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**ELF Communications System
Ecological Monitoring Program:
Electromagnetic Field Measurements
and Engineering Support--1992**

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13. ABSTRACT (Maximum 200 words) 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. <i>In situ</i> 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, studies continued during 1992. Data collection will continue at Michigan study sites through 1993. In support of this research, IIT Research Institute annually documents 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 1992, and is comprehensive for the period 1983-1992. Other engineering activities performed during 1992 in support of the ecological studies are also described.					
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FOREWORD

This report documents measurements of extremely low frequency (ELF) electromagnetic (EM) fields made in support of the U.S. Navy's ELF Communications System Ecological Monitoring Program from 1983 through 1992. The report also describes other engineering activities performed in support of the Program during 1992. This 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).

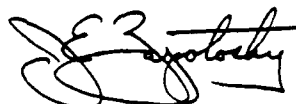
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**ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:
ELECTROMAGNETIC FIELD MEASUREMENTS AND ENGINEERING SUPPORT-1992**

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 will result in adverse effects on resident biota or their interrelationships. Monitoring studies are being performed by investigators from several universities, and their efforts are being supported by IIT Research Institute (IITRI).

IITRI assists the 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 includes design, fabrication, and installation of EM control and recording equipment; mitigation of EM exposures in laboratories; and mitigation of on-site ambient monitoring equipment with respect to EM safety, EM interference, and damage from nearby lightning strikes. IITRI personnel also summarize data on the operational characteristics of the ELF transmitters, and review 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 1992 and provides a comprehensive summary (1983-1992) of EM exposures at study sites and laboratories that were still active in 1992. Documentation of EM field measurements and engineering support for completed studies--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

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 (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

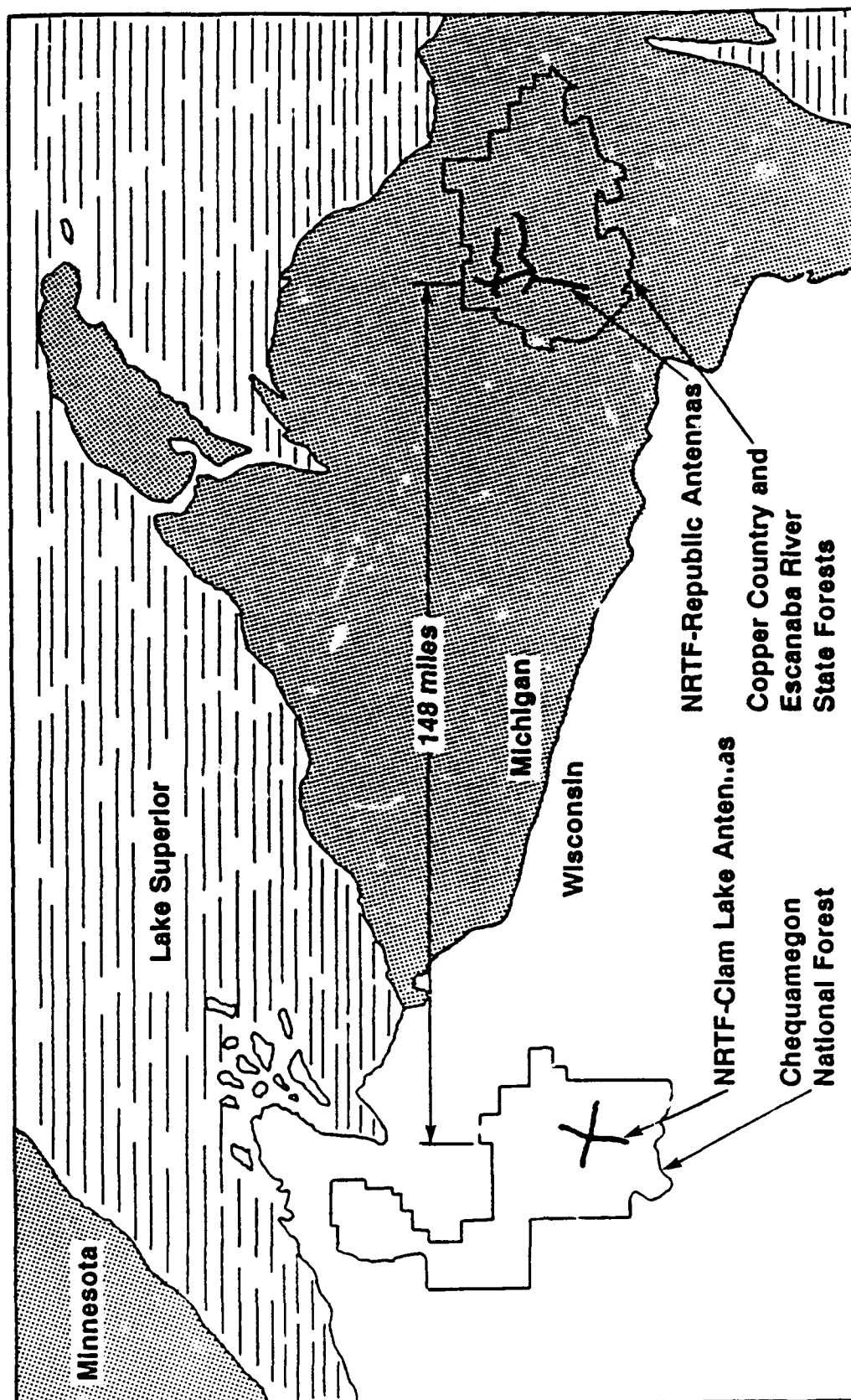


FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

EW antenna comprised 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:

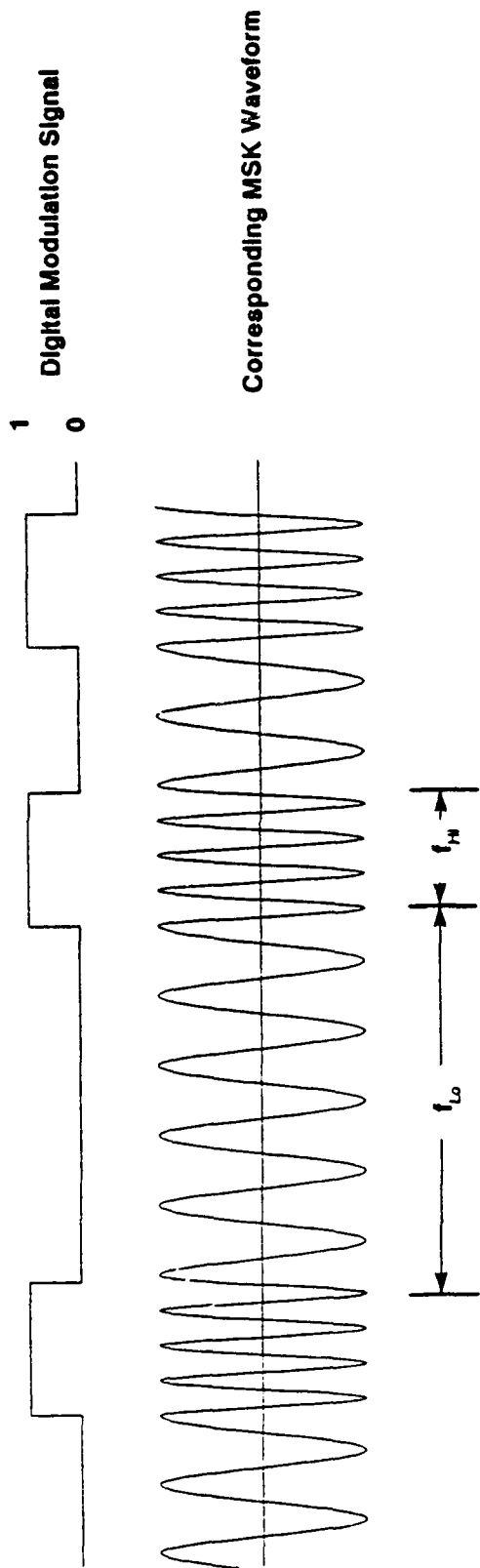
- a magnetic field, essentially the same in the air and the earth, that is generated by the electrical current in the antenna elements and ground terminals
- an electric field in the earth that is the sum of the fields induced by the magnetic field and the current flowing from the buried ground terminals
- 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 an operational ELF Communications System is modulated 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. The planned frequencies for routine operation of the ELF Communications System are modulated between 72 Hz and 80 Hz; in addition, the system can transmit at frequencies between 40 Hz and 48 Hz (44 Hz center frequency). Figure 2 illustrates an MSK waveform and its corresponding binary code and power spectral distribution.

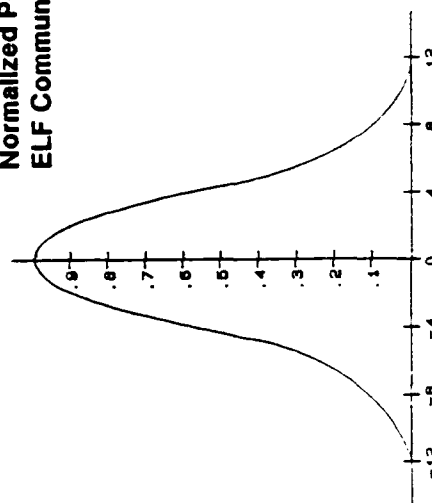
Exposure of resident biota to 76 Hz and 44 Hz EM fields has been quite variable over the development of the ELF Communications System. In order to address these differences, some ecological investigators have divided EM exposure into preoperational, transitional, and operational periods. During the preoperational phase, biota received no EM exposure from the ELF system. The transitional phase began with the intermittent energizing of transmitters for testing, most often at intensities lower than those of a fully operational ELF system. During the operational phase of the ELF system, EM exposures are nearly continuous and at planned, full-power intensities. The NRTF-Clam Lake was first energized in 1969 and became fully operational during the last quarter of 1985; the NRTF-Republic was first energized in early 1986 and became fully operational during the last quarter of 1989.

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



Normalized Power Spectral Distribution of
ELF Communications System, MSK Signal



Deviation from Center Frequency, Hz

FIGURE 2. MSK WAVEFORM AND POWER SPECTRAL DISTRIBUTION.

biotic and 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 76 Hz EM fields.

Dissimilar 76 Hz EM exposures were attained by situating treatment sites relatively close to the ELF Communications System while placing control sites at a greater distance. The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T_{(76 \text{ Hz})}/C_{(76 \text{ Hz})} > 10 \quad (1)$$

$$T_{(76 \text{ Hz})}/T_{(60 \text{ Hz})} > 10 \quad (2)$$

$$T_{(76 \text{ Hz})}/C_{(60 \text{ Hz})} > 10 \quad (3)$$

$$0.1 < T_{(60 \text{ Hz})}/C_{(60 \text{ Hz})} < 10 \quad (4)$$

where $T_{(76 \text{ Hz})}$ = treatment site exposure due to ELF Communications System

$T_{(60 \text{ Hz})}$ = treatment site exposure due to power lines

$C_{(76 \text{ Hz})}$ = control site exposure due to ELF Communications System

$C_{(60 \text{ Hz})}$ = 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).

Nearly all sites paired for ecological characteristics met or exceeded the EM exposure criteria. In a few exceptional cases, pairs came close, but failed to meet all of the EM criteria; because these sites could not be relocated without adversely impacting matched biotic considerations, they were accepted.

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 Hz 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

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.

1.5 1992 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 1992, measurement of geomagnetic field intensity and inclination was included for the first time. 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 order to test a hypothesis that 76 Hz electric fields in the earth account for variations in earthworm abundance, measurements of the field were made at 46 locations within the site just prior to

worm collection. Measurements were made with 1-meter and 10-centimeter probes to determine the uniformity of the field over a 1-meter span. Maximal field direction was also determined. Overall, variations in the field intensity and direction at the sites were small.

A time-domain reflectometry (TDR) technique of measuring soil moisture content was implemented by investigators for the soil arthropods and earthworms studies in 1992. In order to assess effects of the TDR probes on earth electric field intensities, measurements of the field were made at several locations around a probe both before and after its installation. Little difference was found between the two measurement sets if the probe was oriented perpendicular to the earth electric field vector.

EM field measurements were performed for the first time at the soil arthropods and earthworms study laboratory and at the relocated laboratory for the native bees study. 60 Hz magnetic fields were monitored over a 1- to 2-day period at both laboratories. A commercially available magnetic field monitoring system was used for these measurements. 60 Hz air electric fields were also characterized.

In 1991, the principal investigator for the soil arthropods and earthworms study proposed the use of a buried chamber to isolate earthworms for controlled reproduction studies. IITRI assisted in the design of the chamber—a mesh nylon 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 were characterized in 1991 and again in 1992. Electric fields were continuously monitored using data logger systems designed and fabricated by IITRI. These loggers monitored the 76 Hz earth electric field intensity both inside and outside the incubation bags, as well as outside the bags in three soil horizons. 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 aspen 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.

A data logger monitoring system was also installed in 1991 at the aquatic ecosystems treatment study site for continual monitoring of earth electric fields. In 1991 and 1992, earth electric fields at several points in the riverbed were monitored by this logger, as were the air and riverbed temperatures.

In total, six data logger monitoring systems were used in 1992 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 antennas were 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, as defined in Appendix H.

The 76 Hz earth electric field intensity ratios (R1) for several aquatic ecosystems site pairs have been low since the start of the site selection process. 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 R1 ratio continued to be of concern for all aquatic study activities. IITRI made suggestions for site relocations that would improve the intersite exposure ratios. In early 1990, IITRI personnel visited the aquatic ecosystems study sites with the study researchers 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 An overview of all current aquatic ecosystem study sites and activities is given in Figure 4. Although new study locations were established to improve treatment/control exposure ratios, study activities are also continuing at original locations to maintain continuity with historical data. EM field ratios were

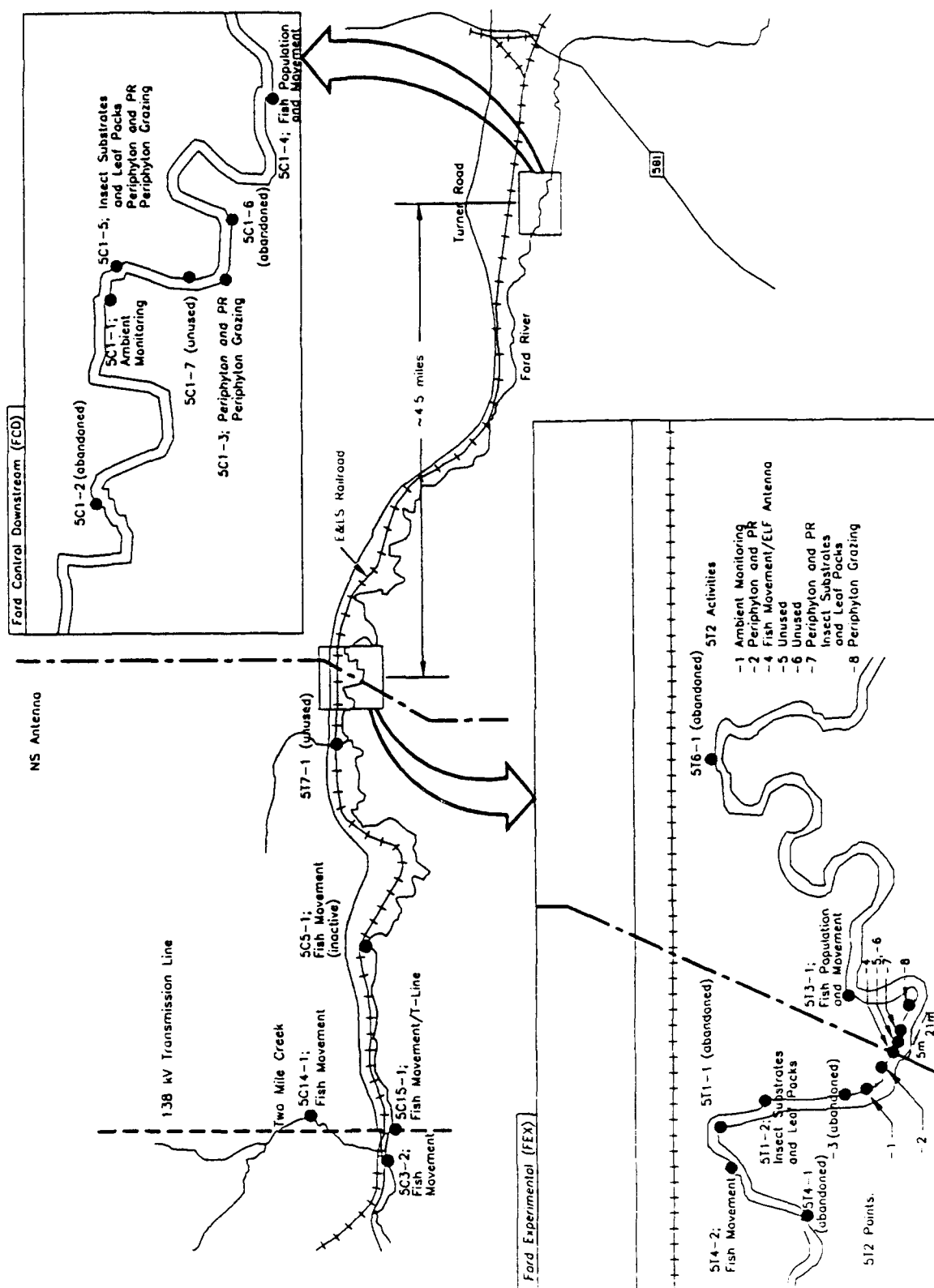


FIGURE 4. AQUATIC ECOSYSTEMS STUDY SITE LOCATIONS.

recalculated for the earth electric field and magnetic field using 1992 measurement data; these ratios are presented in Table 1, together with corresponding values from 1990 and 1991. 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 remains improved over the original pairings.

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

Compared Sites (Treatment/Control)	Activity	E_E			B		
		1990	1991	1992	1990	1991	1992
5T1-2/5C1-5	Insect Substrates and Leaf Packs	2.6	2.6	2.7	66	49	62
5T2-7/5C1-5	* Insect Substrates and Leaf Packs	6.9	6.2	7.7	600	440	570
5T2-2/5C1-5	* Periphyton and PR	5.0	4.8	6.4	300	300	300
5T2-7/5C1-5	* Periphyton and PR	6.9	6.2	7.7	600	440	570
5T2-2/5C1-3	* Periphyton and PR	7.6	7.9	9.3	300	310	290
5T2-7/5C1-3	* Periphyton and PR	10.6	10.1	11.1	600	460	550
5T2-8/5C1-5	Periphyton Grazing	7.7	6.7	10.1	340	310	330
5T2-8/5C1-3	* Periphyton Grazing	11.9	11.0	15	340	330	320

E_E = earth electric field.

B = magnetic field.

*Site pairings for 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 Communications System and power lines. These fields alternate polarity with a frequency equal to that of their source current. Of secondary interest is the earth's static (non-alternating) magnetic field, which has been reported to be one of many cues used by animals for navigation. Both fields are generally unaffected by environmental factors such as weather, vegetation, soil, and nonmetallic structures, and both behave predictably. Magnetic fields are unchanged at such boundaries as air/earth or air/water. Thus, measurement techniques need not consider shielding, enhancements, or perturbations of the magnetic field from the local environment. 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. Variations in the earth's magnetic field occur with geological changes over ages.

The electric field in the earth is measured as a difference in longitudinal potential at the surface of the earth. The two sources of 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 other factors such as large rocks, tree roots, and pools of water. Generally, the intensity of earth electric fields is fairly uniform, and measurements are repeatable when anomalies are avoided. Some year-to-year variations may occur because of changes in soil moisture content, which affect soil conductivity.

The electric field in the air is generated as a result of the operating voltage or transverse potential of the ELF antenna wire with respect to ground and also as a by-product of the earth electric field. Power lines generate a transverse or vertical air electric field in a manner similar to that of the overhead antenna wire. These vertical fields are limited to the ROW and other nearby cleared areas. A difference in potential between two grounded objects such as trees is set up by the earth electric field. This difference in potential, in turn, generates a horizontal electric field in the air. 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 are 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 an earth 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 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 will include 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 calibration factor of the probe at the frequency of interest to obtain the magnitude of the applied field.

The earth electric field probe consists of three electrodes mounted on a fiberglass 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 equal to the earth electric field in the given direction. Note that a compass and a cradle are mounted atop a 1-meter 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 in three orthogonal positions at a 1-meter height and orient the probe precisely with the legs of the probe.

The magnetic field probe is basically a multiturn coil 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.

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

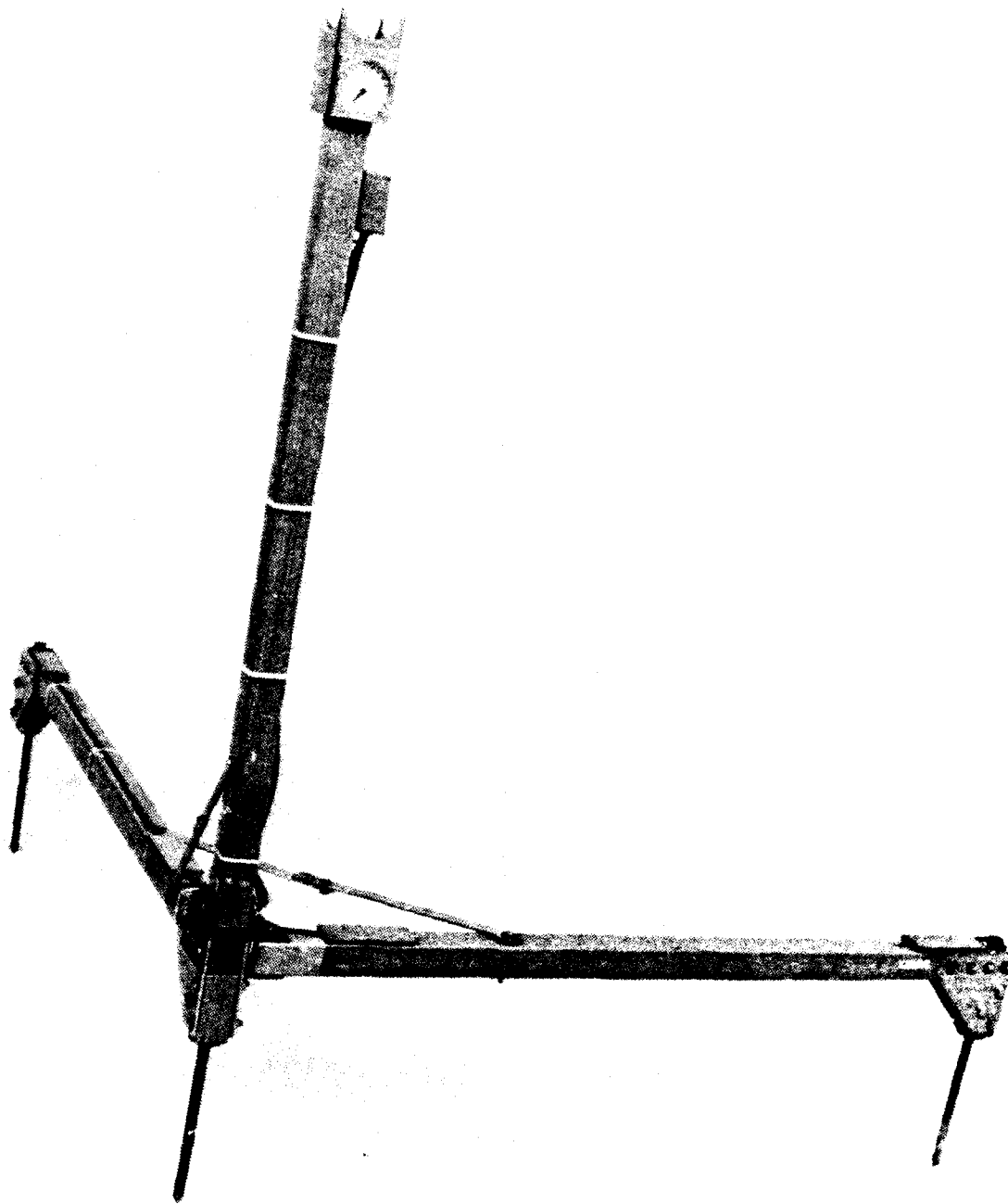


FIGURE 5. EARTH ELECTRIC FIELD PROBE.

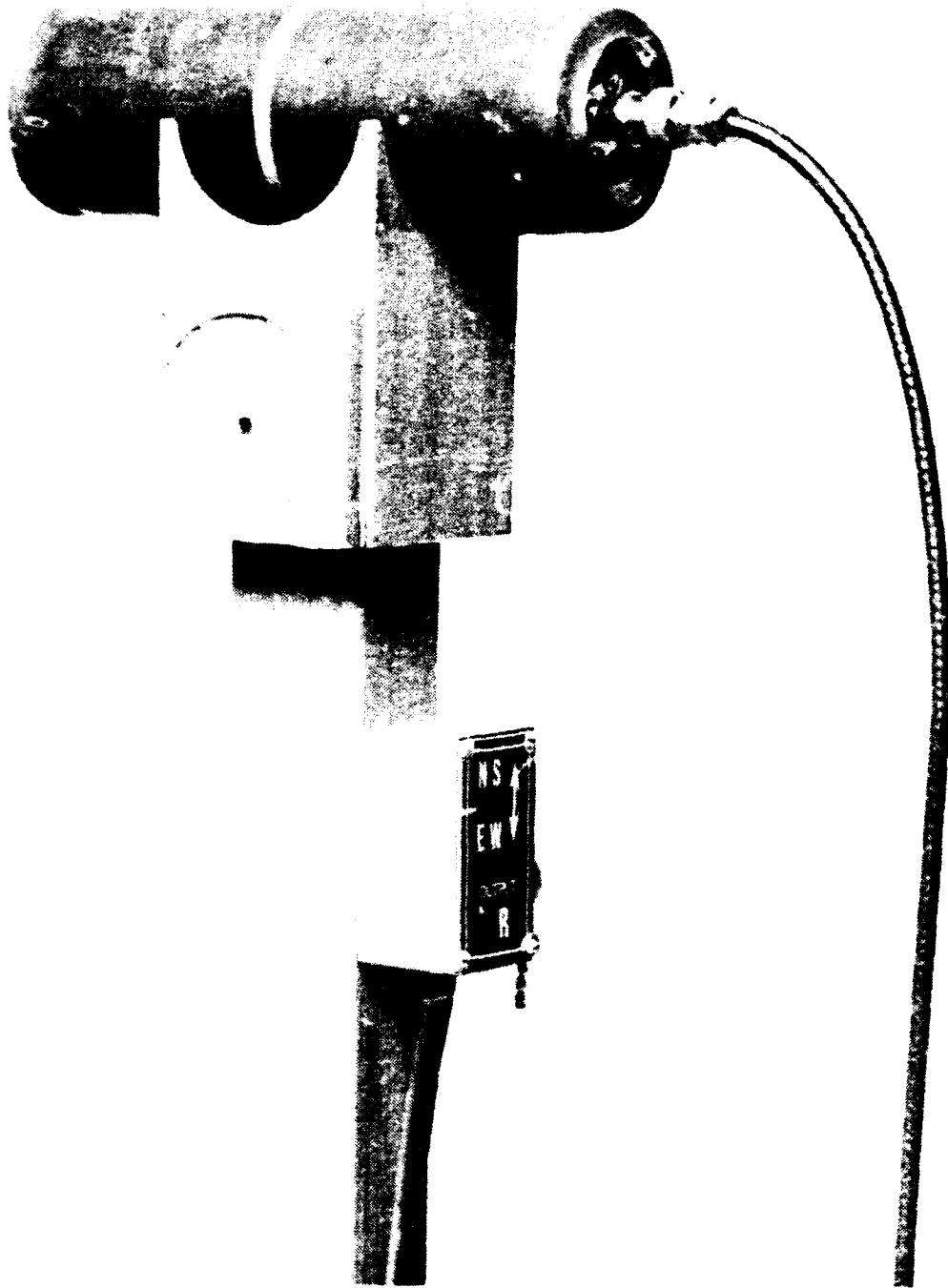


FIGURE 6. MAGNETIC FIELD PROBE.

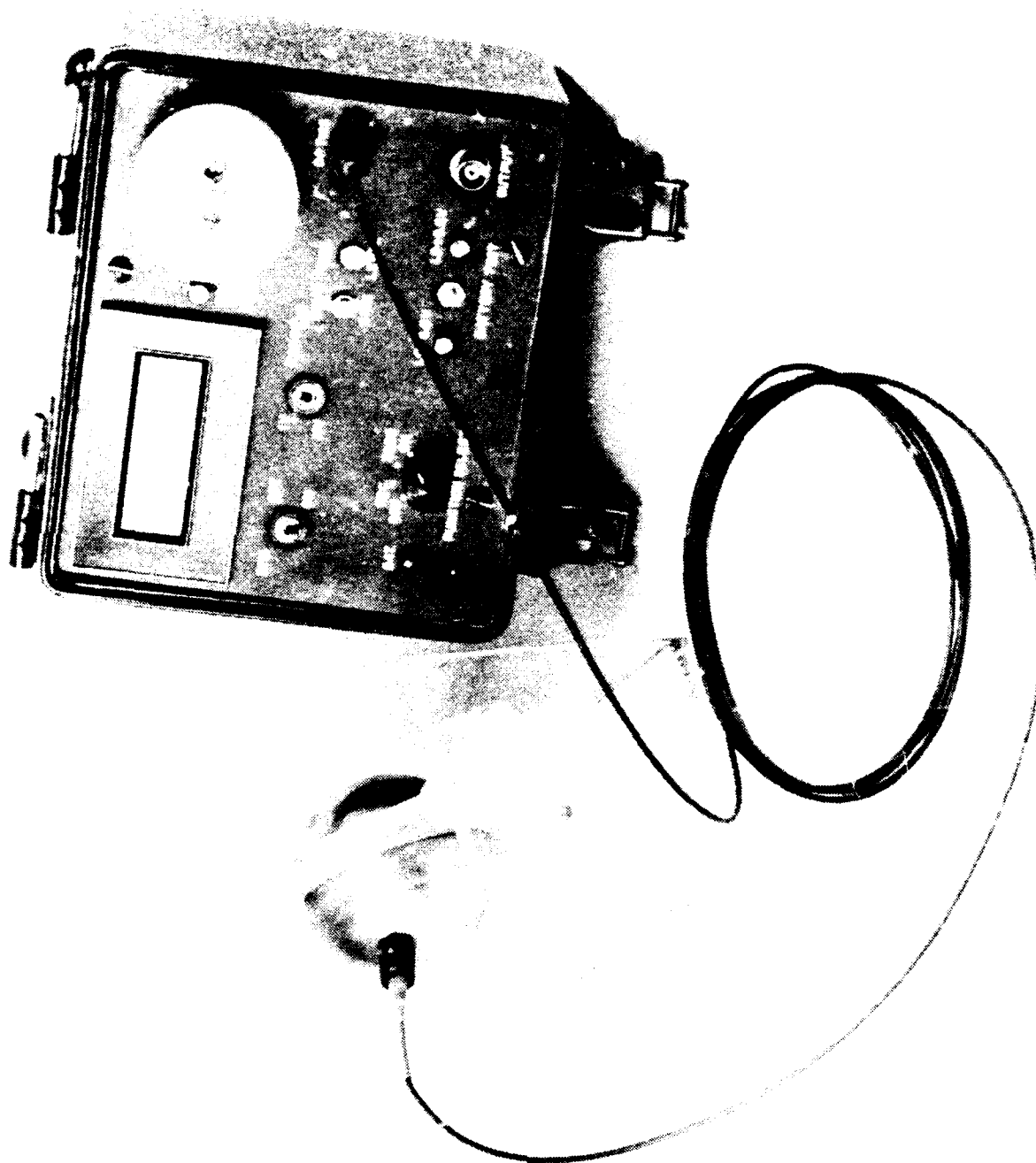


FIGURE 7. AIR ELECTRIC FIELD PROBE.

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-meter-square, 1/3-meter-spaced parallel plates with guard rings. A uniform magnetic field is generated over a large volume by a set of 1-meter-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-meter-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 so that probe operation can be verified periodically.

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 north-south, the east-west, and the vertical directions. The earth electric field intensity has no vertical component; therefore, only the north-south and east-west components are measured. In 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.

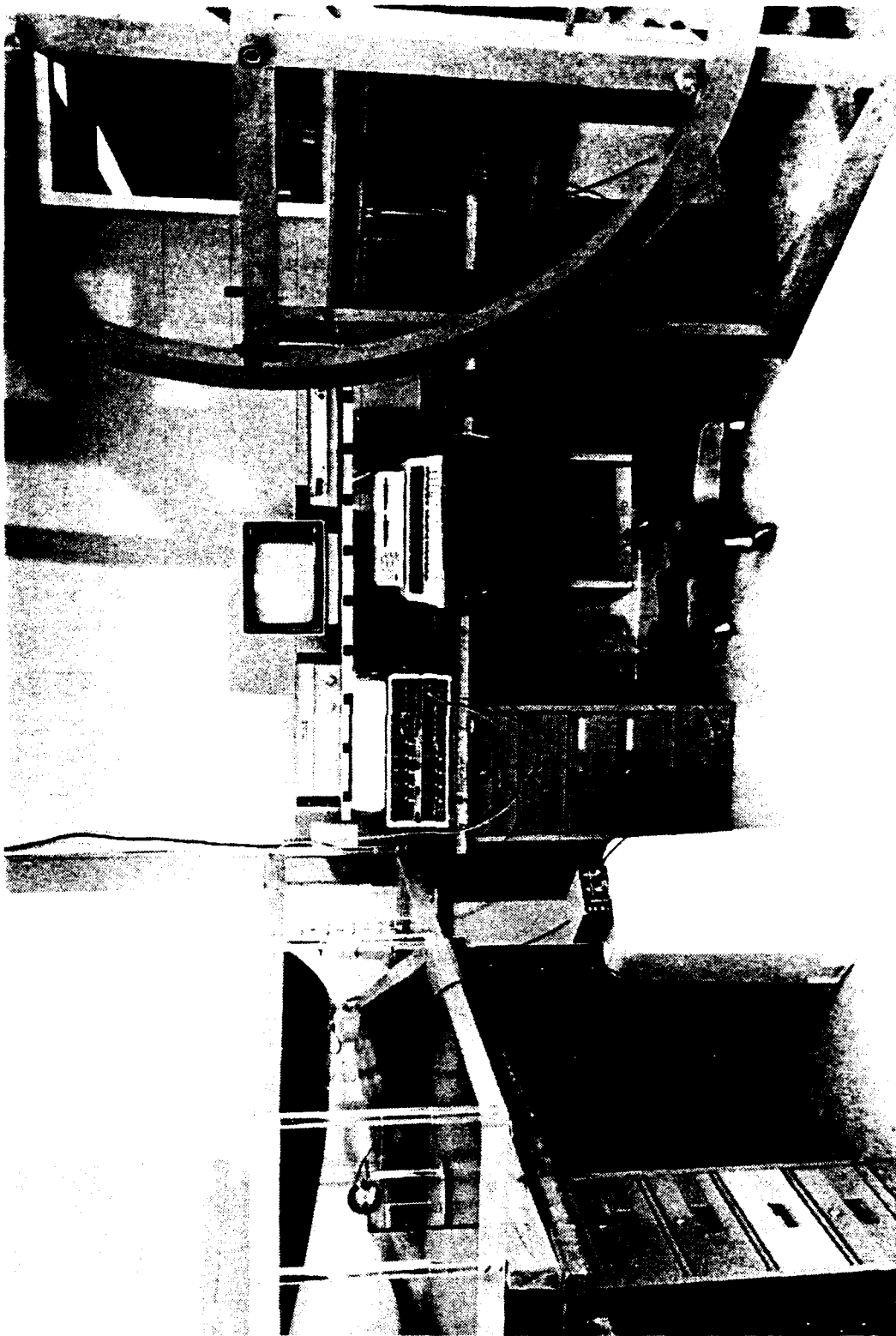


FIGURE 8. COMPUTER-DRIVEN ELECTRIC AND MAGNETIC FIELD PROBE CALIBRATION SYSTEM.

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 a few Michigan migrating bird population transect sites fall in this category. Further, 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 continued through 1985. During this period, the NRTF-Republic was not capable of generating ELF EM fields. Construction of the NRTF-Republic was completed in early 1986, and intermittent operation began with low power levels of 4 to 10 amperes of antenna current. Only one antenna or antenna element was operated at any one time during 1986: the north-south (NS) antenna, the northern east-west (NEW) element, or the southern east-west (SEW) element. From 1987 onward, the NEW and SEW antenna elements have been connected in parallel and operated as one antenna, hereafter referred to as the east-west (EW) antenna. The NRTF-Republic operated intermittently with a 15-ampere antenna current in 1987, and intermittently with 75-ampere antenna currents during 1988 and early 1989. During 15- and 75-ampere 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 amperes. 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.

The following subsections describe the 1986-1992 measurement protocols used in Michigan.

3.3.2.1 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.

3.3.2.2 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.

**TABLE 2. ANTENNA OPERATING CONDITIONS DURING
EM FIELD MEASUREMENTS IN MICHIGAN**

Year	Antenna or Element	Antenna Current, A	Frequency, Hz	Modulation	Phase	*Off* Antenna Status at Transmitter
1986	NEW, SEW, or NS	6 (NEW) 6 (SEW) 4 (NS)	76	No	NA	GND
1987	NS or EW	15 (NS) 15 (EW)	76	No	NA	CON
1988	NS or EW	75 (NS) 75 (EW)	76	No	NA	CON
1989	B	150 (B)	76	PT	86°	NA
1990	B	150 (B)	76	Yes	86°	NA
1991	B or NS	150 (B) 150 (NS)	76	Yes	99°	GND
1992	B	150 (B)	76	Yes	99°	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.

3.3.2.3 1989 Conditions. In 1989, the EM measurement protocol for Michigan changed again because of simultaneous operation of the NS and EW antennas during all measurements. Modulated-signal operation also necessitated protocol modifications. The 1989 protocol was as follows:

- Ambient 60 Hz EM fields at control study sites were typically measured during operation of both antennas, but could be measured under any antenna operating conditions with a 3 Hz meter bandwidth.
- Ambient 60 Hz EM fields at treatment study sites were measured either with the antennas off or operating with an unmodulated signal. Measurements of 60 Hz fields at treatment sites could not be made during modulated-signal operation.
- 76 Hz ELF EM fields were measured with both antennas on and with either a modulated or unmodulated signal. Meter bandwidths were 30 Hz or 3 Hz, respectively.

3.3.2.4 1990-1992 Conditions. In 1990, 1991, and 1992, the EM measurement protocol for Michigan differed little from that of 1989. The significant difference was that essentially all antenna operations in 1990, 1991, and 1992 were with a modulated signal, making it impossible to measure 60 Hz EM fields at treatment sites unless the antennas were off. As a result, efforts were made in all three years to make additional treatment site visits during periods of antenna maintenance in order to measure 60 Hz EM fields. Also, in 1991 and 1992 there were significant periods of time when the EW antenna was down for maintenance. Efforts were made to take EM field measurements at various sites during this condition in 1991 in order to estimate its effect on EM field intensities at all study sites. The 1990-1992 protocol was as follows:

- Ambient 60 Hz EM fields at control study sites were typically measured during operation of both antennas but could be measured under any antenna operating condition.
- Ambient 60 Hz EM fields at treatment study sites were measured with the antennas off.
- 76 Hz ELF EM fields were measured with both antennas on, and, in some cases in 1991, with the NS antenna on and EW antenna off with a modulated signal in both cases.

