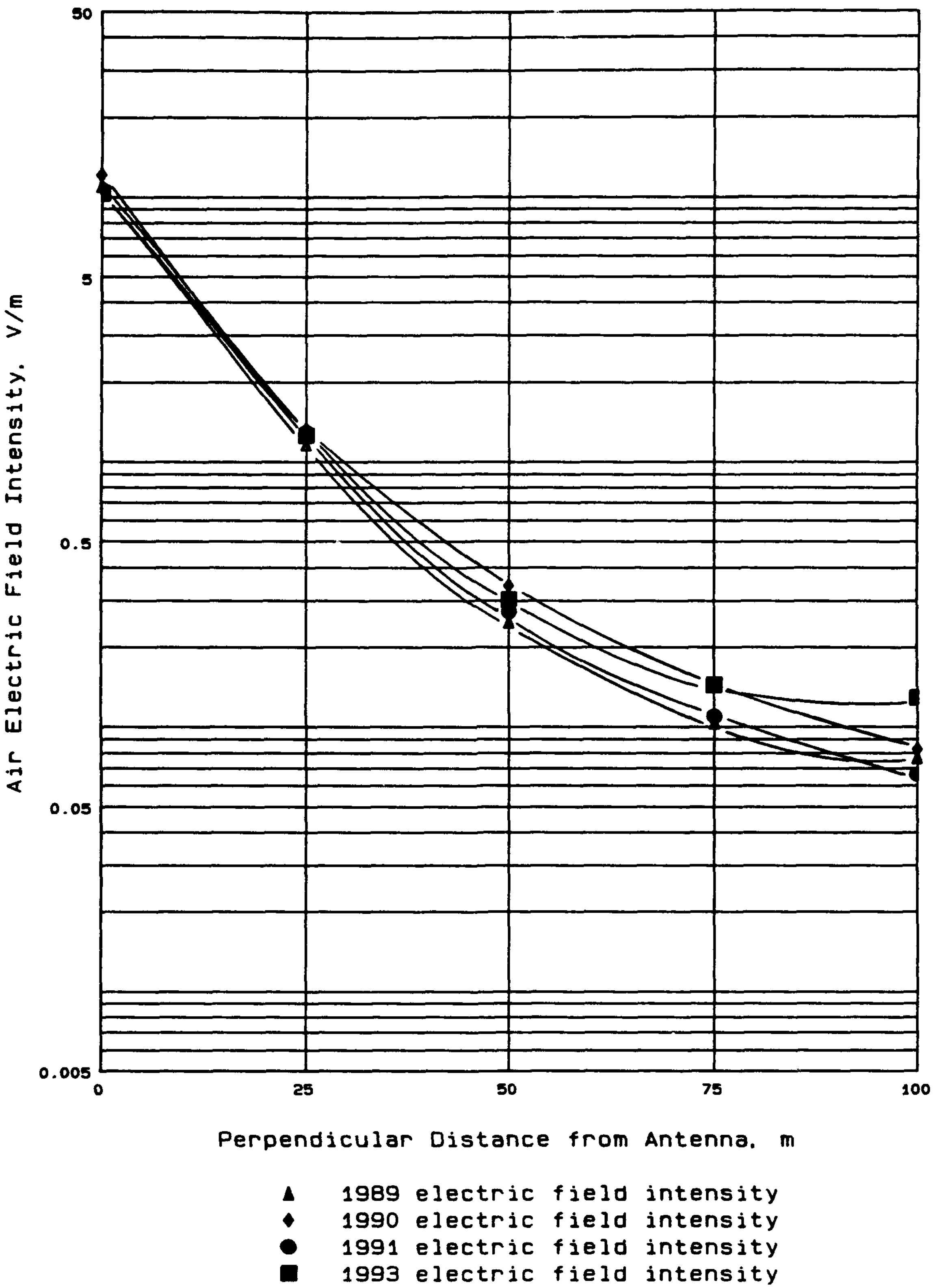


FIGURE A-25. 76 Hz AIR ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

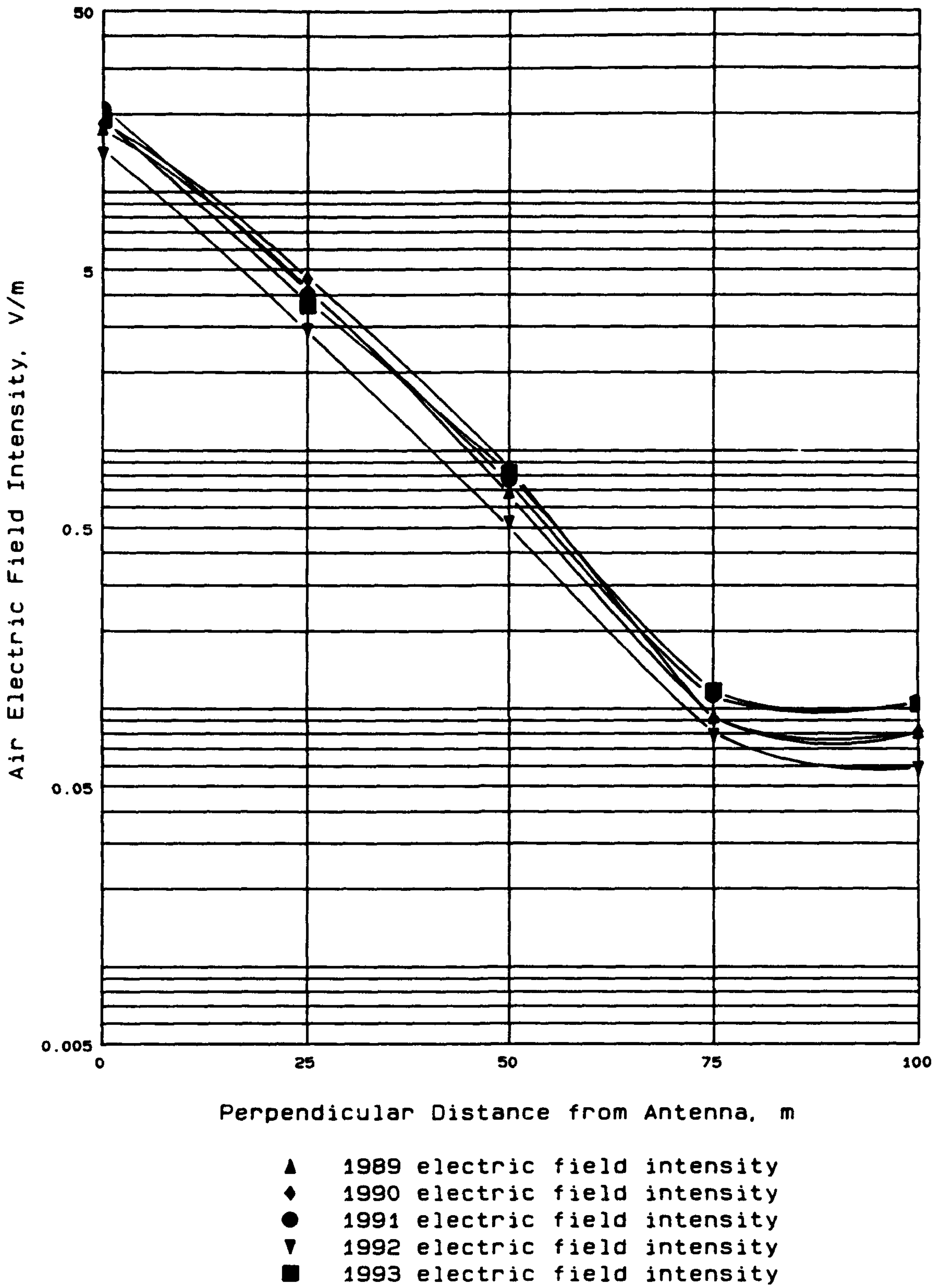


FIGURE A-26. 76 Hz AIR ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

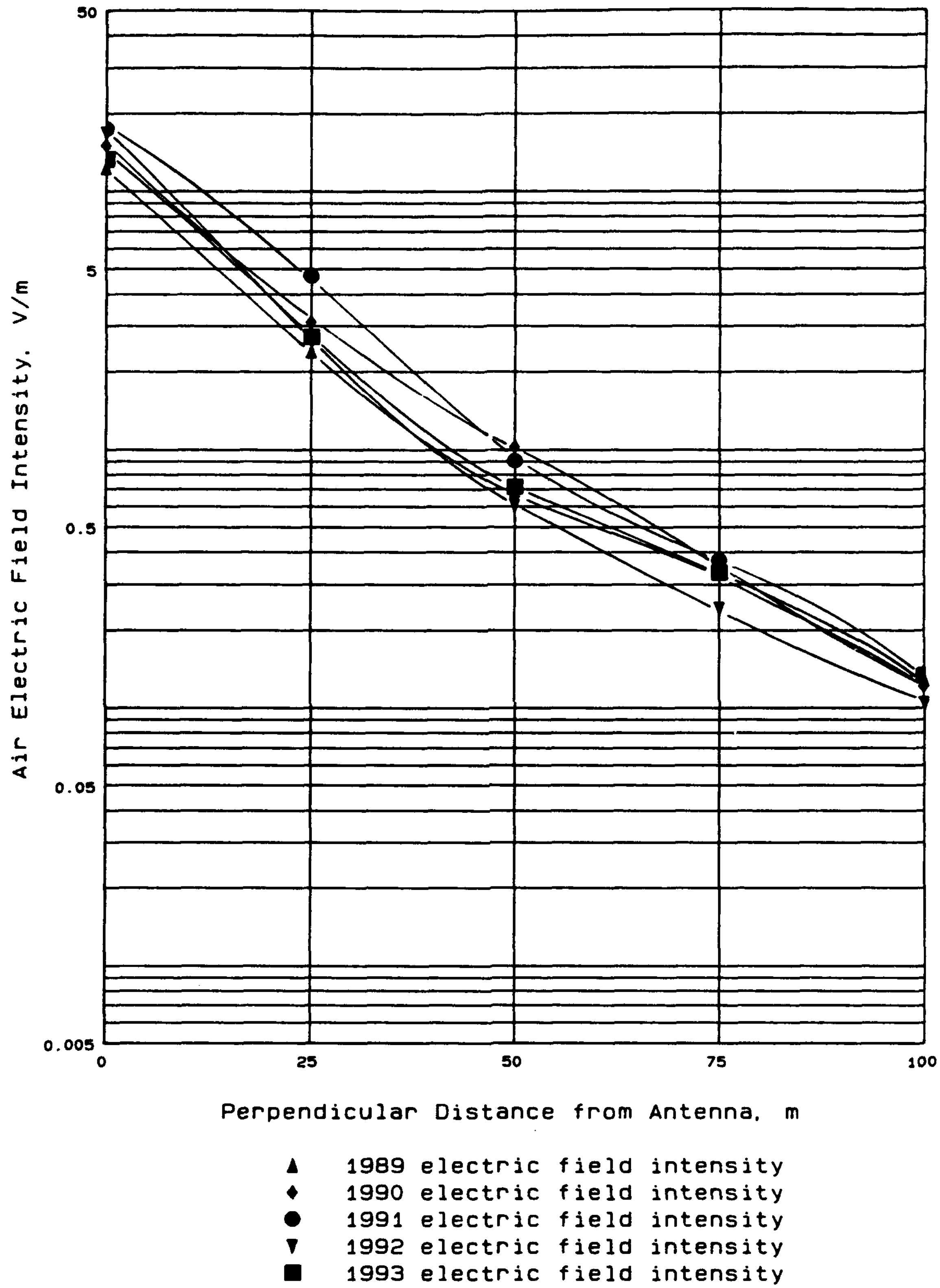


FIGURE A-27. 76 Hz AIR ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

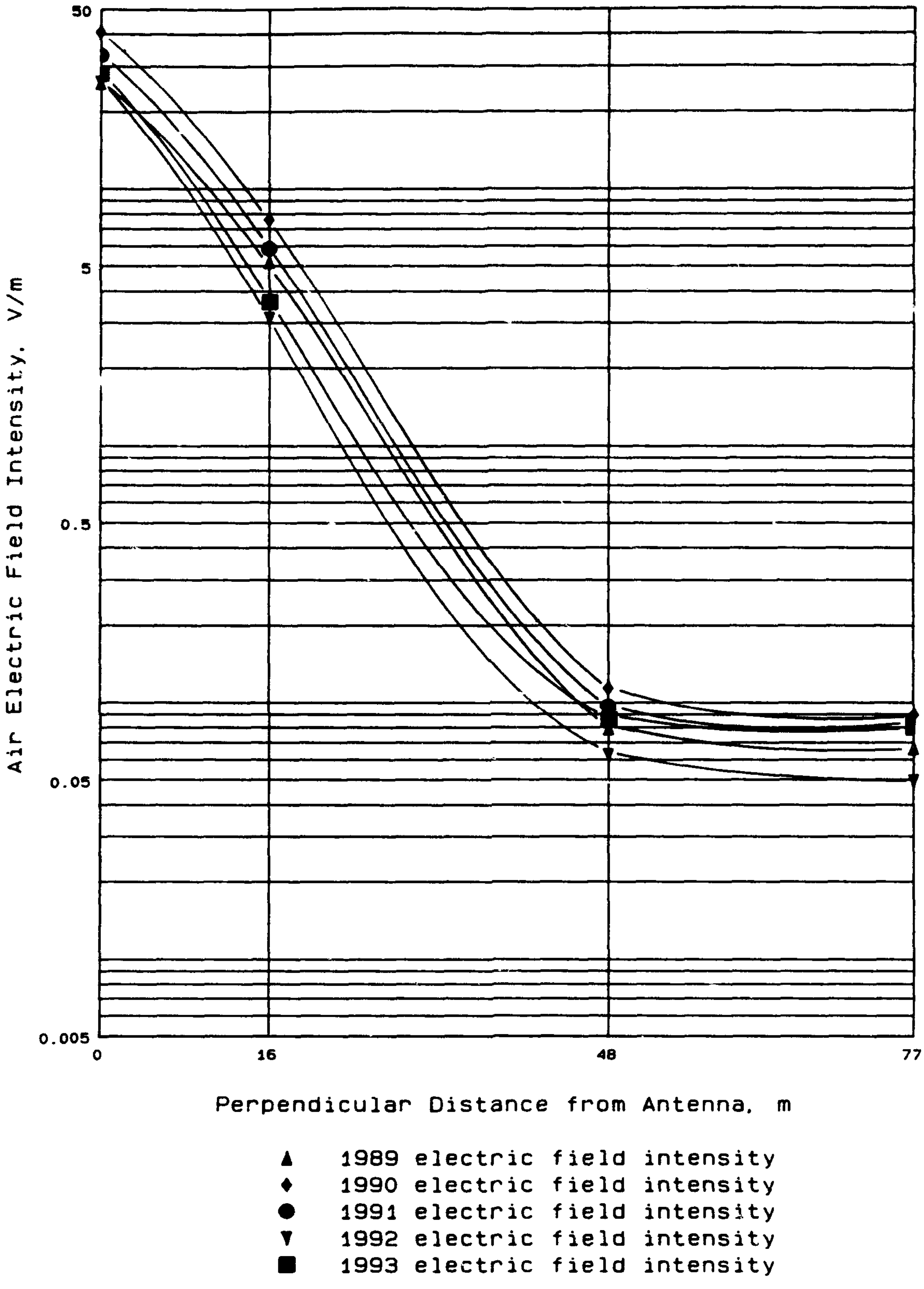


FIGURE A-28. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

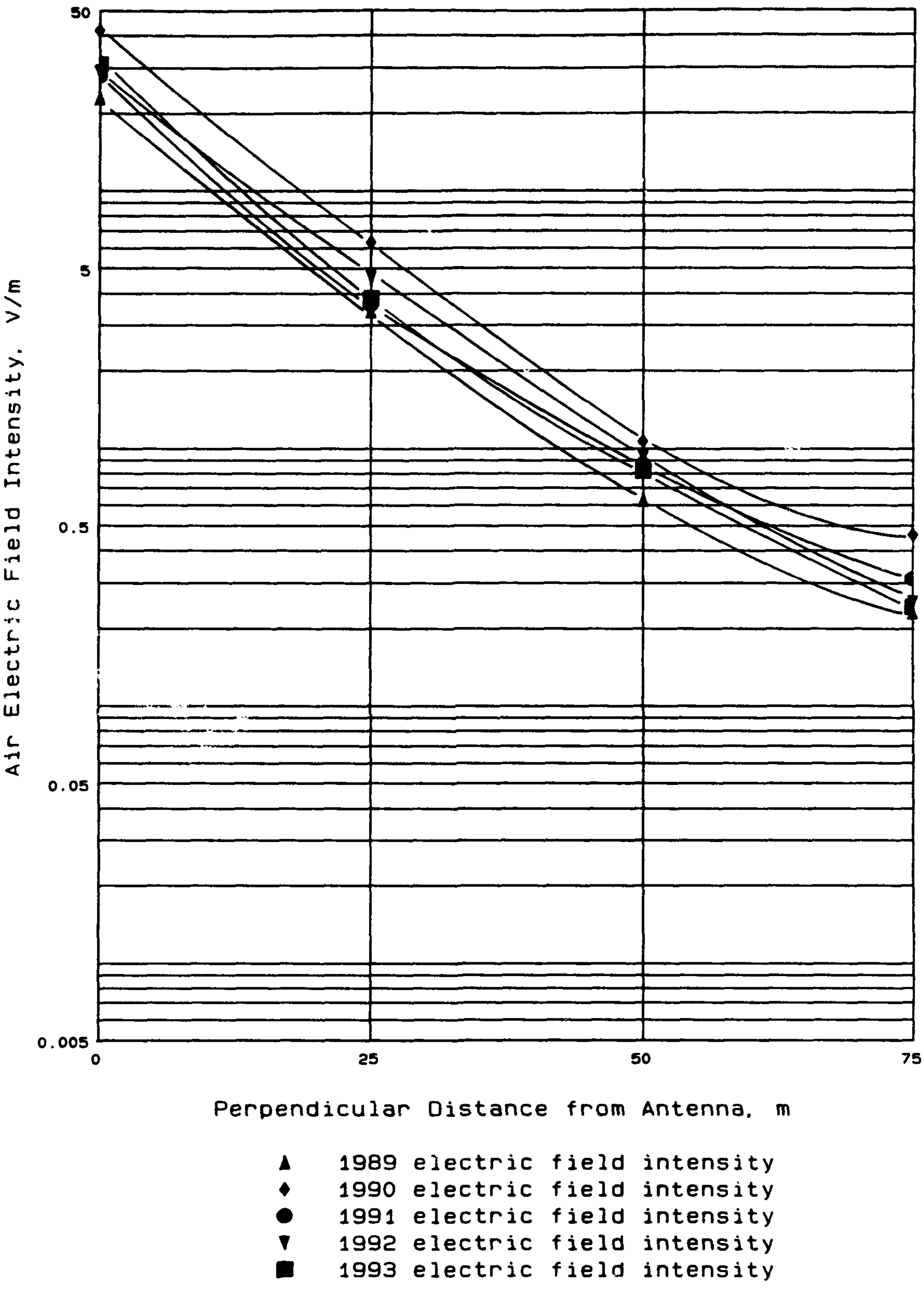


FIGURE A-29. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

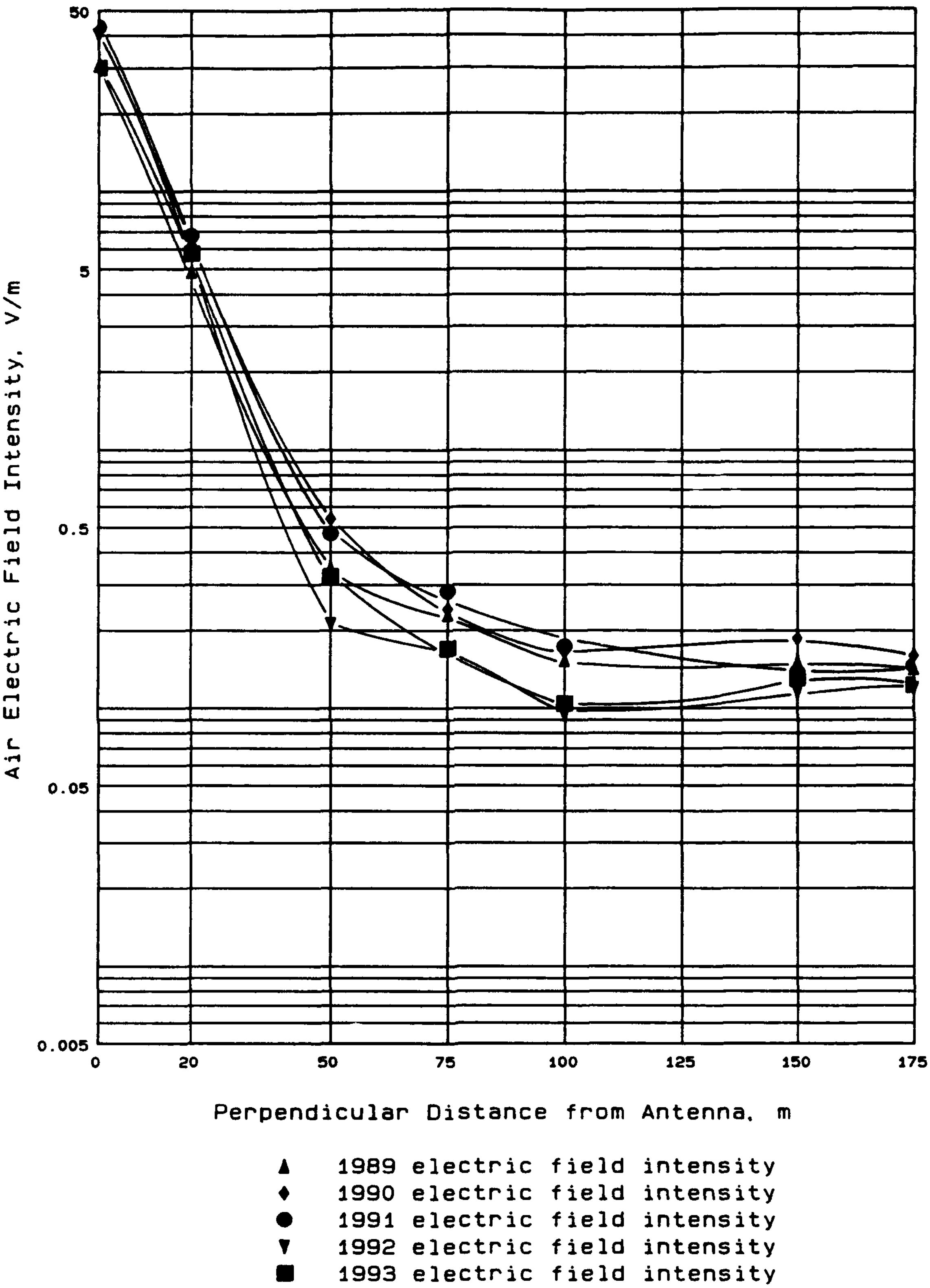


FIGURE A-30. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

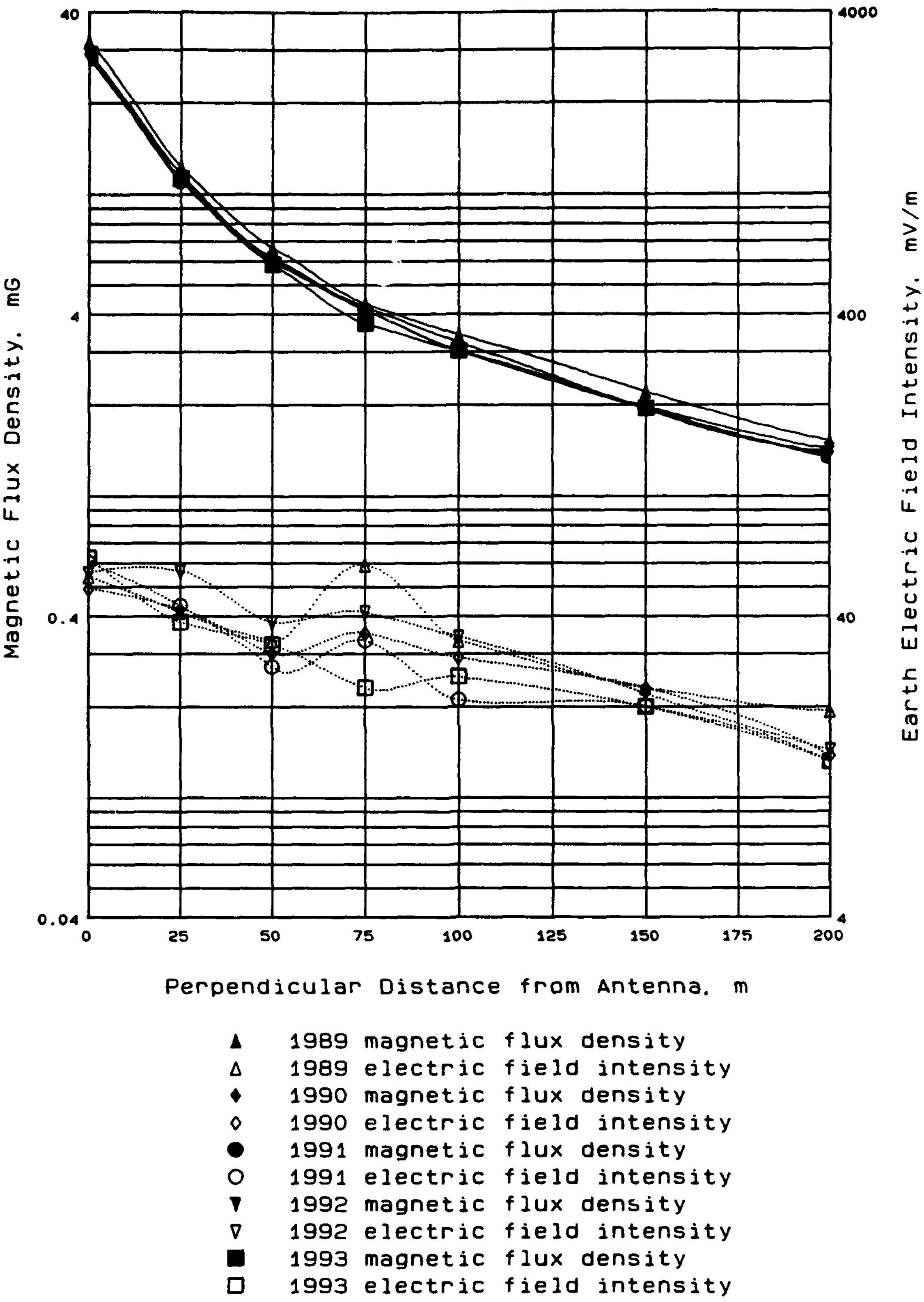


FIGURE A-31. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

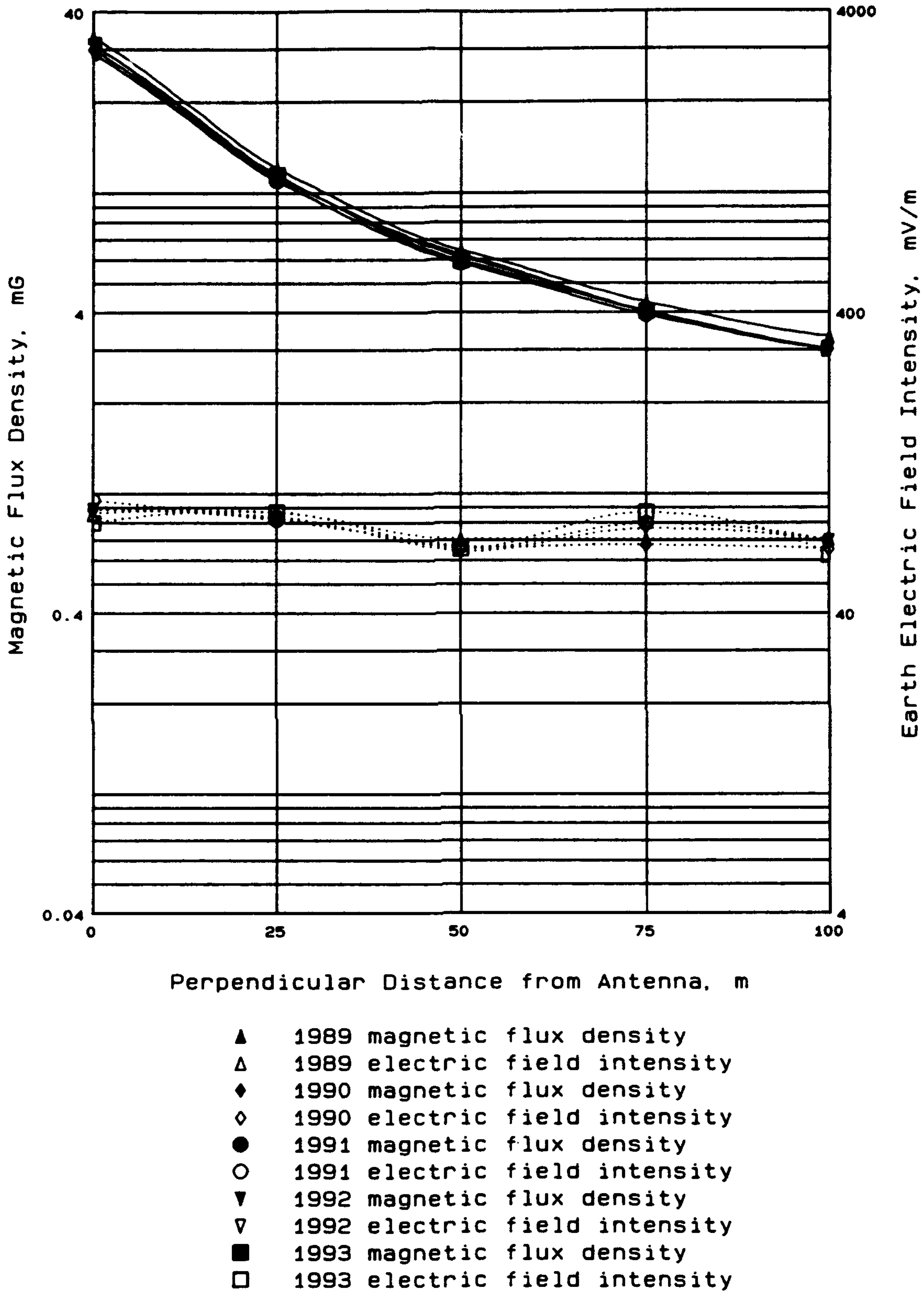


FIGURE A-32. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

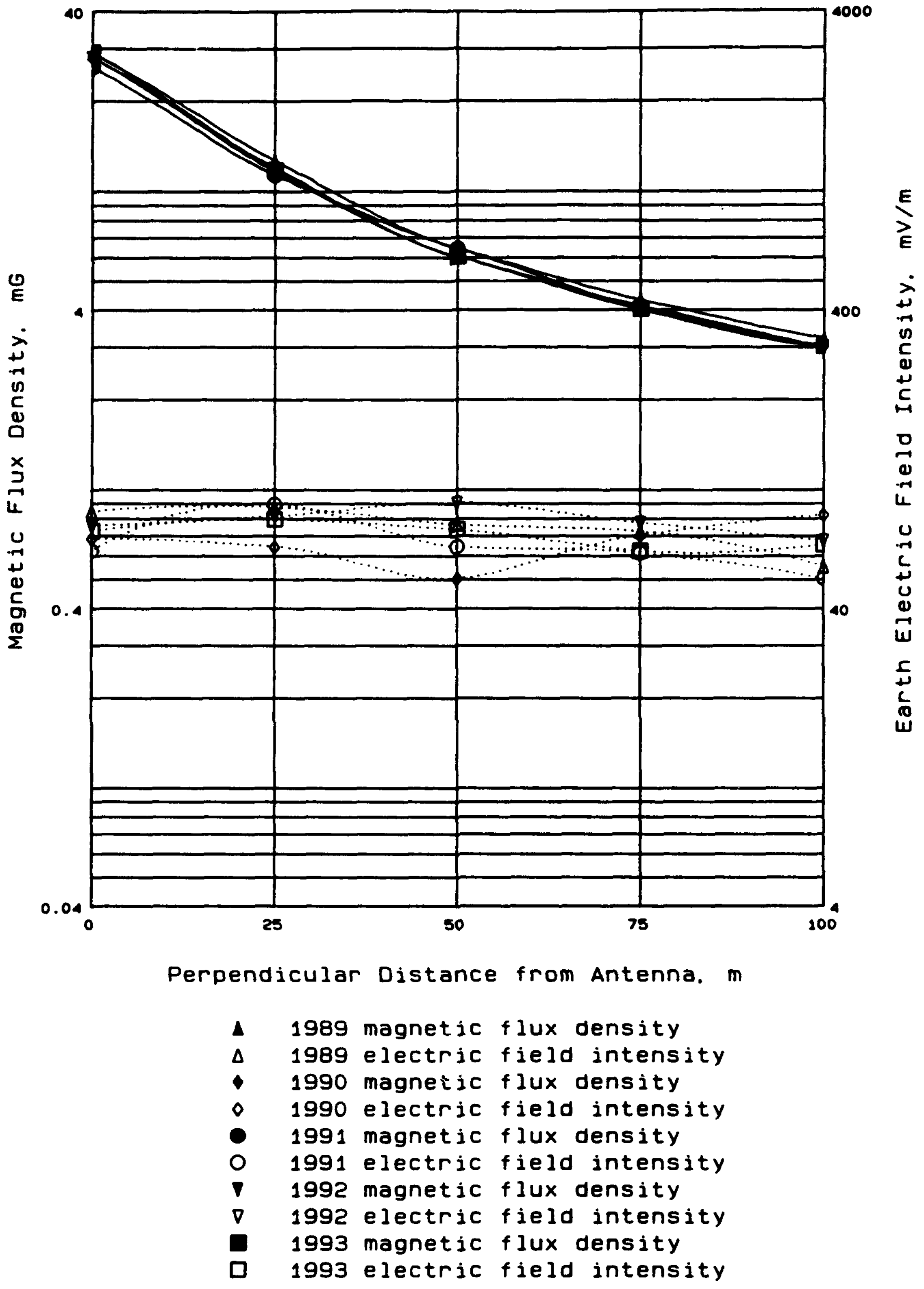


FIGURE A-33. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

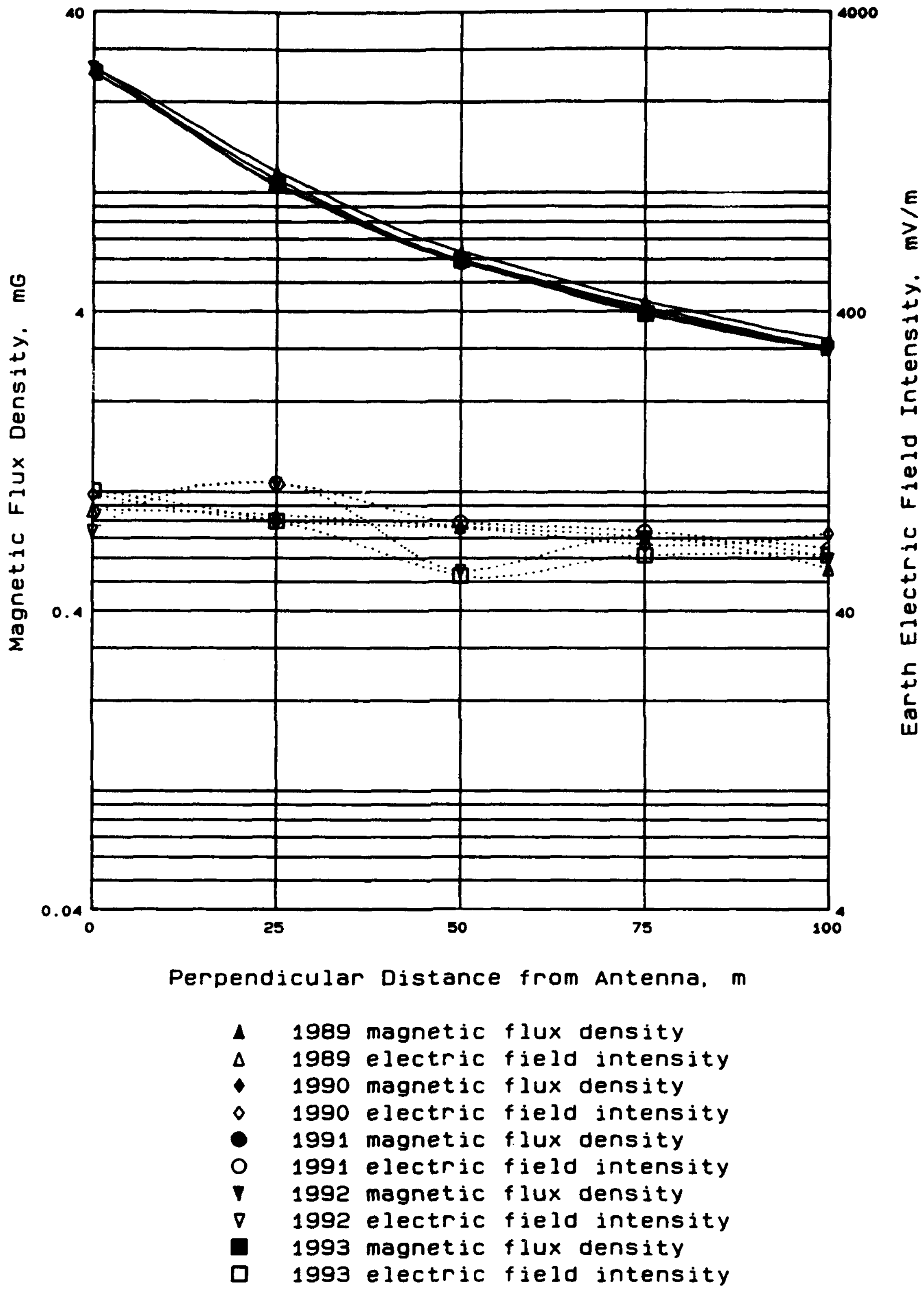


FIGURE A-34. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

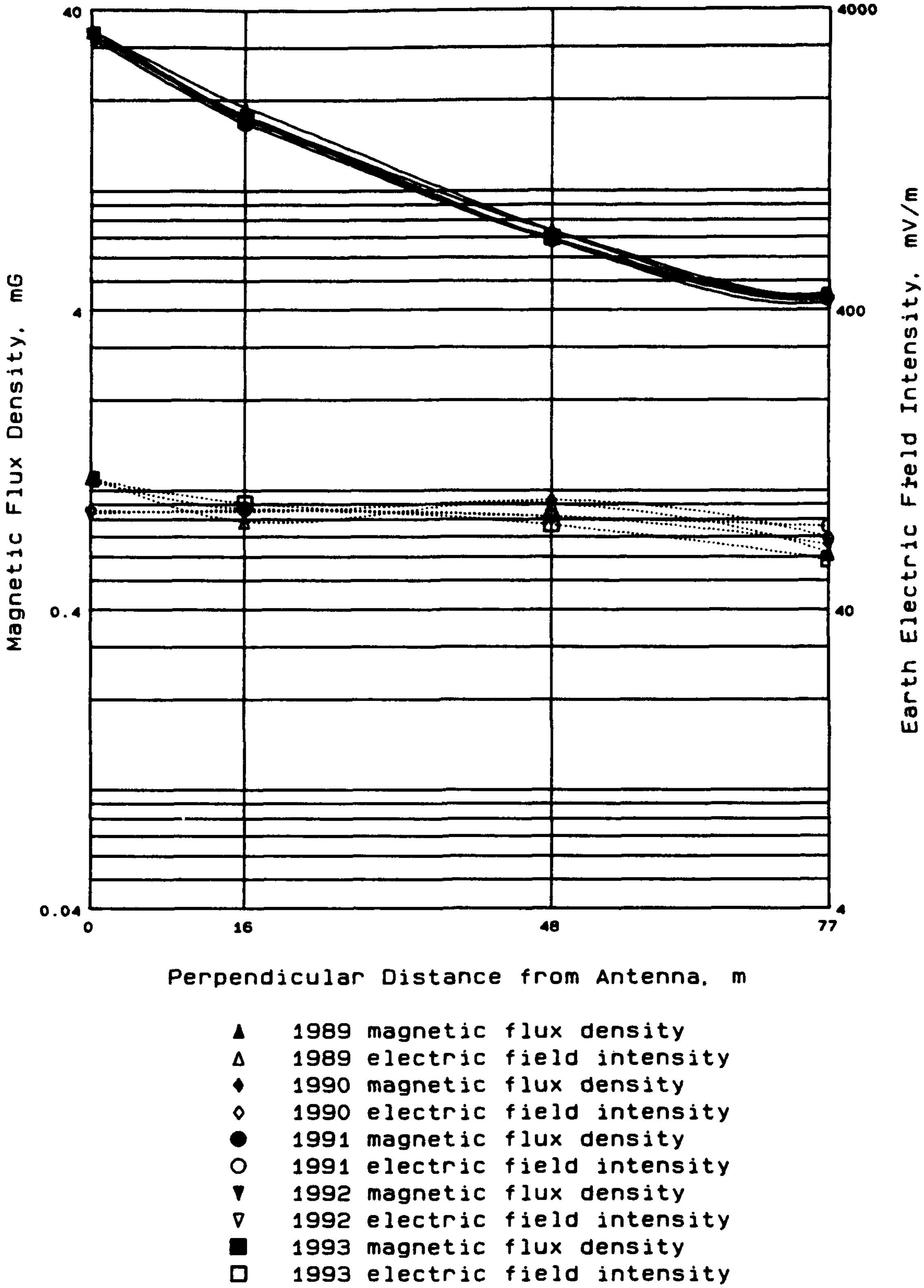


FIGURE A-35. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

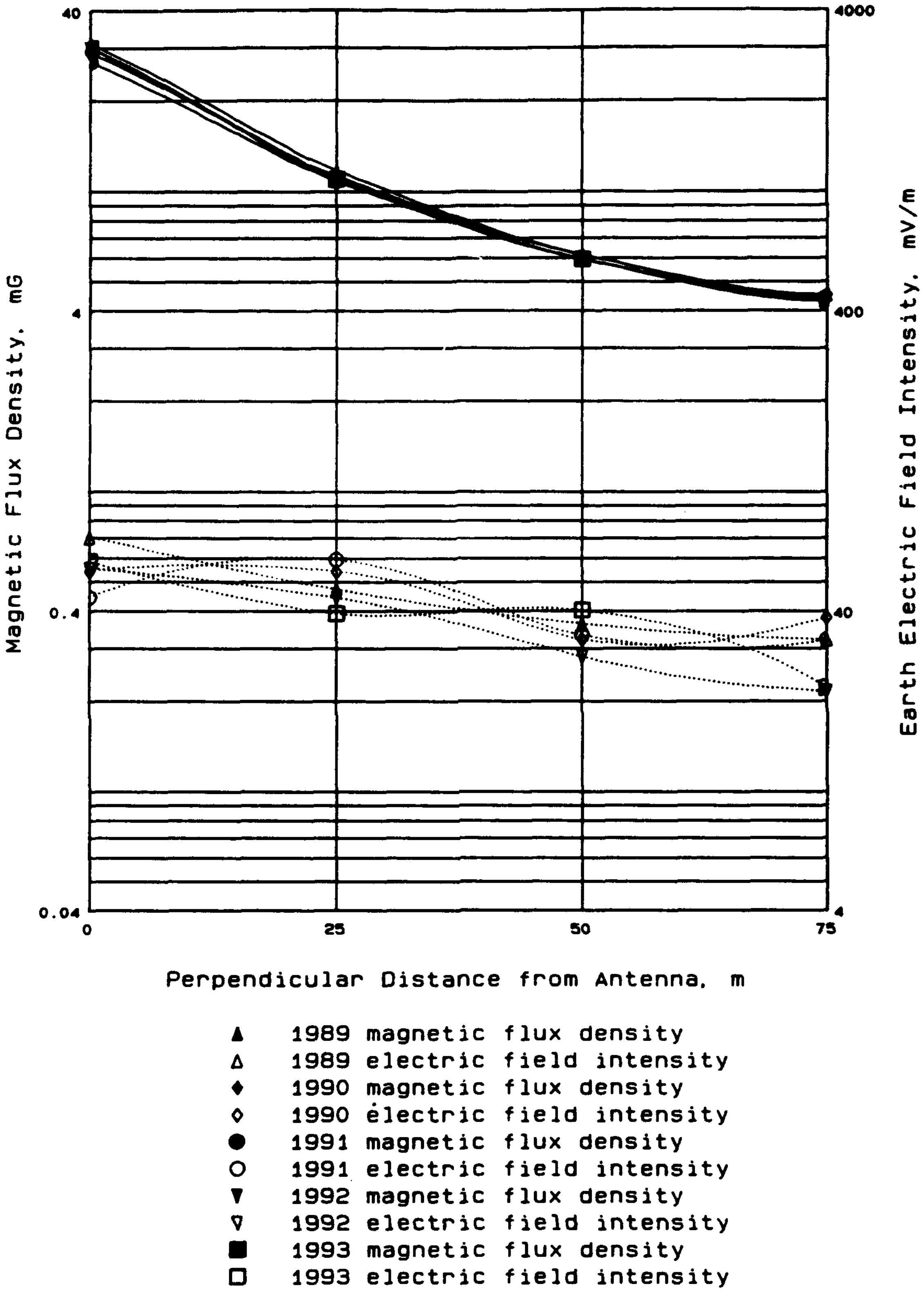


FIGURE A-36. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

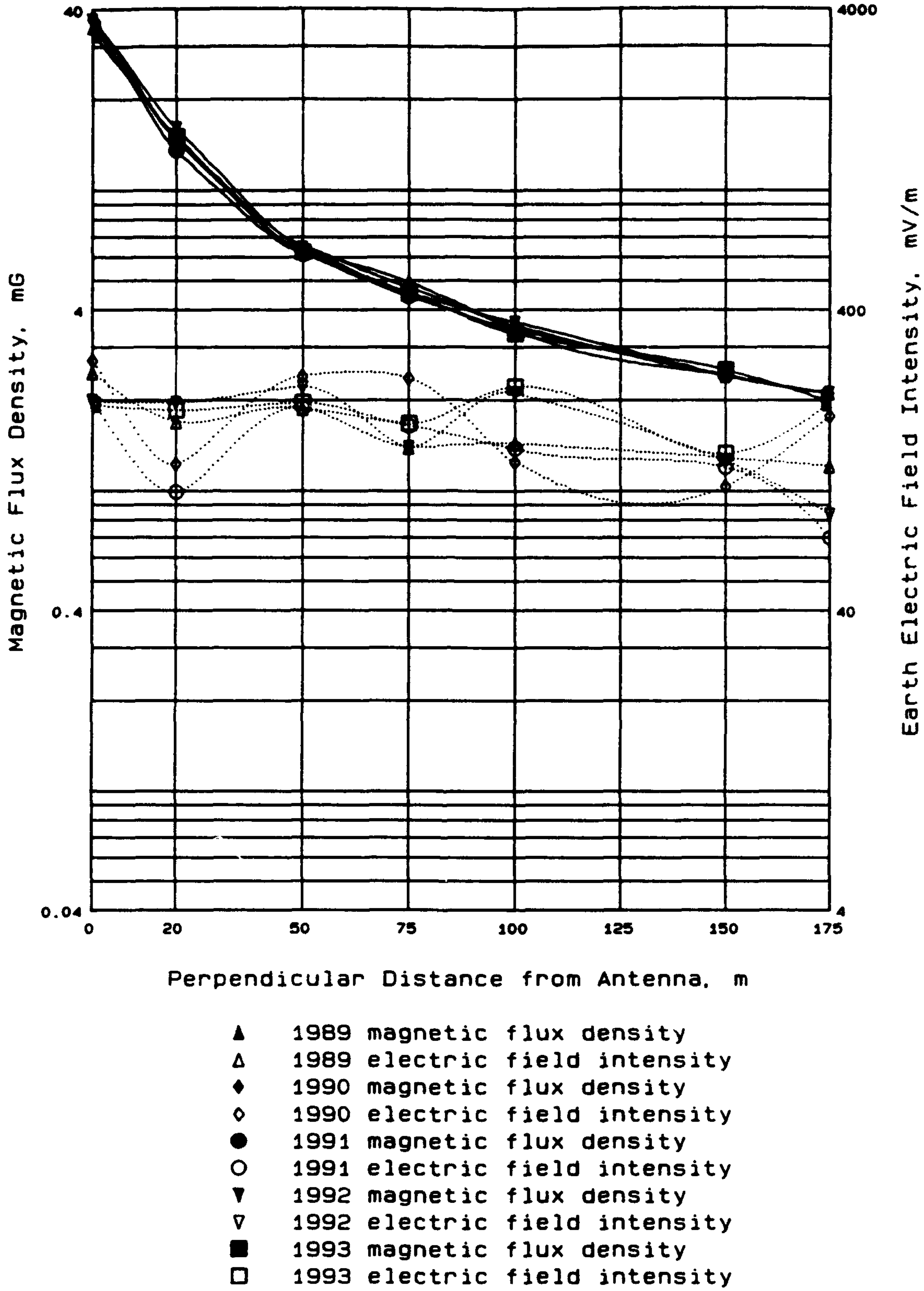


FIGURE A-37. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T6-2, 1, 3, 4, 5, 6, 7.

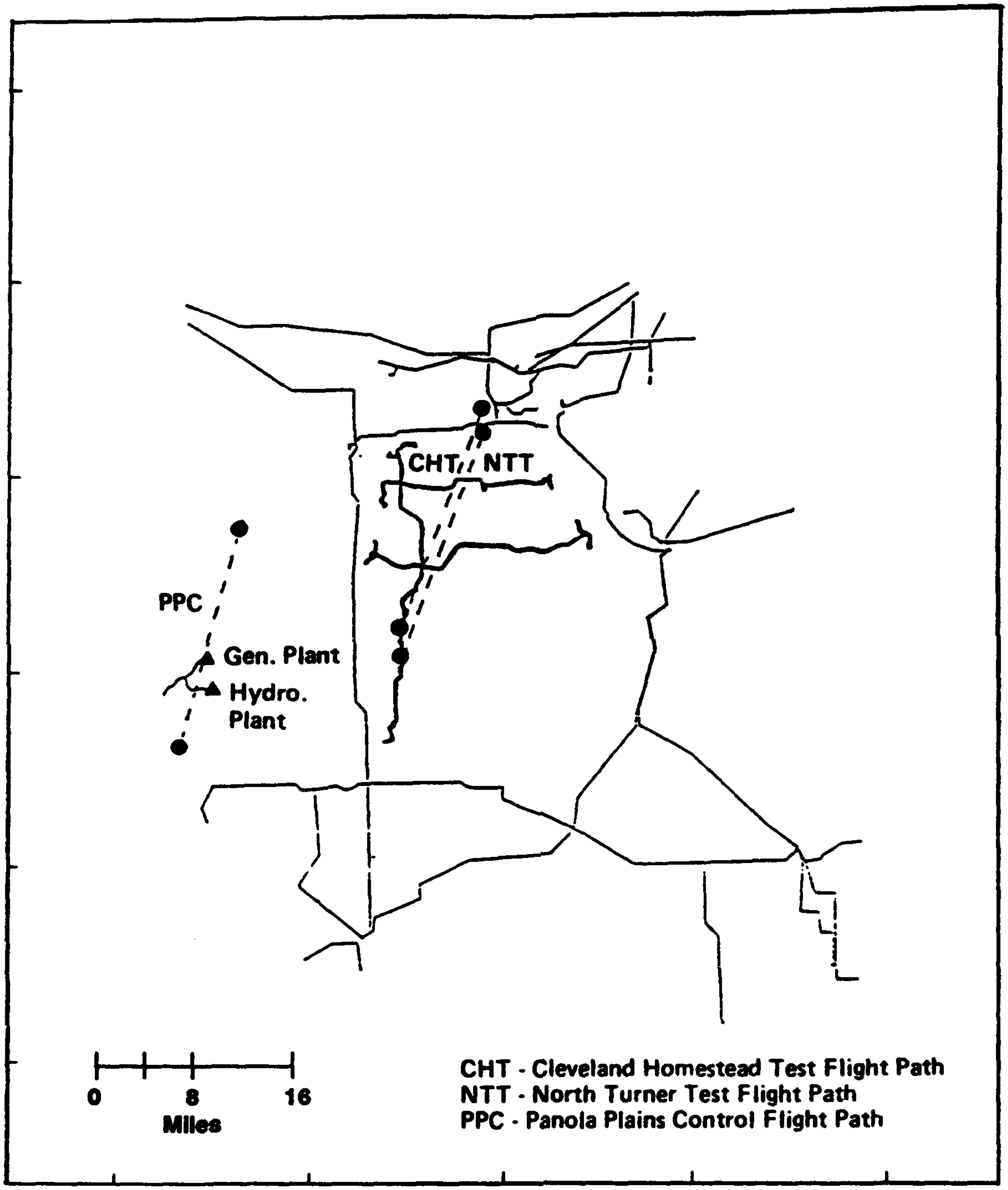


FIGURE A-38. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH-VOLTAGE 60 Hz TRANSMISSION LINES.

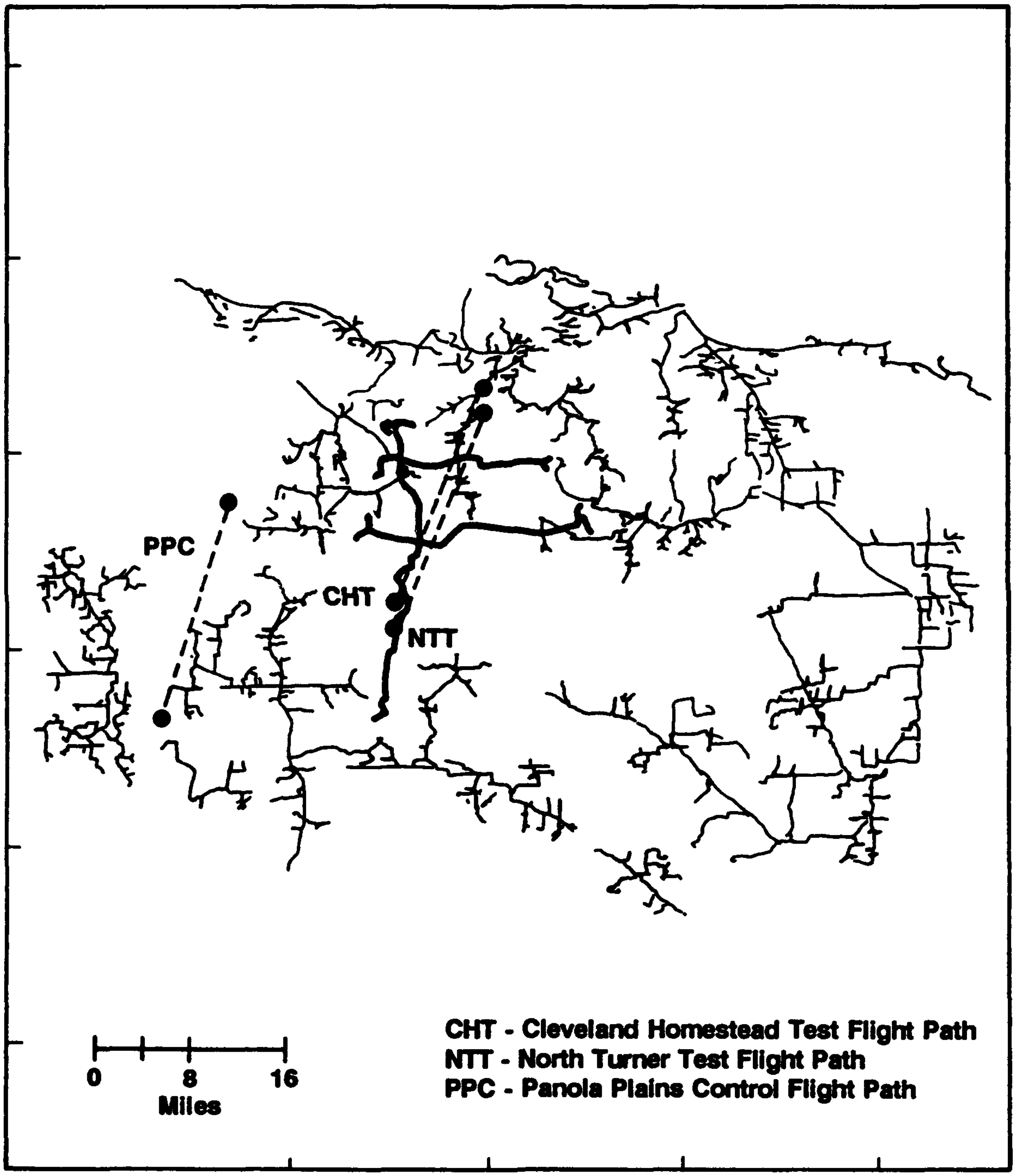


FIGURE A-39. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

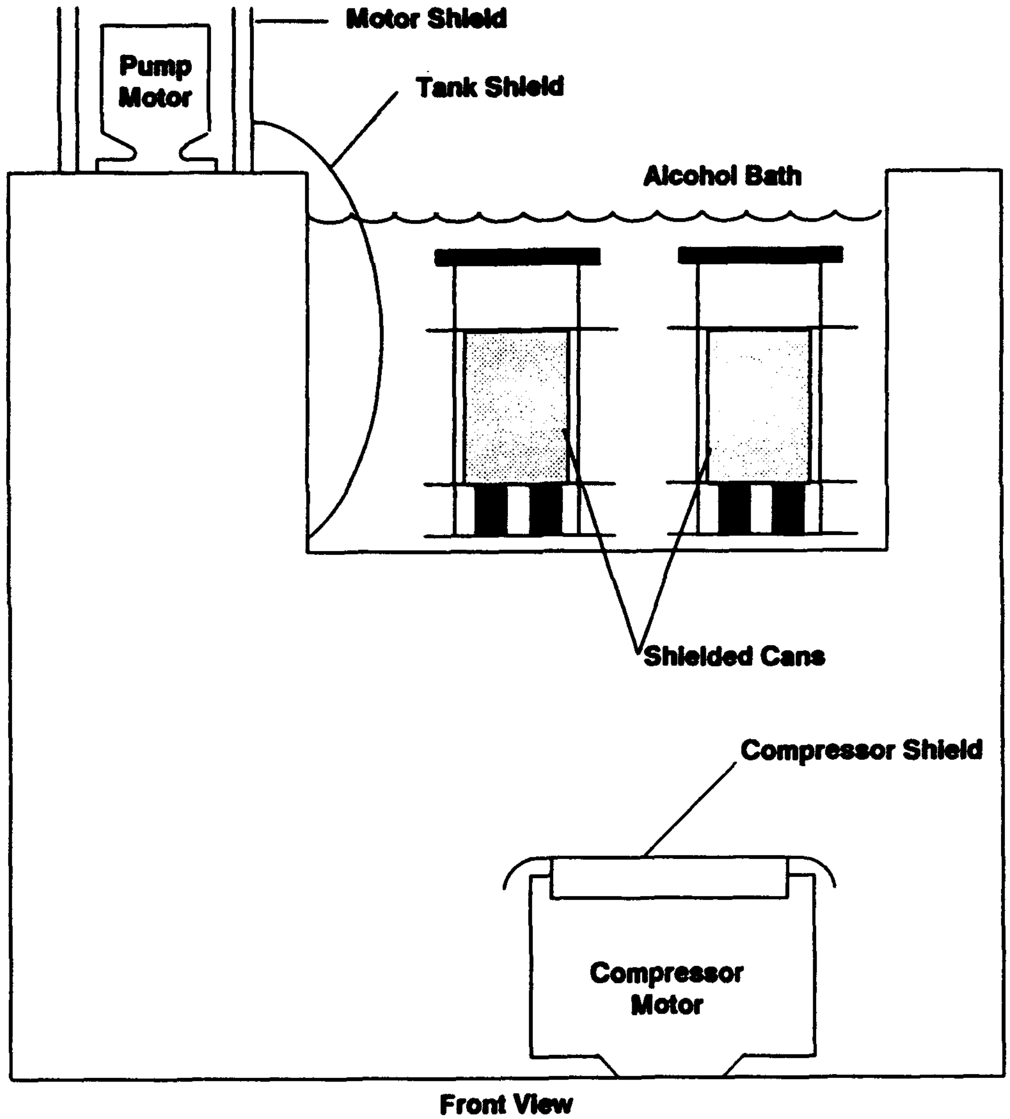


FIGURE A-40. MAGNETIC SHIELD LOCATIONS AT THE METABOLIC COOLING BATH.

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1C1-2	<	<	<	–	–	–	–	–	–	–	–
1C1-3	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C1-4	-	-	-	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C3-1	<	<	<	<	<	<	<	<[d]	<[d]	<[d]	/
1C3-2	<	<	–	–	–	–	–	–	–	–	–
1C3-3	-	-	-	<	<	<	<	<[d]	<[d]	<[d]	/
1C4-1	-	0.001	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C4-2	-	<0.001	<	–	–	–	–	–	–	–	–
1C4-3	-	<0.001	<	<	–	–	–	–	–	–	–
1C4-4	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C4-5	-	-	-	-	<	<	<	<[d]	<[d]	<[d]	<[d]
1D3-1	-	-	-	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C6-1	-	0.001	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C6-3	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1C6-4	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
1L4-1	-	-	-	-	-	<	<	<[d]	<[d]	<[d]	<[d]
1T1-1	0.001	<	<	–	–	–	–	–	–	–	–
1T1-3	-	<	<	–	–	–	–	–	–	–	–
1T1-4	-	<	<	–	–	–	–	–	–	–	–
1T1-10	-	<	<	–	–	–	–	–	–	–	–
1T1-12	-	-	<	–	–	–	–	–	–	–	–
1T1-13	-	-	<	–	–	–	–	–	–	–	–

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1T1-14	-	-	-	<	<	<	<	<[b]	<[c]	<[b]	<[b]
1T1-15	-	-	-	<	<	<	#	<[b]	<[c]	<[b]	<[c]
1T1-16	-	-	-	<	<	<	#	<[b]	<[c]	<[b]	<[c]
1T1-17	-	-	-	<	<	<	#	<[b]	<[b]	/	/
1T1-18	-	-	-	<	<	<	#	<[b]	<[b]	/	/
1T1-19	-	-	-	<	<	<	#	<[b]	<[b]	/	/
1T1-20	-	-	-	<	<	<	#	<[b]	<[b]	/	/
1T1-28	-	-	-	-	-	<	#	<[b]	<[b]	/	/
1T1-29	-	-	-	-	-	<	#	<[b]	<[b]	/	/
1T1-30	-	-	-	-	-	<	#	<[b]	<[b]	/	/
1T1-31	-	-	-	-	-	<	#	<[b]	<[b]	/	/
1T1-21	-	-	-	<	0.086	0.49	0.109	0.076[b]	/	0.050[b]	0.36[c]
1T1-22	-	-	-	<	<0.001	<	<0.001	<0.001[b]	/	<0.001[b]	<0.001[c]
1T1-23	-	-	-	<	<	<	<0.001	<[b]	/	<0.001[b]	<[c]
1T1-24	-	-	-	<	<	<	<	<[b]	/	<[b]	<[c]
1T1-25	-	-	-	<	<	<	<	<[b]	/	<[b]	<[c]
1T1-26	-	-	-	<	<	<	<	<[b]	/	<[b]	<[c]
1T1-27	-	-	-	<	<	<	<	<[b]	/	<[b]	<[c]
1T2-1	<0.001	0.001	<	<	--	--	--	--	--	--	--
1T2-2	-	-	-	<	--	--	--	--	--	--	--
1T2-3	-	-	-	<	--	--	--	--	--	--	--
1T2-4	-	-	-	<	--	--	--	--	--	--	--
1T2-5	-	-	-	-	0.198	/	0.016	0.070[c]	0.119[c]	/	0.040[b]
1T2-6	-	-	-	-	0.024	/	0.002	0.010[c]	0.013[c]	/	0.005[b]
1T2-7	-	-	-	-	0.005	<	<	0.002[c]	0.003[c]	/	<[b]
1T2-8	-	-	-	-	0.002	<	<	0.001[c]	0.001[c]	<[b]	<[b]
1T2-9	-	-	-	-	<0.001	<	<	<0.001[c]	<[b]	<[b]	<[b]

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1D1-1	-	-	-	2.5	2.0	/	0.74	1.35[d]	2.5[d]	/	20[d]
1T4-1	-	<0.001	<	–	–	–	–	–	–	–	–
1T4-3	-	-	<	–	–	–	–	–	–	–	–
1T4-4	-	-	<	–	–	–	–	–	–	–	–
1T4-5	-	-	-	<	0.094	0.066	0.004	0.155[c]	0.182[b]	0.047[b]	0.006[b]
1T4-6	-	-	-	<	0.014	0.014	0.003	0.037[c]	0.045[b]	0.011[b]	<0.001[b]
1T4-7	-	-	-	<	0.004	0.002	<0.001	0.007[c]	0.008[b]	0.005[b]	<[b]
1T4-8	-	-	-	<	<0.001	<0.001	<	0.002[c]	0.002[b]	0.001[b]	<[b]
1T4-9	-	-	-	<	<	<	<	<0.001[c]	<[b]	<[b]	<[b]
1T4-10	-	-	-	-	0.062	0.041	0.009	0.078[c]	0.103[c]	0.040[b]	0.004[b]
1T4-11	-	-	-	-	0.014	0.006	0.002	0.020[c]	0.018[c]	0.008[b]	0.001[b]
1T4-12	-	-	-	-	0.004	0.003	<	0.005[c]	0.006[c]	0.002[b]	<[b]
1T4-13	-	-	-	-	0.002	0.002	<	0.003[c]	0.003[c]	0.001[b]	<[b]
1T4-14	-	-	-	-	0.001	0.001	<	0.001[c]	0.002[c]	<0.001[b]	<[b]
1D2-1	-	-	-	<	<	<	0.004	0.005[d]	0.007[d]	/	0.005[d]
1T5-1	-	<0.001	<	<	0.118	0.157	#	0.29[c]	0.20[b]	0.055[b]	0.006[b]
1T5-7	-	-	-	-	0.019	0.019	#	0.067[c]	0.042[b]	0.010[b]	0.001[b]
1T5-8	-	-	-	-	<0.001	<	#	<0.001[c]	/	<0.001[b]	<[b]
1T5-4	-	-	-	<	<	<	#	<0.001[c]	/	<[b]	<[b]
1T5-2	<0.001	<0.001	<	<	0.074	0.130	#	0.043[b]	0.20[b]	0.048[b]	0.012[b]
1T5-9	-	-	-	-	0.014	0.017	#	0.008[b]	0.025[b]	0.009[b]	0.002[b]
1T5-10	-	-	-	-	0.002	0.004	#	0.001[b]	0.007[b]	0.002[b]	0.001[b]
1T5-6	-	-	-	<	<0.001	<	#	<0.001[b]	0.002[b]	0.001[b]	<[b]

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1T5-3	-	-	-	<	–	–	–	–	–	–	–
1T5-5	-	-	-	<	<0.001	0.001	#	<0.001[b]	0.002[b]	0.003[b]	/
1T6-2	-	-	-	-	0.162	0.46	#	0.141[b], 0.30[c]	/	0.073[b]	0.163[b], 0.23[c]
1T6-1	<0.001	<0.001, 0.001	<	<	0.024	0.079	#	0.024[b], 0.046[c]	/	0.014[b]	0.017[b]
1T6-3	-	-	-	-	0.003	0.003	#	<0.001[b,c]	/	<[b]	0.001[b]
1T6-4	-	-	-	-	0.001	0.003	#	<[b,c]	/	<[b]	<0.001[b]
1T6-5	-	-	-	-	0.001	0.002	#	<[b,c]	/	<[b]	<[b]
1T6-6	-	-	-	-	0.001	<0.001	#	<[b]	/	<[b]	<[b]
1T6-7	-	-	-	-	<0.001	<0.001	#	<[b]	/	<[b]	<[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

- = measurement point not established.
– = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.
< = measurement estimated <0.001 V/m based on earth electric field.

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1C1-2	0.041	0.146	0.056	–	–	–	–	–	–	–	–
1C1-3	-	-	0.128	0.082	0.114	0.59	0.053	0.046[d]	0.085[d]	0.079[d]	0.122[d]
1C1-4	-	-	-	0.117	0.114	0.085	0.22	0.066[d]	0.079[d]	0.115[d]	0.20[d]
1C3-1	0.106	0.26	0.133	0.086	0.118	0.085	0.135	0.056[d]	0.078[d]	0.081[d]	/
1C3-2	0.125	0.191	/	–	–	–	–	–	–	–	/
1C3-3	-	-	-	0.074	0.178	0.148	0.22	0.163[d]	0.125[d]	0.143[d]	/
1C4-1	-	0.028, 0.030	0.045	0.065	0.093	0.087	0.041	0.032[d]	0.081[d]	0.27[d]	0.082[d]
1C4-2	-	0.019, 0.023	0.015	–	–	–	–	–	–	–	–
1C4-3	-	0.036, 0.065	0.103	0.118	–	–	–	–	–	–	–
1C4-4	-	-	0.009, 0.017	0.011	0.011	0.011	0.010	0.016[d]	0.012[d]	0.008[d]	0.014[d]
1C4-5	-	-	-	-	0.037	0.046	0.021	0.018[d]	0.036[d]	0.112[d]	0.070[d]
1D3-1	-	-	-	0.052	0.156	0.053	0.29	0.26[d]	0.103[d]	0.039[d]	0.074[d]
1C6-1	-	0.072	0.095	0.088	0.106	0.057	0.102	0.103[d]	0.101[d]	0.064[d]	0.105[d]
1C6-3	-	-	0.123	0.109	0.141	0.053	0.122	0.075[d]	0.069[d]	0.066[d]	0.100[d]
1C6-4	-	-	0.038	0.007	0.020	0.013	0.013	0.021[d]	0.017[d]	0.012[d]	0.017[d]
1L4-1	-	-	-	-	-	0.019	0.013	0.022[d]	0.015[d]	0.008[d]	0.012[d]
1T1-1	0.090	0.091	0.131	–	–	–	–	–	–	–	–
1T1-3	-	0.21	0.179	–	–	–	–	–	–	–	–
1T1-4	-	0.174	0.171	–	–	–	–	–	–	–	–
1T1-10	-	0.097	0.147	–	–	–	–	–	–	–	–
1T1-12	-	-	0.033	–	–	–	–	–	–	–	–
1T1-13	-	-	0.034	–	–	–	–	–	–	–	–

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1T1-14	-	-	-	0.102	0.058	0.29	0.071	0.071[b]	0.036[c]	0.026[b]	0.182[b]
1T1-15	-	-	-	0.040	0.029	0.064	#	0.025[b]	0.016[c]	0.019[b]	0.126[c]
1T1-16	-	-	-	0.115	0.102	0.40	#	0.179[b]	0.045[c]	0.034[b]	0.27[c]
1T1-17	-	-	-	0.118	0.128	0.37	#	0.102[b]	0.053[b]	/	/
1T1-18	-	-	-	0.100	0.104	0.46	#	0.081[b]	0.048[b]	/	/
1T1-19	-	-	-	0.112	0.132	0.43	#	0.101[b]	0.070[b]	/	/
1T1-20	-	-	-	0.118	0.123	0.43	#	0.099[b]	0.065[b]	/	/
1T1-28	-	-	-	-	-	0.018	#	0.100[b]	0.073[b]	/	/
1T1-29	-	-	-	-	-	0.014	#	0.078[b]	0.046[b]	/	/
1T1-30	-	-	-	-	-	0.019	#	0.066[b]	0.047[b]	/	/
1T1-31	-	-	-	-	-	0.022	#	0.068[b]	0.048[b]	/	/
1T1-21	-	-	-	0.082	0.082	0.53	0.113	0.060[b]	0.137[b]	0.041[b]	0.28[c]
1T1-22	-	-	-	0.050	0.047	0.40	0.086	0.049[b]	0.090[b]	0.042[b]	0.20[c]
1T1-23	-	-	-	0.037	0.037	0.31	0.068	0.024[b]	0.090[b]	0.031[b]	0.163[c]
1T1-24	-	-	-	0.042	0.058	0.23	0.126	0.040[b]	0.070[b]	0.034[b]	0.190[c]
1T1-25	-	-	-	0.033	0.035	0.28	0.070	0.034[b]	0.075[b]	0.024[b]	0.169[c]
1T1-26	-	-	-	0.022	0.025	0.20	0.052	0.023[b]	0.045[b]	0.018[b]	0.124[c]
1T1-27	-	-	-	0.014	0.021	0.094	0.056	0.015[b]	0.032[b]	0.013[b]	0.085[c]
1T2-1	0.170	0.22	0.197	0.122	–	–	–	–	–	–	–
1T2-2	-	-	-	0.047	–	–	–	–	–	–	–
1T2-3	-	-	-	0.083	–	–	–	–	–	–	–
1T2-4	-	-	-	0.044	–	–	–	–	–	–	–
1T2-5	-	-	-	-	0.074	0.074	0.047	0.055[c]	0.078[b]	0.077[b]	0.072[b]
1T2-6	-	-	-	-	0.069	0.087	0.064	0.064[c]	0.065[b]	0.068[b]	0.086[b]
1T2-7	-	-	-	-	0.047	0.062	0.040	0.044[c]	0.049[b]	0.049[b]	0.059[b]
1T2-8	-	-	-	-	0.051	0.067	0.055	0.047[c]	0.047[b]	0.050[b]	0.065[b]
1T2-9	-	-	-	-	0.055	0.067	0.031	0.044[c]	0.048[b]	0.057[b]	0.058[b]

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1D1-1	-	-	-	9.6	2.4	1.15	2.7	1.96[d]	2.5[d]	3.9[d]	1.83[d]
1T4-1	-	0.178, 0.184	0.150	–	–	–	–	–		–	–
1T4-3	-	-	0.22	–	–	–	–	–		–	–
1T4-4	-	-	0.131	–	–	–	–	–		–	–
1T4-5	-	-	-	0.052	0.081	0.135	0.035	0.147[c]	0.160[b]	0.058[b]	0.022[b]
1T4-6	-	-	-	0.104	0.066	0.128	0.039	0.106[c]	0.163[b]	0.065[b]	0.031[b]
1T4-7	-	-	-	0.102	0.090	0.128	0.036	0.126[c]	0.121[b]	0.117[b]	0.031[b]
1T4-8	-	-	-	0.082	0.078	0.096	0.032	0.186[c]	0.113[b]	0.146[b]	0.036[b]
1T4-9	-	-	-	0.088	0.063	0.098	0.032	0.200[c]	0.139[b]	0.137[b]	0.041[b]
1T4-10	-	-	-	-	0.135	0.124	0.126	0.22[c]	0.090[c]	0.062[b]	0.032[b]
1T4-11	-	-	-	-	0.071	0.089	0.047	0.191[c]	0.116[c]	0.063[b]	0.031[b]
1T4-12	-	-	-	-	0.071	0.100	0.041	0.181[c]	0.068[c]	0.049[b]	0.031[b]
1T4-13	-	-	-	-	0.063	0.083	0.037	0.161[c]	0.064[c]	0.043[b]	0.025[b]
1T4-14	-	-	-	-	0.068	0.121	0.037	0.148[c]	0.064[c]	0.046[b]	0.031[b]
1D2-1	-	-	-	0.47	0.160	0.28	0.69	0.59[d]	0.58[d]	0.65[d]	0.51[d]
1T5-1	-	0.24, 0.42	0.25	0.115	0.128	0.34	#	0.41[c]	0.21[b]	0.087[b]	0.041[b]
1T5-7	-	-	-	-	0.107	0.33	#	0.37[c]	0.154[b]	0.073[b]	0.039[b]
1T5-8	-	-	-	-	0.099	0.23	#	0.37[c]	0.138[b]	0.061[b]	0.042[b]
1T5-4	-	-	-	0.061	0.073	0.166	#	0.26[c]	0.106[b]	0.048[b]	0.033[b]
1T5-2	0.23	0.26	0.22	0.042	0.092	0.108	#	0.062[b]	0.135[b]	0.085[b]	0.052[b]
1T5-9	-	-	-	-	0.080	0.089	#	0.054[b]	0.100[b]	0.058[b]	0.033[b]
1T5-10	-	-	-	-	0.036	0.056	#	0.030[b]	0.055[b]	0.045[b]	0.025[b]
1T5-6	-	-	-	0.051	0.034	0.053	#	0.024[b]	0.064[b]	0.046[b]	0.032[b]

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1T5-3	-	-	-	0.125	--	--	--	--	--	--	--
1T5-5	-	-	-	0.077	0.051	0.059	#	0.052[b]	0.26[c]	0.061[b]	0.042[b]
1T6-2	-	-	-	-	0.48	1.52	#	0.29[b], 0.70[c]	0.31[b], 0.23[c]	0.164[b]	0.43[b], 0.52[c]
1T6-1	0.071	0.65, 0.88	0.86, 0.88	0.23	0.54	1.49	#	0.39[b], 0.90[c]	0.149[b], 0.131[c]	0.119[b]	0.182[b]
1T6-3	-	-	-	-	0.32	1.54	#	0.31[b], 0.83[c]	0.29[b], 0.148[c]	0.124[b]	0.179[b]
1T6-4	-	-	-	-	0.25	1.32	#	0.25[b], 0.44[c]	0.161[b], 0.167[c]	0.103[b]	0.138[b]
1T6-5	-	-	-	-	0.21	1.19	#	0.21[b], 0.63[c]	0.29[c]	0.134[b]	0.183[b]
1T6-6	-	-	-	-	0.178	0.90	#	0.169[b]	0.33[c]	0.073[b]	0.126[b]
1T6-7	-	-	-	-	0.100	1.31	#	0.20[b]	0.76[b]	0.119[b]	0.195[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1C1-2	<0.001	0.001	0.001	–	–	–	–	–	–	–	–
1C1-3	-	-	0.001	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]	0.001[d]	0.001[d]
1C1-4	-	-	-	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]	0.001[d]	0.001[d]
1C3-1	<0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]	0.001[d]	/
1C3-2	0.001	0.003	/	–	–	–	–	–	–	–	/
1C3-3	-	-	-	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]	0.001[d]	/
1C4-1	-	<0.001, 0.001	0.001	0.001	0.002	0.001	0.001	0.001[d]	0.001[d]	0.006[d]	0.001[d]
1C4-2	-	0.002	0.002	–	–	–	–	–	–	–	–
1C4-3	-	<0.001, 0.002	<0.001	0.001	–	–	–	–	–	–	–
1C4-4	-	-	0.003	0.002	0.002	0.001	0.001	0.002[d]	0.002[d]	0.001[d]	0.002[d]
1C4-5	-	-	-	-	0.001	0.002	0.001	0.002[d]	0.001[d]	0.002[d]	0.002[d]
1D3-1	-	-	-	0.003	0.002	0.002	0.013	0.009[d]	0.009[d]	0.009[d]	0.006[d]
1C8-1	-	0.003	0.003	0.002	<0.001	0.002	0.003	0.002[d]	0.002[d]	0.002[d]	0.003[d]
1C8-3	-	-	0.003	0.003	0.003	0.002	0.002	0.003[d]	0.002[d]	0.002[d]	0.003[d]
1C8-4	-	-	0.003	0.003	0.004	0.003	0.003	0.004[d]	0.003[d]	0.002[d]	0.003[d]
1L4-1	-	-	-	-	-	0.003	0.002	0.002[d]	0.002[d]	0.001[d]	0.001[d]
1T1-1	0.002	0.002	0.002	–	–	–	–	–	–	–	–
1T1-3	-	0.002	0.002	–	–	–	–	–	–	–	–
1T1-4	-	0.002	0.002	–	–	–	–	–	–	–	–
1T1-10	-	0.004	0.003	–	–	–	–	–	–	–	–
1T1-12	-	-	0.004	–	–	–	–	–	–	–	–
1T1-13	-	-	0.005	–	–	–	–	–	–	–	–

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1T1-14	-	-	-	0.004	0.003	0.014	0.003	0.002[b]	0.003[c]	0.002[b]	0.009[d]
1T1-15	-	-	-	0.004	0.004	0.009	#	0.003[b]	0.001[c]	0.001[b]	0.007[c]
1T1-16	-	-	-	0.009	0.006	0.22	#	0.009[b]	0.002[c]	0.003[b]	0.017[c]
1T1-17	-	-	-	0.007	0.009	0.031	#	0.007[b]	0.006[b]	/	/
1T1-18	-	-	-	0.006	0.006	0.028	#	0.006[b]	0.007[b]	/	/
1T1-19	-	-	-	0.001	0.009	0.032	#	0.007[b]	0.007[b]	/	/
1T1-20	-	-	-	0.006	0.011	0.034	#	0.006[b]	0.006[b]	/	/
1T1-28	-	-	-	-	-	0.001	#	0.006[b]	0.007[b]	/	/
1T1-29	-	-	-	-	-	0.001	#	0.006[b]	0.006[b]	/	/
1T1-30	-	-	-	-	-	0.001	#	0.006[b]	0.007[b]	/	/
1T1-31	-	-	-	-	-	0.001	#	0.006[b]	0.005[b]	/	/
1T1-21	-	-	-	0.055	0.042	0.29	0.072	0.036[b]	0.061[b]	0.027[b]	0.174[c]
1T1-22	-	-	-	0.012	0.018	0.108	0.029	0.014[b]	0.032[b]	0.009[b]	0.076[c]
1T1-23	-	-	-	0.008	0.011	0.060	0.015	0.006[b]	0.017[b]	0.005[b]	0.044[c]
1T1-24	-	-	-	0.005	0.006	0.041	0.008	0.006[b]	0.013[b]	0.003[b]	0.029[c]
1T1-25	-	-	-	0.005	0.005	0.030	0.007	0.004[b]	0.009[b]	0.003[b]	0.022[c]
1T1-26	-	-	-	0.003	0.004	0.021	0.005	0.003[b]	0.006[b]	0.002[b]	0.015[c]
1T1-27	-	-	-	0.002	0.003	0.014	0.004	0.002[b]	0.005[b]	0.001[b]	0.011[c]
1T2-1	<0.001	0.001	0.001	0.077	–	–	–	–	–	–	–
1T2-2	-	-	-	0.009	–	–	–	–	–	–	–
1T2-3	-	-	-	0.006	–	–	–	–	–	–	–
1T2-4	-	-	-	0.006	–	–	–	–	–	–	–
1T2-5	-	-	-	-	0.050	0.023	0.017	0.051[c]	0.054[b]	0.031[b]	0.036[b]
1T2-6	-	-	-	-	0.018	0.011	0.006	0.019[c]	0.020[b]	0.012[b]	0.013[b]
1T2-7	-	-	-	-	0.009	0.007	0.003	0.010[c]	0.010[b]	0.006[b]	0.006[b]
1T2-8	-	-	-	-	0.006	0.005	0.002	0.007[c]	0.006[b]	0.004[b]	0.005[b]
1T2-9	-	-	-	-	0.005	0.006	0.002	0.005[c]	0.005[b]	0.002[b]	0.004[b]

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1D1-1	-	-	-	0.109	0.154	0.040	0.151	0.141[d]	0.25[d]	0.28[d]	0.50[d]
1T4-1	-	0.001	0.001	--	--	--	--	--		--	--
1T4-3	-	-	0.001	--	--	--	--	--		--	--
1T4-4	-	-	0.001	--	--	--	--	--		--	--
1T4-5	-	-	-	0.021	0.060	0.061	0.010	0.090[c]	0.104[b]	0.034[b]	0.006[b]
1T4-6	-	-	-	0.019	0.024	0.017	0.004	0.036[c]	0.046[b]	0.012[b]	0.002[b]
1T4-7	-	-	-	0.011	0.013	0.010	0.003	0.020[c]	0.023[b]	0.006[b]	0.001[b]
1T4-8	-	-	-	0.006	0.008	0.005	0.001	0.014[c]	0.015[b]	0.011[b]	0.001[b]
1T4-9	-	-	-	0.004	0.006	0.004	0.001	0.009[c]	0.012[b]	0.007[b]	0.001[b]
1T4-10	-	-	-	-	0.051	0.041	0.039	0.081[c]	0.060[c]	0.031[b]	0.003[b]
1T4-11	-	-	-	-	0.023	0.013	0.004	0.035[c]	0.026[c]	0.013[b]	0.001[b]
1T4-12	-	-	-	-	0.013	0.010	0.002	0.019[c]	0.013[c]	0.006[b]	0.001[b]
1T4-13	-	-	-	-	0.009	0.007	0.001	0.013[c]	0.009[c]	0.005[b]	<0.001[b]
1T4-14	-	-	-	-	0.007	0.007	0.001	0.009[c]	0.006[c]	0.004[b]	<0.001[b]
1D2-1	-	-	-	0.004	0.006	0.005	0.005	0.005[d]	0.009[d]	0.006[d]	0.006[d]
1T5-1	-	0.001, 0.002	0.001	0.051	0.071	0.159	#	0.156[c]	0.113[b]	0.039[b]	0.005[b]
1T5-7	-	-	-	-	0.039	0.077	#	0.087[c]	0.058[b]	0.020[b]	0.001[b]
1T5-8	-	-	-	-	0.016	0.025	#	0.035[c]	0.024[b]	0.007[b]	0.001[b]
1T5-4	-	-	-	0.006	0.008	0.016	#	0.020[c]	0.014[b]	0.005[b]	0.001[b]
1T5-2	0.001	0.002	0.001	0.038	0.042	0.075	#	0.020[b]	0.112[b]	0.039[b]	0.007[b]
1T5-9	-	-	-	-	0.019	0.028	#	0.010[b]	0.032[b]	0.014[b]	0.003[b]
1T5-10	-	-	-	-	0.011	0.017	#	0.005[b]	0.023[b]	0.007[b]	0.002[b]
1T5-6	-	-	-	0.004	0.008	0.012	#	0.004[b]	0.018[b]	0.005[b]	0.001[b]

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
1T5-3	-	-	-	0.007	–	–	–	–	–	–	–
1T5-5	-	-	-	0.005	0.019	0.018	#	0.004[b]	0.042[c]	0.013[b]	0.001[b]
1T6-2	-	-	-	-	0.111	0.34	#	0.087[b], 0.177[c]	0.103[b], 0.043[c]	0.057[b]	0.077[b], 0.135[c]
1T6-1	0.002	0.001	0.001	0.020	0.058	0.134	#	0.033[b], 0.070[c]	0.041[b], 0.020[c]	0.024[b]	0.027[b]
1T6-3	-	-	-	-	0.020	0.061	#	0.014[b], 0.031[c]	0.019[b], 0.009[c]	0.011[b]	0.011[b]
1T6-4	-	-	-	-	0.014	0.044	#	0.011[b], 0.021[c]	0.012[b], 0.006[c]	0.008[b]	0.008[b]
1T6-5	-	-	-	-	0.011	0.033	#	0.008[b], 0.013[c]	0.011[c]	0.006[b]	0.007[b]
1T6-6	-	-	-	-	0.008	0.023	#	0.005[b]	0.008[c]	0.004[b]	0.005[b]
1T6-7	-	-	-	-	0.008	0.022	#	0.004[b]	0.008[b], 0.007[c]	0.004[b]	0.005[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
– = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE A-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992	1993
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
1C1-3	<	<	<	*	<	<	<	<	<	<	<	<	<
1C1-4	<	<	<	*	<	<	<	<	<	<	<	<	<
1C3-1	<	<	<	*	<	<	<	<	<	<	<	<	/
1C3-3	<	<	<	*	<	<	<	<	<	<	<	<	/
1C4-1	<	<	<	*	<	<	<	<	<	<	<	<	<
1C4-4	<	<	<	*	<	<	<	<	<	<	<	<	<
1C4-5	-	-	-	-	<	<	<	<	<	<	<	<	<
1D3-1	<	<	<	*	<	<	<	<	<	<	<	<	<
1C6-1	<	<	<	*	<	<	<	<	<	<	<	<	<
1C6-3	<	<	<	*	<	<	<	<	<	<	<	<	<
1C6-4	<	<	<	*	<	<	<	<	<	<	<	<	<
1L4-1	-	-	-	-	-	-	<	<	<	<	<	<	<
1T1-14	<	<	<	*	0.004	<	0.017	<	0.036	0.036	0.033	0.024	0.039
1T1-15	<	<	<	*	0.001	<	0.007	<	0.015	0.021	0.015	0.022	0.023
1T1-16	<	<	<	*	0.004	<	0.012	<	0.043	0.037	0.034	0.033	/
1T1-17	0.002	<	<	*	0.004	<	0.023	<	0.043	0.057	0.045	/	/
1T1-18	0.001	<	<	*	0.004	<	0.023	<	0.052	0.055	0.056	/	/
1T1-19	0.002	<	<	*	0.005	<	0.032	<	0.055	0.059	0.072	/	/
1T1-20	0.002	<	<	*	0.004	<	/	/	0.057	0.058	0.046	/	/
1T1-28	-	-	-	-	-	-	/	/	0.043	0.044	0.051	/	/
1T1-29	-	-	-	-	-	-	/	/	0.032	0.036	0.036	/	/
1T1-30	-	-	-	-	-	-	/	/	0.037	0.042	0.036	/	/
1T1-31	-	-	-	-	-	-	/	/	0.035	0.035	0.046	/	/

TABLE A-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
1T1-21	1.08	<	<	*	3.6	0.005	15.7	0.054	32	35	35	40	31
1T1-22	0.002	<	<	*	0.005	<0.001	0.024	<	0.049	0.049	0.048	0.040	0.051
1T1-23	<	<	<	*	0.008	<	0.033	<	0.053	0.073	0.067	0.054	0.058
1T1-24	<	<	<	*	0.013	<	0.045	<	0.150	0.091	0.129	0.072	0.066
1T1-25	<	<	<	*	0.019	<	0.059	<	0.160	0.135	0.126	0.120	0.057
1T1-26	<	<	<	*	0.012	<	0.044	<	0.092	0.102	0.099	0.083	0.104
1T1-27	<	<	<	*	0.008	<	0.032	<	0.060	0.068	0.065	0.051	0.059
1T2-5	-	-	-	-	1.28	0.014	/	/	11.1	12.2	10.7	/	10.3
1T2-6	-	-	-	-	0.169	0.002	/	/	1.17	1.33	1.29	/	1.25
1T2-7	-	-	-	-	0.034	<0.001	/	/	0.25	0.34	0.27	/	0.30
1T2-8	-	-	-	-	0.014	<	/	/	0.104	0.142	0.109	/	0.143
1T2-9	-	-	-	-	0.008	<	/	/	0.077	0.082	0.066	/	0.128
1D1-1	<	<	<	*	<	<	<	<	0.007	0.010	0.009	/	0.038
1T4-5	0.58	<	<	*	2.1	0.003	8.7	0.044	17.6	18.4	21	14.0	18.9
1T4-6	0.091	<	<	*	0.31	<0.001	1.76	0.009	4.2	4.6	4.0	2.9	3.6
1T4-7	0.022	<	<	*	0.089	<	0.35	0.003	0.69	0.86	0.76	0.52	0.61
1T4-8	0.005	<	<	*	0.014	<	0.054	0.002	0.093	0.091	0.112	0.078	0.116
1T4-9	0.002	<	<	*	0.008	<	0.045	0.002	0.081	0.081	0.106	0.058	0.103
1T4-10	-	-	-	-	1.30	0.001	6.4	0.033	12.3	15.1	17.4	16.8	13.3
1T4-11	-	-	-	-	0.30	<0.001	1.48	0.008	2.4	3.1	4.7	2.7	2.7
1T4-12	-	-	-	-	0.090	<0.001	0.39	0.003	0.69	1.02	0.90	0.60	0.71
1T4-13	-	-	-	-	0.033	<0.001	0.115	0.002	0.33	0.36	0.37	0.24	0.33
1T4-14	-	-	-	-	0.015	<0.001	0.066	0.002	0.128	0.120	0.133	0.103	0.132
1D2-1	<	<	<	*	<	0.003	/	/	0.011	0.013	0.019	/	0.014

TABLE A-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
1T5-1	0.81	<	<	*	3.1	0.005	12.4	0.040	26	41	33	26	28
1T5-7	-	-	-	-	0.54	0.001	1.78	0.005	5.2	7.6	5.8	3.1	3.6
1T5-8	-	-	-	-	0.008	<0.001	0.039	<	0.079	0.113	0.096	0.062	0.065
1T5-4	0.002	<	<	*	0.007	<	0.039	<	0.066	0.069	0.066	0.049	0.079
1T5-2	0.59	<	<	*	2.9	0.003	15.8	0.056	23	42	28	29	31
1T5-9	-	-	-	-	0.44	<0.001	1.95	0.007	3.4	6.3	3.6	4.6	3.8
1T5-10	-	-	-	-	0.076	<	0.29	0.001	0.63	1.06	0.86	0.92	0.81
1T5-6	0.009	<	<	*	0.022	<	0.135	<	0.23	0.46	0.31	0.25	0.24
1T5-5	0.005	<	<	*	0.019	<	0.095	0.001	0.178	0.40	0.23	0.260	0.144
1T6-2	-	-	-	-	3.2	0.005	14.3	0.054	31	42	43	40	30
1T6-1	0.182	<	<	*	0.48	<	2.4	0.010	4.9	6.2	6.7	5.8	5.7
1T6-3	-	-	-	-	0.042	<0.001	0.121	<0.001	0.35	0.54	0.47	0.21	0.32
1T6-4	-	-	-	-	0.029	<0.001	0.122	<0.001	0.23	0.24	0.28	0.169	0.168
1T6-5	-	-	-	-	0.021	<0.001	0.107	<0.001	0.153	0.164	0.172	0.093	0.103
1T6-6	-	-	-	-	0.019	<0.001	0.075	<0.001	0.151	0.185	0.137	0.114	0.129
1T6-7	-	-	-	-	0.015	<0.001	0.079	0.001	0.142	0.159	0.145	0.119	0.122

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
< = measurement estimated <0.001 V/m based on earth electric field.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
1C1-3	0.021	0.003	0.010	0.017	0.082	0.028	0.44	0.139	1.31	1.04	1.20	1.07	1.07
1C1-4	/	/	/	/	0.087	0.033	0.42	0.185	1.70	1.33	1.23	1.62	1.65
1C3-1	/	/	/	/	0.050	0.025	0.26	0.119	0.74	0.81	0.95	0.83	/
1C3-3	0.022	0.004	0.012	0.020	0.086	0.032	0.41	0.157	1.18	0.98	0.94	1.11	/
1C4-1	/	/	/	/	0.005	0.004	0.023	0.019	0.070	0.073	0.065	0.052	0.067
1C4-4	<0.001	<0.001	<0.001	*	0.002	0.002	0.005	0.005	0.030	0.023	0.030	0.029	0.025
1C4-5	-	-	-	-	0.003	0.002	0.012	0.008	0.037	0.035	0.044	0.036	0.050
1D3-1	0.008	0.004	0.005	0.008	0.053	0.019	0.21	0.065	0.85	0.89	0.63	0.69	0.65
1C6-1	/	/	/	/	0.004	0.003	0.017	0.017	0.083	0.100	0.069	0.067	0.063
1C6-3	0.001	<0.001	0.001	0.002	0.008	0.004	0.026	0.016	0.110	0.078	0.075	0.074	0.063
1C6-4	/	/	/	/	0.003	0.002	0.017	0.009	0.045	0.043	0.043	0.051	0.044
1L4-1	-	-	-	-	-	-	0.006	0.002	0.013	0.020	0.010	0.010	0.021
1T1-14	0.86	0.026	0.021	0.035	3.1	0.069	18.1	0.21	34	40	39	37	34
1T1-15	0.43	0.013	0.015	0.025	1.60	0.051	9.2	0.21	13.6	14.1	23	32	27
1T1-16	1.11	0.035	0.035	0.058	4.6	0.133	24	0.61	47	50	46	48	49
1T1-17	1.55	0.049	0.053	0.088	6.2	0.139	23	0.57	43	39	55	/	/
1T1-18	1.44	0.042	0.050	0.083	5.6	0.166	26	0.71	49	55	51	/	/
1T1-19	1.54	0.050	0.053	0.088	6.4	0.142	28	0.69	57	58	60	/	/
1T1-20	1.45	0.046	0.043	0.072	6.0	0.142	28	0.77	56	56	53	/	/
1T1-28	-	-	-	-	-	-	25	0.74	54	58	55	/	/
1T1-29	-	-	-	-	-	-	16.1	0.58	35	37	38	/	/
1T1-30	-	-	-	-	-	-	17.2	0.63	39	41	35	/	/
1T1-31	-	-	-	-	-	-	20	0.71	41	40	44	/	/

TABLE A-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
1T1-21	1.45	0.044	0.009	0.015	7.4	0.026	31	0.133	54	49	60	55	62
1T1-22	1.50	0.042	0.009	0.015	4.2	0.021	25	0.62	41	42	43	56	38
1T1-23	0.96	0.030	0.003	0.005	2.9	0.017	18.7	0.109	33	30	27	38	32
1T1-24	1.15	0.036	0.010	0.017	4.7	0.020	14.8	0.117	59	35	33	41	23
1T1-25	0.87	0.027	0.062	0.103	2.9	0.019	15.6	0.079	33	29	21	34	25
1T1-26	0.56	0.017	0.004	0.007	2.0	0.014	12.3	0.082	23	23	20	22	19.9
1T1-27	0.38	0.012	0.004	0.007	1.82	0.015	6.2	0.057	19.3	13.7	13.0	14.3	13.1
1T2-5	-	-	-	-	8.7	0.77	39	3.1	85	88	94	88	79
1T2-6	-	-	-	-	8.5	0.86	41	4.6	86	82	81	83	86
1T2-7	-	-	-	-	7.0	0.56	31	2.7	70	66	66	64	65
1T2-8	-	-	-	-	7.1	0.66	31	3.6	70	67	79	76	86
1T2-9	-	-	-	-	6.2	0.79	31	3.6	70	65	69	69	62
1D1-1	0.042	0.28	0.066	0.110	0.23	0.67	1.15	3.4	7.6	6.1	5.7	7.6	12.8
1T4-5	2.1	0.062	0.054	0.090	6.4	0.191	34	0.76	84	68	62	75	72
1T4-6	2.5	0.076	0.103	0.172	6.3	0.29	45	1.35	87	64	89	81	79
1T4-7	2.2	0.067	0.092	0.153	8.7	0.30	37	1.40	76	50	64	90	73
1T4-8	1.91	0.061	0.123	0.21	7.7	0.31	32	1.59	72	70	61	77	62
1T4-9	2.1	0.062	0.126	0.21	6.2	0.34	35	1.74	55	82	50	67	65
1T4-10	-	-	-	-	12.4	0.29	47	1.30	86	97	84	73	100
1T4-11	-	-	-	-	6.4	0.27	34	1.26	83	79	106	106	79
1T4-12	-	-	-	-	7.4	0.36	39	1.31	76	75	78	54	52
1T4-13	-	-	-	-	5.7	0.33	29	1.60	70	66	73	70	61
1T4-14	-	-	-	-	6.7	0.33	31	1.56	55	72	64	59	61
1D2-1	0.094	0.44	0.113	0.188	0.41	1.36	1.58	4.8	9.7	10.2	10.2	10.0	9.8

TABLE A-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
1T5-1	2.6	0.079	0.074	0.123	9.7	0.21	47	0.94	110	85	107	83	108
1T5-7	-	-	-	-	8.4	0.21	48	1.01	78	84	86	85	90
1T5-8	-	-	-	-	8.2	0.20	38	0.87	90	92	81	81	76
1T5-4	1.39	0.042	0.061	0.102	5.8	0.21	29	0.98	61	69	75	65	58
1T5-2	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77	70	54	44	55	58
1T5-9	-	-	-	-	7.2	0.29	19.5	0.84	47	54	59	44	39
1T5-10	-	-	-	-	3.4	0.170	14.4	1.00	36	32	33	28	40
1T5-6	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98	32	38	32	22	22
1T5-5	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40	45	53	54	63	44
1T6-2	-	-	-	-	27	0.24	71	0.79	250	270	196	198	192
1T6-1	5.4	0.159	0.086	0.143	32	0.25	102	1.03	169	122	98	195	184
1T6-3	-	-	-	-	21	0.144	97	0.67	187	240	188	220	195
1T6-4	-	-	-	-	16.3	0.122	87	0.61	139	236	164	139	166
1T6-5	-	-	-	-	15.3	0.22	80	1.27	143	124	137	210	220
1T6-6	-	-	-	-	11.6	0.132	63	0.66	128	103	119	125	132
1T6-7	-	-	-	-	6.0	0.178	87	1.41	120	177	69	83	195

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
1C1-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007	0.007	0.007	0.006	0.007
1C1-4	/	/	/	/	0.001	<0.001	0.003	0.001	0.006	0.006	0.007	0.006	0.007
1C3-1	/	/	/	/	0.001	<0.001	0.003	0.001	0.008	0.007	0.008	0.008	/
1C3-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007	0.008	0.007	0.007	/
1C4-1	/	/	/	/	<0.001	<0.001	0.001	<0.001	0.001	0.002	0.001	0.001	0.001
1C4-4	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	0.002	0.002	0.002
1C4-5	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002	0.002	0.002	0.002	0.002
1D3-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.002	0.008	0.008	0.004	0.011	0.009
1C6-1	/	/	/	/	<0.001	<0.001	0.001	0.001	0.004	0.003	0.003	0.003	0.003
1C6-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.004	0.004	0.003	0.003	0.003
1C6-4	/	/	/	/	<0.001	<0.001	0.002	0.001	0.005	0.005	0.003	0.005	0.005
1L4-1	-	-	-	-	-	-	<0.001	<0.001	0.002	0.002	0.002	0.001	0.001
1T1-14	0.032	0.001	0.001	0.002	0.115	0.003	0.65	0.014	1.35	1.29	1.24	1.29	1.24
1T1-15	0.027	0.001	0.001	0.002	0.097	0.003	0.47	0.012	1.01	0.98	0.97	1.02	0.95
1T1-16	0.069	0.002	0.001	0.002	0.22	0.002	1.05	0.013	2.1	2.1	2.0	2.1	1.98
1T1-17	0.076	0.003	0.001	0.002	0.23	0.001	1.49	0.012	2.9	2.9	2.8	/	/
1T1-18	0.071	0.002	0.001	0.002	0.27	0.002	1.28	0.012	2.6	2.6	2.5	/	/
1T1-19	0.081	0.003	0.001	0.002	0.32	0.002	1.51	0.013	3.1	3.1	2.9	/	/
1T1-20	0.089	0.003	0.001	0.002	0.36	0.002	1.68	0.013	3.3	3.4	3.2	/	/
1T1-28	-	-	-	-	-	-	1.25	0.015	2.4	2.4	2.4	/	/
1T1-29	-	-	-	-	-	-	1.10	0.015	2.1	2.2	2.1	/	/
1T1-30	-	-	-	-	-	-	1.12	0.015	2.3	2.3	2.1	/	/
1T1-31	-	-	-	-	-	-	1.00	0.015	2.1	2.1	1.91	/	/

TABLE A-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
1T1-21	0.78	0.024	0.004	0.007	2.9	0.005	13.8	0.043	32	29	26	29	29
1T1-22	0.31	0.010	0.002	0.003	1.16	0.003	5.8	0.019	12.3	11.6	11.0	11.2	11.2
1T1-23	0.169	0.005	0.001	0.002	0.64	0.003	3.0	0.013	6.6	6.0	5.9	6.1	5.8
1T1-24	0.113	0.004	0.001	0.002	0.43	0.003	2.1	0.011	4.3	4.2	4.1	4.1	3.7
1T1-25	0.084	0.003	0.007	0.012	0.32	0.003	1.52	0.011	3.4	3.2	3.0	3.0	3.0
1T1-26	0.055	0.002	0.001	0.002	0.21	0.002	1.00	0.010	2.2	1.92	1.93	1.96	1.94
1T1-27	0.040	0.012	0.001	0.002	0.149	0.002	0.69	0.009	1.51	1.39	1.33	1.42	1.36
1T2-5	-	-	-	-	3.2	0.005	15.1	0.053	33	30	29	31	31
1T2-6	-	-	-	-	1.23	0.003	5.8	0.031	12.0	11.1	10.9	11.2	11.4
1T2-7	-	-	-	-	0.64	0.002	3.1	0.023	6.4	6.2	5.8	6.1	5.9
1T2-8	-	-	-	-	0.43	0.003	2.1	0.020	4.3	4.0	3.9	4.0	4.0
1T2-9	-	-	-	-	0.32	0.003	1.59	0.019	3.3	3.0	3.0	3.0	3.0
1D1-1	<0.001	0.003	0.001	0.002	0.001	0.011	0.004	0.053	0.102	0.131	0.167	0.097	0.127
1T4-5	0.70	0.022	0.004	0.007	2.9	0.004	13.4	0.047	29	28	26	28	29
1T4-6	0.32	0.010	0.002	0.003	1.21	0.002	5.7	0.025	12.6	11.6	11.3	11.9	11.7
1T4-7	0.171	0.005	0.001	0.002	0.66	0.001	3.1	0.017	6.4	6.0	6.4	6.0	6.0
1T4-8	0.116	0.003	0.001	0.002	0.43	0.002	2.1	0.014	4.3	4.1	4.0	4.1	4.0
1T4-9	0.065	0.003	0.001	0.002	0.34	0.002	1.55	0.012	3.2	3.0	3.0	3.0	3.0
1T4-10	-	-	-	-	2.7	0.004	16.5	0.042	26	25	25	26	25
1T4-11	-	-	-	-	0.87	0.003	5.3	0.015	11.7	11	10.5	10.5	10.6
1T4-12	-	-	-	-	0.64	0.002	2.9	0.008	6.3	5.9	5.8	5.9	5.9
1T4-13	-	-	-	-	0.43	0.002	2.0	0.007	4.3	4.0	3.9	4.1	3.9
1T4-14	-	-	-	-	0.32	0.002	1.55	0.008	3.2	3.0	3.0	3.0	3.0
1D2-1	<0.001	0.003	0.001	0.002	0.002	0.008	0.009	0.043	0.077	0.078	0.075	0.077	0.080

TABLE A-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992	1993
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
1T5-1	0.89	0.029	0.005	0.008	3.6	0.005	17.0	0.059	34	34	32	33	33
1T5-7	-	-	-	-	1.93	0.002	8.9	0.035	18.9	17.6	16.7	17.7	17.2
1T5-8	-	-	-	-	0.75	0.001	3.5	0.017	7.3	7.3	6.8	6.8	6.9
1T5-4	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013	4.5	4.4	4.3	4.2	4.4
1T5-2	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31	29	27	30	30
1T5-9	-	-	-	-	1.18	0.003	5.6	0.017	11.7	11.2	10.8	11.1	10.9
1T5-10	-	-	-	-	0.67	0.002	3.2	0.009	6.1	6.1	5.9	5.9	5.9
1T5-6	0.125	0.004	<0.001	*	0.46	0.002	2.1	0.007	4.5	4.5	4.4	4.3	4.3
1T5-5	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014	5.1	5.2	4.9	5.2	4.6
1T6-2	-	-	-	-	3.9	0.006	17.8	0.061	35	37	36	37	33
1T6-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021	14.7	14.7	13.5	16.0	15.0
1T6-3	-	-	-	-	0.65	0.002	3.2	0.008	6.5	6.3	6.1	6.4	6.2
1T6-4	-	-	-	-	0.44	0.002	2.1	0.006	4.7	4.9	4.4	4.5	4.5
1T6-5	-	-	-	-	0.34	0.002	1.70	0.004	3.5	3.4	3.4	3.6	3.3
1T6-6	-	-	-	-	0.24	0.002	1.17	0.004	2.4	2.4	2.4	2.4	2.5
1T6-7	-	-	-	-	0.22	0.002	1.05	0.005	2.1	2.1	2.1	2.1	1.96

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-9. PAIRED SITE EM FIELD INTENSITY RATIOS
Small Mammals and Nesting Birds Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
1T1/1C1	23	23	23	1.00	16.4	121	135	0.64 - 2.2	136	116	950	7.0 - 17.0
1T1/1C4	23	23	23	1.00	400	121	330	1.56 - 19.3	480	116	480	3.5 - 17.0
1T1/1C6	23	23	23	1.00	430	121	260	1.22 - 15.9	190	116	320	2.3 - 5.7
1T2/1C4	128	128	128	1.00 - 40	930	1100	760	0.67 - 5.1	1500	750	1500	2.0 - 36
1T2/1C6	128	128	128	1.00 - 40	960	1100	590	0.52 - 4.2	600	750	1000	1.33 - 12.0
1T4/1C4	103	103	103	1.00 - 6.0	780	330	630	0.27 - 2.9	1500	3000	1500	0.50 - 6.0
1T5/1C4	79	48	79	1.00 - 12.0	330	690	270	0.30 - 3.7	2200	3000	2200	0.50 - 7.0
1T6/1C4	103	103	103	1.00 - 230	2000	370	1610	1.54 - 37	960	240	960	2.5 - 135

R1: T(76)/C(76) T(76) = ELF Communications System EM fields at the treatment site.
R2: T(76)/T(60) C(76) = ELF Communications System EM fields at the control site.
R3: T(76)/C(60) T(60) = ambient EM fields at the treatment site.
R4: T(60)/C(60) C(60) = ambient EM fields at the control site.

TABLE A-10. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies Laboratory

Site No.,					1990	
Meas. Pt.	1986	1987	1988	1989	Before Shielding	After Shielding
1L1-1	/	--	--	--	--	--
1L1-2	0.94	0.96	--	--	--	--
1L1-3	0.79	0.034	/	/	/	0.58
1L1-4	0.042	0.047	0.062	/	/	/
1L1-5	-	-	-	/	/	/
1L1-6	-	-	-	/	/	/
1L1-7	-	-	-	8.1	8.5	1.34
1L1-8		-	-	0.88	0.76	0.037
1L1-9		-	-	60	18.1	3.9*
1L1-10		-	-	-	/	0.010

- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.
* = 4.0 V/m with humidifier on.

TABLE A-11. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies Laboratory

Site No., Meas. Pt.	1986	1987	1988	1989	1990
1L1-1	9.13	--	--	--	--
1L1-2	0.179	0.156	--	--	--
1L1-3	0.080	0.143	/	/	0.071
1L1-4	0.114	0.118	0.080	0.075	/
1L1-5	-	-	-	14.1^{a}	5.2^{c}
				21^{b}	0.62^{d}
					0.077^{e}
1L1-6	-	-	-	3.2^{a}	2.4^{c}
				44^{b}	0.195^{d}
					0.081^{e}
1L1-7	-	-	-	0.65	1.69
1L1-8	-	-	-	1.46	0.88
1L1-9	-	-	-	48	0.86
1L1-10	-	-	-	-	0.75

a = measurement made in vertical orientation only in open, unshielded can, submerged to rim.
b = measurement made above bath surface.
c = measurement made in closed, unshielded, fully submerged can.
d = measurement made in closed, shielded, fully submerged can.
e = measurement made in closed, shielded, fully submerged can with motor and pump shielding (final configuration; see Figure A-40).
- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.

APPENDIX B

NATIVE BEES STUDIES

NATIVE BEES STUDIES

These studies incorporate investigations of the nesting and development traits of bees native to the ELF system area in Michigan. The electric and magnetic fields present in the air are considered the most important factors in the orientation and site tenacity of bees during their nesting cycle. The electric and magnetic fields in the earth and near its surface may be of importance in developmental studies. The air electric field and magnetic field in the laboratory where the bee nesting blocks are examined, and in the holding areas used prior to examination, are also of importance.

Laboratory analyses of bee nest blocks were performed for the last time in the spring of 1993. No field activities were conducted at the native bees study sites during 1993; consequently, EM field intensities were not characterized at these sites for this year. The final set of EM field measurements, taken in 1992, as well as historic measurement data, is presented in this appendix.

In 1992, IITRI field crews made ELF electromagnetic (EM) field measurements at 15 measurement points within two treatment sites, two control sites, and the remote holding facility for the native bees studies. Measurements were also made for the first time at the new Crystal Avenue laboratory in Crystal Falls to assess the 60 Hz EM exposures. This new laboratory (2L3) replaced the former laboratory (2L1) on Marquette Street in Crystal Falls. Measurements were not made at the control site measurement point 2C5-2 in 1992 because flooding of a dried lakebed prohibited access to this location. Measurement dates for 1992 and previous years appear in Table B-1.

TABLE B-1. EM FIELD MEASUREMENT DATES
Native Bees Studies

Year		Measurement Dates	
1983	May 25	Jul 13	
1984	May 16	Aug 13-16, 20, 22	
1985	Jul 15, 22, 23		
1986	Oct 6, 8, 13, 16		
1987	Sep 29, 30	Oct 2	
1988	Sep 19-22, 28		
1989	May 10	Sep 13, 20, 22	
1990	May 9	Sep 24	Oct 2, 5, 8
1991	Sep 24, 26	Oct 1, 4, 16	
1992	May 26, 27, 28		

The positions of the seven sites relative to the NRTF-Republic are shown on the composite map in Figure B-1. The site numbers listed on the map are those used by IITRI. Table B-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures B-2 through B-9.

EM field measurements for 1992 and previous years are found in Tables B-3 through B-8. Tables B-3, B-4, and B-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables B-6, B-7, and B-8 present 76 Hz data for these three fields along with the corresponding operating currents of the NRTF-Republic for each year. Paired-site EM field intensity ratios, which were recalculated using 1992 measurement data, appear in Table B-9. Laboratory EM field measurements appear in Tables B-10 through B-13.

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements made at treatment sites in 1986 through 1992 (excluding 1989) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, the antenna status (modulated signal) precluded 60 Hz EM field measurements at the treatment sites. However, measurements were possible at treatment sites for other studies in 1989 during unmodulated operation of the antennas. These measurements indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

TABLE B-2. SITE NUMBER CROSS-REFERENCE
Native Bees Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
2T1	Ford 1 (F1)	T43N	R29W	14
2T2	Ford 2 (F2)	T43N	R29W	14
2C4	County Line Road (CL)	T43N	R30W	19
2C5	Camp 5 (C5)	T42N	R31W	13
2L1	Crystal Falls Laboratory, Marquette Street	T43N	R32W	29
2L2	Remote Holding Facility	T42N	R32W	9
2L3	Crystal Falls Laboratory, Crystal Avenue	T43N	R32W	29

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control sites are about as variable as those at the treatment sites.

Overall, the 60 Hz EM fields measured at all study sites in 1992 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites.

The 76 Hz EM field measurements in 1992 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables B-6 through B-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1992. The 1992 measurements are consistent with the measurements made in 1989 through 1991 at the same current, and proportional to the 1986, 1987, and 1988 measurements made at lower currents.

The 60 Hz EM fields measured at the old Marquette Street laboratory in 1989 were significantly higher (up to 1000 times) than the 60 Hz fields measured at any of the study sites. Some of the laboratory 60 Hz air electric field exposures even exceeded the 76 Hz exposures at the treatment sites. These relatively high intensities could have masked differences caused by exposures at treatment and control sites. As discussed in a previous report,* the duration of exposure of nest boxes at the laboratory was minimized by using the remote holding facility, set up by the researchers for the small mammals and nesting birds studies, for temporary nest storage. In addition, IITRI built wire-mesh Faraday cage shields to reduce the 60 Hz air electric field exposures of the bees while at the laboratory. These cages were installed prior to 1990 laboratory work. The performance of the cages in shielding the air electric field at the Marquette Street laboratory can be seen in Table B-10, which presents 60 Hz air electric field data before and after shielding was implemented. The table shows that the shields provided a nominal factor of 100 reduction in the air electric field exposure at the laboratory work areas. Magnetic field measurements performed at the Marquette Street laboratory are presented in Table B-11. Shielding of the magnetic fields was not considered for the native bees studies.

In 1992, the native bees study laboratory was moved from Marquette Street to Crystal Avenue. Figures B-6 and B-7 show the layout of the old laboratory; Figure B-9 shows the layout of the new laboratory.

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* Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1990. IIT Research Institute, Technical Report E06628-3, 87 pp. plus appendixes, 1991.

Use of the Faraday cages continued at the Crystal Avenue laboratory. Air electric field intensity levels in the cages at this laboratory were similar to those measured at the Marquette Street laboratory as can be seen in Tables B-10 and B-12. The magnetic flux densities at the Crystal Avenue laboratory, however, were up to 10 times greater than those measured at the Marquette Street laboratory (see Tables B-11 and B-13). All 60 Hz field exposures at the new laboratory were typically at least 10 times lower than 76 Hz exposures at the treatment sites, but greater than the 60 Hz exposures at the study sites.

The EMDEX II™ magnetic field meter was used in 1992 to monitor utility-generated 60 Hz fields over a 27-hour period at the Crystal Avenue laboratory. The meter was set in the center of the two-bay workstation (between locations 2L2-[illegible] and 2); it was programmed to measure broadband (40 to 800 Hz) and harmonic (100 to 800 Hz) frequency magnetic field intensities at five-second intervals. Plotted in Figure B-10 is the fundamental (60 Hz) resultant magnetic field, which was calculated by the EMDEX from the broadband and harmonic measurement results. The maximum measurement value was 4.1 mG, with a 0.9 mG mean and a 0.53 mG standard deviation.

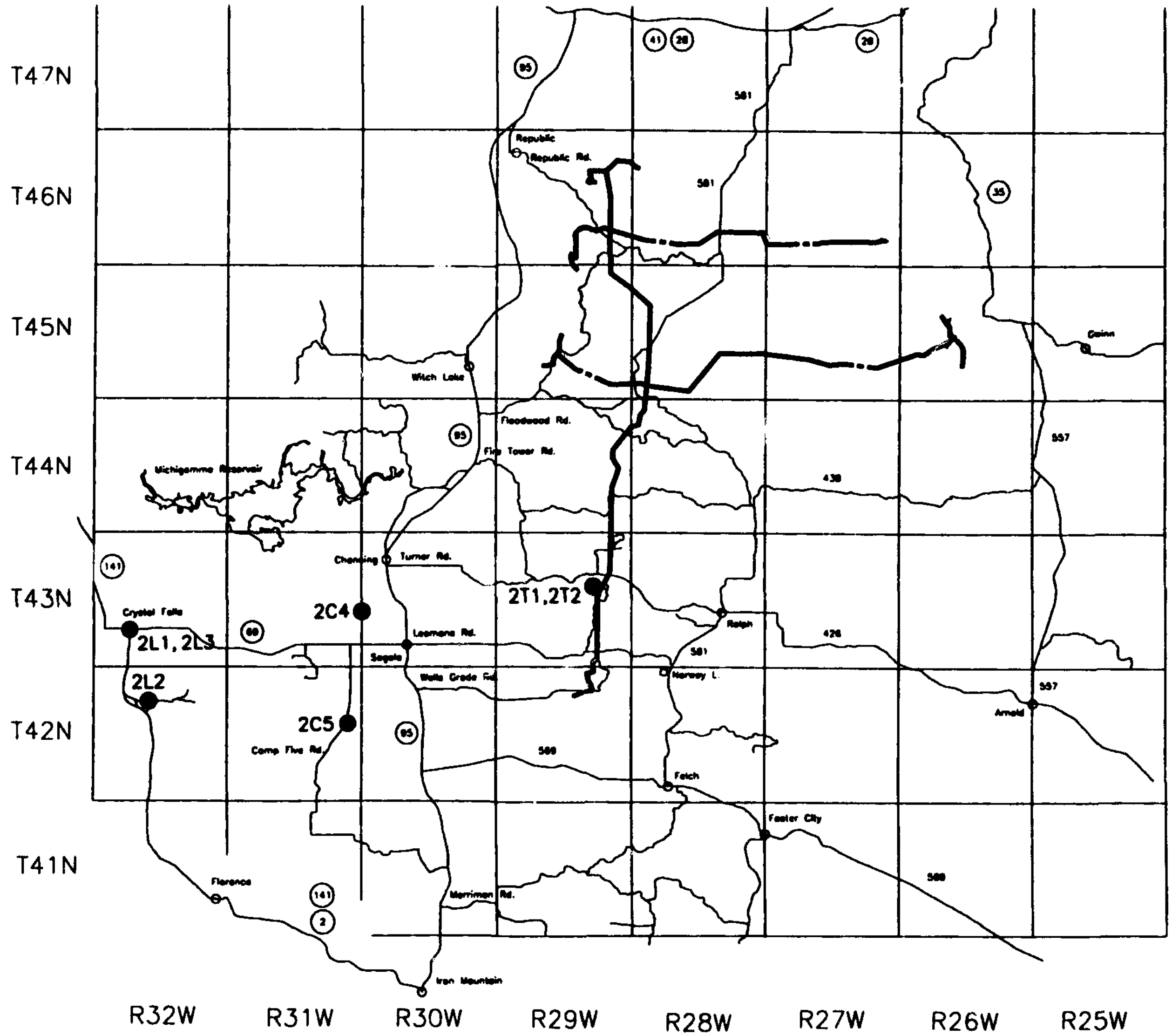

FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

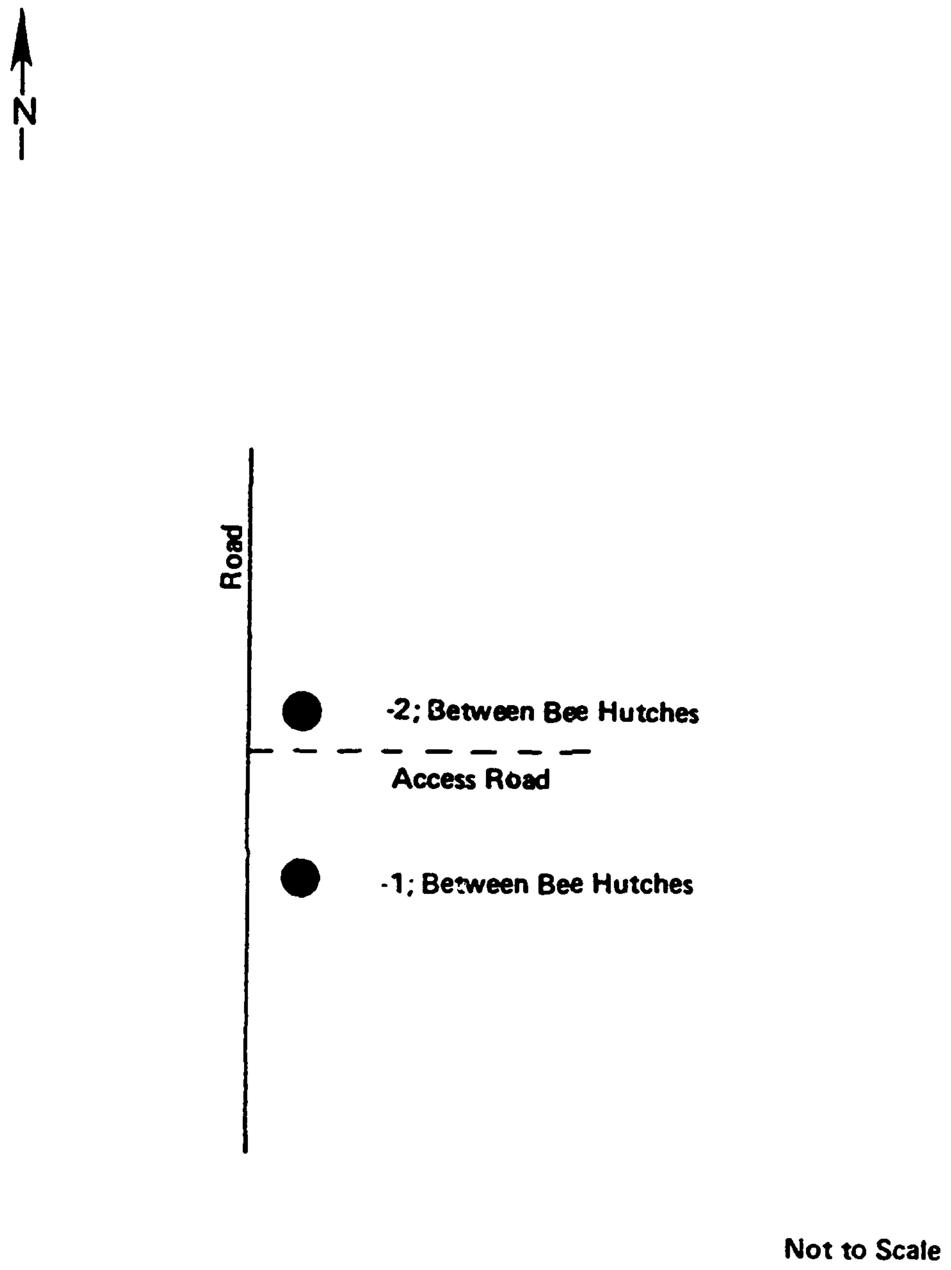

FIGURE B-2. MEASUREMENT POINTS AT COUNTY LINE ROAD (CL); 2C4-1, 2.

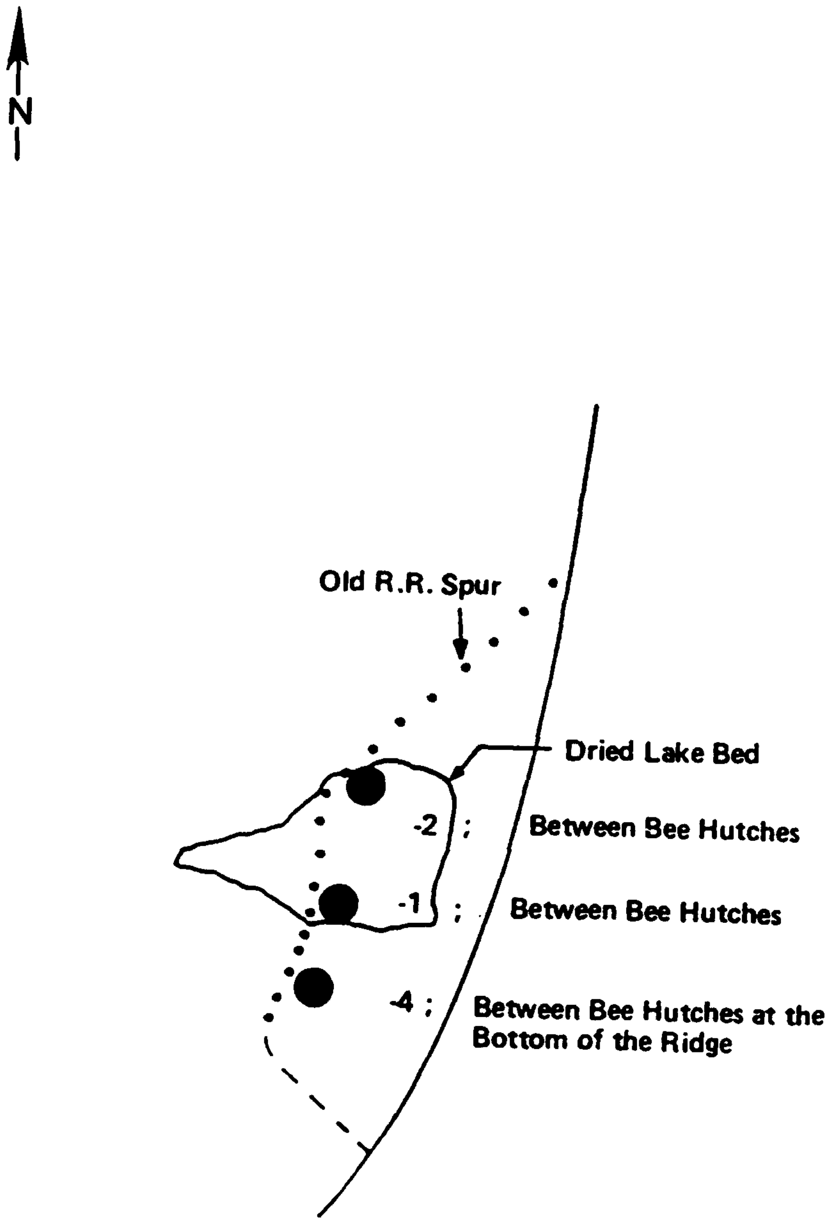

FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5); 2C5-1, 2, 4.

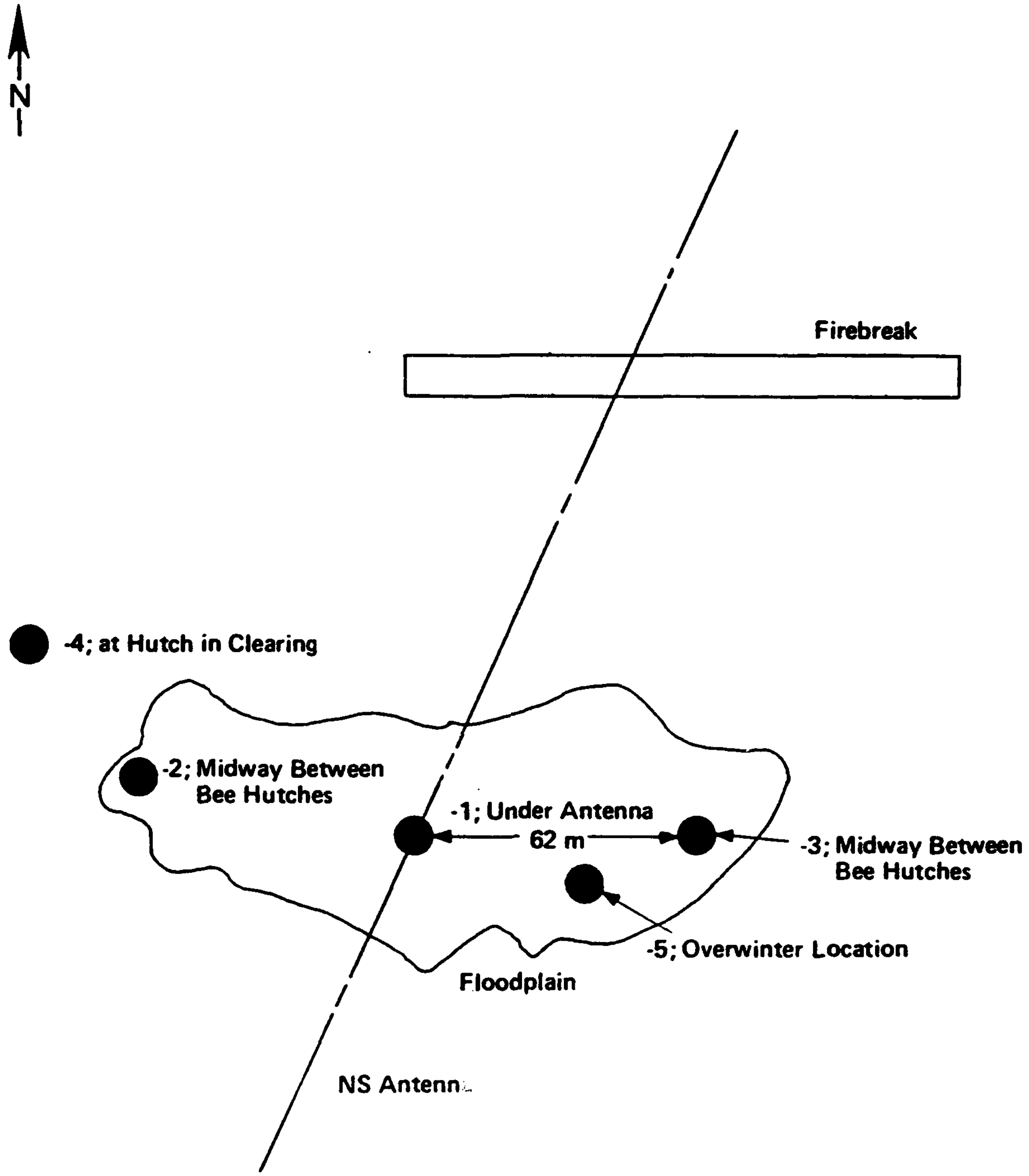

FIGURE B-4. MEASUREMENT POINTS AT FORD 1 (F1); 2T1-1, 2, 3, 4, 5.

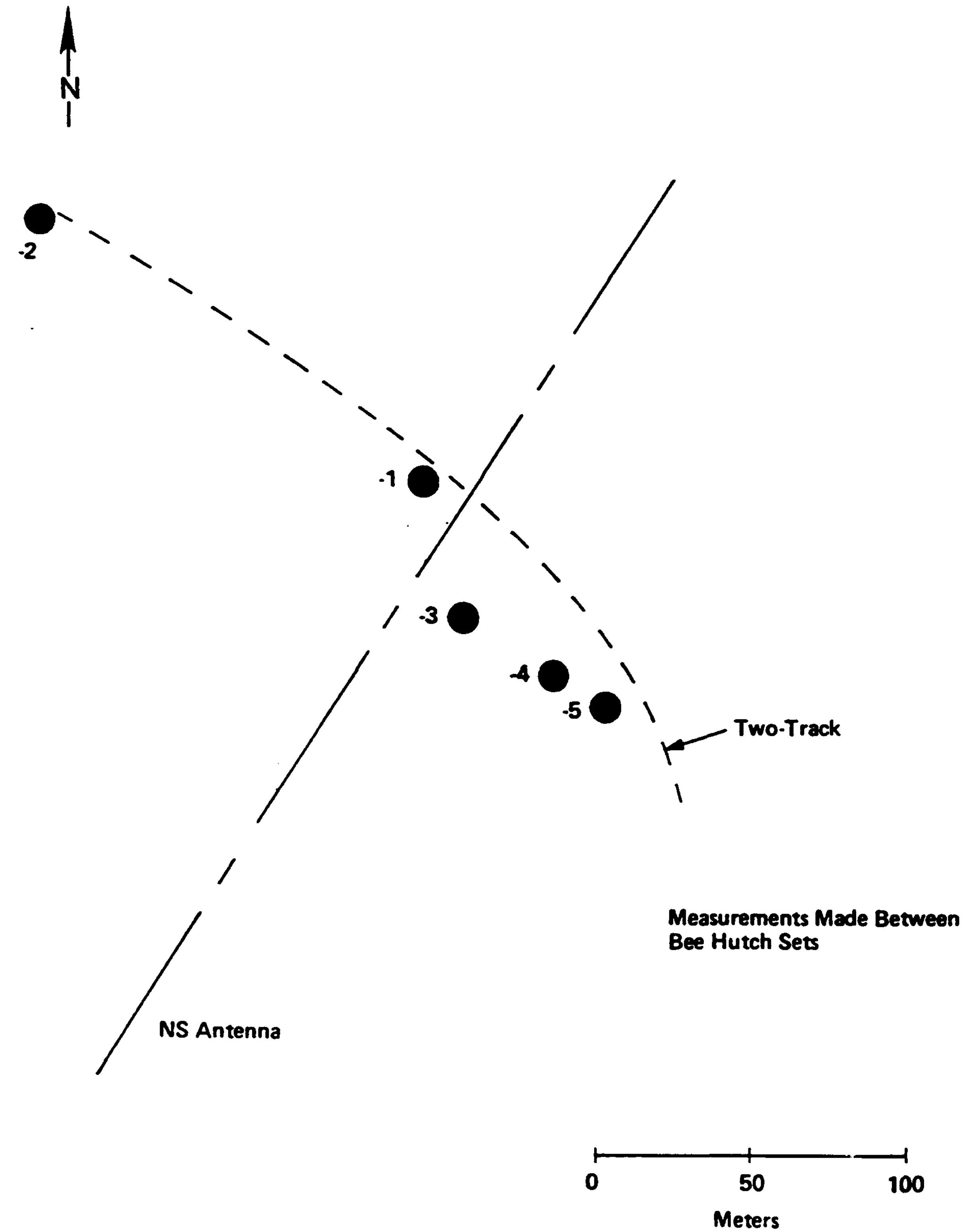

FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2); 2T2-1 THROUGH 5.

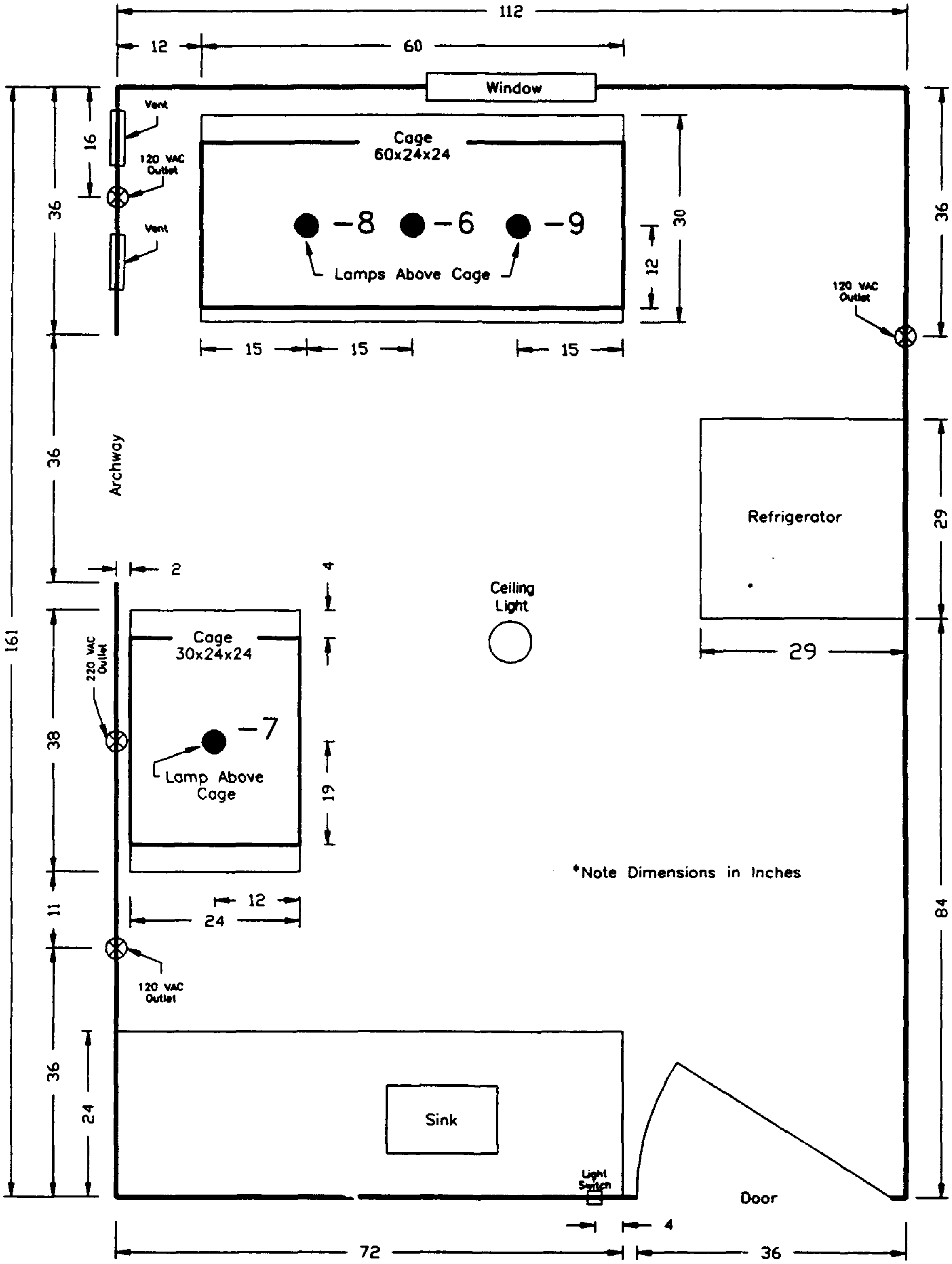

FIGURE B-6. MEASUREMENT POINTS AT CRYSTAL FALLS LABORATORY, 2ND FLOOR WORK AREA; 2L1-6 THROUGH 9.

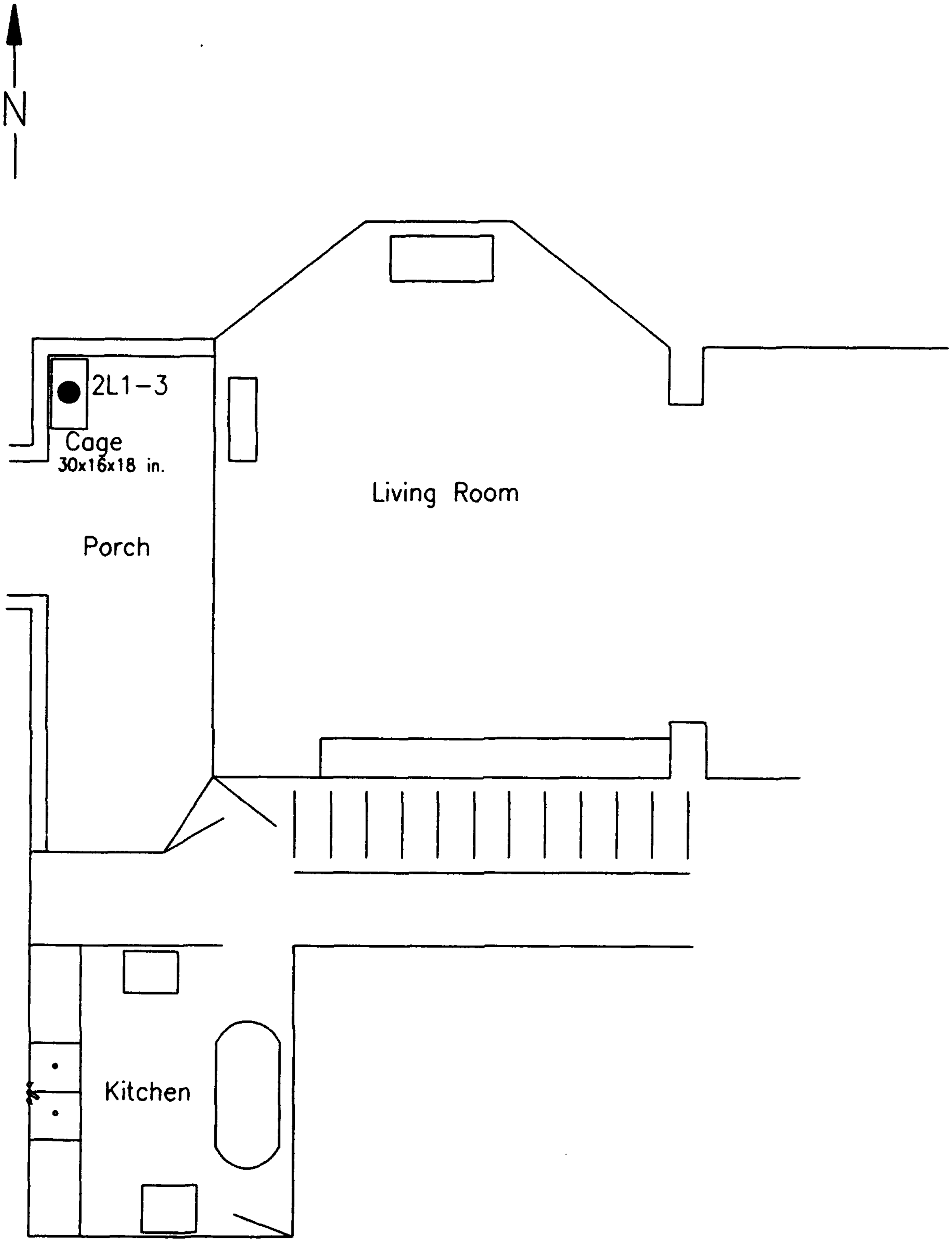

FIGURE B-7. MEASUREMENT POINT AT CRYSTAL FALLS LABORATORY, GROUND LEVEL; 2L1-3.