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 EM field gradients. At small control sites, a single measurement point was deemed sufficient to

characterize the EM fields. Intermediate-size control sites were measured at the points nearest to and farthest from the antenna grid. Large control sites were measured at several more points as well 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 (e.g., the bird species and communities studies), measurements typically were taken at the ends of the transect and often 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-meter 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 vary greatly with distance from the antenna but show little variation 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 at greater and lesser distances from the antenna. 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 1992 Annual Measurement Data

In 1992, annual measurements in Michigan were conducted on 11, 13, and 26-28 May; 14-18, 21-25, and 28-30 September; and 1 and 2 October. All active sites were measured during these periods with the exception of the small mammals and nesting birds laboratory site, where measurements were not conducted in 1992.

Table 3 presents a summary of the number of sites and measurement points examined during 1992. As shown, a total of 180 measurement points were needed to characterize 49 sites, compared with 195 points at 50 sites in 1991. The number of measurement locations per site was determined by plot

TABLE 3. SUMMARY OF 1992 EM FIELD MEASUREMENTS

Study	Number of Measurement Sites		Number of Measurement Points	
	1991	1992	1991	1992
Small Mammals and Nesting Birds	13	13	63	55
Native Bees	5	5	15	15
Soil Arthropods and Earthworms	4	3	18	12
Upland Flora and Soil Microflora	6	6	50	50
Aquatic Ecosystems	9	9	16	16
Soil Amoeba	3	3	9	9
Bird Species and Communities, Michigan	10	10	24	23
Total	50	49	195	180

Table does not include laboratory sites.

size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analyses.

The one site dropped, 3S1, was established in 1991 for earthworm collection for incubation experiments, but never used; site 3S2 has been used instead. Other differences between 1992 and 1991 included the dropping of eight measurement points at mouse enclosures, which are no longer used for the small mammals studies, and six points along the treatment site worm incubation bag line where there is little variation and such detail therefore is not needed. One point for the bird species and communities studies was inaccessible because of a washed out bridge.

3.4.1 Michigan Measurement Data

The data taken during the 1992 EM measurements in Michigan appear in Appendixes A through G. Six data tables in each of these appendixes document 60 Hz and 76 Hz measurements of the air electric field, earth electric field, and magnetic flux density. 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 1992. A footnote for each column describes the physical status of the ELF antenna during the 60 Hz measurements for that year. The physical status of the ELF antenna

has a significant impact on the 60 Hz EM fields measured 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 1992. The 76 Hz EM field intensity data have been taken at several different antenna operating currents, ranging from 4 amperes in 1986 to the full operating power of 150 amperes since 1989. Specific operating currents are given in the column headings of the data tables. EM field intensity values, as shown in the data tables, have increased in proportion to the antenna operating current from 1986 through 1992.

3.4.2 Coupling of 60 Hz Fields

The 60 Hz data for Michigan studies in Appendixes A through G show that there were significant yearly fluctuations of the 60 Hz EM fields from 1983 through 1992. 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 apply only to treatment sites; the last two are relevant at both treatment and control sites.

The 60 Hz EM fields 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 in turn sets up new 60 Hz EM fields nearby. 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 they do not appear to significantly interact with the 60 Hz magnetic fields from 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 due to (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.

In 1988, 60 Hz coupling to the NS antenna appeared to have increased substantially. This correlated with large load increases on a transmission line that parallels the NS antenna element about four miles to the west. Since the Presque Isle power plant was purchased by Wisconsin Electric Power Company in January 1988, its subsequent operation as a major producer of electrical energy in the region suggests that this line will remain heavily loaded.

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 the result of 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, normal operation of the NS antenna alone, with a 150-ampere, 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, to the 150-ampere condition, the 1988 data measured during 75-ampere solo operation of the NS antenna. This estimation method should not be used for sites 10T3 or 10T11, which are close enough to the EW antenna that cross-coupling and NS/EW antenna field interactions not accounted for by the simple estimation method have effects.

The impact of the EW antenna shutdown was greatest for treatment study sites near the EW antenna or its ground--namely, the two treatment sites for the upland flora and soil microflora studies (4T2 and 4T4) and the Schwartz Creek (10T4) and part of the Flat Rock Creek (10T3) and Heart Lake (10T11) treatment transects for the bird species and community studies. Measurements were taken in 1991 at all points for the upland flora and soil microflora treatment study site both while the EW antenna was out of service and during operation of both antennas. The fields were reduced to about one-third their normal intensity level during shutdown of the EW antenna--actual values can be obtained from the tables in 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 this field, 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 fiberglass plate that is mounted on a standard non-ferrous 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 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 monitoring 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

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

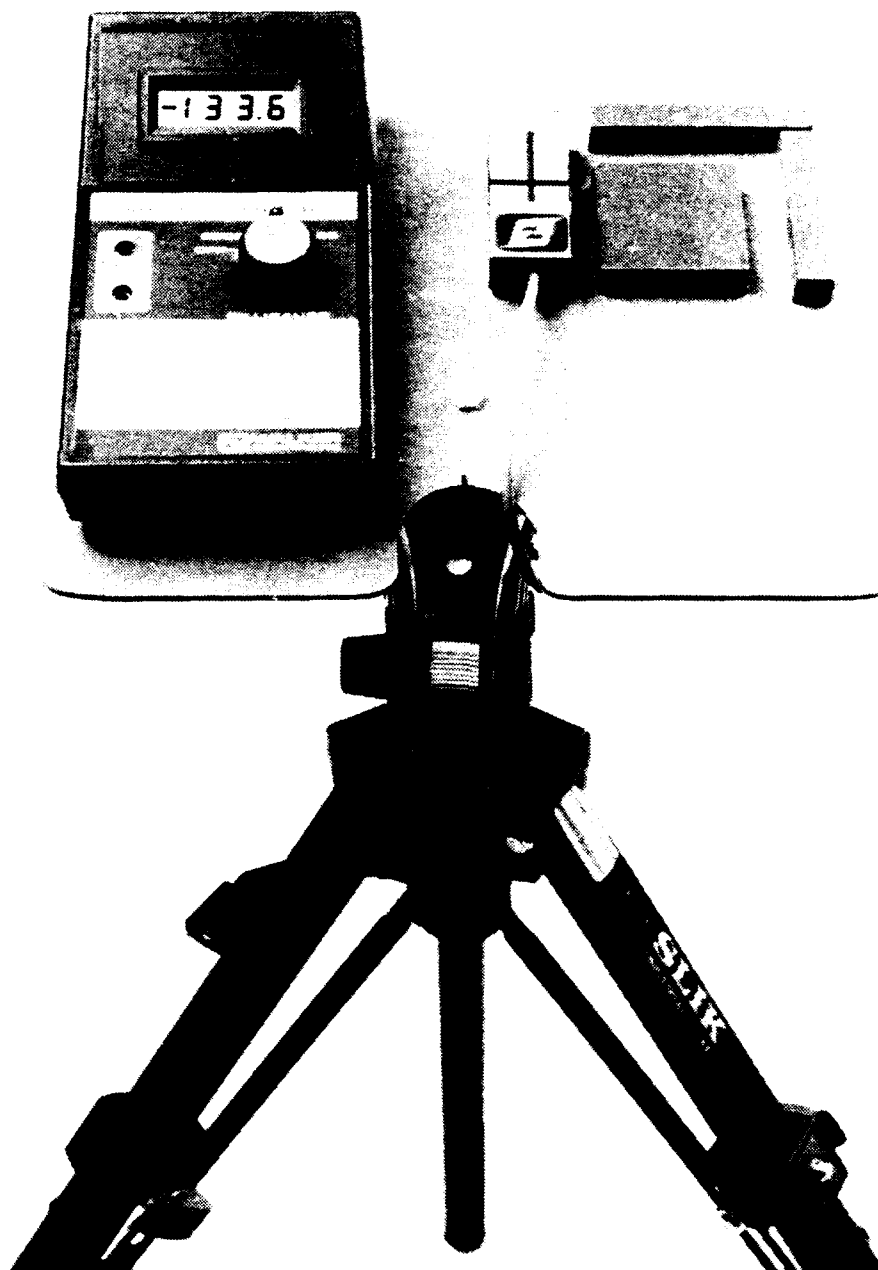


FIGURE 9. FLUXGATE MAGNETOMETER.



FIGURE 10. EMDEX II™ MAGNETIC FIELD METER.

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 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, which 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 similar runs.

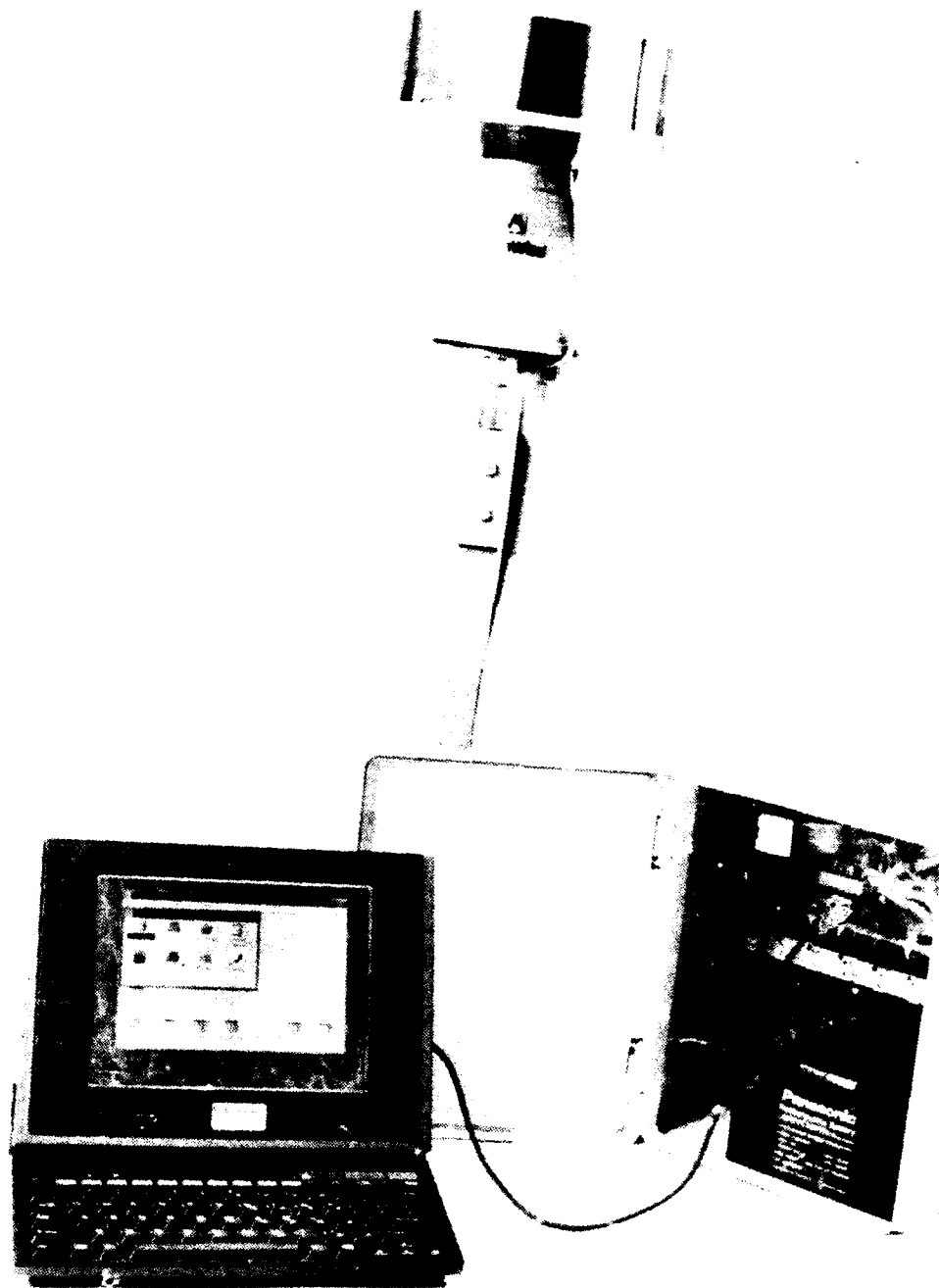


FIGURE 11. DATA LOGGER MONITORING SYSTEM.

4. ENGINEERING SUPPORT ACTIVITIES

4.1 Geomagnetic Field Measurements

Although the geomagnetic field is not under direct study in the Ecological Monitoring Program, it is important because of its reported role 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. Measurements of the field were taken at each of the historic study site measurement points and at several new locations along flight paths for the bird displacement/homing aspect of the small mammals and nesting birds studies. All measurement points along these flight paths are mapped in Figure 12. Historic measurement point locations can be found in the corresponding Appendix for each study.

Geomagnetic field measurement results 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. They are shown on the map in Figure 13 as color-coded section boxes. The number of points comprising each section average varies, and can be determined from discrete values in Table 4. Figure 13 shows the greatest field intensity levels to be near the Ford River antenna crossing and in a section south of the Michigamme Reservoir. Overall measured variation of the geomagnetic field is 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 agreed with those available from the Department of the Interior U.S. Geological Survey. A second set of measurements is planned for the 1993 field measurement season to further confirm results presented here.

4.2 Soil Arthropods and Earthworms Studies

4.2.1 EM Field Characterization at Earthworm Sampling Locations

In order to examine for possible correlations between localized electric field perturbations and earthworm abundance, IITRI measured earth field intensities in study site quadrats used for population sampling. Measurements were made straddling worm sampling locations, with the axis of the probe oriented along the maximum field direction. Both a 10-centimeter probe and a 1-meter probe were used to explore the extent of localized field variations. At the treatment site, multiple 10-centimeter probe measurements were made along the length of the 1-meter probe, while at the control site, a single 10-centimeter probe measurement was made at the middle of the 1-meter probe.

Measured values are presented in Tables 5 and 6. Measurement points were in the corners of quadrats used to divide up the study sites. The locations of the quadrats within each site can be found in Appendix C, Figures C-2 and C-3. Measurement corners are defined in Tables 5 and 6. At both sites, the standard deviation of the 1-meter measurements was about 10 percent of the overall site mean.

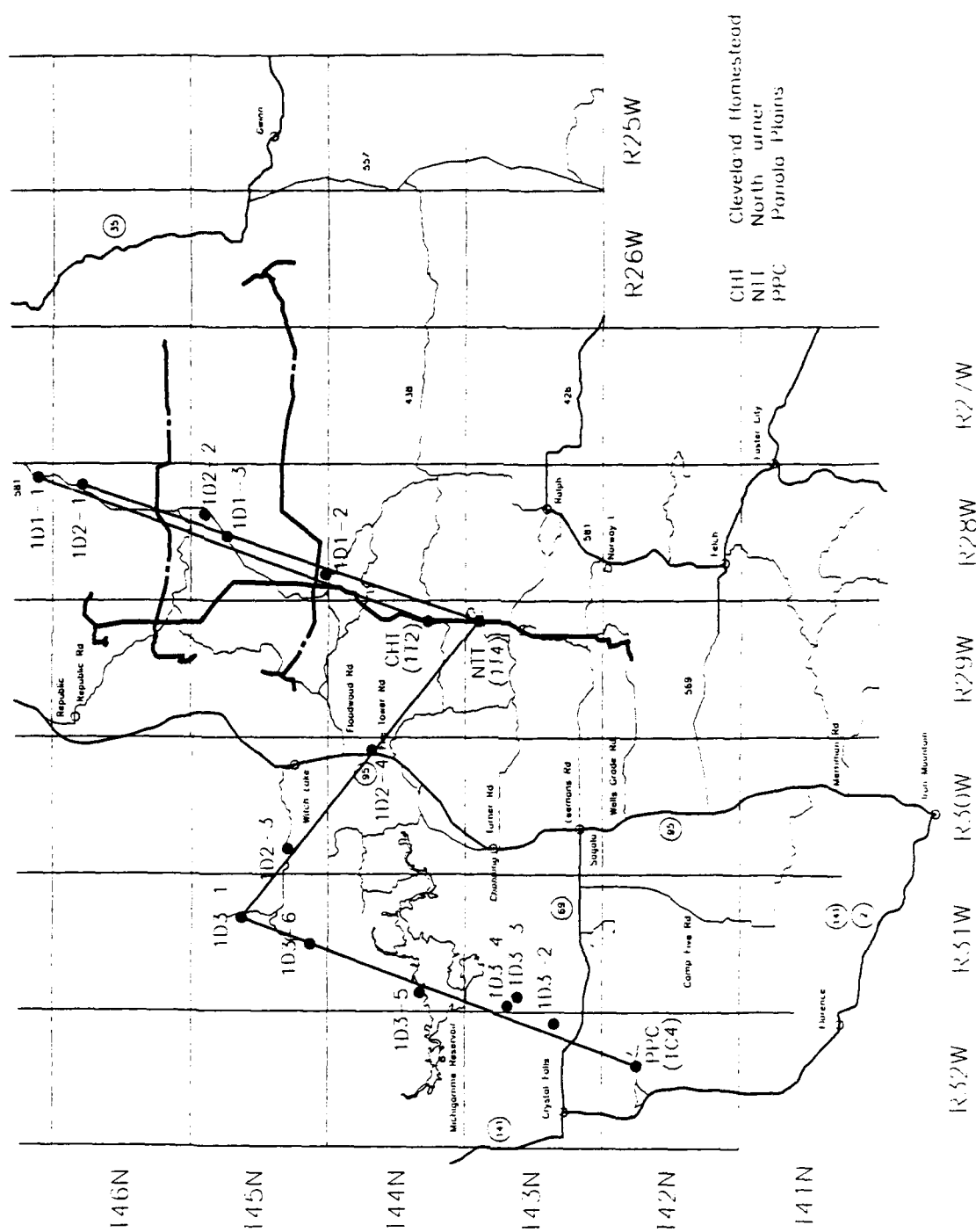


FIGURE 12. GEOMAGNETIC FIELD MEASUREMENT LOCATIONS ALONG BIRD DISPLACEMENT TRANSECTS.

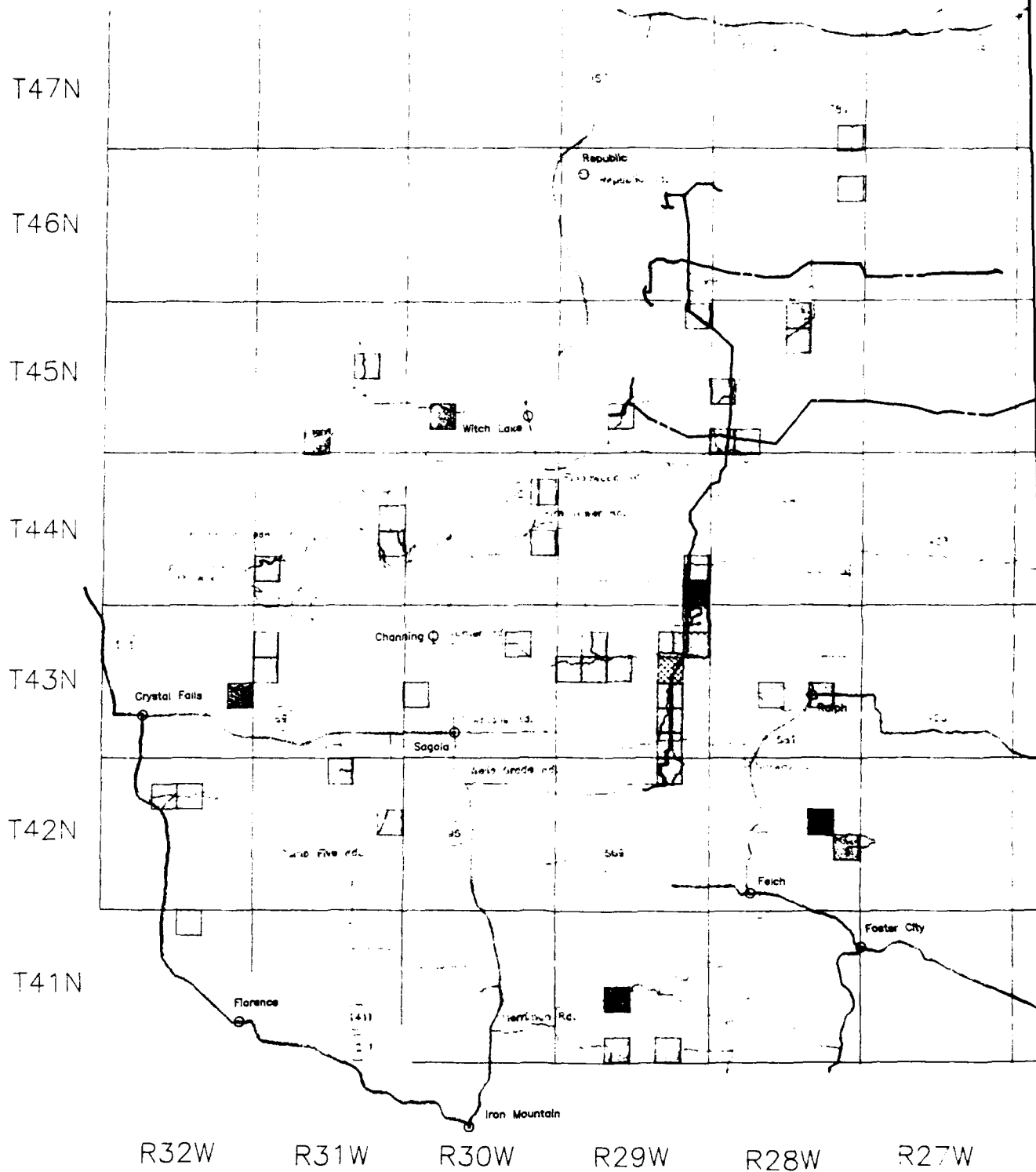
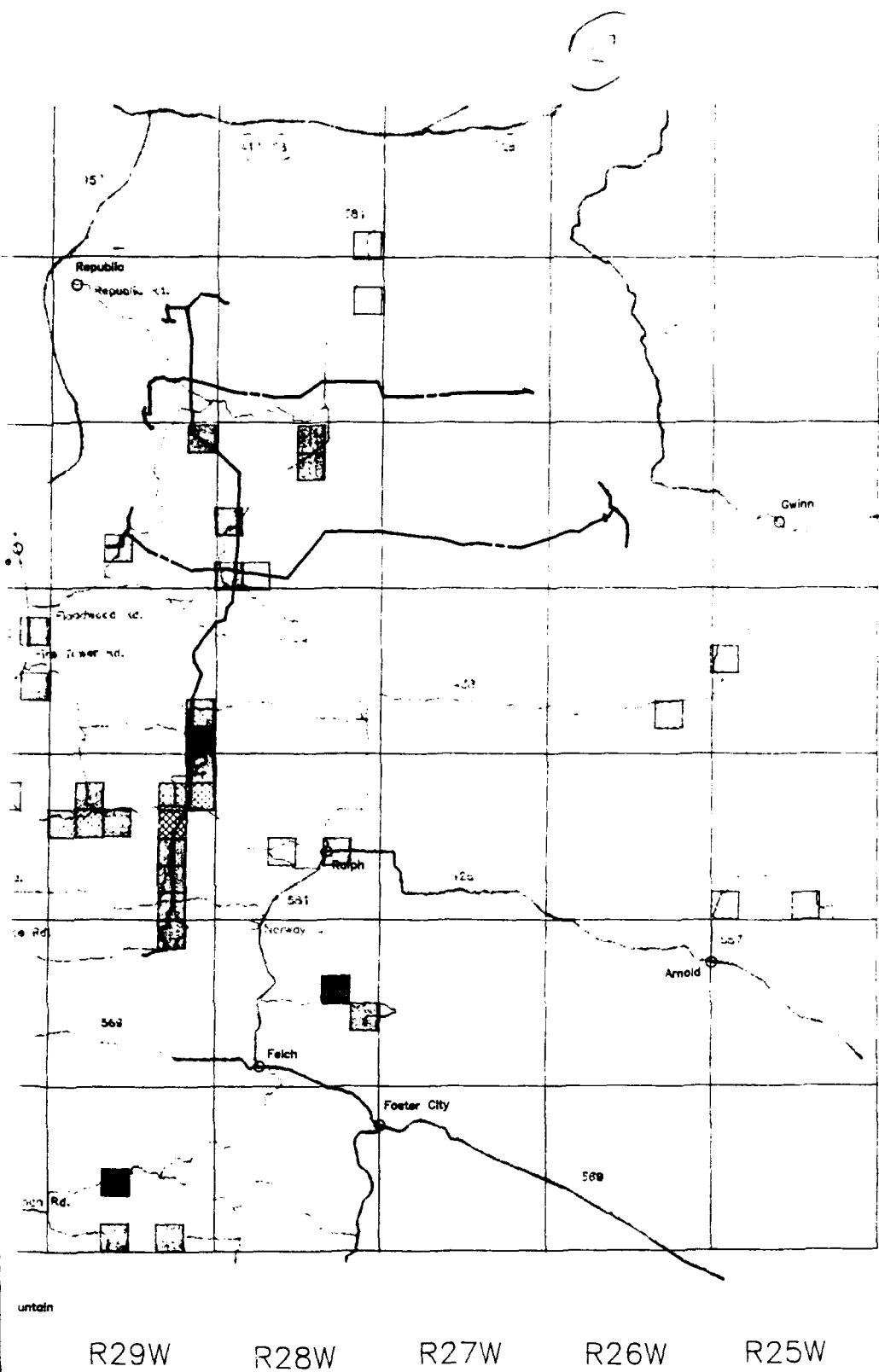


FIGURE 13. GEOMAGNETIC FIELD INTENSITY LEVELS NE

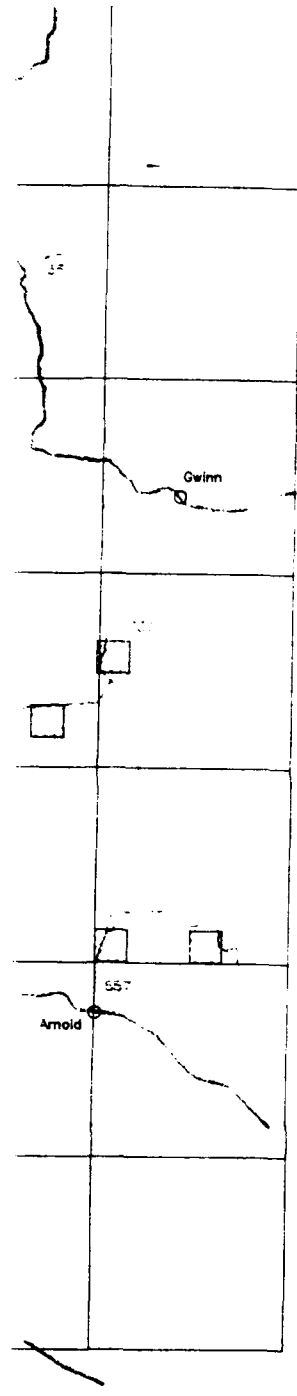


DC Magnetic

- 56
- 58
- 57
- 57
- 58
- 58
- 59
- >

13. GEOMAGNETIC FIELD INTENSITY LEVELS NEAR ECOLOGICAL MONITORING PROGRAM STUDY SITES.

6



DC Magnetic Flux Density (mG)

- 560 - 564.99
- 565 - 569.99
- 570 - 574.99
- 575 - 579.99
- 580 - 584.99
- 585 - 589.99
- 590 - 594.99
- > 594.99

N R25W

IOLOGICAL MONITORING PROGRAM STUDY SITES.

TABLE 4. GEOMAGNETIC FIELD MEASUREMENTS (page 1 of 5)

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

TABLE 4. GEOMAGNETIC FIELD INTENSITY LEVELS (page 2 of 5)

Township	Range	Section	Site No., Meas. Pt.	Field Intensity (mG)	Field Inclination (Degrees)
T43N	R28W	21	5C1-1	570	72.9
T43N	R28W	21	5C1-3	576	72.8
T43N	R28W	21	5C1-4	575	73.4
T43N	R28W	21	5C1-5	574	73.5
T43N	R29W	23	1T1-14	578	74.1
T43N	R29W	23	1T1-16	577	73.8
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
T43N	R29W	23	1T1-22	581	74.1
T43N	R29W	23	1T1-23	579	74.8
T43N	R29W	23	1T1-24	580	74.2
T43N	R29W	23	1T1-25	579	74.7
T43N	R29W	23	1T1-26	577	74.8
T43N	R29W	23	1T1-27	578	74.9
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
T43N	R29W	1	1T4-6	577	74.4
T43N	R29W	1	1T4-7	577	74.5
T43N	R29W	1	1T4-8	578	74.2
T43N	R29W	1	1T4-9	577	74.4
T43N	R29W	1	1T4-10	576	74.4
T43N	R29W	1	1T4-11	577	73.6
T43N	R29W	1	1T4-12	577	74.1
T43N	R29W	1	1T4-13	577	73.9
T43N	R29W	1	1T4-14	577	74.5
T43N	R29W	14	1T5-1	580	74.9
T43N	R29W	14	1T5-2	581	73.7
T43N	R29W	14	1T5-4	578	73.3
T43N	R29W	14	1T5-5	581	73.3
T43N	R29W	14	1T5-6	588	73.4
T43N	R29W	14	1T5-7	580	74.1
T43N	R29W	14	1T5-8	579	73.9
T43N	R29W	14	1T5-9	583	73.6
T43N	R29W	14	1T5-10	591	74.2
T43N	R29W	14	1T6-1	578	74.0
T43N	R29W	14	1T6-2	577	72.3
T43N	R29W	14	1T6-3	578	73.9

TABLE 4. GEOMAGNETIC FIELD INTENSITY LEVELS (page 3 of 5)

Township	Range	Section	Site No., Meas. Pt.	Field Intensity (mG)	Field Inclination (Degrees)
T43N	R29W	14	1T6-4	578	73.9
T43N	R29W	14	1T6-5	580	73.5
T43N	R29W	14	1T6-6	578	73.2
T43N	R29W	14	1T6-7	578	72.8
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
T43N	R29W	14	5T2-1	577	73.6
T43N	R29W	14	5T2-2	578	72.9
T43N	R29W	14	5T2-4	577	73.9
T43N	R29W	14	5T2-7	575	74.0
T43N	R29W	14	5T2-8	578	73.1
T43N	R29W	14	5T3-1	574	74.4
T43N	R29W	11	5T4-3	593	73.0
T43N	R29W	23	6T3-2	577	73.4
T43N	R29W	23	6T3-3	578	73.4
T43N	R29W	35	10T1-1	576	74.2
T43N	R29W	23	10T1-3	573	74.9
T43N	R29W	23	10T1-4	579	73.9
T43N	R29W	26	10T1-5	577	73.7
T43N	R29W	12	10T2-1	591	74.4
T43N	R29W	1	10T2-2	559	74.9
T43N	R30W	19	2C4-1	583	74.5
T43N	R30W	19	2C4-2	582	75.0
T43N	R30W	11	3C5-1	580	74.7
T43N	R30W	11	3C5-2	580	74.8
T43N	R30W	11	3C5-3	580	75.3
T43N	R31W	18	1D3-3	579	74.7
T43N	R31W	7	1D3-4	577	73.1
T43N	R32W	24	1D3-2	609	73.1
T44N	R26W	18	10C13-1	583	73.2

TABLE 4. GEOMAGNETIC FIELD INTENSITY LEVELS (page 4 of 5)

Township	Range	Section	Site No., Meas. Pt.	Field Intensity (mG)	Field Inclination (Degrees)
T44N	R26W	26	10C13-2	580	73.6
T44N	R29W	25	1T2-5	579	73.3
T44N	R29W	25	1T2-6	577	74.5
T44N	R29W	25	1T2-7	576	74.6
T44N	R29W	25	1T2-8	578	73.9
T44N	R29W	25	1T2-9	578	73.4
T44N	R29W	25	3T2-1	577	73.6
T44N	R29W	25	3T2-2	579	74.6
T44N	R29W	25	3T2-3	574	75.3
T44N	R29W	25	3T2-4	576	75.0
T44N	R29W	25	3T2-5	577	74.4
T44N	R29W	25	3T2-6	575	74.2
T44N	R29W	36	10T2-4	569	72.4
T44N	R30W	12	1D2-4	579	73.9
T44N	R30W	24	3S2-1	579	73.5
T44N	R31W	13	1C1-3	568	74.5
T44N	R31W	13	1C1-4	579	74.3
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
T45N	R28W	31	10T3-2	580	73.8
T45N	R28W	31	10T3-3	577	74.7
T45N	R28W	31	10T4-1	576	74.9
T45N	R28W	19	10T11-1	579	74.2
T45N	R29W	28	4T2-2	577	74.2
T45N	R29W	28	4T2-3	577	73.6
T45N	R29W	28	4T2-4	577	74.2
T45N	R29W	28	4T2-5	578	74.2
T45N	R29W	28	4T2-6	577	74.1
T45N	R29W	28	4T2-7	577	73.9
T45N	R29W	28	4T2-8	576	74.0
T45N	R29W	28	4T2-9	577	74.3
T45N	R29W	28	4T2-10	577	74.1
T45N	R29W	28	4T2-11	577	74.0
T45N	R29W	28	4T2-12	576	74.0

TABLE 4. GEOMAGNETIC FIELD INTENSITY LEVELS (page 5 of 5)

Township	Range	Section	Site No., Meas. Pt.	Field Intensity (mG)	Field Inclination (Degrees)
T45N	R29W	28	4T2-13	577	73.9
T45N	R29W	28	4T2-14	576	74.2
T45N	R29W	28	4T2-15	576	74.0
T45N	R29W	28	4T2-16	577	74.0
T45N	R29W	28	4T2-17	577	74.2
T45N	R29W	28	4T2-18	577	73.7
T45N	R29W	28	4T2-19	577	73.9
T45N	R29W	28	4T2-26	577	74.2
T45N	R29W	28	4T2-33	578	74.1
T45N	R29W	28	4T2-34	577	74.1
T45N	R29W	28	4T2-35	576	74.1
T45N	R29W	28	4T2-36	577	74.2
T45N	R29W	28	4T2-35	576	74.1
T45N	R29W	28	4T4-4	578	73.5
T45N	R29W	28	4T4-5	577	74.4
T45N	R29W	28	4T4-6	575	74.7
T45N	R29W	28	4T4-7	576	74.7
T45N	R29W	28	4T4-8	571	74.6
T45N	R29W	28	4T4-9	577	73.6
T45N	R29W	28	4T4-10	577	74.0
T45N	R29W	28	4T4-11	576	74.1
T45N	R29W	28	4T4-12	579	73.9
T45N	R29W	28	4T4-13	577	74.1
T45N	R29W	28	4T4-14	577	73.7
T45N	R29W	28	4T4-15	578	74.2
T45N	R29W	28	4T4-16	574	73.6
T45N	R29W	28	4T4-17	577	73.7
T45N	R29W	28	4T4-18	576	74.1
T45N	R29W	28	4T4-19	578	73.4
T45N	R29W	28	4T4-20	576	73.4
T45N	R29W	1	10T11-2	577	74.1
T45N	R30W	29	1D2-3	585	73.7
T45N	R31W	14	1D3-1	577	73.6
T45N	R31W	33	1D3-6	586	73.8
T47N	R28W	36	1D1-1	570	72.4
T46N	R28W	12	1D2-1	571	73.9
T54N	R34W	5	4S3-1	582	73.5
T55N	R35W	21	4S1-1	583	74.6

TABLE 5. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
1992 Treatment Site Earthworm Sampling Locations

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

a = for locations, see Figure C-2 in Appendix C.

b = N=10, taken along length of 1-meter probe.

c = N=2, taken at middle of 1-meter probe (i.e., at 40 to 50-centimeter and 50 to 60-centimeter positions).

S.D. = standard deviation.

**TABLE 6. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
1992 Control Site Earthworm Sampling Locations**

Quadrat ^a	East Corner (11 May)			West Corner (27 May)		
	Direction of Maximum	10-centimeter ^b	1-meter	Direction of Maximum	10-centimeter ^b	1-meter
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

a = for locations, see Figure C-3 in Appendix C.

b = taken at middle of 1-meter probe.

S.D. = standard deviation.

Orientation of the maximal field intensity varied little at each site, indicating that no major anomalies were present near the sampling locations. Averages of the ten 10-centimeter probe measurements made on 13 May at each sampling location within the treatment site corresponded to the 1-meter values. The standard deviations of the 10-centimeter probe values were nominally 10 percent of their means. On 26 May, only two 10-centimeter measurements were made at the center of the 1-meter probe at each of these locations. Because of variations in the earth electric field over the 1-meter span, averages of the smaller 10-centimeter probe measurement set made on 26 May did not match the 1-meter values as closely as those measured on 13 May.

4.2.2 Time-Domain Reflectometry

In 1992, investigators for the soil arthropods and earthworms studies began the use of time-domain reflectometry (TDR) for weekly measurement of the water content of soil. This technique involves transmitting and measuring the velocity of an electromagnetic pulse in the soil. The pulse velocity depends on the dielectric constant of the soil, which in turn is related to the soil moisture content. The TDR probes used have parallel stainless steel rods approximately 8 inches in length for guided pulse transmission.

The rods are mounted about 2 inches apart on a nonconductive block. The probes are inserted horizontally at 5- and 15-centimeter depths and left in the soil for periodic soil moisture measurements in these horizons throughout the field season. In order to ensure that installation of these probes did not have a significant effect on the electric field intensity in the soil, IITRI performed measurements before and after installation of test probes mimicking the described setup.

A measurement grid measuring 2 meters by 2 meters was established at a location just outside the boundaries of the treatment study site. Earth electric field measurements were then made at 0.5-meter intervals along lines bisecting the grid. After these measurements were made, TDR probes were inserted at the center of the grid at depths of 5 and 15 centimeters. The probes were oriented perpendicular to the direction of the earth electric field so as to cause the minimum possible disturbance in the field. The hole dug for insertion of the probes was then backfilled, and the earth electric field intensities were remeasured. Measurement results appear in Table 7. The TDR probes had essentially no effect on the earth electric field in the general vicinity of the probes when installed in this manner. Effects would be seen, however, extremely close to the stainless steel rods. IITRI therefore recommended that the TDR probes be installed as desired at the study sites, but not within the confined area of the experimental worm incubation bags.