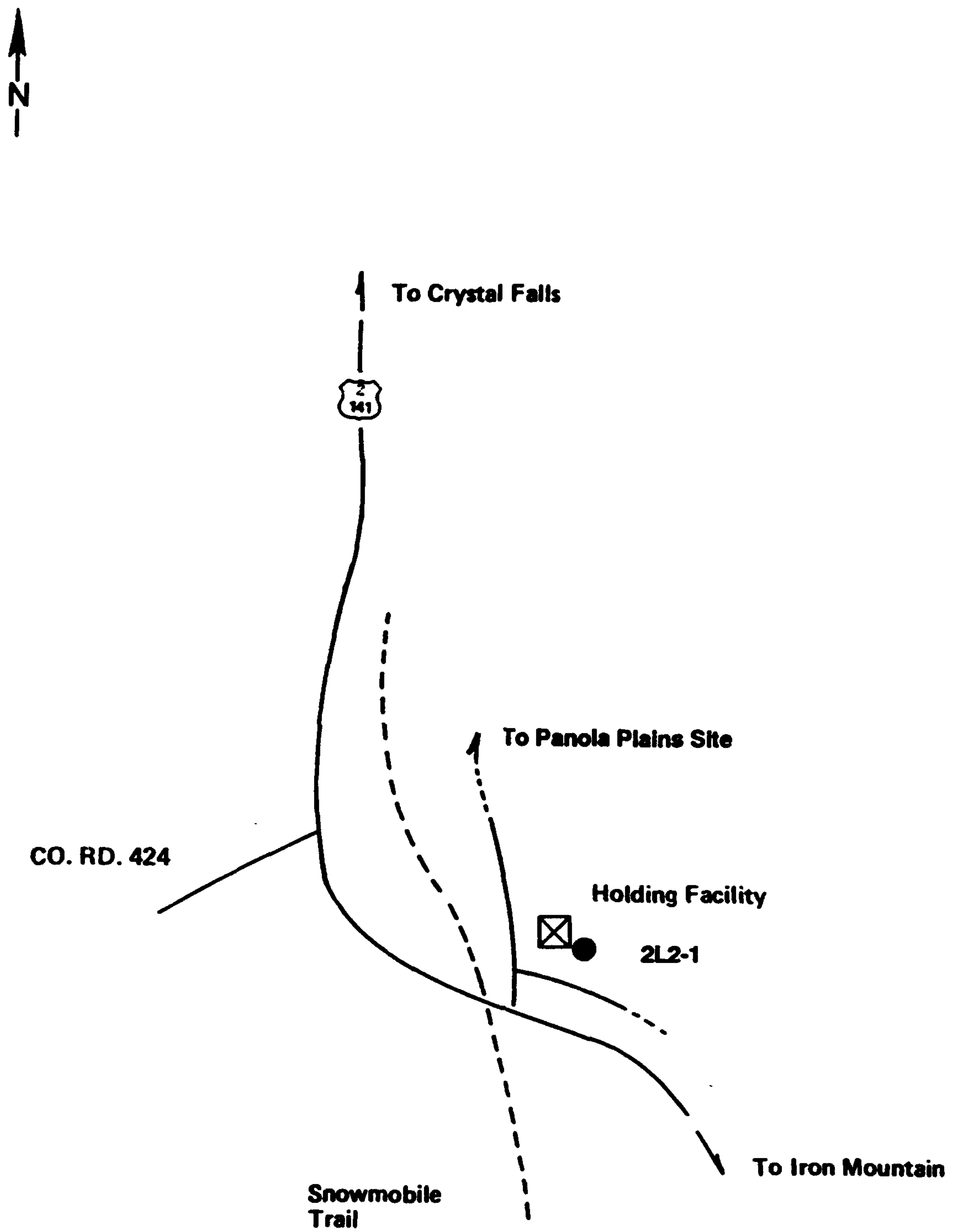

FIGURE B-8. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 2L2-1.

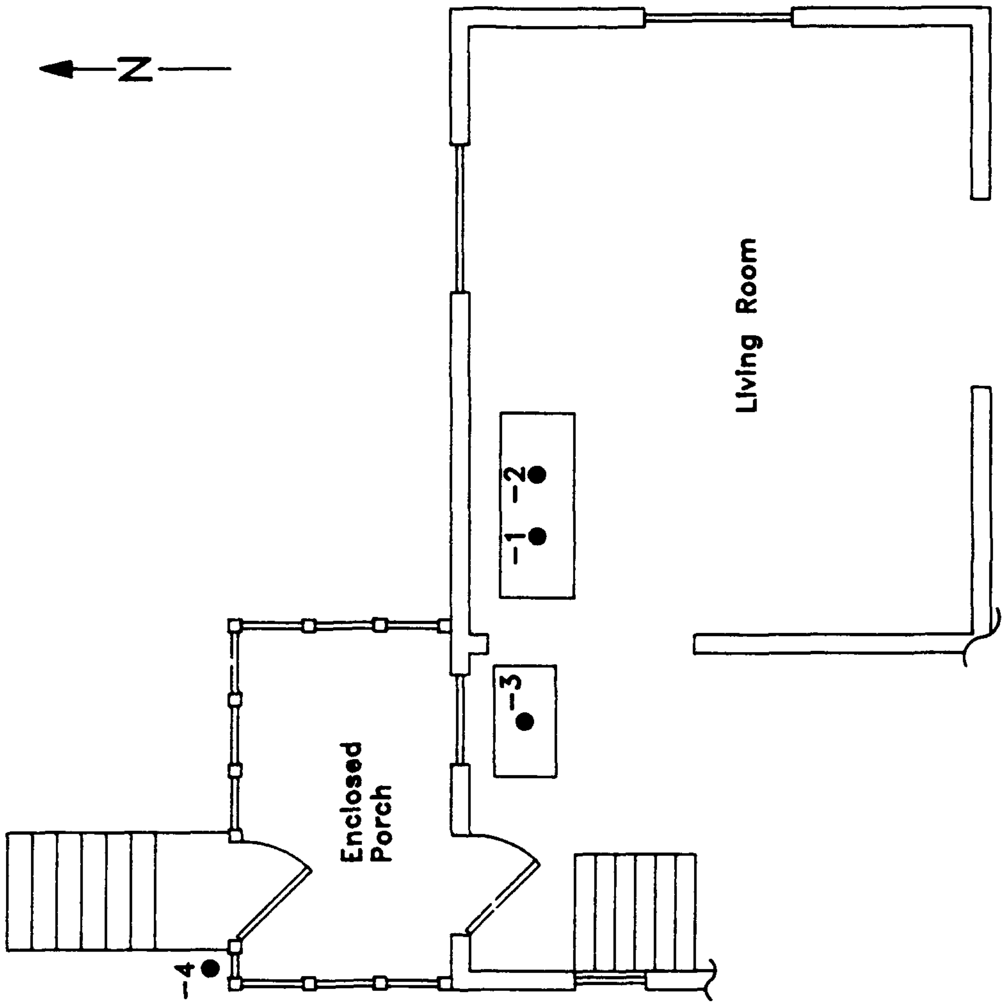

FIGURE B-9. MEASUREMENT POINTS AT CRYSTAL FALLS, CRYSTAL AVE. LABORATORY; 2L2-1, 2, 3, 4.

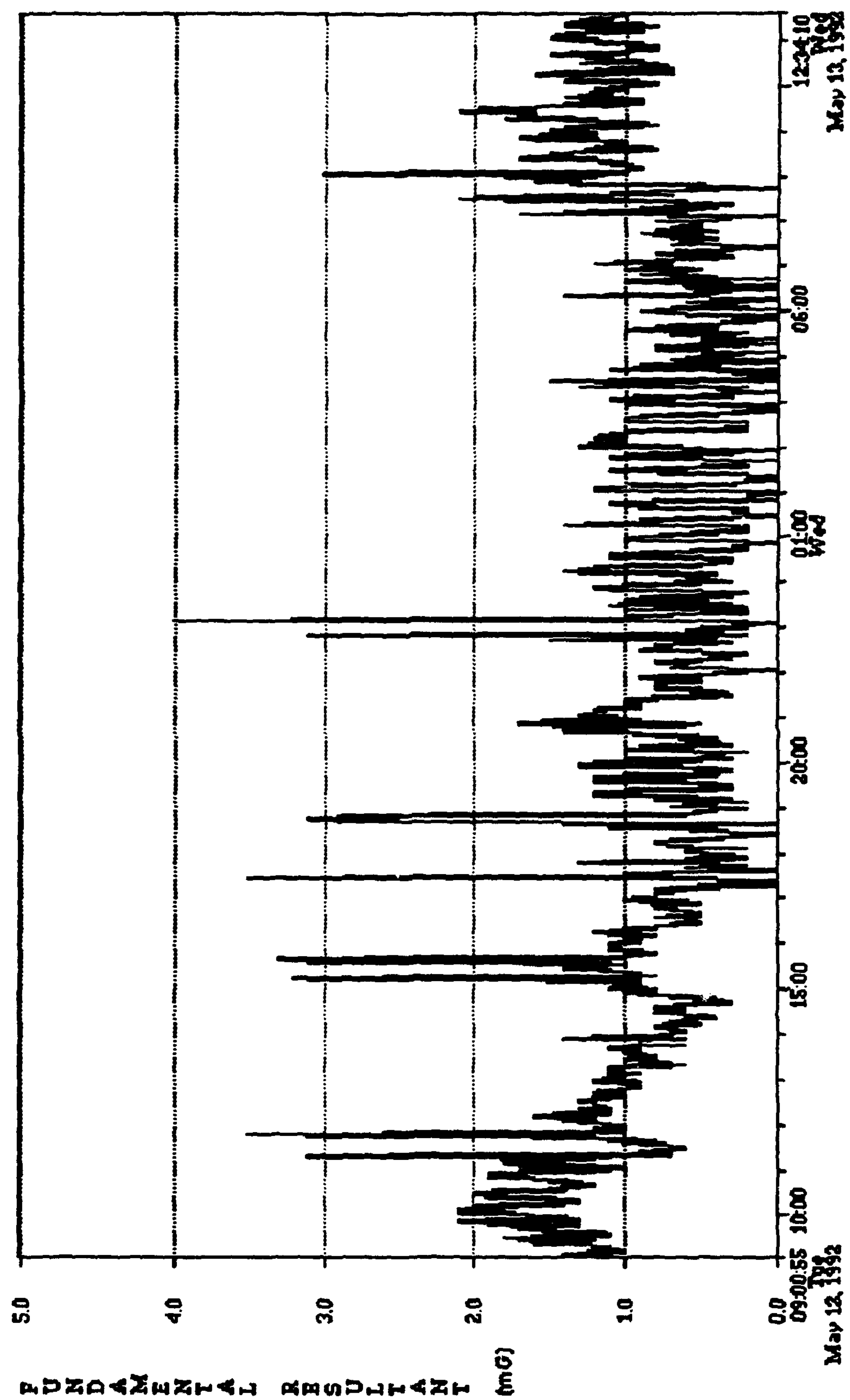

FIGURE B-10. 60 Hz MAGNETIC FLUX DENSITY AT NATIVE BEE STUDY CRYSTAL FALLS, CRYSTAL AVE. LABORATORY.

TABLE B-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992
2C4-1	<0.001	<0.001	<	<	<	<	<	<[d]	<[d]	<[d]
2C4-2	-	-	<	<	<	<	<	<[d]	<[d]	<[d]
2C5-1	-	<0.001	<	<	<	<	<	<[d]	<[d]	<[d]
2C5-2	-	<0.001	<	<	<	<	<	<[d]	/	/
2C5-4	-	-	<	<	<	<	<	<[d]	<[d]	<[d]
2L2-1	-	-	-	-	-	<	<	<[d]	<[d]	<[d]
2T1-1	0.004	<0.001	<	<	0.074	0.13	#	0.043[b]	0.20[b]	0.167[b]
2T1-2	-	-	-	<	<0.001	0.001	#	<0.001[b]	0.002[b]	0.002[b]
2T1-3	-	-	-	<	<0.001	0.001	#	<0.001[b]	0.002[b]	0.003[b]
2T1-4	-	-	-	-	<	<0.001	#	<[b]	/	<[b]
2T1-5	-	-	-	-	<	0.006	#	0.001[b]	0.006[c]	0.003[c]
2T2-1	<0.001	<0.001, 0.001	<	<	0.024	0.079	#	0.024[b], 0.048[c]	/	0.018[b]
2T2-2	-	-	-	<	<0.001	<0.001	#	<[b]	/	<0.001[b]
2T2-3	-	-	-	<	0.023	0.087	#	0.018[b]	/	0.013[b]
2T2-4	-	-	-	<	0.003	0.012	#	0.002[b]	/	0.002[b]
2T2-5	-	-	-	<	0.002	0.005	#	0.001[b]	/	<0.001[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.
< = measurement estimated <0.001 V/m based on earth electric field.
/ = measurement not taken.

TABLE B-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992
2C4-1	0.011	0.102, 0.138, 0.160	0.104	0.133	0.178	0.134	0.095	0.098[d]	0.086[d]	0.066[d]
2C4-2	-	-	0.21	0.21	0.26	0.23	0.169	0.095[d]	0.125[d]	0.078[d]
2C5-1	-	0.64, 0.50, 0.93	0.69	0.49	0.38	0.23	0.21	0.37[d]	0.273[d]	0.32[d]
2C5-2	-	0.23	0.40	0.160	0.23	0.099	0.139	0.26[d]	/	/
2C5-4	-	-	0.148	0.090	0.098	0.078	0.078	0.145[d]	0.125[d]	0.106[d]
2L2-1	-	-	-	-	-	0.019	0.022, 0.013	0.022[d]	0.015[d]	0.008[d]
2T1-1	0.23	0.26	0.22	0.042	0.092	0.108	#	0.062[b]	0.135[b]	0.104[b]
2T1-2	-	-	-	0.051	0.034	0.053	#	0.024[b]	0.064[b]	0.039[b]
2T1-3	-	-	-	0.077	0.051	0.059	#	0.052[b]	0.26[c]	0.051[b]
2T1-4	-	-	-	-	0.040	0.152	#	0.040[b]	0.100[b]	0.063[b]
2T1-5	-	-	-	-	0.050	0.151	#	0.023[b]	0.30	0.042[b]
2T2-1	0.071	0.65, 0.88	0.86, 0.88	0.23	0.54	1.49	#	0.38[b], 0.90[c]	0.149[b], 0.131[c]	0.36[b]
2T2-2	-	-	-	0.092	0.100	1.31	#	0.20[b]	0.76[b]	0.123[b]
2T2-3	-	-	-	0.123	0.25	0.84	#	0.175[b]	0.166[b]	0.120[b]
2T2-4	-	-	-	0.078	0.186	0.67	#	0.161[b]	0.146[b]	0.099[b]
2T2-5	-	-	-	0.120	0.23	1.11	#	0.22[b]	0.108[b]	0.165[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.
/ = measurement not taken.

TABLE B-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992
2C4-1	0.004	0.003, 0.004	0.003	0.003	0.006	0.006	0.005	0.006[d]	0.004[d]	0.003[d]
2C4-2	-	-	0.003	0.003	0.005	0.003	0.004	0.005[d]	0.004[d]	0.003[d]
2C5-1	-	0.001, 0.002	0.002	0.001	0.002	0.001	0.001	0.002[d]	0.001[d]	0.001[d]
2C5-2	-	<0.001	0.002	0.001	0.002	0.001	0.001	0.002[d]	/	/
2C5-4	-	-	0.002	0.002	0.002	0.001	0.001	0.002[d]	0.002[d]	0.001[d]
2L2-1	-	-	-	-	-	0.003	0.002, 0.002	0.002[d]	0.002[d]	0.001[d]
2T1-1	0.001	0.002	0.001	0.038	0.042	0.075	#	0.020[b]	0.112[b]	0.080[b]
2T1-2	-	-	-	0.004	0.008	0.012	#	0.004[b]	0.018[b]	0.012[b]
2T1-3	-	-	-	0.005	0.019	0.018	#	0.004[b]	0.042[c]	0.013[b]
2T1-4	-	-	-	-	0.006	0.010	#	0.001[b]	0.012[b]	0.008[b]
2T1-5	-	-	-	-	0.011	0.027	#	0.005[b]	0.051[c]	0.016[b]
2T2-1	0.002	0.001	0.001	0.020	0.058	0.134	#	0.033[b], 0.070[c]	0.041[b], 0.020[c]	0.027[b]
2T2-2	-	-	-	0.003	0.008	0.022	#	0.004[b]	0.006[b], 0.007[c]	0.003[b]
2T2-3	-	-	-	0.015	0.038	0.115	#	0.028[b]	0.037[b]	0.025[b]
2T2-4	-	-	-	0.006	0.018	0.058	#	0.012[b]	0.017[b]	0.012[b]
2T2-5	-	-	-	0.005	0.013	0.044	#	0.010[b]	0.013[b]	0.008[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.
/ = measurement not taken.

TABLE B-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No.	1986				1987		1988		1989	1990	1991	1992
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A
2C4-1	<	<	<	*	<	<	<	<	<	<	<	<
2C4-2	<	<	<	*	<	<	<	<	<	<	<	<
2C5-1	<	<	<	*	<	<	<	<	<	<	<	<
2C5-2	<	<	<	*	<	<	<	<	<	<	/	/
2C5-4	<	<	<	*	<	<	<	<	<	<	<	<
2L2-1	-	-	-	-	-	-	<	<	<	<	<	<
2T1-1	0.59	<	<	*	2.9	0.003	15.8	0.056	23	42	28	38
2T1-2	0.009	<	<	*	0.022	<	0.135	<0.001	0.23	0.46	0.31	0.36
2T1-3	0.005	<	<	*	0.019	<	0.095	0.001	0.178	0.40	0.23	0.26
2T1-4	-	-	-	-	0.007	<	0.027	0.001	0.054	0.075	0.073	0.085
2T1-5	-	-	-	-	/	/	0.39	0.002	0.63	1.23	0.92	0.95
2T2-1	0.182	<	<	*	0.48	<0.001	2.4	0.010	4.9	6.22	6.7	7.0
2T2-2	0.005	<	<	*	0.015	<0.001	0.079	0.001	0.142	0.159	0.145	0.151
2T2-3	0.123	<	<	*	0.42	<0.001	2.7	0.002	4.9	4.3	4.2	4.6
2T2-4	0.021	<	<	*	0.061	<0.001	0.38	0.002	0.54	0.57	0.62	0.64
2T2-5	0.012	<	<	*	0.039	<0.001	0.159	<0.001	0.29	0.32	0.36	0.30

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
< = measurement estimated <0.001 V/m based on earth electric field.
* = data cannot be extrapolated.

TABLE B-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies

	1986				1987		1988		1989	1990	1991	1992
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A
2C4-1	/	/	/	*	0.006	0.003	0.027	0.017	0.072	0.065	0.060	0.075
2C4-2	0.002	0.001	0.001	0.002	0.006	0.004	0.030	0.022	0.105	0.103	0.105	0.101
2C5-1	0.008	0.004	0.006	0.010	0.022	0.018	0.112	0.110	0.36	0.33	0.31	0.39
2C5-2	/	/	/	*	0.008	0.008	0.041	0.042	0.179	0.197	/	/
2C5-4	/	/	/	*	0.001	0.005	0.020	0.027	0.114	0.113	0.131	0.111
2L2-1	-	-	-	-	-	-	0.006	0.002	0.013	0.020	0.010	0.010
2T1-1	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77	70	54	44	79
2T1-2	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98	32	38	32	39
2T1-3	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40	45	53	54	63
2T1-4	-	-	-	-	4.5	0.191	30	1.38	59	67	67	65
2T1-5	-	-	-	-	/	/	22	0.96	36	26	61	45
2T2-1	5.4	0.159	0.086	0.143	32	0.25	102	1.03	169	122	98	330
2T2-2	1.63	0.054	0.067	0.112	6.0	0.178	87	1.41	120	177	69	145
2T2-3	3.0	0.087	0.063	0.105	13.5	0.21	56	0.76	147	139	98	134
2T2-4	1.93	0.053	0.071	0.118	10.4	0.25	43	1.04	95	85	97	106
2T2-5	3.6	0.101	0.096	0.160	14.0	0.24	75	1.05	188	145	160	172

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE B-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A
2C4-1	/	/	/	*	0.001	<0.001	0.002	0.001	0.006	0.006	0.006	0.006
2C4-2	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.006	0.007	0.007	0.007
2C5-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.002	0.003	0.002	0.003
2C5-2	/	/	/	*	<0.001	<0.001	0.001	0.001	0.002	0.003	/	/
2C5-4	/	/	/	*	<0.001	<0.001	0.001	0.001	0.003	0.003	0.003	0.003
2L2-1	-	-	-	-	-	-	<0.001	<0.001	0.002	0.002	0.002	0.001
2T1-1	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31	29	27	32
2T1-2	0.125	0.004	<0.001	*	0.46	0.002	2.1	0.007	4.5	4.5	4.4	4.7
2T1-3	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014	5.1	5.2	4.9	5.2
2T1-4	-	-	-	-	0.33	0.002	1.47	0.006	3.0	3.0	2.9	3.1
2T1-5	-	-	-	-	/	/	3.2	0.016	6.6	6.4	6.1	6.6
2T2-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021	14.7	14.7	13.5	17.6
2T2-2	0.060	0.002	<0.001	*	0.22	0.002	1.05	0.005	2.1	2.1	2.1	2.3
2T2-3	0.35	0.011	0.002	0.003	1.33	0.002	6.2	0.026	12.8	12.8	11.8	12.8
2T2-4	0.158	0.005	0.001	0.002	0.58	0.001	2.9	0.015	5.5	5.7	5.5	5.9
2T2-5	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013	4.4	4.4	4.4	4.8

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE B-9. 1992 PAIRED SITE EM FIELD INTENSITY RATIOS
Native Bees Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
2T1/2C4	85	85	85	1.00 - 167	390	760	500	0.50 - 1.58	440	390	1030	2.7 - 27
2T1/2C5	85	85	85	1.00 - 167	100	760	122	0.122 - 0.98	1030	390	3100	8.0 - 80
2T2/2C4	151	151	151	1.00 - 18.0	1050	920	1360	1.27 - 5.5	330	490	770	1.00 - 9.0
2T2/2C5	151	151	151	1.00 - 18.0	270	920	330	0.31 - 3.4	770	490	2300	3.0 - 27

R1: T(76)/C(60) T(76) = ELF Communications System EM fields at the treatment site.
R2: T(76)/T(60) C(76) = ELF Communications System EM fields at the control site.
R3: T(76)/C(60) T(60) = ambient EM fields at the treatment site.
R4: T(60)/C(60) C(60) = ambient EM fields at the control site.

TABLE B-10. 60 Hz AIR ELECTRIC FIELD INTENSITIES
Native Bees Studies Crystal Falls, Marquette Street Laboratory

Measurement Point Identification	1988 E-field (V/m)	1989 E-field (V/m)	1990 Hatches	1990 Lamps	1990 Workers	1990 E-field (V/m)
2L1-1	79	31	N/A	N/A	N/A	--[a]
2L1-2	22	19.5	N/A	N/A	N/A	--[a]
2L1-3	0.25	0.45	closed	N/A[b]	N/A[b]	0.001
			open	N/A[b]	N/A[b]	0.023
2L1-4	-	12.5	N/A	N/A	N/A	--[a]
2L1-5	-	18.2	N/A	N/A	N/A	--[a]
2L1-6[c]	-	5.3	N/A	on	none	14.9
2L1-7[c]	-	-	N/A	N/A	N/A	22
2L1-7	-	-	closed	on	none	0.039
			open	on	none	1.14
			open	on	2-not grounded to cage	15.7
			open	on	1-grounded to cage	0.122 - 0.198
2L1-8	-	-	closed	on	none	0.039
			open	on	none	0.84
			open	on	2-grounded to cage	0.122 - 0.198
2L1-9	-	-	closed	on	none	0.040
			open	on	none	0.88
			open	on	2-grounded to cage	0.122 - 0.198

- = measurement point not established.
-- = measurement point dropped.
N/A = not applicable.

[a] Cages were never located here; measurement point was dropped in 1990.
[b] Storage cage on porch, not a workstation; therefore, workers and lamps are not applicable.
[c] No cage present.

TABLE B-11. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies Crystal Falls, Marquette Street Laboratory

Measurement Point Identification	1988	1989	1990
2L1-1	0.93	0.75	--
2L1-2	0.52	0.39	--
2L1-3	0.37	0.43	0.33
2L1-4	-	0.32	--
2L1-5	-	0.32	--
2L1-6	-	0.30	/
2L1-7	-	-	0.26
2L1-8	-	-	0.38
2L1-9	-	-	0.40

- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.

TABLE B-12. 60 Hz AIR ELECTRIC FIELD INTENSITY (V/m)
Native Bees Studies Crystal Falls, Crystal Avenue Laboratory

Site No., Meas. Pt.	1992	Measurement Notes*
2L3-1	0.031	C
2L3-1	0.074	O, W
2L3-2	0.030	C
2L3-2	0.092	O, W
2L3-3	0.015	C
2L3-3	0.036	O, W
2L3-4	<0.001	C

* = measurements made inside Faraday cage with work lights on.
C = closed cage door.
O = open cage door.
W = worker present, grounded to cage.

TABLE B-13. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies Crystal Falls, Crystal Avenue Laboratory

Site No., Meas. Pt.	1992	Measurement Notes
2L3-1	2.0	*
2L3-2	1.78	*
2L3-3	2.1	*
2L3-4	0.56	*

* Measurement made inside Faraday cage with door closed, work lights on where applicable.

APPENDIX C

SOIL ARTHROPODS AND EARTHWORMS STUDIES

SOIL ARTHROPODS AND EARTHWORMS STUDIES

These studies monitor the species composition, population age structure, and distribution of soil arthropods and earthworms. The electric and magnetic fields in the earth are considered the most important electromagnetic (EM) factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

In 1993, IITRI field crews made ELF EM field measurements at 12 measurement points within the treatment site, control site, and species collection sites for the soil arthropods and earthworms studies. The measurement regime was identical to that used in 1992. Measurement dates for 1993 and previous years appear in Table C-1.

The positions of the four sites relative to the NRTF-Republic are shown on the composite map in Figure C-1. The site numbers listed on the map are those used by IITRI. Table C-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures C-2 through C-4.

EM field measurements for 1993 and previous years are found in Tables C-3 through C-8. Tables C-3, C-4, and C-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables C-6, C-7, and C-8 present 76 Hz data for these fields as well as the corresponding operating currents of the NRTF-Republic for each year. Paired site EM field intensity ratios, which were recalculated using 1993 measurement data, appear in Table C-9. Laboratory EM field measurements appear in Tables C-10 and C-11.

TABLE C-1. EM FIELD MEASUREMENT DATES
Soil Arthropods and Earthworms Studies

Year	Measurement Dates	
1983	Jun 6	Jul 13
1984	May 14, 21	Aug 9, 13
1985	Jul 19	
1986	Oct 2, 7	
1987	Sep 25, 28	
1988	Sep 26	Oct 3
1989	Sep 13, 15	
1990	Oct 2, 8	
1991	May 6, 7, 8, 30	
1992	May 11, 13, 26, 28	
1993	Apr 28, 29	

TABLE C-2. SITE NUMBER CROSS-REFERENCE
Soil Arthropods and Earthworms Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
3T2	South Silver Lake	T44N	R29W	25
3C5	Turner Road	T43N	R30W	11
3L1	Sagola Laboratory	T43N	R30W	32
3S2	Firetower Road	T44N	R30W	24

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements made at treatment sites in 1986 through 1993 (excluding 1989) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were made at the treatment site during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control site, nonetheless, are about as variable as those at the treatment site.

Overall, the 60 Hz EM fields measured at both study sites in 1993 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment site consistently dominate the 60 Hz EM fields at both the treatment and control sites.

The 76 Hz EM field measurements in 1993 were made with 150 A currents, the predominant operating current of the NRTF-Republic since May 1989. The antenna currents at which measurements were made in each year are given in the column headings of the Tables C-6 through C-8. The annual increases in field magnitudes reflect the level of antenna currents at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurements made during operation of both antennas are consistent with the measurements made in 1989 through 1992 under the same conditions, and proportional to the 1986, 1987, and 1988 measurements made at lower currents. Measurements made during operation of the NS antenna only in 1991 included seven new locations at the treatment site for which there were no previous measurements for comparison and three locations at the control site. In

1992 and 1993, data were obtained during operation of both antennas for two of the seven new points (five were dropped) at the treatment site. These data show that field intensities were reduced by about 10 percent at these locations during operation of the NS antenna only. The 1992/1993 data indicate nominally a 10- to 20-percent reduction in the earth electric field intensity, and a 20- to 30-percent reduction in the magnetic flux density, at the control site during operation of the NS antenna only. However, any reduction in the 76 Hz EM fields at control sites, where low intensities are desired, should not be of great concern because this situation actually improves the 76 Hz EM ratios between treatment and control sites.

EM field intensities were characterized for the first time in 1992 at the soil arthropods and earthworms laboratory located in Channing, Michigan. The layout of the laboratory, which is housed in a pole barn, is shown in Figure C-5. Locations of concern at the laboratory include a holding area, a screening area where the species are separated from the soil, and a microscope table. The 60 Hz air electric field intensity and magnetic flux density were characterized at these three locations. Measurement results appear in Tables C-10 and C-11. With the exception of the electronic scale used on the microscope table, 60 Hz EM intensities are less than corresponding 76 Hz EM intensitites at the treatment site. They are also typically within a factor of 10 of corresponding 60 Hz fields at all study sites. The principal investigator was advised to minimize the time that the study species are exposed to fields generated by the electronic scale. This is accomplished by storing specimens at a distance from the scale and turning the scale off when it is not in use.

The EMDEX II™ magnetic field meter was used in 1992 to monitor utility-generated fields over a 43-hour period at the laboratory. The meter was set at the holding area, measurement point 3L1-2, where specimens are stored while at the laboratory; it was programmed to measure broadband (40 to 800 Hz) and harmonic (100 to 800 Hz) frequency magnetic field intensities at five-second intervals. Plotted in Figure C-6 is the fundamental (60 Hz) resultant magnetic field, which was calculated by the EMDEX from the broadband and harmonic measurement results. This figure shows that 60 Hz magnetic field intensities at the laboratory are low and consistent. Occasional rises and falls in the field intensity levels correspond with events recorded by the ecological investigator (typically, the turning on of a microscope lamp). The maximum measurement value was 0.3 mG, with a 0.14 mG mean and a 0.04 mG standard deviation.

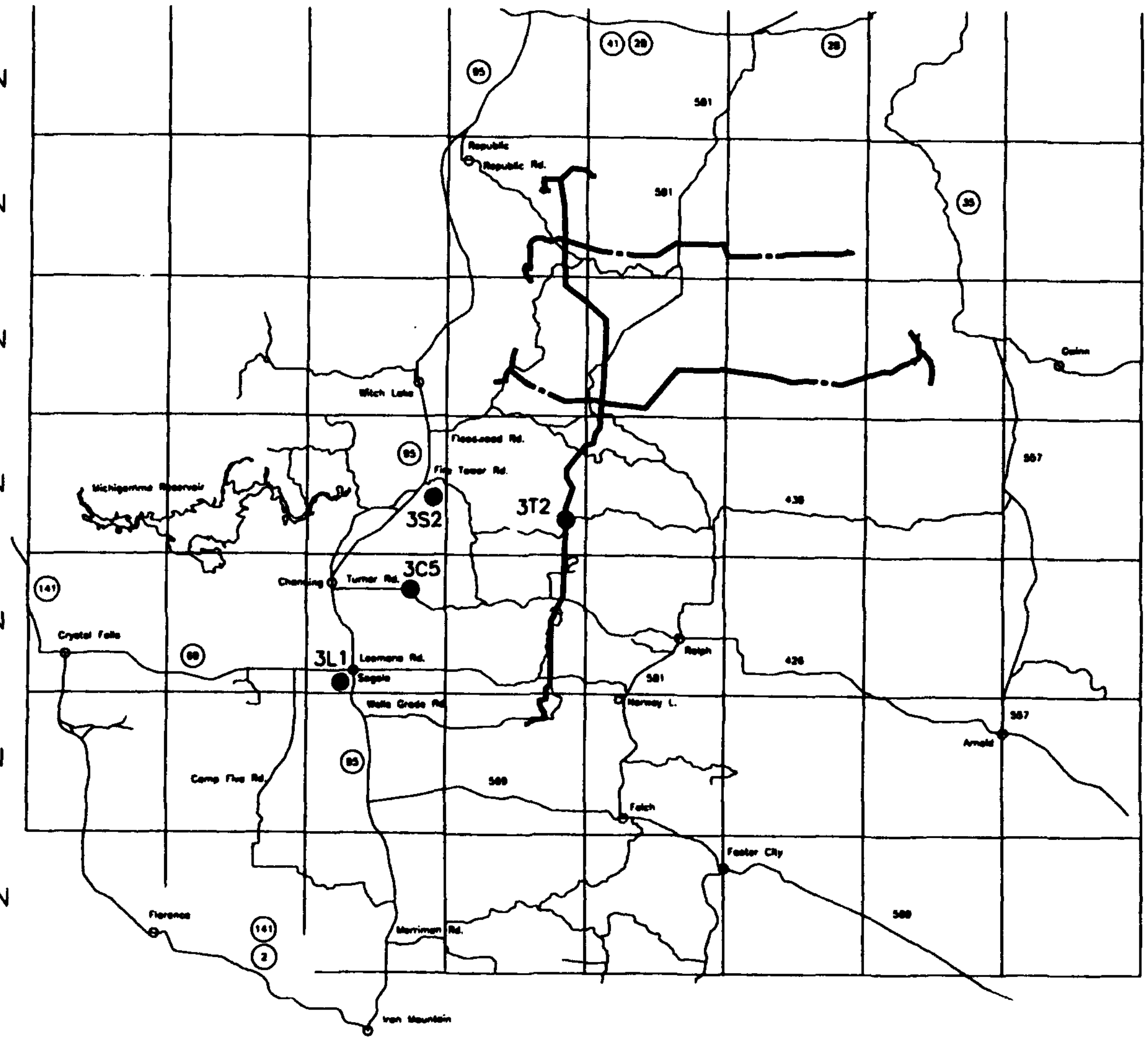

FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

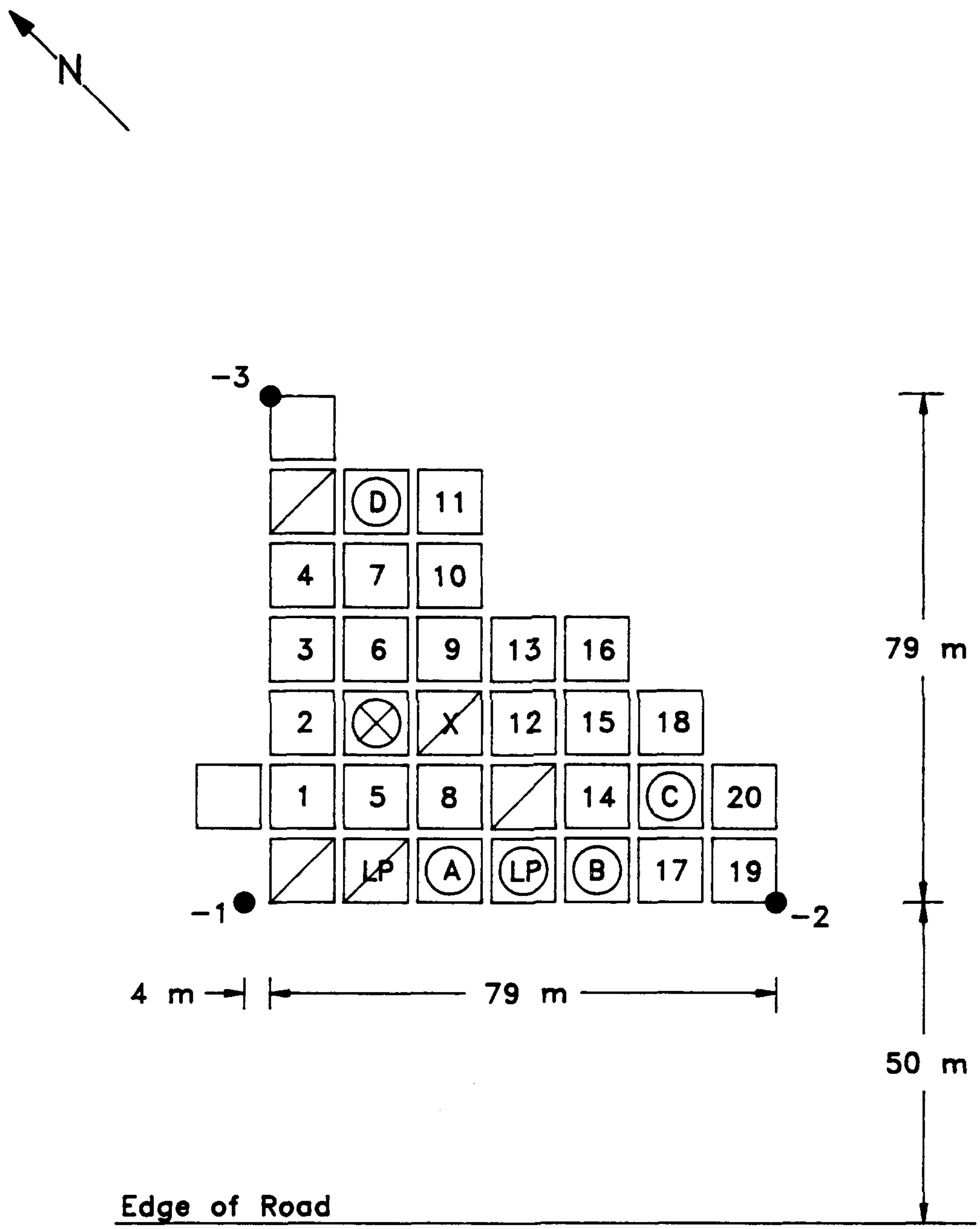

FIGURE C-2. MEASUREMENT POINTS AT TURNER ROAD; 3C5-1 THROUGH 3.

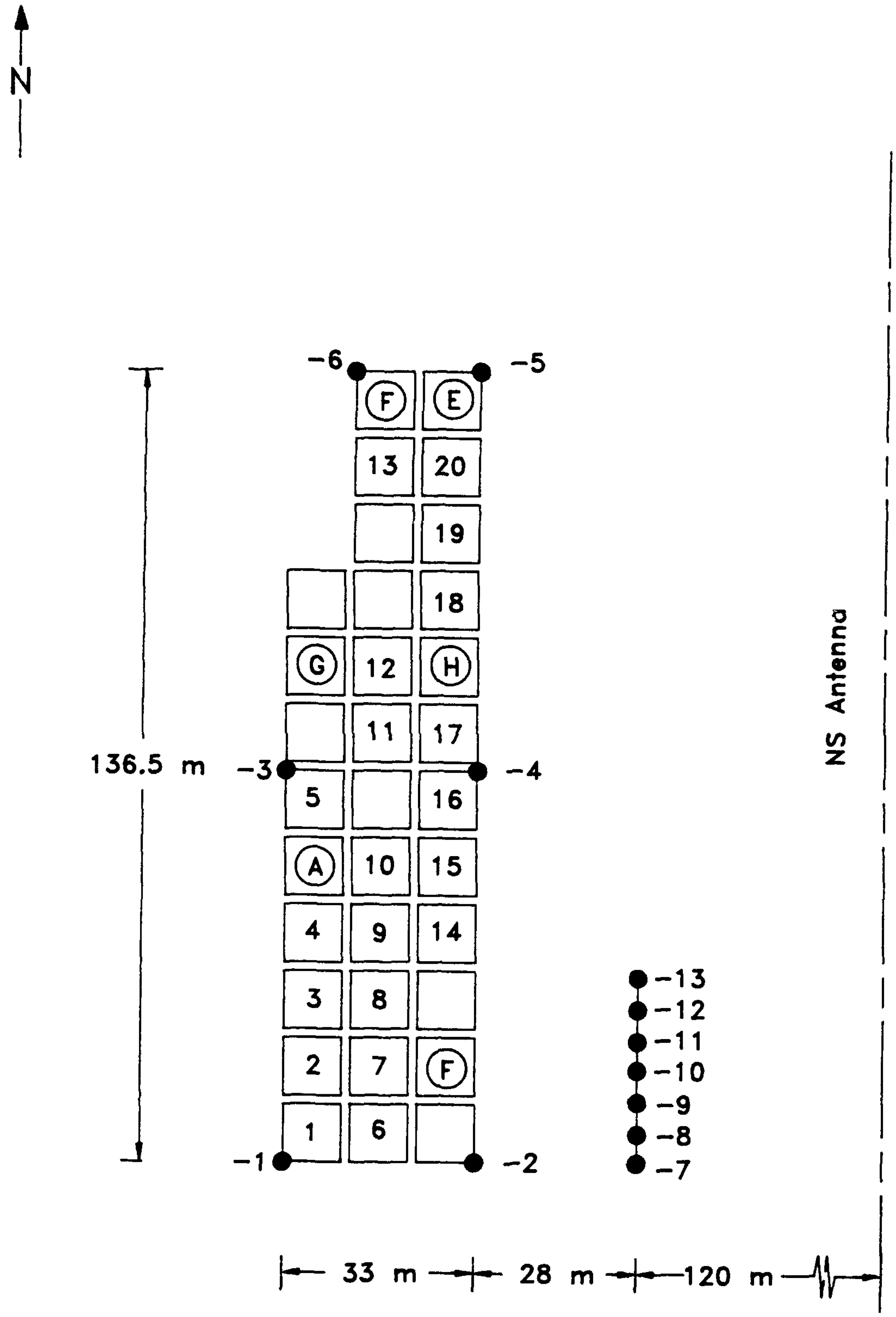

FIGURE C-3. MEASUREMENT POINTS AT SOUTH SILVER LAKE; 3T2-1 THROUGH 13.

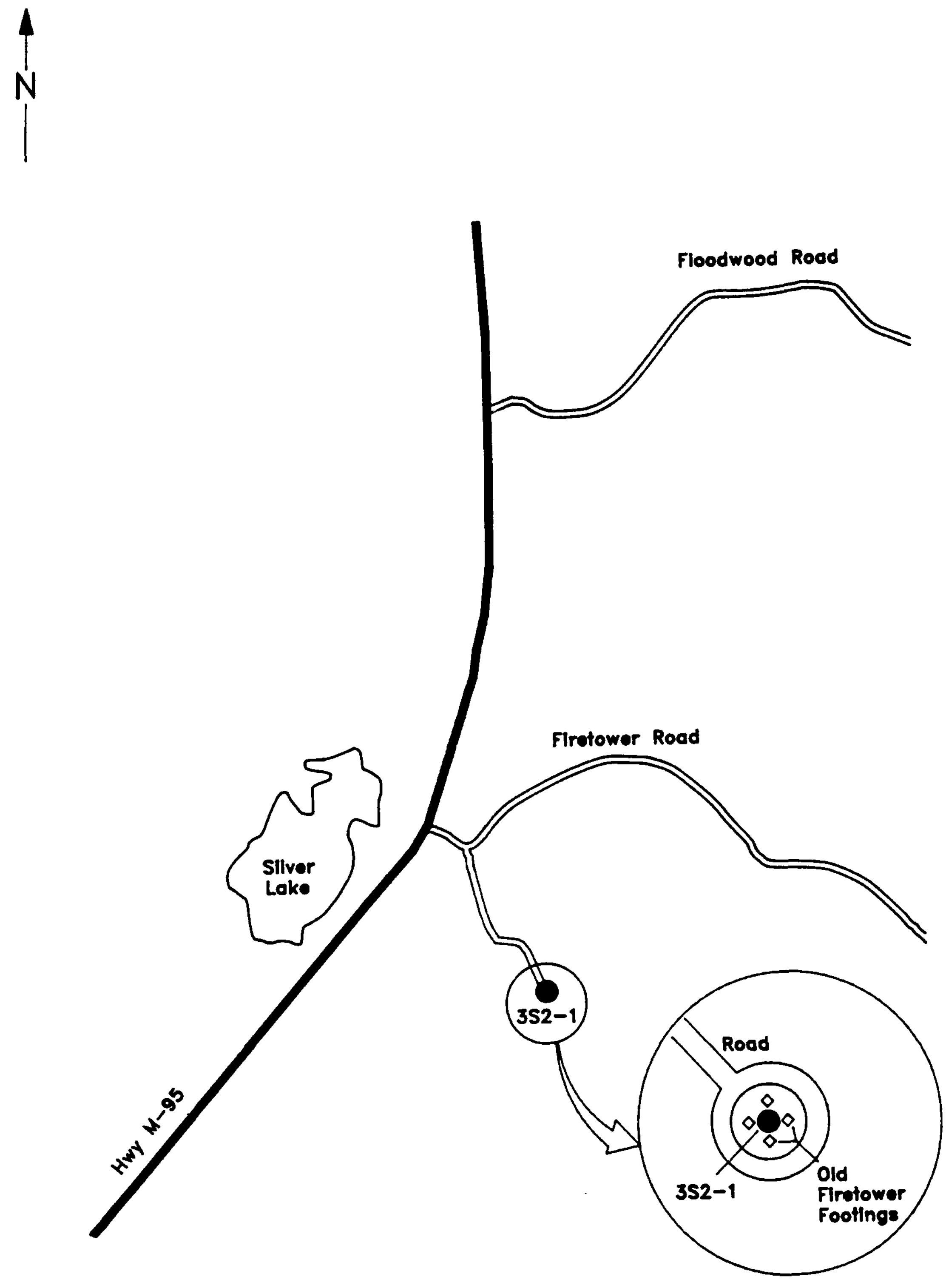

FIGURE C-4. MEASUREMENT POINT AT FIRETOWER ROAD WORM COLLECTION SITE; 3S2-1.

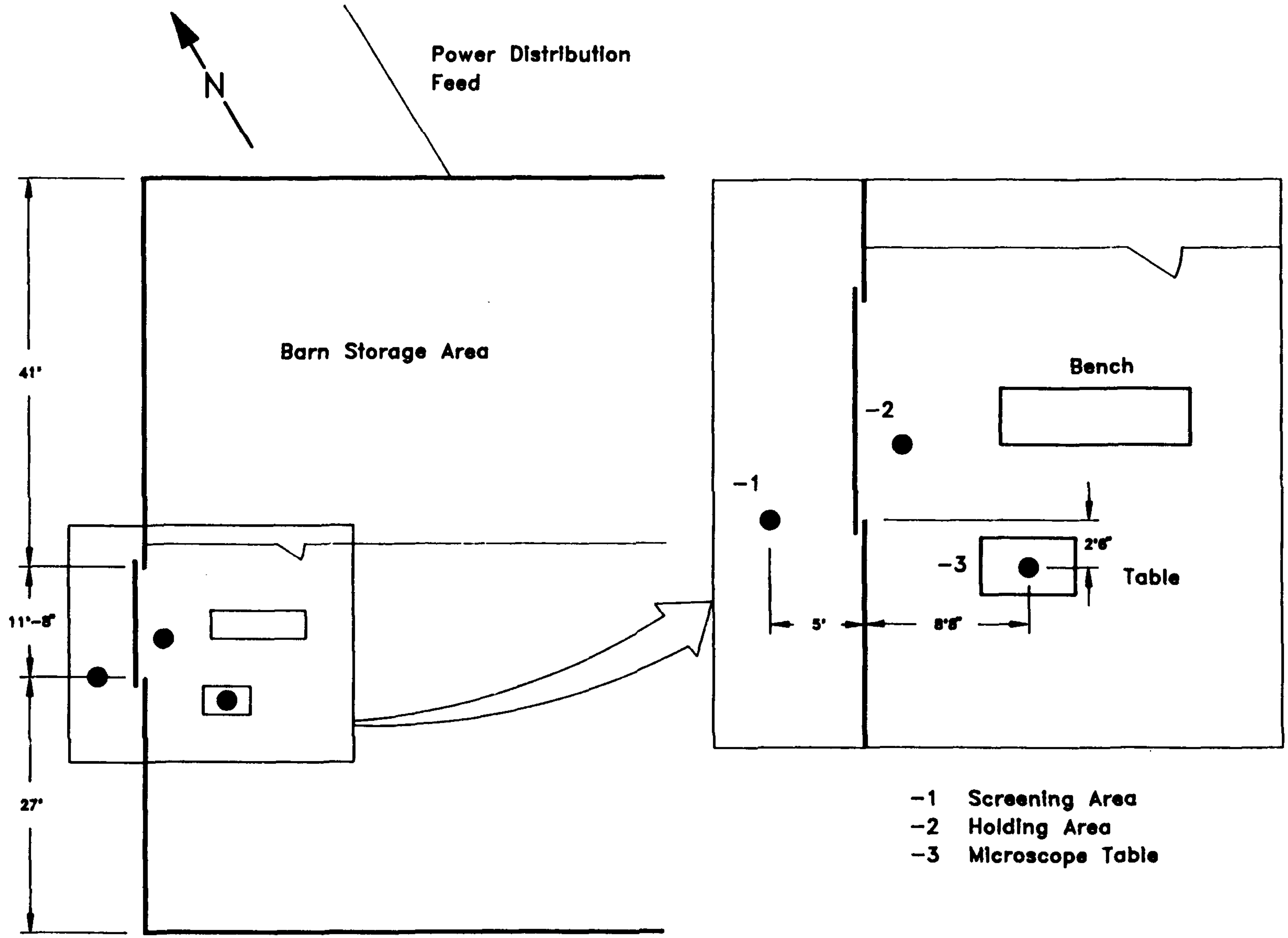

FIGURE C-5. MEASUREMENT POINTS AT SOIL ARTHROPOD AND EARTHWORM CHANNING LABORATORY; 3L1-1, 2, 3.

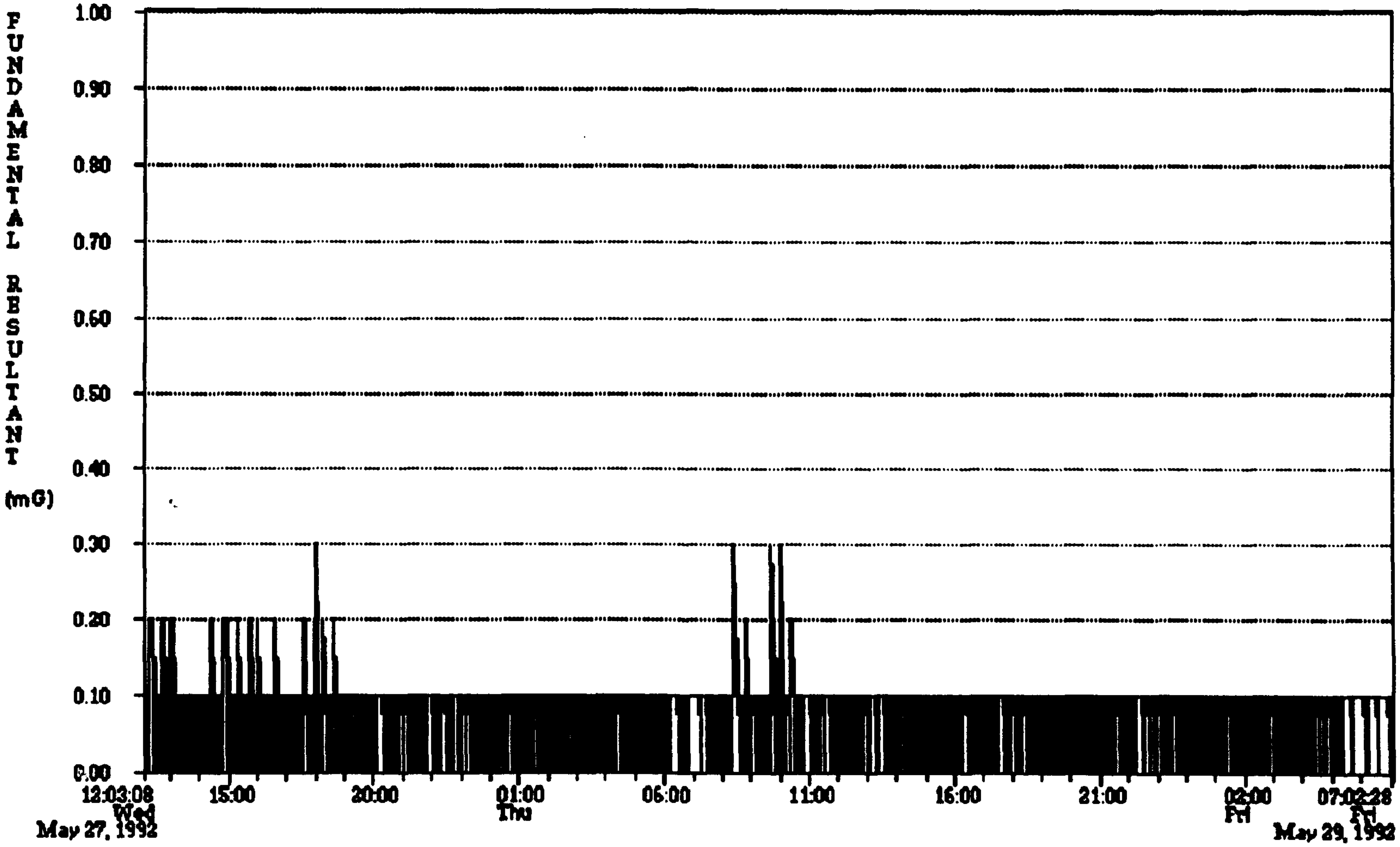

FIGURE C-6. 60 Hz MAGNETIC FLUX DENSITIES AT SOIL ARTHROPOD AND EARTHWORM CHANNING LABORATORY.

TABLE C-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
3C5-1	<0.001	<0.001	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
3C5-2	-	-	-	<	<	<	<	<[d]	<[d]	<[d]	<[d]
3C5-3	-	-	-	-	-	-	-	-	<[d]	<[d]	<[d]
3T2-1	<0.001	<0.001	<	<	<	<	<0.001	<0.001[c]	<[c]	<[b]	<[b]
3T2-2	-	-	-	<	<	<	<	<0.001[c]	<[c]	<[b]	<[b]
3T2-3	-	-	-	<	<	<	<	<[c]	<[c]	<[b]	<[b]
3T2-4	-	-	-	<	<	<	<	<[c]	<[c]	<[b]	<[b]
3T2-5	-	-	-	<	<	<	<	<[c]	<[c]	<[b]	<[b]
3T2-6	-	-	-	<	<	<	<	<[c]	<[c]	<[b]	<[b]
3T2-7	-	-	-	-	-	-	-	-	/	<[b]	<[b]
3T2-8	-	-	-	-	-	-	-	-	/	/	/
3T2-9	-	-	-	-	-	-	-	-	/	/	/
3T2-10	-	-	-	-	-	-	-	-	/	/	/
3T2-11	-	-	-	-	-	-	-	-	/	/	/
3T2-12	-	-	-	-	-	-	-	-	/	/	/
3T2-13	-	-	-	-	-	-	-	-	/	<[b]	<[b]
3S1-1	-	-	-	-	-	-	-	-	<[c]	/	/
3S2-1	-	-	-	-	-	-	-	-	<[c]	<[b]	<[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
< = measurement estimated <0.001 V/m based on earth electric field.
/ = measurement not taken.

TABLE C-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
3C5-1	0.063	0.018, 0.032	0.036	0.027	0.054	0.054	0.062	0.065[d]	0.069[d]	0.044[d]	0.036[d]
3C5-2	-	-	-	0.027	0.071	0.085	0.182	0.118[d]	0.096[d]	0.086[d]	0.047[d]
3C5-3	-	-	-	-	-	-	-	-	0.120[d]	0.077[d]	0.040[d]
3T2-1	0.106	0.129, 0.27	0.194	0.045	0.042	0.091	0.055	0.042[c]	0.050[c]	0.062[b]	0.21[b]
3T2-2	-	-	-	0.068	0.049	0.093	0.049	0.043[c]	0.063[c]	0.053[b]	0.068[b]
3T2-3	-	-	-	0.038	0.043	0.084	0.035	0.047[c]	0.041[c]	0.074[b]	0.051[b]
3T2-4	-	-	-	0.045	0.039	0.087	0.068	0.040[c]	0.176[c]	0.076[b]	0.051[b]
3T2-5	-	-	-	0.044	0.045	0.084	0.053	0.047[c]	0.047[c]	0.065[b]	0.050[b]
3T2-6	-	-	-	0.048	0.033	0.087	0.041	0.042[c]	0.043[c]	0.065[b]	0.042[b]
3T2-7	-	-	-	-	-	-	-	-	/	0.073[b]	0.086[b]
3T2-8	-	-	-	-	-	-	-	-	/	/	/
3T2-9	-	-	-	-	-	-	-	-	/	/	/
3T2-10	-	-	-	-	-	-	-	-	/	/	/
3T2-11	-	-	-	-	-	-	-	-	/	/	/
3T2-12	-	-	-	-	-	-	-	-	/	/	/
3T2-13	-	-	-	-	-	-	-	-	/	0.055[b]	0.069[b]
3S1-1	-	-	-	-	-	-	-	-	0.62[c]	/	/
3S2-1	-	-	-	-	-	-	-	-	0.45[c]	0.064[b]	0.31[b]

a = antennas not constructed.
b = *antennas off, grounded at transmitter.*
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement *not* taken.

TABLE C-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
3C5-1	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002[d]	0.002[d]	0.002[d]	0.002[d]
3C5-2	-	-	-	<0.001	0.001	0.001	0.002	0.001[d]	0.001[d]	0.001[d]	0.001[d]
3C5-3	-	-	-	-	-	-	-	-	0.001[d]	0.001[d]	0.001[d]
3T2-1	<0.001	<0.001	0.001	0.005	0.002	0.004	0.001	0.003[c]	0.005[c]	0.003[b]	0.006[b]
3T2-2	-	-	-	0.006	0.003	0.006	0.002	0.004[c]	0.006[c]	0.003[b]	0.006[b]
3T2-3	-	-	-	0.004	0.003	0.003	0.001	0.003[c]	0.005[c]	0.003[b]	0.006[b]
3T2-4	-	-	-	0.005	0.003	0.005	0.002	0.004[c]	0.010[c]	0.003[b]	0.007[b]
3T2-5	-	-	-	0.005	0.003	0.004	0.002	0.004[c]	0.005[c]	0.003[b]	0.007[b]
3T2-6	-	-	-	0.004	0.003	0.003	0.001	0.004[c]	0.006[c]	0.002[b]	0.006[b]
3T2-7	-	-	-	-	-	-	-	-	/	0.004[b]	0.009[b]
3T2-8	-	-	-	-	-	-	-	-	/	/	/
3T2-9	-	-	-	-	-	-	-	-	/	/	/
3T2-10	-	-	-	-	-	-	-	-	/	/	/
3T2-11	-	-	-	-	-	-	-	-	/	/	/
3T2-12	-	-	-	-	-	-	-	-	/	/	/
3T2-13	-	-	-	-	-	-	-	-	/	0.004[b]	0.010[b]
3S1-1	-	-	-	-	-	-	-	-	0.006[c]	/	/
3S2-1	-	-	-	-	-	-	-	-	0.004[c]	0.002[b]	0.003[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement not taken.

TABLE C-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
3C5-1	<	<	<	*	<	<	<	<	<	<	< (NS)	<	<
3C5-2	<	<	<	*	<	<	<	<	<	<	< (NS)	<	<
3C5-3	-	-	-	-	-	-	-	-	-	-	< (NS)	<	<
3T2-1	0.002	<	<	*	0.006	<	0.031	0.003	0.064	0.056	0.067	0.059	0.059
3T2-2	0.002	<	<	*	0.006	<	0.024	0.003	0.070	0.068	0.064	0.062	0.075
3T2-3	0.002	<	<	*	0.006	<	0.028	0.003	0.048	0.067	0.061	0.061	0.061
3T2-4	0.002	<	<	*	0.006	<	0.026	0.003	0.055	0.061	0.054	0.059	0.060
3T2-5	0.002	<	<	*	0.006	<	0.029	0.005	0.061	0.056	0.097	0.065	0.075
3T2-6	0.002	<	<	*	0.006	<	0.027	0.002	0.048	0.055	0.053	0.050	0.074
3T2-7	-	-	-	-	-	-	-	-	-	-	/	0.060	0.069
3T2-8	-	-	-	-	-	-	-	-	-	-	/	/	/
3T2-9	-	-	-	-	-	-	-	-	-	-	/	/	/
3T2-10	-	-	-	-	-	-	-	-	-	-	/	/	/
3T2-11	-	-	-	-	-	-	-	-	-	-	/	/	/
3T2-12	-	-	-	-	-	-	-	-	-	-	/	/	/
3T2-13	-	-	-	-	-	-	-	-	-	-	/	0.075	0.072
3S1-1	-	-	-	-	-	-	-	-	-	-	/	/	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/	/	0.004

NS = north-south antenna.
(NS) = north-south antenna only due to EW shutdown.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas
EX = extrapolated data.

< = measurement estimated <0.001 V/m based on earth electric field.
* = data cannot be extrapolated.
\- = measurement point not established.
/ = measurement not taken.

TABLE C-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
3C5-1	0.005	0.001	0.002	0.003	0.020	0.006	0.093	0.027	0.22	0.21	0.186 (NS)	0.22	0.21
3C5-2	0.009	0.001	0.003	0.005	0.034	0.009	0.170	0.021	0.36	0.29	0.31 (NS)	0.38	0.44
3C5-3	-	-	-	-	-	-	-	-	-	-	0.27 (NS)	0.33	0.30
3T2-1	1.33	0.057	0.188	0.31	5.4	0.54	27	2.6	58	55	59	64	63
3T2-2	1.46	0.064	0.24	0.40	6.3	0.71	26	3.0	60	53	55	59	56
3T2-3	1.19	0.047	0.149	0.25	5.3	0.60	27	2.7	49	56	58	60	56
3T2-4	1.47	0.060	0.20	0.33	5.6	0.47	29	2.6	62	50	54	56	64
3T2-5	1.56	0.070	0.23	0.36	5.7	0.61	27	2.8	52	59	62	62	55
3T2-6	1.20	0.056	0.180	0.30	5.5	0.54	27	2.4	49	49	55	48	56
3T2-7	-	-	-	-	-	-	-	-	-	-	74 (NS)	85	83
3T2-8	-	-	-	-	-	-	-	-	-	-	68 (NS)	/	/
3T2-9	-	-	-	-	-	-	-	-	-	-	71 (NS)	/	/
3T2-10	-	-	-	-	-	-	-	-	-	-	46 (NS)	/	/
3T2-11	-	-	-	-	-	-	-	-	-	-	56 (NS)	/	/
3T2-12	-	-	-	-	-	-	-	-	-	-	66 (NS)	/	/
3T2-13	-	-	-	-	-	-	-	-	-	-	60 (NS)	66	65
3S1-1	-	-	-	-	-	-	-	-	-	-	/	/	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/	3.9	2.6

NS = north-south antenna.
(NS) = north-south antenna only due to EW shutdown.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas.
EX = extrapolated data.
- = measurement point not established.
/ = measurement not taken.

TABLE C-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
3C5-1	<0.001	<0.001	<0.001	*	0.002	0.001	0.008	0.003	0.019	0.018	0.014 (NS)	0.020	0.018
3C5-2	<0.001	<0.001	<0.001	*	0.002	0.001	0.007	0.002	0.017	0.017	0.014 (NS)	0.019	0.019
3C5-3	-	-	-	-	-	-	-	-	-	-	0.012 (NS)	0.018	0.016
3T2-1	0.048	0.001	0.001	0.002	0.187	0.003	0.88	0.012	1.84	1.81	1.73	1.86	1.80
3T2-2	0.060	0.002	0.001	0.002	0.23	0.003	1.11	0.012	2.3	2.2	2.2	2.3	2.3
3T2-3	0.046	0.001	0.001	0.002	0.182	0.002	0.89	0.012	1.81	1.80	1.68	1.85	1.81
3T2-4	0.055	0.002	0.001	0.002	0.23	0.003	1.08	0.012	2.3	2.2	2.3	2.3	2.2
3T2-5	0.057	0.002	0.001	0.002	0.22	0.003	1.03	0.012	2.2	2.1	2.1	2.2	2.2
3T2-6	0.049	0.001	0.001	0.002	0.190	0.003	0.90	0.012	1.88	1.89	1.77	1.92	1.87
3T2-7	-	-	-	-	-	-	-	-	-	-	2.5 (NS)	2.9	2.8
3T2-8	-	-	-	-	-	-	-	-	-	-	2.5 (NS)	/	/
3T2-9	-	-	-	-	-	-	-	-	-	-	2.5 (NS)	/	/
3T2-10	-	-	-	-	-	-	-	-	-	-	2.5 (NS)	/	/
3T2-11	-	-	-	-	-	-	-	-	-	-	2.6 (NS)	/	/
3T2-12	-	-	-	-	-	-	-	-	-	-	2.6 (NS)	/	/
3T2-13	-	-	-	-	-	-	-	-	-	-	2.6 (NS)	2.9	2.9
3S1-1	-	-	-	-	-	-	-	-	-	-	/	/	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/	0.051	0.052

NS = north-south antenna.
(NS) = north-south antenna only due to EW shutdown.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas.
EX = extrapolated data.
* = data cannot be extrapolated.
- = measurement point not established.
/ = measurement not taken.

TABLE C-9. 1993 PAIRED SITE EM FIELD INTENSITY RATIOS
Soil Arthropods and Earthworms Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
3T2/3C5	59	59	59	1.00	125	300	1170	0.89 - 2.4	95	290	900	3.0 - 10.0

R1: T(76)/C(76)
R2: T(76)/T(60)
R3: T(76)/C(60)
R4: T(60)/C(60)

T(76) = ELF Communications System EM fields at the treatment site.
C(76) = ELF Communications System EM fields at the control site.
T(60) = ambient EM fields at the treatment site.
C(60) = ambient EM fields at the control site.

TABLE C-10. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Earthworm and Soil Arthropod Study Laboratory

Site No., Meas. Pt.	1992	Measurement Notes
3L1-1	0.003	Benchtop level
3L1-2	0.011	Ground level
3L1-3	1.16	Atop electronic scale, scale on

TABLE C-11. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Earthworm and Soil Arthropod Study Laboratory

Site No., Meas. Pt.	1992	Measurement Notes
3L1-1	0.012	Benchtop level
3L1-2	0.013	Ground level
3L1-3	38	Atop electronic scale, scale on

APPENDIX D

UPLAND FLORA AND SOIL MICROFLORA STUDIES

UPLAND FLORA AND SOIL MICROFLORA STUDIES

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies investigate and characterize trees, herbaceous plants, and microflora (fungi and streptomycetes) populations. The electric and magnetic fields in the earth are considered important electromagnetic (EM) factors influencing soil biota and processes. The electric and magnetic fields in the air may influence any object extending above the surface of the earth. The electric field in the air is greatly distorted and shielded by trees or plants on a study plot. Such perturbations were avoided as much as possible when characterizing the air electric field intensities.

The treatment sites for these studies straddle the EW antenna and one of the grounding elements of the NRTF-Republic; the control site is located more than 28 miles from the nearest antenna element. The antenna treatment site and the control site each consist of three overstory tree plots (pole stands), three plots cleared and planted with red pine seedlings (plantations), and three plots set aside for the study of herbaceous plants (reserves). The ground treatment site consists of only three plots cleared and planted with red pine. No overstory tree plots or herbaceous reserves were established at the ground treatment site because the required buffer strips would have resulted in the biota being at too great a distance from the grounding elements for meaningful EM field exposure. Dropped foliage for decomposition studies is collected at the control site and at two sites in Houghton County.

In 1993, IITRI field crews made ELF EM field measurements at 47 historic measurement points within the two treatment sites and one control site. The measurement regime differed from 1992 in that measurements were not made at the three foliage collection points. Foliage was last collected at these points in 1992 for distribution at the study sites during the 1993 field season. Annual EM field measurement dates for 1993 and previous years appear in Table D-1.

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. The annual (historic) measurement point locations are shown in Figures D-2 through D-6. Figures D-3 and D-4 also identify data logger (E) and fixed probe (F) measurement locations, many of which coincide with the historic (H) measurement points.

Annual EM field measurements for 1993 and previous years are found in Tables D-3 through D-8. Tables D-3, D-4, and D-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables D-6, D-7, and D-8 present 76 Hz data for these fields as well as the

TABLE D-1. EM FIELD MEASUREMENT DATES
Upland Flora and Soil Microflora Studies

Year	Measurement Dates		
1983	Jun 7, 14		
1984	May 15, 21	Aug 6, 9	
1985	Jul 15, 17, 19		
1986	Oct 1, 2, 14		
1987	Sep 22, 23	Oct 5, 7	
1988	Sep 22	Oct 5-7	
1989	Sep 19	Oct 11, 12	
1990	Jun 27-30	Aug 9	Oct 1
1991	Jun 19, 20	Oct 3, 15-17	
1992	Sep 28, 29, 30	Oct 1	
1993	Jul 12, 14, 15, 28		

TABLE D-2. SITE NUMBER CROSS-REFERENCE
Upland Flora and Soil Microflora Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
4T2	Martell's Lake (Overhead): ML	T45N	R29W	28
4T4	Martell's Lake (Buried): EP	T45N	R29W	28
4C1	Paint Pond Road Control	T41N	R32W	3
4S1	Red Maple Leaf Collection	T55N	R35W	21
4S2	Oak Leaf Collection	T41N	R32W	3
4S3	Pine Needle Collection	T54N	R34W	5

corresponding operating current of the NRTF-Republic for each year. Paired-site EM field intensity ratios, which were recalculated using 1993 measurement data, appear in Table D-9.*

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and

* Earth electric field measurements, which were performed regularly at several fixed probe since 1990, appear in Tables D-10 through D-13.

differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements at treatment sites in 1986 through 1993 (excluding 1989 and 1990) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989 and 1990, the antenna status (modulated signal) precluded 60 Hz EM field measurements at the treatment sites. However, measurements were possible at treatment sites for other studies in 1989 during unmodulated operation of the antennas. These measurements indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study site are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of this site from the antennas. The 60 Hz fields at the control site show lower spatial variation compared to those at the treatment sites because the antenna is not present to establish a field gradient. In 1992 the 60 Hz EM fields at the control site were found to be many times greater than in previous years. It was expected that these elevated fields resulted from a difference in the loading of a nearby transmission line owned and operated by Wisconsin Electric Power Company (WEPCo). WEPCo personnel informed IITRI, however, that there had been no significant changes in the loading of this or any nearby line that might explain the elevated field intensities. In 1993, the 60 Hz fields were found to be consistent with fields measured in years prior to 1992. Based on these measurements and information received from WEPCo, the elevated field intensities measured in 1992 are believed to correspond to very short exposure times.

Overall, the 60 Hz EM fields measured at all study sites in 1993 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the variability in EM intensities associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites.

The 76 Hz EM field measurements in 1993 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The energized antenna elements and currents at the time of measurement are given below the year in the column headings of Tables D-6 through D-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurement values for full-power operation with both antennas are consistent with those obtained in 1989 through 1992 under the same antenna conditions and are proportional to the measurements made in 1986, 1987, and 1988 at lower currents.

The extended shutdown of the EW antenna for repairs in 1991 and 1992 had a significant impact on the 76 Hz EM exposure levels at the treatment sites for this study, which are located along the SEW antenna element and ground 5. A complete set of EM field measurements was made in 1991 at both treatment sites during operation of the NS antenna only. These data are included in Tables D-6 through

D-8. It was found that the EM exposures at all locations at the treatment sites were reduced to about one-third of those with both antennas energized. The relatively high levels along the de-energized EW antenna are caused by cross-coupling from the energized NS antenna. Although EW antenna shutdown continued through 27 March 1992, EM field measurements could not be made during this period because of weather restrictions. Also, comprehensive data collected during 1991 under this condition sufficiently describe field reduction levels.

Measurements were not made in 1991 or 1992 at the control site with the EW antenna shutdown. However, 76 Hz EM field contributions from the NS and EW antennas are known to be of similar magnitude at this site, as evidenced by the 1987 and 1988 measurements during individual antenna operation. EM exposures at the control site, therefore, were likely reduced to about one-half of their normal levels when only the NS antenna was operating. While the actual amount of exposure reduction at the control site is unknown, any reduction in the EM fields here is desirable from the standpoint of maintaining proper EM exposure ratios.

Regular measurements continued to be made at the fixed electric field probes, which were established at numerous locations at the treatment sites in 1990. Fixed probe measurement locations are designated by an "F" in the measurement point symbols in Figures D-3 and D-4. All fixed probe locations established in 1990 are still in use. The fixed probe measurement set was expanded in 1991 to include the electrode pairs monitored by the data loggers. Data for all fixed probe measurements made in 1990 through 1993 are presented in Tables D-10 through D-13. Measurements made during shutdown of the EW antenna are labeled "NS Only" in the column headings. Summary statistics computed for each probe for each year are also included in these tables. Statistics for 1991 and 1992 do not include data for NS antenna operation only.

Special efforts were made in 1990 to provide a detailed characterization of the earth electric field gradients at the treatment study sites. Resulting earth electric field contour maps for the two treatment sites and the survey data used in their generation are presented in Figures D-7 through D-10 for convenient reference. Discussion of these data may be found in a previous report.* In 1991-1993, efforts were made to characterize both the spatial and temporal variability of these fields. EM field profiles comparing annual, fixed probe, and data logger data for these sites are presented in Section 4.4.1.2 of this report.

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* Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1990. IIT Research Institute, Technical Report E06628-3, 87 pp. plus appendixes, 1991.

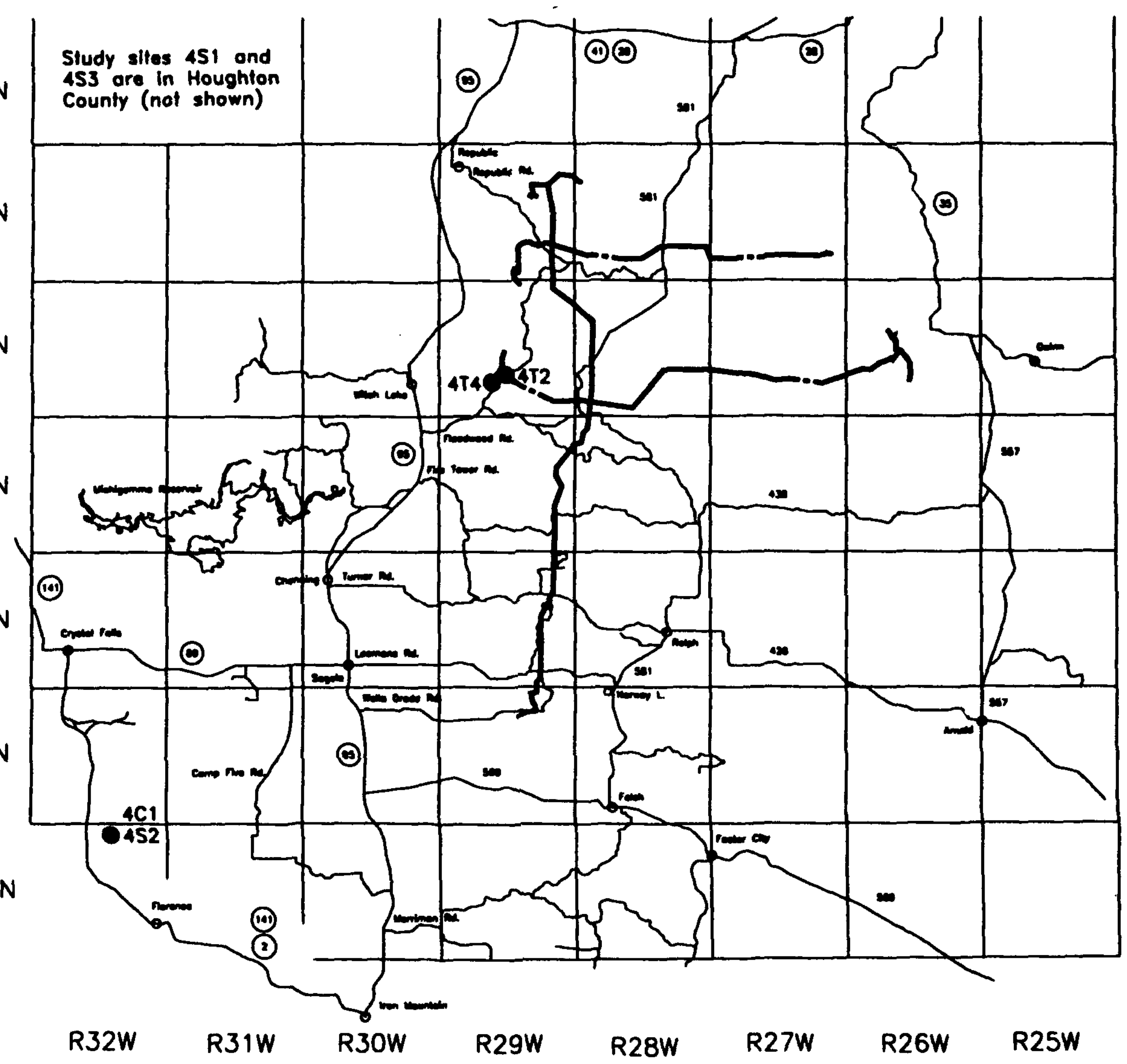


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

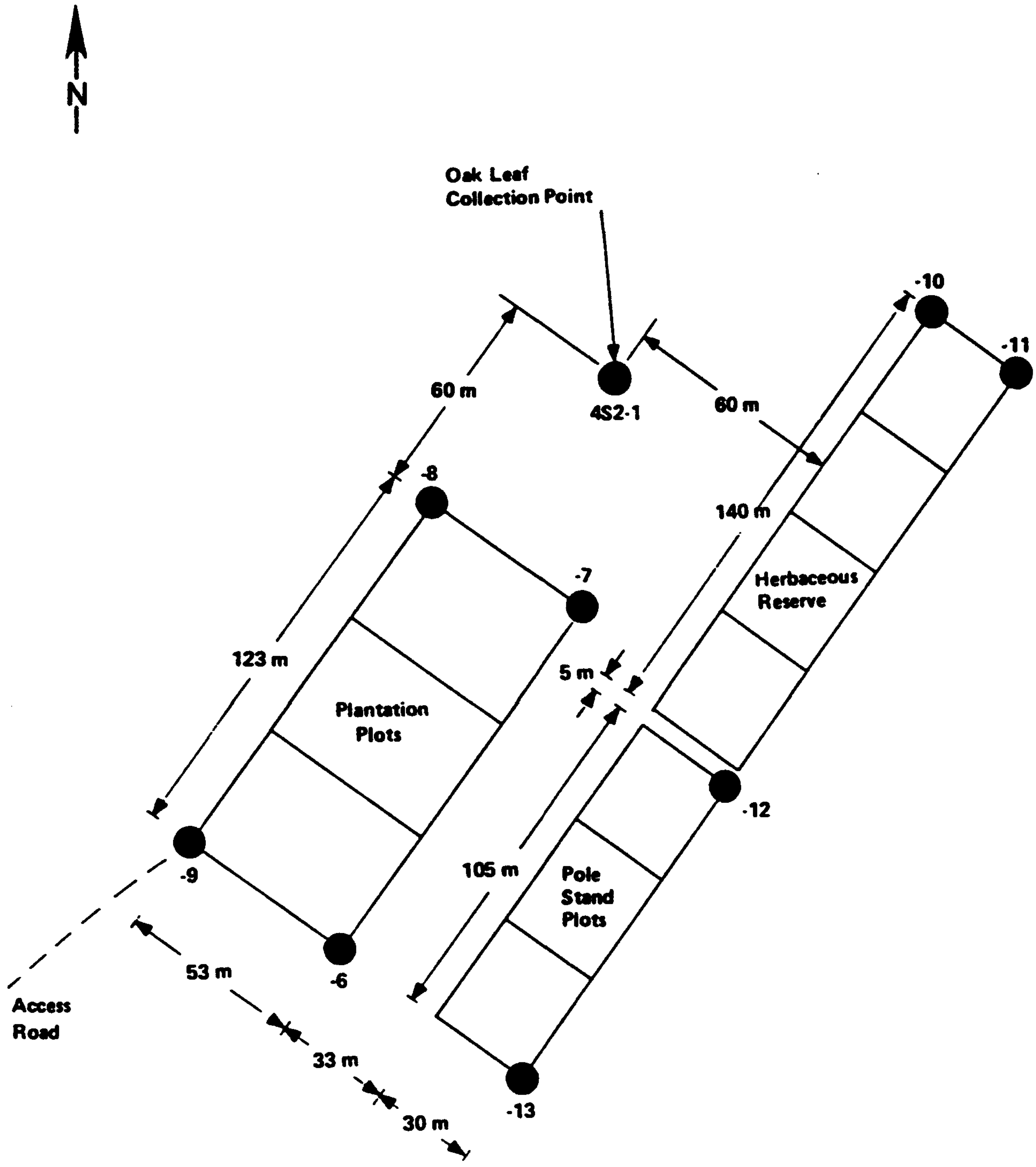


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

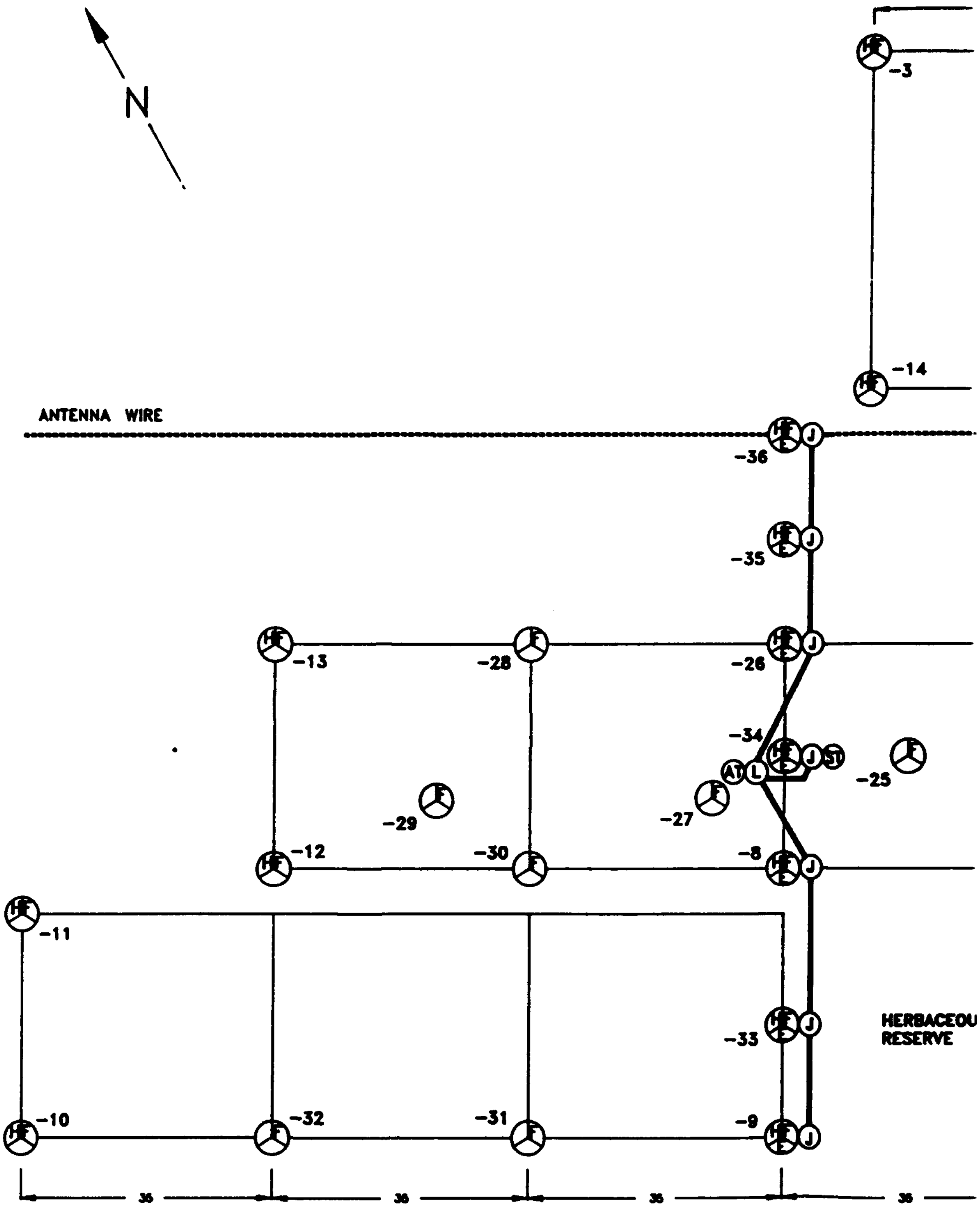
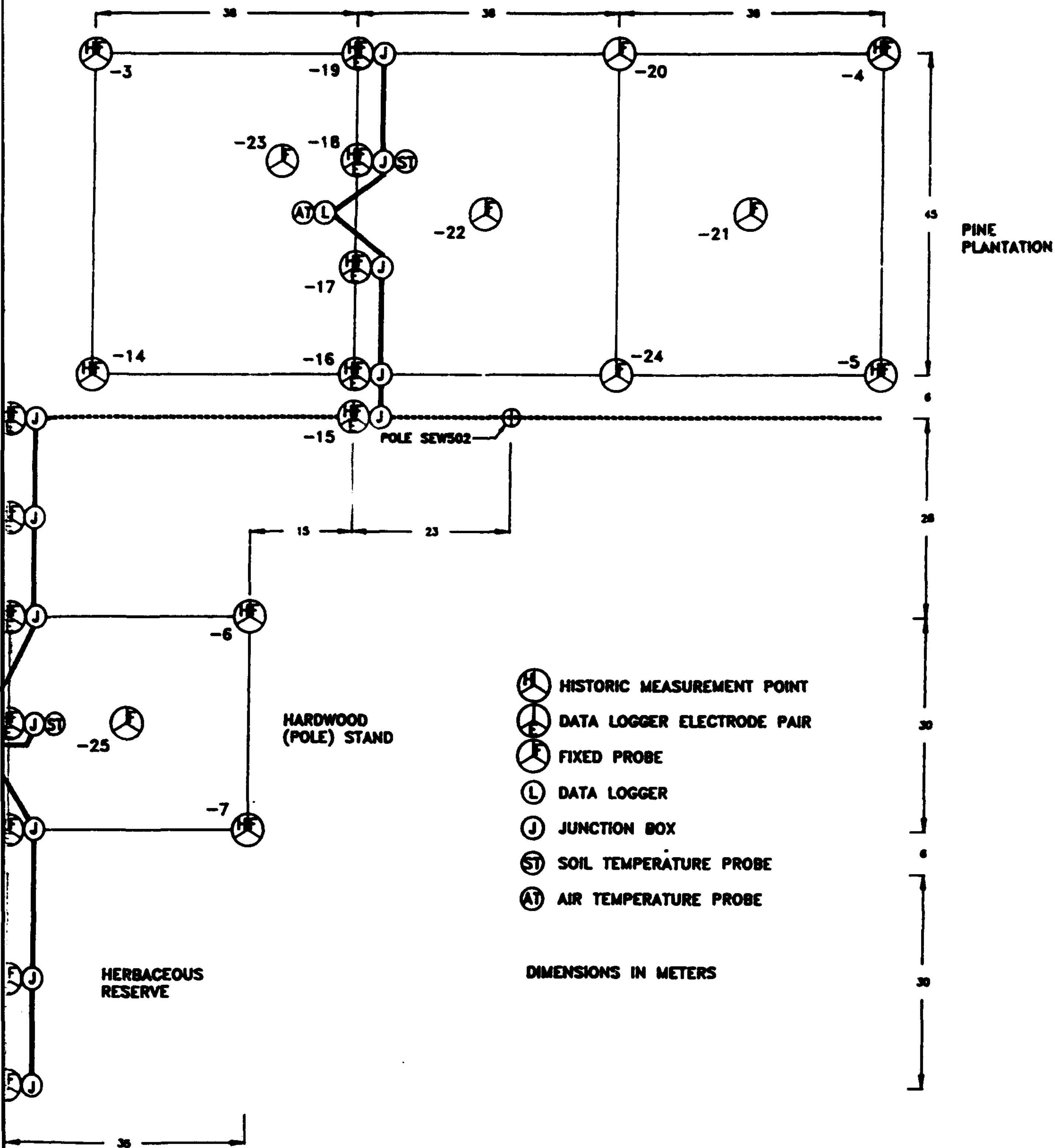


FIGURE D-3. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTEL

1



POINTS AT MARTELL'S LAKE (OVERHEAD): ML; 4T2-3 THROUGH 19.

2

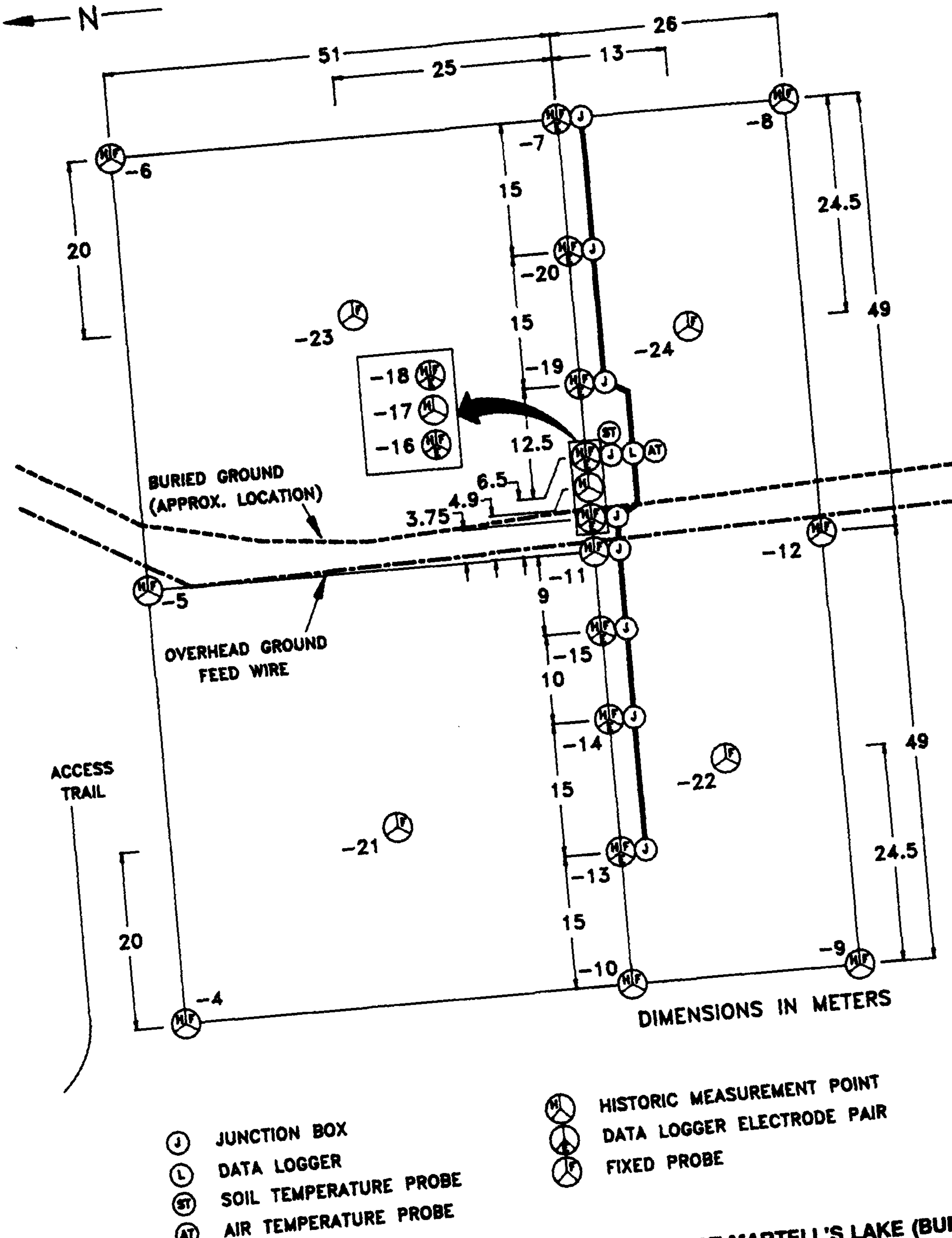


FIGURE D-4. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTELL'S LAKE (BURIED): EP; 4T4-4 THROUGH 24.

IITRI D06209-1

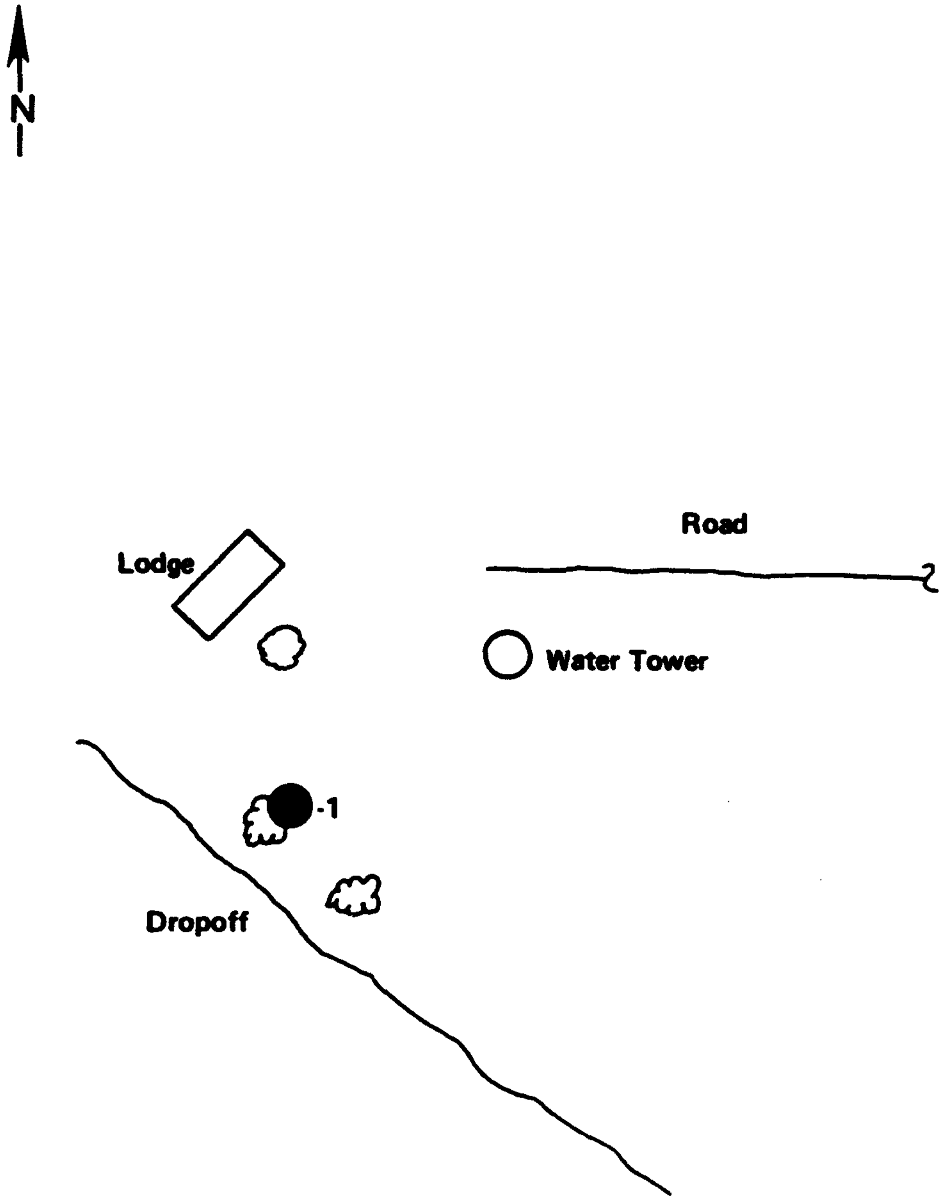


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF COLLECTION SITE; 4S1-1.

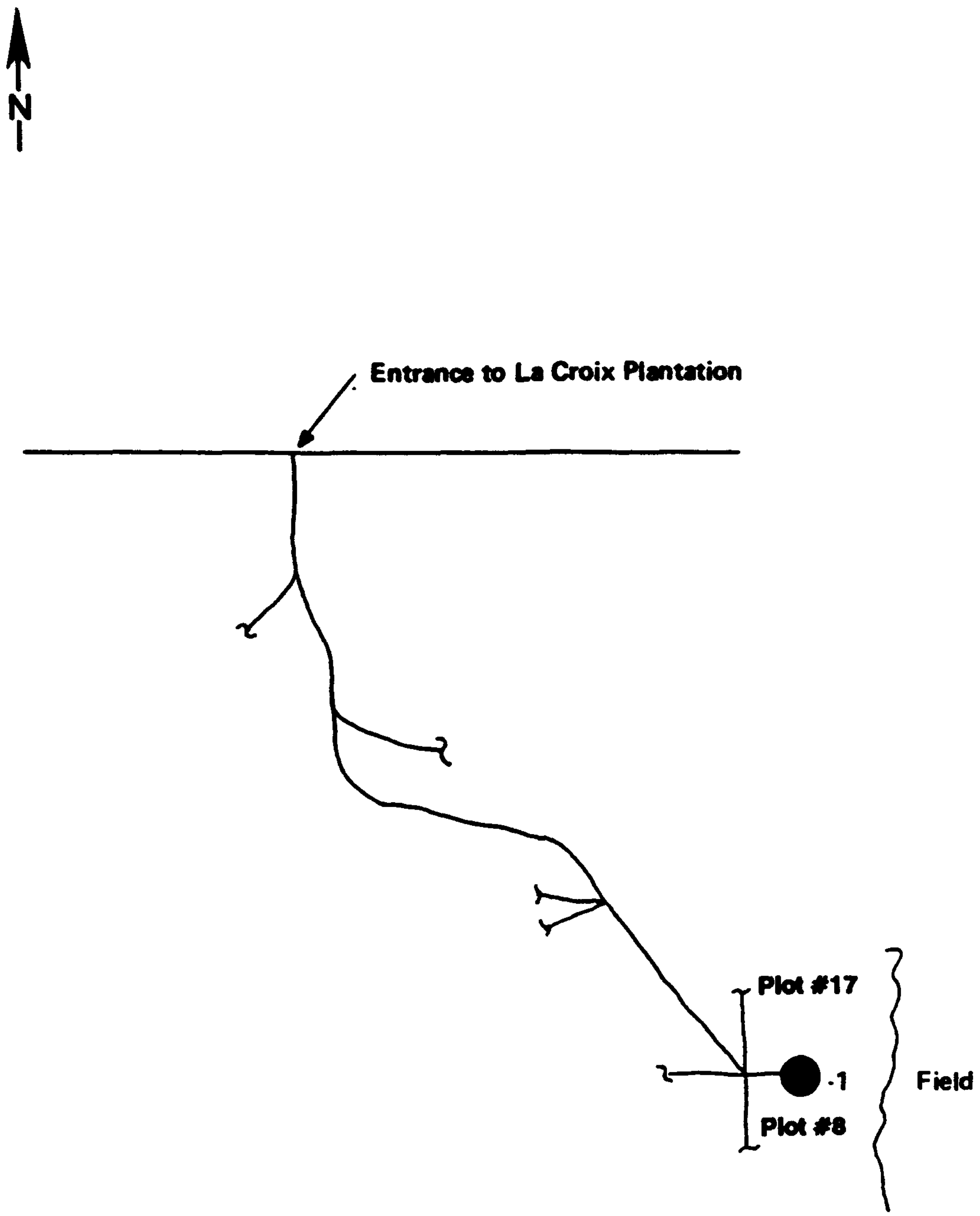


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE COLLECTION SITE; 4S3-1.

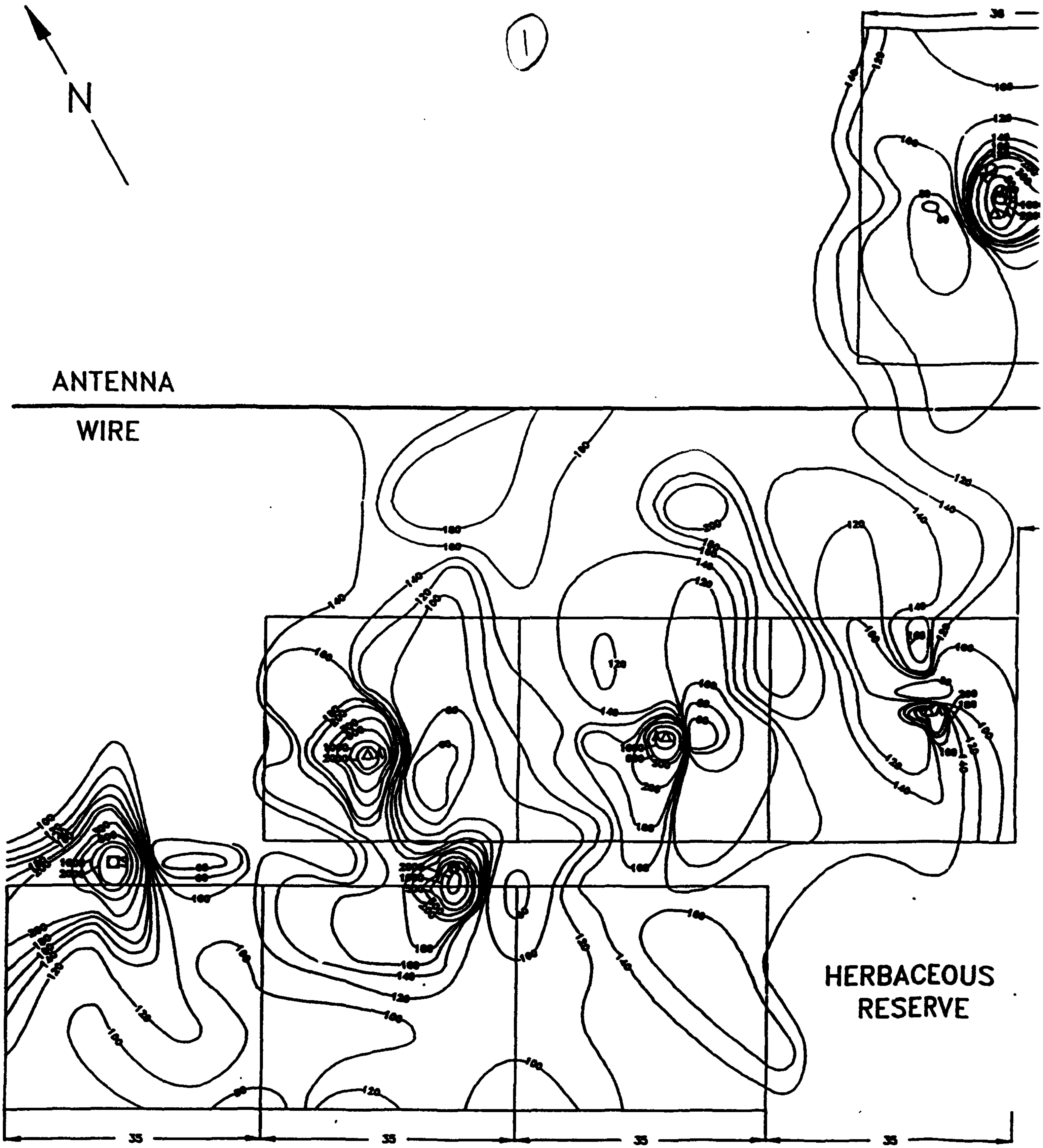
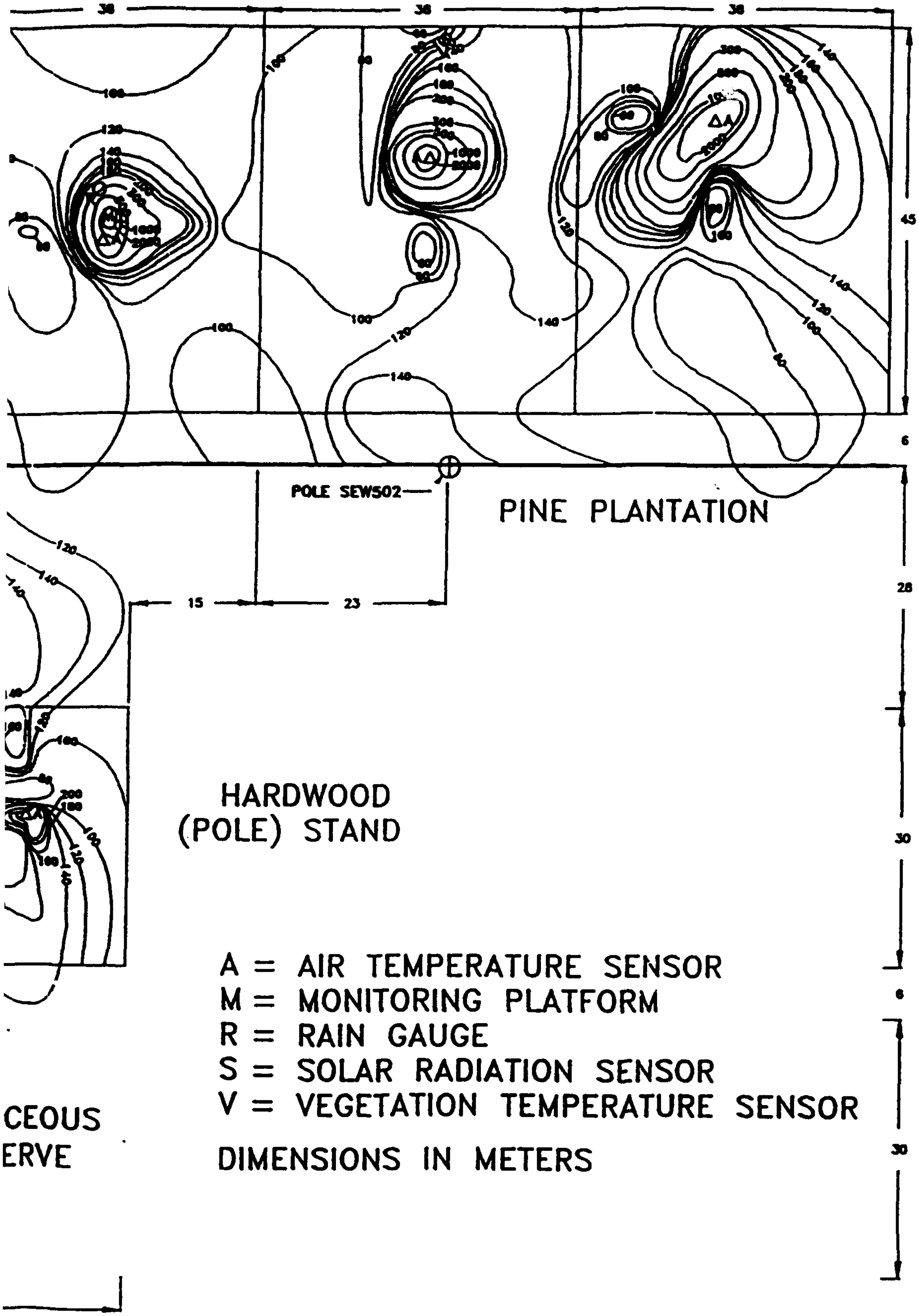
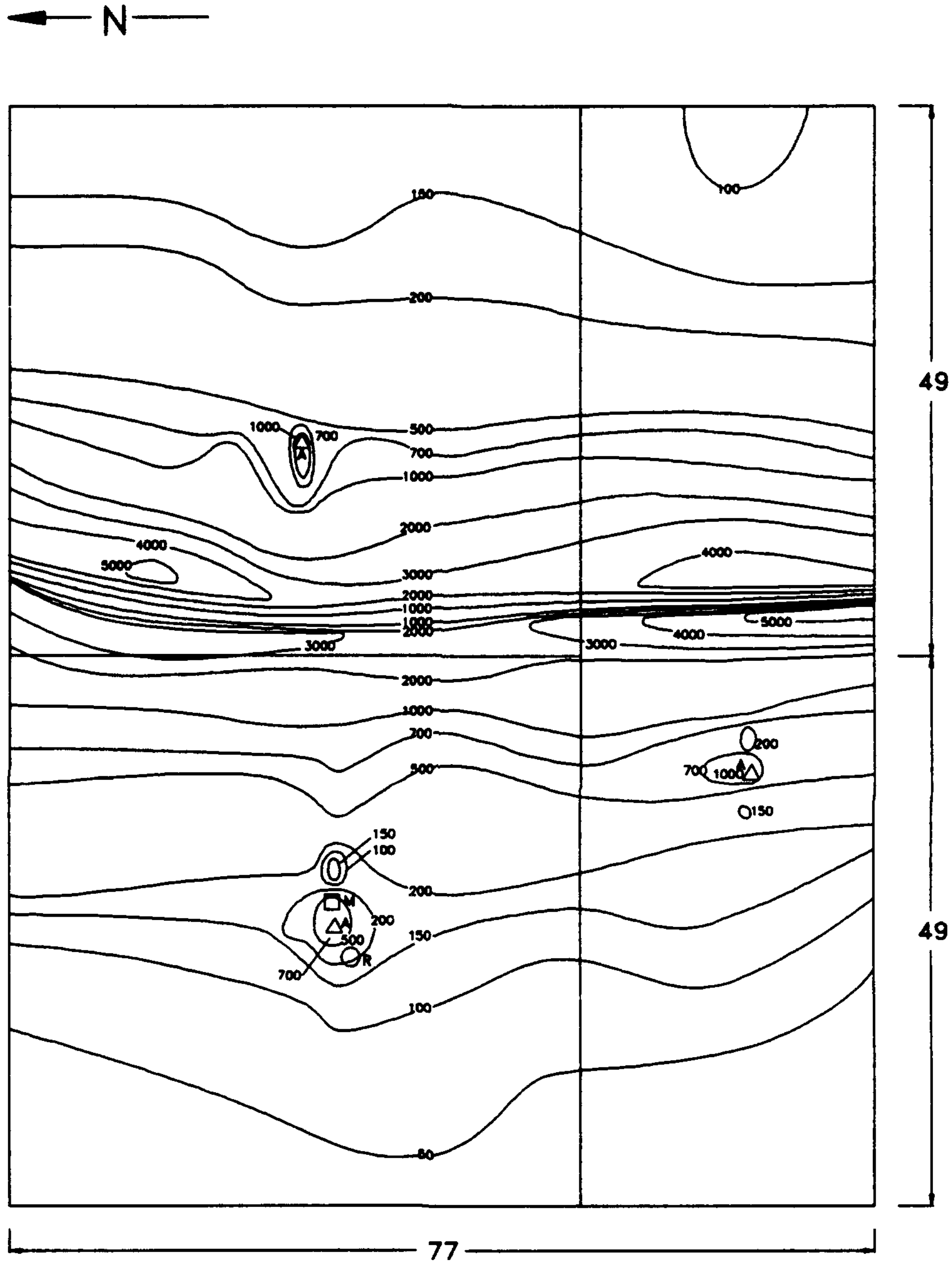


FIGURE D-7. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTE



(mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.



A=AIR TEMPERATURE SENSOR
R=RAIN GAUGE
M=MONITORING PLATFORM

DIMENSIONS IN METERS

FIGURE D-8. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (BURIED): EP; JUNE 1990.

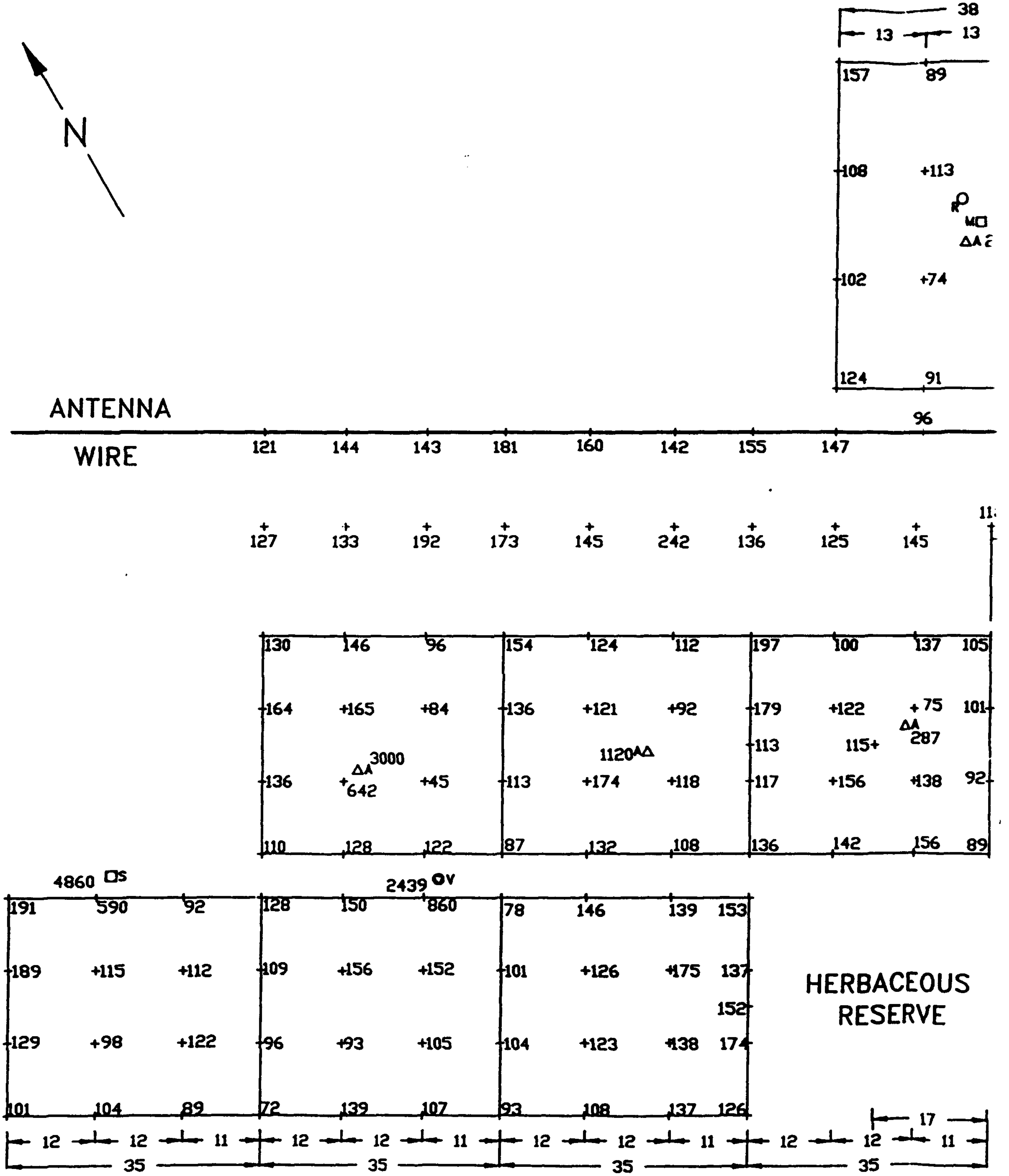
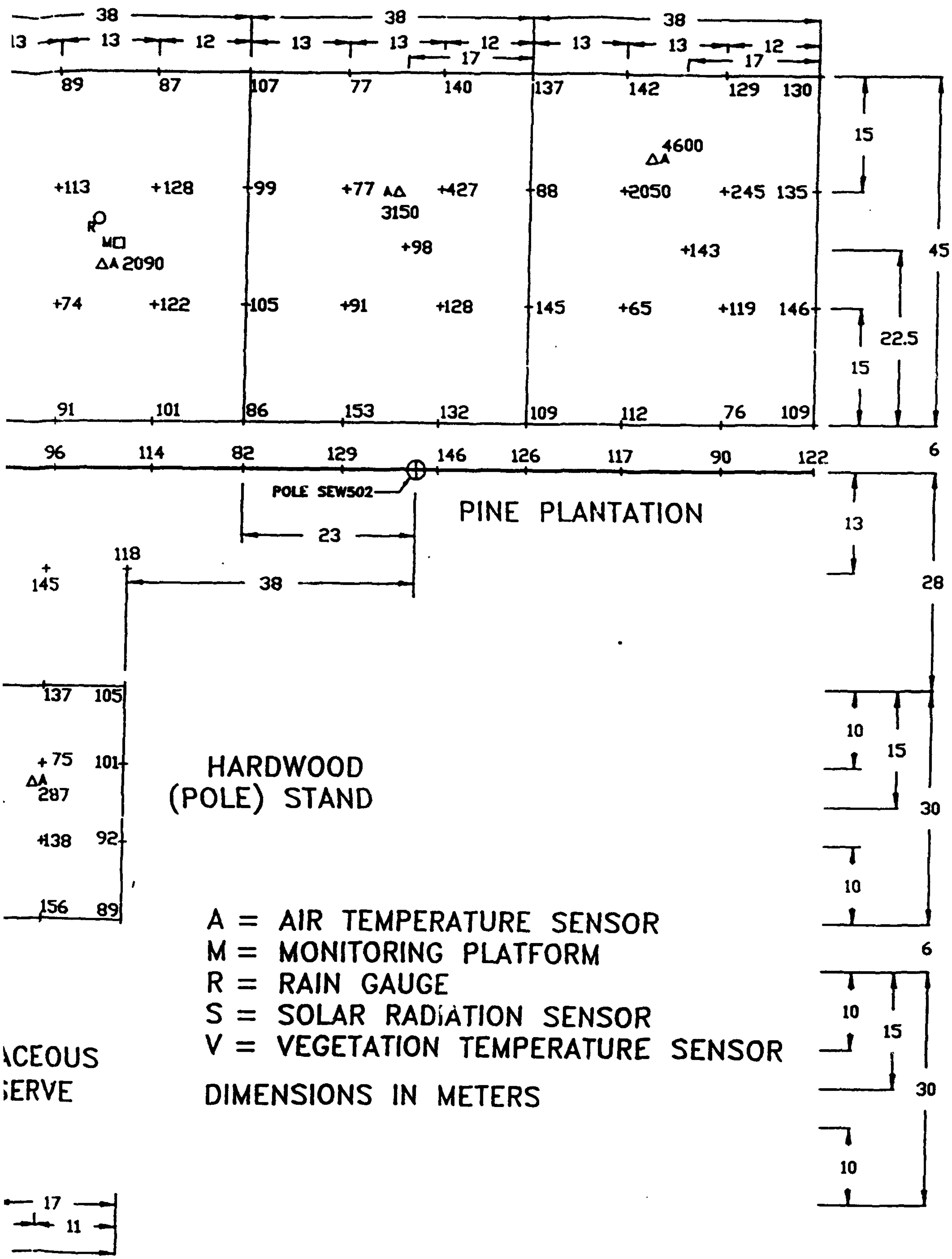
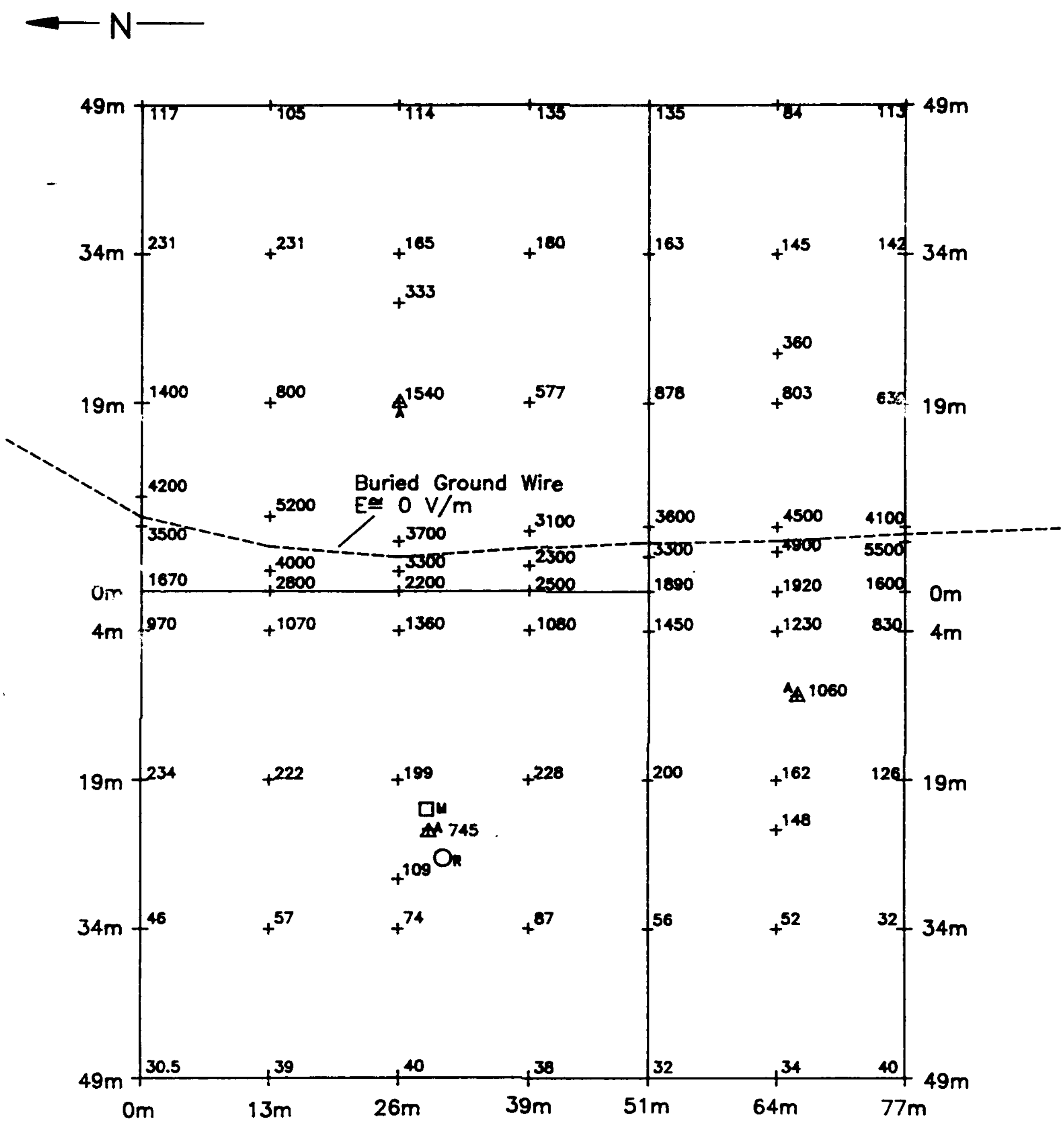


FIGURE D-9. EARTH ELECTRIC FIELD SURVEY (mV/m), MARTEL



mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.



A=AIR TEMPERATURE SENSOR
R=RAIN GAUGE
M=MONITORING PLATFORM

DIMENSIONS IN METERS

FIGURE D-10. EARTH ELECTRIC FIELD SURVEY (mV/m), MARTELL'S LAKE (BURIED): EP; JUNE 1990.

TABLE D-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4C1-6	-	0.003	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-7	-	0.006	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-8	-	0.004	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-9	-	0.002	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-10	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-11	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-12	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4C1-13	-	-	<	<	<	<	<[d]	<[b]	<[d]	/	<[d]
4T2-3	-	0.001	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-4	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-5	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-6	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-7	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-8	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-9	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T2-10	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T2-11	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T2-12	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-13	-	-	<	<	<	/	#[d]	#[d]	/	<[b]	<[b]
4T2-14	-	-	<	<	<	/	#[d]	#[d]	/	/	<[b]
4T2-15	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-16	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-17	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-18	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-19	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T2-26	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-33	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-34	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-35	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]
4T2-36	-	-	-	-	-	-	-	#[d]	/	<[b]	<[b]

TABLE D-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4T4-4	-	0.003	<	<	<0.001	/	#[d]	#[d]	/	<[b]	<[b]
4T4-5	-	-	<	<	0.006	/	#[d]	#[d]	/	<[b]	<[b]
4T4-6	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-7	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-8	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-9	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-10	-	-	<	<	<	<	#[d]	#[d]	/	<[b]	<[b]
4T4-11	-	-	<	<	0.010	/	#[d]	#[d]	/	<[b]	<[b]
4T4-12	-	-	-	<	0.005	/	#[d]	#[d]	/	<[b]	<[b]
4T4-13	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-14	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-15	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-16	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-17	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-18	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-19	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4T4-20	-	-	-	-	-	-	#[d]	#[d]	/	<[b]	<[b]
4S1-1	-	-	-	-	0.013	0.033	0.011[b]	0.017[b]	0.018[b]	0.007[b]	/
4S2-1	-	-	-	-	<	<	<[d]	<[b]	<[d]	<[d]	/
4S3-1	-	-	-	-	<0.001	<0.001	<0.001[b]	<0.001[b]	/	<[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement not taken.
\# = measurement precluded by antenna operation.
< = measurement estimated <0.001 V/m based on earth electric field.

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4C1-6	-	0.022	0.016	0.005	0.043	0.023	0.016[d]	0.024[b]	0.012[d]	1.51[d]	0.022[d]
4C1-7	-	0.143	0.123	0.077	0.178	0.118	0.030[d]	0.039[b]	0.043[d]	6.7[d]	0.064[d]
4C1-8	-	0.104	0.117	0.077	0.131	0.078	0.018[d]	0.063[b]	0.020[d]	6.1[d]	0.049[d]
4C1-9	-	0.011	0.019	0.024	0.034	0.032	0.023[d]	0.023[b]	0.018[d]	1.64[d]	0.022[d]
4C1-10	-	-	0.090	0.068	0.118	0.106	0.054[d]	0.041[b]	0.030[d]	7.5[d]	0.059[d]
4C1-11	-	-	0.160	0.107	0.132	0.146	0.066[d]	0.068[b]	0.048[d]	9.1[d]	0.077[d]
4C1-12	-	-	0.104	0.101	0.075	0.093	0.042[d]	0.042[b]	0.033[d]	4.2[d]	0.055[d]
4C1-13	-	-	0.040	0.030	0.046	0.065	0.025[d]	0.039[b]	0.014[d]	2.9[d]	0.026[d]
4T2-3	-	0.51	0.39	0.194	0.27	0.28	#[d]	#[d]	0.52[b]	0.20[b]	0.25[b]
4T2-4	-	-	0.27	0.24	0.30	0.25	#[d]	#[d]	0.59[b]	0.24[b]	0.199[b]
4T2-5	-	-	0.43	0.32	0.20	0.20	#[d]	#[d]	0.77[b]	0.25[b]	0.24[b]
4T2-6	-	-	0.66	0.46	0.192	0.22	#[d]	#[d]	0.84[b]	0.30[b]	0.31[b]
4T2-7	-	-	0.42	0.52	0.197	0.28	#[d]	#[d]	0.71[b]	0.22[b]	0.32[b]
4T2-8	-	-	0.47	0.190	0.22	/	#[d]	#[d]	0.79[b]	0.24[b]	0.28[b]
4T2-9	-	-	0.49	0.31	0.183	0.25	#[d]	#[d]	0.62[b]	0.23[b]	0.26[b]
4T2-10	-	-	0.44	0.32	0.155	0.166	#[d]	#[d]	0.71[b]	0.25[b]	0.33[b]
4T2-11	-	-	0.51	0.40	0.31	0.43	#[d]	#[d]	0.72[b]	0.34[b]	0.33[b]
4T2-12	-	-	0.47	0.38	0.24	/	#[d]	#[d]	0.73[b]	0.28[b]	0.35[b]
4T2-13	-	-	0.76	0.31	0.31	0.25	#[d]	#[d]	0.87[b]	0.27[b]	0.28[b]
4T2-14	-	-	0.61	0.29	0.35	0.21	#[d]	#[d]	0.78[b]	0.28[b]	0.29[b]
4T2-15	-	-	-	-	-	-	#[d]	#[d]	1.01[b]	0.35[b]	0.59[b]
4T2-16	-	-	-	-	-	-	#[d]	#[d]	0.66[b]	0.23[b]	0.30[b]
4T2-17	-	-	-	-	-	-	#[d]	#[d]	0.93[b]	0.173[b]	0.31[b]
4T2-18	-	-	-	-	-	-	#[d]	#[d]	0.73[b]	0.158[b]	0.29[b]
4T2-19	-	-	-	-	-	-	#[d]	#[d]	0.64[b]	0.25[b]	0.36[b]
4T2-26	-	-	-	-	-	-	-	#[d]	0.61[b]	0.26[b]	0.30[b]
4T2-33	-	-	-	-	-	-	-	#[d]	0.75[b]	0.27[b]	0.34[b]
4T2-34	-	-	-	-	-	-	-	#[d]	0.81[b]	0.28[b]	0.35[b]
4T2-35	-	-	-	-	-	-	-	#[d]	0.73[b]	0.26[b]	0.35[b]
4T2-36	-	-	-	-	-	-	-	#[d]	0.60[b]	0.30[b]	0.32[b]

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4T4-4	-	0.72	0.42	0.185	0.56	0.079	#[d]	#[d]	0.40[b]	0.30[b]	0.32[b]
4T4-5	-	-	0.58	0.58	4.3	1.12	#[d]	#[d]	3.1[b]	3.2[b]	2.6[b]
4T4-6	-	-	0.22	0.16	0.61	0.188	#[d]	#[d]	0.35[b]	0.45[b]	0.37[b]
4T4-7	-	-	0.44	0.29	0.64	0.22	#[d]	#[d]	0.28[b]	0.32[b]	0.48[b]
4T4-8	-	-	0.42	0.193	0.40	0.23	#[d]	#[d]	0.27[b]	0.28[b]	0.30[b]
4T4-9	-	-	0.50	0.21	0.27	0.073	#[d]	#[d]	0.31[b]	0.36[b]	0.24[b]
4T4-10	-	-	0.42	0.22	0.29	0.063	#[d]	#[d]	0.23[b]	0.28[b]	0.30[b]
4T4-11	-	-	0.40	0.60	2.7	1.27	#[d]	#[d]	4.1[b]	3.8[b]	3.3[b]
4T4-12	-	-	-	0.75	3.4	1.35	#[d]	#[d]	0.34[b]	2.2[b]	1.78[b]
4T4-13	-	-	-	-	-	-	#[d]	#[d]	0.22[b]	0.26[b]	0.30[b]
4T4-14	-	-	-	-	-	-	#[d]	#[d]	0.53[b]	0.78[b]	0.38[b]
4T4-15	-	-	-	-	-	-	#[d]	#[d]	1.29[b]	1.86[b]	0.99[b]
4T4-16	-	-	-	-	-	-	#[d]	#[d]	4.4[b]	4.8[b]	4.4[b]
4T4-17	-	-	-	-	-	-	#[d]	#[d]	/	2.1[b]	/
4T4-18	-	-	-	-	-	-	#[d]	#[d]	4.6[b]	4.7[b]	4.7[b]
4T4-19	-	-	-	-	-	-	#[d]	#[d]	1.17[b]	1.02[b]	0.75[b]
4T4-20	-	-	-	-	-	-	#[d]	#[d]	0.27[b]	0.33[b]	0.33[b]
4S1-1	-	-	-	-	8.5	12.2	11.6[b]	15.7[b]	9.1[b]	3.3[b]	/
4S2-1	-	-	-	-	0.155	0.109	0.032[b]	0.068[b]	0.060[b]	7.2[b]	/
4S3-1	-	-	-	-	0.65	1.73	0.73[b]	0.87[b]	0.69[b]	0.43[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE D-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4C1-6	-	0.003	0.003	0.003	0.002	0.003	0.002[d]	0.002[b]	0.001[d]	0.28[d]	0.004d
4C1-7	-	0.003	0.002	0.001	0.003	0.002	0.001[d]	0.002[b]	0.001[d]	0.25[d]	0.001d
4C1-8	-	0.003	0.003	0.002	0.003	0.002	0.001[d]	0.002[b]	0.002[d]	0.24[d]	0.002d
4C1-9	-	0.003	0.003	0.002	0.001	0.002	0.002[d]	0.002[b]	0.001[d]	0.29[d]	0.004d
4C1-10	-	-	0.002	0.002	0.002	0.002	0.002[d]	0.002[b]	0.001[d]	0.22[d]	0.002d
4C1-11	-	-	0.002	0.002	0.002	0.002	0.001[d]	0.002[b]	0.001[d]	0.23[d]	0.002d
4C1-12	-	-	0.002	0.003	0.001	0.002	0.001[d]	0.002[b]	0.001[d]	0.26[d]	0.002d
4C1-13	-	-	0.002	0.003	0.001	0.003	0.002[d]	0.002[b]	0.001[d]	0.30[d]	0.003d
4T2-3	-	0.002	0.001	0.001	0.003	0.005	#[d]	#[d]	0.004[b]	0.002[b]	0.002b
4T2-4	-	-	0.001	0.001	0.003	0.008	#[d]	#[d]	0.005[b]	0.002[b]	0.003b
4T2-5	-	-	0.001	0.007	0.017	0.030	#[d]	#[d]	0.029[b]	0.004[b]	0.011b
4T2-6	-	-	0.001	0.006	0.006	0.014	#[d]	#[d]	0.017[b]	0.001[b]	0.005b
4T2-7	-	-	0.001	0.004	0.004	0.007	#[d]	#[d]	0.010[b]	0.001[b]	0.003b
4T2-8	-	-	0.001	0.002	0.004	/	#[d]	#[d]	0.010[b]	0.001[b]	0.002b
4T2-9	-	-	0.001	0.003	0.003	0.005	#[d]	#[d]	0.007[b]	0.001[b]	0.002b
4T2-10	-	-	0.001	0.003	0.003	0.005	#[d]	#[d]	0.007[b]	0.001[b]	0.002b
4T2-11	-	-	0.001	0.004	0.005	0.007	#[d]	#[d]	0.009[b]	0.002[b]	0.003b
4T2-12	-	-	0.002	0.004	0.005	/	#[d]	#[d]	0.010[b]	0.002[b]	0.003b
4T2-13	-	-	0.001	0.005	0.008	0.013	#[d]	#[d]	0.016[b]	0.002[b]	0.004b
4T2-14	-	-	0.002	0.011	0.018	0.029	#[d]	#[d]	0.035[b]	0.004[b]	0.011b
4T2-15	-	-	-	-	-	-	#[d]	#[d]	0.043[b]	0.005[b]	0.013b
4T2-16	-	-	-	-	-	-	#[d]	#[d]	0.033[b]	0.004[b]	0.011b
4T2-17	-	-	-	-	-	-	#[d]	#[d]	0.016[b]	0.003[b]	0.005b
4T2-18	-	-	-	-	-	-	#[d]	#[d]	0.009[b]	0.002[b]	0.003b
4T2-19	-	-	-	-	-	-	#[d]	#[d]	0.004[b]	0.002[b]	0.003b
4T2-26	-	-	-	-	-	-	-	#[d]	0.015[b]	0.001[b]	0.004b
4T2-33	-	-	-	-	-	-	-	#[d]	0.006[b]	0.001[b]	0.002b
4T2-34	-	-	-	-	-	-	-	#[d]	0.012[b]	0.001[b]	0.003b
4T2-35	-	-	-	-	-	-	-	#[d]	0.030[b]	0.001[b]	0.009b
4T2-36	-	-	-	-	-	-	-	#[d]	0.042[b]	0.003[b]	0.014b

TABLE D-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991	1992	1993
4T4-4	-	0.004	0.002	0.001	0.003	0.003	#[d]	#[d]	0.003[b]	0.002[b]	0.002b
4T4-5	-	-	0.002	0.006	0.010	0.017	#[d]	#[d]	0.006[b]	0.006[b]	0.006b
4T4-6	-	-	0.002	0.001	0.004	0.007	#[d]	#[d]	0.002[b]	0.003[b]	0.003b
4T4-7	-	-	0.001	0.001	0.004	0.005	#[d]	#[d]	0.002[b]	0.003[b]	0.002b
4T4-8	-	-	0.002	0.001	0.004	0.005	#[d]	#[d]	0.002[b]	0.003[b]	0.002b
4T4-9	-	-	0.002	0.001	0.002	0.003	#[d]	#[d]	0.001[b]	0.002[b]	0.002b
4T4-10	-	-	0.001	0.001	0.002	0.002	#[d]	#[d]	0.001[b]	0.002[b]	0.002b
4T4-11	-	-	0.002	0.002	0.002	0.019	#[d]	#[d]	0.006[b]	0.010[b]	0.011b
4T4-12	-	-	-	0.002	0.010	0.016	#[d]	#[d]	0.006[b]	0.006[b]	0.007b
4T4-13	-	-	-	-	-	-	#[d]	#[d]	0.001[b]	0.002[b]	0.003b
4T4-14	-	-	-	-	-	-	#[d]	#[d]	0.001[b]	0.003[b]	0.004b
4T4-15	-	-	-	-	-	-	#[d]	#[d]	0.003[b]	0.005[b]	0.007b
4T4-16	-	-	-	-	-	-	#[d]	#[d]	0.012[b]	0.015[b]	0.010b
4T4-17	-	-	-	-	-	-	#[d]	#[d]	0.013[b]	0.016[b]	0.009b
4T4-18	-	-	-	-	-	-	#[d]	#[d]	0.009[b]	0.011[b]	0.006b
4T4-19	-	-	-	-	-	-	#[d]	#[d]	0.003[b]	0.005[b]	0.004b
4T4-20	-	-	-	-	-	-	#[d]	#[d]	0.002[b]	0.004[b]	0.003b
4S1-1	-	-	-	-	0.035	0.043	0.052[b]	0.052[b]	0.032[b]	0.012[b]	/
4S2-1	-	-	-	-	0.003	0.002	0.002[d]	0.001[b]	0.001[d]	0.23[d]	/
4S3-1	-	-	-	-	0.036	0.095	0.028[b]	0.030[b]	0.035[b]	0.020[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE D-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No.,	1986				1987		1988		1989	1990	1991		1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4C1-6	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-7	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-8	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-9	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-10	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-11	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-12	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4C1-13	<	<	<	*	<	<	<	<	<	<	/	/	<	<
4T2-3	<	<	0.004	0.007	0.002	0.014	/	/	0.142	0.110	0.047	0.122	/	0.100
4T2-4	<	<	0.005	0.008	0.001	0.014	/	/	0.149	0.122	0.041	0.095	/	0.092
4T2-5	0.018	<	0.092	0.153	0.003	0.23	/	/	1.31	1.16	0.30	1.08	/	1.07
4T2-6	<	<	0.005	0.008	0.003	0.013	/	/	0.138	0.148	0.051	0.123	/	0.155
4T2-7	<	<	0.007	0.012	0.001	0.018	/	/	0.173	0.177	0.044	0.150	/	0.20
4T2-8	<	<	0.004	0.007	0.002	0.012	/	/	0.124	0.112	0.045	0.103	/	0.102
4T2-9	<	<	0.005	0.008	0.002	0.010	/	/	0.116	0.119	0.031	0.110	/	0.101
4T2-10	<	<	0.004	0.007	0.002	0.011	/	/	0.113	0.076	0.034	0.112	/	0.104
4T2-11	<	<	0.003	0.005	0.002	0.012	/	/	0.22	0.180	0.042	0.132	/	0.104
4T2-12	<	<	0.002	0.003	0.002	0.014	/	/	0.095	0.096	0.041	0.086	/	0.087
4T2-13	<	<	0.005	0.008	0.002	0.012	/	/	0.125	0.130	0.036	0.125	/	0.117
4T2-14	0.030	<	0.155	0.26	0.003	0.186	/	/	1.66	1.94	0.23	1.68	/	1.14
4T2-15	-	-	-	-	-	-	-	-	2.3	1.67	0.32	0.58	/	0.70
4T2-16	-	-	-	-	-	-	-	-	1.92	1.84	0.46	1.17	/	0.35
4T2-17	-	-	-	-	-	-	-	-	0.69	0.59	0.075	0.27	/	0.149
4T2-18	-	-	-	-	-	-	-	-	0.28	0.21	0.039	0.152	/	0.157
4T2-19	-	-	-	-	-	-	-	-	0.107	0.105	0.029	0.092	/	0.100
4T2-26	-	-	-	-	-	-	-	-	-	0.182	0.059	0.136	/	0.159
4T2-33	-	-	-	-	-	-	-	-	-	0.141	0.042	0.146	/	0.144
4T2-34	-	-	-	-	-	-	-	-	-	0.144	0.041	0.129	/	0.132
4T2-35	-	-	-	-	-	-	-	-	-	0.24	0.101	0.38	/	0.38
4T2-36	-	-	-	-	-	-	-	-	-	4.7	0.94	4.7	/	4.1

TABLE D-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
4T4-4	<	<	0.006	0.010	0.002	0.005	/	/	0.067	0.058	0.015	0.071	/	0.043
4T4-5	0.033	0.008	0.20	0.33	0.019	0.27	/	/	4.8	3.8	1.37	4.4	/	14.1
4T4-6	0.005	<	0.023	0.038	0.002	0.021	/	/	0.175	0.117	0.040	0.186	/	0.144
4T4-7	<	<	0.006	0.010	0.002	0.015	/	/	0.133	0.129	0.026	0.33	/	0.124
4T4-8	<	<	0.008	0.013	0.002	0.016	/	/	0.145	0.145	0.032	0.130	/	0.118
4T4-9	<	<	0.009	0.015	0.001	0.008	/	/	0.095	0.072	0.017	0.130	/	0.080
4T4-10	<	<	0.007	0.012	0.001	0.001	/	/	0.112	0.085	0.026	0.107	/	0.065
4T4-11	<	0.005	0.38	0.63	0.025	0.43	/	/	5.0	4.6	1.37	4.8	/	3.2
4T4-12	0.055	0.005	0.43	0.72	0.017	0.30	/	/	4.5	3.8	1.26	4.6	/	5.1
4T4-13	-	-	-	-	-	-	-	-	0.26	0.21	0.042	0.28	/	0.121
4T4-14	-	-	-	-	-	-	-	-	0.88	0.84	0.194	0.90	/	0.51
4T4-15	-	-	-	-	-	-	-	-	2.7	2.6	0.51	2.8	/	1.77
4T4-16	-	-	-	-	-	-	-	-	5.9	5.4	1.68	6.7	/	3.7
4T4-17	-	-	-	-	-	-	-	-	4.5	4.3	1.28	5.7	/	3.5
4T4-18	-	-	-	-	-	-	-	-	4.8	3.8	1.24	4.9	/	4.2
4T4-19	-	-	-	-	-	-	-	-	1.16	0.98	0.25	1.15	/	0.54
4T4-20	-	-	-	-	-	-	-	-	0.32	0.183	0.067	0.47	/	0.166
4S1-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	<	<	<	<	<	<	<	<	<	/
4S3-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
< = measurement estimated <0.001 V/m based on earth electric field.
* = data cannot be extrapolated.