4.2.3 Earthworm Incubation Bags

4.2.3.1 Protocol Development

In 1991, a pilot study of earthworm reproduction using populations confined to *in situ* incubation bags was begun. These bags are intended to isolate the study populations while subjecting them to essentially the same environmental factors and EM exposures as unrestricted worms. To achieve this, soil-filled nylon mesh bags are used to contain the worms. The bags are buried and the location is carefully backfilled to permit flow of earth currents through the bag wall. In order to ensure containment of the earthworms, a fine mesh size is needed. Because of this, the soil-to-soil interface is not perfect, and some reduction of the earth electric field within the bag occurs. Emphasis has been placed on monitoring the earth electric field intensities inside and outside the incubation bags.

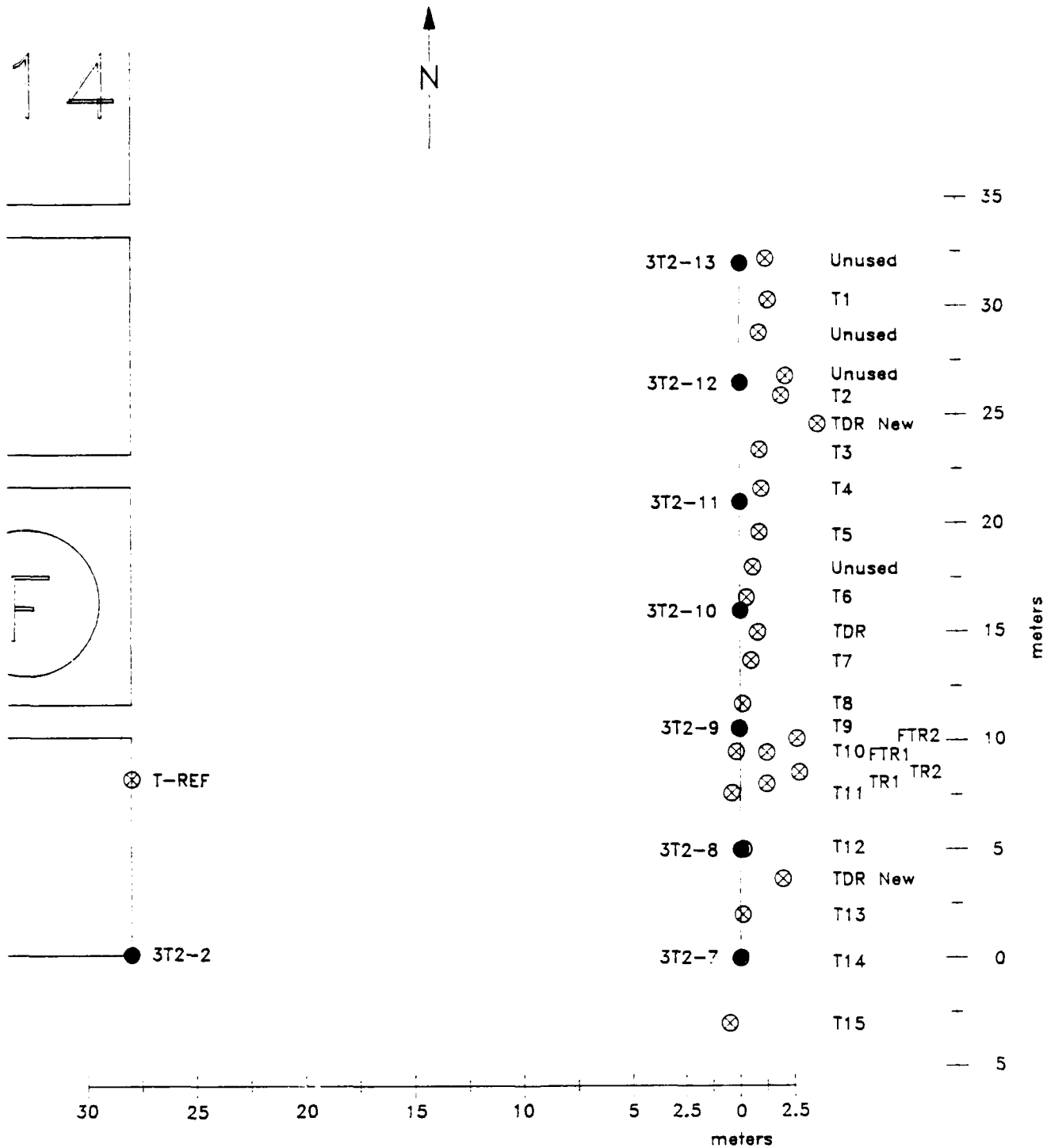
Locations for the worm incubation bags at the treatment site were selected on the basis of earth electric field intensity. Ideally, the bags at this site would be placed in an area where the electric field intensities were greater than those within the historic study plots in order to compensate for the 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 meters east of, and parallel to, the eastern border of the existing site. Based on electric field measurements taken for other studies located along the NS antenna, it was expected that a new site having significantly greater

**TABLE 7. EFFECTS OF TDR SOIL MOISTURE PROBES
ON 76 Hz EARTH ELECTRIC FIELD INTENSITIES
Soil Arthropods and Earthworms Studies Treatment Site**

Direction from Probe	Distance from Probe (m)	Electric Field Intensity (mV/m)		Difference (%)
		Without Probes	With Probes	
Grid Center		65.0	65.3	0.46
North	0.5	64.0	64.7	1.1
	1.0	70.5	69.0	2.1
	1.5	73.0	72.8	0.27
	2.0	72.5	72.0	0.69
South	0.5	65.5	64.3	1.3
	1.0	63.9	63.8	0.16
	1.5	68.9	/	/
	2.0	69.8	/	/
East	0.5	62.6	62.9	0.48
	1.0	64.2	64.4	0.31
	1.5	70.2	71.1	0.13
	2.0	72.3	72.0	0.42
West	0.5	63.5	64.0	0.79
	1.0	60.5	60.8	0.50
	1.5	58.7	58.6	0.17
	2.0	60.3	60.3	0.0
Average				0.63

earth electric field intensities as well as matched habitat would not be found. Therefore, the incubation bags for the treatment site were placed along the line described. The bag locations, together with nearby historic measurement points, are shown in Figure 14. Note that the 1992 bag numbering differs from that used in 1991.

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 15. The 1992 bag numbering for this site also differs from that used in 1991.



- ⊗ Worm incubation bag
- Annual test point

FIGURE 14. WORM INCUBATION BAG LOCATIONS AT SOUTH SILVER LAKE; 3T2.

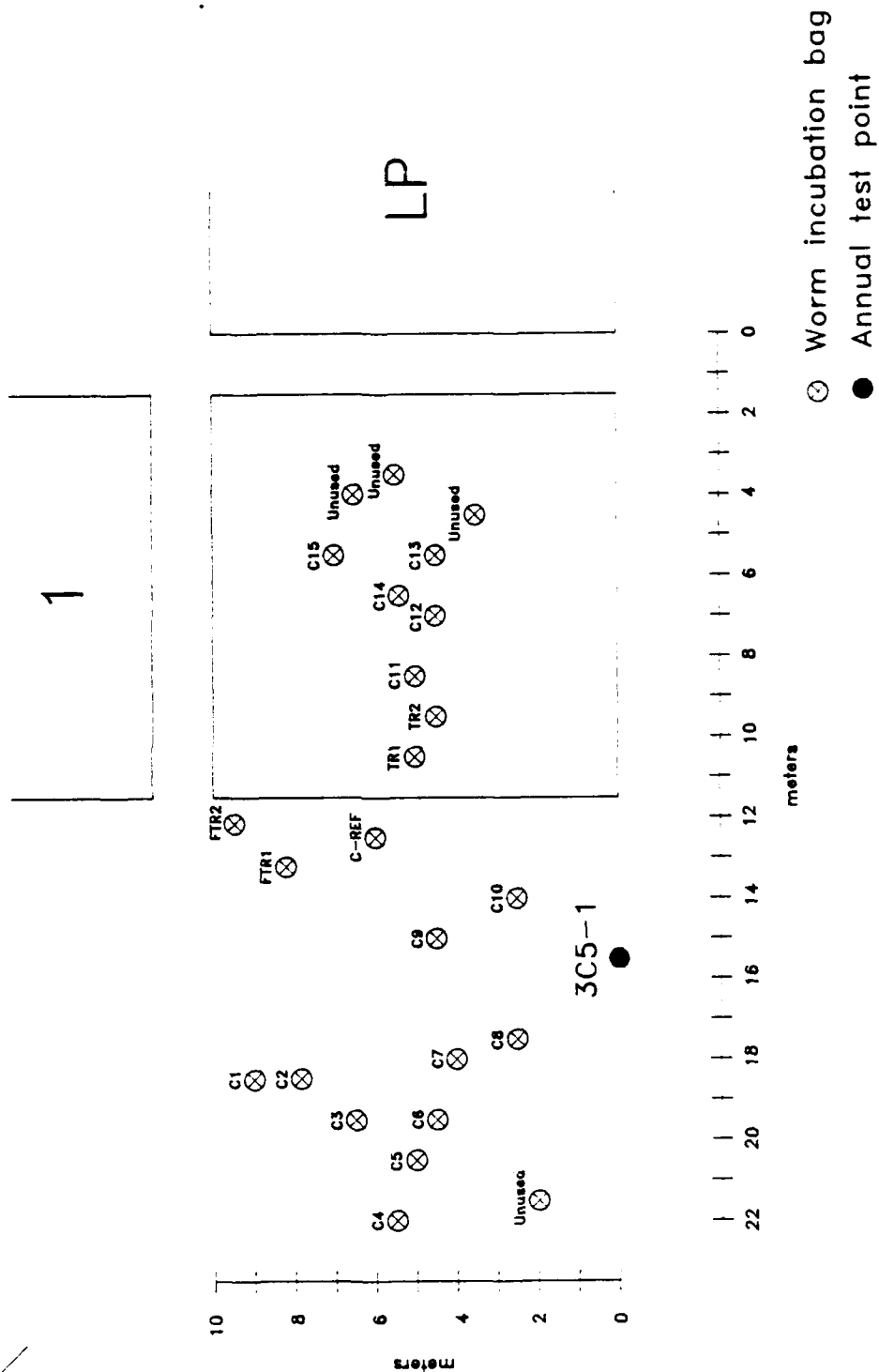
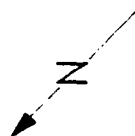


FIGURE 15. WORM INCUBATION BAG LOCATIONS AT TURNER ROAD; 3C5.

4.2.3.2 Experimental Monitoring

Annual measurements have been made of the earth electric field intensity within and next to each of the incubation bags; measurement results are presented in Tables 8 and 9. It can be seen from these tables that the average field reduction ratio improved from 0.47 in 1991 to over 0.70 in 1992 at both sites. There had been no change in protocol between the two measurement sets, and the improvement in the field reduction ratio is most likely attributable to differences in the soil-to-soil contact through the bag walls at the times of each measurement set.

More frequent monitoring of the field reduction ratios was performed with data logger monitoring systems. The layout of the monitoring systems is shown in the site section enlargements in Figures 16 and 17. One worm incubation bag was set aside at each site to be used as a reference for electric field monitoring. An electric field probe having 1-meter-spaced electrodes was installed alongside each reference bag and oriented with the line of maximum field. A 10-centimeter electric field probe, aligned parallel to its adjacent 1-meter probe, was installed inside each reference bag. In this manner, the field measurements in the surrounding soil could be used to assess any field variations in the fields inside the bags. Earth electric fields were recorded hourly within and next to each reference bag. Results of these measurements are plotted in Figure 18 for the treatment study site. Marked on this figure are times when the incubation bags were removed and replaced with new bags (changeout) or watered (to maintain a moist environment for the earthworms). All bags, reference and test, underwent these treatments at the marked times. It can be seen from the figure that in each case, watering and changeout (which included watering) lowered the electric field intensity within the bag. The electric field then slowly increased over the next few days as the soil settled and dried. Other changes in the incubation bag field intensities can be seen in this figure, such as an abrupt increase in the beginning of March. It is likely that this was due to interface impedance changes associated with the seasonal thaw, although an opposite decrease in the field intensity is not seen at the end of the year, when the ground froze. Continued monitoring will provide more data and hopefully a better understanding of these variations. Earth electric fields in the reference bag at the control site were below the sensitivity of the monitoring system and therefore are not presented in this report. Electric fields presented for the treatment site reference bag, however, are indicative of the type of field variations that can be expected at both treatment and control site incubation bags.

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.

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

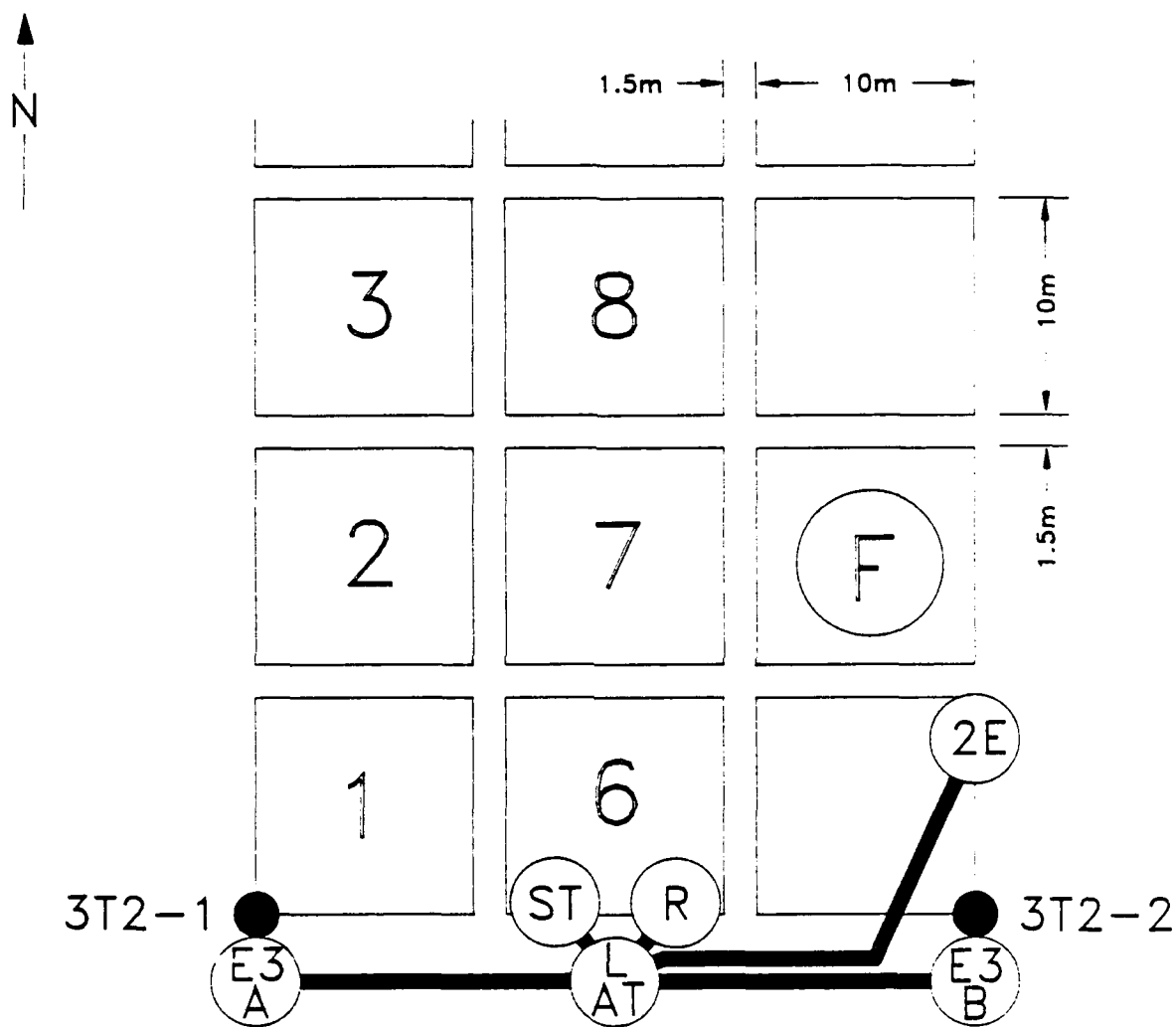
Incubation Bag Number	Earth Electric Field (mV/m)								Field Reduction Ratio	
	Within Bag									
	Next to Bag									
	East Side		West Side							
1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	
T1		45		47		22		0.48		
T2	T1	52	67	53	61	16.5	23	0.31	0.36	
T3		60		52		19.5		0.35		
T4		60		55		22		0.37		
T5	T2	52	56	43	50	16.0	32	0.34	0.60	
T6	T3	54	51	64	69	33	40	0.56	0.67	
T7	T4	53	51	57	52	30	39	0.55	0.76	
T8	T5	42	38	49	55	24	29	0.66	0.62	
T9		67		64		17.0		0.26		
T10	T6	43	57	40	44	19.5	38	0.47	0.75	
T11		52		53		17.0		0.32		
T12	T7	67	80	70	80	31	62	0.45	0.78	
T13	T8	55	60	56	57	21	43	0.56	0.74	
T14	T9	52	66	58	75	21	48	0.37	0.68	
T15	T10	49	60	54	57	20	47	0.39	0.80	
T16	T11	52	58	46	54	22	45	0.45	0.80	
T17	T12	52	66	53	59	37	55	0.70	0.88	
T18	T13	50	58	50	66	25	47	0.50	0.76	
T19	T14	51	63	68	75	36	59	0.61	0.86	
T20	T15	53	73	63	81	34	48	0.59	0.62	
T _{REF}	T _{REF}	51		58		26		0.48		
FTR1			85		70		61		0.79	
FTR2			80		80		55		0.69	
TR1			63		76		55		0.79	
TR2			74		72		54		0.74	
Mean		53	63	55	65	24	46	0.47	0.72	
S.D.		6.4	11.2	7.9	11.1	6.7	10.6	0.12	0.114	

S.D. = standard deviation.

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

Incubation Bag Number		Earth Electric Field (mV/m)				Field Reduction Ratio	
		Next to Bag		Within Bag			
1991	1992	1991	1992	1991	1992	1991	1992
C1		0.110		0.039		0.35	
C2	C5	0.185	0.188	0.078	0.132	0.42	0.70
C3	C4	0.130	0.153	0.048	0.106	0.37	0.69
C4	C3	0.100	0.163	0.056	0.109	0.56	0.67
C5	C1	0.23	0.21	0.086	0.133	0.37	0.63
C6	C6	0.21	0.183	0.115	0.173	0.55	0.95
C7	C7	0.170	0.158	0.058	0.123	0.34	0.78
C8	C8	0.22	0.168	0.086	0.140	0.39	0.83
C9	C9	0.21	0.135	0.078	0.113	0.38	0.84
C10	C10	0.22	0.148	0.095	0.109	0.44	0.74
C11	TR1	0.155	0.27	0.095	0.22	0.61	0.81
C12	TR2	0.26	0.26	0.125	0.23	0.49	0.88
C13	C11	0.190	0.188	0.110	0.148	0.58	0.79
C14	C12	0.160	0.178	0.095	0.153	0.59	0.86
C15	C14	0.120	0.188	0.062	0.143	0.52	0.76
C16	C15	0.095	0.195	0.049	0.125	0.52	0.64
C17		0.26		0.135		0.53	
C18	C13	0.36	0.21	0.150	0.148	0.42	0.70
C19		0.68		0.23		0.34	
C20		0.22		0.120		0.55	
C _{REFERENCE}		0.115		0.067		0.58	
	C2		0.163		0.098		0.60
	FTR1		0.173		0.158		0.91
	FTR2		0.23		0.195		0.85
Mean		0.21	0.186	0.094	0.144	0.47	0.77
S.D.		0.13	0.035	0.044	0.036	0.094	0.096

S.D. = standard deviation.



- 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, 1 m probe outside

FIGURE 16. DATA LOGGER MONITORING SYSTEM AT SOUTH SILVER LAKE; 3T2.

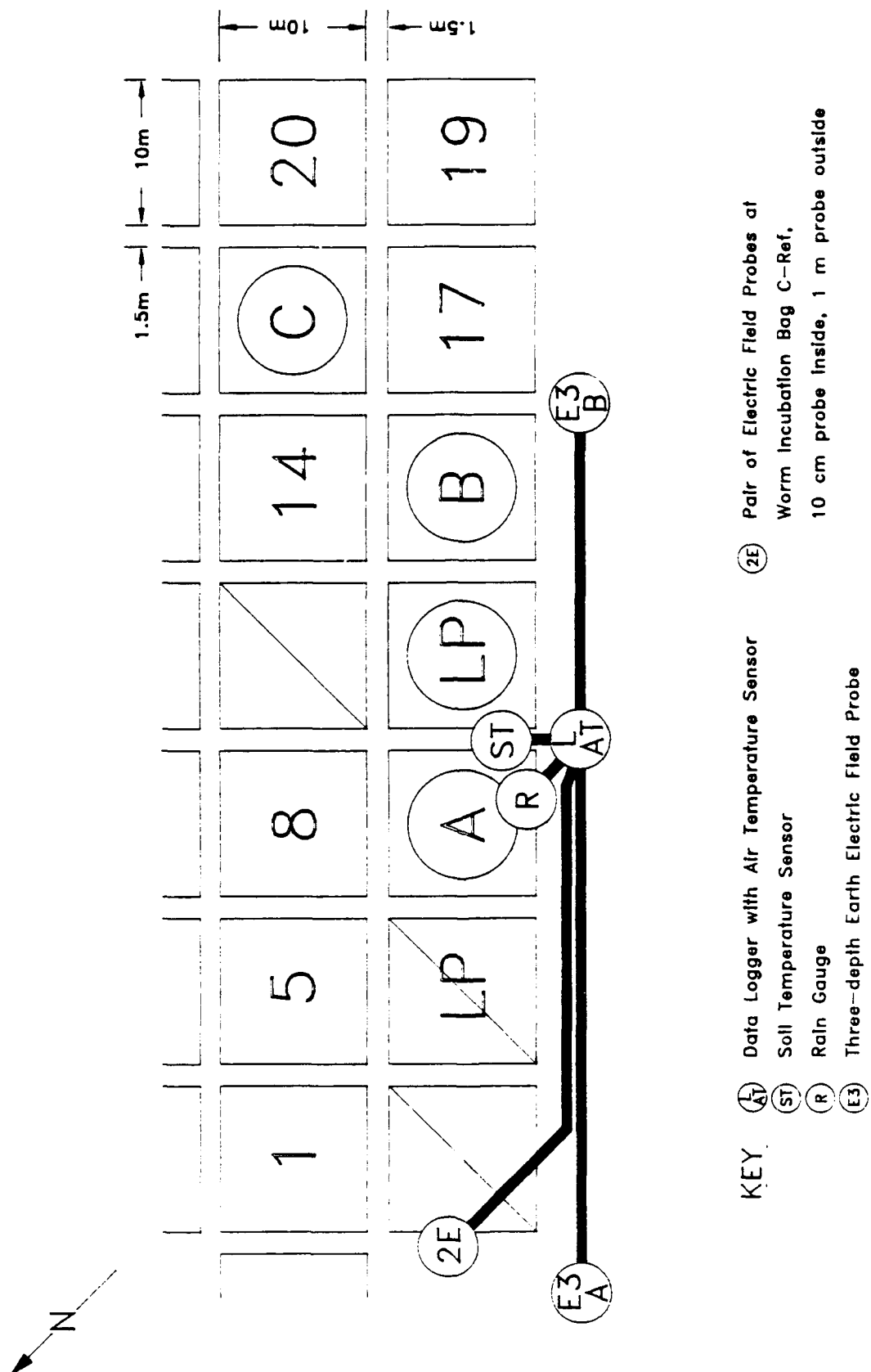


FIGURE 17. DATA LOGGER MONITORING SYSTEM AT TURNER ROAD; 3C5.

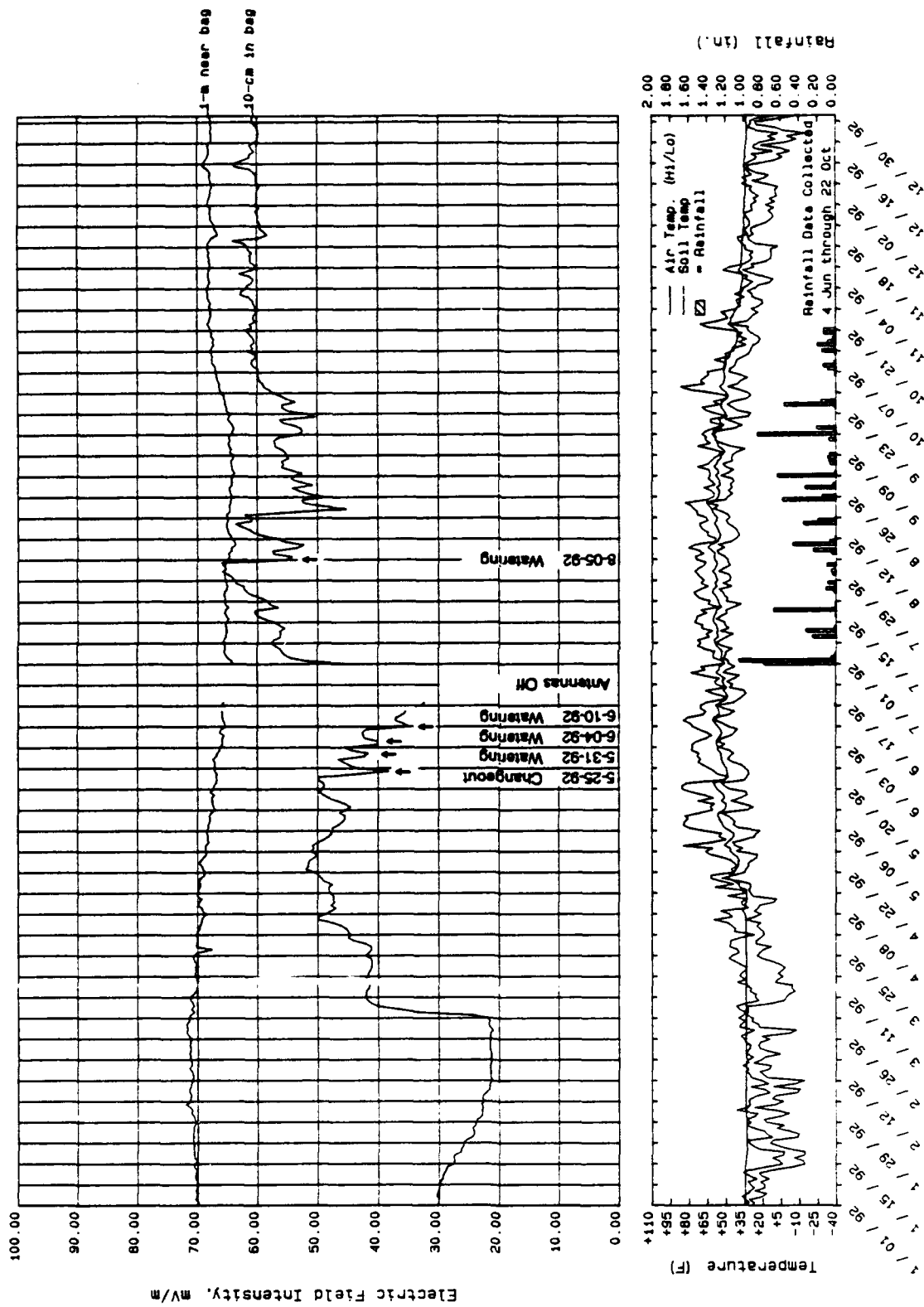


FIGURE 18. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES IN AND NEAR TEST BAG. EARTHWORM TREATMENT SITE (LOGGER CHANNEL NUMBERS 7, 8).

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 on 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. The presentation of data in support of these efforts appears in Appendixes A and B.

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.

4.3.1 Native Bee Laboratory

In 1992, the native bee study laboratory in Crystal Falls, Michigan was moved from Marquette Street to Crystal Avenue. Figure 19 shows the layout of the new laboratory. When at the laboratory, bee nest blocks are kept in wire-mesh Faraday cages to minimize 60 Hz air electric field exposures. These are the same cages developed for and used in the Marquette Street laboratory (see Appendix B). They include a holding cage and three workstations. The 60 Hz air electric field intensity and magnetic flux density were characterized under various conditions at the cage locations. Measurement results appear in Tables 10 and 11. Air electric field intensity levels at the Crystal Avenue laboratory are similar to those measured at the Marquette Street laboratory (see Table 11, below, and Table B-9 in Appendix B). The magnetic flux densities at the Crystal Avenue laboratory, however, are up to 10 times greater than those measured at the Marquette Street laboratory (see Tables 10 and B-10). All 60 Hz field exposures at the new laboratory are 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 investigators were encouraged to make use of the nearby, low-EM-field-environment holding facility to minimize the amount of time that bee nest blocks were kept at the laboratory.

**TABLE 10. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies Crystal Falls, Crystal Avenue Laboratory**

Site No., Meas. Pt.	1992	Measurement Notes
2L2-1	2.0	*
2L2-2	1.78	*
2L2-3	2.1	*
2L2-4	0.56	*

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

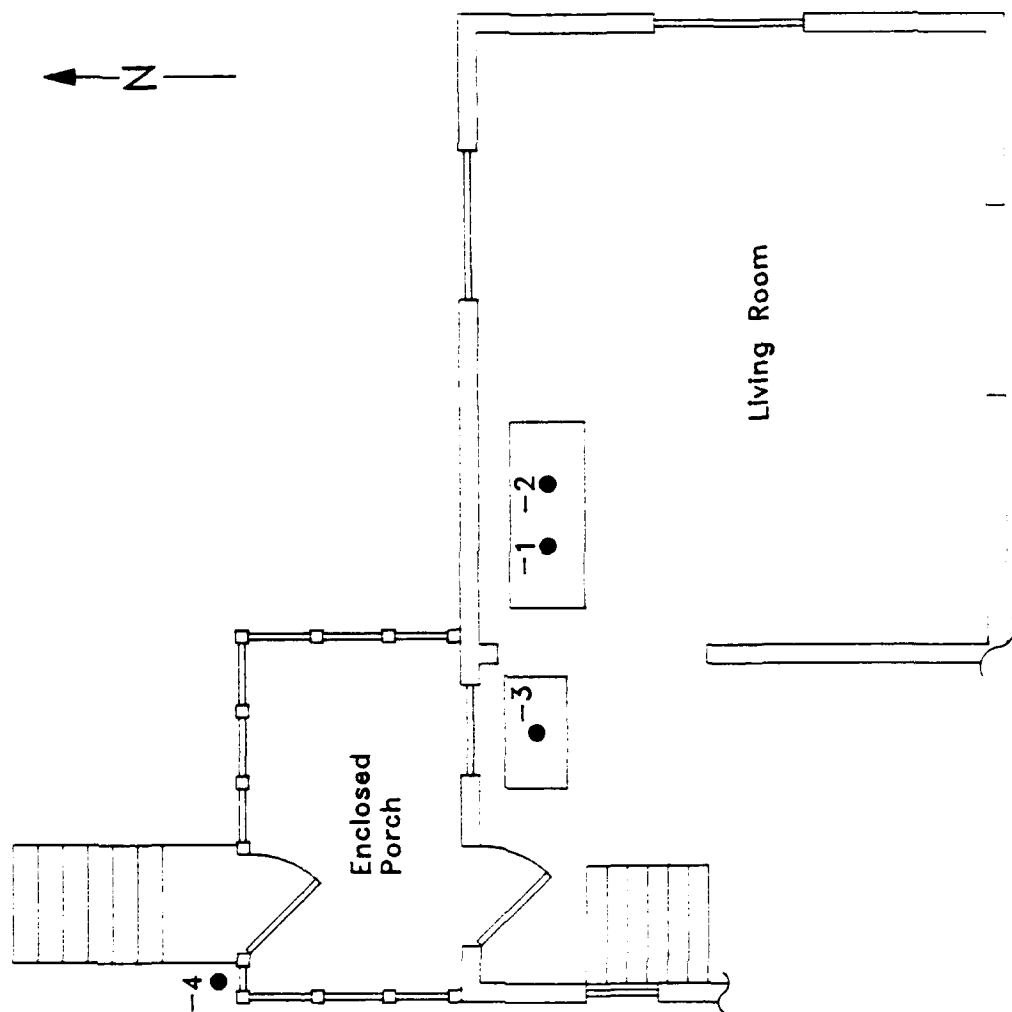


FIGURE 19. MEASUREMENT POINTS AT CRYSTAL FALLS, CRYSTAL AVE. LABORATORY;
2L2-1, 2, 3, 4.

**TABLE 11. 60 Hz AIR ELECTRIC FIELD INTENSITY (V/m)
Native Bees Studies Crystal Falls, Crystal Avenue Laboratory**

Site No., Meas. Pt.	1992	Measurement Notes*
2L2-1	0.031	C
2L2-1	0.074	O, W
2L2-2	0.030	C
2L2-2	0.092	O, W
2L2-3	0.015	C
2L2-3	0.036	O, W
2L2-4	<0.001	C

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

C = closed cage door.

O = open cage door.

W = worker present, grounded to cage.

The EMDEX II™ magnetic field meter was also used to monitor utility-generated 60 Hz fields over a 27-hour period. The meter was set in the center of the two-bay workstation (between locations 2L2-1 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 20 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.

4.3.2 Soil Arthropods and Earthworms Study Laboratory

EM field intensities were characterized for the first time in 1992 at the soil arthropods and earthworms laboratory in Channing, Michigan. The layout of the laboratory, which is housed in a pole barn, is shown in Figure 21. 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 12 and 13. With the exception of the electronic scale used on the microscope table, 60 Hz EM intensities are less than corresponding 76 Hz EM intensities 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.

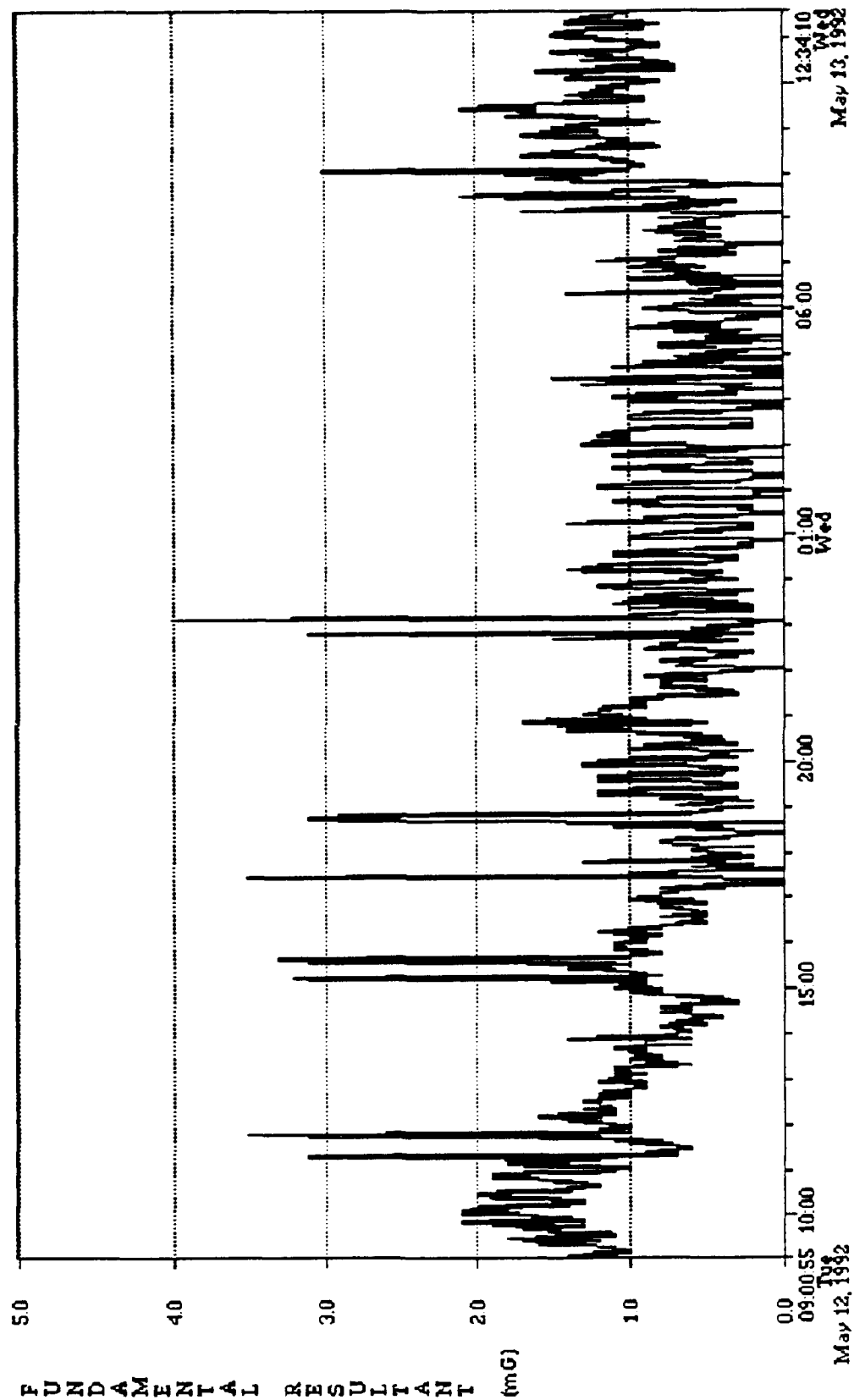


FIGURE 20. 60 Hz MAGNETIC FLUX DENSITY AT NATIVE BEE STUDY CRYSTAL FALLS, CRYSTAL AVE. LABORATORY.

**TABLE 12. 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

**TABLE 13. 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

The EMDEX IITM magnetic field meter was also used to monitor utility-generated fields over a 43-hour period. 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 22 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.

4.4 Characterization of EM Variability

EM field intensity levels are dependent on several factors, making them subject to both spatial and temporal variability. Some of this variation has already been seen in data logger plots from the earthworm study sites and is precisely the reason for the establishment of continuous monitoring systems at these and several other study sites. Strong efforts have also been made through these and other measurements and data analyses to accurately characterize EM field intensity levels at all study areas for all times. A simplified mathematical description of the three fields of interest is given to help explain variables 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.