TABLE D-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No.,	1986				1987		1988		1989	1990	1991		1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4C1-6	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.005	0.030	0.028	/	0.026	0.029	0.030
4C1-7	<0.001	<0.001	<0.001	*	0.005	0.006	0.024	0.023	0.091	0.065	/	0.079	0.096	0.096
4C1-8	<0.001	<0.001	<0.001	*	0.004	0.004	0.017	0.016	0.076	0.067	/	0.069	0.065	0.063
4C1-9	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.006	0.030	0.022	/	0.028	0.021	0.029
4C1-10	<0.001	<0.001	<0.001	*	0.005	0.004	0.026	0.023	0.087	0.079	/	0.089	0.095	0.094
4C1-11	<0.001	<0.001	<0.001	*	0.006	0.005	0.028	0.028	0.113	0.103	/	0.101	0.106	0.104
4C1-12	<0.001	<0.001	<0.001	*	0.004	0.003	0.016	0.016	0.068	0.072	/	0.053	0.063	0.062
4C1-13	<0.001	<0.001	<0.001	*	0.002	0.002	0.012	0.011	0.051	0.044	/	0.037	0.047	0.045
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2	7.7	76	131	140	22	126	142	127
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7	6.2	68	135	129	44	134	151	113
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7	8.2	62	86	105	41	123	142	130
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4	10.4	56	105	101	39	114	112	98
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7	8.8	71	90	89	28	94	89	71
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8	/	/	141	135	40	139	133	107
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7	7.1	63	119	125	40	121	133	114
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5	8.1	50	96	91	35	98	101	87
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7	9.6	122	182	170	38	155	178	88
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5	/	/	99	114	45	119	113	117
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9	8.2	71	138	144	36	142	145	151
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3	6.6	56	124	121	42	138	133	122
4T2-15	-	-	-	-	-	-	-	-	73	82	32	82	87	72
4T2-16	-	-	-	-	-	-	-	-	88	86	33	92	103	71
4T2-17	-	-	-	-	-	-	-	-	104	105	29	107	106	91
4T2-18	-	-	-	-	-	-	-	-	95	99	29	124	108	91
4T2-19	-	-	-	-	-	-	-	-	107	107	31	103	111	85
4T2-26	-	-	-	-	-	-	-	-	-	210	57	189	220	163
4T2-33	-	-	-	-	-	-	-	-	-	113	41	130	126	128
4T2-34	-	-	-	-	-	-	-	-	-	152	36	127	140	100
4T2-35	-	-	-	-	-	-	-	-	-	136	45	137	169	142
4T2-36	-	-	-	-	-	-	-	-	-	155	44	133	125	120

TABLE D-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Upland Flora and Soil Microflora Studies (page 2 of 2)

	1986				1987		1988		1989	1990	1991		1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4T4-4	0.33	0.181	1.46	2.4	1.63	3.7	7.2	16.5	42	31	10.2	25	28	45
4T4-5	13.8	2.0	81	135	14.0	194	68	910	2100	1670	510	1790	1740	1450
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9	10.3	62	140	117	29	141	152	132
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1	9.1	62	119	135	30	101	153	161
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7	6.8	65	106	113	31	111	113	108
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0	7.5	18.1	47	42	4.5	18	21	39
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9	5.1	16.0	39	43	8.1	30	29	38
4T4-11	0.59	1.82	89	148	10.7	178	50	850	1870	1890	630	2200	2100	1730
4T4-12	21	2.2	118	197	13.8	260	40	760	1950	1600	380	1380	1550	1070
4T4-13	-	-	-	-	-	-	-	-	64	56	15.2	59	66	52
4T4-14	-	-	-	-	-	-	-	-	220	200	59	320	290	210
4T4-15	-	-	-	-	-	-	-	-	760	760	220	820	880	720
4T4-16	-	-	-	-	-	-	-	-	3000	3800	690	3300	3000	2700
4T4-17	-	-	-	-	-	-	-	-	130	30	/	/	/	/
4T4-18	-	-	-	-	-	-	-	-	3200	3600	1000	4100	3400	2800
4T4-19	-	-	-	-	-	-	-	-	750	880	196	880	930	430
4T4-20	-	-	-	-	-	-	-	-	200	163	49	200	210	152
4S1-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	0.005	0.005	0.026	0.026	0.126	0.103	/	0.097	0.096	/
4S3-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE D-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
4C1-6	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003	0.003	0.003
4C1-7	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-8	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-9	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003	0.003	0.003
4C1-10	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-11	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-12	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002	0.002	0.002
4C1-13	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003	0.003	0.003
4T2-3	0.047	0.001	0.22	0.37	0.008	0.55	0.040	2.8	5.7	5.9	1.69	5.5	5.7	5.6
4T2-4	0.049	0.001	0.24	0.40	0.008	0.57	0.041	2.9	5.8	5.9	1.74	5.7	6.0	5.6
4T2-5	0.197	<0.001	1.00	1.67	0.011	2.4	0.061	12.4	24	27	6.9	23	26	26
4T2-6	0.058	0.001	0.44	0.73	0.006	1.16	0.020	5.0	10.3	11	3.0	10.3	10.3	10.3
4T2-7	0.046	0.001	0.22	0.37	0.006	0.59	0.024	2.6	5.4	5.8	1.63	5.4	5.4	5.5
4T2-8	0.045	0.001	0.22	0.37	0.006	0.59	/	/	5.6	5.8	1.67	5.3	5.5	5.4
4T2-9	0.029	0.001	0.138	0.23	0.007	0.38	0.027	1.72	3.4	3.6	0.96	3.3	3.5	3.3
4T2-10	0.033	0.001	0.149	0.25	0.006	0.39	0.027	1.78	3.5	3.7	1.14	3.4	3.6	3.5
4T2-11	0.043	0.001	0.21	0.35	0.006	0.56	0.025	2.6	5.0	5.3	1.54	4.9	5.1	5.0
4T2-12	0.047	0.001	0.23	0.38	0.006	0.61	/	/	5.6	5.9	1.71	5.7	5.7	5.5
4T2-13	0.086	<0.001	0.43	0.72	0.005	1.14	0.020	5.1	10.1	10.8	3.1	10.4	10.5	10.2
4T2-14	0.21	<0.001	1.03	1.72	0.012	2.5	0.061	11.9	25	28	7.7	26	27	25
4T2-15	-	-	-	-	-	-	-	-	33	36	9.6	32	33	33
4T2-16	-	-	-	-	-	-	-	-	28	29	7.8	26	27	26
4T2-17	-	-	-	-	-	-	-	-	13.6	13.9	3.9	13.0	13.2	12.9
4T2-18	-	-	-	-	-	-	-	-	8.6	8.6	2.4	7.7	8.1	7.9
4T2-19	-	-	-	-	-	-	-	-	5.9	6.0	1.73	5.7	5.9	5.9
4T2-26	-	-	-	-	-	-	-	-	-	10.5	2.8	9.7	9.9	9.4
4T2-33	-	-	-	-	-	-	-	-	-	4.2	1.21	3.8	4.0	3.8
4T2-34	-	-	-	-	-	-	-	-	-	7.4	2.1	7.0	7.0	6.7
4T2-35	-	-	-	-	-	-	-	-	-	21	5.9	20	19.1	19.3
4T2-36	-	-	-	-	-	-	-	-	-	36	10.0	33	34	35

TABLE D-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No.,	1986				1987		1988		1989	1990	1991		1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4T4-4	0.019	<0.001	0.096	0.160	0.005	0.24	0.027	1.15	2.5	2.3	0.63	2.3	2.4	2.6
4T4-5	0.114	0.001	0.57	0.95	0.008	1.40	0.033	6.9	13.9	13.3	4.2	13.7	14.2	16.3
4T4-6	0.045	0.001	0.22	0.37	0.008	0.53	0.034	2.7	5.3	5.1	1.60	5.3	5.6	5.9
4T4-7	0.038	0.001	0.186	0.31	0.008	0.45	0.033	2.3	4.4	4.1	1.30	4.4	4.6	4.6
4T4-8	0.035	0.001	0.179	0.30	0.007	0.43	0.033	2.1	4.2	4.1	1.25	4.2	4.4	4.7
4T4-9	0.025	0.001	0.118	0.197	0.005	0.29	0.027	1.41	2.8	2.7	0.79	2.8	3.0	3.2
4T4-10	0.022	<0.001	0.116	0.193	0.005	0.27	0.027	1.33	2.7	2.6	0.75	2.8	2.8	3.2
4T4-11	0.161	0.001	0.80	1.33	0.011	1.89	0.042	8.9	18.7	19.1	5.9	18.3	19.1	23
4T4-12	0.115	0.001	0.58	0.97	0.010	1.37	0.041	7.1	14.5	13.4	4.4	14.0	14.7	18.2
4T4-13	-	-	-	-	-	-	-	-	2.7	3.8	1.12	4.0	4.1	4.5
4T4-14	-	-	-	-	-	-	-	-	7.0	7.0	2.0	7.4	7.0	8.1
4T4-15	-	-	-	-	-	-	-	-	11.9	12.0	3.4	11.5	12.1	13.2
4T4-16	-	-	-	-	-	-	-	-	18	14.6	5.2	14.7	15.8	20
4T4-17	-	-	-	-	-	-	-	-	14.3	13.6	4.3	13.8	14.9	18.7
4T4-18	-	-	-	-	-	-	-	-	16.8	15.7	5.0	15.8	16.3	19.6
4T4-19	-	-	-	-	-	-	-	-	9.8	9.1	2.8	9.7	10.3	10.9
4T4-20	-	-	-	-	-	-	-	-	5.9	5.4	1.76	5.9	6.0	6.3
4S1-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002	0.001	/	0.002	0.002	/
4S3-1	-	-	-	-	/	/	/	/	/	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE D-9. 1993 PAIRED SITE EM FIELD INTENSITY RATIOS
Upland Flora and Soil Microflora Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
4T2PIN/4C1PIN	92	92	92	1.00	740	240	1110	3.1 - 16.4	1870	1870	1400	0.50 -11.0
4T4PIN/4C1PIN	43	43	43	1.00	400	126	590	3.8 - 210	870	1300	650	0.50 -11.0
4T2HDW/4C1HDW	87	87	87	1.00	1150	220	1290	5.1 - 13.5	1800	1830	1800	0.67 - 2.5
4T2HER/4C1HER	101	101	101	1.00	850	260	1140	3.4 - 5.8	1650	1650	1650	1.00 - 1.50

R1: T(76)/C(76) T(76) = ELF Communications System EM fields at the treatment site.
R2: T(76)/T(60) C(76) = ELF Communications System EM fields at the control site.
R3: T(76)/C(60) T(60) = ambient EM fields at the treatment site.
R4: T(60)/C(60) C(60) = ambient EM fields at the control site.

TABLE D-10. 1990 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)

Test Point	Measurement Date												Summary Statistics		
	6/28	7/10	7/24	8/7	8/21	9/4	9/18	10/2	10/22	11/7	12/5	12/21	Mean	SD	Coeff. of Variab.
4T2-3	140	135	139	145	142	141	139	141	143	147	153	157	144	6.0	0.042
4T2-4	129	128	124	125	126	127	126	126	126	125	120	121	125	2.5	0.020
4T2-5	105	99	97	94	102	99	104	105	111	108	110	106	103	5.0	0.049
4T2-6	101	100	96	97	100	94	96	97	106	104	104	105	100	3.9	0.039
4T2-7	89	86	84	82	80	84	81	85	87	87	88	83	85	2.7	0.032
4T2-8	135	130	142	143	132	138	133	137	141	143	141	145	138	4.7	0.034
4T2-9	125	122	119	116	120	118	117	119	122	122	136	141	123	7.4	0.060
4T2-10	91	87	88	88	87	89	88	92	97	95	96	98	91	4.0	0.043
4T2-11	170	168	160	158	168	165	168	168	177	171	123	125	160	16.8	0.105
4T2-12	114	144	113	114	110	110	106	108	114	116	154	163	122	18.8	0.154
4T2-13	144	142	144	145	144	146	146	143	147	146	156	160	147	5.2	0.035
4T2-14	121	115	117	113	118	117	122	124	127	126	122	125	121	4.3	0.036
4T2-16	91	88	85	81	90	91	90	96	97	99	94	95	91	5.0	0.054
4T2-19	107	106	106	103	106	105	106	106	107	107	105	106	106	1.10	0.010
4T2-20	107	107	102	108	107	105	106	107	111	110	114	121	109	4.7	0.043
4T2-21	143	139	122	132	139	142	139	140	149	144	141	144	140	6.6	0.047
4T2-22	98	92	91	85	93	86	89	93	90	89	85	85	90	3.9	0.043
4T2-23	114	108	109	107	112	109	115	115	126	122	113	115	114	5.4	0.047
4T2-24	120	121	114	112	117	117	120	123	127	126	128	123	121	4.8	0.040
4T2-25	115		117	121	116	114	115	114	118	120	129	129	119	5.2	0.044
4T2-26	210	200	200	210	210	199	198	197	210	220	230	220	210	9.4	0.045
4T2-27	118	112	124	130	119	116	115	116	129	133	124	131	122	6.9	0.056
4T2-28	151	151	153	157	152	153	152	153	149	151	152	149	152	2.0	0.013
4T2-29	55	55	61	63	53	53	54	53	53	59	53	54	56	3.4	0.060
4T2-30	106	105	113	122	110	107	112	113	115	124	120	122	114	6.3	0.055
4T2-31	94	96	98	99	99	100	101	100	102	102	103	104	100	2.8	0.028
4T2-32	75	73	73	72	74	74	75	74	75	73	72	75	74	1.10	0.015

TABLE D-10. 1990 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

Test Point	Measurement Date												Summary Statistics		
	6/26	7/10	7/24	8/7	8/21	9/4	9/18	10/2	10/22	11/7	12/5	12/21	Mean	SD	Coeff. of Variab.
4T4-4	31	29	27	28	31	31	32	32	12	9	8.7	8.3	23	9.9	0.42
4T4-5	1670	1800	1830	1950	2100	2000	2000	1980	1720	1740	1980	1910	1900	134	0.071
4T4-6	117	115	115	125	136	138	141	143	148	140	142	140	133	11.4	0.086
4T4-7	135	132	130	132	137	135	137	139	144	146	145	149	138	6.0	0.043
4T4-8	113	108	105	106	109	105	108	109	112	113	109	111	109	2.7	0.025
4T4-9	42	42	42	43	42	43	43	44	18	20	20	22	35	10.7	0.31
4T4-10	32	30	30	30	30	29	32	33	35	37	37	37	33	3.0	0.090
4T4-11	1890	1940	2200	2300	2000	2100	2000	2000	2200	2200	2400	2500	2200	185	0.086
4T4-12	1600	1610	1700	1820	1850	1820	1900	1960	1820	1770	1820	1860	1790	104	0.058
4T4-21	109	107	91	97	122	127	131	134	146	135	132	136	122	16.5	0.135
4T4-22	148	137	139	148	153	154	159	169	177	174	170	165	158	12.8	0.081
4T4-23	330	340	330	350	380	370	390	400	410	380	370	390	370	25	0.069
4T4-24	360	360	340	340	390	380	410	430	430	420	420	420	390	32	0.081

**Table D-11. 1991 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)**

Test	Measurement Date																	Summary Statistics*		
						NS Antenna Only														
Point	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/9	9/30	10/11	10/23	11/8	12/6	Mean	SD	Coeff. of Variab.
4T2-3	147	144	146	153	152	48	49	49	153	159	160	150	150	148	149	149	140	150	5.1	0.034
4T2-4	112	117	112	128	131	44	44	43	135	136	138	139	136	130	135	124	129	129	8.9	0.069
4T2-5	108	111	132	130	111	35	34	35	118	112	108	118	120	120	119	122	122	118	7.1	0.061
4T2-6	112	119	113	112	109	38	37	40	109	121	120	112	113	116	114	114	116	114	3.6	0.031
4T2-7	95	101	102	97	97	27	26	26	83	84	84	87	90	89	91	90	93	92	5.9	0.065
4T2-8	149	150	150	146	147	43	42					137	134	139	140	144	153	145	5.9	0.041
4T2-9	137	134	141	138	128	37	38						165	164	156		140	145	12.7	0.088
4T2-10	100	99	98	101	100	35	35	35	96	102	103	95	103	103	105	103	102	101	2.8	0.028
4T2-11	139	131	136	128	167	50	41	55	173	144	106	167	166	165	162	172	119	148	21	0.143
4T2-12	161	162	165	151	132	39	45	39	124	131	132	129	120	123	124	136	160	139	16.1	0.115
4T2-13	180	169	167	149	139	41	43	41	150	149	146	148	147	149	150	149	149	153	10.6	0.070
4T2-14	113	121	119	126	131	39	39	39	128	128	133	127	133	130	135	123	128	127	5.8	0.046
4T2-15										58	60	65	66	64	65	63	59	63	2.9	0.046
4T2-16	81	85	87	100	101	33	34					108	118	114	120		100	101	13.1	0.129
4T2-17										99	92	111	109	111	111	111	100	106	7.0	0.066
4T2-18										118	116	112	108	110	110	110	103	111	4.3	0.039
4T2-19	98	103	99	106	104	33	33					107	116	101	108	124	103	106	7.3	0.069
4T2-20	129	122	123	121	117	39	39	38	116	113	114	112	112	114	114	113	106	116	5.6	0.048
4T2-21	141	128	135	140	145	57	52	54	144	135	82	140	131	130	127	132	120	131	15.1	0.116
4T2-22	86	89	94	91	109	43	40	43	98	86	86	99	104	94	97	88	94	94	6.7	0.072
4T2-23	106	107	108	120	117	40	35	39	116	116	114	129	129	127	129	123	107	118	8.4	0.071
4T2-24	121	130	132	133	133	37	36	36	122	115	120	124	124	125	126	118	124	125	5.4	0.043
4T2-25	138	135	132	125	107	28	15	4.5	88	69	76	57	61	65	63	124	103	96	30	0.31
4T2-26	250	240	230	220	230	67	62			200	192	220	210	210	210	240	240	220	15.8	0.071
4T2-27	149	146	146	134	138	37	30	37	129	135	131	122	126	132	130	155	130	136	9.2	0.068
4T2-28	178	168	164	154	153	52	55	54	162	167	155	156	153	157	153	153	150	159	7.6	0.048
4T2-29	70	70	78	73	72	15	14	15	64	66	66	54	54	58	56	64	58	65	7.3	0.114
4T2-30	130	129	131	124	128	40	38	40	116	125	67	107	114	121	120	132	120	119	16.0	0.134
4T2-31	103	104	105	104	98	37	39	38	106	97	91	108	108	107	109	103	100	103	4.9	0.047
4T2-32	58	63	61	77	80	28	28	28	76	74	74	82	79	77	80	76	84	74	7.7	0.104
4T2-33										114	138	116	116	114	117	126	122	120	7.7	0.064
4T2-34										97	100	118	110	111	112	114	119	110	7.4	0.067
4T2-35											162	155	155	161	158	179	163	162	7.6	0.047
4T2-36											128	142	140	136	135	136	142	137	4.6	0.033

Table D-11. 1991 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

Test Point	Measurement Date																	Summary Statistics*		
						NS Antenna Only														
	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/9	9/30	10/11	10/23	11/8	12/6	Mean	SD	Coeff. of Variab.
4T4-4	6.8	7.1	8.3	10.3	9.2	10.6	9.9	10.4	11.1	11.3	11.5	12.8	12.6	12	13	12	11	10.6	2.0	0.186
4T4-5	2100	2100	2200	2200	1850	480	480	410	1780	1780	1850	1910	1900	1900	1850	1460	1580	1890	210	0.109
4T4-6	131	131	135	135	100	32	29	30	123	125	133	140	141	143	141	132	110	130	11.8	0.091
4T4-7	136	147	135	155	134	37	36										145	142	7.7	0.054
4T4-8	108	112	109	115	108	30	29	29	110	102	102	105	105	108	108	112	110	108	3.6	0.033
4T4-9	25	25	27	26	22	8.0	7.1	7.8	18.2	17.9	18.5	17.9	18.6	19	19	16	19	21	3.5	0.168
4T4-10	37	36	33	27	30	9.4	8.6	9.0	32	31	24	32	33	34	34	36	30	32	3.5	0.109
4T4-11	2600	2800	3200	2900	2400	550	550	480	2000	2200	2400	2100	2100	2100	2200	1790	2000	2300	390	0.167
4T4-12	2500	2300	2600	2700	1890	470	450	380	1550	1520	1580	1700	1800	1900	1830	1400	1520	1910	420	0.22
4T4-13													76	79				78	1.5	0.019
4T4-14												260	220	230	230	200	270	310	128	0.42
4T4-15										640	850	790	790	790	800	710	750	780	60	0.079
4T4-16										3500	3600	3100	3100	3200	3300	3400	3600	3300	194	0.058
4T4-18										4100	4400	4100	4200	4400	4400	4500	5000	4400	270	0.062
4T4-19												750	780	820	840	710	700	770	55	0.072
4T4-20																	220	220	0.0	0.0
4T4-21	128	123	120	149	92	39	34	33	113	89	100	124	130	128	130	111	98	117	16.5	0.141
4T4-22	154	148	143	161	123	52	44	46	133	149	152	156	152	157	160	151	129	148	11.2	0.076
4T4-23	390	380	400	390	310	91	88	83	340	370	390	400	390	400	400	340	320	370	30	0.081
4T4-24	450	440	450	470	350	115	104	100	370	350	360	410	430	430	430	310	370	400	49	0.121

*Summary statistics exclude data measured during solo operation of the NS antenna.

Table D-12. 1992 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)

Test Point	NS Antenna Only			Measurement Date													Summary Statistics*		
	1/3	2/5	3/4	4/1	4/27	5/29	7/8	7/22	8/5	8/19	9/2	9/16	10/5	10/14	11/9	12/7	Mean	SD	Coeff. of Variab.
4T2-3	45	40	40	132	153	162	156	155	156	149	148	142	154	150	136	130	148	9.6	0.065
4T2-4	41	40	43	126	137	142	137	142	141	141	150	155	148	150	127	122	140	9.6	0.069
4T2-5	35	32	34	123	126	129	133	137	130	138	137	136	139	140	133	123	133	5.7	0.043
4T2-6	39	38	40	115	117	112	116	112	114	111	110	109	114	112	102	103	111	4.4	0.039
4T2-7	29	28	31	100	95	90	90	88	85	86	84	86	87	88	85	80	88	4.9	0.055
4T2-8	45	47	49	146	151	150	146	144	155	146	145	143	153	150	141	141	147	4.3	0.029
4T2-9	42	45	45	144	139	135	134	138	135	135	135	133	140	137	132	139	137	3.2	0.023
4T2-10	38	36	38	108	111	103	103	100	94	92	91	93	97	95	80	82	96	8.7	0.091
4T2-11	36	35	35	113	152	157	175	180	173	180	174	179	182	180	110	107	159	28	0.177
4T2-12	52	53	52	157	127	122	121	119	124	121	123	115	125	123	142	144	128	11.6	0.091
4T2-13	41	42	43	149	148	149	148	134	155	152	155	151	151	148	146	144	148	5.2	0.035
4T2-14	38	39	40	133	129	135	139	137	137	132	132	131	133	132	124	120	132	5.0	0.038
4T2-15	26	27	28	65	67	65	69	70	68	69	69	70	71	69	59	56	67	4.3	0.065
4T2-16	34	34	35	109	105	104	104	101	102	107	108	112	109	111	96	86	104	6.7	0.065
4T2-17	31	28	28	100	106	106	108	111	110	109	110	108	113	112	103	95	107	4.9	0.046
4T2-18	30	29	32	112	106	110	107	108	110	105	106	103	105	103	96	99	105	4.3	0.041
4T2-19	33	33	32	107	107	105	107	108	99	107	108	111	109	107	101	97	106	3.9	0.037
4T2-20	37	42	43	104	114	123	117	119	120	115	116	114	119	119	106	115	115	5.1	0.045
4T2-21	45	48	50	128	124	118	131	133	127	136	134	139	136	138	111	108	128	9.7	0.076
4T2-22	37	39	40	94	95	98	103	104	93	100	98	103	99	97	78	72	95	9.2	0.097
4T2-23	35	33	37	118	123	126	126	135	126	134	130	136	131	133	111	98	125	10.4	0.083
4T2-24	36	36	39	127	140	135	128	128	124	124	124	126	129	128	121	115	127	5.9	0.046
4T2-25	20	40	39	129	125	126	126	125	127	125	124	120	129	124	120	122	125	2.7	0.022
4T2-26	73	78	80	230	240	240	230	230	230	220	220	210	230	220	200	210	220	11.5	0.051
4T2-27	38	42	41	130	153	148	141	140	147	139	133	132	150	145	117	125	138	10.2	0.073
4T2-28	54	54	54	150	144	128	136	135	153	142	143	140	157	146	124	130	141	9.4	0.067
4T2-29	17.2	19.2	19.1	61	73	75	67	66	72	62	61	58	63	60	45	61	63	7.4	0.117
4T2-30	44	47	47	125	142	140	131	128	139	126	126	123	136	130	105	113	128	10.1	0.079
4T2-31	37	37	38	104	105	104	105	107	105	103	105	103	105	104	88	87	102	6.2	0.061
4T2-32	30	30	30	89	84	76	77	79	73	74	78	82	77	79	71	69	78	5.2	0.067
4T2-33	44	45	45	118	119	119	112	110	109	110	109	108	112	112	97	98	110	6.5	0.059
4T2-34	42	46	48	131	130	122	117	118	115	114	115	115	120	118	101	102	117	8.3	0.071
4T2-35	55	54	54	156	163	165	163	167	164	164	164	158	171	164	146	140	160	8.3	0.052
4T2-36	48	50	52	150	145	141	136	139	137	135	136	140	137	136	121	120	136	7.9	0.058

Table D-12. 1992 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

Test Point	Measurement Date: NS Antenna Only 1/3	2/5	3/4	4/1	4/27	5/29	7/8	7/22	8/5	8/19	9/2	9/16	10/5	10/14	11/9	12/7	Summary Statistics*: Mean	SD	Coeff. of Variab.
4T4-4	9.2	8.4	9.1	10	11	11	12	12.4	11.4	12	12	13	13	12	36	35	15.4	8.8	0.56
4T4-5	500	550	580	2000	1980	1900	1870	1810	1830	1700	1730	1730	1620	1580	1340	1350	1730	200	0.117
4T4-6	29	31	36	129	98	115	133	136	136	140	144	145	150	146	139	108	132	15.2	0.115
4T4-7	31	33	64	130	119	126	139	141	134	135	136	138	139	139	143	124	134	7.0	0.052
4T4-8	28	28	27	115	109	113	117	117	115	113	113	113	115	114	119	113	114	2.4	0.021
4T4-9	7.3	8.1	8.4	19	23	21	15.9	16	17.2	16	16.5	15.7	15.1	16.2	61	65	24	16.6	0.68
4T4-10	8.7	9.2	10.4	33	25	26	31	32	30	30	31	31	33	33	19.4	16.1	29	5.2	0.182
4T4-11	670	[illegible]	770	2600	2500	2300	2200	2000	2200	2000	2000	2000	2100	2000	1710	1880	2100	230	0.111
4T4-12	520	580	620	2100	1870	1900	1710	1670	1720	1660	1670	1700	1690	1630	1290	1400	1690	195	0.115
4T4-13	25	19	168	54	30	42	58	59	55	59	60	64	64	63	39	31	52	11.8	0.23
4T4-14	85	94	101	380	230	290	320	320	330	310	330	330	330	320	240	200	300	48	0.159
4T4-15	230	280	300	980	770	820	870	840	840	810	830	850	850	830	660	650	820	82	0.101
4T4-16	1170	1260	1220	4200	4200	3600	3200	3100	3900	3100	3200	3000	3000	3000	2700	3500	3400	460	0.138
4T4-18	1590	1890	1890	5100	5000	4500	3800	3700	4500	3600	3700	3600	3700	3700	3300	4300	4000	550	0.137
4T4-19	210	220	22	880	780	850	860	820	790	790	790	820	830	810	700	610	790	68	0.086
4T4-20	50	48	94	178	160	194	230	230	230	230	240	240	240	240	220	167	220	29	0.132
4T4-21	31	34	37	124	83	108	130	131	112	124	126	135	134	134	90	60	115	23	0.197
4T4-22	41	44	51	163	101	140	168	160	145	150	148	148	158	154	108	78	140	26	0.189
4T4-23	86	95	102	380	310	370	410	400	400	400	400	410	420	400	360	310	380	35	0.091
4T4-24	106	119	134	450	340	400	430	430	400	420	420	440	430	420	360	310	400	40	0.100

*Summary statistics exclude data measured during solo operation of the NS antenna.

Table D-13. 1993 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 1 of 2)

Test Point	Measurement Date																Summary Statistics*		
	1/13	2/15	3/24	4/23	5/10	5/26	6/9	6/21	7/7	7/19	8/2	8/16	9/1	9/13	9/27	11/10	Mean	SD	Coeff. of Variab.
4T2-3	116	108	101	128	136	138	135	135	134	137	132	129	128	127	130	130	128	10.2	0.080
4T2-4	122	120	128	119	123	126	124	123	129	128	114	129	124	128	118	119	123	4.4	0.036
4T2-5	116	114	111	127	130	131	132	135	130	128	120	125	121	123	130	133	125	7.0	0.056
4T2-6	106	102	106	104	103	100	99	102	99	102	103	100	95	96	100	98	101	3.1	0.031
4T2-7	89	93	106	91	86	85	85	85	83	83	79	82	82	83	83	86	86	6.1	0.071
4T2-8	135	88	139	136	136	139	134	134	133	137	140	134	133	133	137	138	133	11.8	0.089
4T2-9	136	145	145	132	132	127	127	131	131	133	117	134	135	134	133	130	133	6.4	0.048
4T2-10	82	82	87	81	82	83	83	85	82	83	80	82	82	83	83	86	83	1.73	0.021
4T2-11	103	104	106	102	101	104	102	106	105	105	104	106	105	104	109	108	105	2.1	0.020
4T2-12	143	149	148	140	140	134	131	131	135	137	131	136	135	130	138	144	138	5.8	0.042
4T2-13	139	146	151	142	150	150	151	154	158	158	153	162	160	162	160	154	153	6.6	0.043
4T2-14	127	132	131	116	121	122	124	123	125	128	123	126	121	128	125	126	125	3.9	0.031
4T2-15	56	60	58	60	56	56	56	58	56	58	53	58	56	58	57	58	57	1.69	0.030
4T2-16	90	87	88	86	91	92	96	89	93	89	82	92	92	94	91	93	90	3.3	0.037
4T2-17	90	84	83	99	96	98	93	95	94	98	100	101	101	102	101	103	96	5.9	0.061
4T2-18	101	98	109	89	97	99	95	95	102	108	109	109	109	107	104	98	102	6.1	0.060
4T2-19	106	104	103	94	94	96	96	97	97	95	92	95	94	96	96	100	97	3.9	0.040
4T2-20	130	115	117	106	110	110	109	109	108	108	103	105	106	108	106	104	110	6.3	0.057
4T2-21	108	112	106	111	112	111	111	112	106	105	93	102	98	98	97	103	105	6.0	0.057
4T2-22	70	69	72	84	86	83	84	85	78	72	57	71	64	68	69	74	74	8.2	0.111
4T2-23	99	97	95	103	102	105	102	101	98	101	98	102	97	97	101	103	100	2.7	0.027
4T2-24	111	112	131	121	130	130	131	132	130	125	120	124	122	123	125	124	124	6.2	0.050
4T2-25	126	131	132	125	121	122	152	141	135	142	143	150	176	186	162	140	143	18.2	0.127
4T2-26	213	220	240	210	200	199	198	199	199	199	200	194	197	188	200	200	204	11.9	0.058
4T2-27	130	131	144	109	108	110	90	89	89	99	107	90	99	89	99	109	106	16.2	0.153
4T2-28	132	129	136	127	128	128	129	132	135	140	138	140	137	139	144	134	134	5.0	0.037
4T2-29	65	68	74	57	56	55	54	49	56	62	65	56	57	55	54	48	58	6.7	0.116
4T2-30	118	119	123	102	100	102	169	172	173	170	170	166	169	165	169	170	147	29	0.197
4T2-31	88	92	96	88	86	87	88	89	88	89	84	92	90	88	88	90	89	2.7	0.030
4T2-32	67	77	75	77	77	73	75	75	70	69	63	69	67	69	65	68	71	4.4	0.062
4T2-33	99	103	109	96	98	97	96	96	92	92	87	87	93	93	95	100	96	5.4	0.056
4T2-34	106	116	143	104	105	106	103	102	96	97	96	97	102	101	100	106	105	11.0	0.105
4T2-35	137	133	127	138	141	143	139	140	139	138	129	138	137	139	143	141	138	4.3	0.031
4T2-36	124	139	168	127	128	128	126	124	122	123	120	129	127	127	120	119	128	11.3	0.088

Table D-13. 1993 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points
(page 2 of 2)

Test Point	Measurement Date																Summary Statistics*		
	1/13	2/15	3/24	4/23	5/10	5/26	6/9	6/21	7/7	7/19	8/2	8/16	9/1	9/13	9/27	11/10	Mean	SD	Coeff. of Variab.
4T4-4	37	38	38	34	35	35	36	36	35	35	37	38	38	38	36	36	36	1.32	0.037
4T4-5	1630	1800	1950	1640	1480	1550	1430	1470	1450	1510	1570	1650	1630	1700	1430	1410	1580	144	0.091
4T4-6	107	109	117	111	101	110	111	116	109	114	122	134	136	130	138	137	119	11.8	0.099
4T4-7	133	130	148	129	127	123	129	132	128	132	130	134	137	136	136	138	133	5.6	0.042
4T4-8	114	112	111	119	115	118	119	122	120	125	120	120	114	116	116	120	118	3.7	0.031
4T4-9	73	80	77	60	63	64	62	62	62	66	72	69	69	67	67	66	67	5.5	0.082
4T4-10	17	16.3	19.2	16.8	15.3	14.6	14.4	15.1	14.7	14.1	16.8	14.9	14.4	15.2	17.4	19	16.0	1.56	0.098
4T4-11	2000	2300	2500	1990	1910	1920	1770	1750	1760	1890	2200	2000	2000	2000	1900	1860	1980	195	0.098
4T4-12	1610	1730	2100	1500	1410	1540	1370	1390	1290	1310	1450	1390	1420	1500	1440	1360	1490	192	0.129
4T4-13	38	40	41	35	31	31	32	32	32	34	31	38	39	40	38	41	36	3.8	0.106
4T4-14	230	250	220	210	180	198	200	210	210	220	240	260	250	270	250	240	230	25	0.109
4T4-15	820	970	1000	710	650	720	660	690	650	680	720	700	700	700	710	680	740	102	0.138
4T4-16	3800	3900	4800	3200	3000	2900	2600	2500	2700	3000	3700	3000	3200	3200	2800	2900	3200	570	0.178
4T4-18	4700	5900	7000	3800	3600	3500	3200	3000	3300	3400	4300	3400	3500	3500	3100	3500	3900	1060	0.270
4T4-19	660	710	740	710	640	700	670	690	660	660	650	650	640	630	680	690	670	30	0.045
4T4-20	160	156	172	170	160	169	169	176	171	181	183	198	196	210	210	210	181	18.0	0.099
4T4-21	68	72	87	74	58	69	70	75	67	68	60	78	80	83	85	85	74	8.5	0.115
4T4-22	91	105	110	91	75	84	79	90	85	/	93	97	99	106	113	113	95	11.7	0.123
4T4-23	330	350	340	341	310	340	340	340	340	350	390	400	400	400	400	370	380	29	0.081
4T4-24	360	400	480	330	307	350	330	350	330	350	340	380	380	390	390	380	370	39	0.105

* Summary statistics exclude data measured during solo operation of the NS antenna.

APPENDIX E

AQUATIC ECOSYSTEMS STUDIES

AQUATIC ECOSYSTEMS STUDIES

The approach of the aquatic ecosystems studies is to integrate the major interrelated and interactive components of aquatic ecosystems (periphytic algae, aquatic insects, and fish) and to monitor events and processes critical to stream ecosystems. The earth electric field and the magnetic field are considered the most important factors influencing the aquatic ecosystems studies. The electric field in the air is not expected to have any impact on the components of these studies.

In 1993, IITRI field crews made ELF electromagnetic (EM) field measurements at 12 measurement points within four treatment and one control site for the aquatic ecosystems studies. The measurement regime differed from 1992 in that measurements were not made at four upstream fish movement control sites (5C3, 5C5, 5C14, and 5C15), which are no longer in use. Annual EM field measurement dates for 1993 and previous years appear in Table E-1.

TABLE E-1. EM FIELD MEASUREMENT DATES
Aquatic Ecosystems Studies

Year	Measurement Dates	
1983	Jun 13, 15, 16	
1984	May 16, 17	Aug 21, 22
1985	Jul 22, 23	
1986	Oct 8-10	
1987	Sep 28, 29	
1988	Sep 26, 28-30	
1989	Sep 11-13	
1990	May 8, 9, 11	
1991	May 29, 30	
1992	Sep 23, 24, 25	
1993	Jul 21, 22	

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure E-1. The site numbers listed on the map are those used by IITRI. Table E-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures E-2 through E-8.

TABLE E-2. SITE NUMBER CROSS-REFERENCE
Aquatic Ecosystems Studies

IITRI Site No.	Investigator's Site Name		Location Township	Range	Section(s)
	Ambient Monitoring				
5T2-1	FEX 2		T43N	R29W	14
5C1-1	FCD		T43N	R28W	21
	Insect Substrates and Leaf Packs				
5T1-2	FEX 1		T43N	R29W	14
5T2-7	FEX 2		T43N	R29W	14
5C1-5	FCD		T43N	R28W	21
	Periphyton and PR				
5T2-2	FEX 2		T43N	R29W	14
5T2-7	FEX N		T43N	R29W	14
5C1-3	FCD N		T43N	R28W	21
5C1-5	FCD		T43N	R28W	21
	Periphyton Grazing				
5T2-8	FEX 2		T43N	R29W	14
5C1-3	FCD N		T43N	R28W	21
5C1-5	FCD		T43N	R28W	21
	Fish Movement				
5T2-4	FEX 2		T43N	R29W	14
5T3-1	FEX 3		T43N	R29W	14
5T4-3	FEX 4		T43N	R29W	11, 14
5C1-4	FCD		T43N	R28W	21
5C3-2	FCU		T43N	R29W	18
5C5-1	FS1 (inactive)		T43N	R29W	16
5C14-1	TM		T43N	R29W	8
5C15-1	T-Line		T43N	R29W	17
	Fish Population				
5T3-1	FEX 3		T43N	R29W	14
5C1-4	FCD		T43N	R28W	21
	Inactive Locations				
5T2-5	Unused		T43N	R29W	14
5T2-6	Unused		T43N	R29W	14
5T7-1	Unused		T43N	R29W	11
5C1-7	Unused		T43N	R28W	21
5T2-3	FEX 2; Insect Movement	(abandoned)	T43N	R29W	14
5C1-3	FCU; Insect Movement	(abandoned)	T43N	R28W	21
5C1-6	FCU; Insect Movement	(abandoned)	T43N	R28W	21
5T1-1	FEX 1; Fish Parasites	(abandoned)	T43N	R29W	11
5T4-1	FEX 4; Fish Parasites	(abandoned)	T43N	R29W	14
5T6-1	FEX 6; Fish Parasites	(abandoned)	T43N	R29W	12, 13
5C1-2	FCU; Fish Parasites	(abandoned)	T43N	R28W	21
5T4-2	FEX 4; Fish Feeding	(abandoned)	T43N	R29W	11, 14

EM field measurements for 1993 and previous years are found in Tables E-3 through E-8. Tables E-3, E-4, and E-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables E-6, E-7, and E-8 present 76 Hz data for these fields as well as the corresponding operating currents of the NRTF-Republic for each year. Paired-site EM field intensity ratios, which were recalculated using 1993 measurement data, appear in Table E-9.

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements made in 1986 through 1993 (excluding 1989) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were made at some treatment sites during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control site, nonetheless, are about as variable as those at the treatment sites.

Overall, the 60 Hz EM fields measured at both treatment and control study sites in 1993 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment site consistently dominate the 60 Hz EM fields at both the treatment and control sites.

The 76 Hz EM field measurements in 1993 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables E-6 through E-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurement values for full-power operation with both antennas are consistent with those obtained in 1989 through 1992 (excluding 1991) under the same antenna conditions and are proportional to the measurements made in 1986, 1987, and 1988 at lower currents.

Shutdown of the EW antenna does not appear to have had a significant effect on the 76 Hz EM exposure levels at these study sites. EM field measurements that were made at these study sites in 1991, while the EW antenna was shut down, are comparable to those conducted in previous and future years during operation of both antennas. This period of single-antenna operation can therefore be treated as a full-exposure operation period.

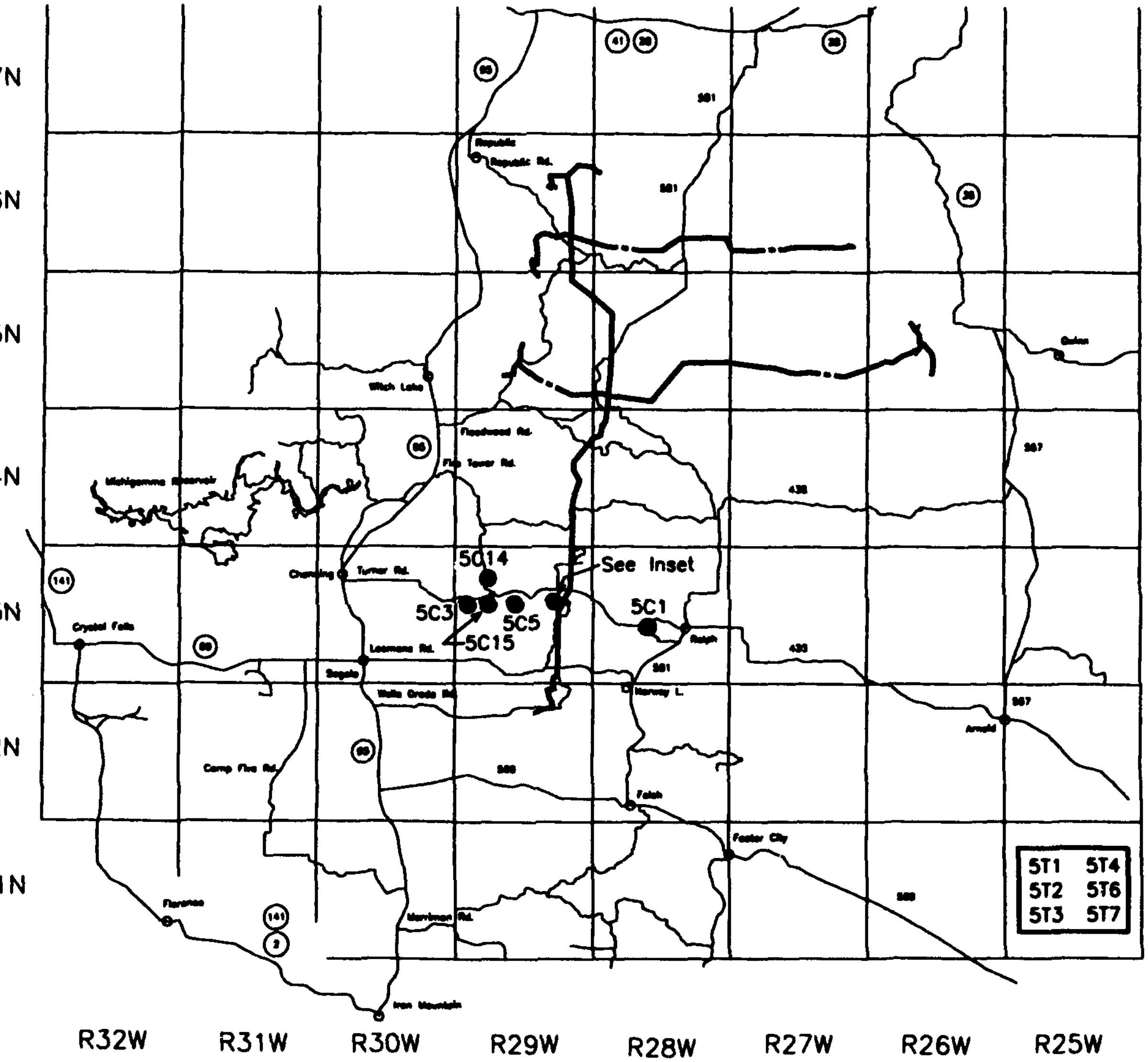


FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

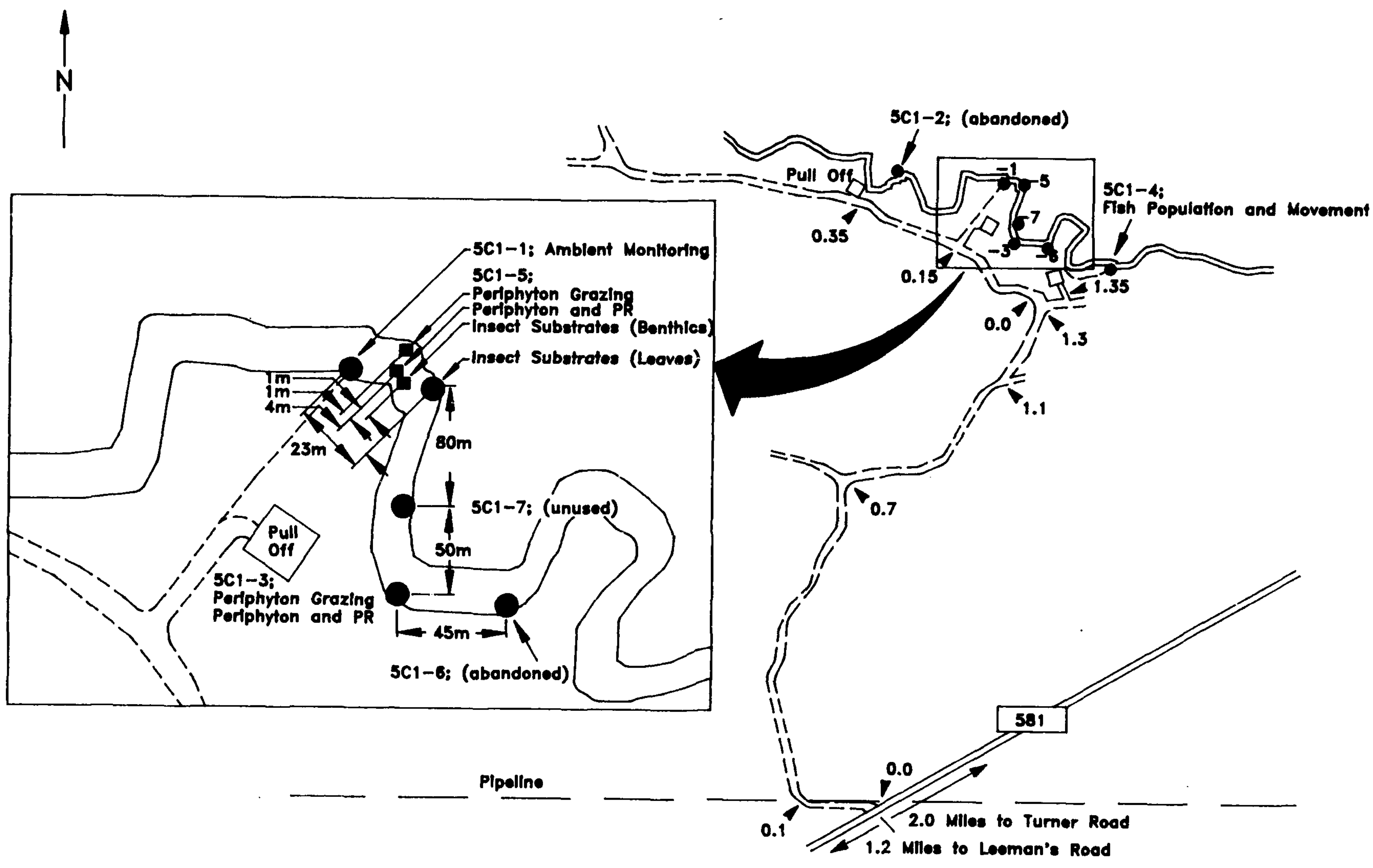


FIGURE E-2. MEASUREMENT POINTS AT FCD; 5C1-1 THROUGH 7.

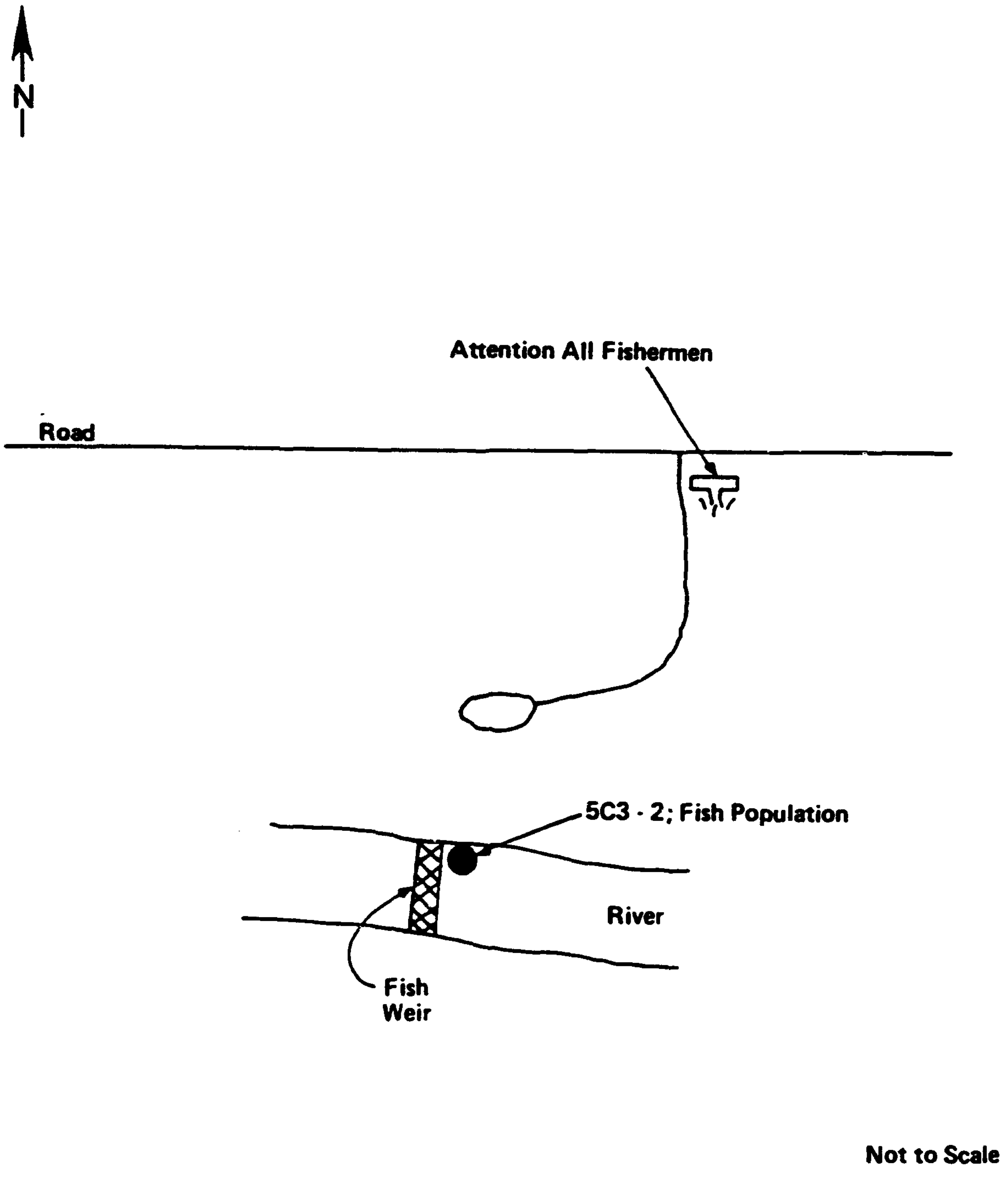


FIGURE E-3. MEASUREMENT POINT AT FCU; 5C3-2.

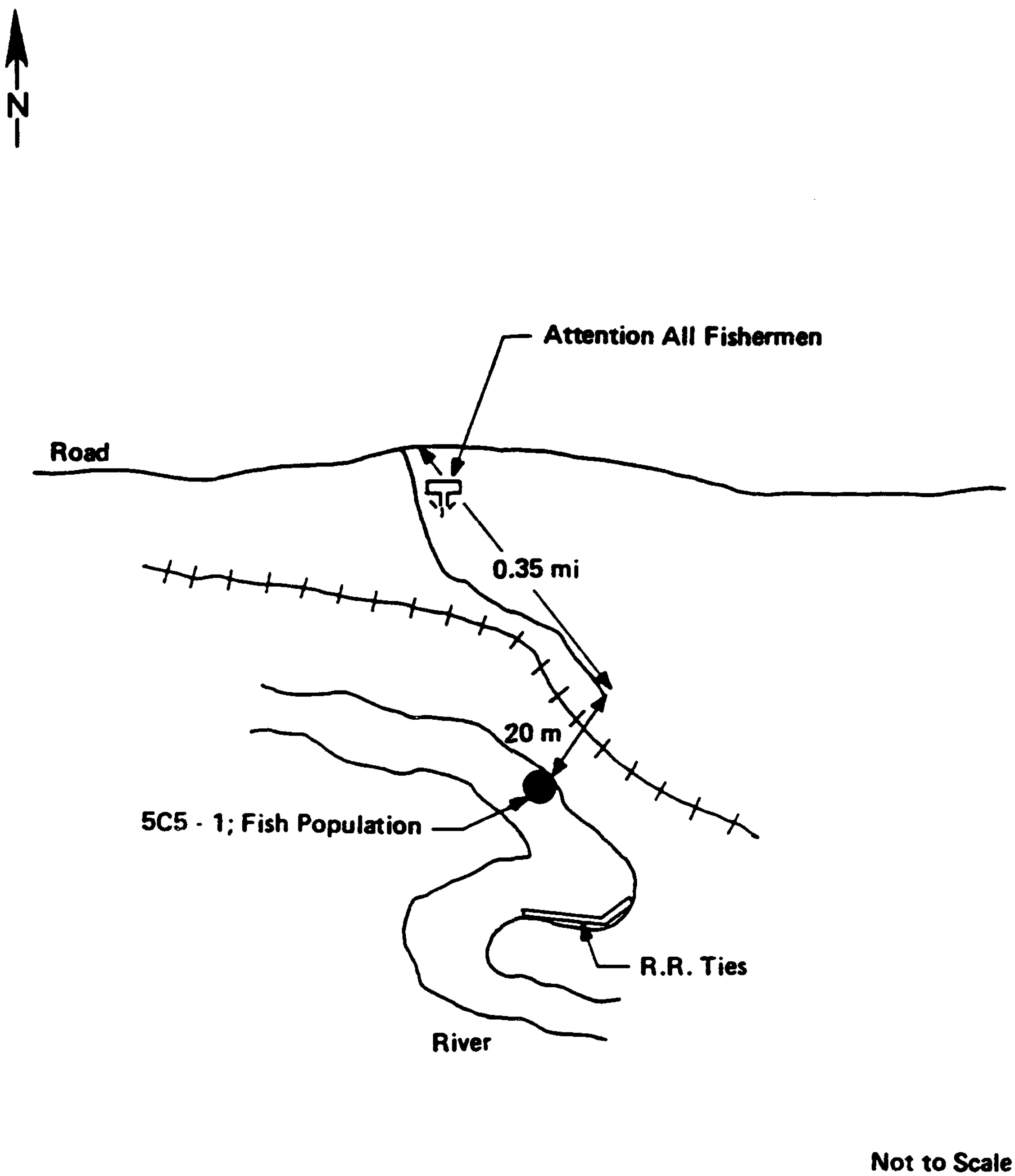


FIGURE E-4. MEASUREMENT POINT AT FS1; 5C5-1.

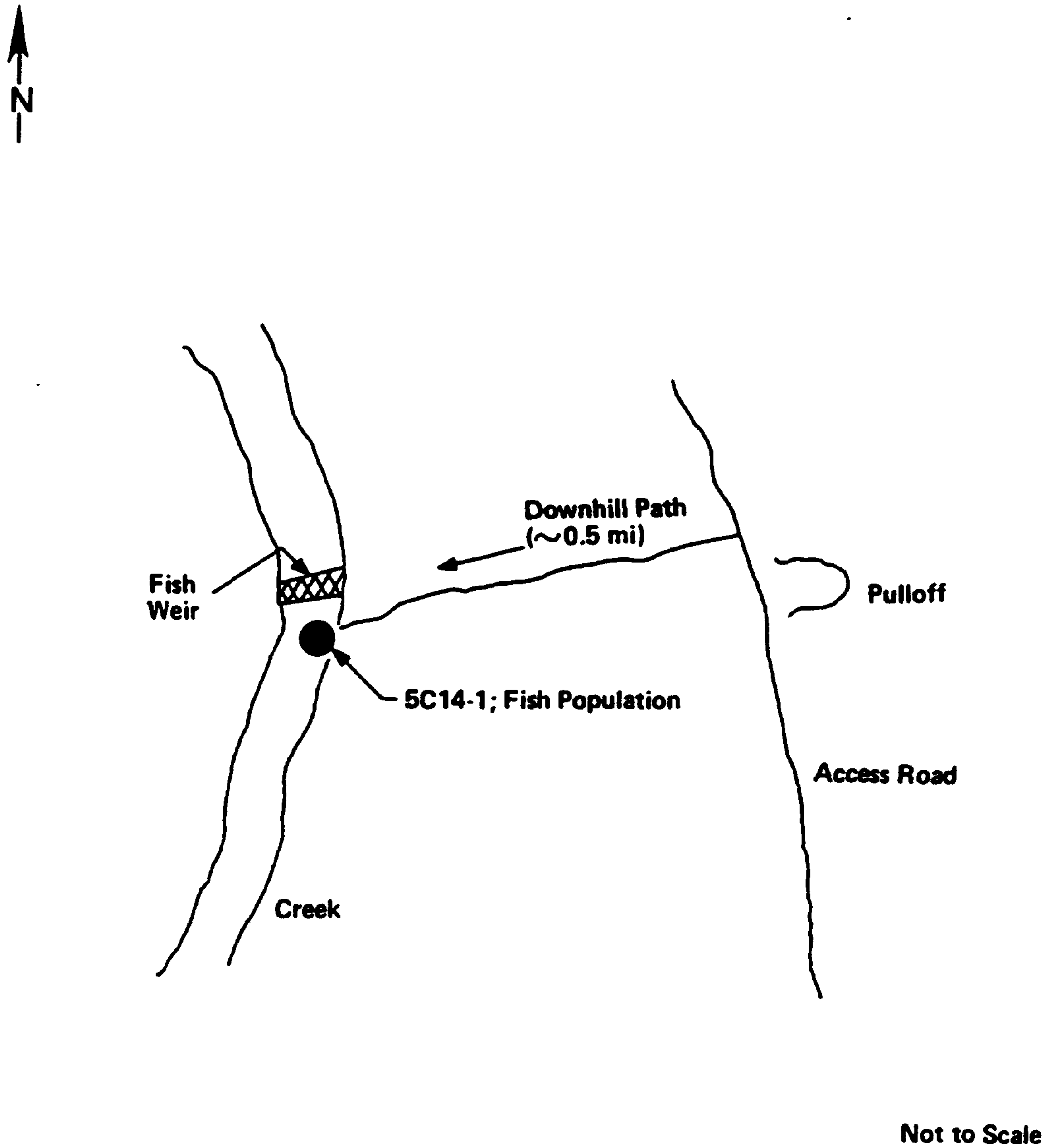


FIGURE E-5. MEASUREMENT POINT AT TM; 5C14-1.

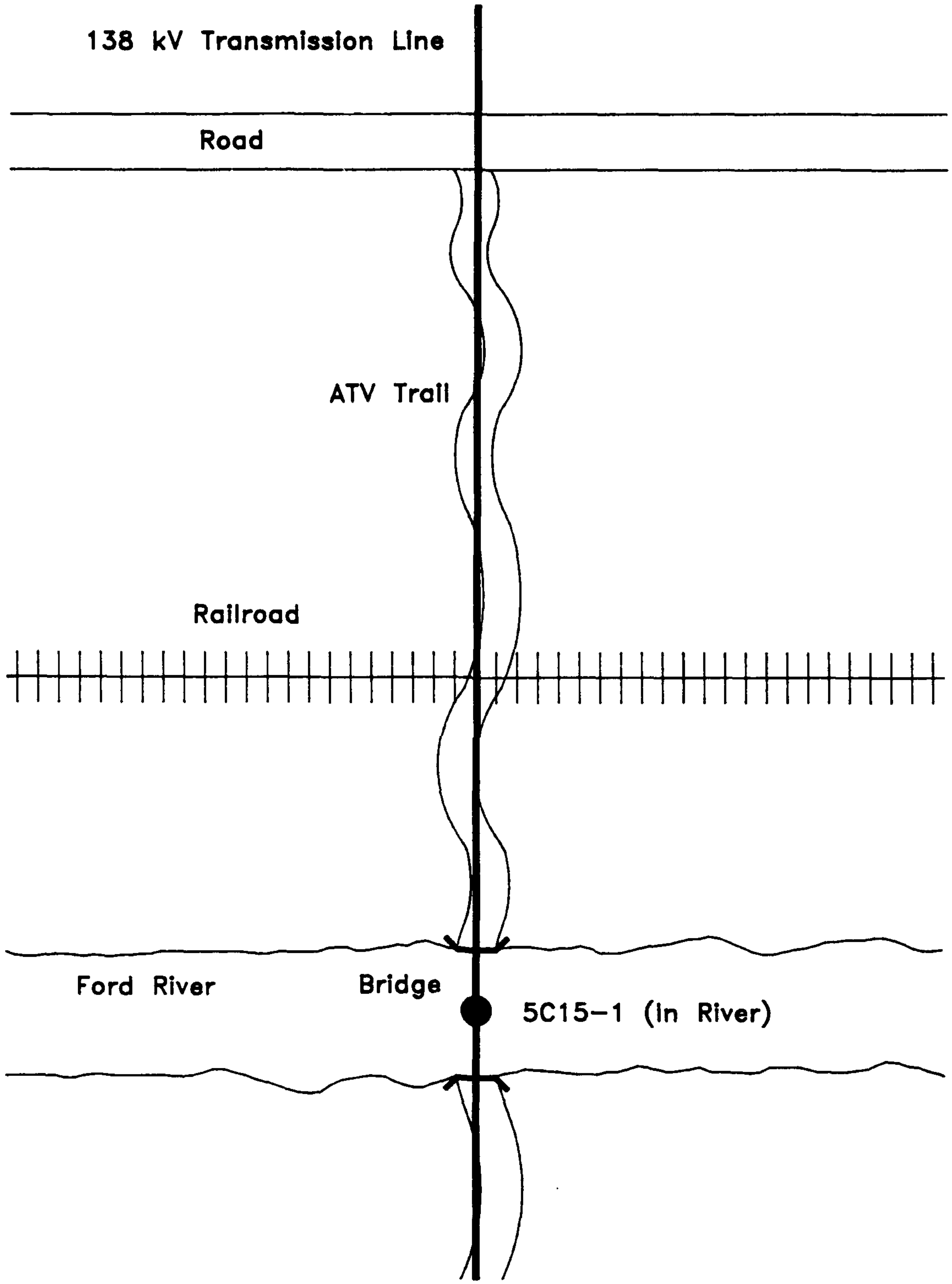


FIGURE E-6. MEASUREMENT POINT AT TRANSMISSION LINE; 5C15-1.

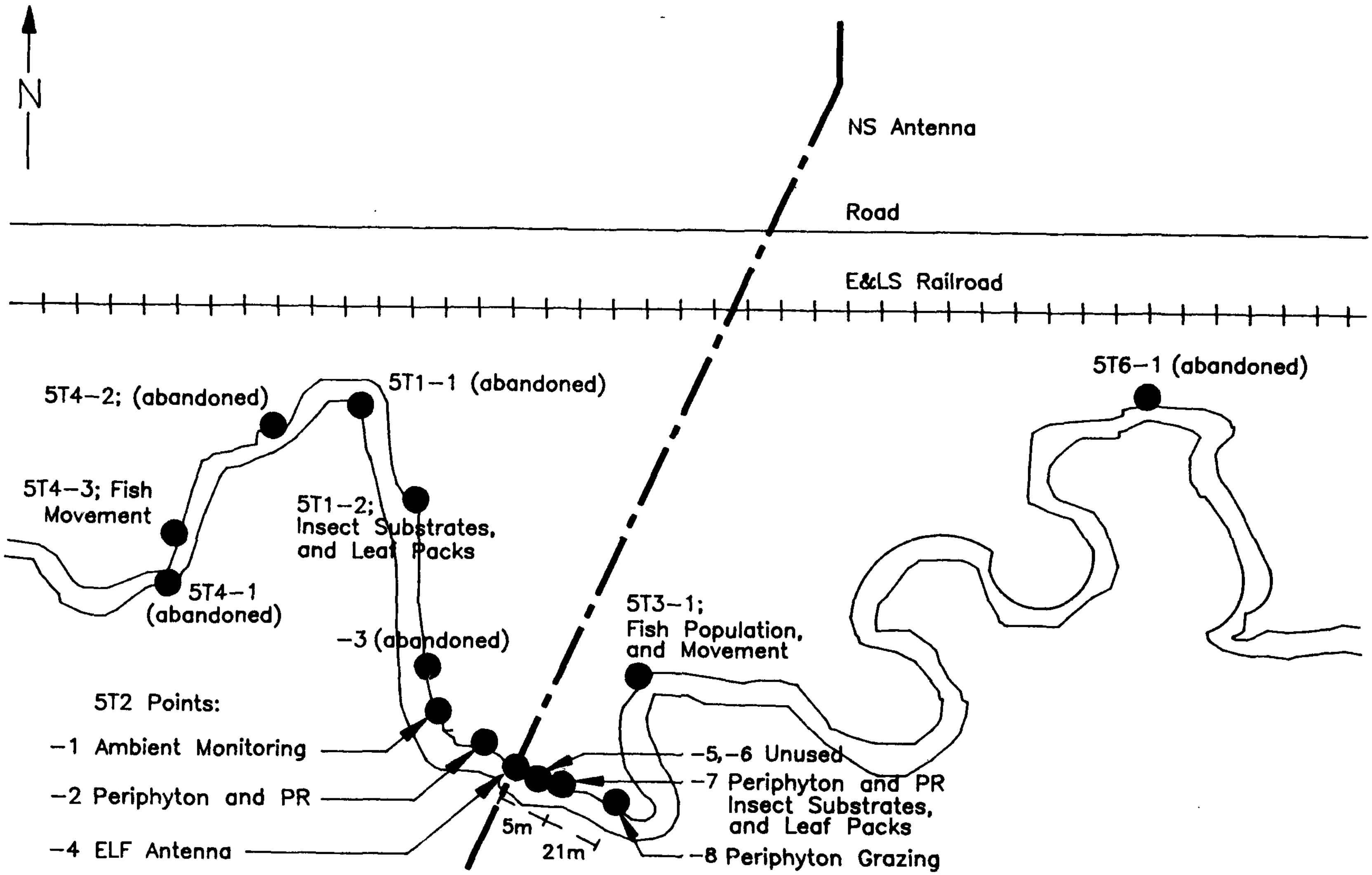


FIGURE E-7. MEASUREMENT POINTS AT FEX; 5T1-1, 2; 5T2-1 THROUGH 8; 5T3-1; 5T4-1, 2; 5T6-1.

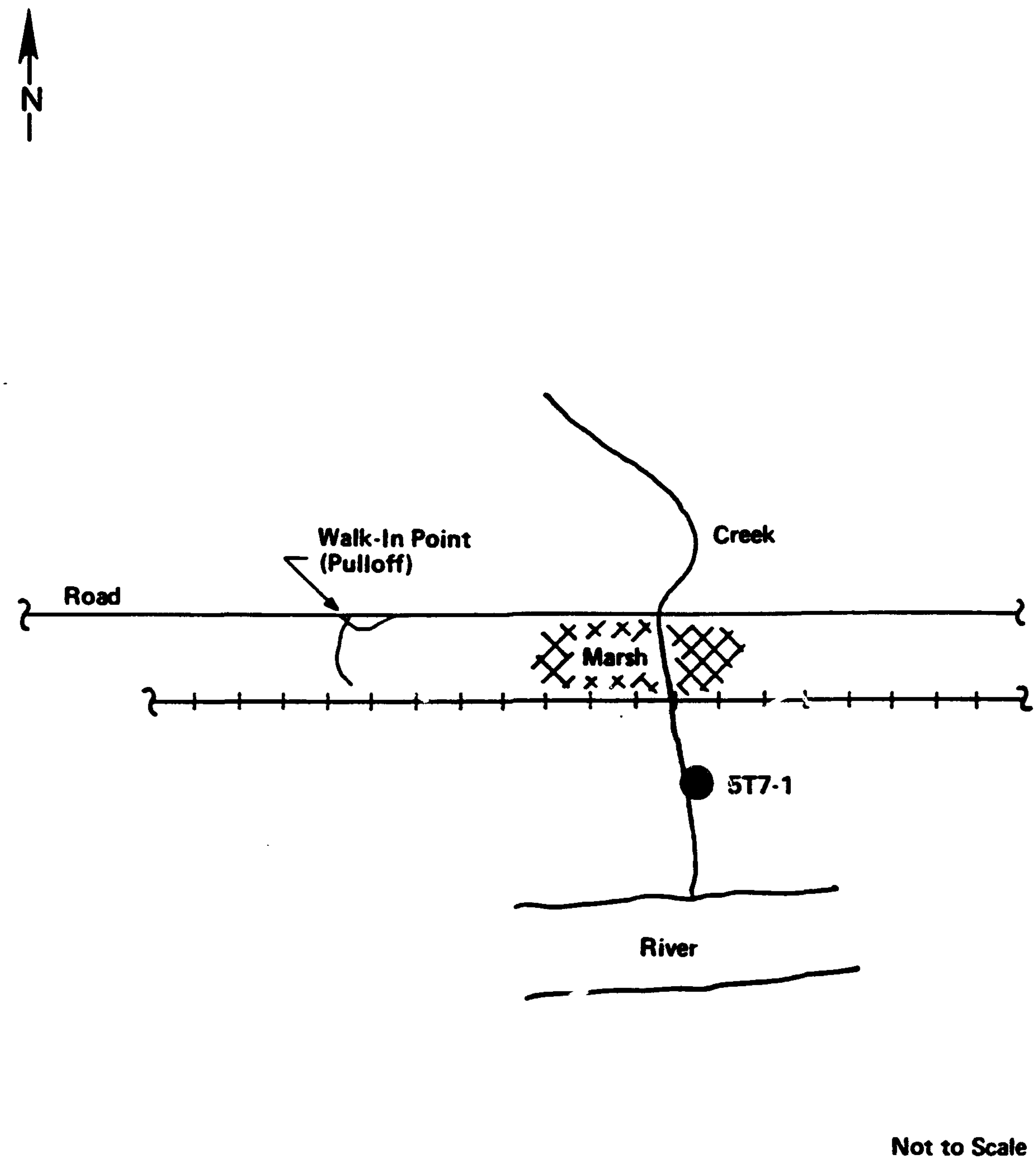


FIGURE E-8. MEASUREMENT POINT AT FEX 7;

TABLE E-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies (page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990[d]	1991[b]	1992	1993
5C1-1	0.002	<0.001	<	<	<	<	<	#	<	<[b]	<[b]
5C1-2	<0.001	/	/	<	<	<	<	#	–	–	–
5C1-3	<0.001	/	/	<	<	<	<	#	<	<[b]	<[b]
5C1-4	-	<0.001	<	<	<	<	<	#	<	<[b]	<[b]
5C1-5	-	-	-	-	-	<	<	#	<	<[b]	<[b]
5C1-6	-	-	-	-	-	-	<	#	–	–	–
5C1-7	-	#	-	-	-	-	-	#	–	–	–
5C3-2	<0.001	0.003	<	<	<	<	<	#	<	<[d]	/
5C5-1	0.001	<0.001	<	<	<	<	<	#	<	<[d]	/
5C14-1	-	0.033		<	<	<	<	#	<	<[c]	/
5C15-1	-	-	-	-	-	-	6.5	50	32	59[d]	/
5T1-1	-	/	/	<	<	<	<	#	–	–	–
5T1-2	<0.001	<	<	<	<	<	<	#	<	<[b]	<[b]
5T2-1	-	<	<	<	<	<	<0.001	#	<0.001	<[b]	<[b]
5T2-2	-	<	<	<	<0.001	0.002	<0.001	#	0.019	<0.001[b]	<[b]
5T2-3	-	-	-	<	<	<0.001	<	#	–	–	–
5T2-4	-	-	-	-	-	-	-	#	0.065	0.010[b]	<[b]
5T2-5	-	-	-	-	-	-	-	#	–	–	–
5T2-6	-	-	-	-	-	-	-	#	–	–	–
5T2-7	-	-	-	-	-	-	-	#	0.037	0.005[b]	<[b]
5T2-8	-	-	-	-	-	-	-	#	0.017	0.003[b]	<[b]
5T3-1	-	<	<	<	0.001	<0.001	/	#	<	<[b]	<[b]

TABLE E-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies (page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990[d]	1991[b]	1992	1993
5T4-1	-	<	/	<	<	<	<	#	--	--	--
5T4-2	-	-	-	<	<	<	--	#	--	--	--
5T4-3	-	-	-	-	-	-	-	-	<	<[b]	<[b]
5T6-1	-	<0.001	<	<	<	<0.001	<	#	--	--	--
5T7-1	-	-	-	<	<	<0.001	<	--	--	--	--

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.
< = measurement estimated <0.001 V/m based on earth electric field.