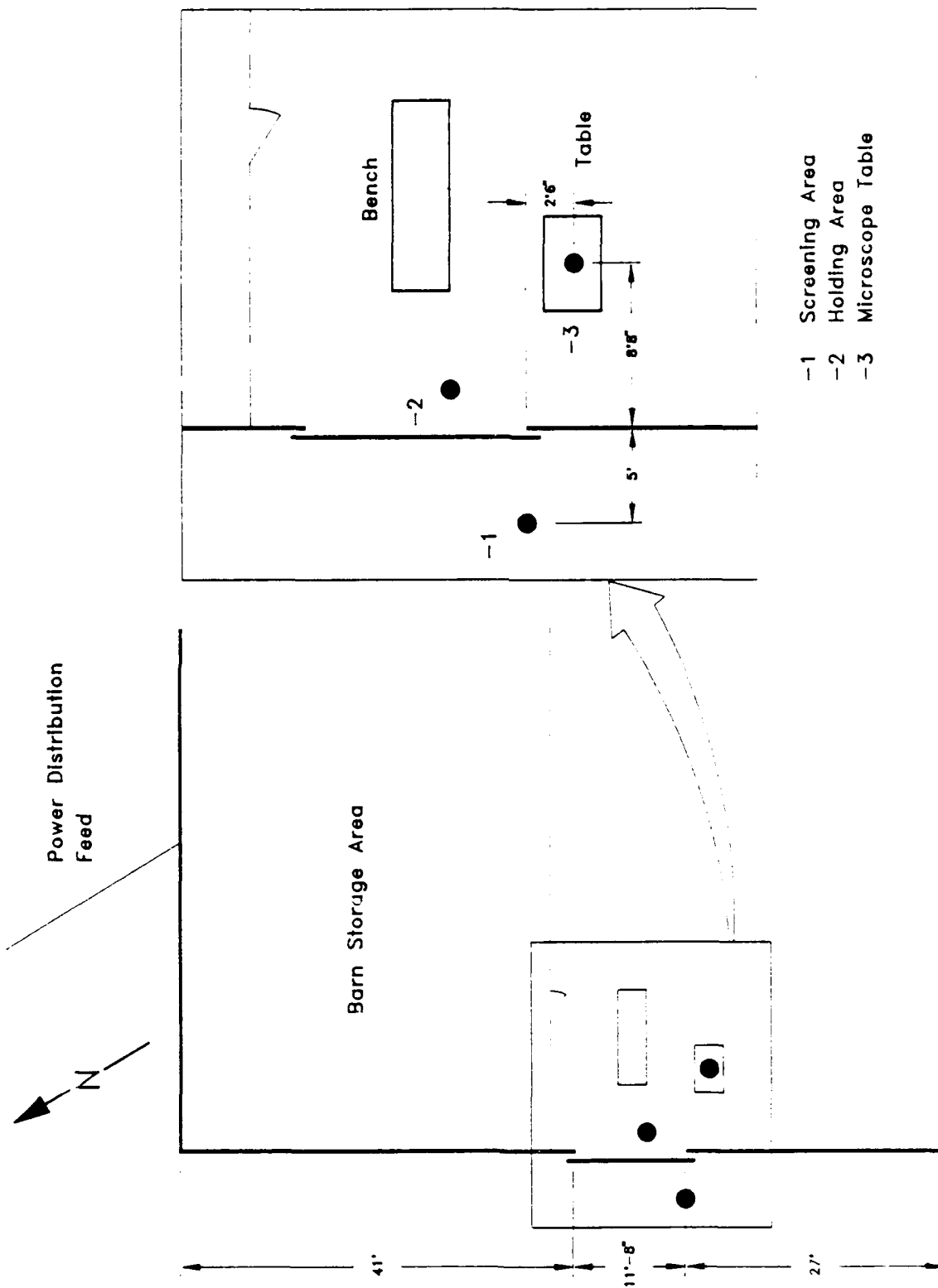


FIGURE 21. MEASUREMENT POINTS AT SOIL ARTHROPOD AND EARTHWORM CHANNING LABORATORY; 3L1-1, 2, 3.

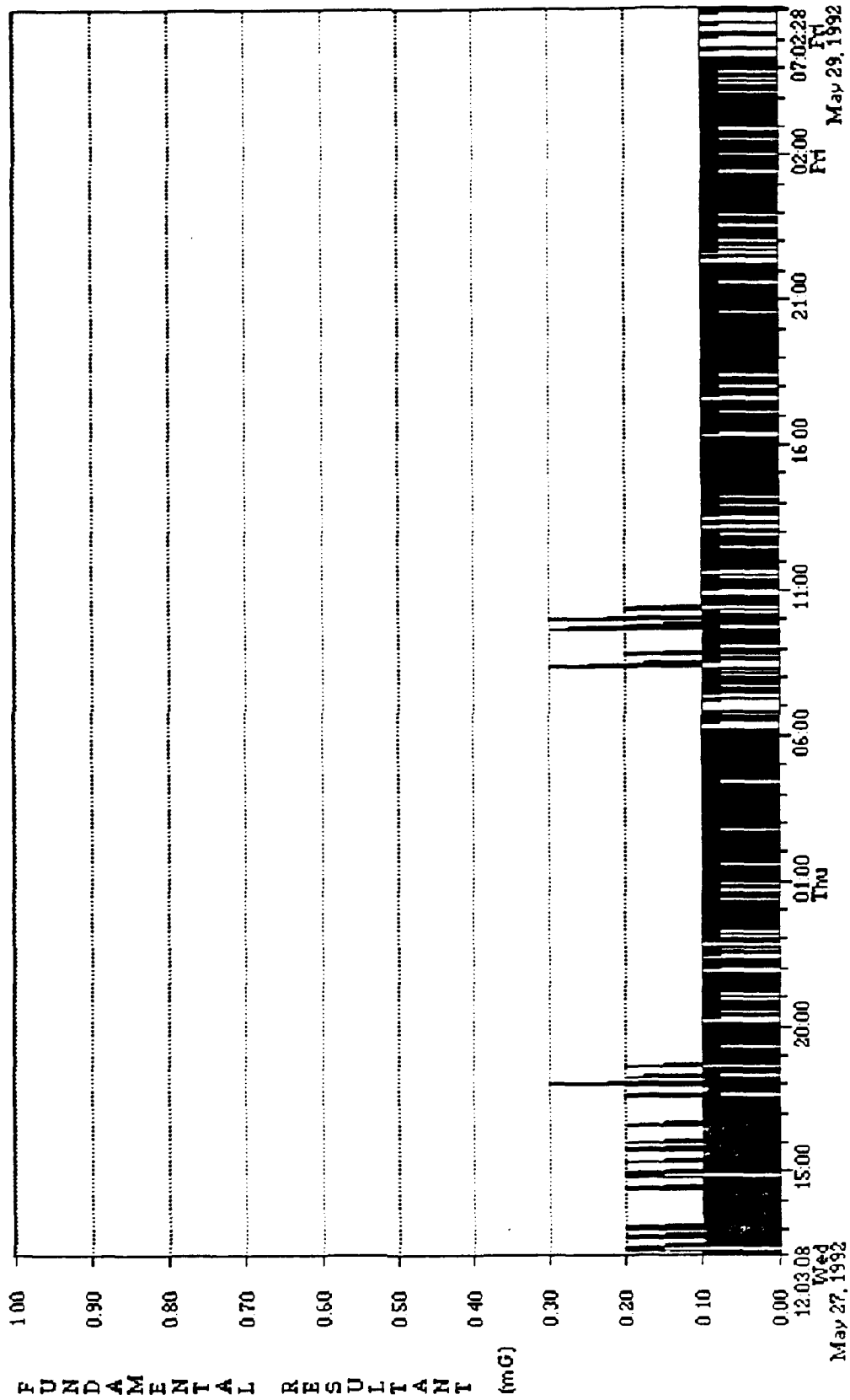


FIGURE 22. 60 Hz MAGNETIC FLUX DENSITIES AT SOIL ARTHROPOD AND EARTHWORM CHANNING LABORATORY.

The top diagram in Figure 23 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 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.

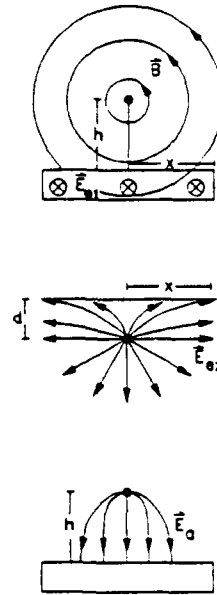


FIGURE 23. EM FIELD ORIENTATIONS.

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

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

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

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

where B	=	magnetic flux density	V	=	voltage on antenna wire
E _{e1}	=	induced earth electric field	a	=	radius of antenna wire
E _{e2}	=	conducted earth electric field	l	=	ground wire length
E _a	=	air electric field	d	=	depth of buried ground wire
I	=	antenna or ground wire current	σ _b	=	bulk earth conductivity
μ ₀	=	magnetic permeability in free space	σ _s	=	surface earth conductivity
h	=	height of antenna wire	j	=	√-1
x	=	horizontal distance to antenna wire	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 antenna. 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 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 by large rocks, roots, elevation changes, or soil moisture variability, among other factors.

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 creates it.

4.4.1.2 Measured Spatial Variability--EM Field Profiles. EM field profiles were first characterized in 1987 at bird nest box study sites in an attempt to characterize the EM fields across these large-area study sites. The profiles are generated from a series of measurements at prescribed distances along a line perpendicular to the antenna wire. These measurements have been made annually since 1987. Resulting profiles for 1989 through 1992, when the antennas were operating with a 150 ampere current, are presented in Figures A-17 through A-37. Similar profiles for 1987 and 1988 can be found in a previous report.¹¹ They are not included here because of the large number of curves on each graph. All profiles provide excellent examples of 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 are essentially as predicted. Site anomalies affecting the earth conductivity result in peculiarities in the earth electric fields, such as rises in the field intensity level with increasing distance from the antenna and other unusual fall-off patterns.

Similar annual profile characterizations were begun at the upland flora and soil microflora antenna and ground study sites in 1989. Since then, profiles have been constructed from annual measurement data collected during operation of both antennas and during operation of the NS antenna only, which was the operating condition over extended periods of time in 1991 and 1992. Profiles of the earth electric field intensities have also been constructed from averages of fixed probe and data logger measurements during these two operating conditions. Various profiles from these years are presented and discussed below.

Profiles of the 76 Hz air electric field and magnetic flux density along transects perpendicular to the upland flora antenna and ground ROWs appear in Figures 24 through 27. Each figure has multiple profiles relating to normal operation with both antennas for the years 1989-1992 and one profile for the period of NS antenna operation only in 1991. The historic measurement points that comprise each profile are identified just 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 24 and less apparent in Figure 26 result from different start locations beneath the antenna wire for the two profiles.

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.

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. It cannot be used to predict field intensity levels at other points on the plots.

The magnetic flux density 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

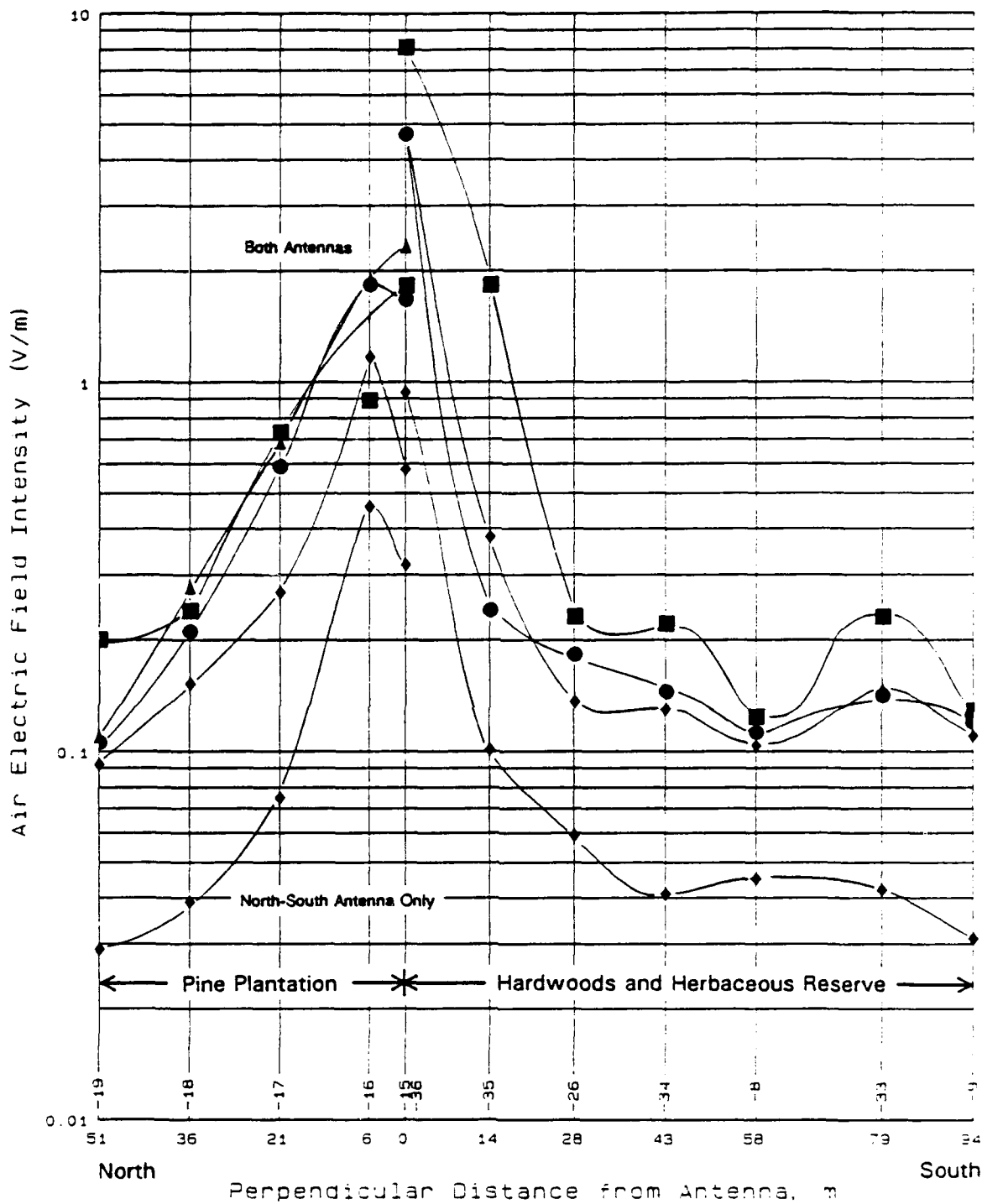


FIGURE 24. 76 Hz AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (OVERHEAD):
ML; 4T2-8, 9, 15-19, 26, 33-36.

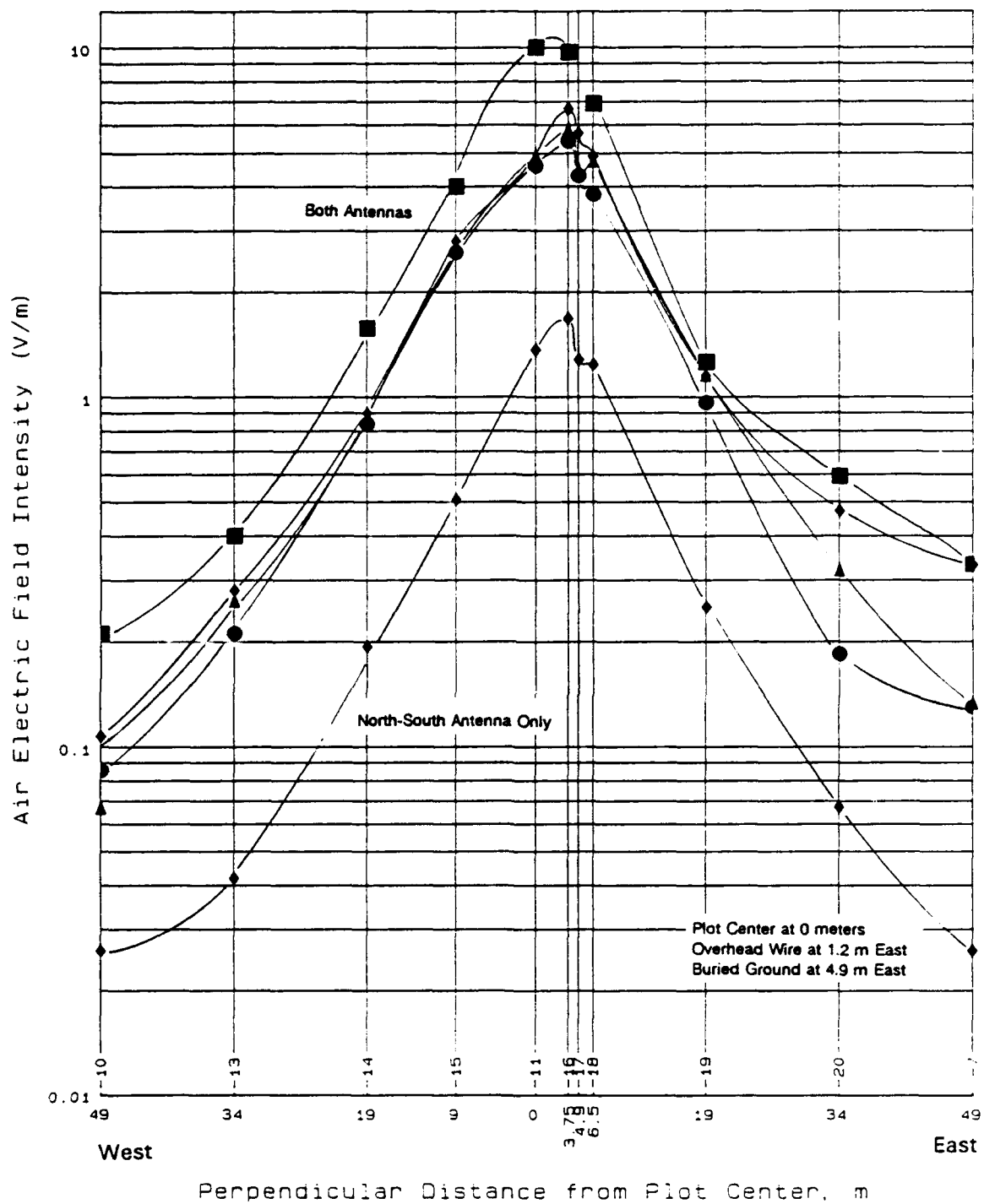


FIGURE 25. 76 Hz AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (BURIED):
EP; 4T4-7, 10, 11, 13-20.

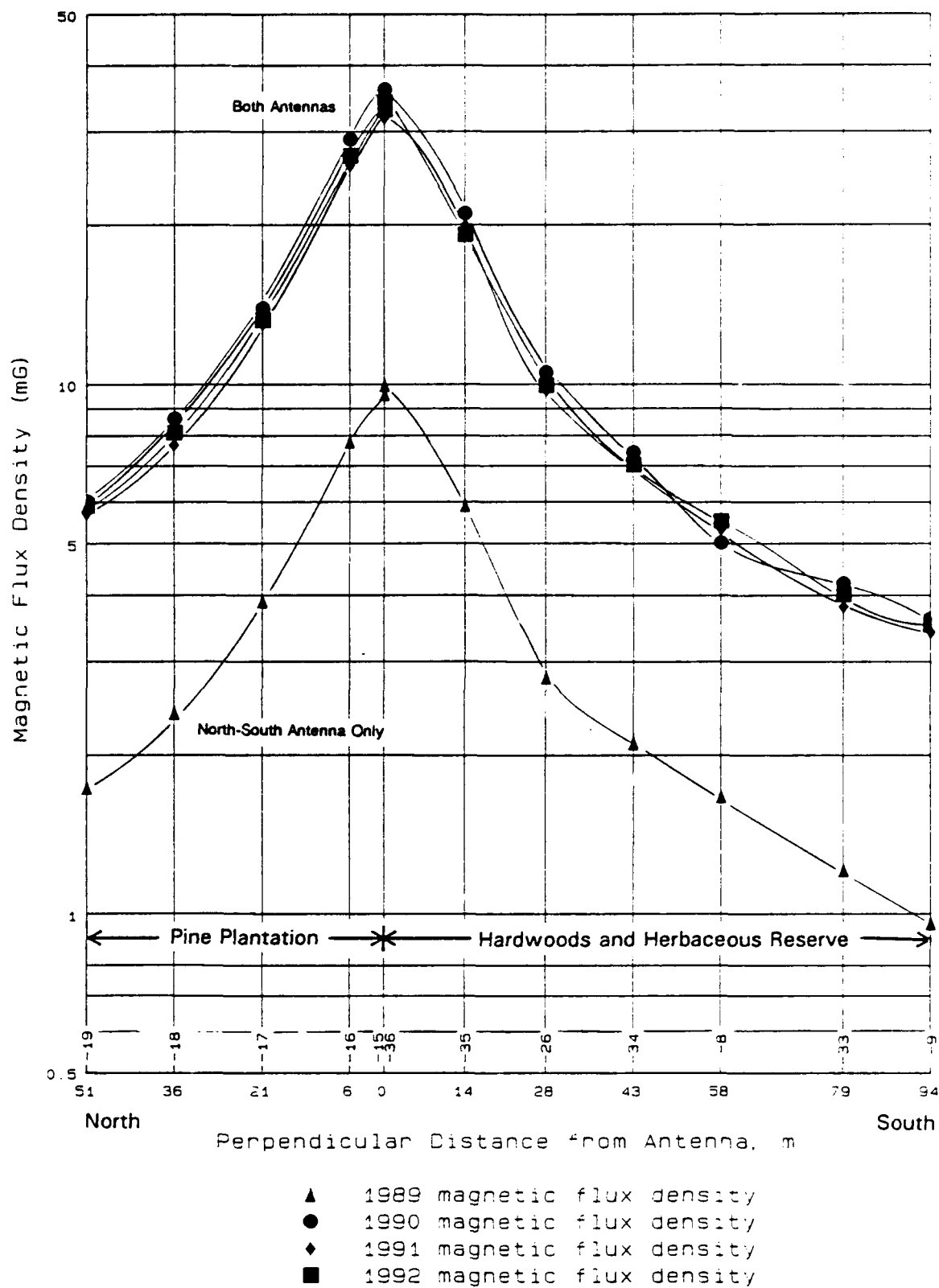


FIGURE 26. 76 Hz MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (OVERHEAD): ML; 4T2-8, 9, 15-19, 26, 33-36.

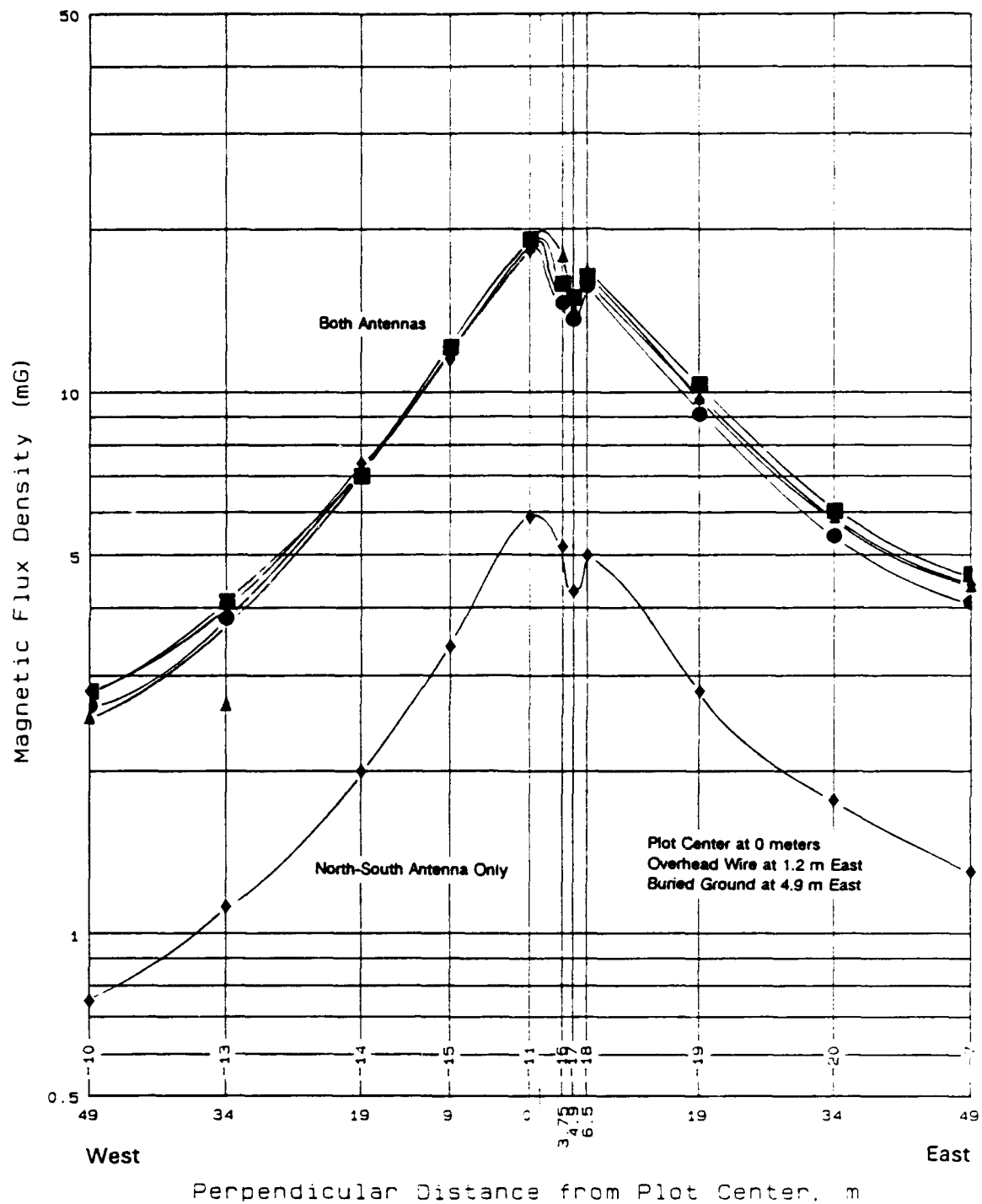


FIGURE 27. 76 Hz MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (BURIED):
EP; 4T4-7, 10, 11, 13-20.

shown in Figures 26 and 27, 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 an interaction between and 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 at the treatment sites with very good accuracy.

In 1992, earth electric field profile data for the upland flora and soil microflora treatment study sites were obtained from three sources:

- annual measurements
- periodic measurements at fixed probes
- hourly measurements by data logger monitoring systems

Statistical summaries of the 1992 earth electric field data from the data loggers and fixed probes are presented in Tables 14 and 15. Table 14 summarizes data for the period 1 January through 27 March, when only the NS antenna was operating. Table 15 covers the period 28 March through 31 December, when both antennas were operating, and includes annual measurement data, which was taken in this time frame. There is good agreement between the different measurement sets. The mean plus one standard deviation from the logger generally includes the fixed probe means. The annual measurement values track the logger and fixed probe means, even though these measurements are only made once a year and are taken with a separate probe at a slightly offset position from the fixed probe.

The means of the fixed probe and data logger measurements, along with the annual earth electric field intensity measurements listed in Tables 14 and 15, are plotted as electric field profiles in Figures 28 and 29. Each figure has one set of profiles for normal operation with both antennas and one set for NS antenna operation only. Error bars (± 1 standard deviation) are plotted for the data logger mean values. Again, discontinuities at zero distance in the curves in Figure 28 result from different start locations beneath the antenna wire for the two profiles.

The earth electric field at treatment sites is influenced by several factors, making it very difficult to predict. At the antenna site, the field shows both increases and decreases with increasing distance from the antenna. Such irregularities are the result of varying terrain elevations and differing soil conductivity. At the ground site, there is a null in the earth electric field over the buried ground wire, with relatively high peaks on both sides of the wire. This is characteristic of the earth electric field near an ELF ground wire and was modeled by Equation 7. The field at the ground site decays much more uniformly than at the antenna site, indicating that the soil conductivity is much more uniform here.

Because the earth electric field behaves unpredictably across these treatment sites, the 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

**TABLE 14. 1992 EARTH ELECTRIC FIELD STATISTICAL SUMMARY
FOR THE PERIOD 1 JANUARY THROUGH 27 MARCH;
NORTH-SOUTH ANTENNA ONLY ACTIVATED**

Location	Data Logger				Fixed Probe			
	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variability	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variability
Antenna Site, Hardwood Stand								
4T2-36	1951	54	13.5	0.25	3	50	1.63	0.033
4T2-35	1949	57	13.6	0.24	3	54	0.47	0.009
4T2-26	1953	75	20	0.27	3	77	2.9	0.038
4T2-34	1945	46	13.5	0.29	3	45	2.5	0.056
4T2-8	1953	50	14.8	0.30	3	47	1.63	0.035
4T2-33	1951	45	12.1	0.27	3	45	0.47	0.010
4T2-9	1954	43	14.7	0.34	3	44	1.41	0.032
Antenna Site, Pine Plantation								
4T2-15	1945	27	10.8	0.40	3	27	0.82	0.030
4T2-16	1951	34	13.3	0.39	3	34	0.47	0.014
4T2-17	1948	30	13.1	0.44	3	29	1.41	0.049
4T2-18	1950	31	14.0	0.45	3	30	1.25	0.042
4T2-19	1947	35	13.2	0.38	3	33	0.47	0.014
Ground Site, Pine Plantation								
4T4-7	268	34	9.5	0.28	2	32	1.00	0.031
4T4-20	269	51	11.0	0.22	2	49	1.00	0.020
4T4-19	1952	230	78	0.34	3	220	4.7	0.021
4T4-18	1952	1770	430	0.24	3	1790	141	0.079
4T4-16	1952	1190	280	0.24	3	1220	37	0.030
4T4-15	1952	300	87	0.29	3	370	29	0.078
4T4-14	1952	101	38	0.38	3	93	6.5	0.070
4T4-13	-	-	-	-	2	22	3.0	0.136

- = monitoring system errors; valid data not acquired.
S.D. = standard deviation.

**TABLE 15. 1992 EARTH ELECTRIC FIELD STATISTICAL SUMMARY
FOR THE PERIOD 28 MARCH THROUGH 31 DECEMBER;
BOTH ANTENNAS ACTIVATED**

Location	Data Logger				Fixed Probe				
	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variability	No. of Data Points	Mean, mV/m	S.D., mV/m	Coefficient of Variability	Annual, mV/m
Antenna Site, Hardwood Stand									
4T2-36	5922	129	10.5	0.081	13	136	7.9	0.058	125
4T2-35	5922	150	13.0	0.087	13	160	8.3	0.052	169
4T2-26	5922	220	12.6	0.057	13	220	11.5	0.051	220
4T2-34	5922	110	11.6	0.106	13	117	8.3	0.071	140
4T2-8	5922	139	9.2	0.066	13	147	4.3	0.029	133
4T2-33	5922	104	10.9	0.105	13	110	6.5	0.059	126
4T2-9	5492	132	8.6	0.065	13	137	3.2	0.023	133
Antenna Site, Pine Plantation									
4T2-15	5915	65	10.5	0.162	13	67	4.3	0.065	87
4T2-16	5915	105	11.7	0.111	13	104	6.7	0.065	103
4T2-17	5915	106	11.2	0.106	13	107	4.9	0.046	106
4T2-18	5914	105	11.2	0.107	13	105	4.3	0.041	108
4T2-19	5890	105	9.9	0.094	13	106	3.9	0.037	111
Ground Site, Pine Plantation									
4T4-7	5177	132	15.6	0.118	13	134	7.0	0.052	153
4T4-20	4049	240	39	0.163	13	220	29	0.132	210
4T4-19	5882	760	84	0.111	13	790	68	0.086	930
4T4-18	5882	3800	540	0.142	13	4000	550	0.137	3400
4T4-16	5882	3100	440	0.142	13	3400	460	0.138	3000
4T4-15	1780	850	80	0.094	13	820	62	0.101	880
4T4-14	5882	290	53	0.183	13	300	48	0.159	290
4T4-13	3781	59	13.2	0.220	13	52	11.8	0.23	66

S.D. = standard deviation.

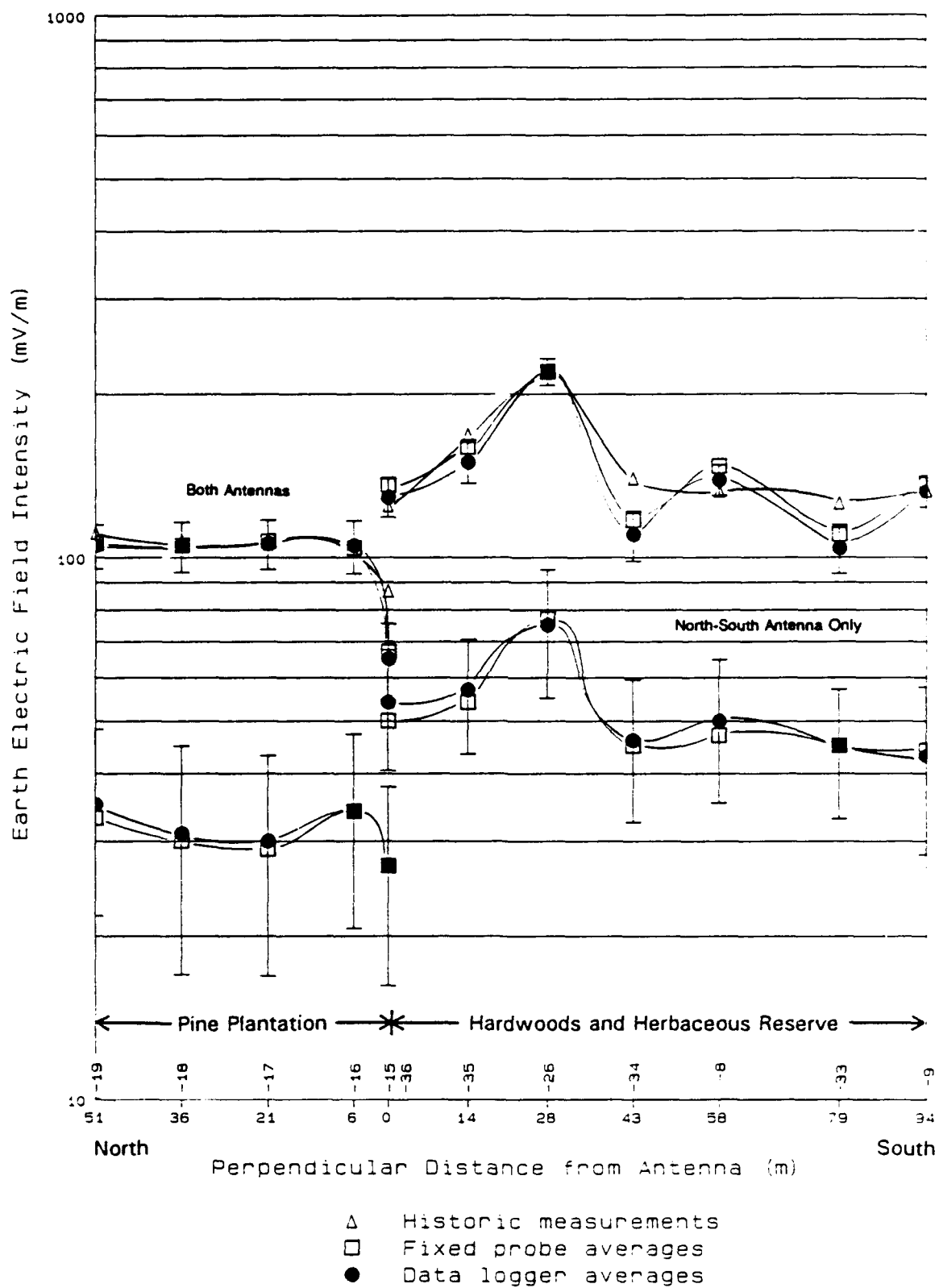


FIGURE 28. COMPARISON OF 1992 76 Hz EARTH ELECTRIC FIELD MEASUREMENTS AT SITE 4T2. ERROR BARS ARE ± 1 SD OF LOGGER DATA.

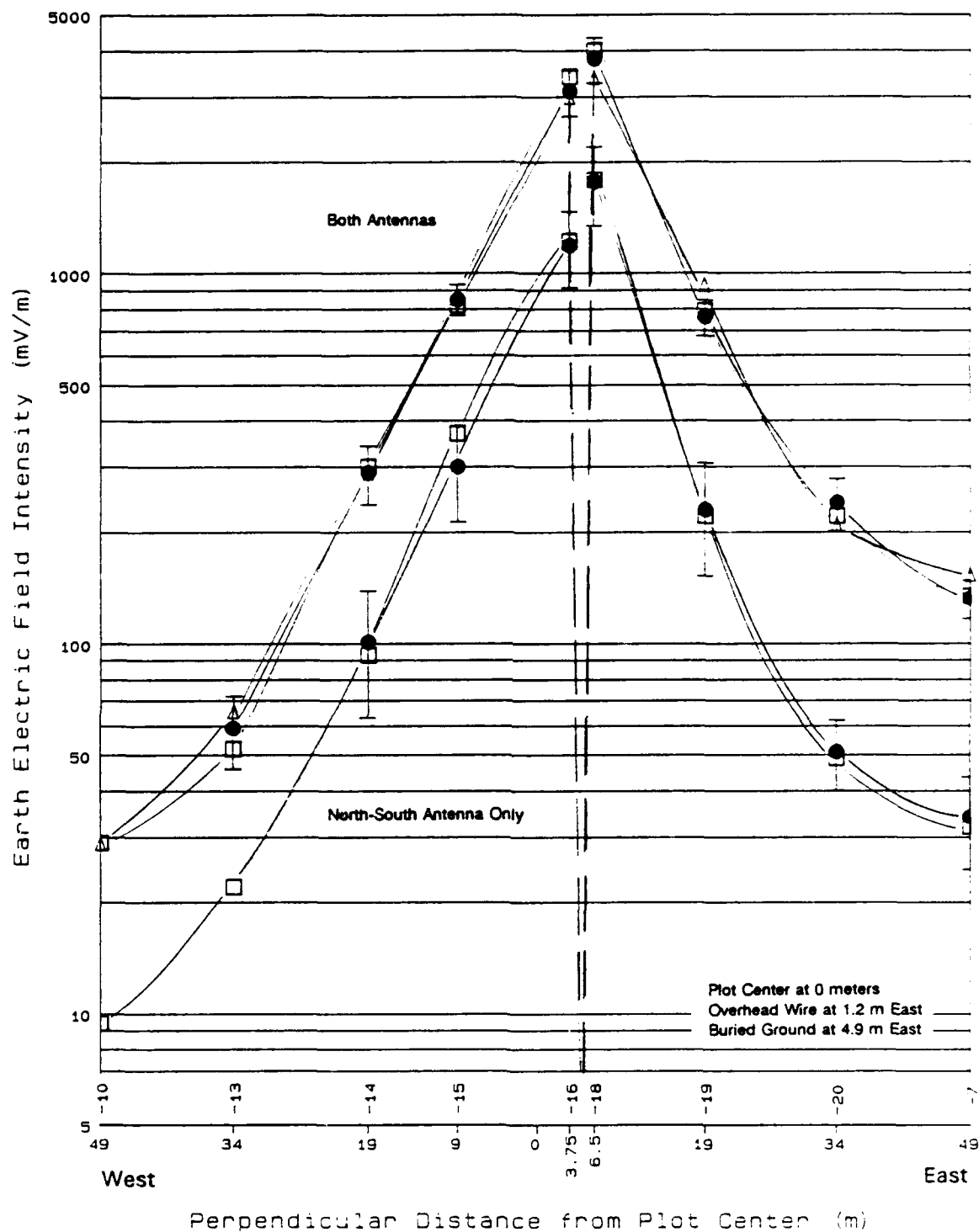


FIGURE 29. COMPARISON OF 1992 76 Hz EARTH ELECTRIC FIELD MEASUREMENTS AT SITE 4T4. ERROR BARS ARE ± 1 SD OF LOGGER DATA.

made at these sites in 1990. The 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 affinities for different 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 centimeters, 25 centimeters, and 60 centimeters. In actuality, the electrode measurement spans were 0 to 5 centimeters, 25 ± 4 centimeters, and 60 ± 6 centimeters in order to provide enough electrode surface area for good soil contact. Pairs of these 1-meter-spaced, coaxial electrodes were installed at two locations within each study site (labeled E3 in Figures 16 and 17) and connected to data loggers for continual monitoring.

Monitoring of the coaxial electrodes continued throughout 1991 and 1992. Graphs of the multidepth electric field measurements from 1992 are provided in Figures 30 and 31. The electric field and soil temperature data presented are daily averages of the hourly measurements. Air temperatures are the daily maximum and minimum, and rainfall is the daily total. Valid rainfall data were not obtained at the control site and therefore do not appear in Figure 31. Initial measurements made at the time of electrode installation showed no differences in the earth electric field intensity as a function of depth for any of the measurement locations. However, slight differences between levels became apparent within hours of the start of monitoring and persisted. Despite these differences, no consistent trend appears in the relative level of field intensity versus soil depth. What is evident in both figures is a slight reduction in electric field intensity when the EW antenna is off.

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 variations related to differences in the operating parameters of the ELF transmitters and to climatic variables such as temperature, rainfall, and soil moisture levels are expected. 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 illustrate the differences in the earth electric field near antenna ROWs and ground terminals, respectively, 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. Electric field intensities during 44 Hz operation should be a little more than half the intensity levels induced during 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.

In addition to these differences in effective conductivity, the earth electric field near ground terminals varies inversely with conductivity, while the earth electric field along antenna ROWs varies in proportion to the natural logarithm of the inverse of the square root of conductivity. Thus, 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

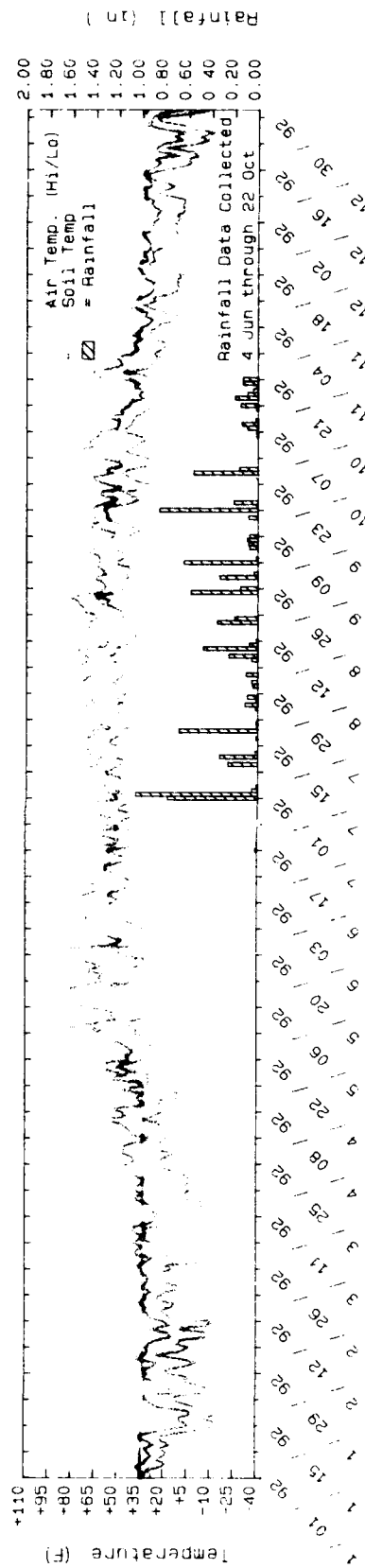
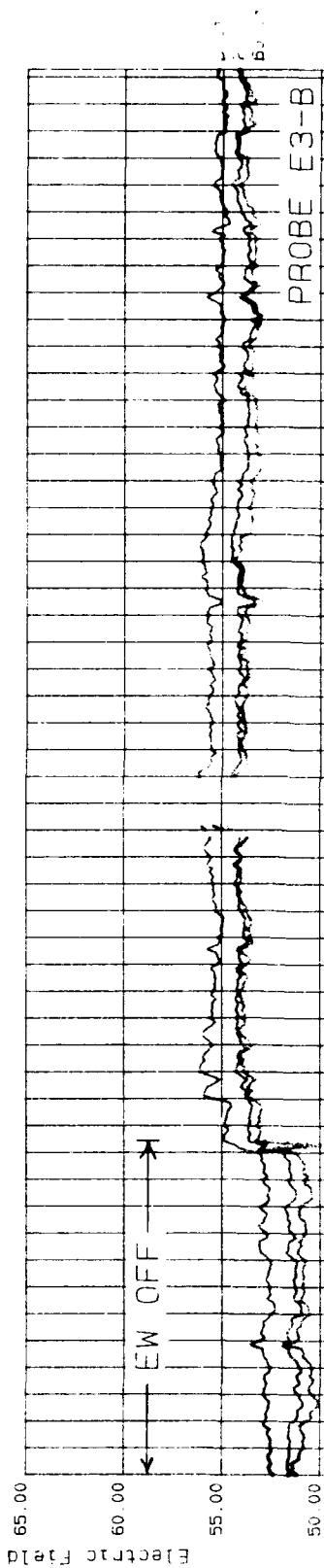
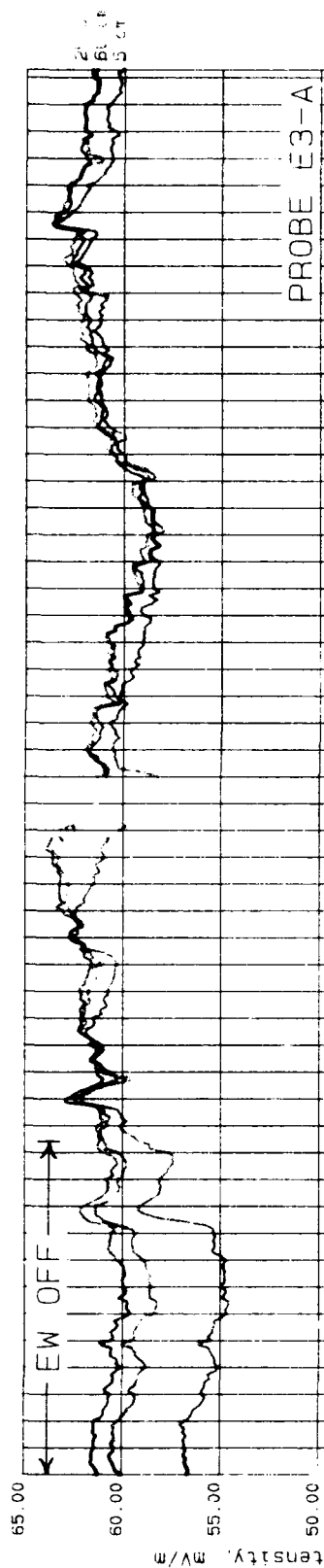


FIGURE 30. TREATMENT SITE 76 Hz ELECTRIC FIELDS VS. SOIL DEPTH--DAILY AVERAGE OF HOURLY MEASUREMENTS.

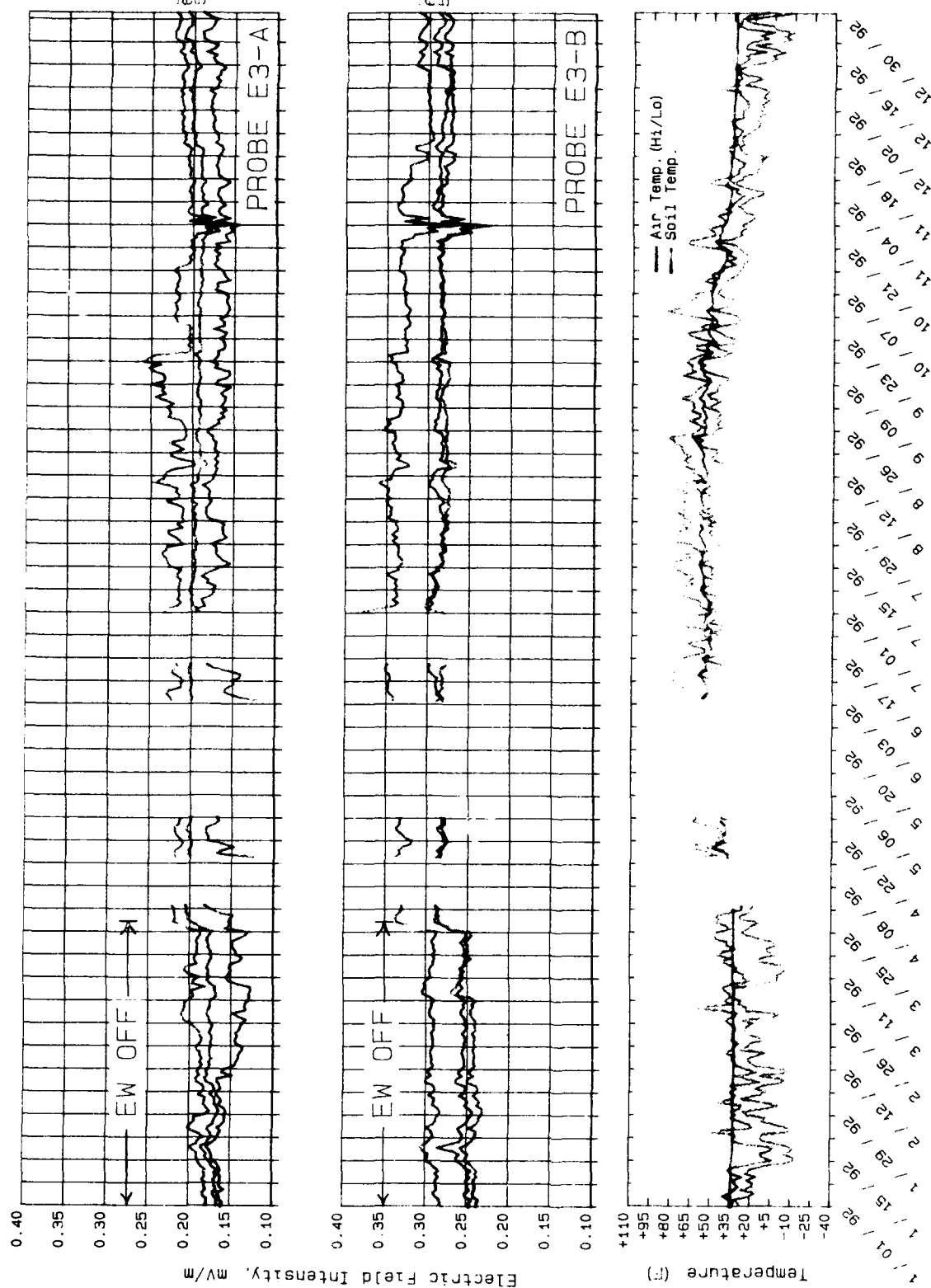


FIGURE 31. CONTROL SITE WIDEBAND ELECTRIC FIELDS VS. SOIL DEPTH--DAILY AVERAGE OF HOURLY MEASUREMENTS.

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 climatic-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 Hz 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 Hz and 76 Hz field intensity levels are proportional to the signal center frequency. Throughout 1992, 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 1992 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 estimates at the upland flora and soil microflora treatment study sites. They do not, however, provide 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 through December 1992 are listed in Tables D-9 through D-14. With few exceptions, the fields at the fixed probes have shown coefficients of variation typically at or below 10 percent. No consistent reason has been found for the few exceptional cases of high variability. They are believed to be related to changes in soil-to-electrode contact impedance and not actually representative of earth electric field variations.

4.4.2.4 Data Logger Seasonal Measurements. Data logger monitoring systems were installed in 1988 and have been in operation at soil amoeba study sites 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 16. The 1992 data for the earthworm study sites as well as the monitoring system layouts have already been presented in Sections 4.2.2 and 4.4.1.3. Summary plots of 1992 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 installed in 1992, although some data logger weather monitoring continued. These data are also presented in Appendix F.

Daily averages of the hourly earth electric field intensity measurements at the upland flora and soil microflora logger sites for 1992 are plotted in Figures 32 through 34. 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.

Several phenomena related to antenna operating conditions appear in Figures 32 through 34. Reduced field intensity levels from 1 January through 27 March resulted from continued shutdown of the

**TABLE 16. 1991, 1992 DATA LOGGER MEASUREMENT PARAMETERS
Earthworms, Upland Flora, and Aquatics Study Sites**

Measurement Parameter	Data Logger Site Identification*					
	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.

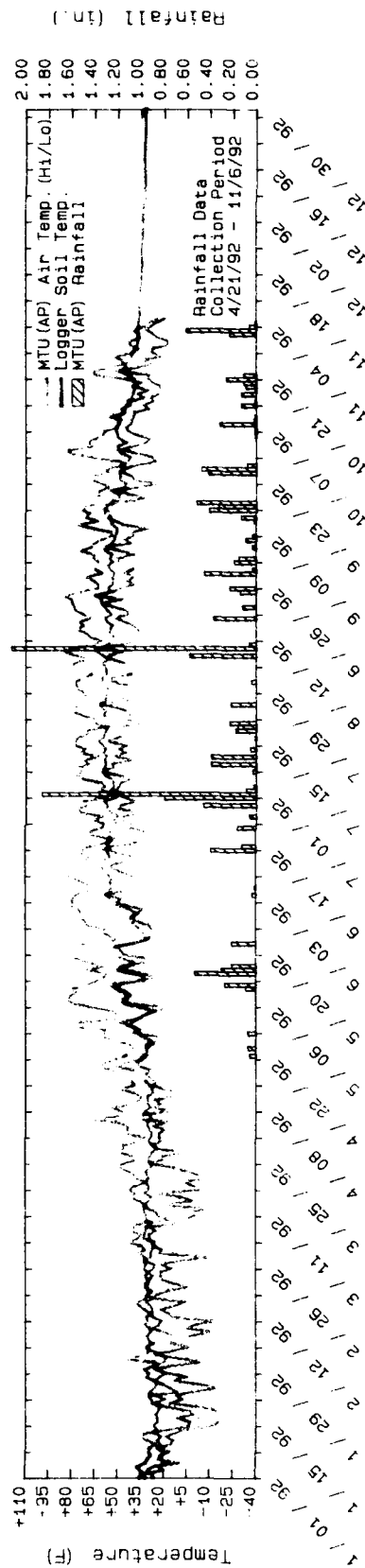
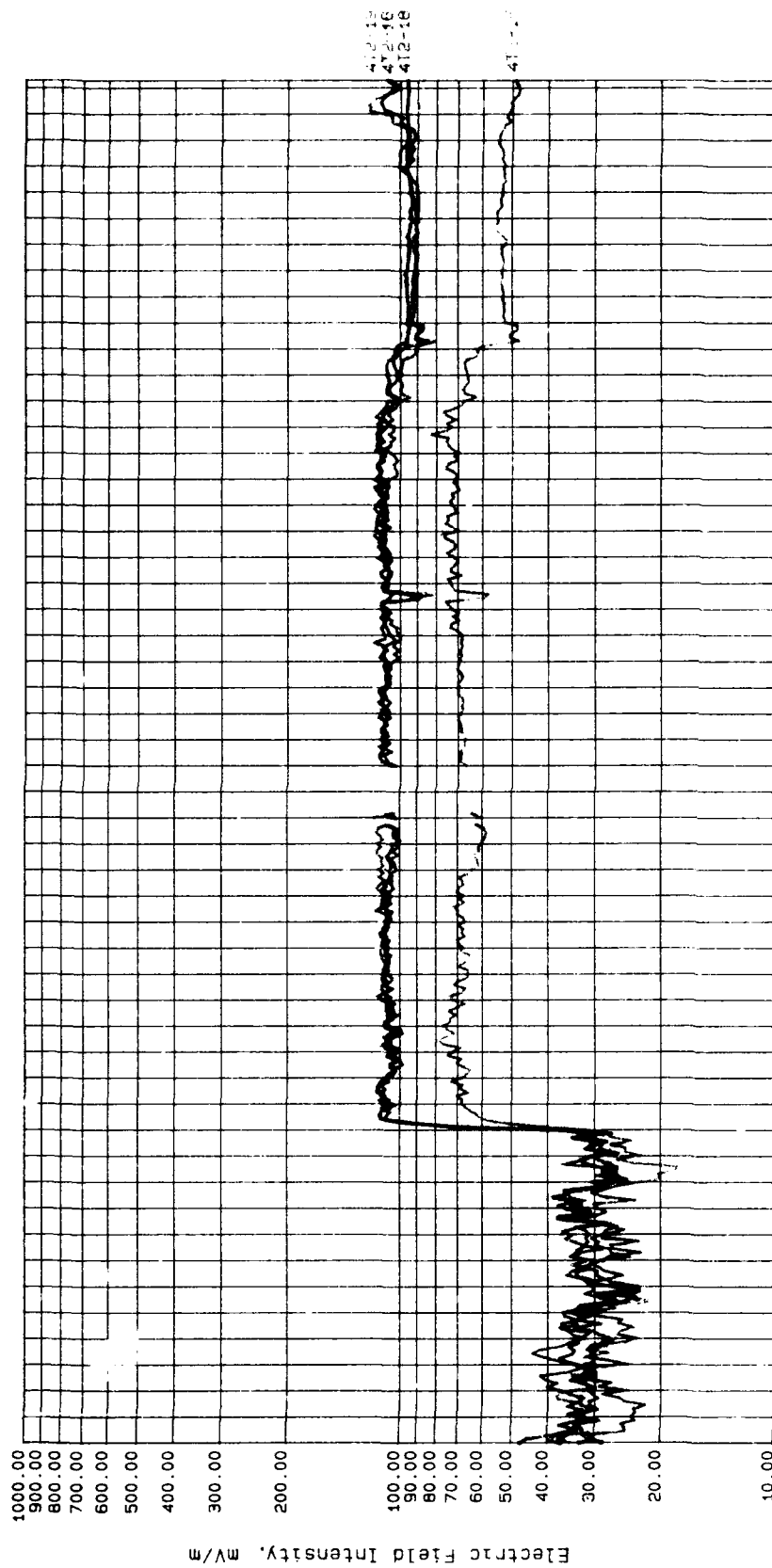


FIGURE 32. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT ANTENNA SITE PINE PLANTATION: 4T2-19, 18, 17, 16, 15.

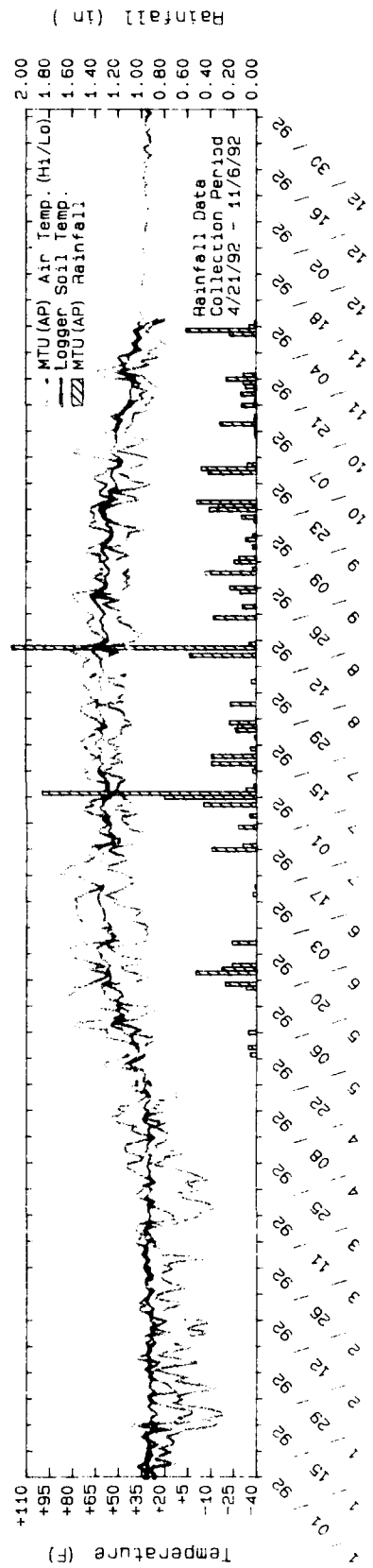
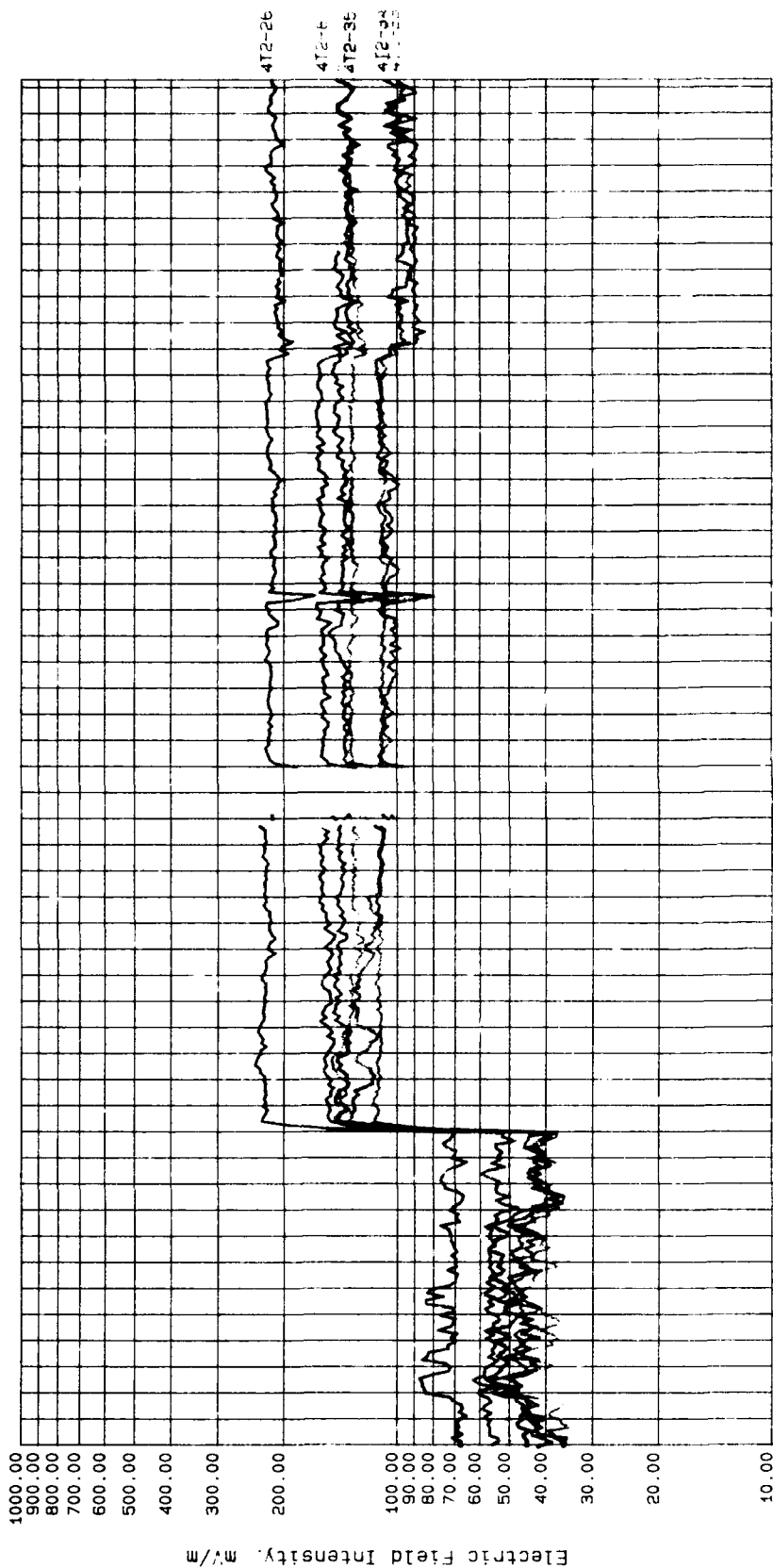


FIGURE 33. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT ANTENNA SITE HARDWOOD STAND: 4T2-9, 33, 8, 34, 26, 35, 36.

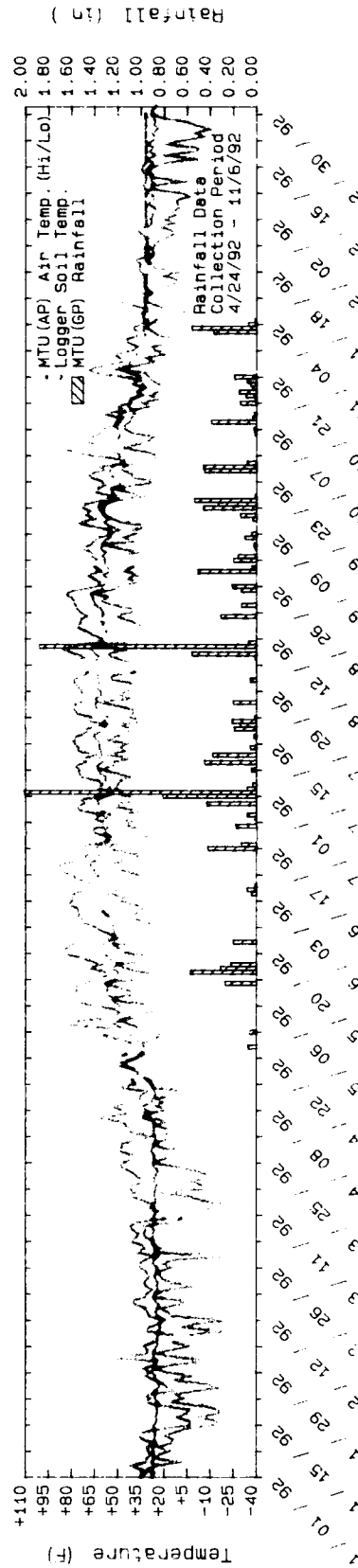
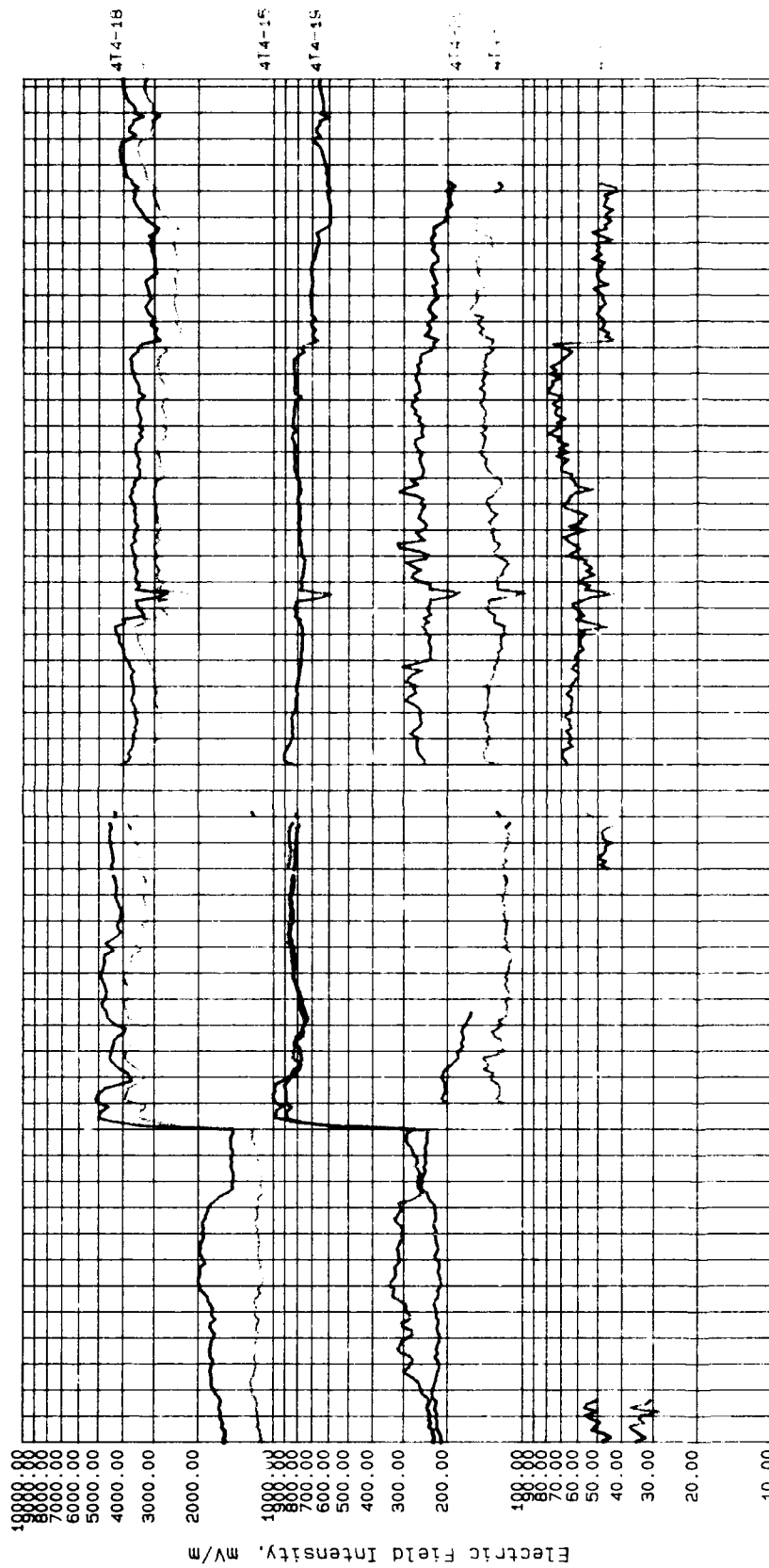


FIGURE 34. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT GROUND SITE PINE PLANTATION:
4T4-7, 20, 19, 18, 16, 15, 14.

EW antenna for maintenance. Earth electric fields at these sites were reduced to roughly one-third of their full operation value during EW antenna shutdown. The gap in the data at the end of June resulted from both antennas being shutdown for unscheduled maintenance. Also, the depression in the daily average intensity levels on 16 August resulted from the EW antenna being shut down for about a nine-hour period on that day. Around 21 October, currents were redistributed at ground 5, resulting in a reduction of current to the ground wire branch at the upland flora and soil microflora ground site. This is evidenced by a uniform decrease in field intensities at all probes at this site. The earth electric fields at the antenna site for this study, which is at the end of the antenna line terminating at ground 5, also decreased in a manner similar to the decrease at the ground site. This is also thought to be related to the current redistribution at ground 5. Because the current redistribution is a permanent change, earth electric field intensities will remain reduced at these sites. They will continue to be monitored through 1993.

In 1991, it was observed that earth electric field intensities at the upland flora and soil microflora study sites increased slightly in the winter months, presumably because of the increased impedance of the frozen earth. A similar increase appears to be present in the 1992 data as well, but is somewhat masked by the effects of the current redistribution at the end of October. Continued monitoring will also help to verify and better understand this effect.

Figure 35 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 1992 are plotted in Figure 36. This figure indicates a 10 to 20 percent temporal variation of the earth electric field intensities at each of the four measurement locations. The pattern of variation is similar at all these locations and is most likely attributable to water conductivity changes. Similar temporal variations in the earth electric field are expected at the other aquatics study sites, assuming similar changes in water conductivity.

Also plotted in Figure 36 is the daily rainfall, as measured at the upland flora study site, which is about 10 miles north of the aquatics treatment site. As in 1991,¹² electric field variations appear to be well correlated with rainfall activity. This is most likely explained by changes in the river ion concentrations associated with the rainfall. A decrease in ion concentrations, and therefore conductance, would be expected to cause an increase in electric field intensities.

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 37. 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 38. 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 is about 3.5 percent.

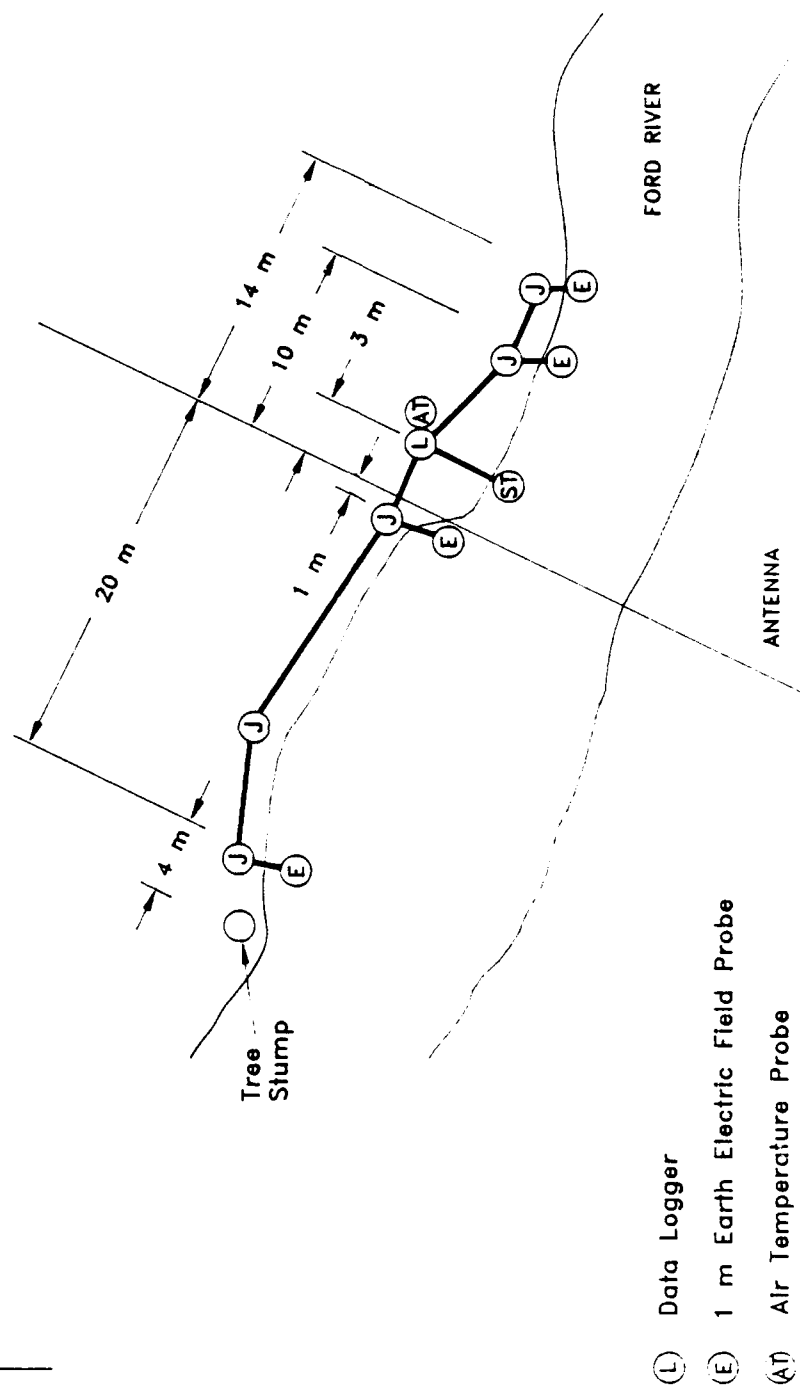
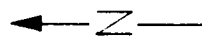


FIGURE 35. DATA LOGGER MONITORING SYSTEM AT FORD EXPERIMENTAL SITE 5T2.

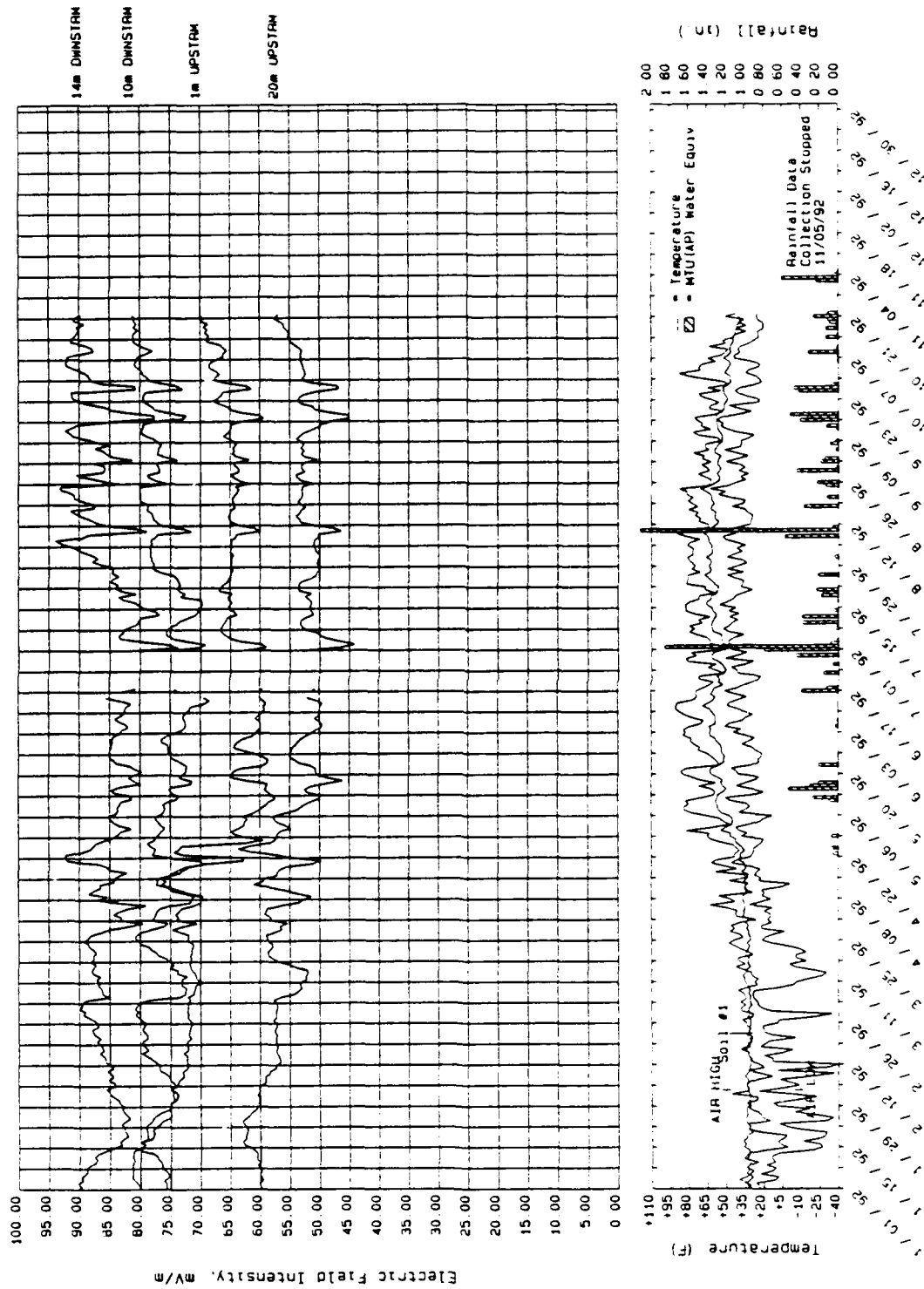


FIGURE 36. 76 Hz DAILY AVERAGE EARTH ELECTRIC FIELD DATA AT SITE 5T2.