TABLE E-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Aquatic Ecosystems Studies (page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990[d]	1991[b]	1992	1993
5C1-1	1.47, 1.73	2.7	2.6	0.22	0.26	0.32	0.27	#	0.50	0.182[b]	0.133[b]
5C1-2	1.8	/	/	0.155	0.160	0.21	0.21	#	–	–	–
5C1-3	1.3	/	/	0.126	0.148	0.179	0.22	#	0.32	0.101[b]	0.118[b]
5C1-4	-	2.5, 2.7	2.2	0.174	0.25	0.21	0.44	#	0.065	0.119[b]	0.26[b]
5C1-5	-	-	-	-	-	0.27	0.33	#	0.43	0.151[b]	0.122[b]
5C1-6	-	-	-	-	-	-	0.22	#	–	–	–
5C1-7	-	-	-	-	-	-	-	#	–	–	–
5C3-2	0.049	0.045	0.060	0.119	0.079	0.110	0.110	#	0.50	0.158[d]	/
5C5-1	0.076	0.062	0.059	0.077	0.118	0.140	0.029	#	0.39	0.110[d]	/
5C14-1	-	0.174, 0.24	0.22	0.167	0.31	0.41	1.27	#	1.31	0.35[c]	/
5C15-1	-	-	-	-	-	-	1.40	2.2	2.8	0.95[d]	/
5T1-1	0.38	0.38	/	0.125	0.062	0.093	0.26	#	–	–	–
5T1-2	0.184	0.154, 0.22	0.175	0.037	0.032	0.044	0.048	#	0.111	0.044[b]	0.034[b]
5T2-1	-	0.22, 0.31	0.23	0.057	0.061	0.126	0.037	#	0.166	0.074[b]	0.061[b]
5T2-2	-	0.26	0.165	0.082	0.076	0.198	0.040	#	0.194	0.077[b]	0.078[b]
5T2-3	-	-	-	0.050	0.056	0.063	0.033	#	–	–	–
5T2-4	-	-	-	-	-	-	-	#	0.26	0.076[b]	0.063[b]
5T2-5	-	-	-	-	-	-	-	#	–	–	–
5T2-6	-	-	-	-	-	-	-	#	–	–	–
5T2-7	-	-	-	-	-	-	-	#	0.26	0.063[b]	0.090[b]
5T2-8	-	-	-	-	-	-	-	#	0.179	0.104[b]	0.099[b]
5T3-1	-	0.22, 0.26	0.23	0.046	0.053	0.115	/	#	0.114	0.064[b]	0.149[b]

TABLE E-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies (page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990[d]	1991[b]	1992	1993
5T4-1	-	0.170, 0.195	/	0.032	0.028	0.035	0.099	#	--	--	--
5T4-2	-	-	-	0.073	0.048	0.064	--	#	--	--	--
5T4-3	-	-	-	-	-	-	-	-	0.107	0.045[b]	0.044[b]
5T6-1	-	0.37, 0.42	0.34	0.047	0.043	0.116	/	#	--	--	--
5T7-1	-	-	-	0.040	0.012	0.053	/	--	--	--	--

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE E-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies (page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991[b]	1992	1993
5C1-1	0.008	0.008	0.003	0.001	0.001	0.001	0.001	#	0.001	0.001[b]	0.001[b]
5C1-2	0.006	/	/	0.001	0.001	<0.001	0.001	#	–	–	–
5C1-3	0.004	/	/	0.001	0.001	0.001	0.001	#	0.002	0.001[b]	0.001[b]
5C1-4	-	0.007, 0.008	0.007	0.001	0.001	0.001	0.002	#	0.001	0.001[b]	0.001[b]
5C1-5	-	-	-	-	-	<0.001	0.001	#	0.003	0.001[b]	0.001[b]
5C1-6	-	-	-	-	-	-	0.001	#	–	–	–
5C1-7	-	-	-	-	-	-	-	#	–	–	–
5C3-2	0.003	0.003	0.003	0.005	0.004	0.009	0.008	#	0.029	0.007[d]	/
5C5-1	0.002	0.002	0.002	0.001	0.001	0.002	<0.001	#	0.005	0.006[d]	/
5C14-1	-	0.013, 0.021	0.020	0.017	0.094	0.034	0.057	#	0.065	0.027[c]	/
5C15-1	-	-	-	-	-	-	4.4	5.7	11	0.59[d]	/
5T1-1	<0.001	<0.001	/	0.002	0.003	<0.001	0.006	#	–	–	–
5T1-2	<0.001	0.001	0.001	0.004	0.005	0.001	0.008	#	0.018	0.003[b]	0.005[b]
5T2-1	-	0.001, 0.002	0.001	0.005	0.009	0.015	0.003	#	0.037	0.006[b]	0.011[b]
5T2-2	-	0.002	0.001	0.014	0.021	0.047	0.009	#	0.103	0.011[b]	0.025[b]
5T2-3	-	-	-	0.004	0.007	0.007	0.003	#	–	–	–
5T2-4	-	-	-	-	-	-	-	#	0.157	0.024[b]	0.049[b]
5T2-5	-	-	-	-	-	-	-	#	–	–	–
5T2-6	-	-	-	-	-	-	-	#	–	–	–
5T2-7	-	-	-	-	-	-	-	#	0.133	0.022[b]	0.042[b]
5T2-8	-	-	-	-	-	-	-	#	0.083	0.014[b]	0.022[b]
5T3-1	-	0.001, 0.002	0.001	0.005	0.009	0.021	/	#	0.031	0.006[b]	0.007[b]

TABLE E-5. 60 Hz MAGNETIC FLUX DENSITIES (mG) Aquatic Ecosystems Studies (page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991[b]	1992	1993
5T4-1	-	0.001	/	<0.001	0.002	<0.001	0.004	#	--	--	--
5T4-2	-	-	-	0.001	0.002	<0.001	--	#	--	--	--
5T4-3	-	-	-	-	-	-	-	-	0.009	0.002[b]	0.002[b]
5T6-1	-	0.001	0.001	0.001	0.002	0.003	/	--	--	--	--
5T7-1	-	-	-	0.001	0.001	0.005	/	#	--	--	--

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE E-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies (page 1 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1992 B 150 A	1993 B 150 A
5C1-1	<	<	<	*	<	<	<	<	<	<	<	/	/
5C1-2	<	<	<	*	<	<	<	<	<	–	–	–	–
5C1-3	<	<	<	*	<	<	<	<	<	<	<	/	/
5C1-4	<	<	<	*	<	<	<	<	<	<	<	/	/
5C1-5	-	-	-	-	-	-	<	<	<	<	<	/	/
5C1-6	-	-	-	-	-	-	-	-	<	–	–	–	–
5C1-7	-	-	-	-	-	-	-	-	-	<	–	–	–
5C3-2	<	<	<	*	<	<	<	<	<	<	<	<	/
5C5-1	<	<	<	*	<	<	<	<	<	<	<	<	/
5C14-1	<	<	<	*	<	<	<	<	<	<	<	<	/
5C15-1	-	-	-	-	-	-	-	-	#	#	#	#	/
5T1-1	<	<	<	*	0.009	<	0.037	0.001	0.091	–	–	–	–
5T1-2	<	<	<	*	<0.001	<	0.014	0.002	0.029	0.042	0.035	0.046	0.030
5T2-1	0.001	<	<	*	0.005	<	0.026	0.002	0.062	/	0.048	0.058	0.051
5T2-2	0.011	<	<	*	0.022	<0.001	0.130	<0.001	0.54	0.27	1.02	0.29	0.29
5T2-3	<	<	<	*	0.005	<	0.030	<0.001	0.049	–	–	–	–
5T2-4	-	-	-	-	-	-	-	-	-	9.8	4.0	6.1	5.1
5T2-5	-	-	-	-	-	-	-	-	-	8.3	–	–	–
5T2-6	-	-	-	-	-	-	-	-	-	8.3	–	–	–
5T2-7	-	-	-	-	-	-	-	-	-	6.7	2.8	5.6	3.0
5T2-8	-	-	-	-	-	-	-	-	-	1.06	1.51	1.11	0.49
5T3-1	0.008	<	<	*	0.020	<	0.104	<0.001	0.175	0.24	0.165	0.161	0.149

TABLE E-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies (page 2 of 2)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A
5T4-1	<	<	<	*	0.003	<	0.014	<0.001	0.036	--	--	--	--
5T4-2	<	<	<	*	0.007	<	0.054	<0.001	--	0.088	--	--	--
5T4-3	-	-	-	-	-	-	-	-	-	-	0.033	0.082	0.042
5T6-1	<	<	<	*	0.006	<	0.035	0.002	0.057	--	--	--	--
5T7-1	<	<	<	*	/	<	0.014	<0.001	0.029	--	--	--	--

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
< = measurement estimated <0.001 based on earth electric field.
* = data cannot be extrapolated.
# = measurement precluded by ambient 60 Hz fields.

TABLE E-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies (page 1 of 2)

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A
5C1-1	0.33	0.020	0.052	0.087	1.33	0.158	6.8	0.81	11.7	12.5	10.6	11.1	10.2
5C1-2	0.24	0.016	0.053	0.088	1.07	0.186	4.9	0.76	9.9	–	–	–	–
5C1-3	0.191	0.013	0.047	0.078	0.85	0.130	4.1	0.73	7.6	8.0	7.0	7.1	7.3
5C1-4	0.26	0.014	0.075	0.125	1.02	0.160	4.6	0.64	10.5	10.5	7.3	9.7	9.5
5C1-5	-	-	-	-	-	-	7.1	0.83	11.9	12.3	11.5	10.3	9.2
5C1-6	-	-	-	-	-	-	-	-	7.7	–	–	–	–
5C1-7	-	-	-	-	-	-	-	-	-	7.9	–	–	–
5C3-2	0.013	0.002	0.007	0.012	0.067	0.023	0.26	0.091	0.58	0.61	0.59	0.53	/
5C5-1	0.034	0.002	0.009	0.015	0.138	0.035	0.68	0.150	1.39	1.51	1.37	1.31	/
5C14-1	0.042	0.004	0.015	0.025	0.183	0.055	0.81	0.25	1.86	1.70	1.47	1.26	/
5C15-1	-	-	-	-	-	-	-	-	#	#	1.37	1.50	/
5T1-1	2.5	0.080	0.108	0.180	7.5	0.33	46	1.47	98	–	–	–	–
5T1-2	0.77	0.034	0.097	0.162	2.9	0.30	16.1	1.61	27	32	30	28	28
5T2-1	1.33	0.045	0.077	0.128	5.4	0.22	25	1.16	47	48	45	51	47
5T2-2	1.62	0.052	0.067	0.112	6.1	0.184	31	0.100	65	61	55	66	60
5T2-3	1.17	0.042	0.079	0.132	4.9	0.23	21	1.18	40	–	–	–	–
5T2-4	-	-	-	-	-	-	-	-	-	59	64	69	61
5T2-5	-	-	-	-	-	-	-	-	-	61	–	–	–
5T2-6	-	-	-	-	-	-	-	-	-	73	–	–	–
5T2-7	-	-	-	-	-	-	-	-	-	85	71	79	70
5T2-8	-	-	-	-	-	-	-	-	-	95	77	104	81
5T3-1	1.22	0.045	0.082	0.137	4.8	0.27	18.8	1.07	45	42	48	40	43

TABLE E-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m) Aquatic Ecosystems Studies (page 2 of 2)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
	NS	NEW	SEW	SEW	NS	EW	NS	EW	B	B	NS	B	B
Meas. Pt.	4 A	6 A	6 A	10 A, EX	15 A	15 A	75 A	75 A	150 A	150 A	150 A	150 A	150 A
5T4-1	0.75	0.026	0.061	0.102	3.0	0.182	17.3	1.06	35	--	--	--	--
5T4-2	1.91	0.056	0.077	0.128	5.3	0.21	37	1.06	--	66	--	--	--
5T4-3	-	-	-	-	-	-	-	-	-	-	36	38	39
5T6-1	1.21	0.030	0.066	0.110	4.5	0.20	24	0.96	45	--	--	--	--
5T7-1	0.76	0.033	0.072	0.120	2.6	0.189	15.3	1.09	9.4	--	--	--	--

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.
= measurement precluded by ambient 60 Hz fields.

TABLE E-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies (page 1 of 2)

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A
5C1-1	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.039	0.036	0.042	0.038	0.036
5C1-2	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.038	–	–	–	–
5C1-3	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.038	0.035	0.043	0.038	0.037
5C1-4	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.040	0.037	0.043	0.039	0.038
5C1-5	-	-	-	-	-	-	0.022	0.005	0.038	0.035	0.045	0.037	0.036
5C1-6	-	-	-	-	-	-	-	-	0.038	–	–	–	–
5C1-7	-	-	-	-	-	-	-	-	-	0.035	–	–	–
5C3-2	0.001	<0.001	<0.001	*	0.003	0.001	0.016	0.004	0.038	0.037	0.033	0.038	/
5C5-1	0.003	<0.001	0.001	0.002	0.013	0.002	0.061	0.007	0.138	0.125	0.115	0.131	/
5C14-1	0.001	<0.001	<0.001	*	0.005	0.001	0.024	0.004	0.060	0.053	0.059	0.055	/
5C15-1	-	-	-	-	-	-	-	-	#	#	0.20	0.23	/
5T1-1	0.045	0.001	<0.001	*	0.170	0.002	0.81	0.006	1.79	–	–	–	–
5T1-2	0.063	0.002	<0.001	*	0.25	0.002	1.19	0.006	2.3	2.3	2.2	2.3	2.1
5T2-1	0.129	0.004	0.001	0.002	0.50	0.002	2.3	0.008	4.8	4.8	4.4	4.9	4.6
5T2-2	0.31	0.009	0.001	0.002	1.20	0.003	5.5	0.018	12.7	10.6	13.5	11.2	11.4
5T2-3	0.110	0.003	<0.001	*	0.41	0.002	1.90	0.007	3.7	–	–	–	–
5T2-4	-	-	-	-	-	-	-	-	-	22	21	22	21
5T2-5	-	-	-	-	-	-	-	-	-	22	–	–	–
5T2-6	-	-	-	-	-	-	-	-	-	22	–	–	–
5T2-7	-	-	-	-	-	-	-	-	-	21	19.9	21	19.1
5T2-8	-	-	-	-	-	-	-	-	-	12	14	12.3	11.3
5T3-1	0.137	0.004	0.001	0.002	0.51	0.001	2.6	0.014	5.1	4.7	4.9	4.9	4.7

TABLE E-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies (page 2 of 2)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A
5T4-1	0.028	0.001	<0.001	*	0.118	0.002	0.58	0.007	1.17	–	–	–	–
5T4-2	0.033	0.001	<0.001	*	0.123	0.002	0.60	0.006	–	1.22	–	–	–
5T4-3	-	-	-	-	-	-	-	-	-	-	1.06	1.16	1.07
5T6-1	0.029	0.001	0.001	0.002	0.109	0.002	0.51	0.008	1.03	–	–	–	–
5T7-1	0.011	<0.001	0.001	0.002	0.040	0.002	0.20	0.008	0.40	–	–	–	–

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
- = measurement point not established.
– = measurement point dropped.
/ = data not taken.
* = data cannot be extrapolated.

TABLE E-9. 1993 PAIRED SITE EM FIELD INTENSITY RATIOS
Aquatic Ecosystems Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
5T1-2/5C1-5	30	30	30	1.00	3.0	820	230	0.28	58	420	2100	5.0
5T2-7/5C1-5	3000	3000	3000	1.00	7.6	780	570	0.74	530	450	19100	42
5T2-2/5C1-5	290	290	290	1.00	6.5	770	490	0.64	320	460	11400	25
5T2-7/5C1-5	3000	3000	3000	1.00	7.6	780	570	0.74	530	450	19100	42
5T2-2/5C1-3	290	290	290	1.00	8.2	770	510	0.66	310	460	11400	25
5T2-7/5C1-3	3000	3000	3000	1.00	9.6	780	590	0.76	520	450	19100	42
5T2-8/5C1-5	490	490	490	1.00	8.8	820	660	0.81	310	510	11300	22
5T2-8/5C1-3	490	490	490	1.00	11.1	820	690	0.84	310	510	11300	22

R1: T(76)/C(76) T(76) = ELF Communications System EM fields at the treatment site.
R2: T(76)/T(60) C(76) = ELF Communications System EM fields at the control site.
R3: T(76)/C(60) T(60) = ambient EM fields at the treatment site.
R4: T(60)/C(60) C(60) = ambient EM fields at the control site.

APPENDIX F

SOIL AMOEBA STUDIES

SOIL AMOEBA STUDIES

The objectives of the soil amoeba studies are to monitor population and species characteristics, cell cycle, cropping efficiency, and distribution in the soil. The electric and magnetic fields in the earth are considered the most important electromagnetic (EM) factors to be examined. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

In 1993, IITRI field crews made ELF EM field measurements at nine measurement points within the two treatment sites and single control site for the soil amoeba studies. The study sites and the measurement points within those sites were unchanged from 1992. Measurement dates for 1993 and previous years appear in Table F-1.

TABLE F-1. EM FIELD MEASUREMENT DATES
Soil Amoeba Studies

Year	Measurement Dates	
1983	Jun 9, 10, 15	
1984	May 14	Aug 10, 13, 15
1985	May 6	Jul 16, 23
1986	Oct 3, 10, 16	
1987	Sep 30	Oct 1, 2
1988	Sep 20, 23, 27	Oct 25
1989	Sep 11, 18, 20	
1990	Sep 27	Oct 3, 9
1991	Sep 24, 25, 27	Oct 2
1992	May 6	Sep 14, 15, 16
1993	Jul 20, 23, 26, 27	Sep 17

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure F-1. The site numbers listed on the map are those used by IITRI. Table F-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures F-2 through F-4.

EM field measurements for 1993 and previous years are found in Tables F-3 through F-8. Tables F-3, F-4, and F-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables F-6, F-7, and F-8 present 76 Hz data for these fields as well as the corresponding

TABLE F-2. SITE NUMBER CROSS-REFERENCE
Soil Amoeba Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
6T3	Leeman's Road	T43N	R29W	23
6T4	Wells Grade Ground	T42N	R29W	2
6C2	Merriman Truck Road Control	T41N	R29W	21

operating currents of the NRTF-Republic for each year. Paired-site EM field intensity ratios, which were recalculated using 1993 measurement data, appear in Table F-9.

Considerable year-to-year variability in the 60 Hz fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements made at treatment sites in 1986 through 1993 (excluding 1989) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were made at the ground site during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz EM fields measured at the control study site are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of this site from the antennas. The 60 Hz EM field values at the control site, nonetheless, are about as variable as those at the treatment sites.

Overall, the 60 Hz EM fields measured at all study sites in 1993 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites.

The 76 Hz EM field measurements in 1993 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables F-6 through F-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurements are consistent with the measurements made in 1989 through 1992 at the same current, and are proportional to the measurements made in 1986, 1987, and 1988 at lower currents.

Plots of growth chamber data collected by data loggers during the 1988 through 1991 field seasons are presented in Figures F-5 through F-16. Each figure presents data for the four field seasons for each chamber. Only current densities are presented for the matched current density chambers, and electric fields for the matched electric field chambers, although both fields are measured for each chamber. The figures illustrate the gradation of EM exposure as the NRTF-Republic progressed through various stages before reaching full-power operation in 1989.

In addition to growth chamber data, the data loggers also monitored the earth electric field intensity at the soil amoeba study sites in 1988 through 1992. These data are presented for the antenna and ground sites in Figures F-17 through F-24. Similar data for the control site was below the logger sensitivity level and is, therefore, not presented. Electric field summary statistics were calculated for 1990 and 1991 when antenna operating parameters were rather consistent, and are included in the upper right-hand corner of the plots for these years. These data show that the treatment site electric field intensities were less variable than at the ground site. A thorough discussion of temporal EM field variability is given in Section 4.4.2 of this report.

Soil amoeba growth chambers were not used during the 1992 or 1993 field seasons. Data logger monitoring systems were left on the study sites, however, to monitor climatological parameters during these years. Figures F-25 and F-26 show climatological data collected in 1992 and 1993, respectively. Included are daily high and low air temperatures, soil temperature, and rainfall. Temperatures at the three sites are similar throughout the field seasons. Rainfall events are also similar, as might be expected, but the rainfall levels differ considerably. In 1993, efforts were made to determine whether differences in rainfall levels were actual or simply the effect of differences in the rain gauge placement relative to canopy openings. To this end, additional rain gauges were placed in clearings near each of the three study sites on 22, 23 July. These rain gauge levels were read each time data loggers were offloaded, giving cumulative rainfall levels for periods between offloads. Cumulative rainfall levels measured under the canopies and in clearings are compared in the bar chart in Figure F-27. This chart suggests that differences in rainfall levels measured under the canopies may simply be expected because of differences in rainfall levels in the localized areas. Differences in localized areas are evidenced by the rainfall measurements in clearings near each site. In addition to this variation, the percentage of total rainfall that reaches the rain gauge under the canopy can also be seen in Figure F-27 to differ with time at any given site. Reasons for this variation include the obvious defoliation in the fall. During periods of consistent canopy coverage as in the summer, however, reasons are less obvious. Possibilities include variations in accompanying winds and intensity of rainfall. Such unknowns confound the interpretation of these data; however, it remains useful for corroboration with soil moisture data taken at each site by the study investigator.

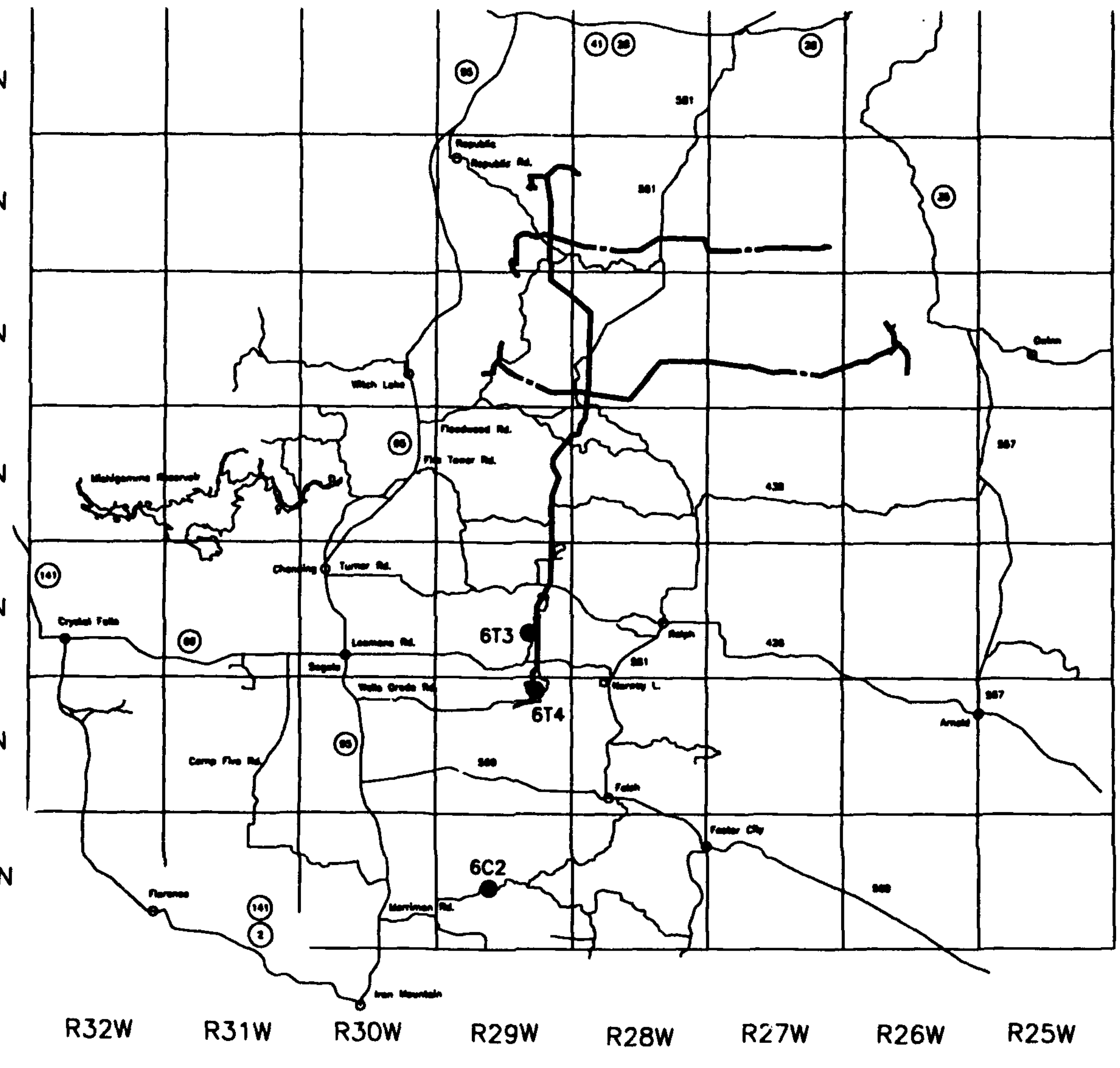


FIGURE F-1. POSITIONS OF SOIL AMOEBA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

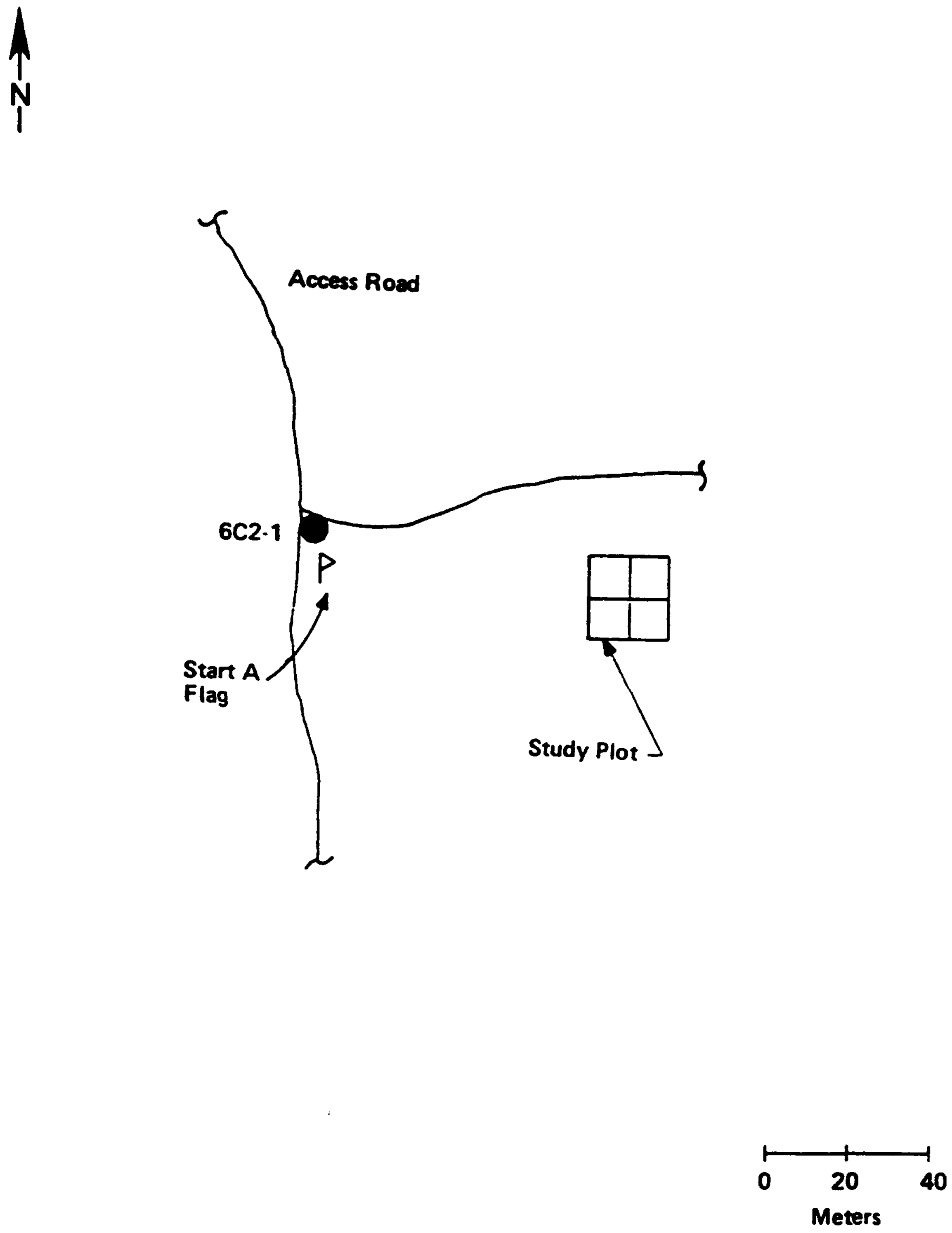


FIGURE F-2. MEASUREMENT POINT AT MERRIMAN TRUCK ROAD CONTROL; 6C2-1.

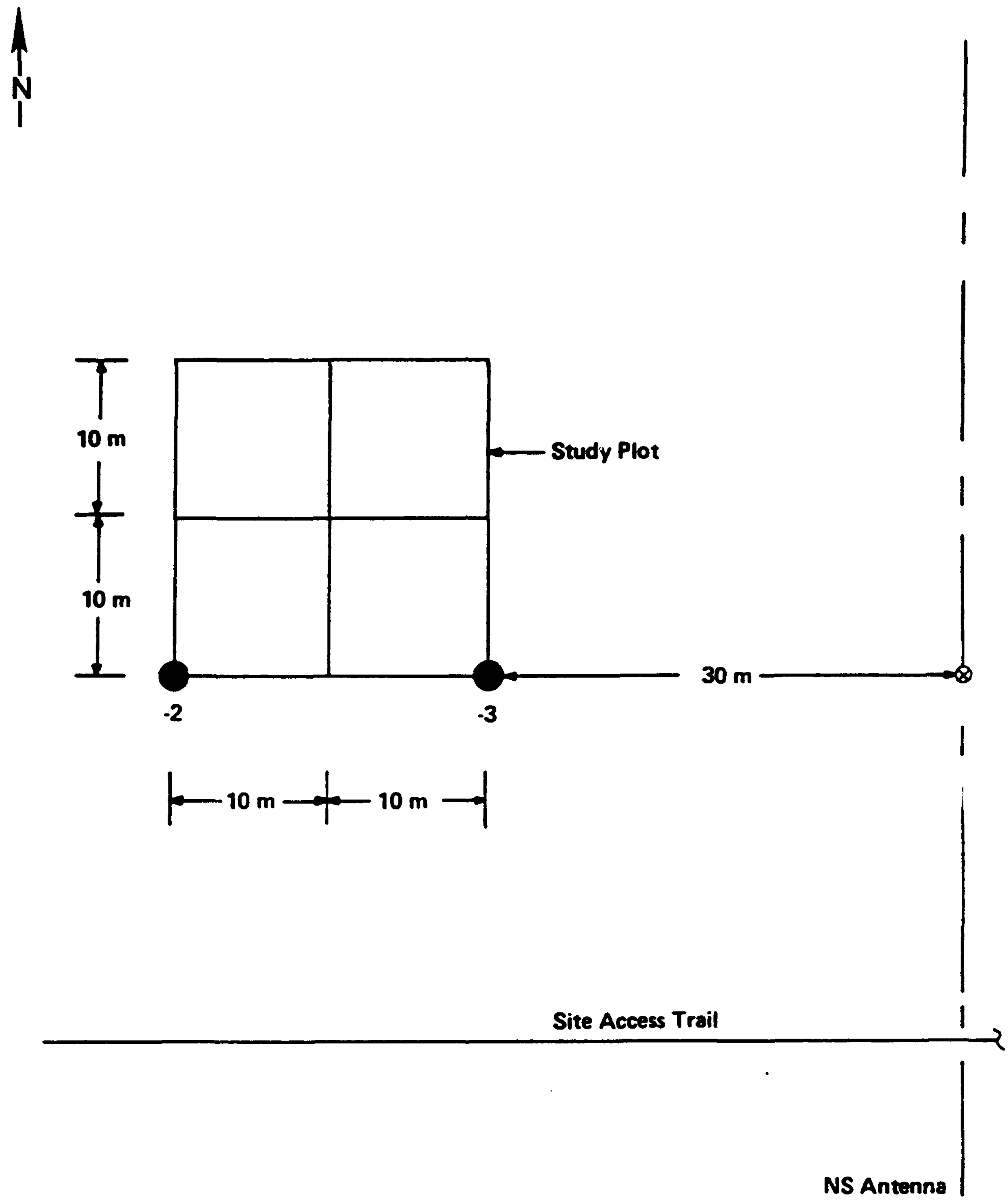


FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD; 6T3-2, 3.

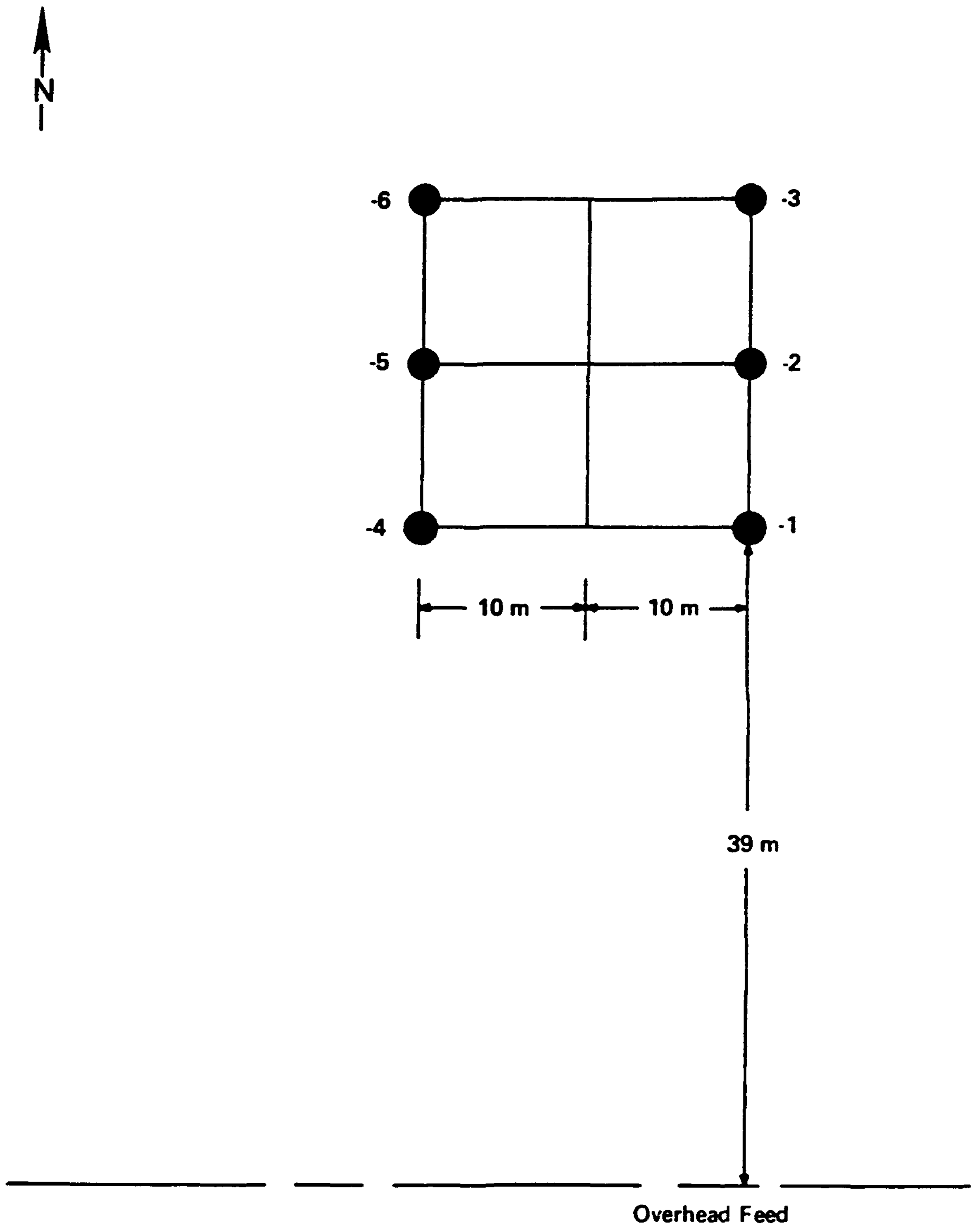


FIGURE F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND; 6T4-1 THROUGH 6.

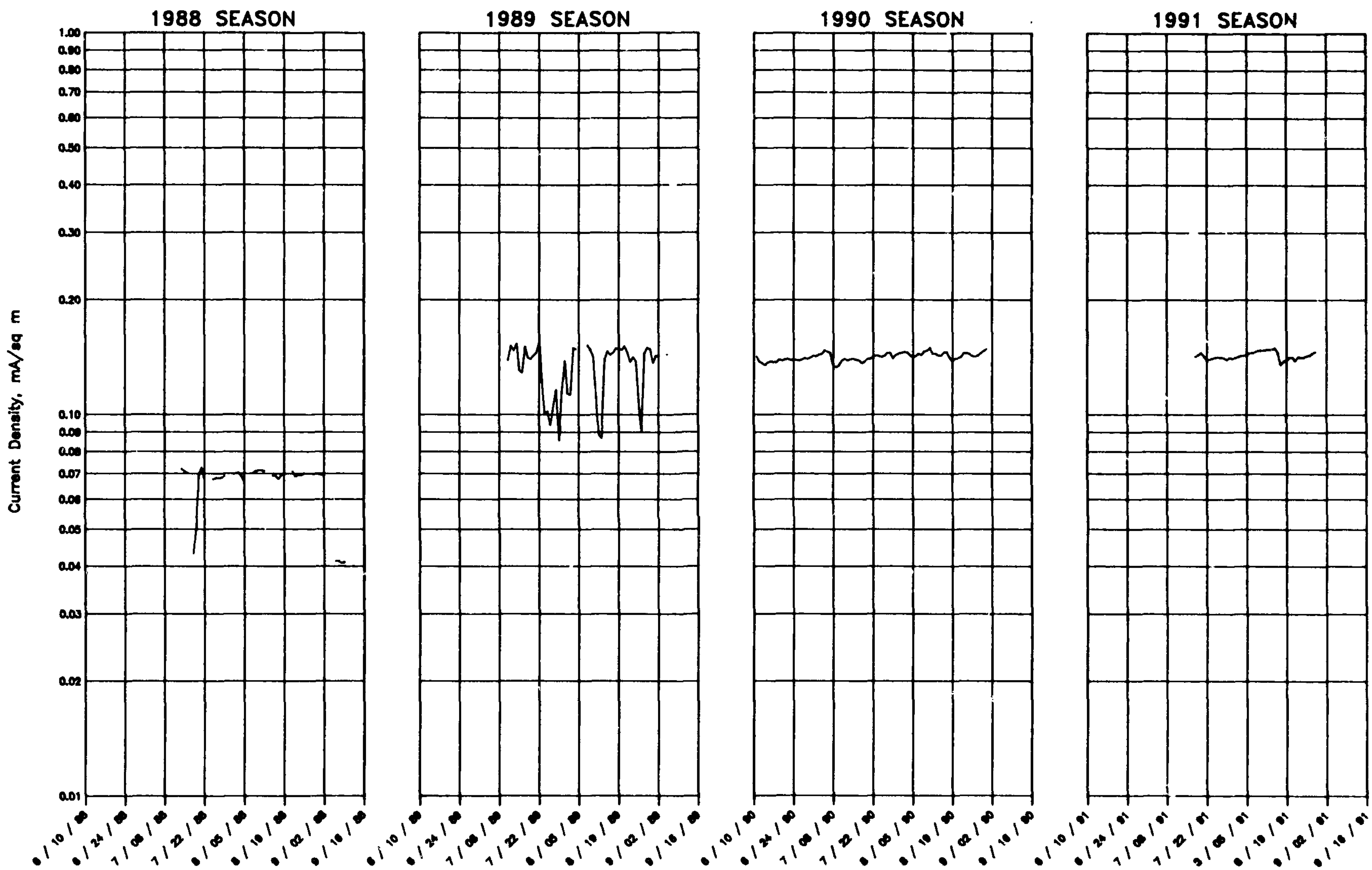


FIGURE F-5. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 1 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

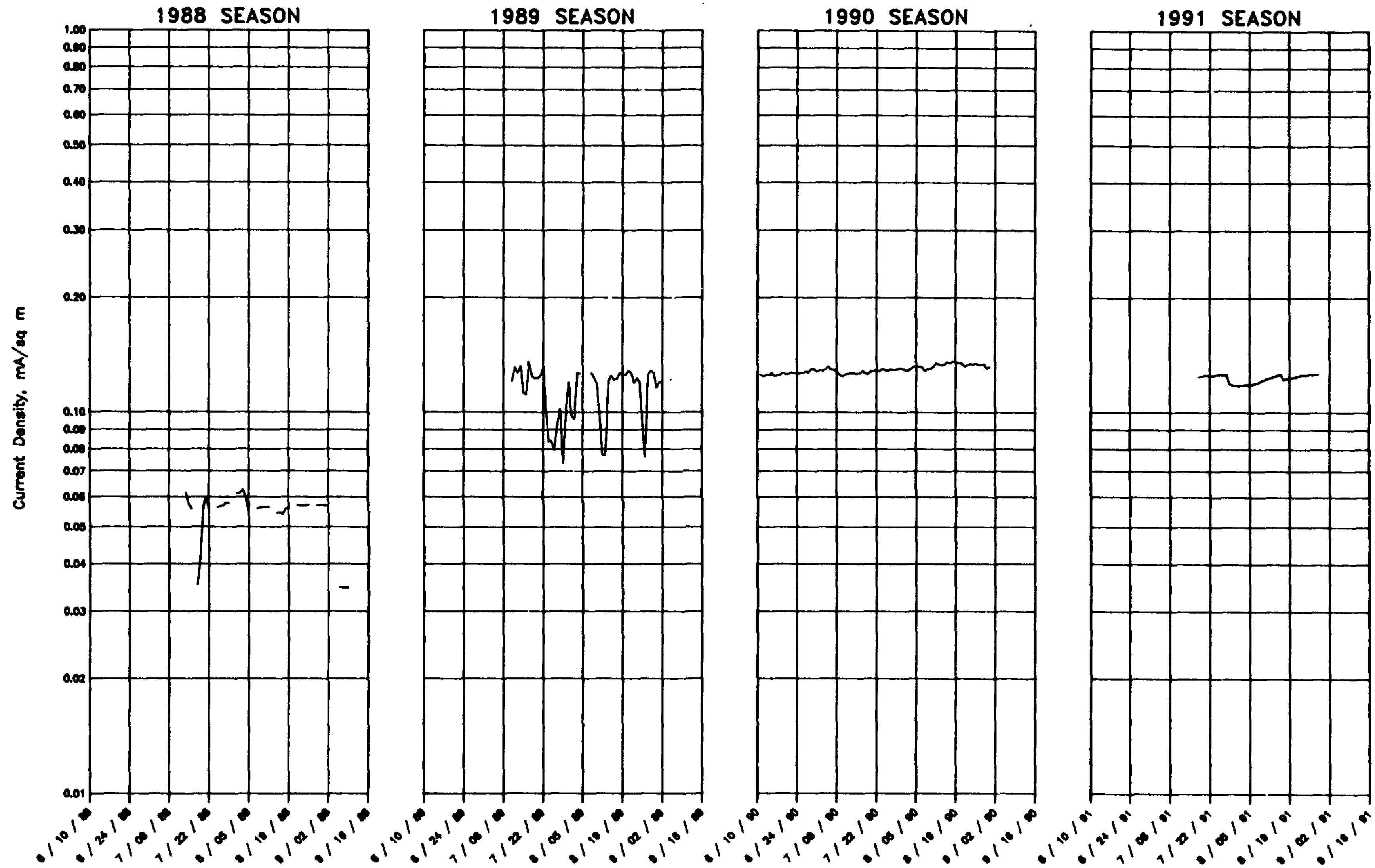


FIGURE F-6. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 2 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

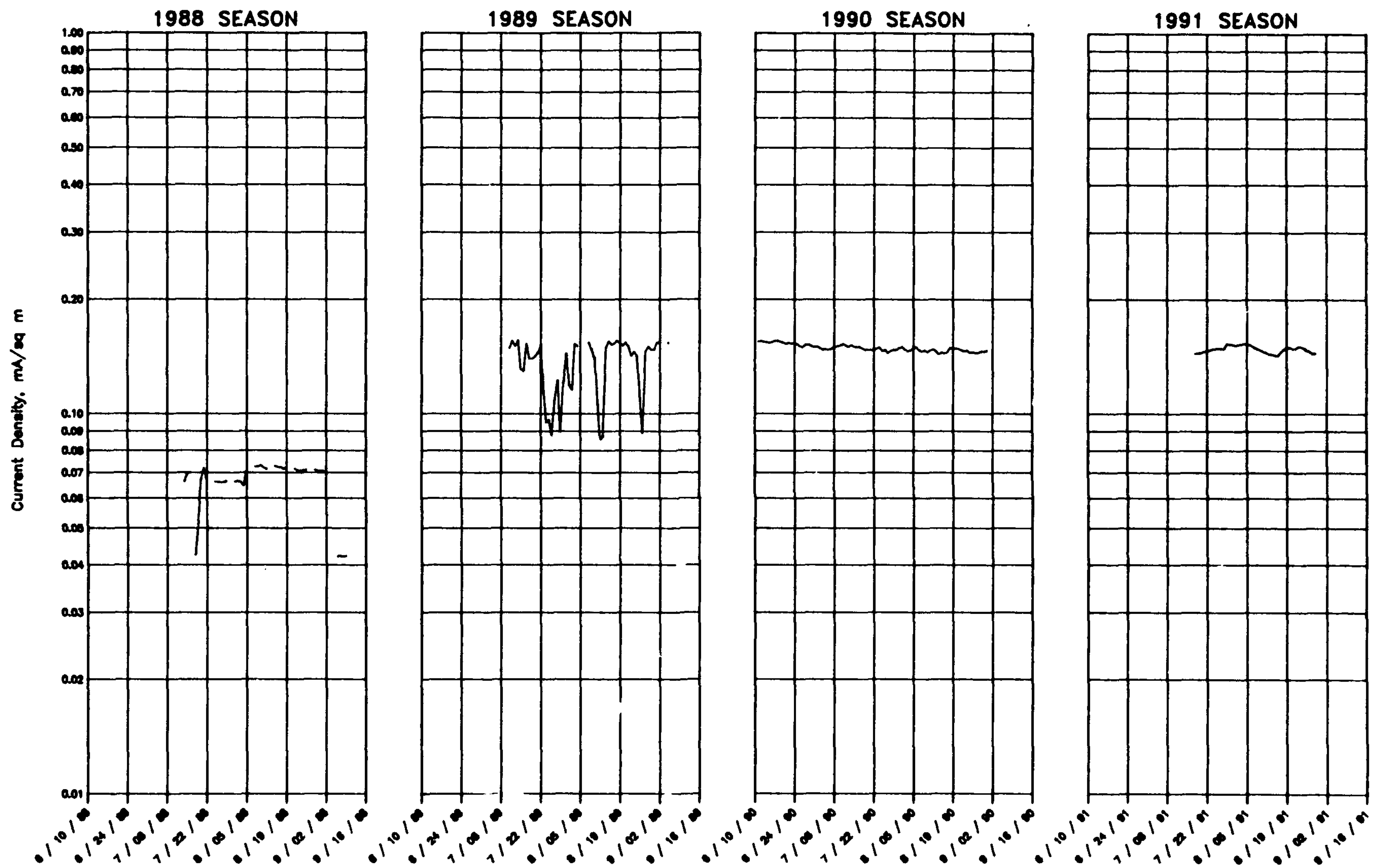


FIGURE F-7. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 3 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

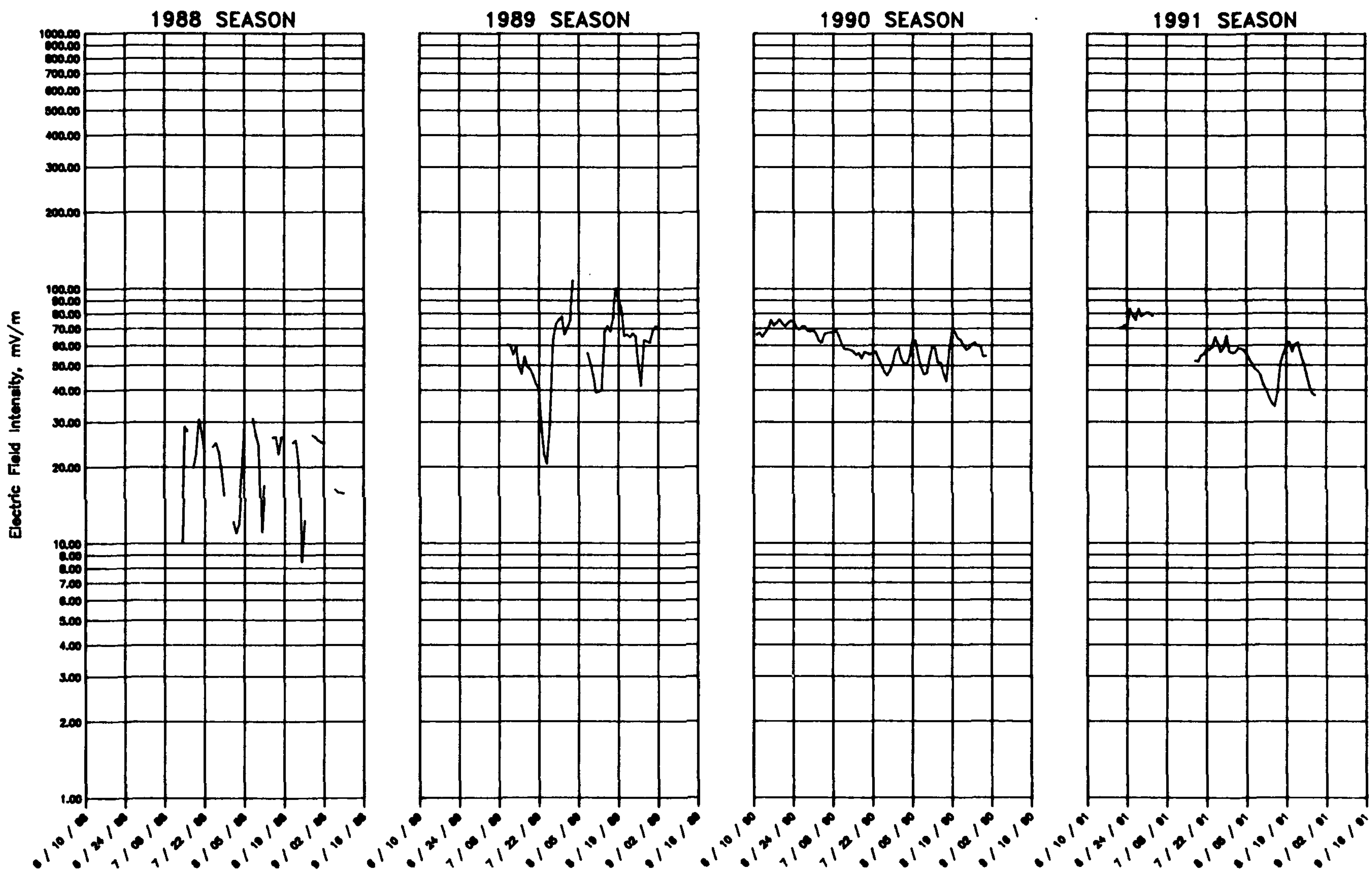


FIGURE F-8. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 4 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

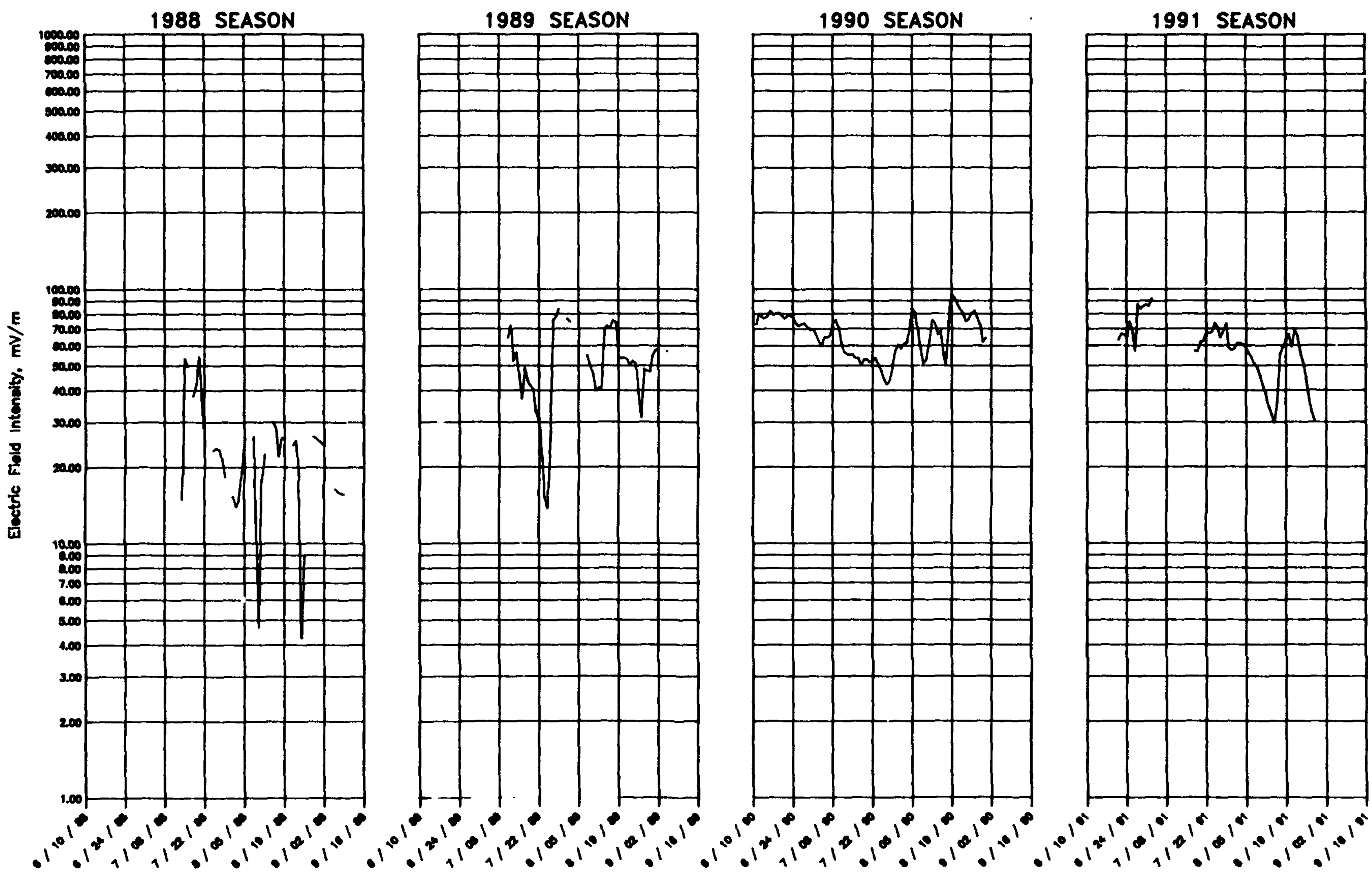


FIGURE F-9. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 5 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

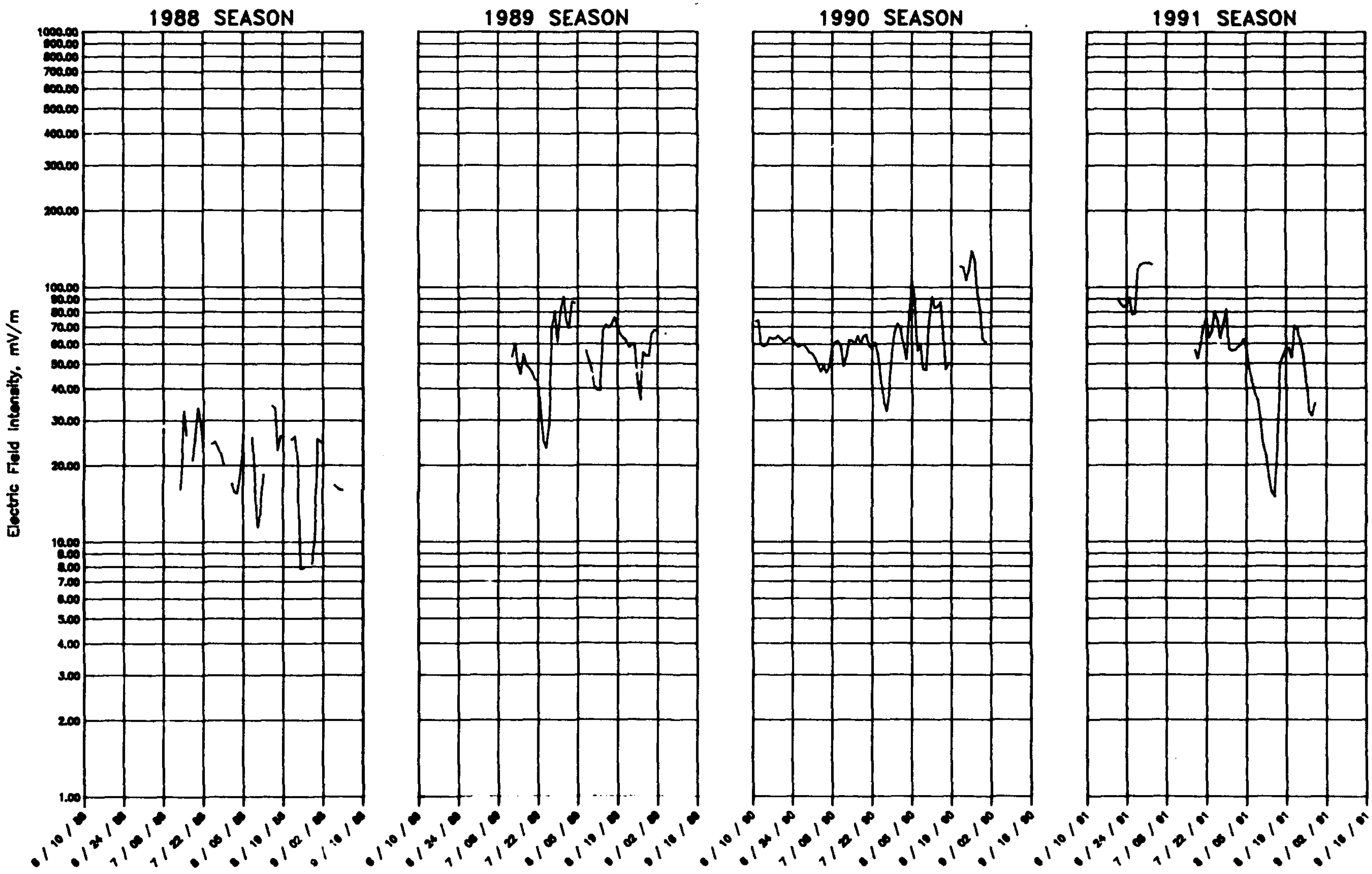


FIGURE F-10. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 6 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

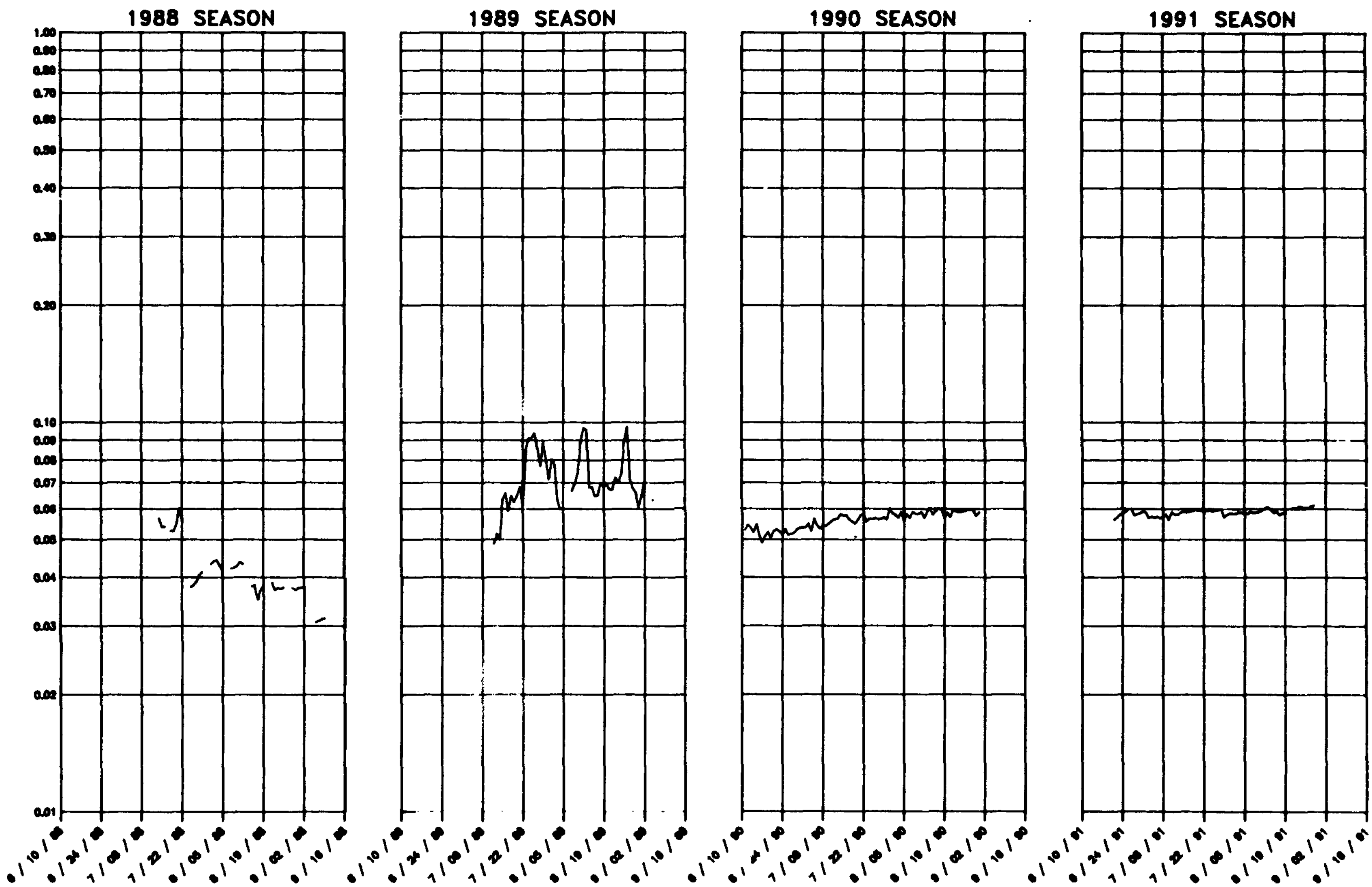


FIGURE F-11. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 1 AT THE SOIL AMOEBA GROUND STUDY SITE.

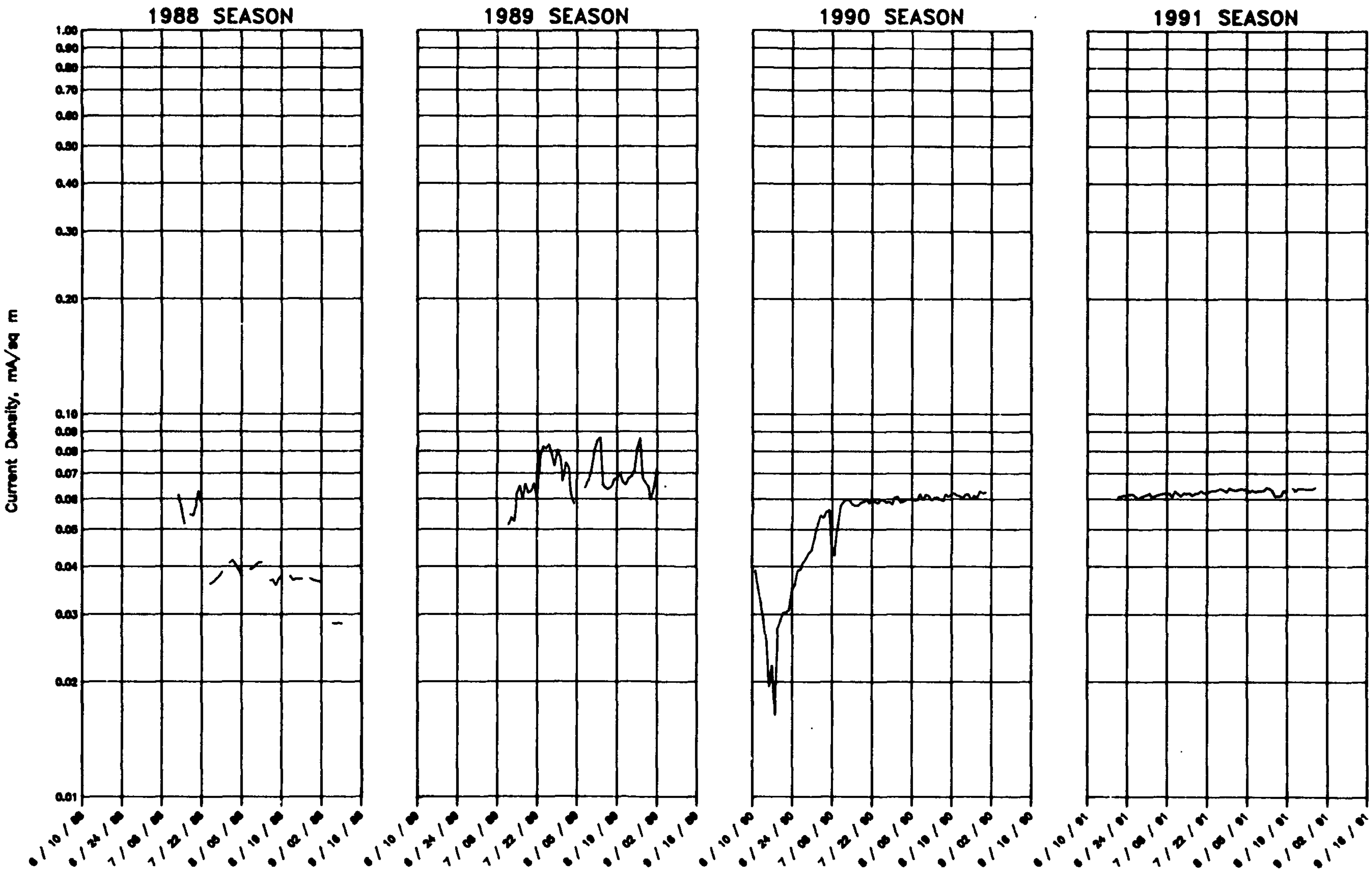


FIGURE F-12. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 2 AT THE SOIL AMOEBA GROUND STUDY SITE.

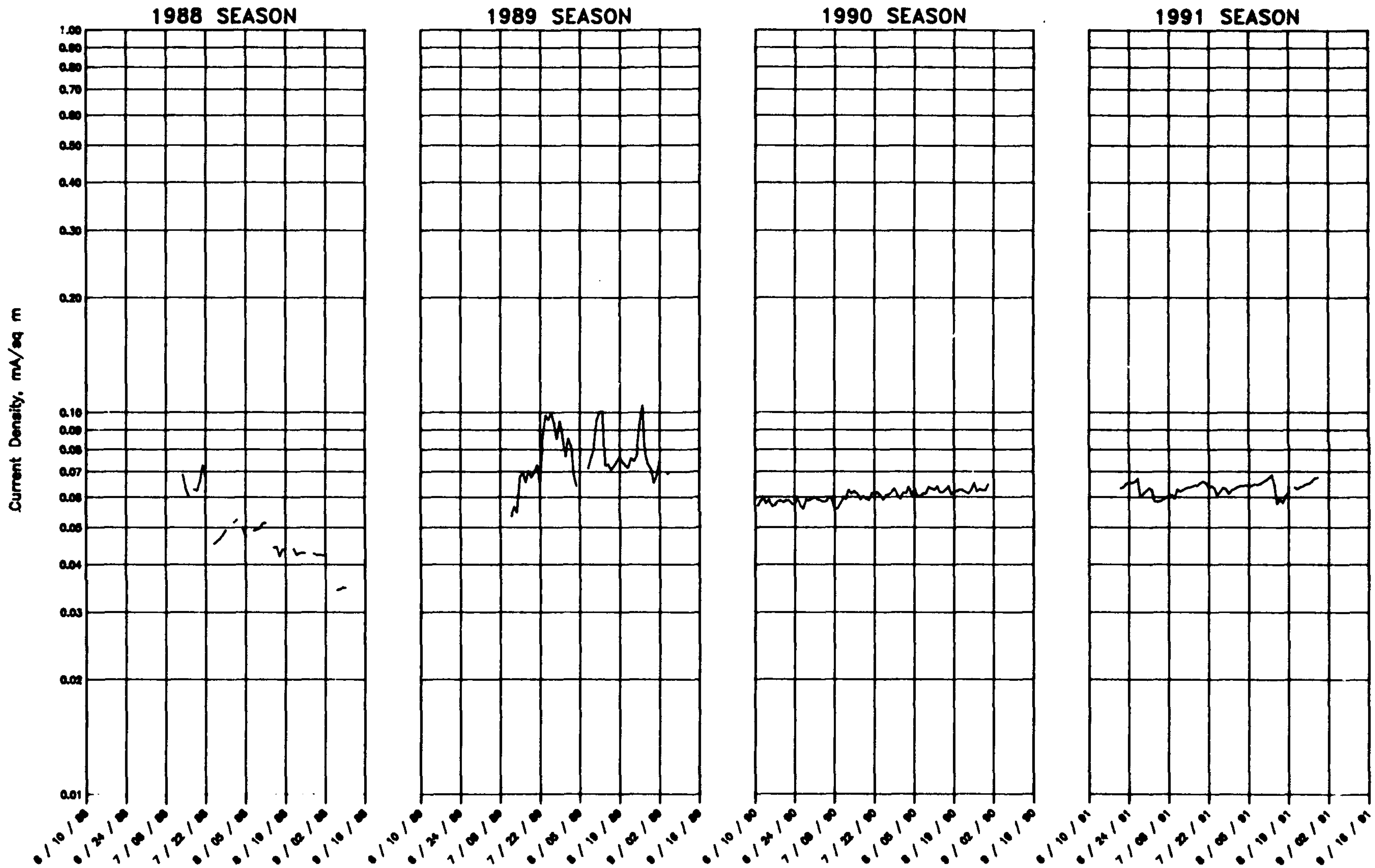


FIGURE F-13. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 3 AT THE SOIL AMOEBA GROUND STUDY SITE.

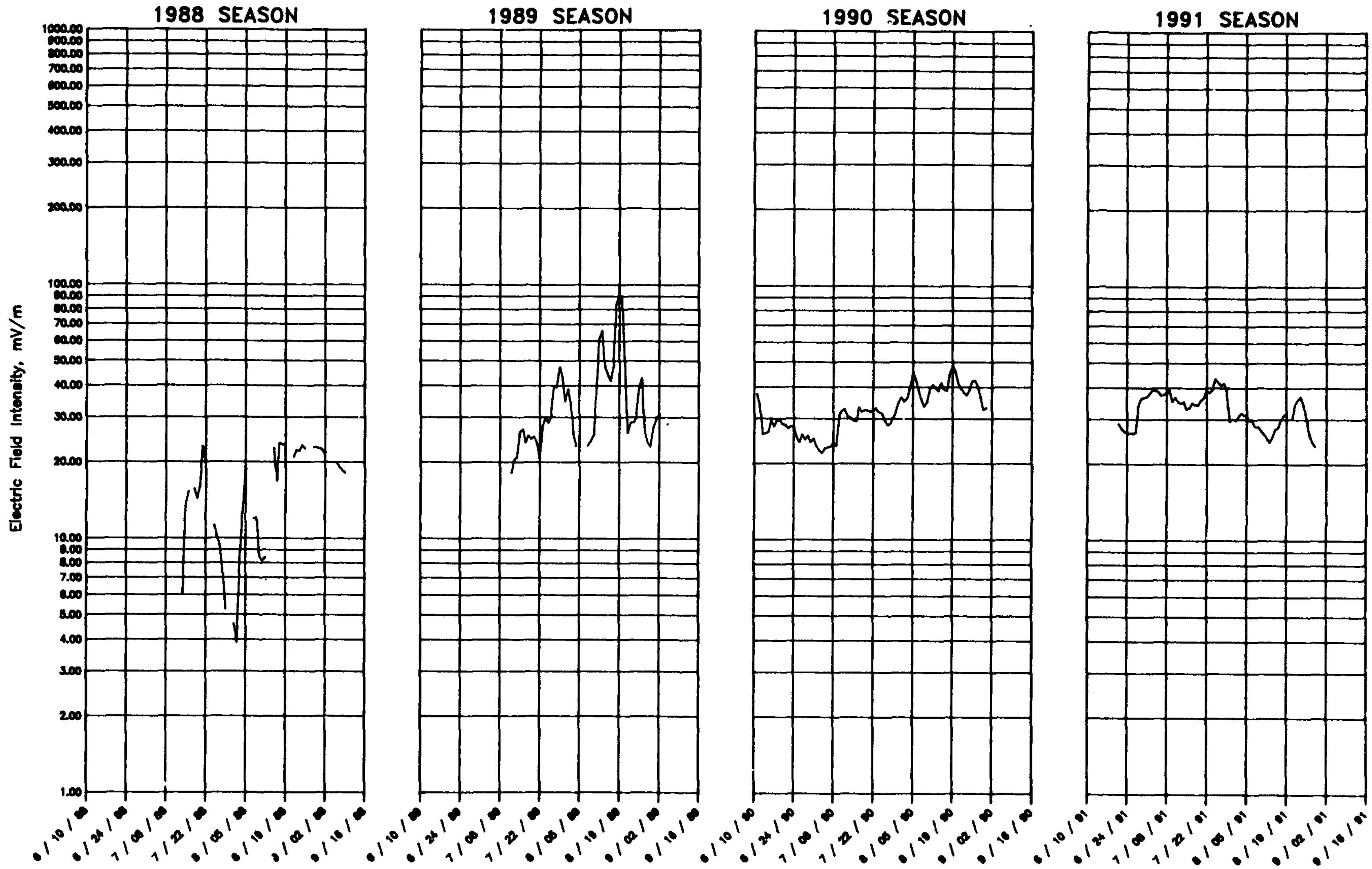


FIGURE F-14. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 4 AT THE SOIL AMOEBA GROUND STUDY SITE.

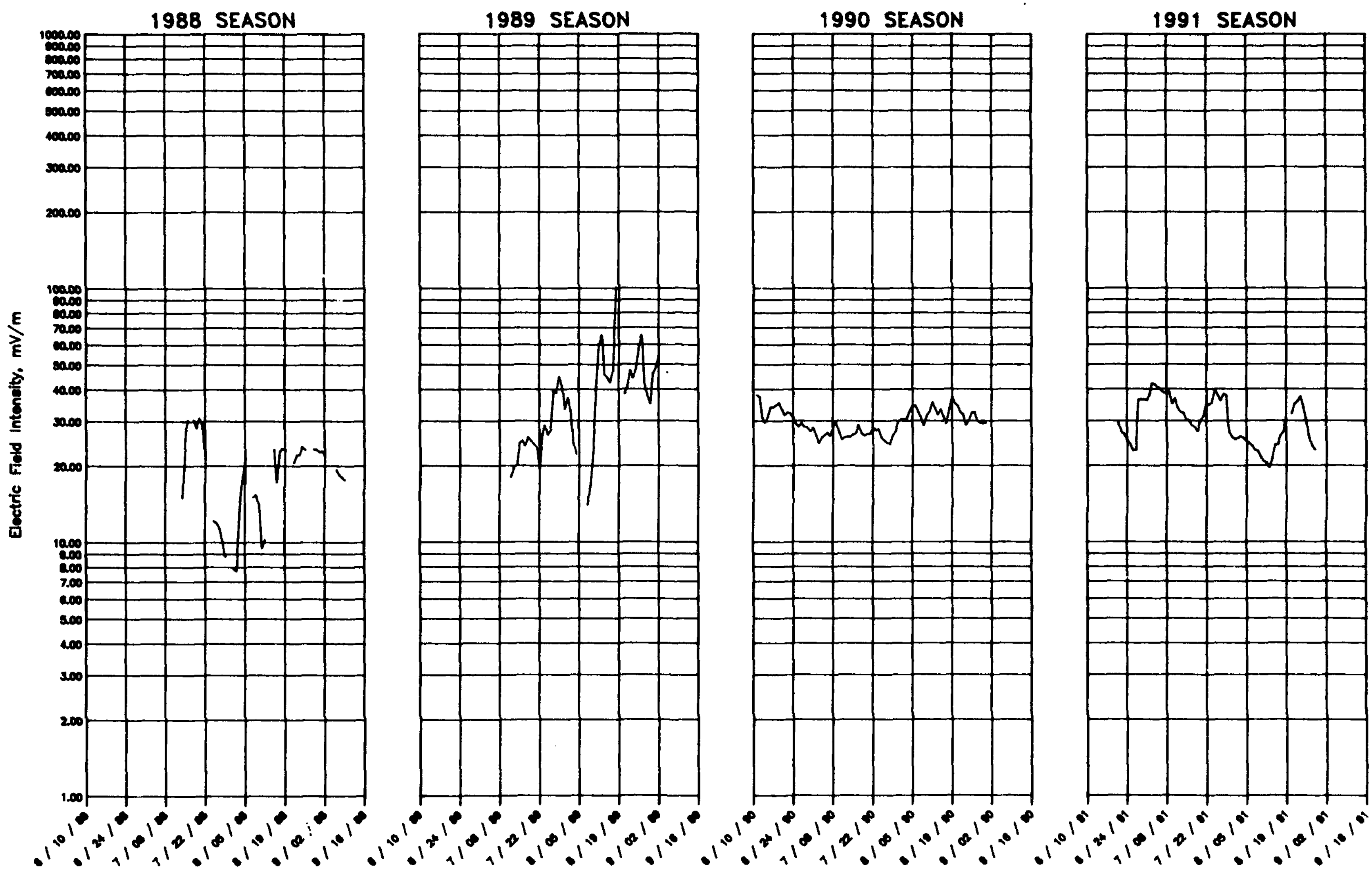


FIGURE F-15. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 5 AT THE SOIL AMOEBA GROUND STUDY SITE.

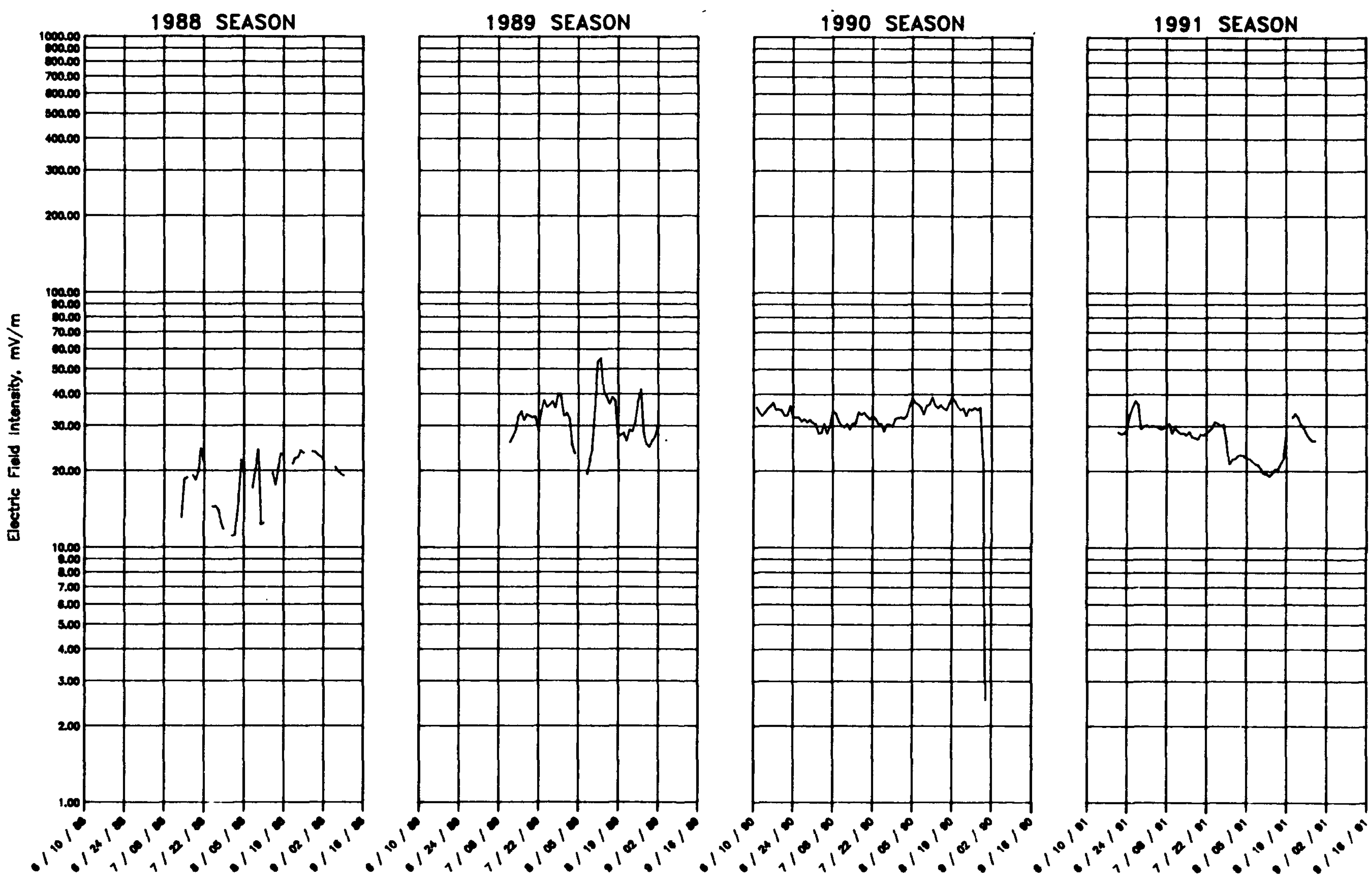


FIGURE F-16. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 6 AT THE SOIL AMOEBA GROUND STUDY SITE.

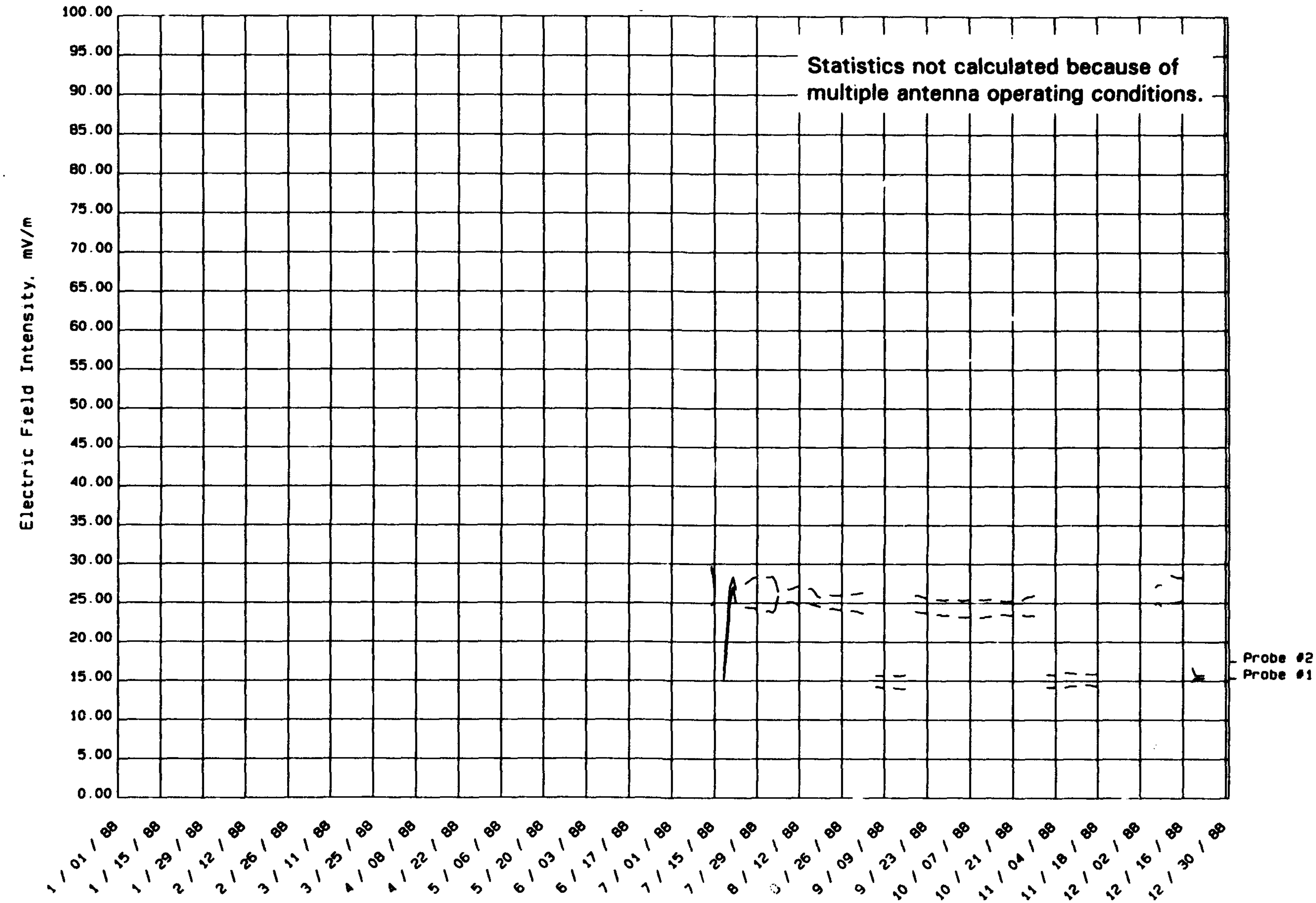


FIGURE F-17. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA ANTENNA SITE; 6T3.

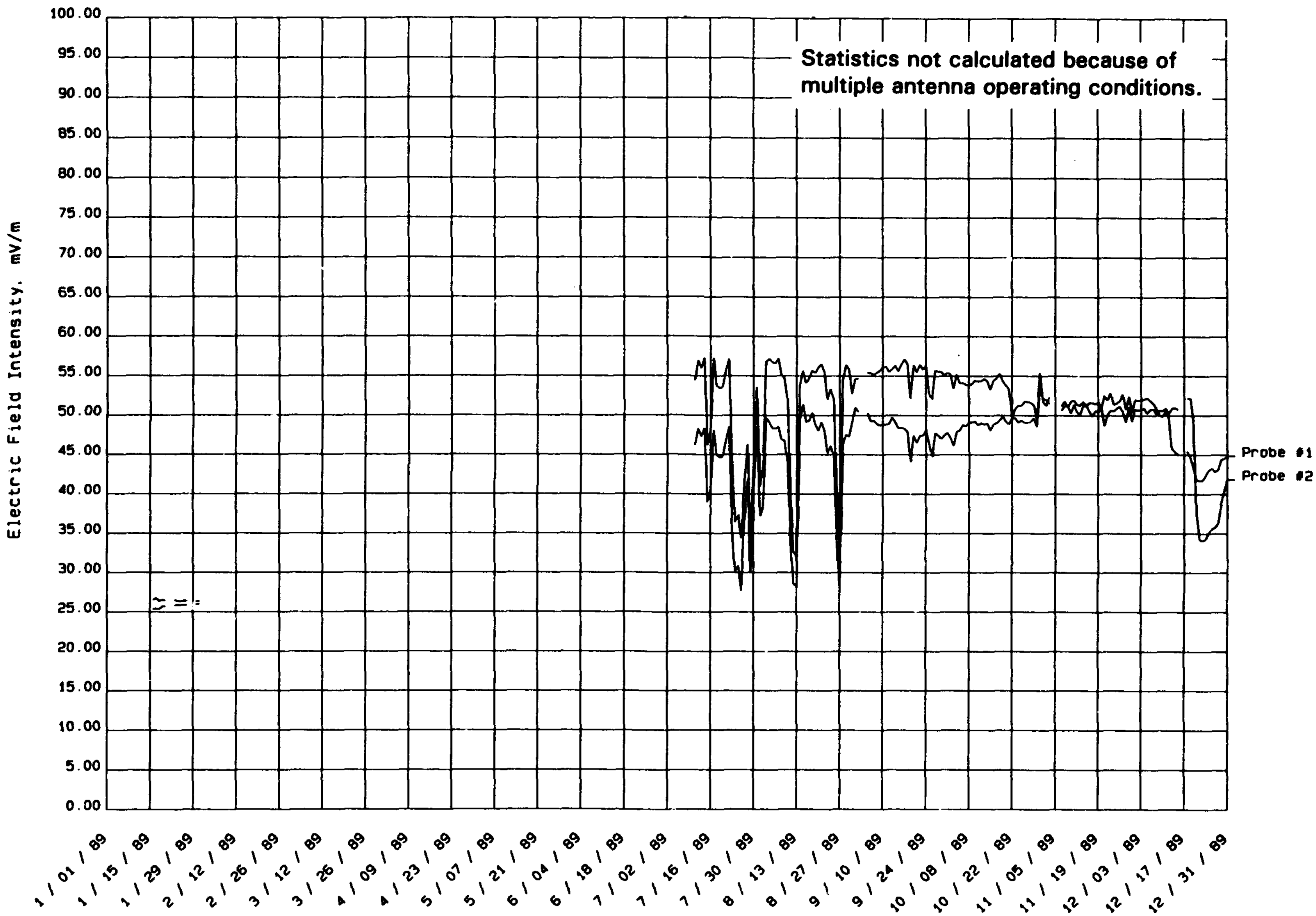
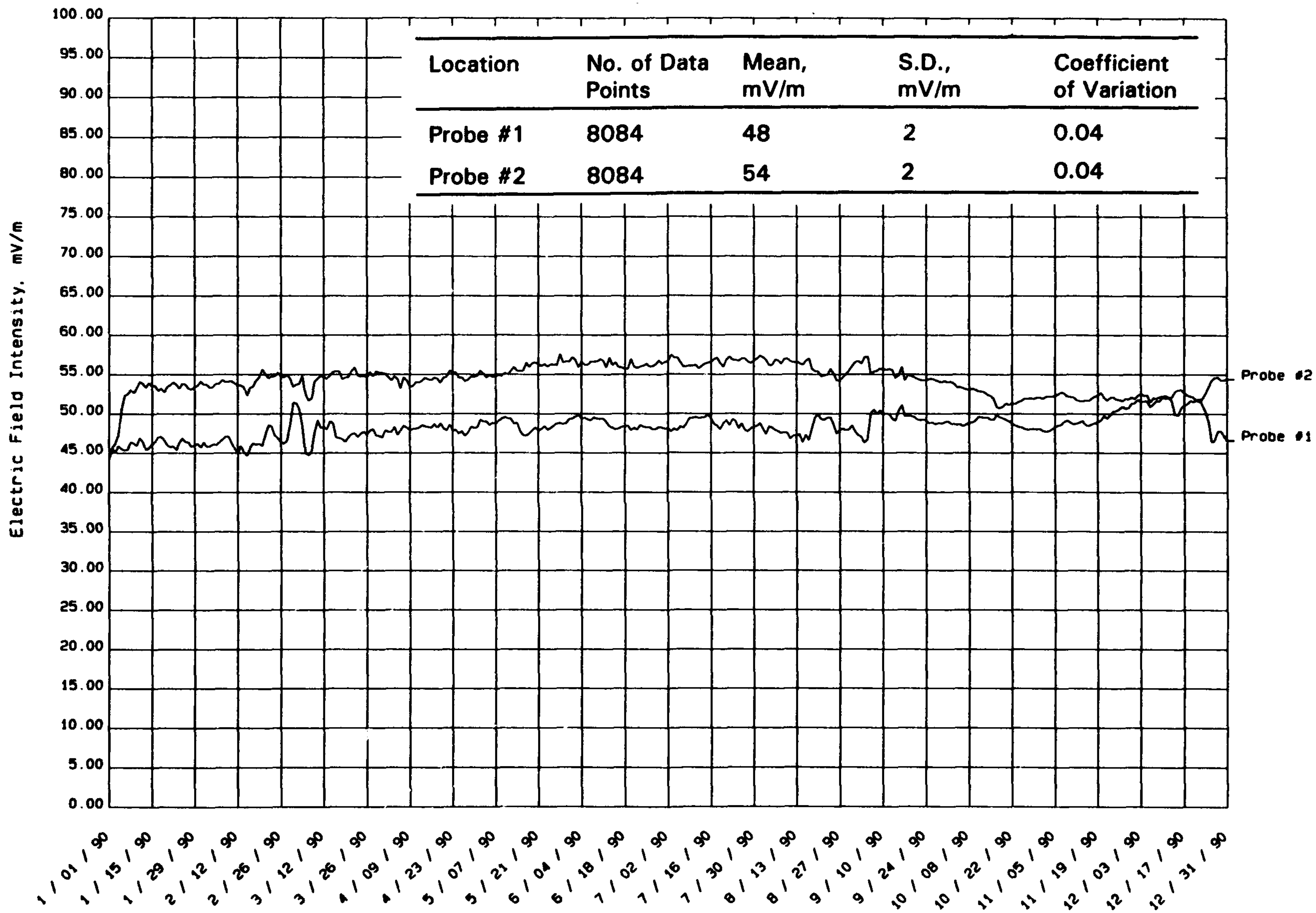
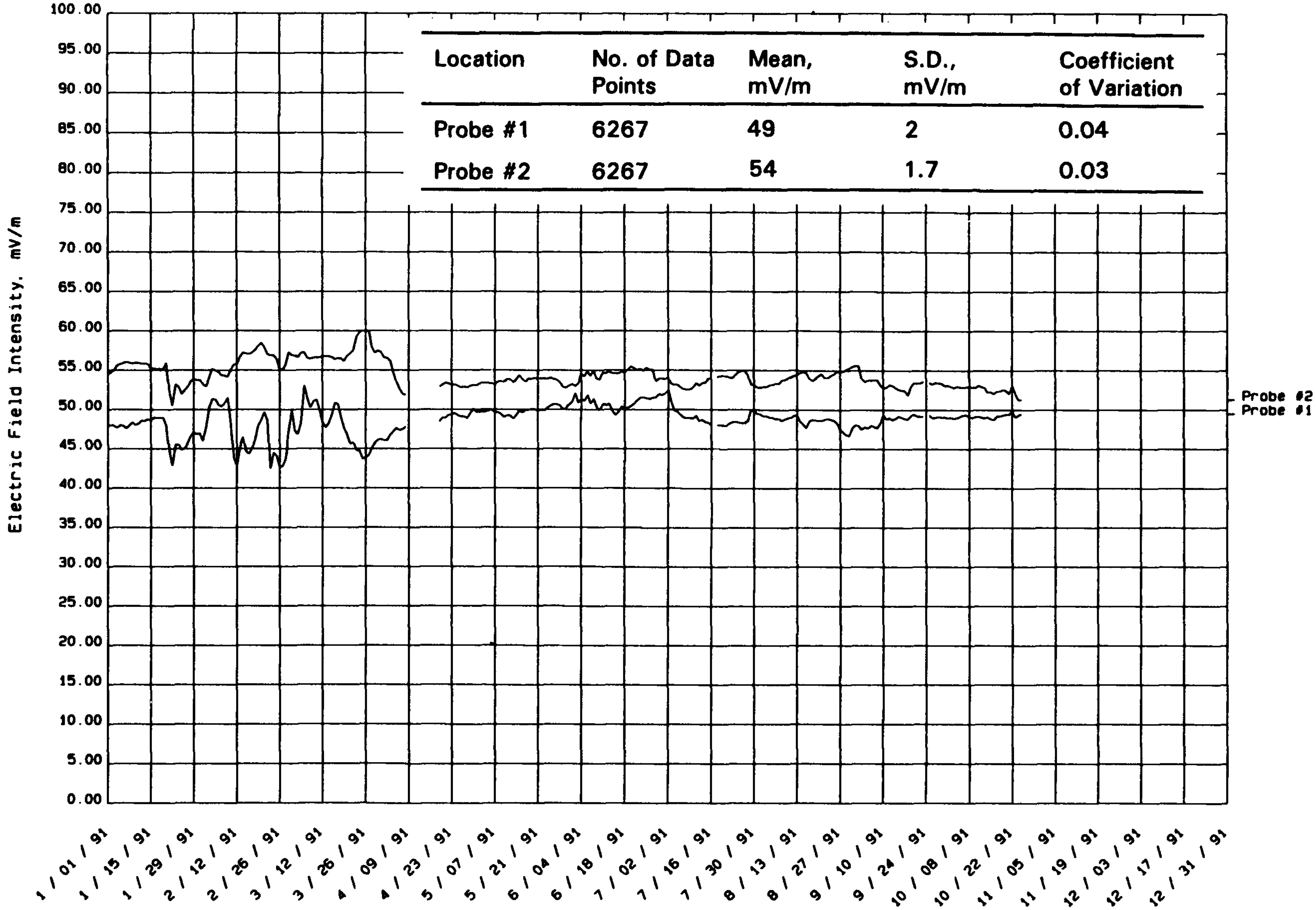


FIGURE F-18. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA ANTENNA SITE; 6T3.



Location	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variation
Probe #1	8084	48	2	0.04
Probe #2	8084	54	2	0.04

FIGURE F-19. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA ANTENNA SITE; 6T3.



Location	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variation
Probe #1	6267	49	2	0.04
Probe #2	6267	54	1.7	0.03

FIGURE F-20. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA ANTENNA SITE; 6T3.

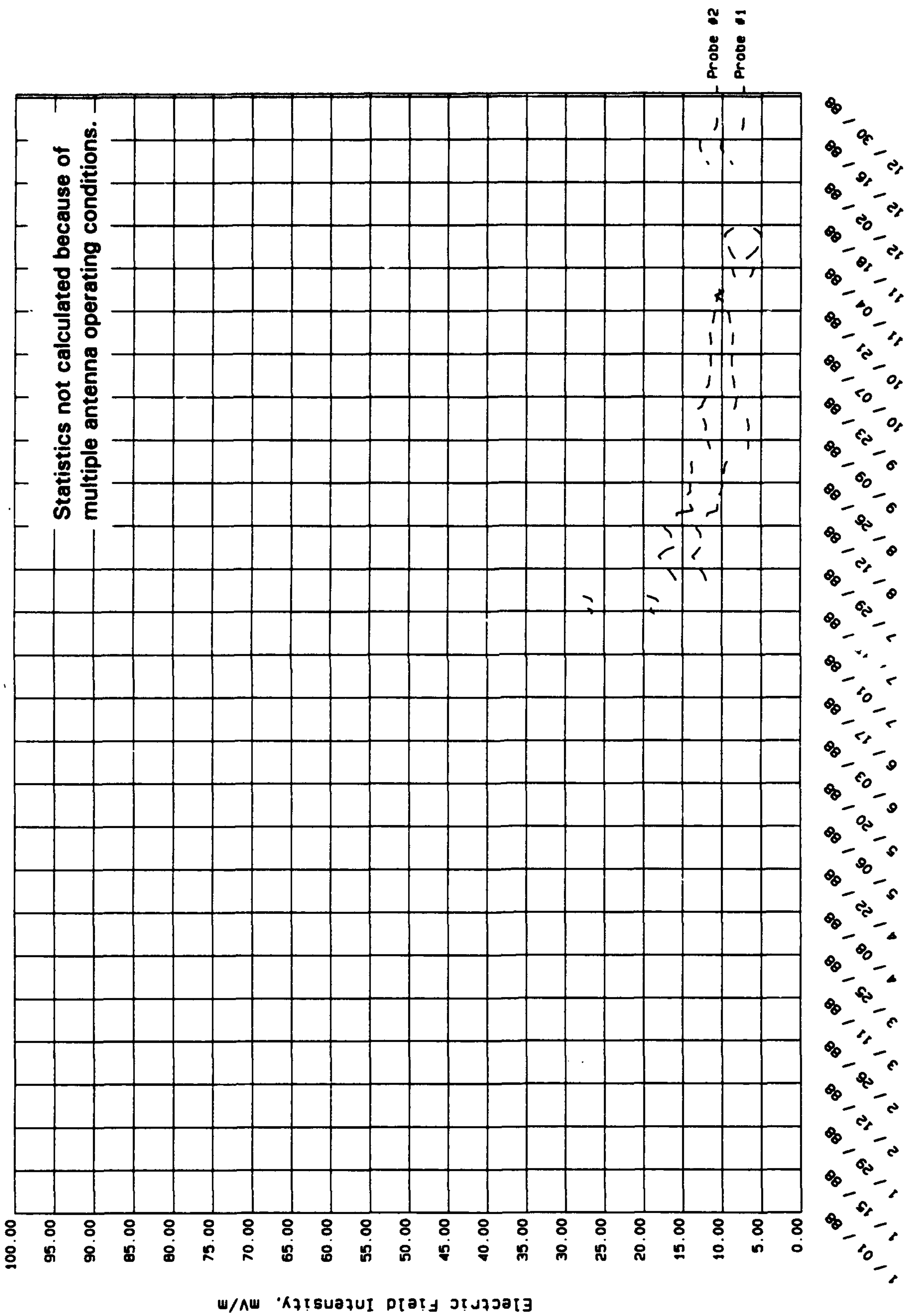


FIGURE F-21. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA GROUND SITE; 6T4.

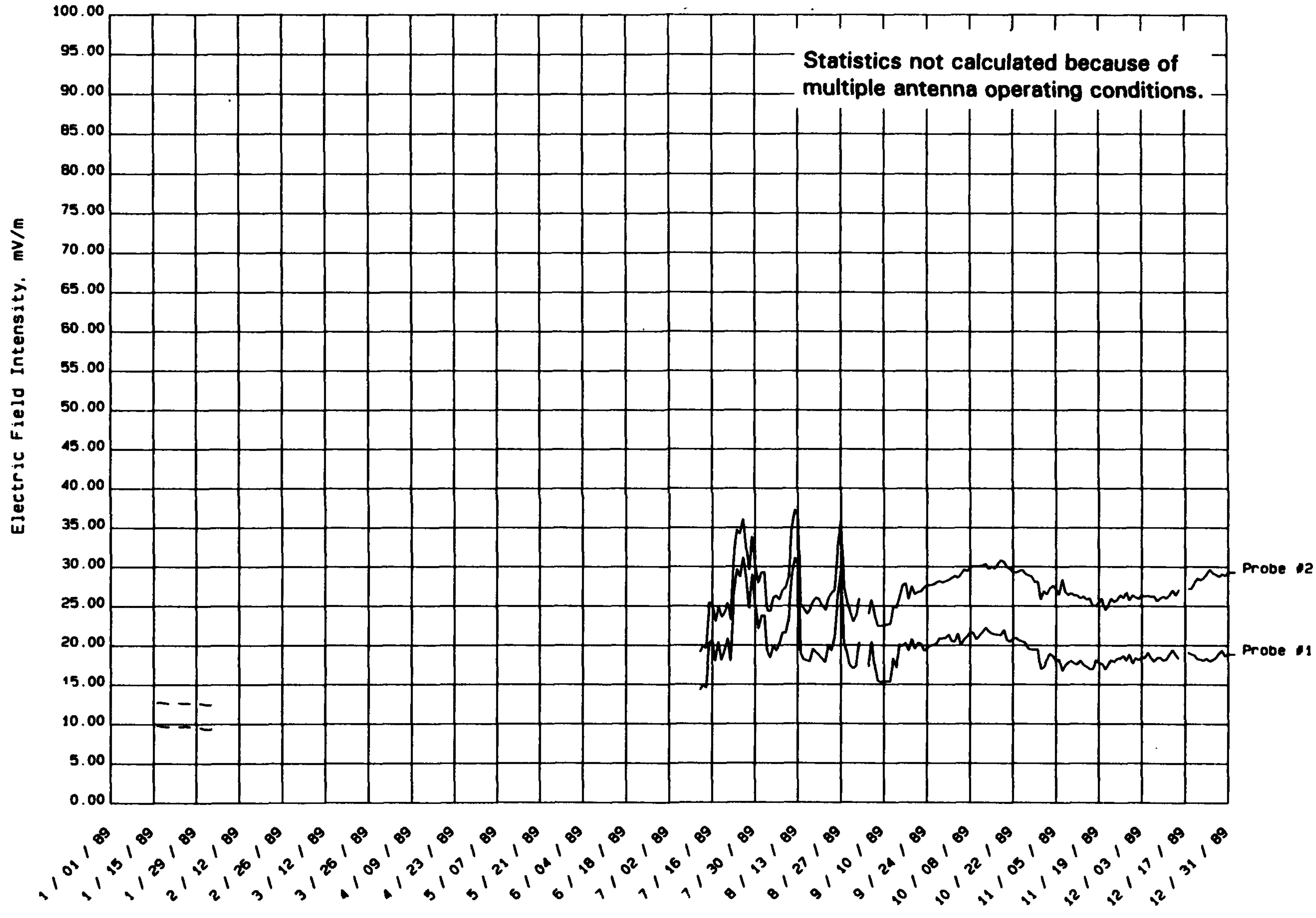
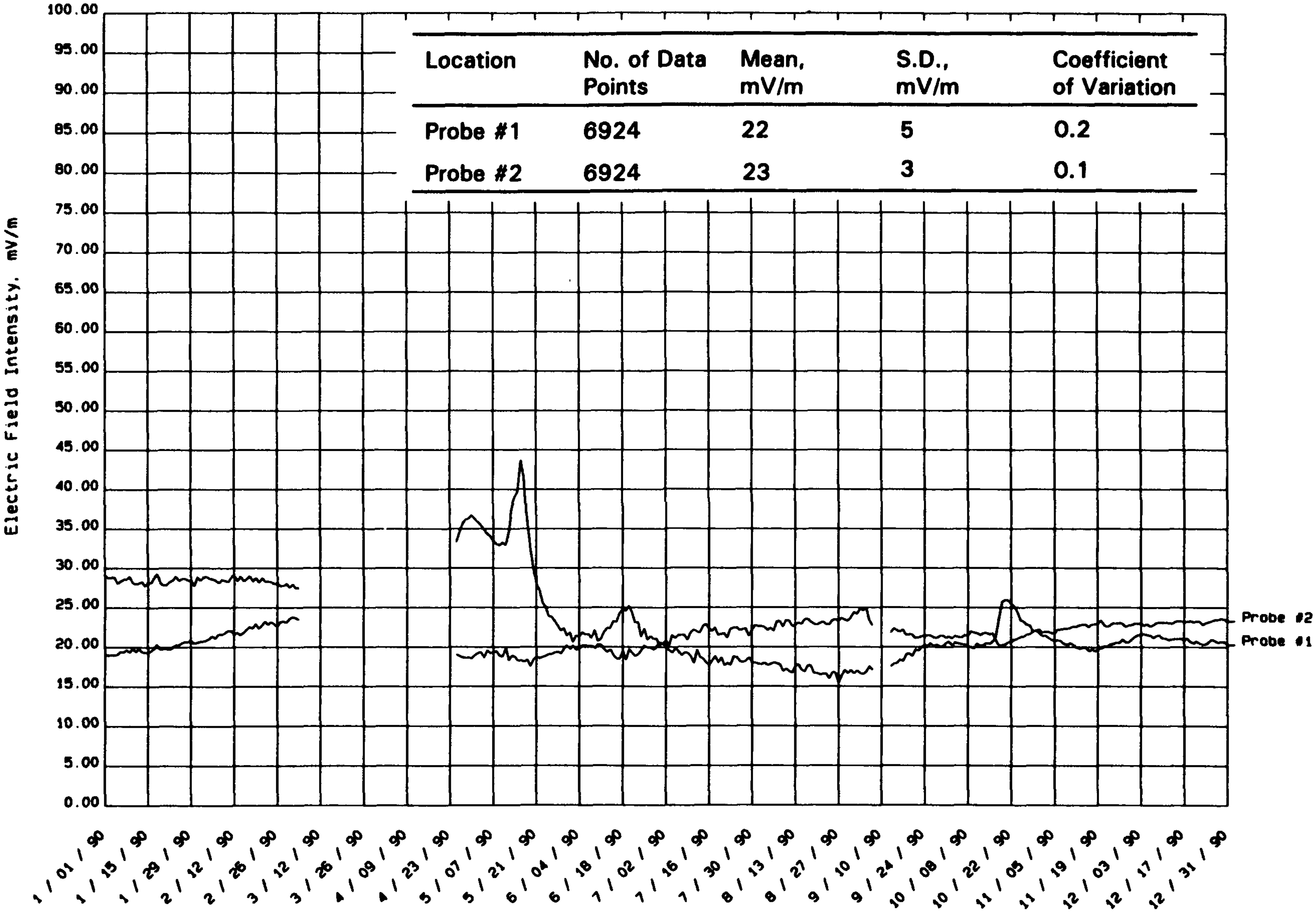
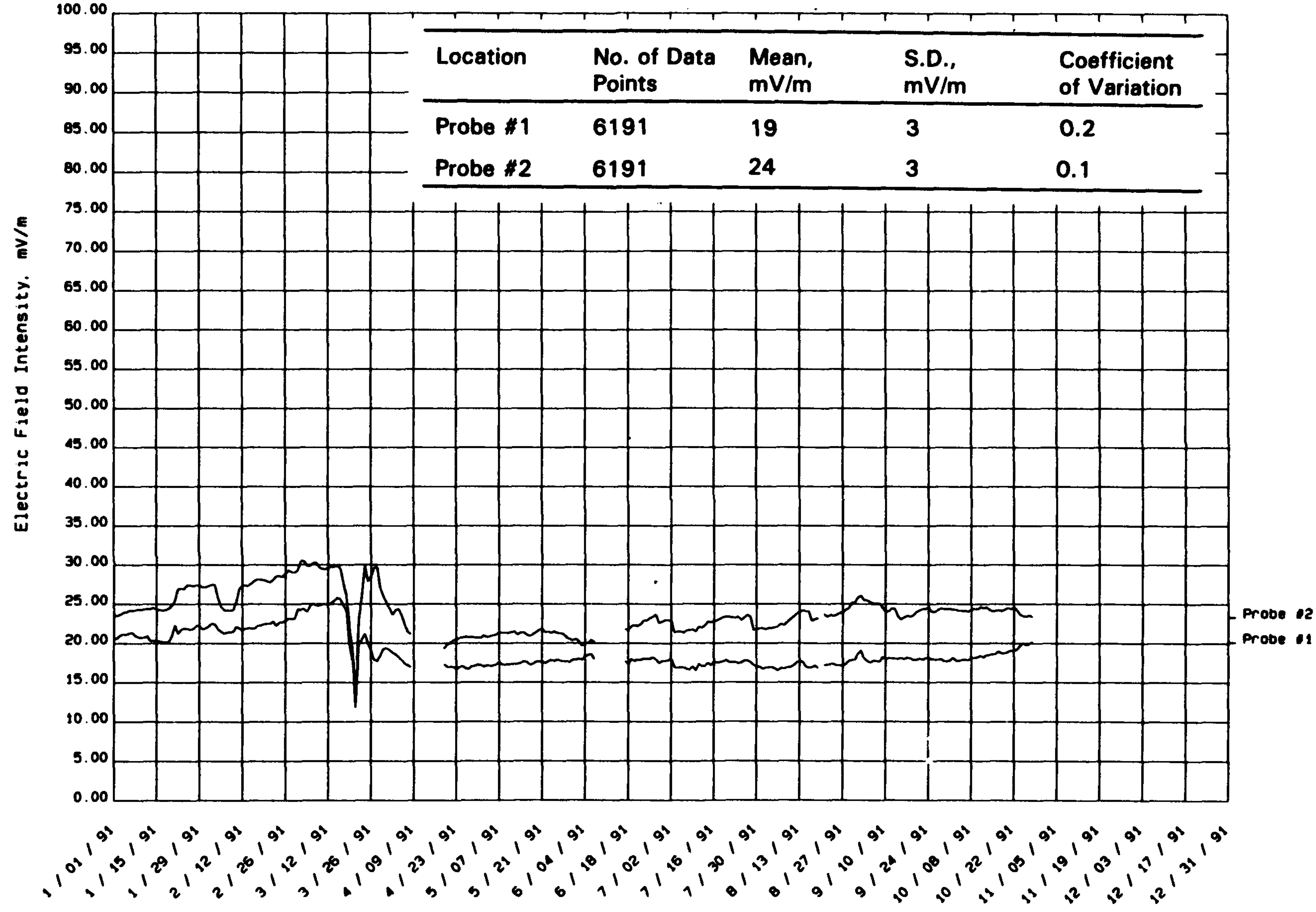


FIGURE F-22. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA GROUND SITE; 6T4.



Location	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variation
Probe #1	6924	22	5	0.2
Probe #2	6924	23	3	0.1

FIGURE F-23. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA GROUND SITE; 6T4.



Location	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variation
Probe #1	6191	19	3	0.2
Probe #2	6191	24	3	0.1

FIGURE F-24. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT SOIL AMOEBA GROUND SITE; 6T4.

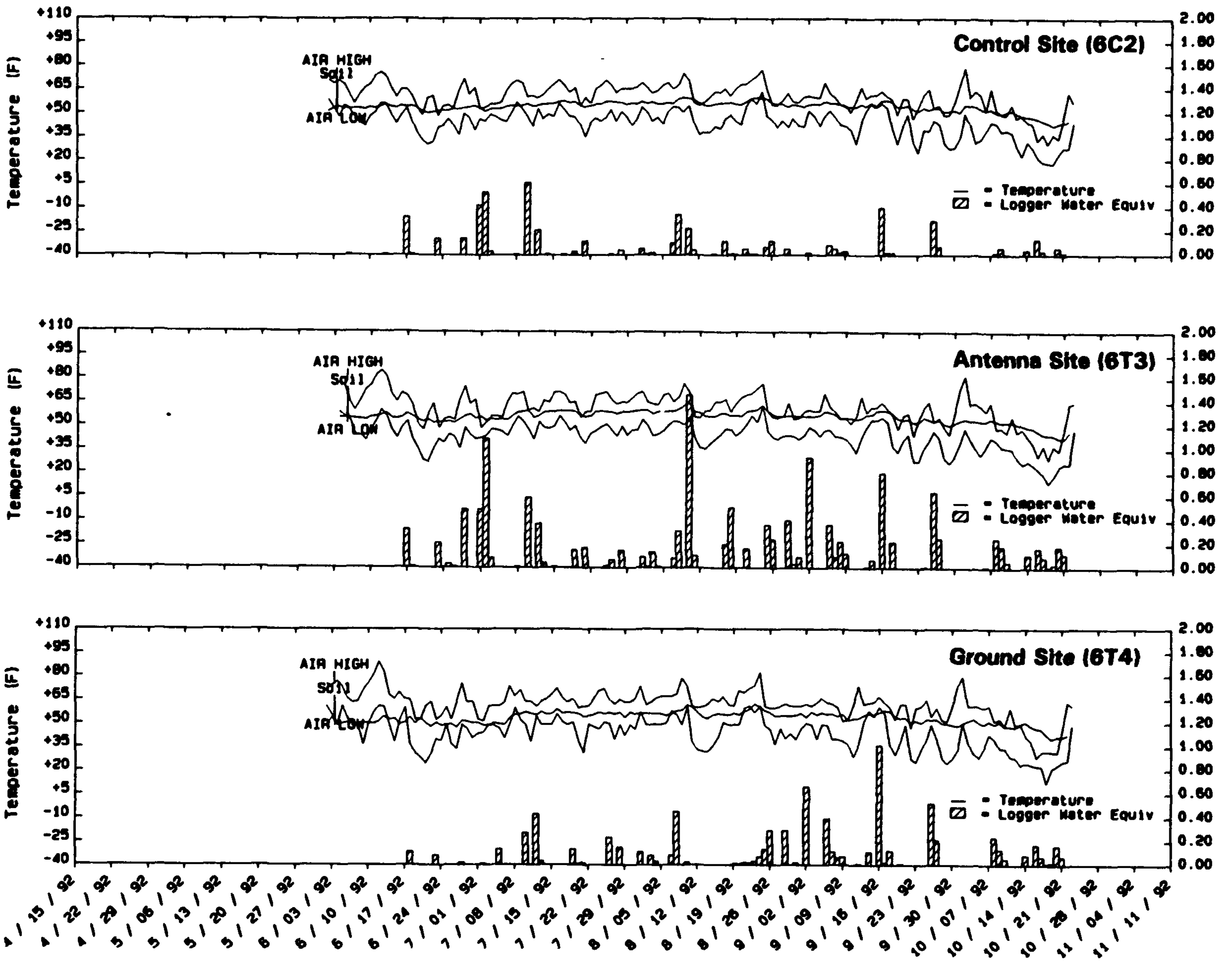


FIGURE F-25. 1992 CLIMATOLOGICAL DATA COLLECTED AT SOIL AMOEBA STUDY SITES.

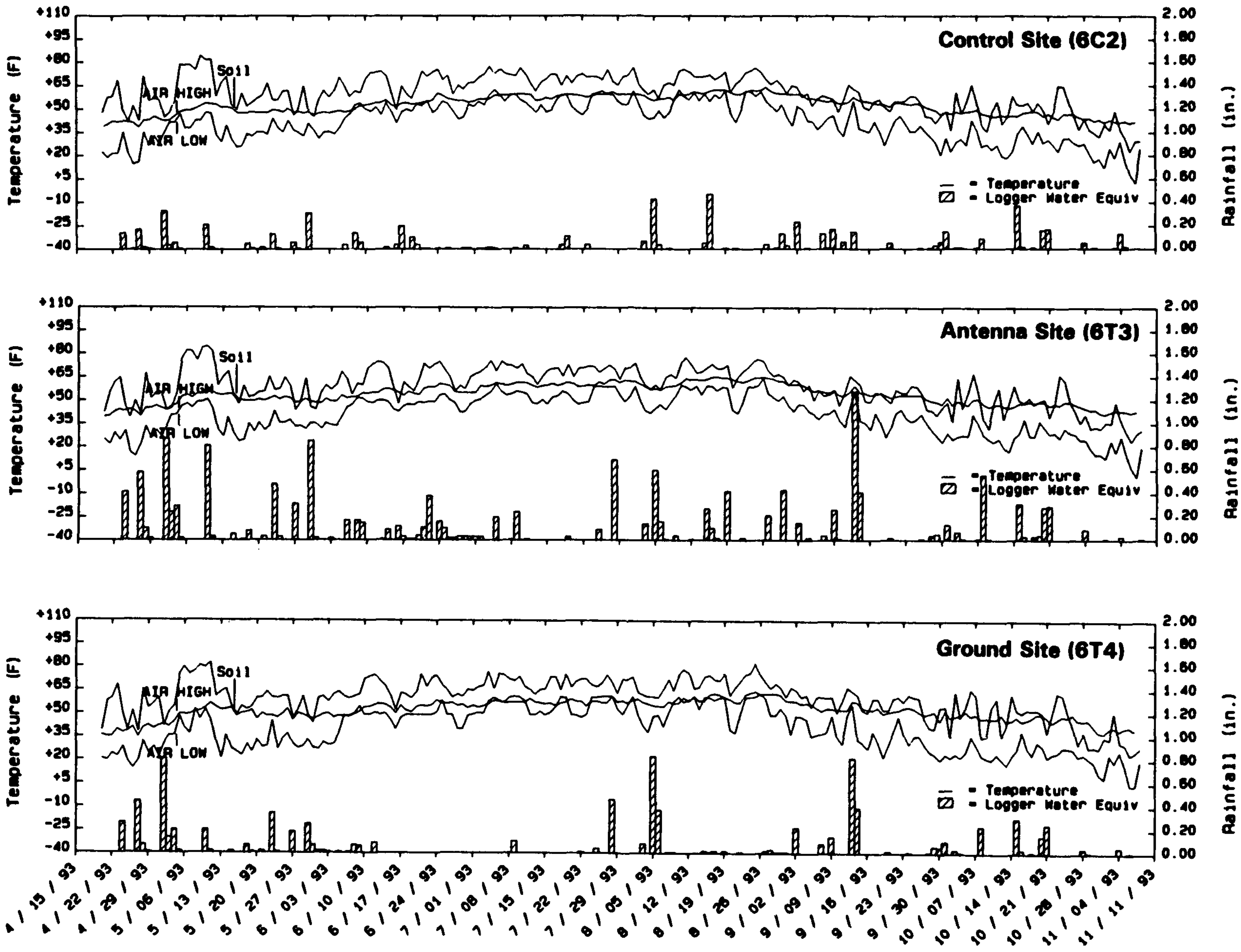
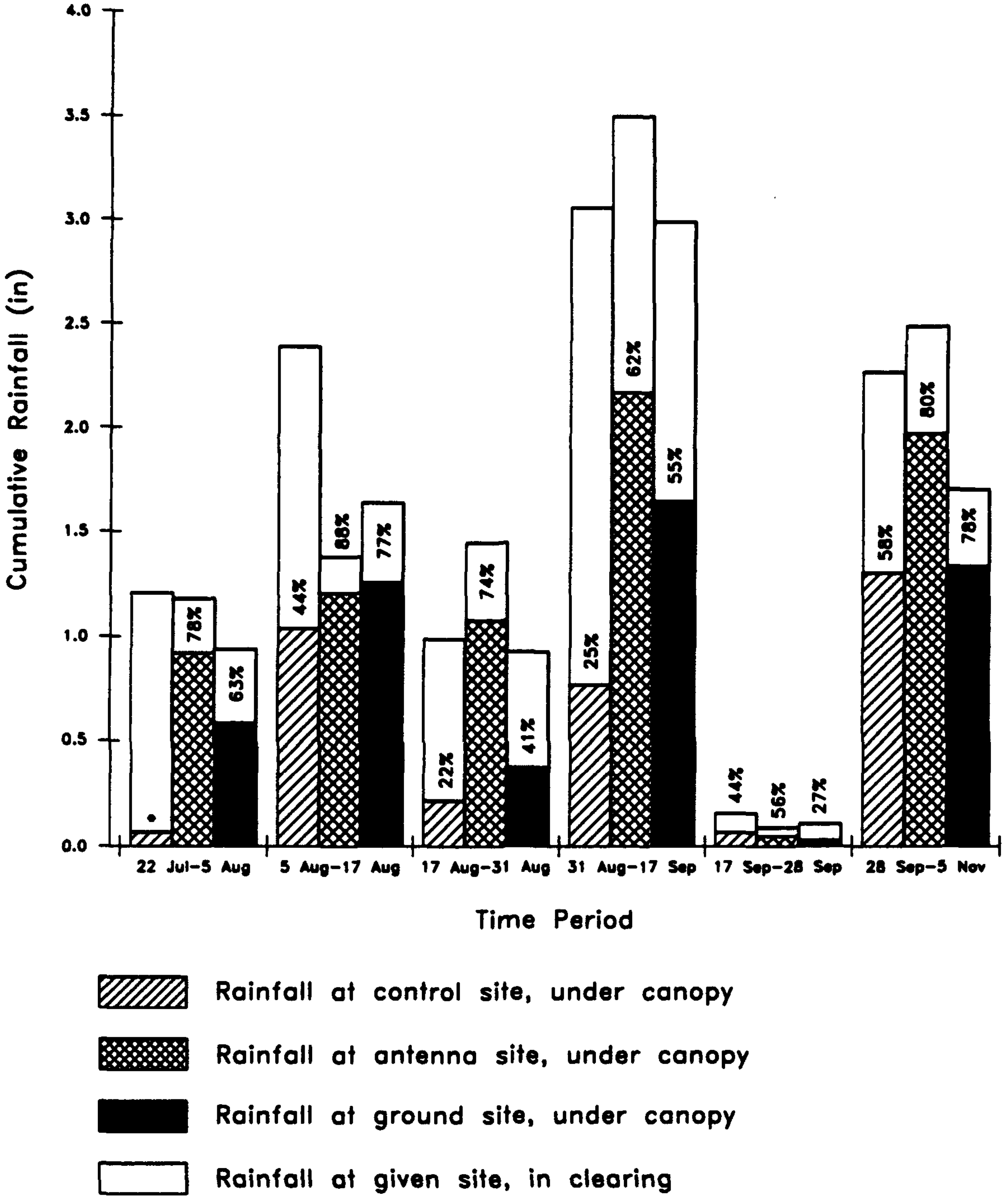


FIGURE F-26. 1993 CLIMATOLOGICAL DATA COLLECTED AT SOIL AMOEBA STUDY SITES.



* Time period 23 Jul-3 Aug
Rain gauge under canopy found broken off post on 3 Aug.

Percentages reflect ratio of cumulative rainfall under canopy to that in clearing.

FIGURE F-27. COMPARISON OF RAINFALL LEVELS UNDER CANOPY AND IN CLEARING NEAR SOIL AMOEBA STUDY SITES.

TABLE F-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
6C2-1	<0.001	<	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
6T3-2	-	<	<	<	<	<	<	<0.001[c]	<[c]	<[b]	<[c]
6T3-3	-	-	-	<	<	<	<	<[c]	<[c]	<[b]	<[c]
6T4-1	-	<	<	<	<	<	<0.001	<[b]	<[c]	<[b]	<[b]
6T4-2	-	-	-	<	<	/	<	<[b]	<[c]	<[b]	<[b]
6T4-3	-	-	-	<	<	<	<	<[b]	<[c]	<[b]	<[b]
6T4-4	-	-	-	<	<	<	<	<[b]	<[c]	<[b]	<[b]
6T4-5	-	-	-	<	<	<	<	<[b]	<[c]	<[b]	<[b]
6T4-6	-	-	-	<	<	<	<	<[b]	<[c]	<[b]	<[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
< = measurement estimated <0.001 V/m based on earth electric field.
/ = measurement not taken.

TABLE F-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
6C2-1	0.32	0.61	0.194, 0.28	0.058	0.256	0.98	1.19	0.22[d]	1.32[d]	0.065[d]	0.46[d]
6T3-2	0.087	0.130	0.134	0.078	0.130	0.41	#	0.193[c]	0.056[c]	0.056[b]	0.33[c]
6T3-3	-	-	-	0.085	0.125	0.35	#	0.186[c]	0.060[c]	0.053[b]	0.28[c]
6T4-1	-	0.48, 0.52	0.40	0.072	0.32	0.18	0.35	0.070[b]	0.066[c]	0.065[b]	0.106[b]
6T4-2	-	-	-	0.046	0.162	0.145	0.30	0.048[b]	0.086[c]	0.070[b]	0.147[b]
6T4-3	-	-	-	0.065	0.082	0.24	0.34	0.068[b]	0.106[c]	0.101[b]	0.127[b]
6T4-4	-	-	-	0.037	0.24	0.27	0.23	0.057[b]	0.061[c]	0.048[b]	0.096[b]
6T4-5	-	-	-	0.053	0.182	0.18	0.33	0.049[b]	0.091[c]	0.066[b]	0.102[b]
6T4-6	-	-	-	0.098	0.084	0.33	0.34	0.069[b]	0.120[c]	0.107[b]	0.199[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
= measurement precluded by antenna operation.

TABLE F-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
6C2-1	0.004	0.008	0.001, 0.003	0.002	0.003	0.011	0.009	0.001[d]	0.014[d]	0.006[d]	0.006[d]
6T3-2	-	0.002	0.003	0.013	0.033	0.103	#	0.193[c]	0.006[c]	0.015[b]	0.077[c]
6T3-3	-	-	-	0.020	0.023	0.065	#	0.029[c]	0.013[c]	0.010[b]	0.049[c]
6T4-1	-	0.005, 0.007	0.007	0.005	0.006	0.019	0.011	0.006[b]	0.005[c]	0.007[b]	0.013[b]
6T4-2	-	-	-	0.005	0.006	0.016	0.009	0.005[b]	0.005[c]	0.006[b]	0.011[b]
6T4-3	-	-	-	0.004	0.005	0.014	0.008	0.005[b]	0.004[c]	0.005[b]	0.010[b]
6T4-4	-	-	-	0.002	0.006	0.018	0.010	0.006[b]	0.005[c]	0.006[b]	0.012[b]
6T4-5	-	-	-	0.003	0.006	0.017	0.009	0.005[b]	0.004[c]	0.006[b]	0.011[b]
6T4-6	-	-	-	0.005	0.005	0.015	0.009	0.004[b]	0.004[c]	0.005[b]	0.010[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.
\- = measurement point not established.
= measurement precluded by antenna operation.

TABLE F-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
	NS	NEW	SEW	SEW	NS	EW	NS	EW	B	B	B	B	B
Meas. Pt.	4 A	6 A	6 A	10 A, EX	15 A	15 A	75 A	75 A	150 A	150 A	150 A	150 A	150 A
6C2-1	<	<	<	*	<	<	<	<	<	<	<	<	<
6T3-2	<	<	<	*	0.005	<	0.028	<	0.061	0.065	0.042	0.038	0.066
6T3-3	<	<	<	*	0.005	<	0.027	<	0.058	0.058	0.050	0.038	0.075
6T4-1	<	<	<	*	0.020	<	/	<	0.036	0.056	0.058	/	0.046
6T4-2	<	<	<	*	0.007	<	/	/	0.030	0.030	0.033	/	0.032
6T4-3	<	<	<	*	0.004	<	/	<	0.045	0.041	0.048	/	0.044
6T4-4	<	<	<	*	0.014	<	/	<	0.028	0.044	0.037	/	0.036
6T4-5	<	<	<	*	0.007	<	/	/	0.047	0.033	0.038	/	0.041
6T4-6	<	<	<	*	0.004	<	/	<	0.050	0.047	0.050	/	0.047

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW an[illegible]s, standard phasing.

EX = extrapolated data.
< = measurement estimated <0.001 V/m based on earth electric field.
* = data cannot be extrapolated.
/ = measurement not taken.

TABLE F-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
6C2-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140	1.37	0.76	0.90	0.94	1.02
6T3-2	1.45	0.046	0.040	0.067	5.9	0.110	25	0.46	54	53	53	52	53
6T3-3	1.34	0.041	0.030	0.050	5.4	0.087	21	0.47	47	52	51	54	46
6T4-1	1.73	0.059	0.007	0.012	18.9	0.056	25	0.22	30	48	32	43	31
6T4-2	0.72	0.023	0.009	0.015	8.5	0.038	12.4	0.150	35	28	29	33	38
6T4-3	1.14	0.035	0.018	0.030	4.3	0.031	21	0.191	49	40	41	46	44
6T4-4	1.31	0.042	0.006	0.010	12.8	0.040	21	0.174	18.4	35	27	29	30
6T4-5	0.78	0.027	0.012	0.020	10.2	0.045	15.5	0.194	33	29	29	33	33
6T4-6	1.27	0.040	0.015	0.025	4.4	0.034	26	0.22	50	43	48	51	48

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

TABLE F-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
6C2-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004	0.004	0.002	0.005	0.005
6T3-2	0.28	0.009	0.001	0.002	1.03	0.004	4.9	0.011	10.1	10.1	9.6	9.9	9.6
6T3-3	0.170	0.006	0.001	0.002	0.64	0.003	3.1	0.007	6.3	6.2	5.9	6.3	5.8
6T4-1	0.100	0.003	0.001	0.002	0.35	0.001	1.82	0.007	4.1	3.7	3.4	3.6	3.5
6T4-2	0.082	0.003	0.001	0.002	0.29	0.001	1.50	0.006	3.3	3.1	2.9	3.0	2.9
6T4-3	0.071	0.002	<0.001	*	0.26	0.001	1.30	0.005	2.9	2.6	2.5	2.7	2.6
6T4-4	0.090	0.003	0.001	0.002	0.38	0.001	1.64	0.006	3.8	3.3	3.2	3.4	3.2
6T4-5	0.078	0.002	<0.001	*	0.27	<0.001	1.41	0.006	3.4	2.8	2.7	2.8	2.7
6T4-6	0.067	0.002	<0.001	*	0.24	0.001	1.22	0.005	2.7	2.4	2.4	2.5	2.4

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
* = data cannot be extrapolated.

TABLE F-9. 1993 PAIRED SITE EM FIELD INTENSITY RATIOS
Soil Amoeba Studies

Compared Sites	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
6T3/6C2	75	75	75	1.00	45	160	100	0.61 - 0.72	1160	118	970	8.2 - 128
6T4/6C2	32	32	32	1.00	29	241	65	0.21 - 0.43	480	240	400	1.67 - 2.2

R1: T(76)/C(76) T(76) = ELF Communications System EM fields at the treatment site.
R2: T(76)/T(60) C(76) = ELF Communications System EM fields at the control site.
R3: T(76)/C(60) T(60) = ambient EM fields at the treatment site.
R4: T(60)/C(60) C(60) = ambient EM fields at the control site.

APPENDIX G

BIRD SPECIES AND COMMUNITIES STUDIES

BIRD SPECIES AND COMMUNITIES STUDIES

The bird species and communities studies census migrating and resident bird populations using a line transect method. Bird populations in a given area are determined both as a whole and by individual species. The magnetic field is considered the most important electromagnetic (EM) factor influencing migrating birds; however, the electric fields in the air and the earth may also have an influence on population distributions.

In 1993, IITRI field crews made ELF EM field measurements at 24 points within the five treatment and five control transects for the bird species and communities studies in Michigan. The study transects and the historical measurement points within those transects were unchanged from 1992. One measurement point (10T4-3), which was inaccessible in 1992 because of a washed-out bridge, was measured in 1993. Measurement dates for 1993 and previous years appear in Table G-1.

TABLE G-1. EM FIELD MEASUREMENT DATES
Bird Species and Communities Studies, Michigan

Year	Measurement Dates	
1984	Aug 23, 24	
1985	May 6, 7	
1986	Sep 30	Oct 3, 6, 7, 13, 16
1987	Sep 23-25, 30	
1988	Sep 21, 23, 29, 30	Oct 4-6
1989	Sep 11, 14, 15, 18, 20, 22	
1990	Sep 25-28	Oct 3-5, 9, 11, 12
1991	Sep 24-27, 30	Oct 1-4, 15, 17
1992	Sep 14, 15, 16, 21, 22, 28, 29	Oct 1, 2
1993	Jul 12-14, 16, 19, 20, 26, 27	

The positions of the 10 Michigan transects relative to the NRTF-Republic are shown on the composite map in Figure G-1. The transect numbers listed on the map are those used by IITRI. Table G-2 provides a cross-reference of IITRI transect numbers, investigator transect names, and township, range, and section numbers for the transects.

EM field measurements for Michigan for 1993 and previous years are found in Tables G-3 through G-8. Tables G-3, G-4, and G-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables G-6, G-7, and G-8 present 76 Hz data for these fields as well as the

TABLE G-2. TRANSECT NUMBER CROSS-REFERENCE
Bird Species and Communities Studies

IITRI Transect No.	Investigator's Transect Name	Location Township	Range	Section(s)
10C1	Carney Lake	T41N	R29W	33, 34, 35, 36
10C2	Skunk Creek	T42N	R27W	19, 30
		T42N	R28W	14, 23, 24
10C5	Arnold	T43N	R25W	31, 32, 33, 34
10C12	Lost Lake	T41N	R29W	21, 26, 27, 28, 35
10C13	Bob's Creek	T44N	R26W	13, 23, 24, 26
10T1	Leeman's Road	T43N	R29W	14, 23, 26, 35
10T2	Turner Road	T43N	R29W	1, 12
		T44N	R29W	36
10T3	Flat Rock Creek	T45N	R28W	19, 30, 31
10T4	Schwartz Creek	T45N	R28W	31
		T45N	R29W	26, 27, 35, 36
10T11	Heart Lake	T45N	R28W	7, 18, 19
		T45N	R29W	1, 12

corresponding operating currents of the NRTF-Republic. Paired-site EM field intensity ratios, which were recalculated using 1993 measurement data, appear in Table G-9.

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. The 60 Hz measurements made at treatment transects in 1986 through 1993 (excluding 1989) were made while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, 60 Hz measurements were made during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off. It was not possible to make 60 Hz measurements at some points on treatment transects in 1989 and 1990 because of antenna operation with a modulated signal. These cases are noted in the data tables.

Annual variations in the 60 Hz EM fields measured at the control transects are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these transects from the antenna. The 60 Hz EM field values at the control transects, nonetheless, are about as variable as those at the treatment transects.

Overall, the 60 Hz EM fields measured at all transects in 1993 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment transects consistently dominate the 60 Hz EM fields at the treatment and control transects.

The 76 Hz EM field measurements made in 1993 were made with 150 A antenna currents, the predominant operating current of the NRTF-Republic since May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables G-6 through G-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 A in 1986, 15 A in 1987, 75 A in 1988, and 150 A in 1989 through 1993. The 1993 measurements are consistent with the measurements made in 1989 through 1992 at the same current, and are proportional to the measurements made in 1986, 1987, and 1988 at lower currents.

No measurements were made along these study transects during the periods when the EW antenna was down for repairs in 1991 and 1992. However, engineering estimates of the EM exposures at the treatment transects under this antenna condition have been made on the basis of measurements made at other ecological study sites. The Schwartz Creek transect (10T4), which parallels the SEW antenna, was the most affected. Measurements at the upland flora and soil microflora study site situated along this same antenna element indicate that EM exposure at all locations along 10T4 were reduced to about one-third those with both antennas on at full current. The relatively high exposures along the de-energized EW antenna are caused by significant cross-coupling from the operating NS antenna.

Based on 1988 measurements during individual operation of the two antennas, EM exposures along the Leeman's Road and Turner Road transects are expected to have been reduced by less than 10 percent during the EW antenna shutdown periods in 1991 and 1992. Similar predictions are more difficult to make for the Flat Rock Creek transect, which parallels the NS antenna but crosses the SEW antenna element, and for the Heart Lake transect, which parallels the NS antenna between the NEW and SEW antenna elements. EM field reductions along these two transects during periods of EW antenna shutdown are expected to have been somewhere between the reduction levels experienced along the Leeman's and Turner Road transects (less than 10 percent) and those along the Schwartz Creek transect (about 30 percent).

EM field reductions are also expected to have occurred along control transects during periods when the EW antenna was off. Such reductions would have been unique to each transect because of differences in their positions relative to the antenna elements. Nonetheless, any reduction in the 76 Hz EM fields along control transects, where low intensities are desired, should not be of great concern because this situation actually improves the 76 Hz EM field ratios between treatment and control transects.

Measured values of the electric and magnetic fields taken along transects 10T1, 10T2, 10T3, 10T4, and 10T11 in 1990 are included in this report in Table G-10. Measurements were made at the start and finish of each transect and at the "X" flags between transect sub-segments. Table G-10 also includes data from applicable historical measurement locations. Graphs of the EM field intensities along these transects are presented in Figures G-2 through G-6. A more thorough discussion of these special measurements and results appears in a previous report.*

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* Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1990. IIT Research Institute, Technical Report E06628-3, 87 pp. plus appendixes, 1991.

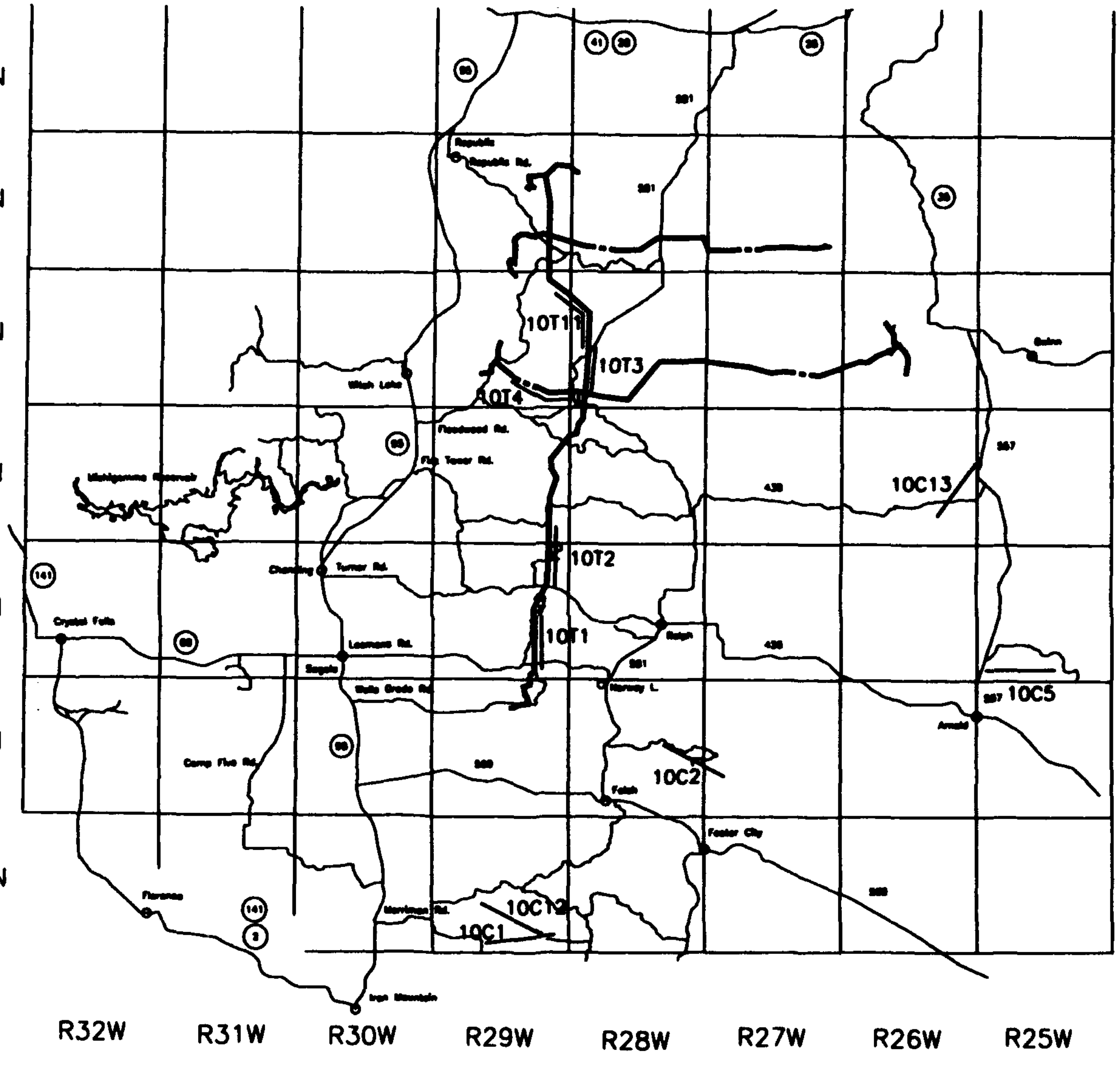


FIGURE G-1. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

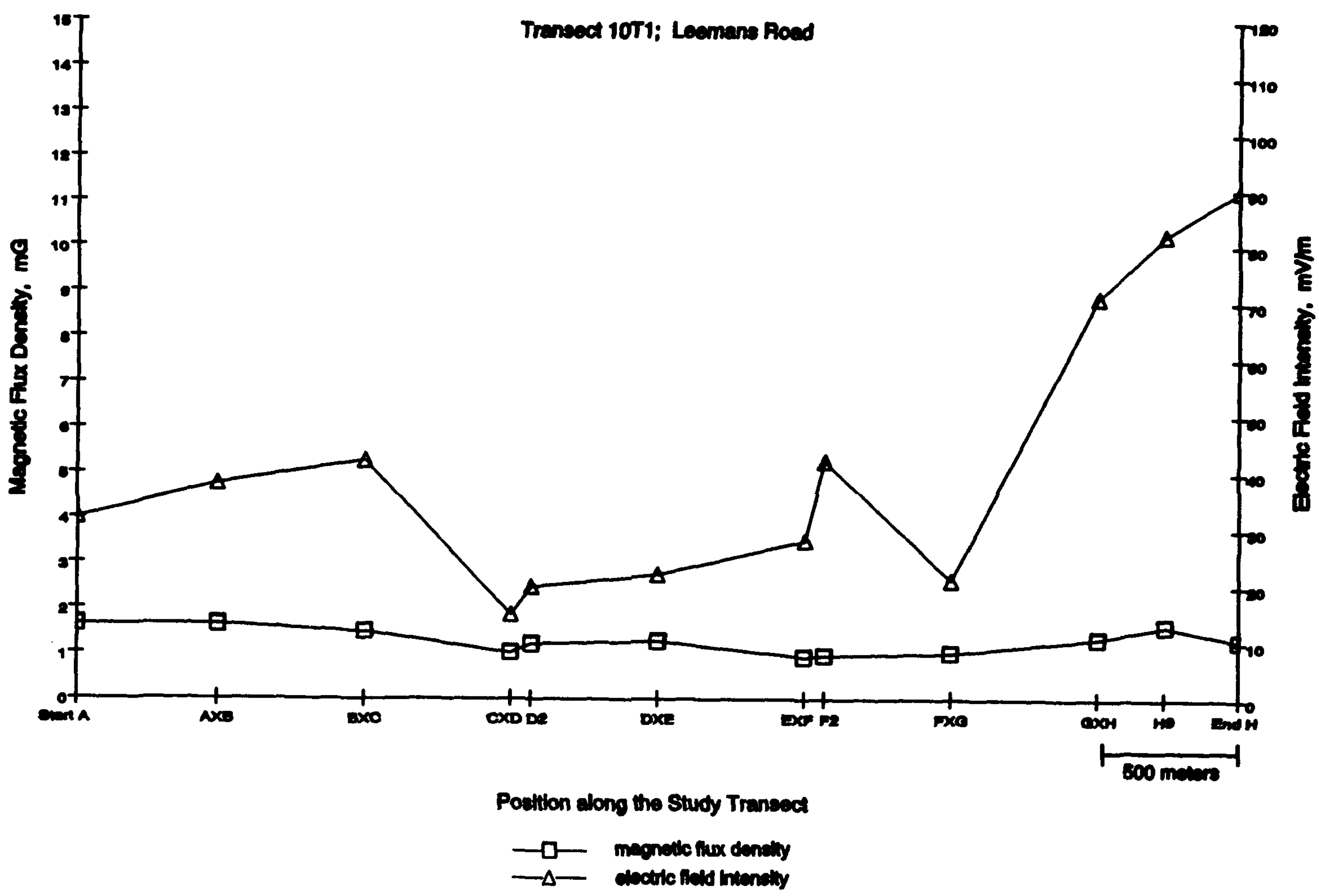


FIGURE G-2. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T1.