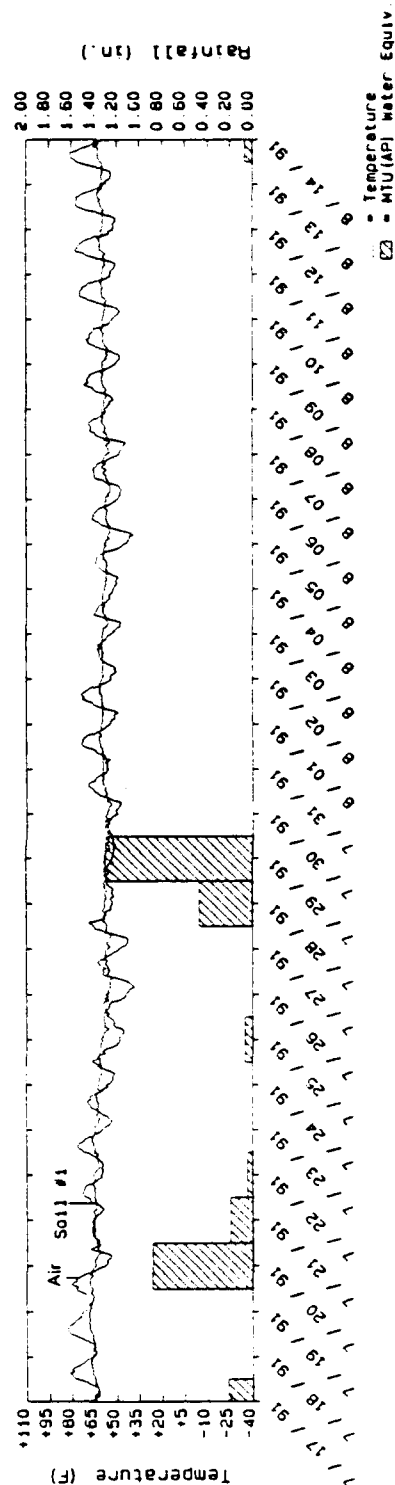
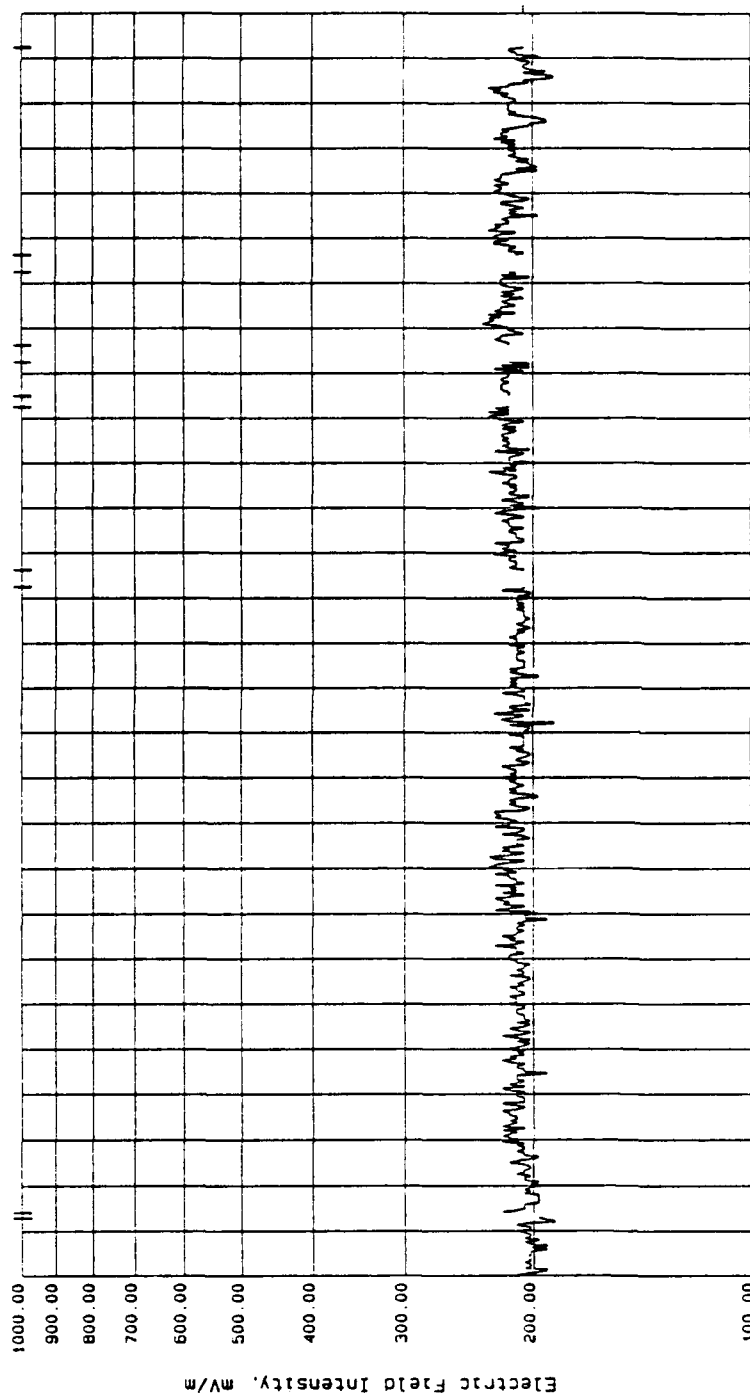


FIGURE 37. HOURLY EARTH ELECTRIC FIELD INTENSITIES AT ANTENNA SITE HARDWOOD STAND: MEASUREMENT POINT 4T2-26.

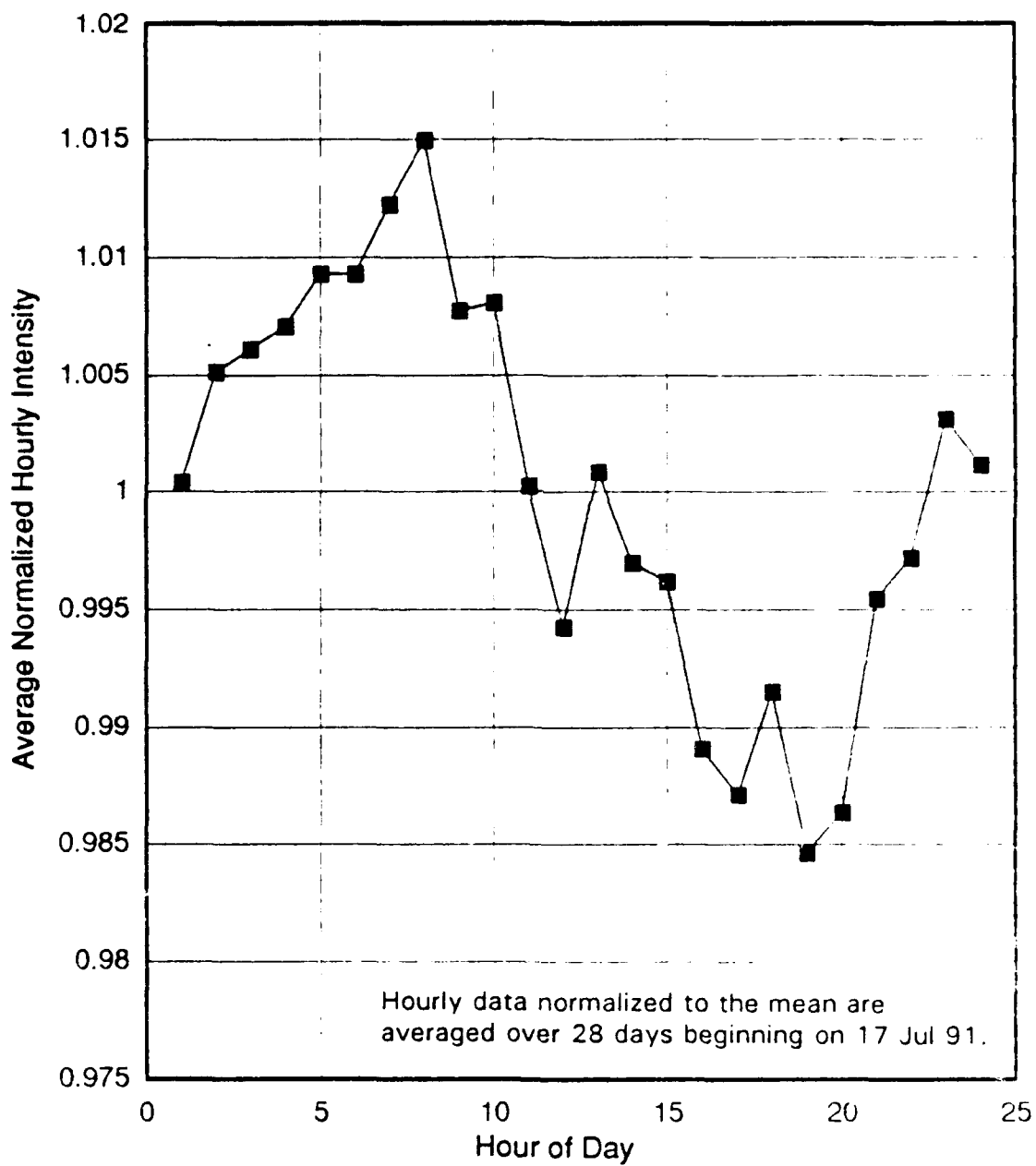


FIGURE 38. EARTH ELECTRIC FIELD DIURNAL CYCLE AT GROUND SITE PINE PLANTATION: MEASUREMENT POINT 4T4-18.

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 with some regularity at both sites. When present, they 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 measurements at the study sites and data on the operating times of the antennas. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through G. Data on antenna operating conditions are provided to IITRI by the Navy's Submarine Communications Project Office. These data include changes in the operating frequency, modulation, power, and phasing for each antenna element. This information is entered into a computer-based spreadsheet that allows the generation of operating condition summaries in both graphic and tabular form. 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, 1986-1992

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 amperes) unmodulated signal, and the antenna elements were operated individually. In 1987, antenna currents were increased to 15 amperes, and the NEW and SEW antenna elements were permanently connected in parallel, constituting the EW antenna. In 1988, antenna currents were increased to 75 amperes. In May 1989, currents were increased to full power (150 amperes), 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 throughout 1990, 1991, and 1992, with the exception of the previously mentioned 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-ampere 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% duty cycle for each antenna during the testing period. The rotational schedule was not used after 150-ampere testing began in May 1989.

Figures 39 and 40 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 39. 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 1989-1992 are shown in Figure 40. They are broken down into periods of operation with both antennas, the NS antenna only, and EW antenna only.

The pie charts in Figure 41 present NRTF-Republic annual operating summaries for 1986-1992. 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 1992. 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 1992.

NRTF-Republic operations in 1986-1992 can be summarized as follows:

1986

- The NRTF-Republic was transmitting about 1.5 percent of the time (about 160 hours) (see Figures 39 and 41).
- 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 5 amperes for the NS antenna and the NEW antenna element, respectively, and both 6 and 10 amperes for the SEW antenna element.

1987

- The NRTF-Republic was transmitting about 4.5 percent of the time (about 400 hours) (see Figures 39 and 41).
- 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-ampere current.

1988

- The NRTF-Republic was transmitting about 11.6 percent of the time (about 1000 hours) (see Figures 39 and 41).

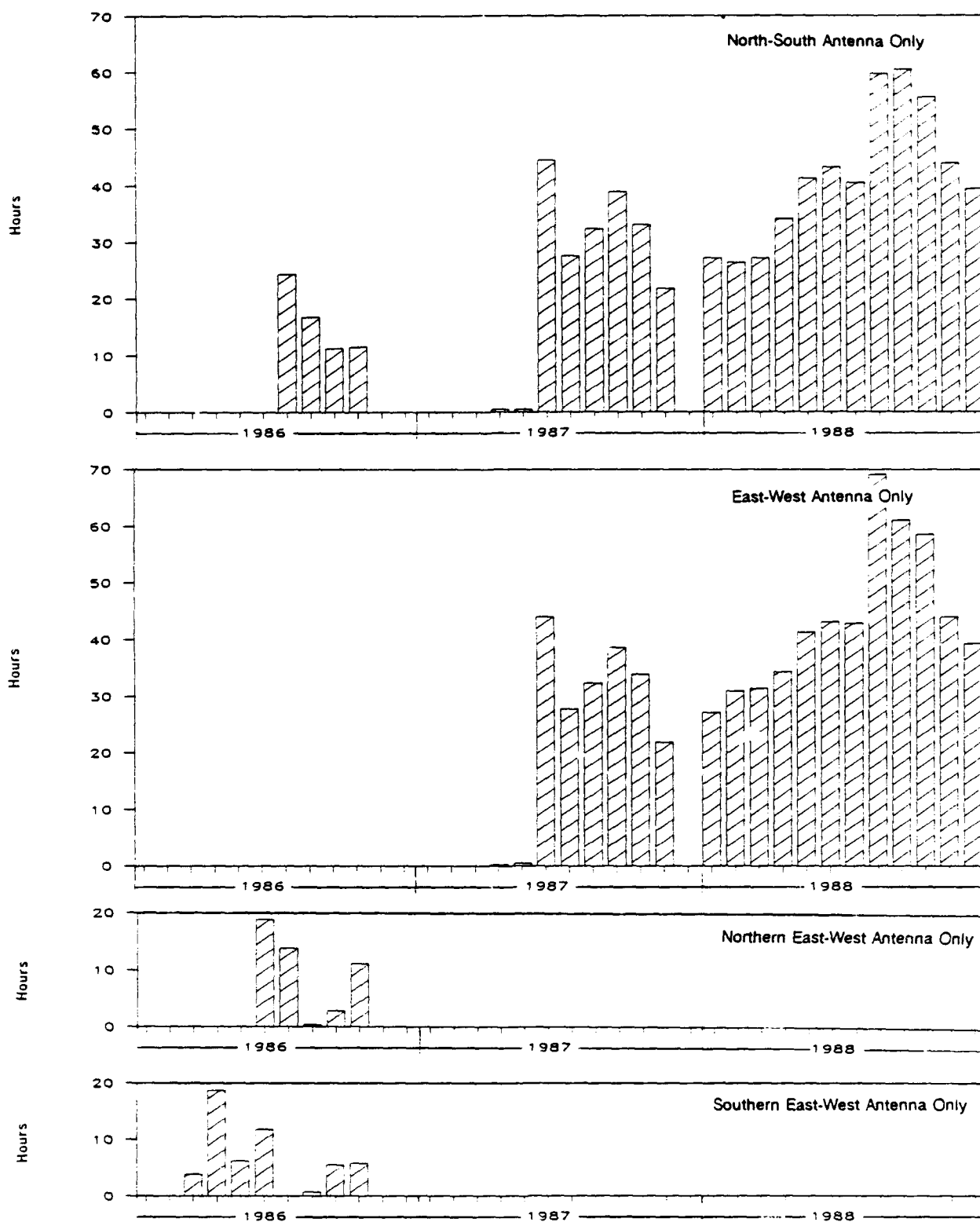


FIGURE 39. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1986-1988.

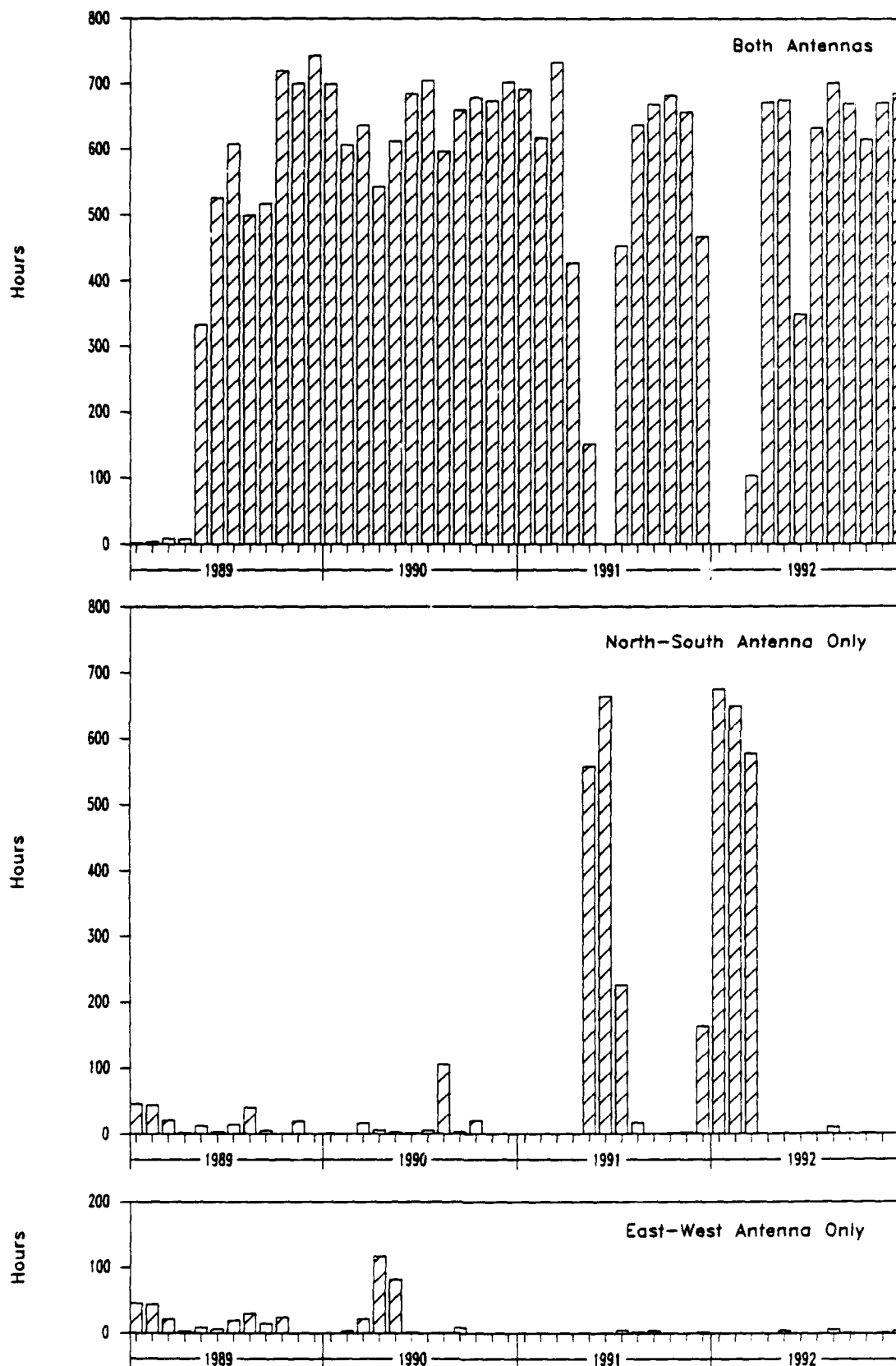


FIGURE 40. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1989-1992.

TOTAL TRANSMITTER OPERATING TIMES

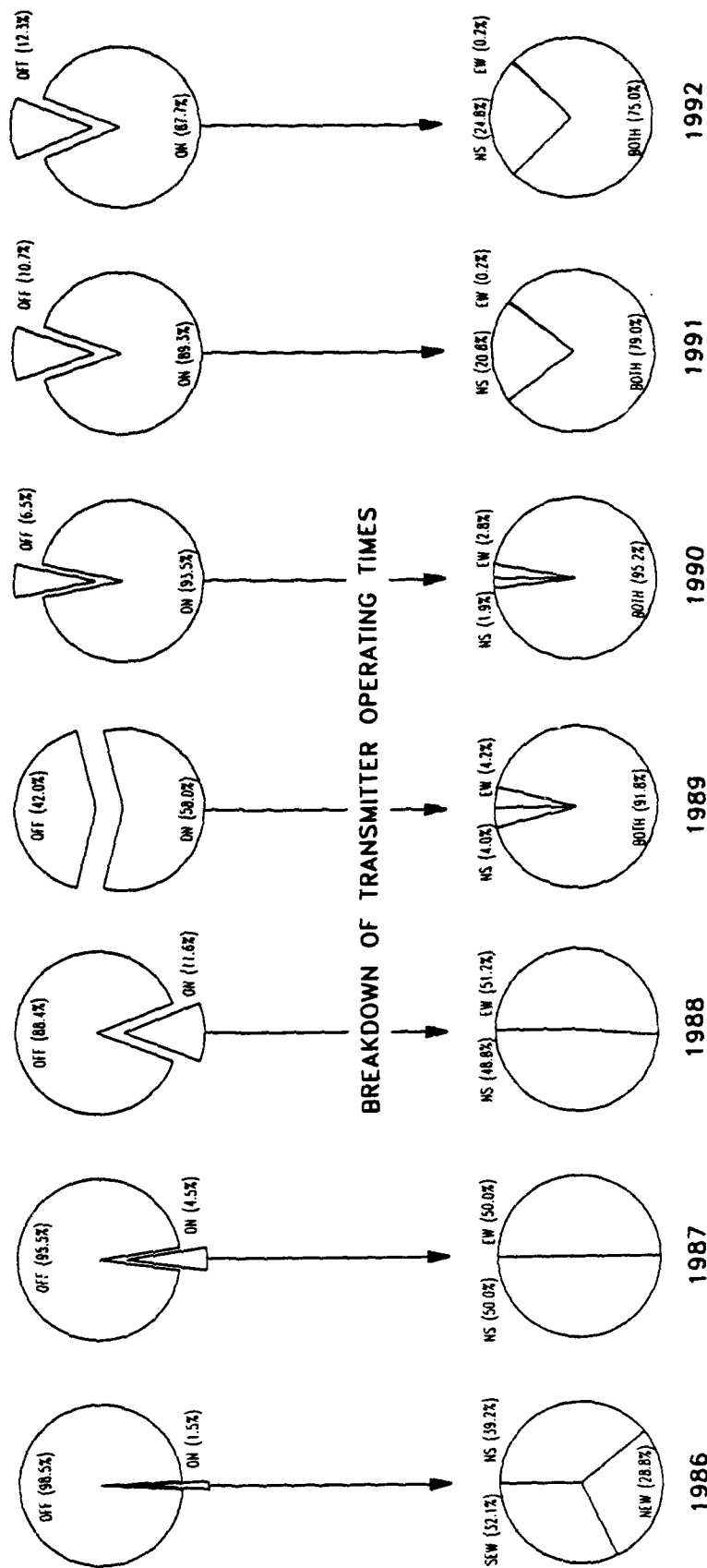


FIGURE 41. NRTF-REPUBLIC OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-1992.

- About 98 percent of "on" time was with an unmodulated 76 Hz or 44 Hz signal.
- The NS and EW antennas were always operated individually.
- Primary operating currents were 15 and 75 amperes. 40.6 percent of "on" time was at 15 amperes, and 59.2 percent of "on" time was at 75 amperes.

1989

- The NRTF-Republic was transmitting about 58 percent of the time (about 5100 hours) (see Figures 40 and 41).
- 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 amperes. 95 percent of "on" time was at 150 amperes.

1990

- The NRTF-Republic was transmitting about 93.5 percent of the time (about 8200 hours) (see Figures 40 and 41).
- 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 amperes.

1991

- The NRTF-Republic was transmitting about 89 percent of the time (about 7825 hours) (see Figures 40 and 41).
- 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 amperes with a modulated 76 Hz signal.

1992

- The NRTF-Republic was transmitting about 88 percent of the time (about 7680 hours) (see Figures 40 and 41).
- 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 amperes with a modulated 76 Hz signal.

5. CONCLUSIONS AND DISCUSSION

Annual EM field measurement surveys in support of the Ecological Monitoring Program were performed during May, September, and October of 1992. Measurements were made at a total of 180 points at 49 study sites, compared with 195 points at 50 sites in 1991. There were no new measurement points added in 1992. The reduction in the number of sites and measurement points primarily corresponded to completion of several ecological monitoring activities.

The NRTF-Republic continued operation with a modulated 76 Hz, 150 ampere antenna current during 1992, employing either both antennas or the NS antenna only. Annual EM field measurements were made at all points during simultaneous operation of both antennas. Earth electric field measurements were obtained by data logger monitoring systems and at fixed probe locations during operation of the NS antenna only as well as during operation of both antennas in 1992. Measurements of the ambient 60 Hz EM fields at treatment study 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 study sites, 60 Hz measurements were made regardless of antenna condition.

Geomagnetic field intensities throughout the Ecological Monitoring Program study area were characterized for the first time in 1992. Overall 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.

Earth electric field intensities were measured at several earthworm collection locations at the treatment and control study sites in support of a test for correlation between the field intensity and earthworm abundance. Electric field variation between the sample locations was approximately 10 percent. Also, the standard deviation of ten 10-centimeter probe measurements along a 1-meter line was found to be roughly 10 percent of their mean. Field directions were nominally within a 25 degree range of each other at each site.

The effects of TDR probes on the earth electric field were assessed by measuring the field at several locations both before and after installation of a probe pair. Results showed essentially no difference between the two measurement sites. Electric fields will be altered immediately adjacent to the steel rods of the probe, however, and it was therefore recommended that the probes not be used in the small confined area of the incubation bags. Other locations at the sites are acceptable.

60 Hz magnetic fields were monitored nominally for a one-day period at laboratory sites for the native bee and earthworm studies. Field intensities were relatively stable over the period of a day. Variations were typically associated with the turning on and off of electrical equipment. Other EM field intensities were also characterized at these sites for the first time.

Incubation bags used to isolate earthworms for reproduction studies were designed and used in the field in 1991 and 1992. 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. Multiple bags were deployed at both the treatment and the control study sites, including reference bags, which were monitored by data logger systems. Monitoring of the electric field in the control site reference bag proved to be very difficult, 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 the probe sets.

Six data loggers monitored earth electric field temporal variations. Seasonal variations were typically 10 to 30 percent during 1992. Shorter-term variations were typically 10 to 20 percent. 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 in 1992. 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 had its greatest impact.

In 1993, the NRTF-Republic is expected to operate both antennas simultaneously with a 150 ampere MSK signal, as it did during 1992. IITRI plans to remeasure all points characterized in 1993 with some exceptions where study activities have been completed. Measurement protocols to be used in 1993 will be determined by the actual antenna status at the time, although they are not expected to differ from those used in 1992.

6. REFERENCES

1. Enk, J. O.; Gauger, J. R. ELF Communications System Ecological Monitoring Program: Measurement of ELF Electromagnetic Fields for Site Selection and Characterization--1983. IIT Research Institute, Technical Report E06549-10, 19 pp. plus appendixes, 1985.
2. Brosh, R. M.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Measurement of ELF Electromagnetic Fields for Site Selection and Characterization--1984. IIT Research Institute, Technical Report E06549-14, 37 pp. plus appendixes, 1985.
3. Brosh, R. M.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute, Technical Report E06549-24, 48 pp. plus appendixes, 1986.
4. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1986. IIT Research Institute, Technical Report E06549-37, 52 pp. plus appendixes, 1987.
5. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1987. IIT Research Institute, Technical Report E06595-1, 54 pp. plus appendixes, 1988.
6. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1988. IIT Research Institute, Technical Report E06595-5, 69 pp. plus appendixes, 1989.
7. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1989. IIT Research Institute, Technical Report E06620-5, 77 pp. plus appendixes, 1990.
8. ELF Communications System Ecological Monitoring Program: Wetland Studies--Final Report. IIT Research Institute, Technical Report E06620-2, November 1989, 250 pp.
9. ELF Communications System Ecological Monitoring Program: Slime Mold Studies--Final Report. IIT Research Institute, Technical Report E06620-3, January 1990, 83 pp.
10. ELF Communications System Ecological Monitoring Program: Wisconsin Bird Studies--Final Report. IIT Research Institute, Technical Report E06628-2, February 1991, 99 pp.
11. 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.
12. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1991. IIT Research Institute, Technical Report D06200-4, 81 pp. plus appendixes, 1992.

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 1992, IITRI field crews made ELF electromagnetic (EM) field measurements at 55 measurement points within the five treatment sites, four control sites, three (bird) displacement sites, and the remote holding facility for the small mammals and nesting birds studies. The measurement regime differed from 1991 in that measurements were not made at the mouse enclosures (1T1-17 through 20, 28 through 31), since they are no longer in use. Documentation of previous measurements 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 1992 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

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	Piriot 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 1992 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. 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 1992 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 1992 (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 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, and the ratios of 60 Hz EM fields between matched treatment and control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1992 were made with 150 ampere 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 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989 through 1992. The 1992 measurements are consistent with the measurements made in 1989 through 1991 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 1992 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; measurements were not made at the laboratory in 1991 or 1992.

Table A-9 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-10, 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.

* 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.

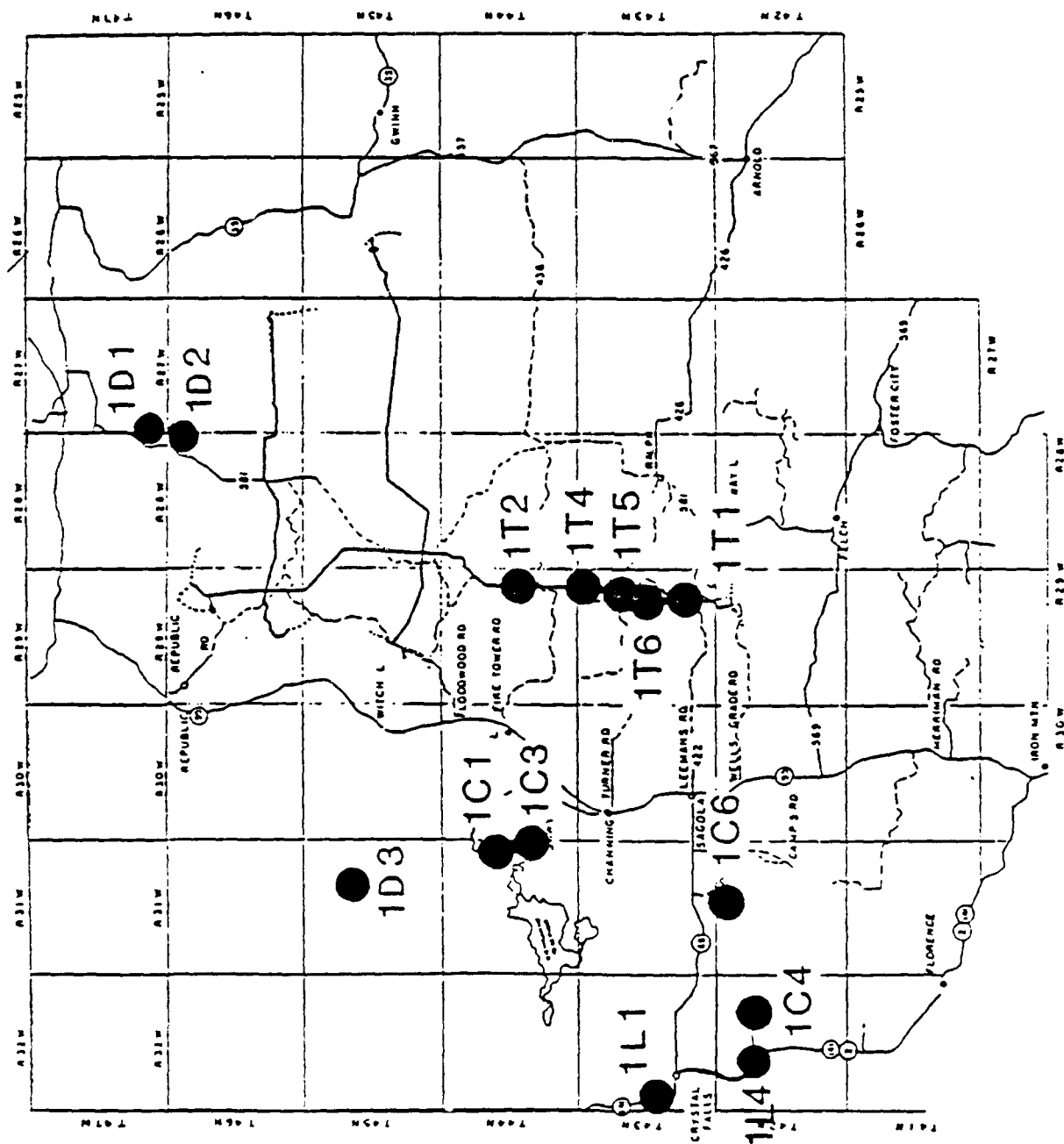


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

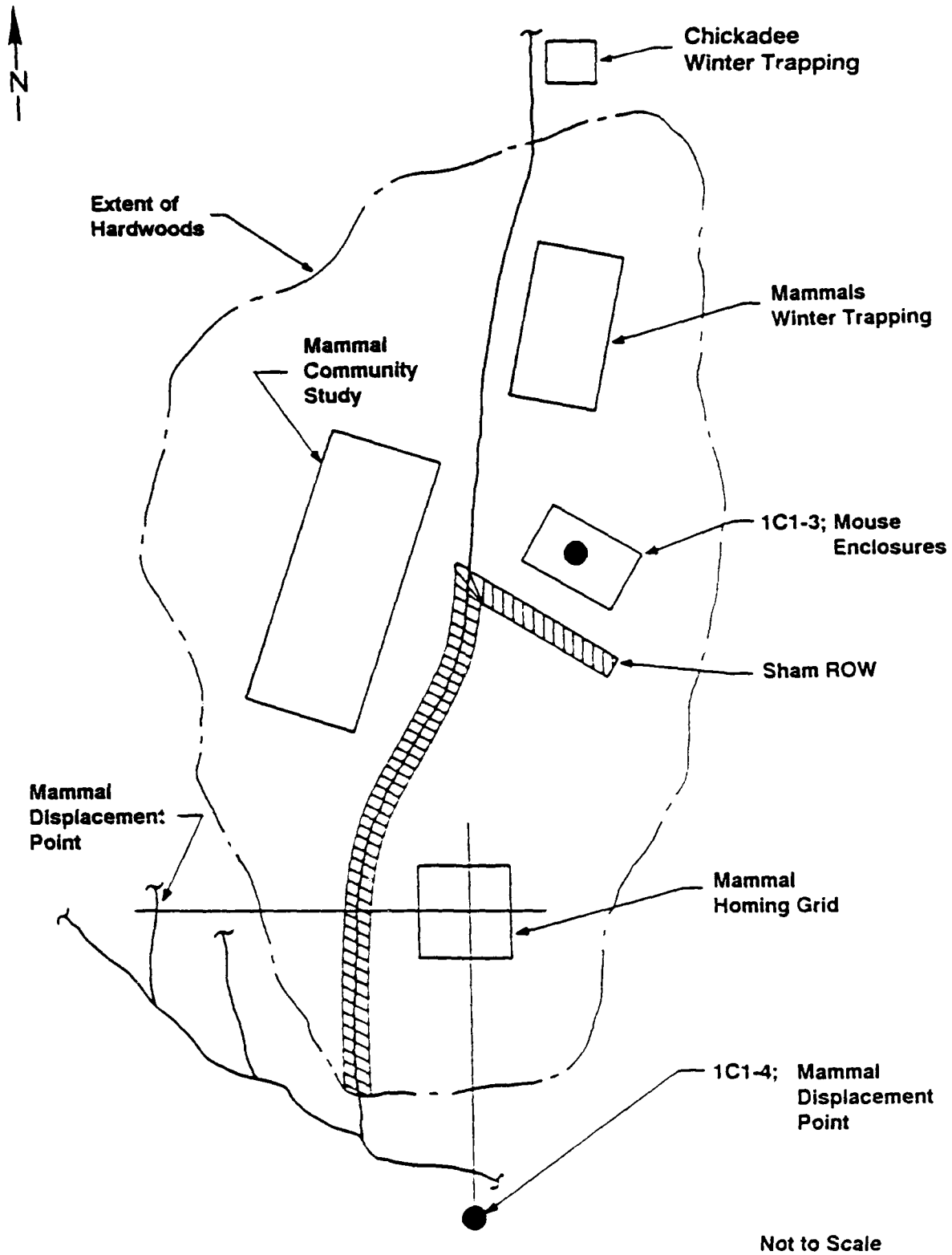


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH; 1C1-3, 4.

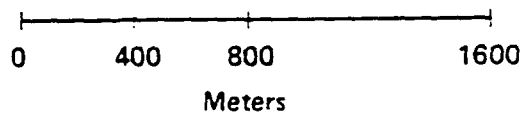
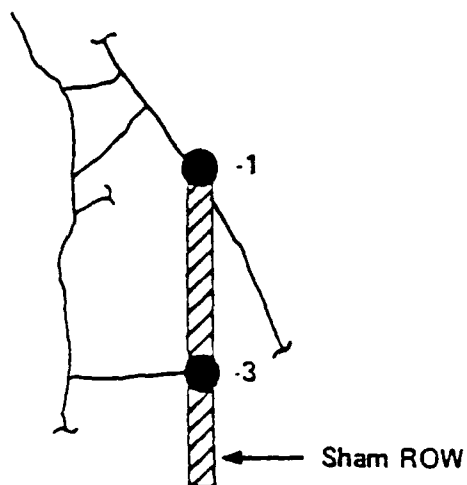
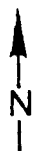


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH; 1C3-1, 3.

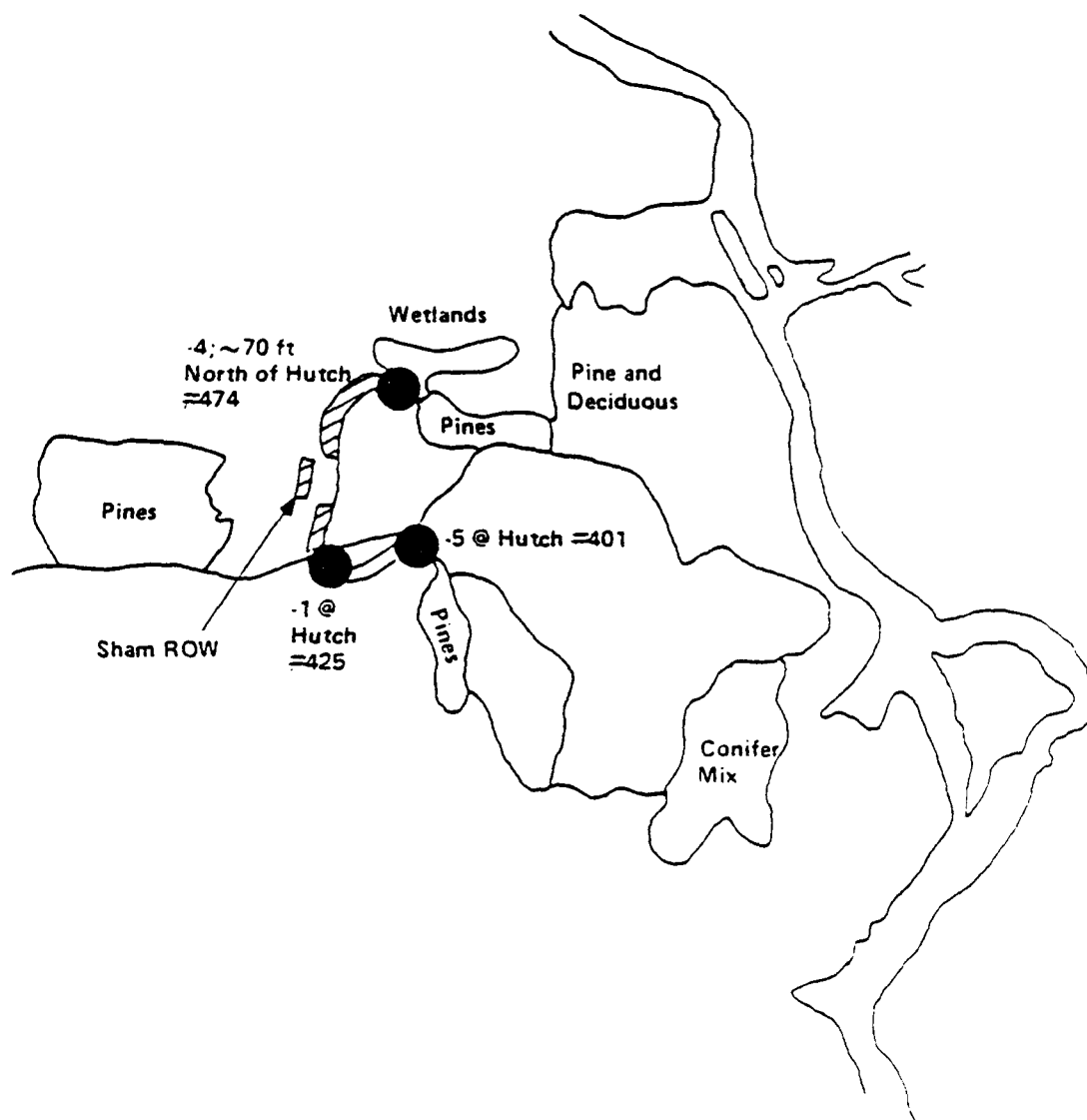
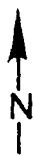


FIGURE A-4. MEASUREMENT POINTS AT PANOLA PLAINS; 1C4-1, 4, 5.

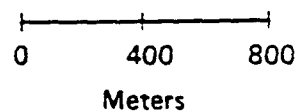
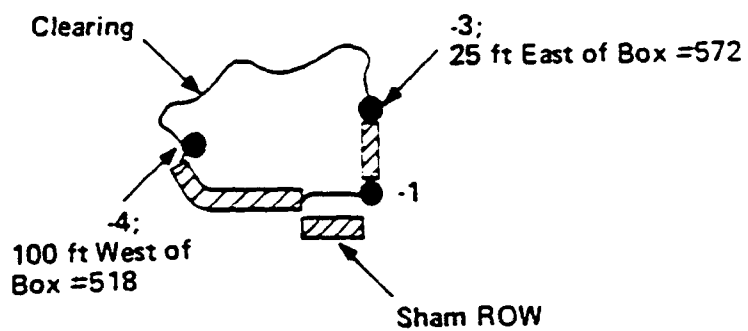
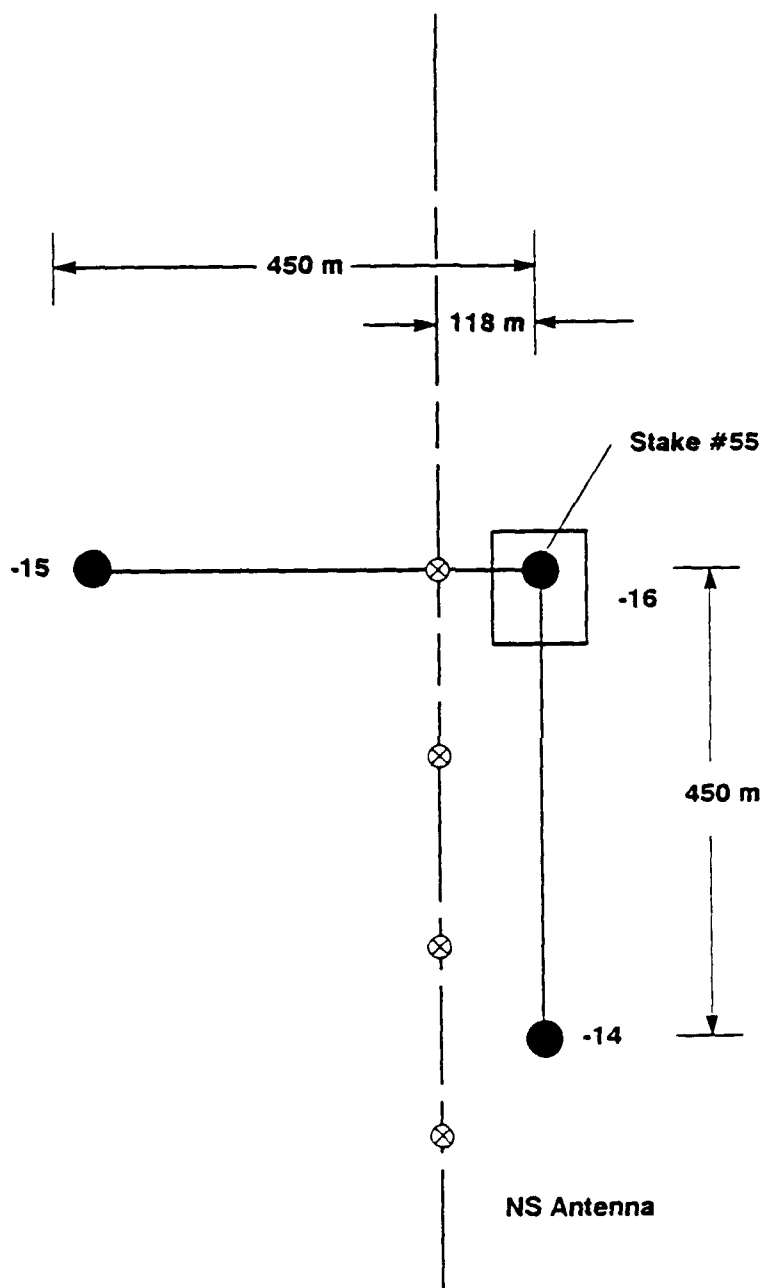
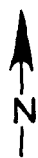
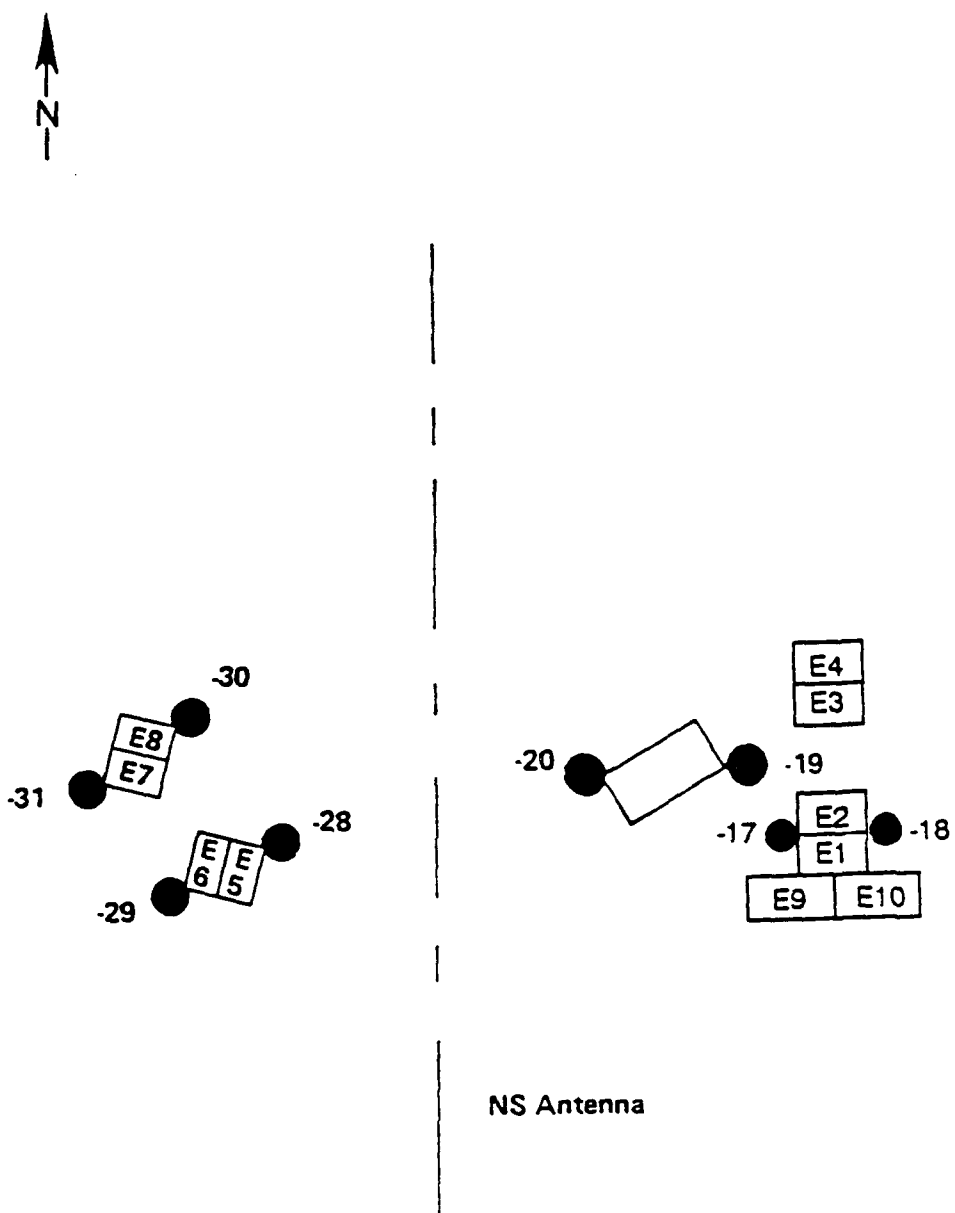


FIGURE A-5. MEASUREMENT POINTS AT TACHYCINETA MEADOW; 1C6-1, 3, 4.



Not to Scale

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



Not to Scale

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

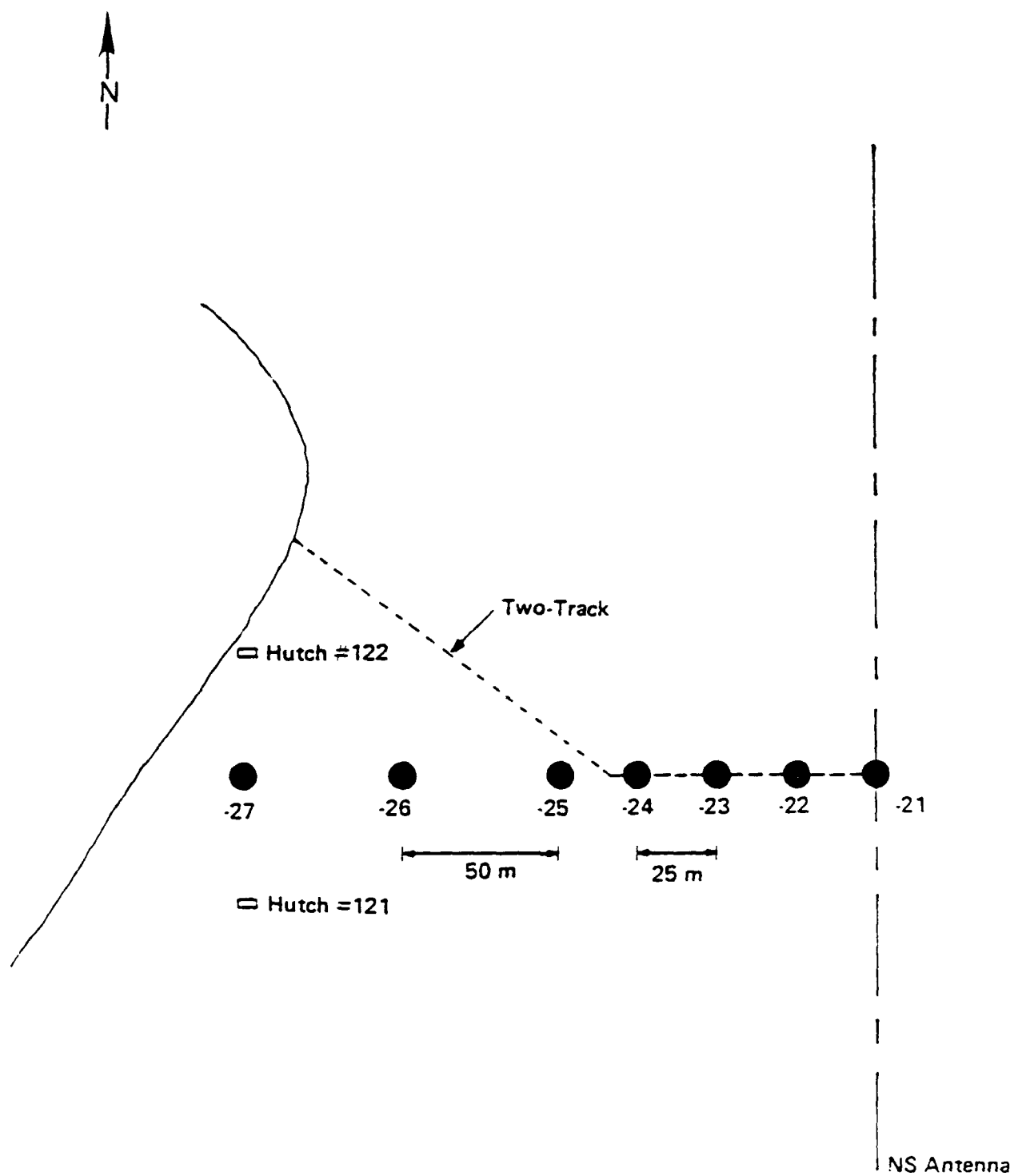


FIGURE A-8. MEASUREMENT POINTS AT PIRLOT ROAD; 1T1-21 THROUGH 27.

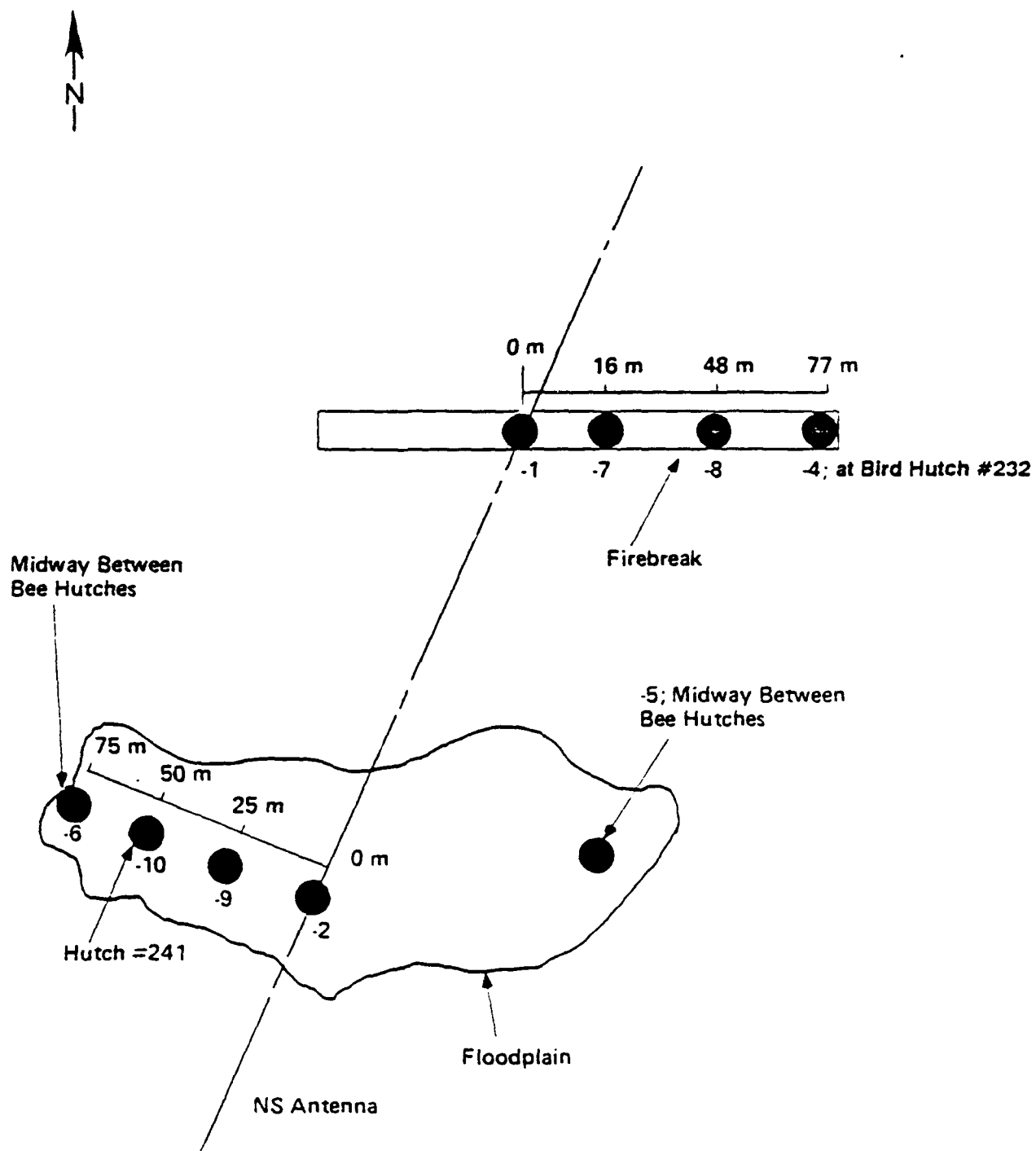


FIGURE A-11. MEASUREMENT POINTS AT FORD RIVER NORTH;
1T5-1, 2, 4, 6, 7, 8, 9, 10.

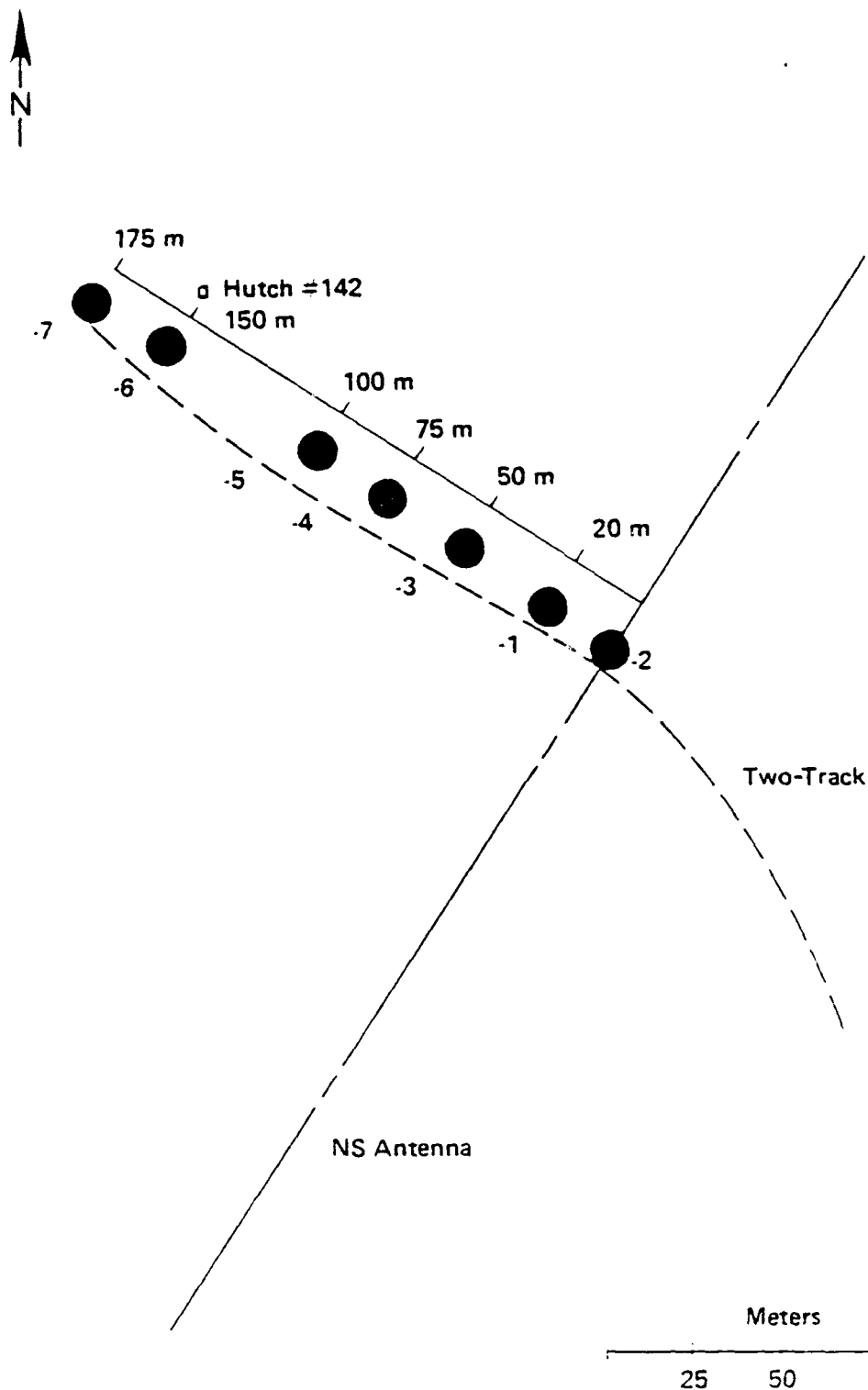


FIGURE A-12. MEASUREMENT POINTS AT FORD RIVER SOUTH; 1T6-1 THROUGH 7.

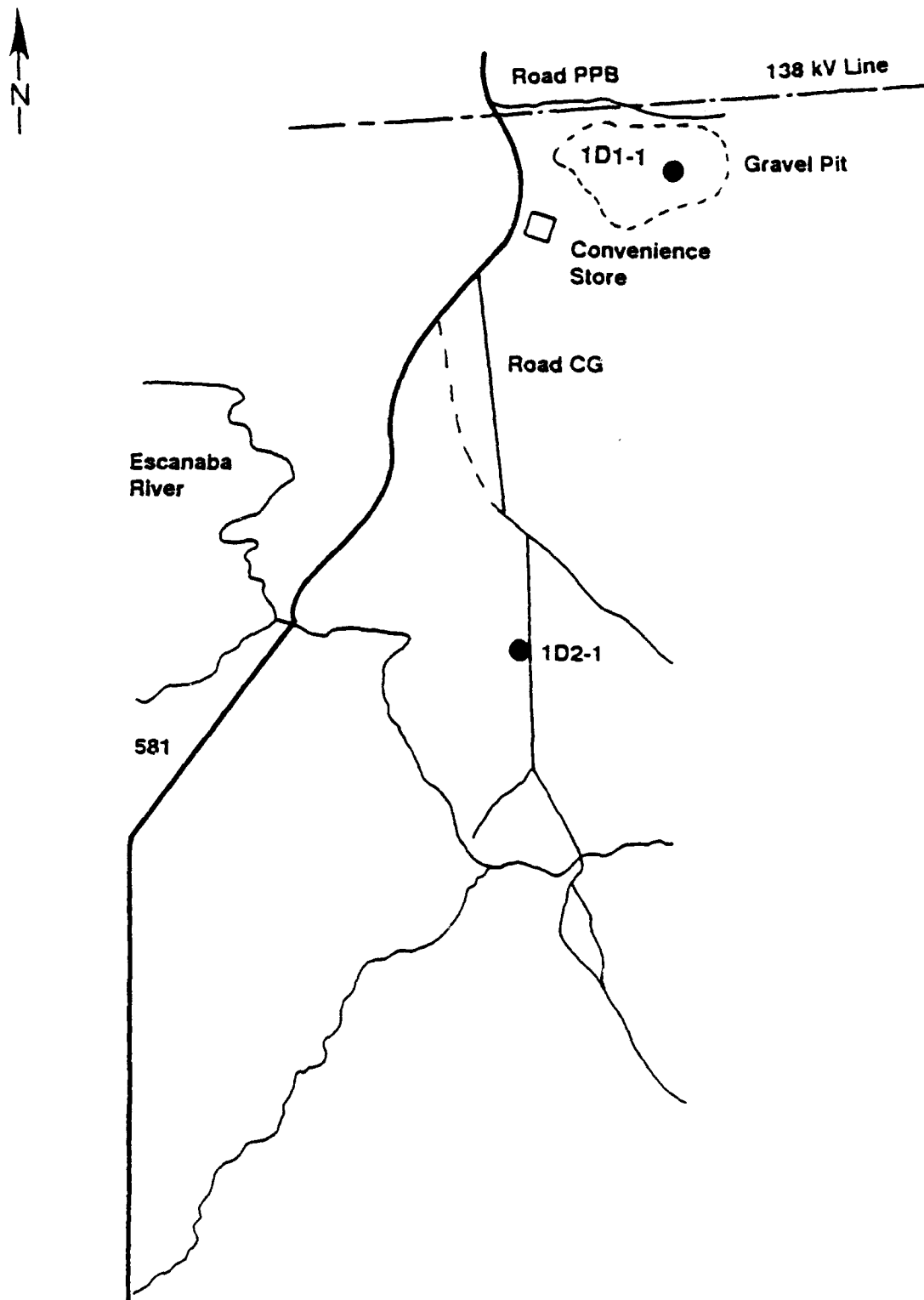


FIGURE A-13. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD AND NORTH TURNER ROAD DISPLACEMENT POINTS; 1D1-1 AND 1D2-1.

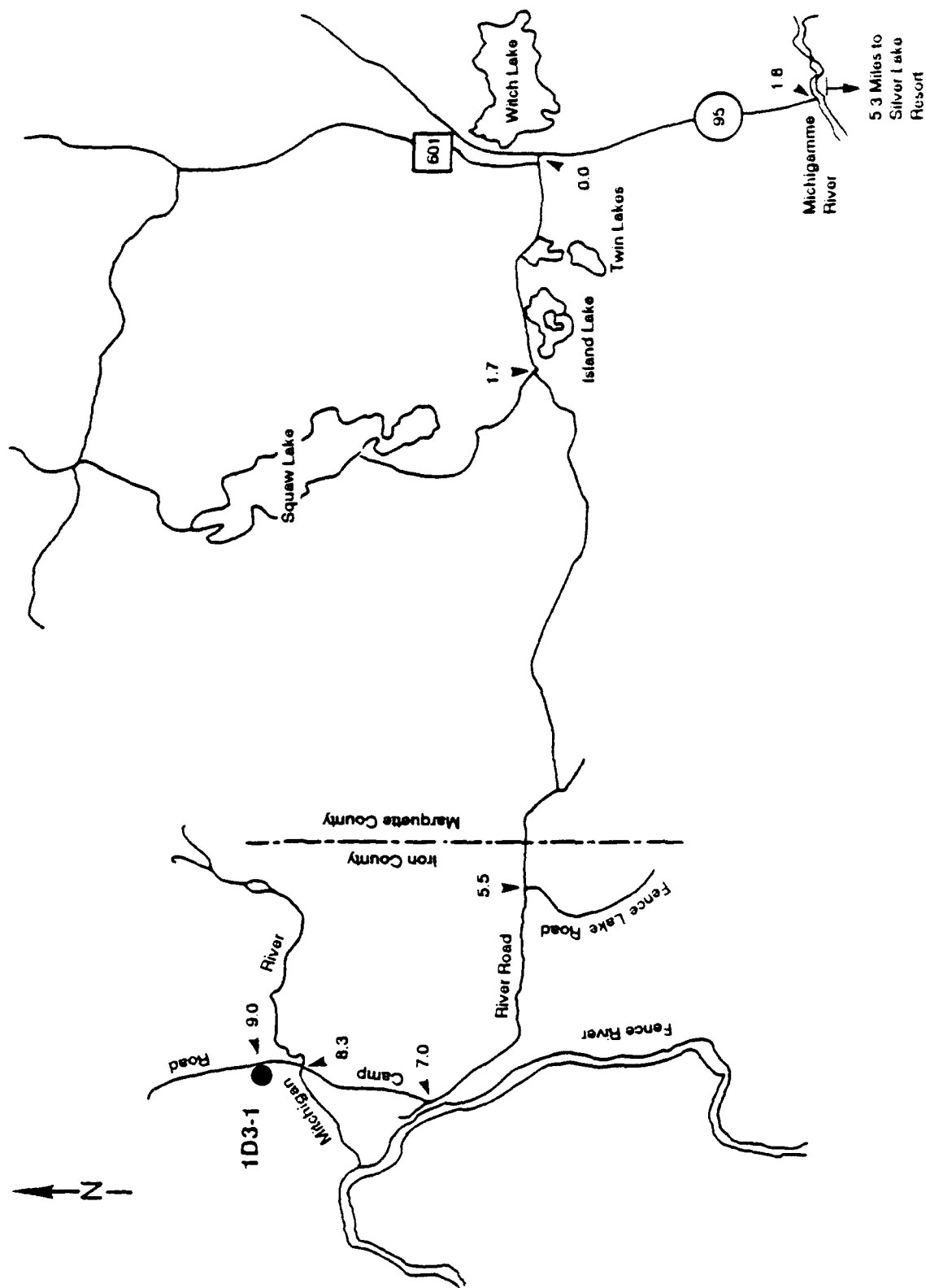
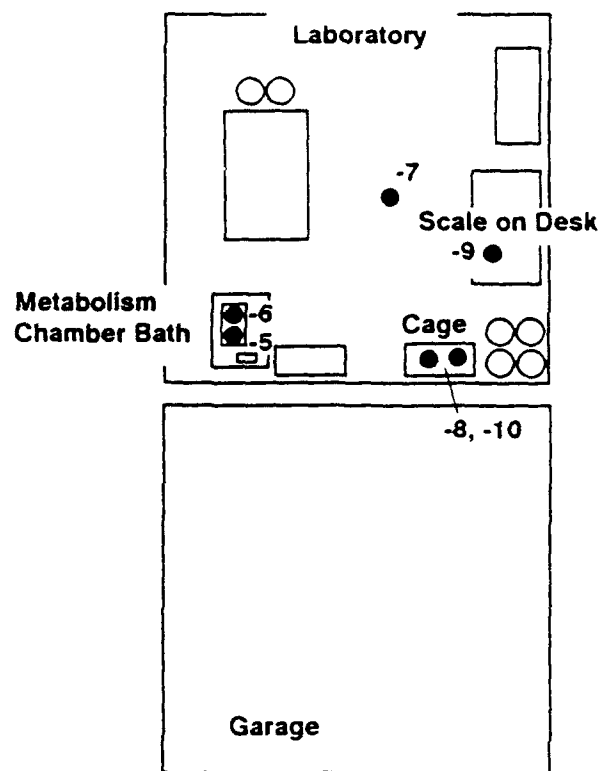
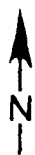
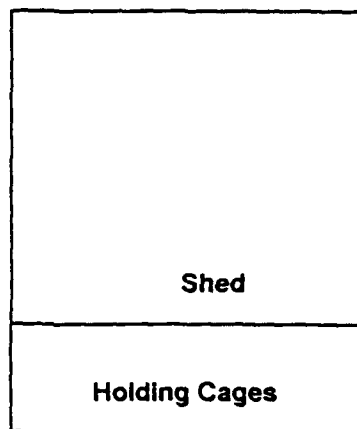


FIGURE A-14. MEASUREMENT POINT AT PANOLA PLAINS DISPLACEMENT; 1D3-1.



60 Hz Power Line



• A

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

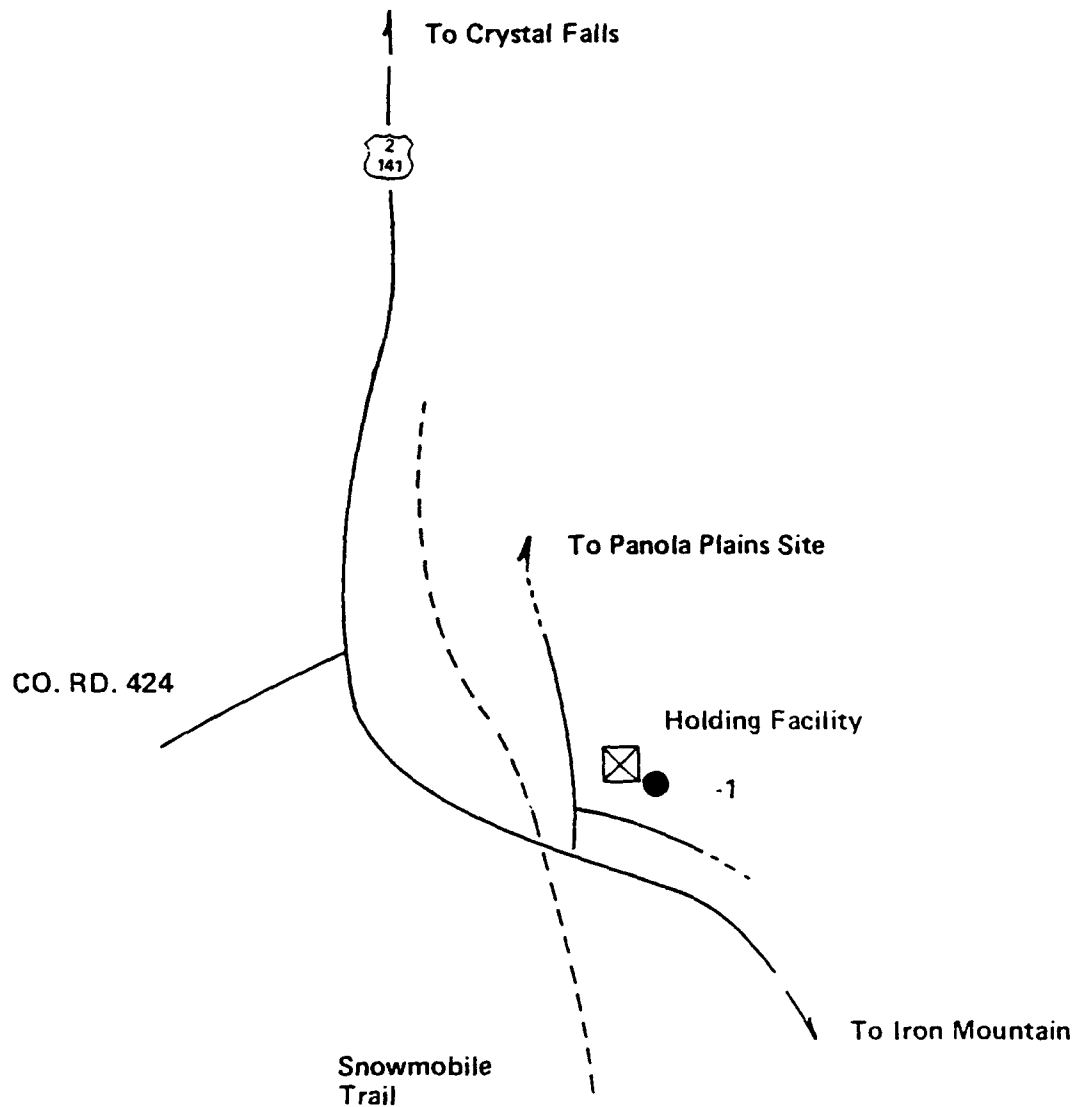
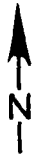


FIGURE A-16. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 1L4-1.