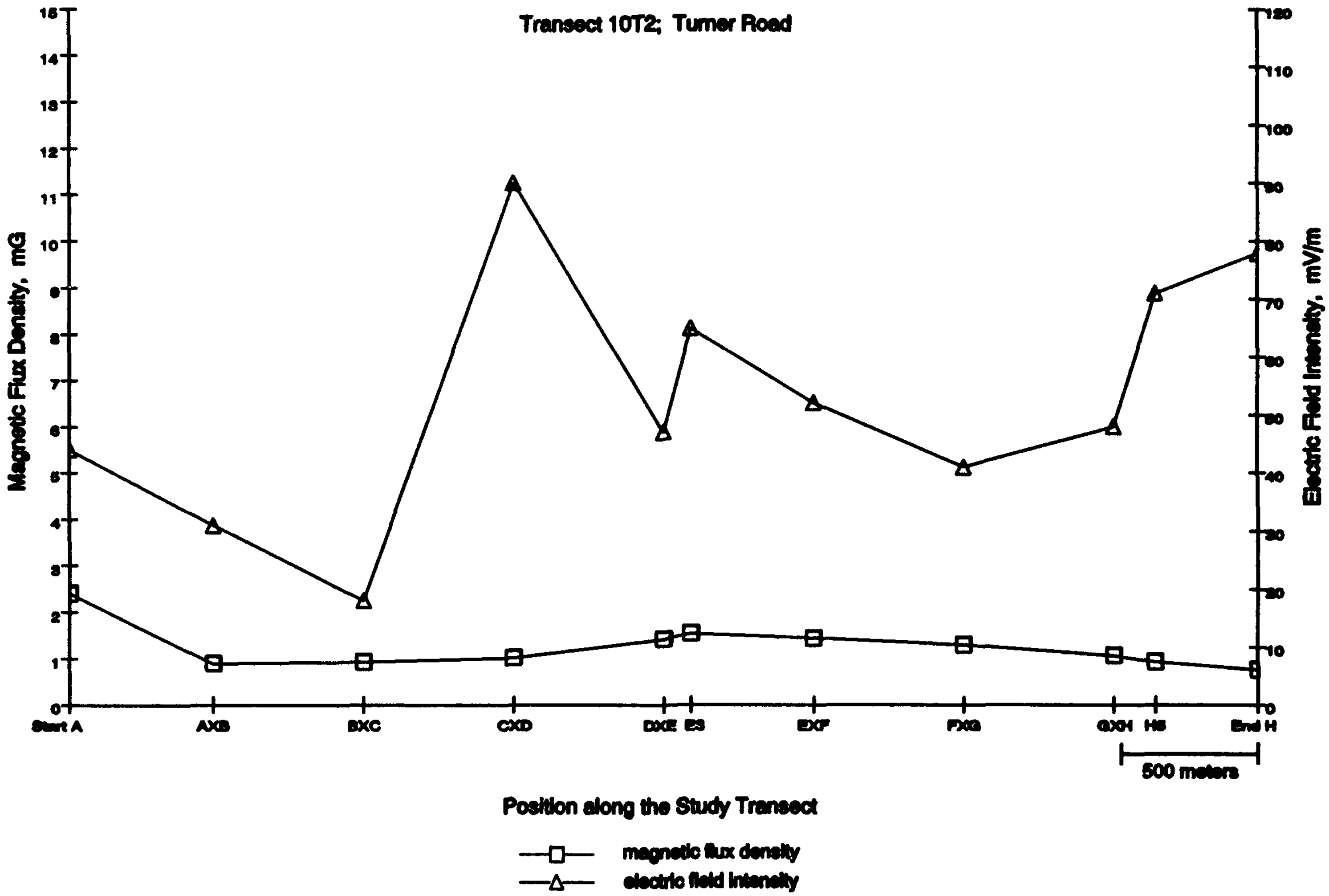


FIGURE G-3. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T2.

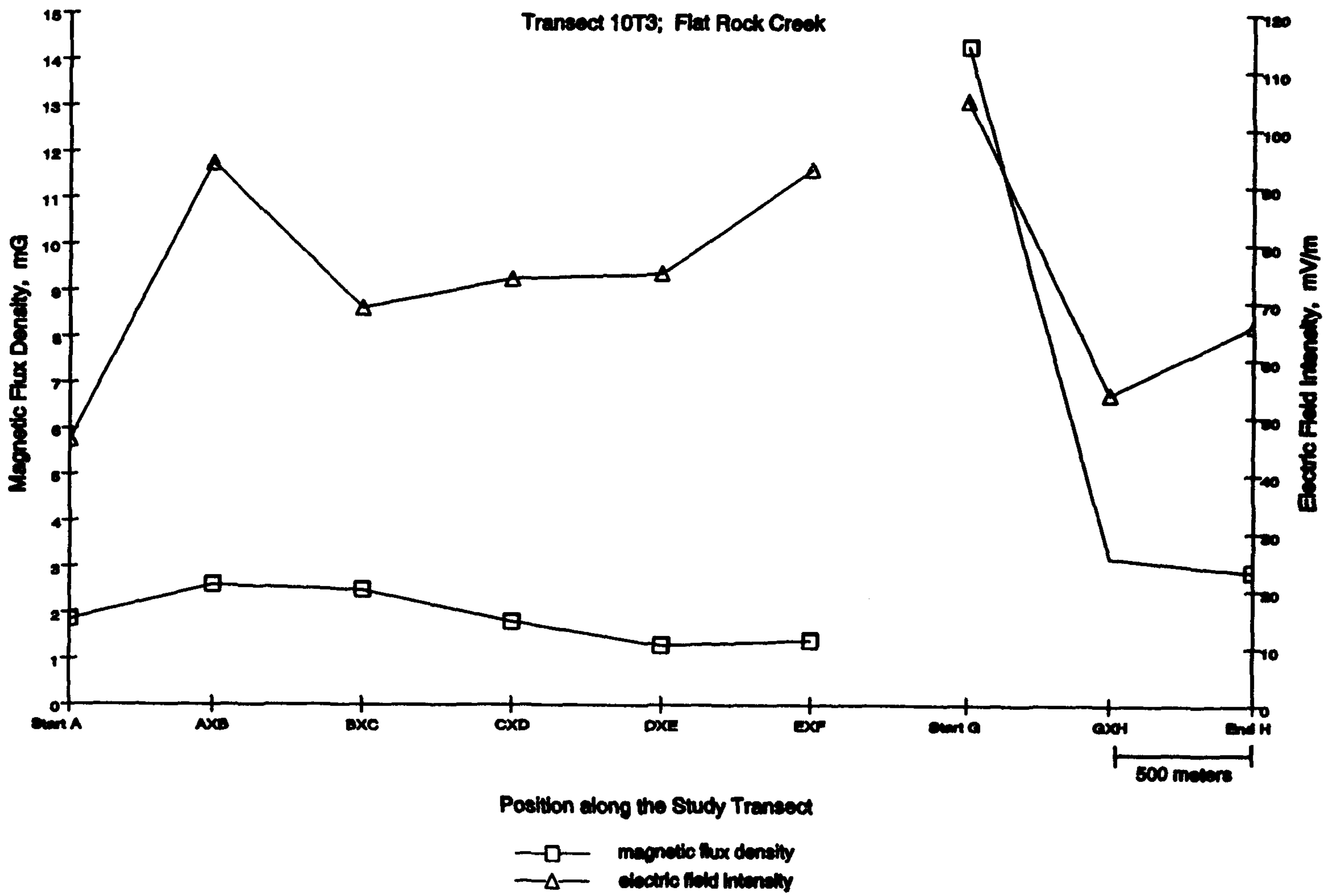


FIGURE G-4. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T3.

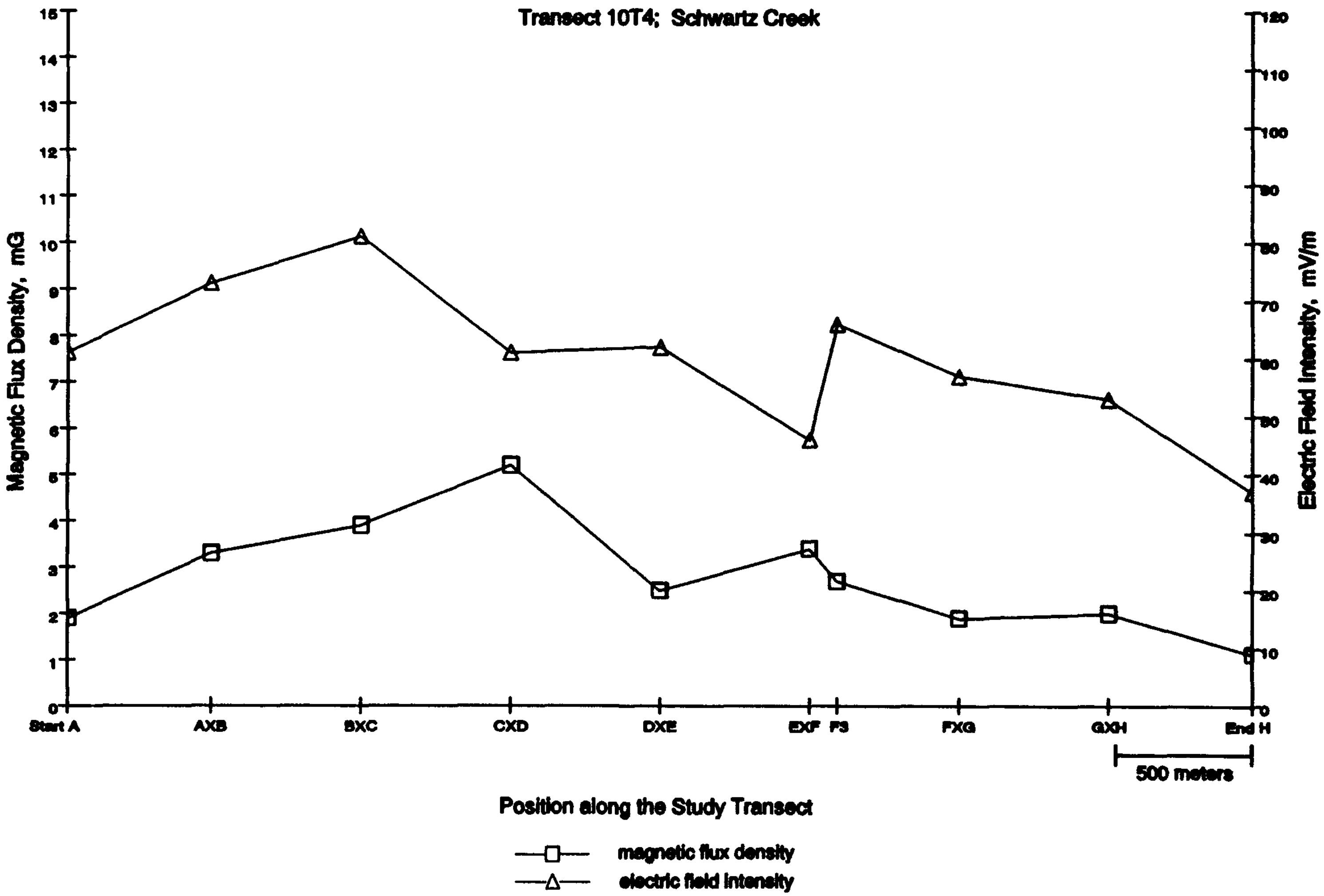


FIGURE G-5. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T4.

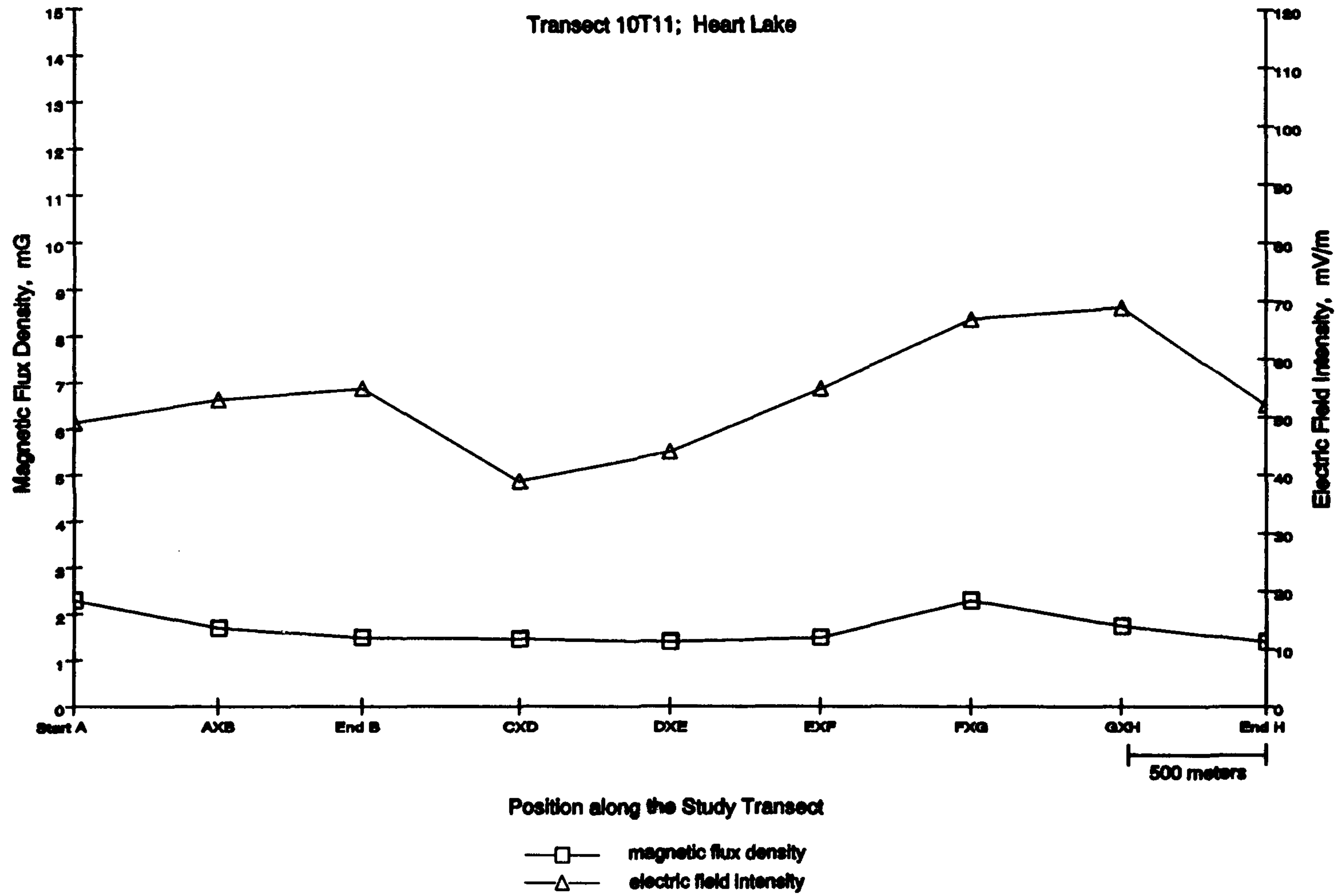


FIGURE G-6. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T11.

TABLE G-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
10C1-2	-	<	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C1-3	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C2-1	-	<	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C2-2	-	<	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C5-2	-	<	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C5-3	-	<	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C12-1	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C12-2	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C13-1	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10C13-2	-	-	<	<	<	<	<	<[d]	<[d]	<[d]	<[d]
10T1-1	-	<	<	<	<	<	<0.001	<[b]	<[c]	<[b]	<[c]
10T1-3	-	-	<	<	<	<	<	<[b]	<[b]	<[b]	<[b]
10T1-4	-	-	-	<	<	<	<	<[b]	<[c]	<[b]	<[c]
10T1-5	-	-	-	<	<	<	<0.001	<[b]	<[c]	<[b]	<[b]
10T2-1	-	<0.001	<	<	<	<	<	<[c]	<[b]	<[b]	<[b]
10T2-2	-	-	-	<	<	<	<	<[b]	<[b]	<[b]	<[b]
10T2-4	-	-	<	<	<	0.008	#	<[b]	<[b]	<[b]	<[b]
10T3-1	-	<	<	<	<	<	<	#	<[b]	<[b]	<[b]
10T3-2	-	<	<	<	<	<	<	#	<[c]	<[b]	<[b]
10T3-3	-	-	-	<	<	/	<0.001	#	<[c]	<[b]	<[b]

TABLE G-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects (page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
10T4-1	-	<	<	<	<	<	<	#	<[c]	<[b]	<[b]
10T4-3	-	-	-	<	<	<	<	#	<[c]	/	<[b]
10T11-1	-	-	<	<	<	/	<0.001	#	<[b]	<[b]	<[b]
10T11-2	-	-	<	<	0.011	/	<0.001	#	<[b]	<[b]	<[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

- = measurement point not established.
= measurement precluded by antenna operation.
< = measurement estimated <0.001 V/m based on earth electric field.
/ = measurement not taken.

TABLE G-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
10C1-2	-	0.62	0.106, 0.141	0.101	0.059	0.20	0.073	0.27[d]	0.105[d]	0.098[d]	0.099[d]
10C1-3	-	-	0.26, 0.27	0.055	0.21	0.32	0.72	0.079[d]	0.78[d]	0.50[d]	0.41[d]
10C2-1	-	0.98	0.138	0.041	0.038	0.087	0.080	0.076[d]	0.076[d]	0.031[d]	0.088[d]
10C2-2	-	0.35	0.21	0.055	0.048	0.047	0.069	0.076[d]	0.057[d]	0.045[d]	0.064[d]
10C5-2	-	0.35	0.45	0.193	0.116	0.23	0.053	0.050[d]	0.037[d]	0.44[d]	0.89[d]
10C5-3	-	0.111	0.23	0.25	0.103	0.126	0.050	0.073[d]	0.160[d]	0.27[d]	0.46[d]
10C12-1	-	-	0.194, 0.28	0.058	0.256	0.98	1.19	0.22[d]	1.32[d]	0.65[d]	0.46[d]
10C12-2	-	-	0.106, 0.141	0.101	0.059	0.20	0.073	0.27[d]	0.105[d]	0.098[d]	0.099[d]
10C13-1	-	-	0.34, 0.52	0.30	0.40	0.37	0.78	0.099[d]	0.156[d]	0.70[d]	1.10[d]
10C13-2	-	-	0.143, 0.31	0.139	0.157	0.121	0.039	0.074[d]	0.212[d]	0.30[d]	0.33[d]
10T1-1	-	0.076	0.061	0.034	0.099	0.21	0.077	0.039[b]	0.038[c]	0.056[b]	0.23[c]
10T1-3	-	-	0.38	0.120	0.20	0.51	#	0.106[b]	0.092[b]	0.036[b]	0.102[b]
10T1-4	-	-	-	0.111	0.085	0.30	0.076	0.029[b]	0.040[c]	0.032[b]	0.21[c]
10T1-5	-	-	-	0.040	0.052	0.116	0.052	0.021[b]	0.023[c]	0.030[b]	0.033[b]
10T2-1	-	0.42	0.194	0.050	0.058	0.23	0.034	0.130[c]	0.123[b]	0.081[b]	0.035[b]
10T2-2	-	-	-	0.058	0.052	0.24	0.023	0.028[b]	0.090[b]	0.046[b]	0.038[b]
10T2-4	-	-	0.158	0.054	0.029	0.166	0.164	0.013[b]	0.093[b]	0.038[b]	0.065[b]
10T3-1	-	0.30	0.23	0.145	0.164	0.070	#	#	0.148[b]	0.170[b]	0.148[b]
10T3-2	-	0.26	0.117	0.069	0.103	0.075	#	#	0.173[c]	0.091[b]	0.107[b]
10T3-3	-	-	-	0.094	0.120	0.132	0.32	#	0.39[c]	0.105[b]	0.133[b]

TABLE G-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects (page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
10T4-1	-	0.29	0.132	0.129	0.093	0.067	#	#	0.20[c]	0.076[b]	0.198[b]
10T4-3	-	-	-	0.112	0.22	0.166	0.067	#	0.21[c]	/	0.159[b]
10T11-1	-	-	0.23	0.172	0.106	0.095	0.25	#	0.145[b]	0.116[b]	0.150[b]
10T11-2	-	-	0.26, 0.50	0.56	0.45	0.196	0.21	#	0.34[b]	0.22[b]	0.32[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
= measurement precluded by antenna operation.
/ = measurement not taken.

TABLE G-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
10C1-2	-	0.001	0.001	<0.001	<0.001	0.001	0.001	0.001[d]	0.001[d]	0.001[d]	<0.001[d]
10C1-3	-	-	0.001, 0.003	<0.001	0.003	0.002	0.007	0.002[d]	0.010[d]	0.004[d]	0.004[d]
10C2-1	-	0.005	0.004	<0.001	<0.001	<0.001	0.001	0.001[d]	0.001[d]	<0.001[d]	0.001[d]
10C2-2	-	0.003	0.003	<0.001	0.001	0.001	0.001	0.001[d]	0.001[d]	<0.001[d]	0.001[d]
10C5-2	-	0.008	0.009	0.006	0.005	0.006	0.002	0.001[d]	0.008[d]	0.014[d]	0.021[d]
10C5-3	-	0.001	0.002	0.002	0.001	0.001	0.001	0.001[d]	0.002[d]	0.002[d]	0.003[d]
10C12-1	-	-	0.001, 0.003	0.002	0.003	0.011	0.009	0.001[d]	0.014[d]	0.006[d]	0.006[d]
10C12-2	-	-	0.001	<0.001	<0.001	0.001	0.001	0.001[d]	0.001[d]	0.001[d]	<0.001[d]
10C13-1	-	-	0.007, 0.010	0.007	0.005	0.003	0.009	0.003[d]	0.011[d]	0.017[d]	0.026[d]
10C13-2	-	-	0.001, <0.001	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]	0.002[d]	0.002[d]
10T1-1	-	0.006	0.004	0.002	0.005	0.016	0.005	0.002[b]	0.002[c]	0.003[b]	0.015[c]
10T1-3	-	-	0.002	0.003	0.005	0.017	#	0.003[b]	0.005[b]	0.002[b]	0.004[b]
10T1-4	-	-	-	0.003	0.003	0.009	0.002	0.001[b]	0.002[c]	0.002[b]	0.007[c]
10T1-5	-	-	-	0.003	0.016	0.012	0.003	0.001[b]	0.002[c]	0.002[b]	0.002[b]
10T2-1	-	0.002	0.002	0.003	0.005	0.012	0.001	0.007[c]	0.009[b]	0.003[b]	0.001[b]
10T2-2	-	-	-	<0.001	0.002	0.008	0.001	0.001[b]	0.006[b]	0.002[b]	<0.001[b]
10T2-4	-	-	0.001	0.002	0.001	0.004	0.001	<0.001[b]	0.004[b]	0.001[b]	<0.001[b]
10T3-1	-	0.001	0.001	0.006	0.003	0.004	#	#	0.003[b]	0.002[b]	0.004[b]
10T3-2	-	0.001	<0.001	0.008	0.005	0.004	#	#	0.012[c]	0.003[b]	0.011[b]
10T3-3	-	-	-	0.012	0.007	0.017	0.010	#	0.030[c]	0.001[b]	0.010[b]

TABLE G-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects (page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991	1992	1993
10T4-1	-	0.001	<0.001	0.002	0.002	0.003	#	#	0.004[c]	0.001[b]	0.002[b]
10T4-3	-	-	-	0.001	0.003	0.004	0.002	#	0.006[c]	/	0.003[b]
10T11-1	-	-	<0.001	0.006	0.006	0.003	0.003	#	0.003[b]	0.002[b]	0.004[b]
10T11-2	-	-	0.001, <0.001	0.008	0.005	0.004	<0.001	#	0.006[b]	0.003[b]	0.010[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 ampere current.

\- = measurement point not established.
= measurement precluded by antenna operation.
/ = measurement not taken.

TABLE G-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects (page 1 of 2)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
10C1-2	<	<	<	*	<	<	<	<	<	<	<	<	<
10C1-3	<	<	<	*	<	<	<	<	<	<	<	<	<
10C2-1	<	<	<	*	<	<	<	<	<	<	<	<	<
10C2-2	<	<	<	*	<	<	<	<	<	<	<	<	<
10C5-2	<	<	<	*	<	<	<	<	<	<	<	<	<
10C5-3	<	<	<	*	<	<	<	<	<	<	<	<	<
10C12-1	<	<	<	*	<	<	<	<	<	<	<	<	<
10C12-2	<	<	<	*	<	<	<	<	<	<	<	<	<
10C13-1	<	<	<	*	<	<	<	<	<	<	<	<	<
10C13-2	<	<	<	*	<	<	<	<	<	<	<	<	<
10T1-1	<	<	<	*	0.005	<	0.022	<	0.036	0.036	0.037	0.032	0.036
10T1-3	0.002	<	<	*	0.007	<	0.038	<0.001	0.068	0.081	0.084	0.055	0.076
10T1-4	<	<	<	*	0.004	<	0.024	<	0.036	0.040	0.033	0.026	0.054
10T1-5	<	<	<	*	0.003	<	0.010	<	0.022	0.020	0.022	0.016	0.027
10T2-1	0.002	<	<	*	0.006	<	0.033	<0.001	0.059	0.088	0.072	0.072	0.104
10T2-2	0.002	<	<	*	0.007	<	0.047	0.003	0.062	0.062	0.069	0.036	0.056
10T2-4	0.002	<	<	*	0.007	<	0.028	0.007	0.062	0.060	0.075	0.039	0.065
10T3-1	0.004	<	<	*	0.005	0.003	/	/	0.040	0.050	0.050	/	0.040
10T3-2	0.004	<	0.001	0.002	0.006	0.003	/	/	0.071	0.070	0.067	/	0.044
10T3-3	0.005	<	0.017	0.028	0.005	0.009	/	/	0.170	0.130	0.125	/	0.080

TABLE G-6. 76 Hz AIR ELECTRIC FIELD NSITIES (V/m)
Bird Species and Communities ies
Michigan Transects (page 2 of 2)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992	1993
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
10T4-1	0.002	<	0.003	0.005	0.003	0.006	/	/	0.049	0.051	0.067	0.075	0.051
10T4-3	<	<	0.003	0.005	0.001	0.008	/	/	0.078	0.062	0.072	/	0.053
10T11-1	<	<	<	*	0.004	0.002	/	/	0.051	0.053	0.064	0.063	0.053
10T11-2	<	<	<	*	0.038	0.009	/	/	0.108	0.27	0.185	1.32	0.141

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.

EX = extrapolated data.
* = data cannot be extrapolated.
< = measurement estimated <0.001 V/m based on earth electric field.
/ = measurement not taken.

TABLE G-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects (page 1 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A	1992 B 150 A	1993 B 150 A
10C1-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058	0.153	0.31	0.139	0.158	0.158
10C1-3	0.013	0.004	0.002	0.003	0.049	0.011	0.26	0.060	0.41	0.44	0.50	0.55	0.70
10C2-1	0.017	0.002	0.007	0.012	0.073	0.021	0.30	0.095	0.78	0.70	0.64	0.62	0.63
10C2-2	0.011	0.003	0.007	0.012	0.037	0.020	0.176	0.100	0.33	0.43	0.30	0.40	0.33
10C5-2	0.001	0.003	0.007	0.012	0.014	0.023	0.073	0.119	0.26	0.28	0.21	0.179	0.23
10C5-3	0.005	0.003	0.009	0.015	0.017	0.027	0.091	0.143	0.30	0.28	0.24	0.29	0.29
10C12-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140	1.37	0.76	0.90	0.94	1.02
10C12-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058	0.153	0.31	0.139	0.158	0.158
10C13-1	0.024	0.027	0.104	0.173	0.057	0.24	0.32	1.39	4.8	4.2	3.3	3.9	4.3
10C13-2	0.024	0.023	0.098	0.163	0.089	0.29	0.34	1.07	2.1	2.7	2.4	2.7	2.5
10T1-1	0.85	0.026	0.008	0.013	2.8	0.015	13.0	0.115	42	32	41	38	29
10T1-3	2.2	0.068	0.077	0.128	7.1	0.147	33	0.86	74	82	77	76	78
10T1-4	0.96	0.030	0.031	0.052	4.1	0.087	19.8	0.46	35	42	40	43	40
10T1-5	0.65	0.020	0.006	0.010	2.3	0.015	10.9	0.098	20	19.7	19.0	21	19
10T2-1	1.42	0.043	0.077	0.128	5.3	0.25	31	1.05	48	44	76	83	95
10T2-2	1.69	0.056	0.107	0.178	7.0	0.34	33	1.77	53	65	67	63	62
10T2-4	0.59	0.056	0.158	0.26	5.0	0.49	26	2.6	79	71	57	74	71
10T3-1	0.82	0.23	0.60	1.00	4.9	2.1	26	10.1	47	46	47	46	48
10T3-2	1.24	0.133	1.05	1.75	5.4	2.7	21	31	61	66	76	78	75
10T3-3	1.36	0.34	3.6	6.0	4.8	7.5	43	54	111	105	105	112	110

TABLE G-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects (page 2 of 2)

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
10T4-1	0.88	0.137	1.58	2.6	2.4	4.8	14.5	19.3	62	61	58	54	59
10T4-3	0.46	0.139	1.92	3.2	1.30	8.1	5.4	39	68	66	67	/	57
10T11-1	0.67	0.27	0.59	0.98	3.9	1.97	17.6	8.9	47	49	47	52	49
10T11-2	1.38	0.93	0.44	0.73	7.3	2.9	32	12.6	105	86	72	77	94

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
/ = measurement not taken.

TABLE G-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects (page 1 of 2)

Site No.,	1986				1987		1988		1989	1990	1991	1992	1993
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
10C1-2	<0.001	<0.001	<0.001	*	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001
10C1-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	<0.001	0.003	0.003	0.001	0.003	0.003
10C2-1	<0.001	<0.001	<0.001	*	0.001	0.001	0.005	0.002	0.009	0.009	0.007	0.006	0.007
10C2-2	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.002	0.005	0.005	0.005	0.005	0.005
10C5-2	<0.001	<0.001	<0.001	*	<0.001	0.001	0.001	0.002	0.005	0.005	0.005	0.005	0.005
10C5-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	0.003	0.003	0.003
10C12-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004	0.004	0.002	0.005	0.005
10C12-2	<0.001	<0.001	<0.001	*	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001
10C13-1	<0.001	<0.001	<0.001	*	0.001	0.002	0.002	0.009	0.066	0.066	0.047	0.066	0.059
10C13-2	<0.001	<0.001	<0.001	*	<0.001	0.001	0.002	0.006	0.015	0.015	0.014	0.013	0.014
10T1-1	0.044	0.001	<0.001	*	0.179	0.001	0.84	0.005	1.87	1.63	1.60	1.77	1.68
10T1-3	0.047	0.001	0.007	0.012	0.176	0.001	0.84	0.010	1.70	1.62	1.64	1.68	1.57
10T1-4	0.026	0.001	0.001	0.002	0.103	0.002	0.49	0.014	1.02	0.95	0.91	0.94	0.92
10T1-5	0.034	0.001	0.001	0.002	0.49	0.002	0.61	0.008	1.31	1.20	1.19	1.22	1.16
10T2-1	0.066	0.002	0.001	0.002	0.25	0.001	1.21	0.010	2.5	2.4	2.3	2.4	2.3
10T2-2	0.043	0.001	0.001	0.002	0.165	0.002	0.80	0.010	1.61	1.54	1.55	1.60	1.53
10T2-4	0.026	0.001	0.001	0.002	0.097	0.002	0.46	0.005	0.97	0.92	0.91	0.91	0.91
10T3-1	0.029	0.003	0.007	0.012	0.188	0.015	0.96	0.078	1.89	1.87	1.85	1.94	1.90
10T3-2	0.081	0.002	0.013	0.022	0.29	0.031	1.61	0.161	2.9	2.9	2.8	3.0	2.9
10T3-3	0.116	0.40	0.58	0.97	0.196	0.89	1.11	7.7	15.0	14.3	14.0	15.0	14.2

TABLE G-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects (page 2 of 2)

	1986				1987		1988		1989	1990	1991	1992	1993
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	B 150 A	B 150 A
10T4-1	0.025	0.001	0.081	0.135	0.038	0.191	0.20	1.00	1.92	1.89	1.90	2.0	1.94
10T4-3	0.025	0.001	0.119	0.198	0.011	0.32	0.051	1.42	2.9	2.7	2.6	/	2.8
10T11-1	0.033	0.002	0.006	0.010	0.24	0.015	1.09	0.072	2.3	2.3	2.0	2.2	2.2
10T11-2	0.042	0.003	0.003	0.005	0.31	0.006	1.42	0.033	2.9	2.8	2.8	3.0	2.8

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
* = data cannot be extrapolated.
/ = measurement not taken.

TABLE G-9. 1993 PAIRED SITE EM FIELD INTENSITY RATIOS
Bird Species and Communities Studies

Compared	Air Electric Field				Earth Electric Field				Magnetic Flux Density			
Transects	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
10T1/10C1	27	27	27	1.00	120	126	46	0.080 - 2.3	310	112	230	0.50 - 15.0
10T1/10C2	27	27	27	1.00	30	126	220	0.38 - 3.6	131	112	920	2.0 - 15.0
10T1/10C5	27	27	27	1.00	66	126	21	0.037 - 0.50	184	112	44	0.095 - 5.0
10T1/10C12	27	27	27	1.00	18.6	126	41	0.072 - 2.3	184	112	153	0.33 - 15.0
10T1/10C13	27	27	27	1.00	4.4	126	17.3	0.030 - 0.70	15.6	112	35	0.077 - 7.5
10T2/10C1	56	56	56	1.00	390	1090	151	0.085 - 0.66	300	910	230	0.25 - 1.00
10T2/10C2	56	56	56	1.00	98	1090	700	0.40 - 1.02	130	910	910	1.00
10T2/10C5	56	56	56	1.00	210	1090	70	0.039 - 0.141	182	910	43	0.048 - 0.33
10T2/10C12	56	56	56	1.00	61	1090	135	0.076 - 0.66	182	910	152	0.167 - 1.00
10T2/10C13	56	56	56	1.00	14.4	1090	56	0.032 - 0.20	15.4	910	35	0.038 - 0.50
10T3/10C1	40	40	40	1.00	300	320	117	0.26 - 1.49	630	260	480	1.00 - 11.0
10T3/10C2	40	40	40	1.00	76	320	550	1.22 - 2.3	270	260	1900	4.0 - 11.0
10T3/10C5	40	40	40	1.00	166	320	54	0.120 - 0.32	380	260	90	0.190 - 3.7
10T3/10C12	40	40	40	1.00	47	320	104	0.23 - 1.49	380	260	320	0.67 - 11.0
10T3/10C13	40	40	40	1.00	11.2	320	44	0.097 - 0.45	32	260	73	0.154 - 5.5
10T4/10C1	51	53	51	1.00	360	300	139	0.39 - 2.0	650	930	490	0.50 - 3.0
10T4/10C2	51	53	51	1.00	90	300	650	1.81 - 3.1	280	930	1940	2.0 - 3.0
10T4/10C5	51	53	51	1.00	200	300	64	0.179 - 0.43	390	930	92	0.095 - 1.00
10T4/10C12	51	53	51	1.00	56	300	124	0.35 - 2.0	390	930	320	0.33 - 3.0
10T4/10C13	51	53	51	1.00	13.3	300	52	0.145 - 0.60	33	930	75	0.077 - 1.50
10T11/10C1	53	53	53	1.00	310	290	120	0.37 - 3.2	730	280	550	1.00 - 10.0
10T11/10C2	53	53	53	1.00	78	290	560	1.70 - 5.0	310	280	2200	4.0 - 10.0
10T11/10C5	53	53	53	1.00	169	290	55	0.169 - 0.70	440	280	105	0.190 - 3.3
10T11/10C12	53	53	53	1.00	48	290	107	0.33 - 3.2	440	280	370	0.67 - 10.0
10T11/10C13	53	53	53	1.00	11.4	290	45	0.136 - 0.97	37	280	85	0.154 - 5.0

R1: T(76)/C(76) T(76) = ELF Communications System EM fields at the treatment sites.
R2: T(76)/T(60) C(76) = ELF Communications System EM fields at the control sites.
R3: T(76)/C60) T(60) = ambient EM fields at the treatment site.
R4: T(60)/C(60) C(60) = ambient EM fields at the control site.

TABLE G-10. 1990 EM FIELD VARIATIONS ALONG MICHIGAN TRANSECTS
Bird Species and Communities Studies
(page 1 of 2)

Study Transect	Sub-Transect Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10T1	Start A	11.63	32
10T1	AXB	1.64	38
10T1	BXC	1.48	42
10T1	CXD	1.02	14.8
10T1	D2	51.20	19.7
10T1	DXE	1.26	22
10T1	EXF	0.93	28
10T1-4	F2	0.95	42
10T1	FXG	1.01	21
10T1	GXH	1.34	71
10T1-3	H9	1.62	82
10T1	End H	1.30	90
10T2-1	Start A	2.4	44
10T2	AXB	0.89	31
10T2	BXC	0.92	18
10T2	CXD	1.01	90
10T2	DXE	1.42	47
10T2-2	E3	1.54	65
10T2	EXF	1.43	52
10T2	FXG	1.30	41
10T2	GXH	1.06	48
10T2-4	H5	0.92	71
10T2	End H	0.75	78
10T3-1	Start A	1.87	46
10T3	AXB	2.6	94
10T3	BXC	2.5	69
10T3	CXD	1.80	74
10T3	DXE	1.30	75
10T3	EXF	1.40	93
10T3-3	Start G	14.3	105
10T3	GXH	3.2	54
10T3-2	End H	2.9	66
10T4-1	Start A	1.89	61
10T4	AXB	3.3	73
10T4	BXC	3.9	81
10T4	CXD	5.2	61
10T4	DXE	2.5	62
10T4	EXF	3.4	46
10T4-3	F3	2.7	66
10T4	FXG	1.90	57
10T4	GXH	2.0	53
10T4	End H	1.13	37

TABLE G-10. 1990 EM FIELD VARIATIONS ALONG MICHIGAN TRANSECTS
Bird Species and Communities Studies
(page 2 of 2)

Study Transect	Sub-Transect Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10T11-1	Start A	2.3	49
10T11	AXB	1.70	53
10T11	End B	1.50	55
10T11	CXD	1.46	39
10T11	DXE	1.40	44
10T11	EXF	1.50	55
10T11	FXG	2.3	67
10T11	GXH	1.74	69
10T11	End H	1.40	52

Notes: Measurements taken at "X" flag between sub-transects except as noted.
Antenna conditions: 150 amperes, 76 Hz.

APPENDIX H

ELECTROMAGNETIC EXPOSURE CRITERIA

ELECTROMAGNETIC EXPOSURE CRITERIA

Because the electromagnetic (EM) field intensities and/or exposure durations required to produce a bioeffect are not known, EM exposure criteria were established to assist investigators in selecting study sites. These exposure criteria ensure that the 76 Hz EM fields at a treatment site are significantly larger than the 76 Hz EM fields at its paired control site, and also significantly larger than the 60 Hz EM fields at both sites. In addition, the exposure criteria verify that there is not a substantial difference in the ambient 60 Hz EM field intensities between the treatment and control sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T_{(76\ Hz)}/C_{(76\ Hz)} > 10 \tag{1}$$

$$T_{(76\ Hz)}/T_{(60\ Hz)} > 10 \tag{2}$$

$$T_{(76\ Hz)}/C_{(60\ Hz)} > 10 \tag{3}$$

$$0.1 < T_{(60\ Hz)}/C_{(60\ Hz)} < 10 \tag{4}$$

where $T_{(76\ Hz)}$ = treatment site exposure due to ELF Communications System
$T_{(60\ Hz)}$ = treatment site exposure due to power lines
$C_{(76\ Hz)}$ = control site exposure due to ELF Communications System
$C_{(60\ Hz)}$ = control site exposure due to power lines

Based on the exposure assessment, each possible treatment and control site pairing was classified as acceptable, conditionally acceptable, or unacceptable. These categories are defined as follows:

Acceptable. A treatment/control site pair was placed in this category if it satisfied all four EM exposure inequalities for each of the EM fields applicable to the study. For example, the small mammals and nesting birds studies would be concerned with both the soil and air electric fields as well as the magnetic fields. The soil arthropods and earthworms studies, however, would not be concerned with the electric field in the air, since this field terminates at the earth's surface and would not be expected to impact biota existing in the soil or litter layer.

Conditionally Acceptable. A treatment/control site pair was placed in this category if it approached, but did not meet, the criteria for acceptability. This category was established because the EM exposure criteria were not rigidly defined. The assumption was made that a difference of one order of magnitude or more would constitute a significant difference between treatment and control sites for these studies, but without knowing what effects will be experienced, if any. It is difficult to define this difference *a priori*. Furthermore, the EM field measurements themselves encompass a certain degree of error, as do any physical measurements.

Unacceptable. A treatment/control site pair was placed in this category if it neither satisfied the criteria for acceptability nor qualified for conditional acceptability.

APPENDIX I

ELECTROMAGNETIC EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

ELECTROMAGNETIC EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

This appendix documents the protocol written by IITRI to assist the soil amoeba study investigator in setting up his study sites using the culture chamber exposure hardware fabricated by IITRI. The protocol also provides guidelines for adjusting the control boxes for proper EM exposures in the cells and for measuring the control voltages necessary to determine the cell exposure parameters.

MATCHED ELECTRIC FIELD PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1-m probe.

(2) Multiply electric field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

$$V_{DR}\text{ (min)} = E \times 0.15 \text{ (volts)}$$

(3) Locate collector electrodes in line with the maximum electric field in the earth, and spaced far enough apart to generate a voltage across a 2000-ohm resistor that is greater than or equal to V_{DR} (min) (see Figure I-1).

(4) Measure and record electrode spacing and the open-circuit (no load) electrode voltage, V_{OC}.

(5) Connect the test cell and control box to the electrodes (see Figure I-2). While monitoring the test cell voltage, V_{CL}, adjust the variable resistor so that V_{CL} is equal to the value given by the following formula:

$$V_{CL} = E \times 0.113 \text{ (volts)}$$

(6) With the cell voltage set, measure and record the voltage across the 100-ohm series resistor, V_R. This allows calculation of the cell current and current density.

(7) Measure and record the electrode voltage, V_{DR}, with the test cell and monitoring box connected and adjusted as per step 5, above.

MATCHED CURRENT DENSITY PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1-m probe.

(2) Locate collector electrodes in line with maximum electric field, with a separation of 1 m.

(3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC}. Measured voltage should be within a few percent of that measured in step 1. If not, correct electrode spacing as appropriate.

(4) Connect current-limiting control box (see Figure I-3) to electrodes. Place the current limit select switch to the 2.5-megohm position (2.5 MΩ).

(5) Measure and record the voltages across the test cell, V_{CL}, the resistor, V_R, and the electrodes, V_{DR}, using the test point jacks (see Figure I-3 for test point numbering).

The voltages across the resistor and across the electrodes should be close in value to V_{OC} from step 3.

$$V_R \approx V_{DR} \approx V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \approx 0.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

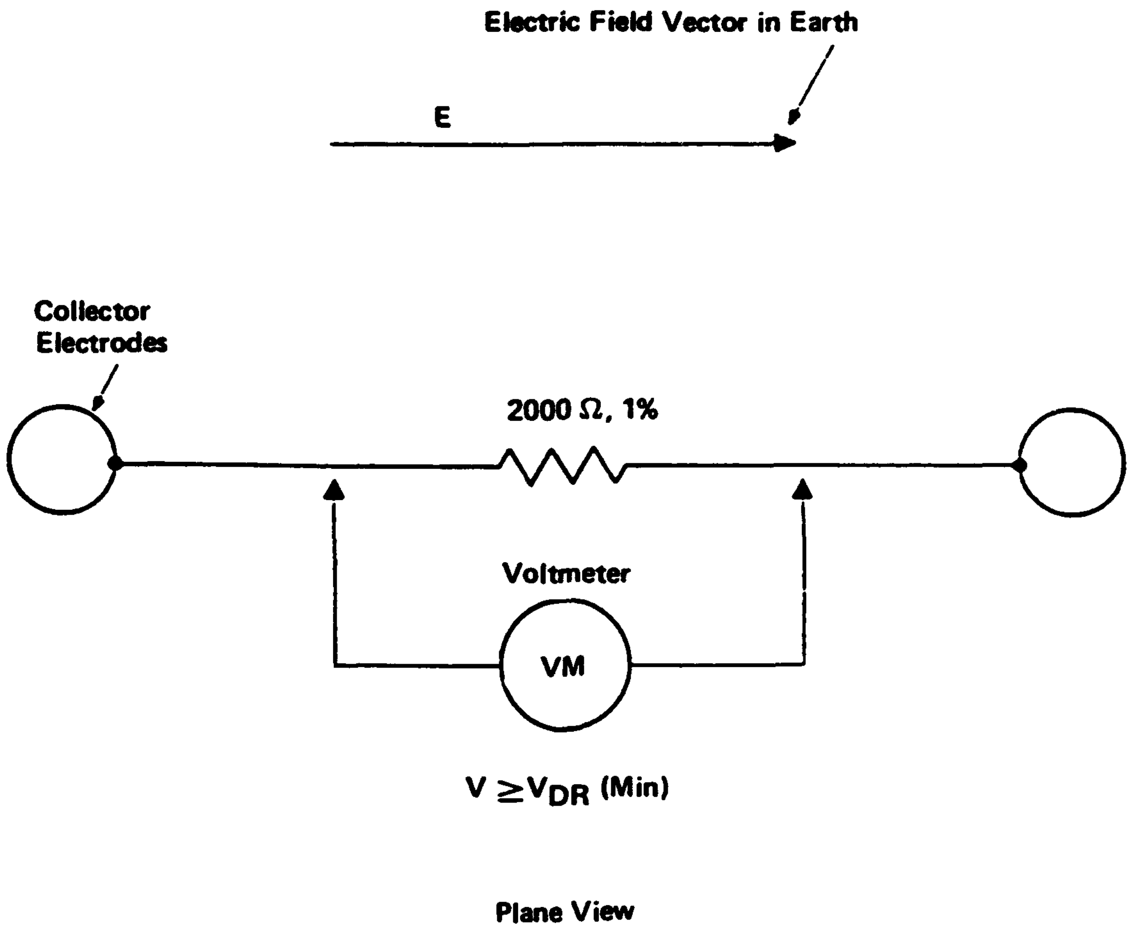
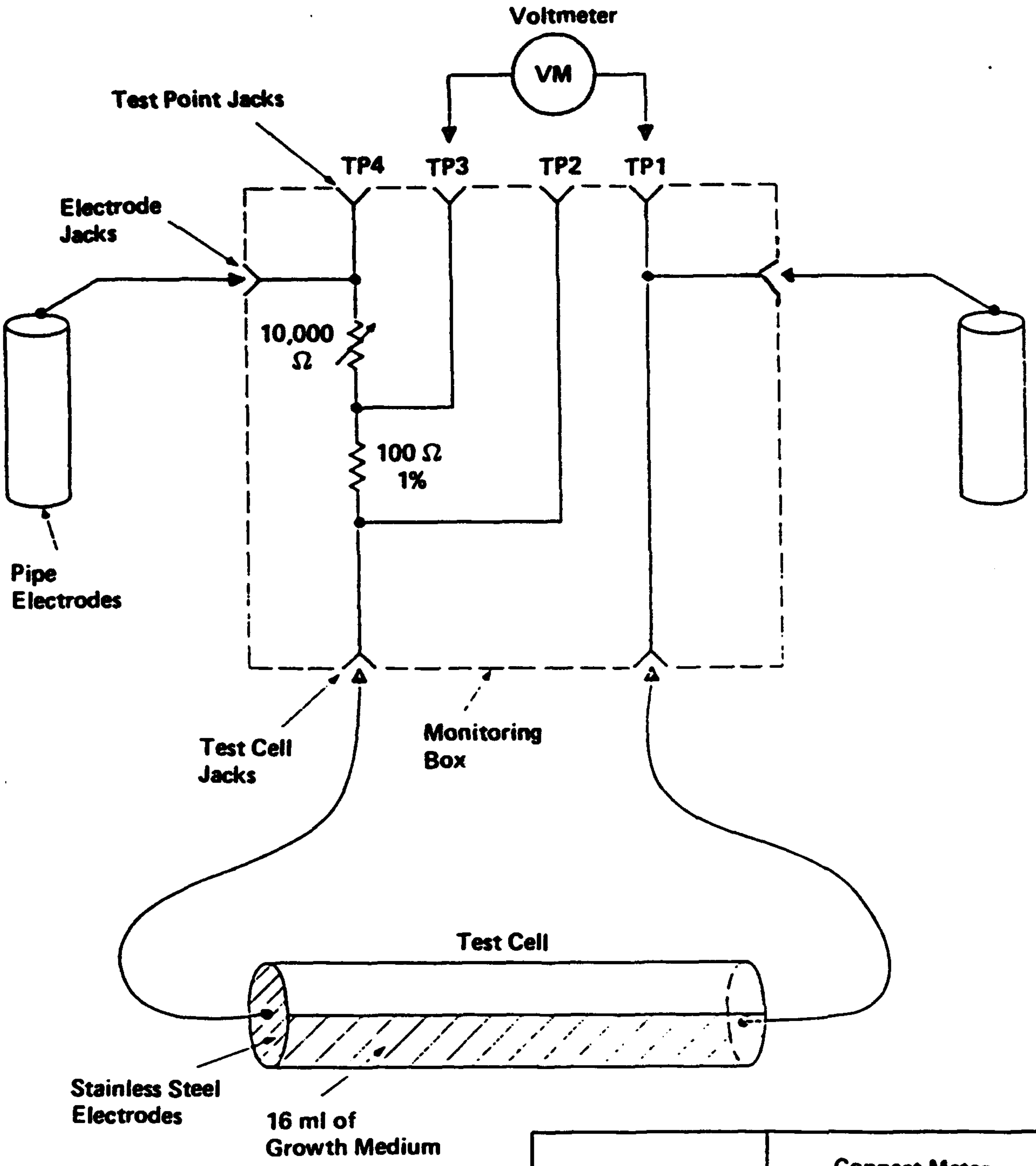
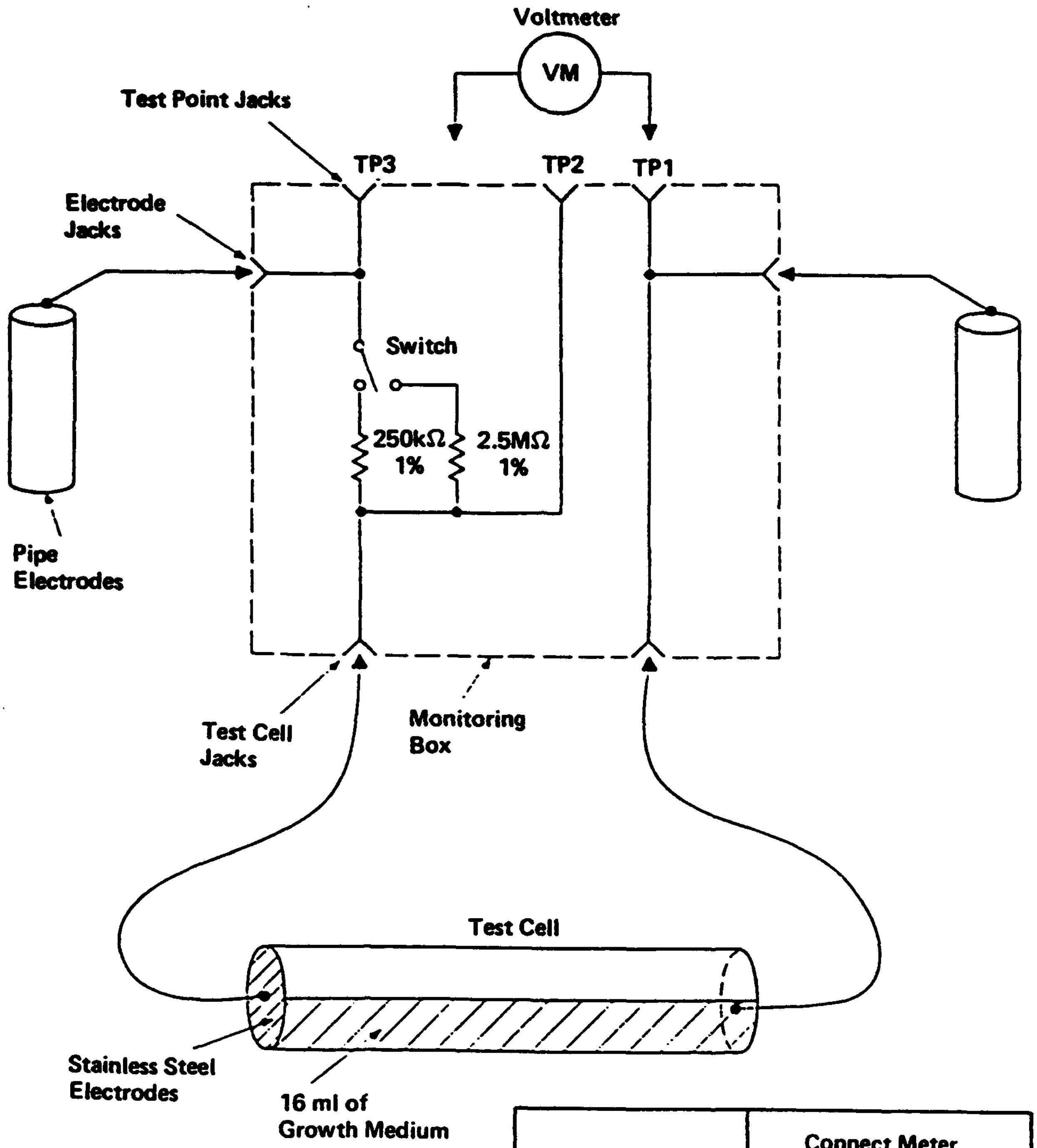


FIGURE I-1. DETERMINATION OF DRIVE VOLTAGE FOR THE SOIL AMOEBA STUDIES MATCHED ELECTRIC FIELD PROTOCOL.



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP4

FIGURE I-2. CONTROL BOX CONNECTIONS FOR MATCHED ELECTRIC FIELD CHAMBERS.



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP3

FIGURE I-3. CONTROL BOX CONNECTIONS FOR MATCHED CURRENT DENSITY CHAMBERS.

APPENDIX J

SUMMARY OF OPERATION, NRTF-REPUBLIC

SUMMARY OF OPERATION, NRTF-REPUBLIC

The operations of the NRTF-Republic from 1986 through 1993 have been summarized in response to requests from investigators for information on operating schedules. The summary is partitioned according to antenna configuration, modulation, frequency, and antenna current. Separate tables exist for each antenna configuration for each year. Tables J-1 through J-3 show the number of hours of operation per month in 1986 for the NS, NEW, and SEW antenna or antenna element. Tables J-4 through J-7 show the number of hours of operation per month in 1987 and 1988 for the NS and EW antennas. Tables J-8 through J-22 show the number of hours of operation per month in 1989 through 1993 for the NS, EW, and both (B) antennas. These tables provide monthly and annual breakdowns of the operation of the NRTF-Republic by antenna current, frequency, and signal type. Subtotals within each column denote the hours of modulated and unmodulated signal operation. The bottom row of the tables gives an estimate of the number of on/off cycles of the antenna or element on a monthly and annual basis. An on/off cycle is defined as one power-up and one power-down of an antenna or element.

Throughout 1986, 1987, 1988, and early 1989, the NRTF-Republic operated primarily to conduct system testing and to take measurements of coupled interference on public utilities. In this operating mode, the antenna elements were cycled on and off as needed to facilitate measurements. In 1986, the cycling of the antennas was dictated primarily by measurement crews via radio communication with the transmitting site. As testing efforts grew in 1987, 1988, and early 1989, the antennas were automatically cycled on and off during testing hours on a 15-minute rotational cycle. The cycle was divided into three 5-minute periods of NS antenna operation, EW antenna operation, and no antenna operation, as described in Section 4.5.2 of this report. This procedure permitted several measurement crews to perform measurements simultaneously.

The NRTF-Republic operating logs routinely provided to IITRI for this period typically showed only the daily beginning and ending times of the 15-minute rotational cycle operation periods. Separate entries were not included for each change of antenna elements during the cycling, nor were deviations from the cycle necessarily accounted for. Thus, the exact number of on/off cycles and duration of operating time for each antenna element could not be determined exactly, but were estimated by the procedure described below for 1987, 1988, and early 1989.

The total number of on/off cycles for each element was calculated by multiplying the number of hours between the start and finish of the rotational cycling of the antenna elements by 4, since each element had one on/off cycle every 15 minutes. The monthly operation time for each antenna during rotational cycling of the NRTF-Republic was calculated by multiplying the total time period of the rotational cycling by one-third, since each element was estimated to have a 33% duty cycle during cyclic operation periods.

Calculation of operating times and the number of on/off cycles during periods when rotational cycling was not employed (during 1986, and from late 1989 through 1993) were made by directly summing operating time periods and antenna power-up events from the NRTF-Republic operating logs. The estimates of NRTF-Republic operating time and on/off cycles calculated by the above procedures were judged adequate for general use. However, IITRI can obtain exact, minute-by-minute log data for the NRTF-Republic for specific periods as required by the researchers.

TABLE J-1. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month: Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.71	11.49	0.00	0.00	63.37
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.11
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.82	11.49	0.00	0.00	63.48
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07
Totals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.89	11.49	0.00	0.00	63.55
Antenna On/Off Cycles	0	0	0	0	0	0	145	23	31	60	0	0	259

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE J-2. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTHERN EAST-WEST ANTENNA ELEMENT ONLY
(Hours of Operation)

Frequency, Hz	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.00	0.00	0.16
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.36	2.46	9.15	0.00	0.00	44.64
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.57	9.15	0.00	0.00	44.80
Other[b]	0.00	0.00	0.00	0.00	C.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.06
Totals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.63	9.15	0.00	0.00	44.86
Antenna On/Off Cycles	0	0	0	0	0	55	10	2	26	83	0	0	176

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE J-3. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: SOUTHERN EAST-WEST ANTENNA ELEMENT ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.05
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	11.72	0.00	0.00	5.26	5.76	0.00	0.00	22.74
76 (10 Amps)	0.00	0.00	3.87	18.64	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.66
Subtotals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.27	5.76	0.00	0.00	51.45
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
Totals	**0.00**	**0.00**	**3.87**	**18.64**	**6.15**	**11.72**	**0.00**	**0.04**	**5.30**	**5.76**	**0.00**	**0.00**	**51.48**
Antenna On/Off Cycles	0	0	27	39	5	6	0	2	30	78	0	0	187

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE J-4. 1987 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Subtotals	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Other[b]	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Totals	0.00	0.00	0.00	0.42	0.42	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.96
Antenna On/Off Cycles	0	0	0	1	1	533	331	389	466	397	262	0	2380

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-5. 1987 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Subtotals	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Other[b]	0.00	0.00	[illegible]	0.25	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
Totals	0.00	0.00	0.00	0.25	0.42	43.95	27.81	32.39	38.61	33.94	21.90	0.00	199.27
Antenna On/Off Cycles	0	0	0	1	1	527	334	389	463	407	263	0	2385

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-6. 1988 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
						Mode: Unmodulated Signal							
76 (15 Amps)	27.13	26.36	27.14	34.14	41.23	43.27	0.19	0.00	0.00	0.00	0.00	0.00	199.46
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	27.62	59.53	34.24	52.86	12.67	23.76	210.68
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	26.16	2.61	31.20	15.68	76.92
Subtotals	27.13	26.36	27.14	34.14	41.23	43.27	29.08	59.53	60.40	55.47	43.87	39.44	487.06
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	8.09	0.00	0.00	0.00	0.00	0.00	8.09
Totals	27.13	26.36	27.14	34.14	41.23	43.27	40.44	59.67	60.40	55.47	43.87	39.44	496.56
Antenna On/Off Cycles	326	316	326	410	495	519	485	714	725	666	526	473	5961

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-7. 1988 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month: Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[a]													
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
Mode: Unmodulated Signal													
76 (15 Amps)	27.14	30.95	31.48	34.34	41.33	43.13	0.22	0.00	0.00	0.00	0.00	0.00	208.59
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	31.10	68.99	34.71	56.05	12.67	23.76	227.28
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	26.38	2.52	31.29	15.58	76.83
Subtotals	27.14	30.95	31.48	34.34	41.33	43.13	32.38	68.99	61.09	58.57	43.96	39.34	512.70
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	7.20	0.00	0.00	0.00	0.00	0.00	7.20
Totals	27.14	30.95	31.48	34.34	41.33	43.13	42.90	69.13	61.09	58.57	43.96	39.34	523.36
Antenna On/Off Cycles	326	371	378	412	496	518	526	827	733	703	527	472	6289

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-8. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[b]													
44	0.00	0.00	0.00	0.00	0.19	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.20
76	0.00	0.00	0.00	0.00	6.91	0.00	0.00	0.05	0.85	0.00	19.00	0.00	26.81
78	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
Subtotals	0.00	0.00	0.00	0.00	7.42	0.00	0.01	0.05	0.85	0.00	19.00	0.00	27.33
Mode: Unmodulated Signal													
44	8.02	22.24	12.28	0.86	0.43	0.60	4.51	14.16	0.00	0.00	0.15	0.00	63.25
72	0.00	0.00	[illegible]	0.00	0.00	0.27	0.00	0.48	0.00	0.00	0.00	0.00	0.75
76	37.53	21.16	[illegible]	0.30	3.82	0.42	9.19	25.30	3.55	0.00	0.00	0.00	109.46
80	0.00	0.00	[illegible]	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.38
Subtotals	45.55	43.40	20.47	1.16	4.25	1.67	13.70	39.94	3.55	0.00	0.15	0.00	173.84
Other[c]	0.00	0.00	0.00	0.00	0.40	1.24	0.35	0.02	0.00	0.00	0.00	0.00	2.01
Totals	45.55	43.40	20.47	1.16	12.07	2.91	14.06	40.01	4.40	0.00	19.15	0.00	203.18
Antenna On/Off Cycles	547	521	245	2	30	73	9	24	97	1	7	0	1556

[a]75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-9. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month: Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: Modulated Signal[b]							
44	0.00	0.00	0.00	0.00	0.11	0.20	0.29	0.00	0.00	0.00	0.00	0.00	0.60
76	0.00	0.00	0.00	0.00	1.85	0.13	0.48	0.00	0.34	23.70	0.00	0.00	26.50
78	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Subtotals	0.00	0.00	0.00	0.00	2.09	0.33	0.77	0.00	0.34	23.70	0.00	0.00	27.23
						Mode: Unmodulated Signal							
44	8.02	22.24	12.53	0.00	0.60	0.94	5.2	11.78	0.29	0.00	0.00	0.00	61.60
72	0.00	0.00	0.00	0.00	0.00	0.82	0.52	0.00	0.00	0.00	0.00	0.00	1.34
76	37.56	21.16	8.11	2.65	4.78	1.57	9.22	17.83	13.68	0.00	0.00	0.00	116.56
80	0.00	0.00	0.00	0.00	0.00	0.59	0.85	0.00	0.00	0.00	0.00	0.00	1.44
Subtotals	45.58	43.40	20.64	2.65	5.38	3.92	15.79	29.61	13.97	0.00	0.00	0.00	180.94
Other[c]	0.00	0.00	0.00	0.00	1.00	0.99	2.16	0.00	0.00	0.00	0.00	0.00	4.15
Totals	45.58	43.40	20.64	2.65	7.47	4.25	16.56	29.61	14.31	23.70	0.00	0.00	212.32
Antenna On/Off Cycles	548	521	246	1	32	70	57	17	70	2	13	1	1578

[a]75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-10. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY (Hours of Operation)

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
Mode: Modulated Signal[b]													
44	0.00	0.00	0.00	0.00	23.99	26.03	69.78	51.97	0.00	0.36	0.00	0.00	172.13
76	0.00	0.00	0.00	0.00	56.09	0.84	96.42	229.01	345.51	679.61	690.11	743.38	2840.97
78	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.35
Subtotals	0.00	0.00	0.00	0.00	80.11	26.87	166.2	280.98	345.51	680.29	690.11	743.38	3013.45
Mode: Unmodulated Signal													
44	0.35	1.12	0.61	4.30	119.33	76.04	82.41	49.14	7.18	0.00	0.47	0.00	340.95
72	0.00	0.00	0.00	0.00	0.42	1.64	0.46	0.02	0.07	0.00	0.00	0.00	2.61
76	1.04	1.84	7.37	2.95	125.65	389.56	354.51	121.39	164.37	9.70	4.97	0.00	1183.35
80	0.00	0.00	0.00	0.00	6.05	24.75	0.00	46.03	0.09	0.00	0.00	0.00	76.92
Subtotals	1.39	2.96	7.98	7.25	251.45	491.99	437.38	216.58	171.71	9.70	5.44	0.00	1603.83
Other[c]	0.00	0.00	0.00	0.00	1.30	6.90	4.09	1.69	0.00	29.69	4.68	0.00	48.35
Totals	1.39	2.96	7.98	7.25	332.86	525.76	607.67	499.25	517.22	719.68	700.23	743.38	4665.63
Antenna On/Off Cycles	24	24	16	2	73	125	110	88	145	80	68	55	810

[a]75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-11. 1990 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
76	0.43	0.10	15.98	5.20	2.15	0.55	5.08	105.23	2.78	19.78	0.00	0.03	157.31
Subtotals	0.43	0.10	15.98	5.20	2.15	0.55	5.08	105.23	2.78	19.78	0.00	0.03	157.31
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	0.43	0.10	15.98	5.20	2.15	0.55	5.08	105.23	2.78	19.78	0.00	0.03	157.31
Antenna On/Off Cycles	4	1	3	4	2	1	2	6	5	1	0	1	30

[a]150 ampere antenna current used throughout 1990.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-12. 1990 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	0.00	3.16	20.90	1.42	0.62	0.73	0.07	0.50	8.65	0.00	0.00	0.05	36.10
Subtotals	0.00	3.16	20.90	1.42	0.62	0.73	0.07	0.50	8.65	0.00	0.00	0.05	36.10
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	115.74	80.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	196.45
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	115.74	80.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	196.45
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	0.00	3.16	20.90	117.16	81.33	0.73	0.07	0.50	8.65	0.00	0.00	0.05	232.55
Antenna On/Off Cycles	75	14	5	89	73	4	1	0	5	0	0	1	267

[a]150 ampere antenna current used throughout 1990.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-13. 1990 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	699.75	606.50	636.26	542.87	612.78	684.44	704.67	591.42	659.63	678.11	674.35	702.78	7793.56
Subtotals	699.75	606.50	636.26	542.87	612.78	684.44	704.67	591.42	659.63	678.11	674.35	702.78	7793.56
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.45
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.47	0.00	0.00	0.00	0.00	4.47
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.92	0.00	0.00	0.00	0.00	4.92
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	699.75	606.50	636.26	542.87	612.78	684.44	704.67	596.34	659.63	678.11	674.35	702.78	7798.48
Antenna On/Off Cycles	30	19	18	88	71	41	15	27	13	12	17	33	384

[a]150 ampere antenna current used throughout 1990.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-14. 1991 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
76	0.00	0.00	0.02	0.00	557.4	663.43	225.24	16.81	0.02	0.54	1.56	162.45	1627.47
Subtotals	0.00	0.00	0.02	0.00	557.4	663.43	225.24	16.81	0.02	0.54	1.56	162.45	1627.47
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.18
Totals	0.00	0.00	0.02	0.00	557.4	663.43	225.24	16.81	0.02	0.54	1.74	162.45	1627.65
Antenna On/Off Cycles	2	0	1	0	35	73	30	4	2	4	4	14	169

[a] 150 ampere antenna current used throughout 1991.

[b] Frequency listed refers to the center frequency of operation.

[c] Denotes small periods of time at other currents or undesignated operation.

TABLE J-15. 1991 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Month												
Mode: Modulated Signal[b]													
76	0.00	0.00	0.00	0.00	0.00	0.00	3.25	2.01	3.95	0.09	0.00	0.00	9.30
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	3.25	2.01	3.95	0.09	0.00	0.00	9.30
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	2.00	3.13
Totals	0.00	0.00	0.00	0.00	0.00	0.00	4.38	2.01	3.95	0.09	0.00	2.00	12.43
Antenna On/Off Cycles	0	0	0	0	0	0	10	4	2	9	0	1	26

[a]150 ampere antenna current used throughout 1991.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-16. 1991 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	691.89	617.68	732.65	427.16	150.88	0.00	452.80	637.22	668.79	682.45	656.04	466.73	6184.29
Subtotals	691.89	617.68	732.65	427.16	150.88	0.00	452.80	637.22	668.79	682.45	656.04	466.73	6184.29
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.50
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.50
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	691.89	617.68	732.65	427.16	150.88	0.00	452.80	637.22	668.79	682.45	656.54	466.73	6184.79
Antenna On/Off Cycles	33	18	27	8	1	0	18	62	38	42	25	10	282

[a]150 ampere antenna current used throughout 1991.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-17. 1992 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Mode: Modulated Signal[b]												
76	673.85	648.50	576.74	0.08	0.06	0.00	0.28	9.67	0.15	0.71	0.12	0.00	1910.16
Subtotals	673.85	648.50	576.74	0.08	0.06	0.00	0.28	9.67	0.15	0.71	0.12	0.00	1910.16
	Mode: Unmodulated Signal												
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
Totals	**673.97**	**648.50**	**576.74**	**0.08**	**0.06**	**0.00**	**0.28**	**9.67**	**0.15**	**0.71**	**0.12**	**0.00**	**1910.28**
Antenna On/Off Cycles	10	11	10	2	1	0	4	3	4	3	2	0	50

[a] 150 ampere antenna current used throughout 1992.

[b] Frequency listed refers to the center frequency of operation.

[c] Denotes small periods of time at other currents or undesignated operation.

TABLE J-18. 1992 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	0.00	0.00	0.00	0.00	3.99	0.00	0.06	5.62	0.23	0.00	0.85	4.28	15.03
Subtotals	0.00	0.00	0.00	0.00	3.99	0.00	0.06	5.62	0.23	0.00	0.85	4.28	15.03
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.05	0.41
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.05	0.41
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	0.00	0.00	0.00	0.00	3.99	0.00	0.06	5.62	0.23	0.00	1.21	4.33	15.44
Antenna On/Off Cycles	0	0	0	0	2	0	1	8	5	0	5	2	23

[a]150 ampere antenna current used throughout 1992.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-19. 1992 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
76	0.00	0.00	103.12	672.56	675.30	348.22	632.61	701.77	670.13	615.33	670.90	685.53	5775.47
Subtotals	0.00	0.00	103.12	672.56	675.30	348.22	632.61	701.77	670.13	615.33	670.90	685.53	5775.47
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.29
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.29
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	0.00	0.00	103.12	672.56	675.30	348.22	632.61	701.77	670.13	615.33	671.19	685.53	5775.76
Antenna On/Off Cycles	0	0	4	10	19	9	27	14	26	19	17	10	155

[a]150 ampere antenna current used throughout 1992.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-20. 1993 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	0.03	0.00	0.00	0.17	0.00	1.97	0.04	0.02	0.00	0.05			2.28
Subtotals	0.03	0.00	0.00	0.17	0.00	1.97	0.04	0.02	0.00	0.05			2.28
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00			0.03
Subtotals	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00			0.03
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Totals	0.03	0.00	0.00	0.17	0.03	1.97	0.04	0.02	0.00	0.05			2.31
Antenna On/Off Cycles	1	0	0	4	1	3	1	1	0	1			12

[a]150 ampere antenna current used throughout 1993.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-21. 1993 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
76	0.00	0.00	0.00	0.00	0.05	0.21	0.40	0.15	0.13	0.30			1.24
Subtotals	0.00	0.00	0.00	0.00	0.05	0.21	0.40	0.15	0.13	0.30			1.24
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Totals	0.00	0.00	0.00	0.00	0.05	0.21	0.40	0.15	0.13	0.30			1.24
Antenna On/Off Cycles	0	0	0	0	1	3	4	3	2	6			19

[a]150 ampere antenna current used throughout 1993.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-22. 1993 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY (Hours of Operation)

Frequency, Hz	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
	Month												
Mode: Modulated Signal[b]													
76	702.70	636.44	690.94	666.99	696.50	659.13	689.65	695.06	664.82	695.93			6797.66
Subtotals	702.70	636.44	690.94	666.99	696.50	659.13	689.65	695.06	664.82	695.93			6797.66
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Totals	702.70	636.44	690.44	666.99	696.50	659.13	689.65	695.06	664.82	695.93			6797.66
Antenna On/Off Cycles	7	7	9	14	14	16	24	20	16	16			143

[a]150 ampere antenna current used throughout 1993.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.