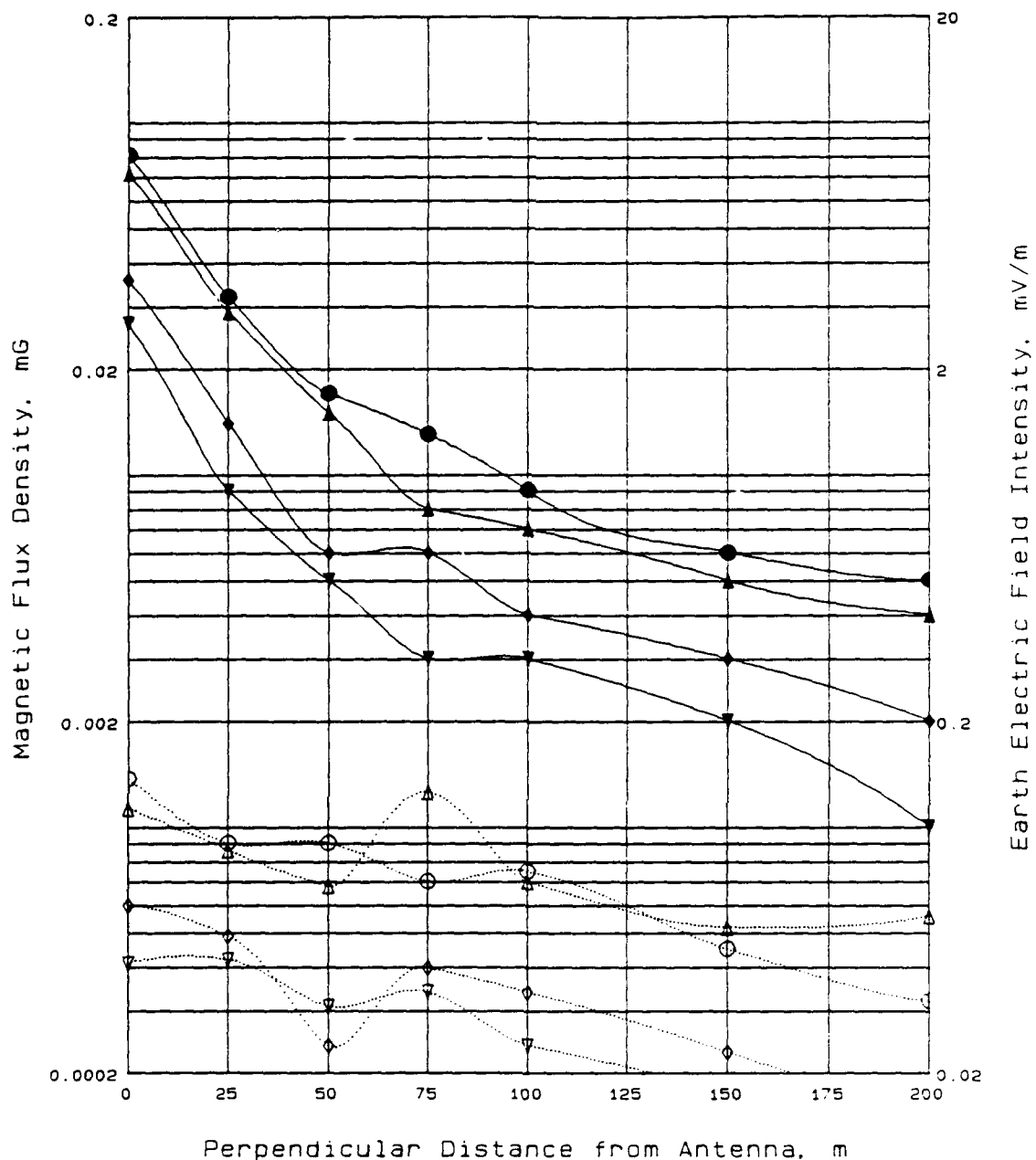


FIGURE A-17. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

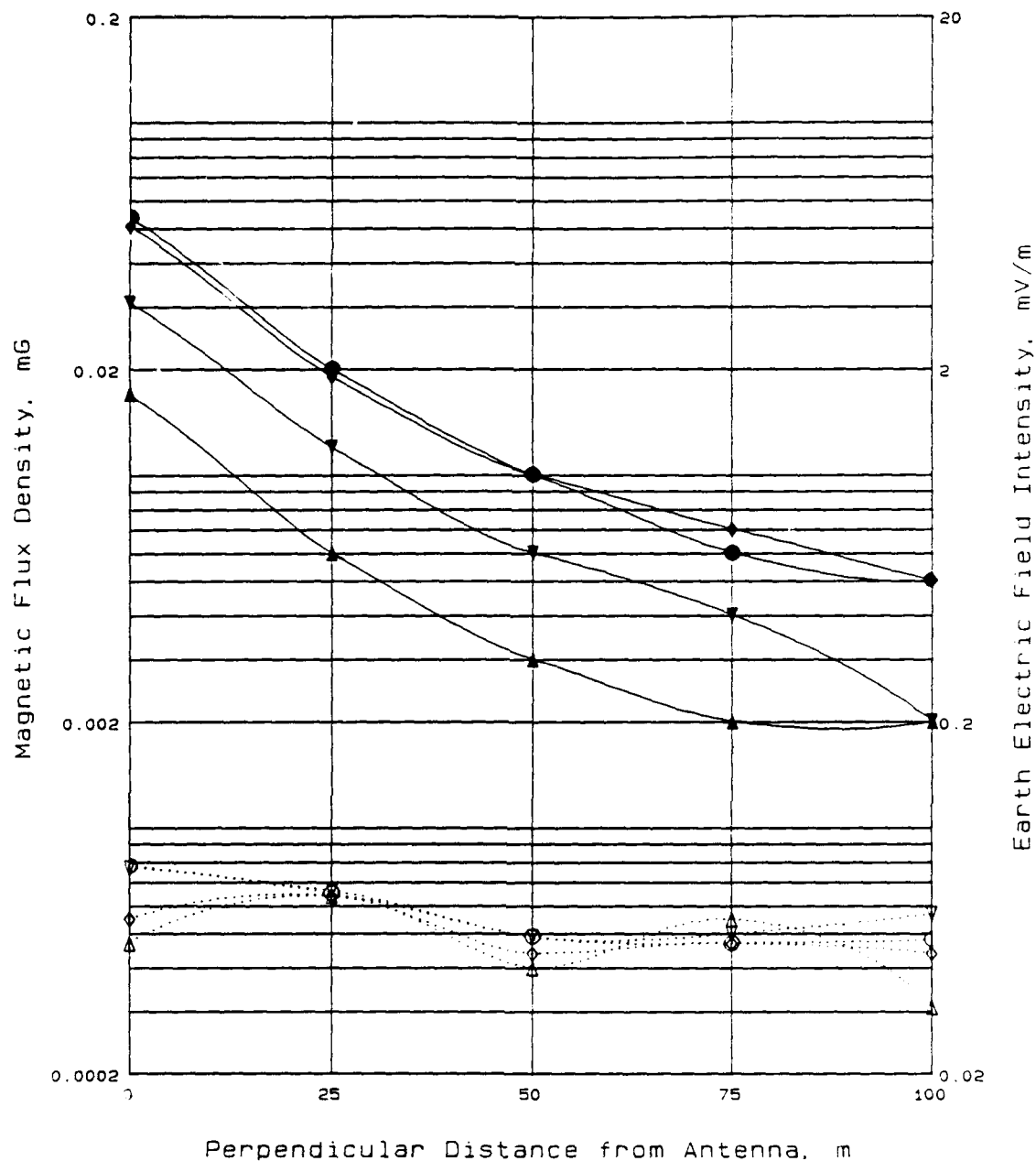


FIGURE A-18. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

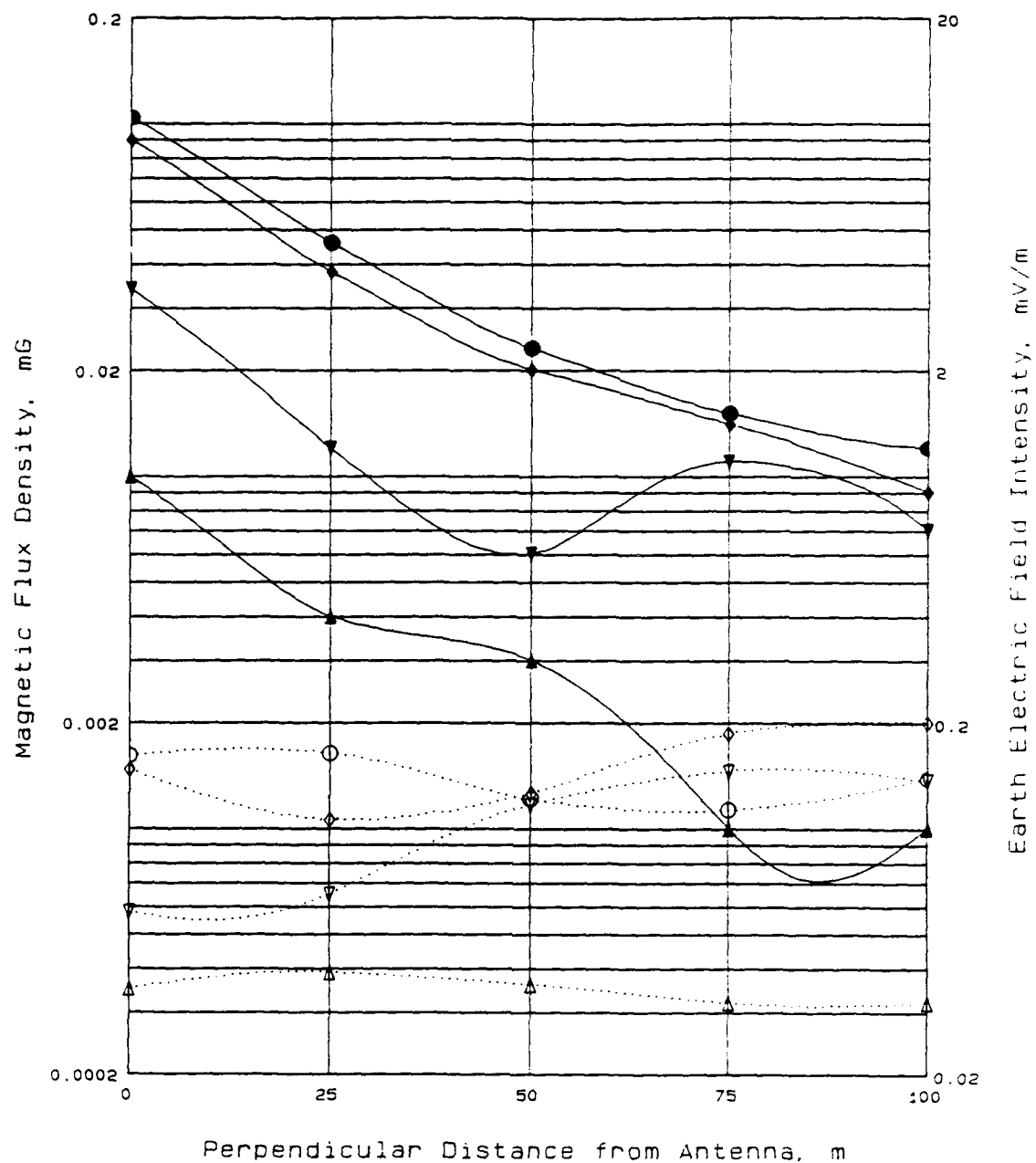
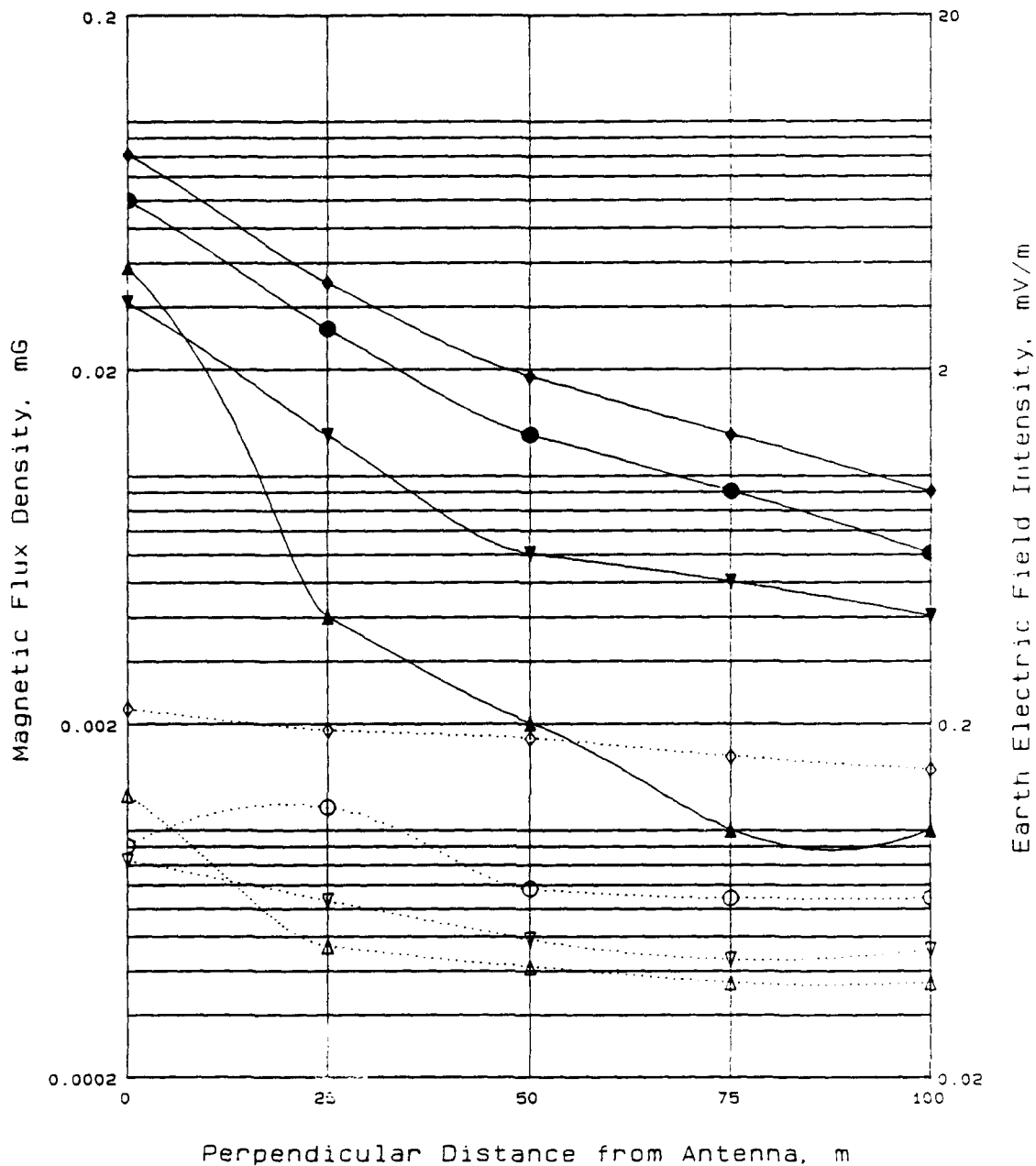


FIGURE A-19. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.



- ▲ 1989 magnetic flux density
- △ 1989 electric field intensity
- ◆ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- 1991 magnetic flux density
- 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity

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

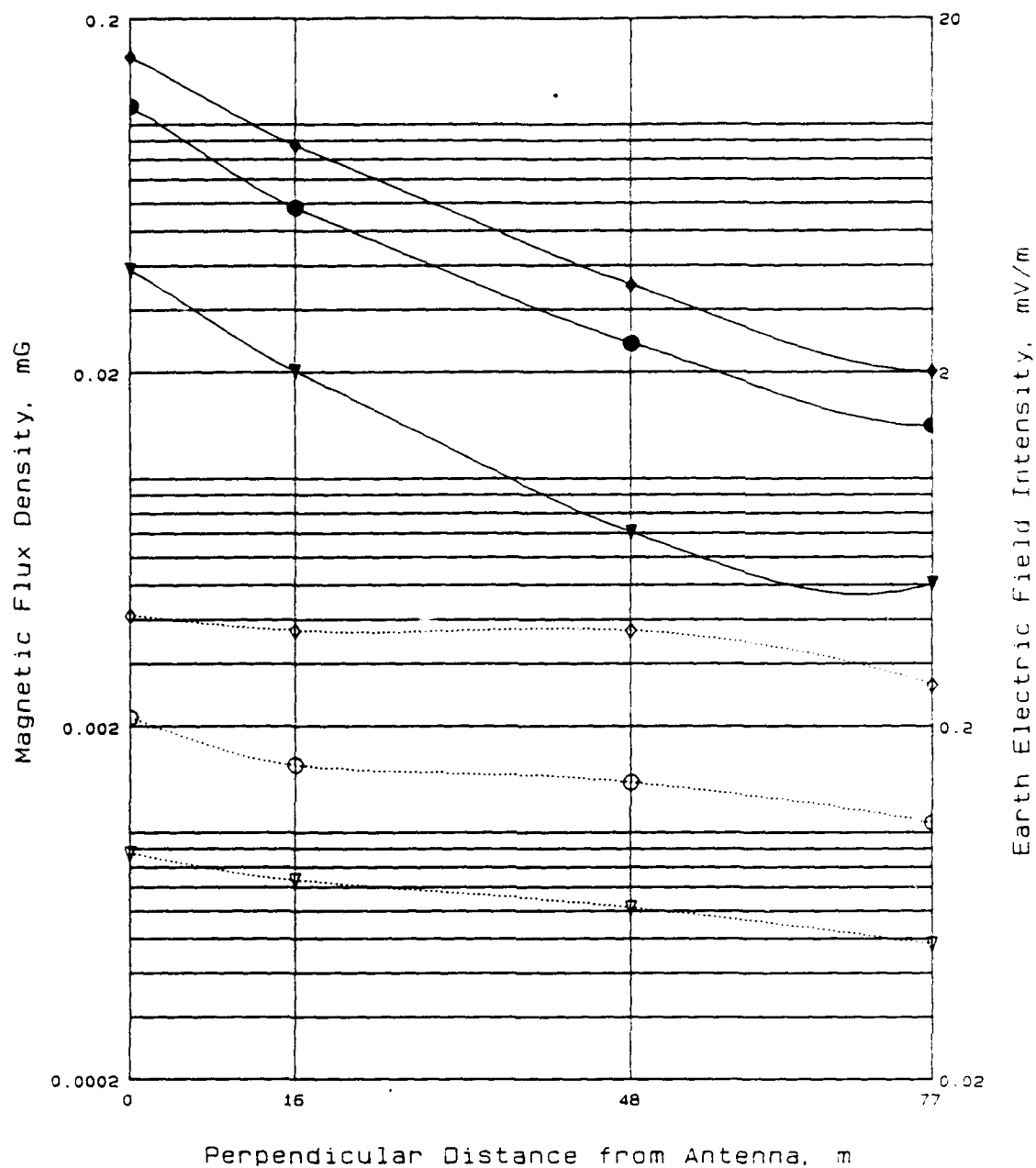
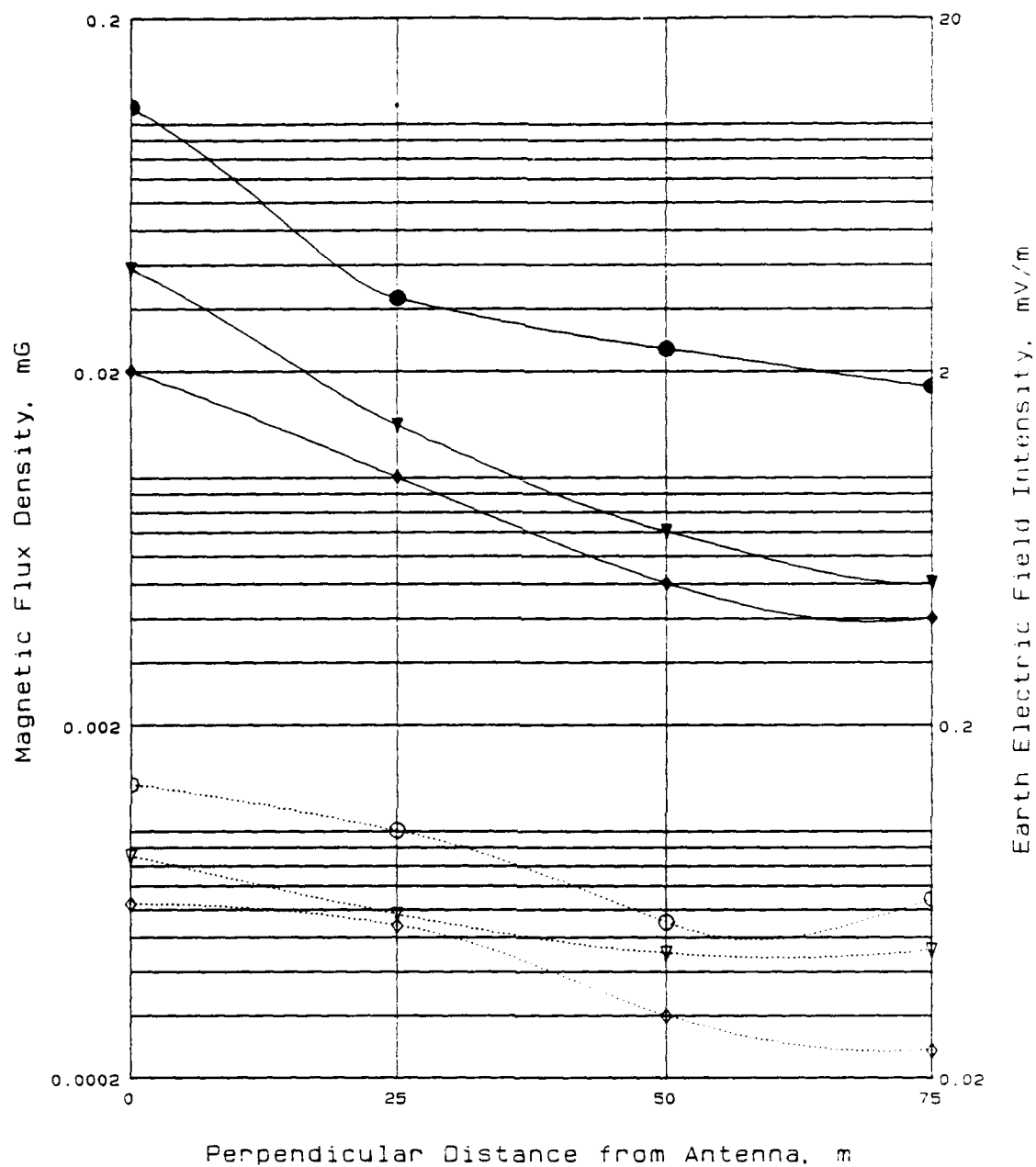


FIGURE A-21. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.



- ▲ 1989 magnetic flux density
- △ 1989 electric field intensity
- ◆ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- 1991 magnetic flux density
- 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity

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

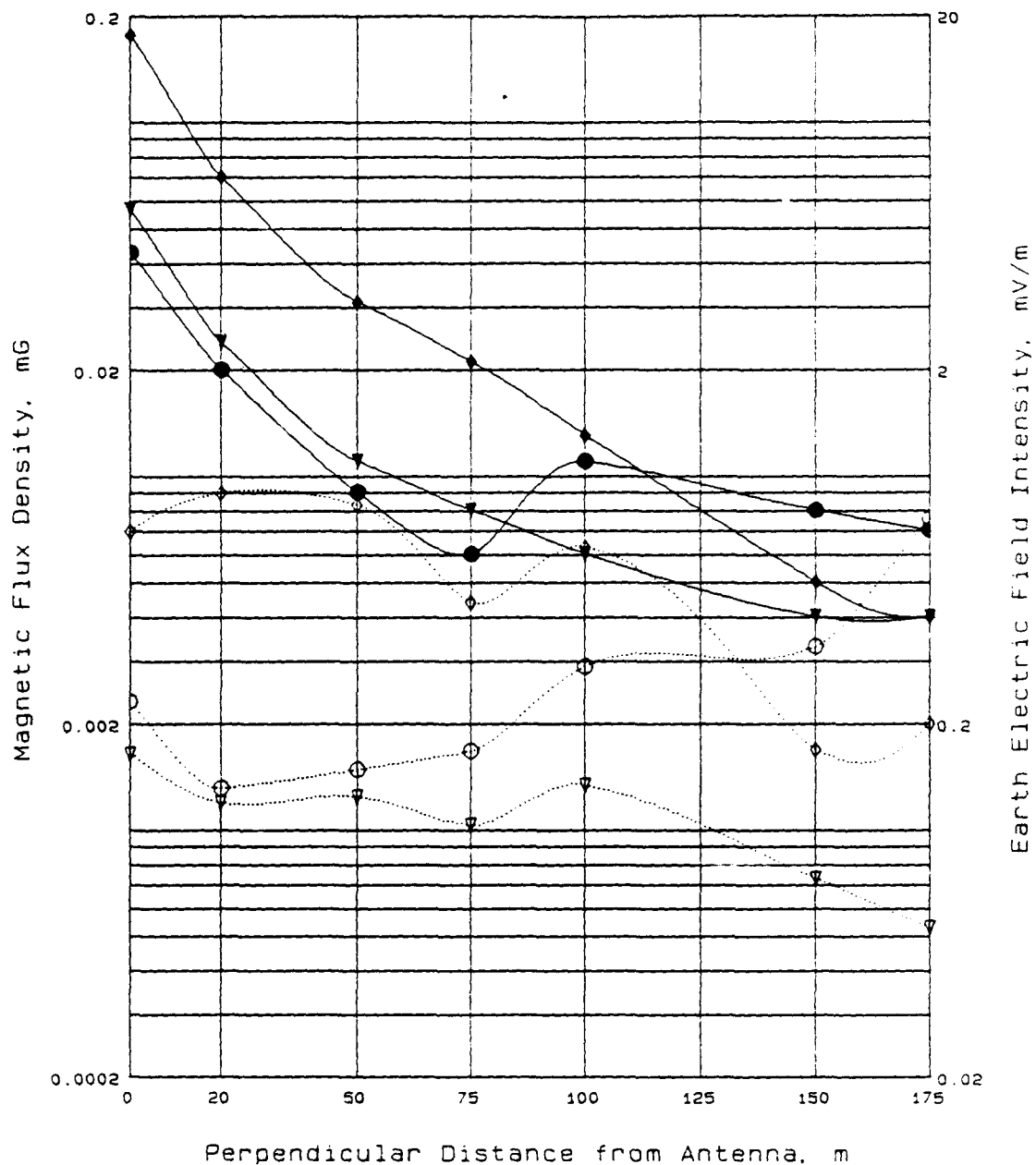
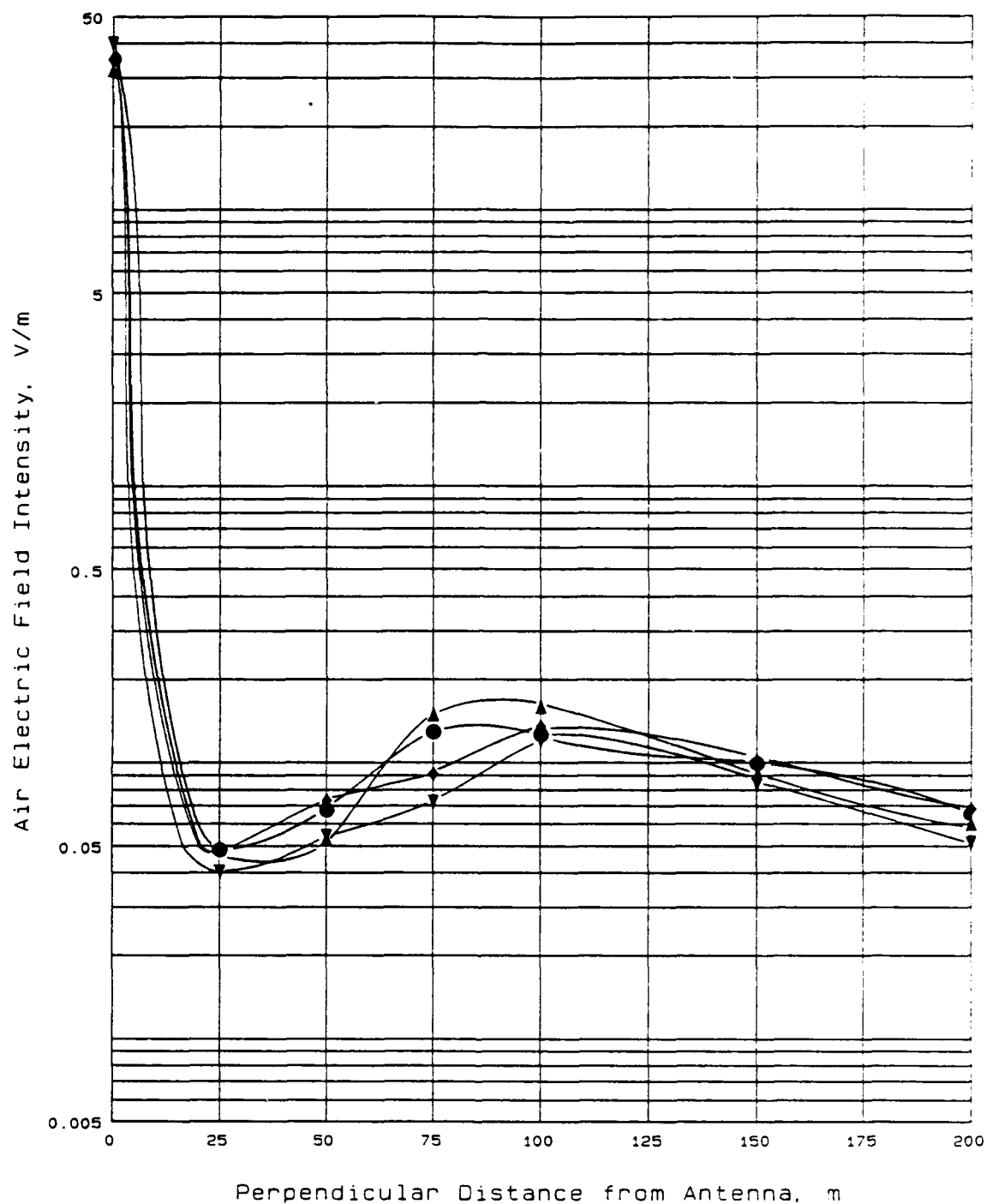


FIGURE A-23. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.



- ▲ 1989 electric field intensity
- ◆ 1990 electric field intensity
- 1991 electric field intensity
- ▼ 1992 electric field intensity

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

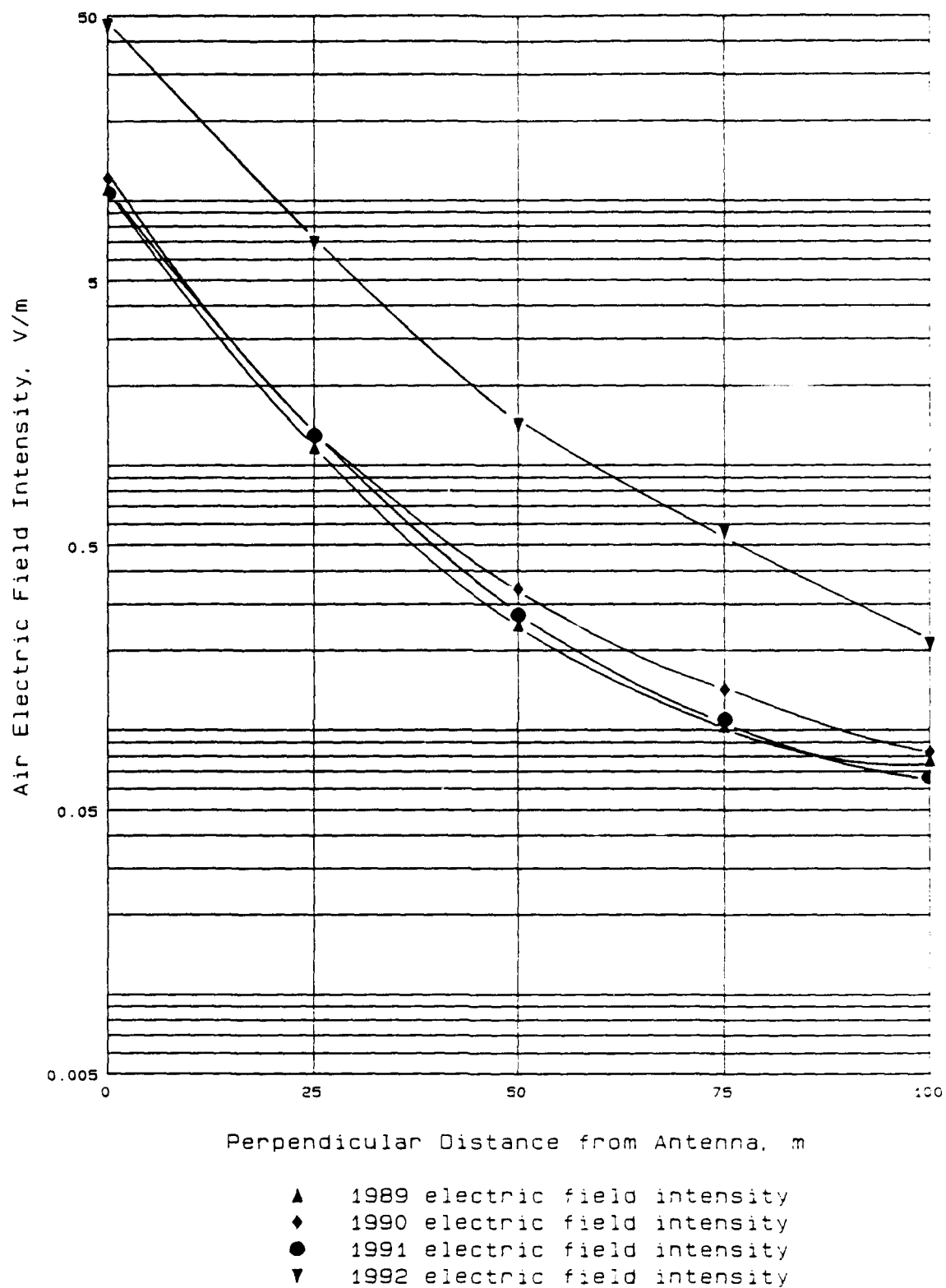


FIGURE A-25. 76 Hz AIR ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD;
1T2-5 THROUGH 9.

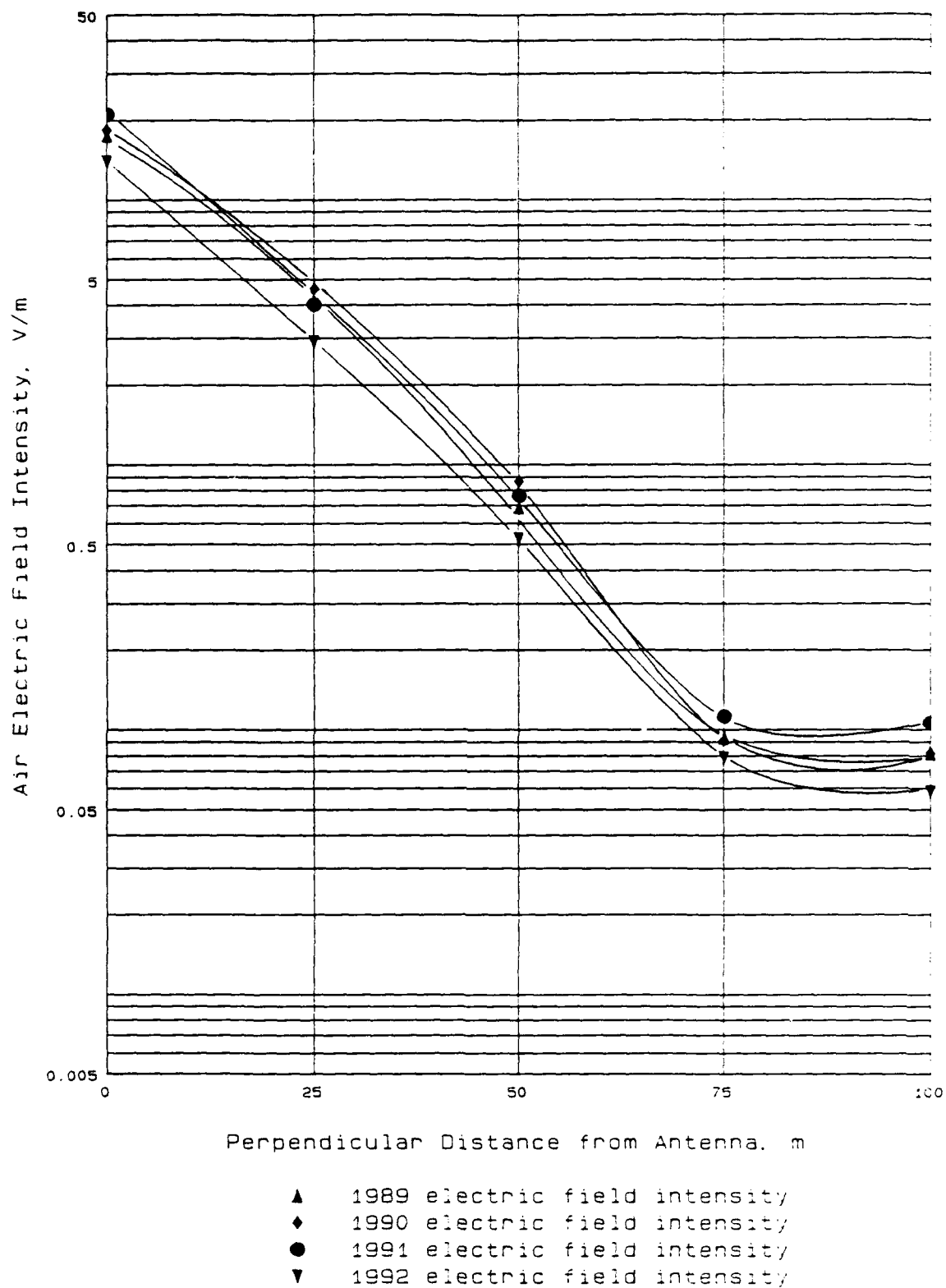


FIGURE A-26. 76 Hz AIR ELECTRIC FIELD PROFILES, NORTH TURNER ROAD;
1T4-5 THROUGH 9.

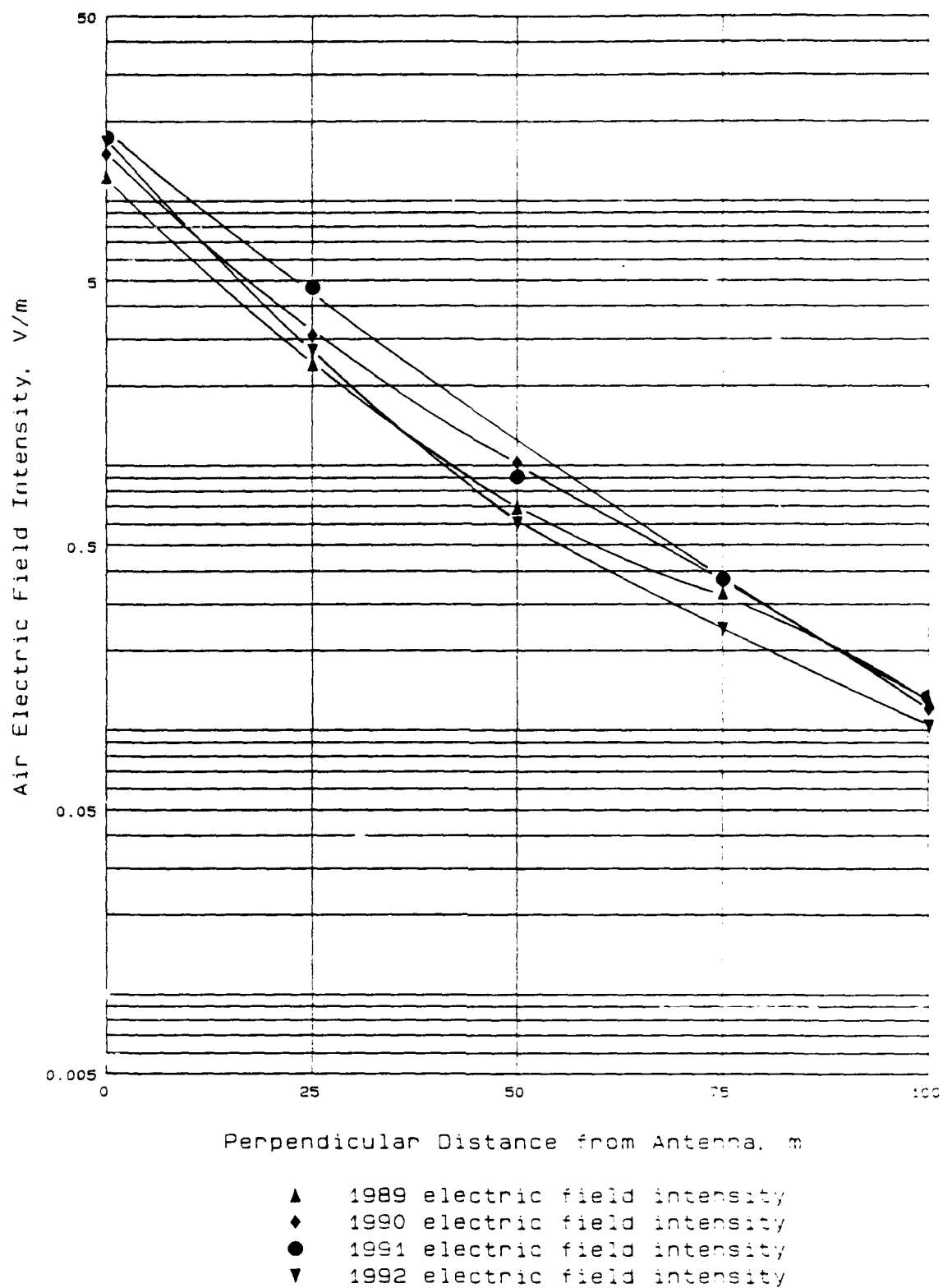


FIGURE A-27. 76 Hz AIR ELECTRIC FIELD PROFILES, NORTH TURNER ROAD;
1T4-10 THROUGH 14.

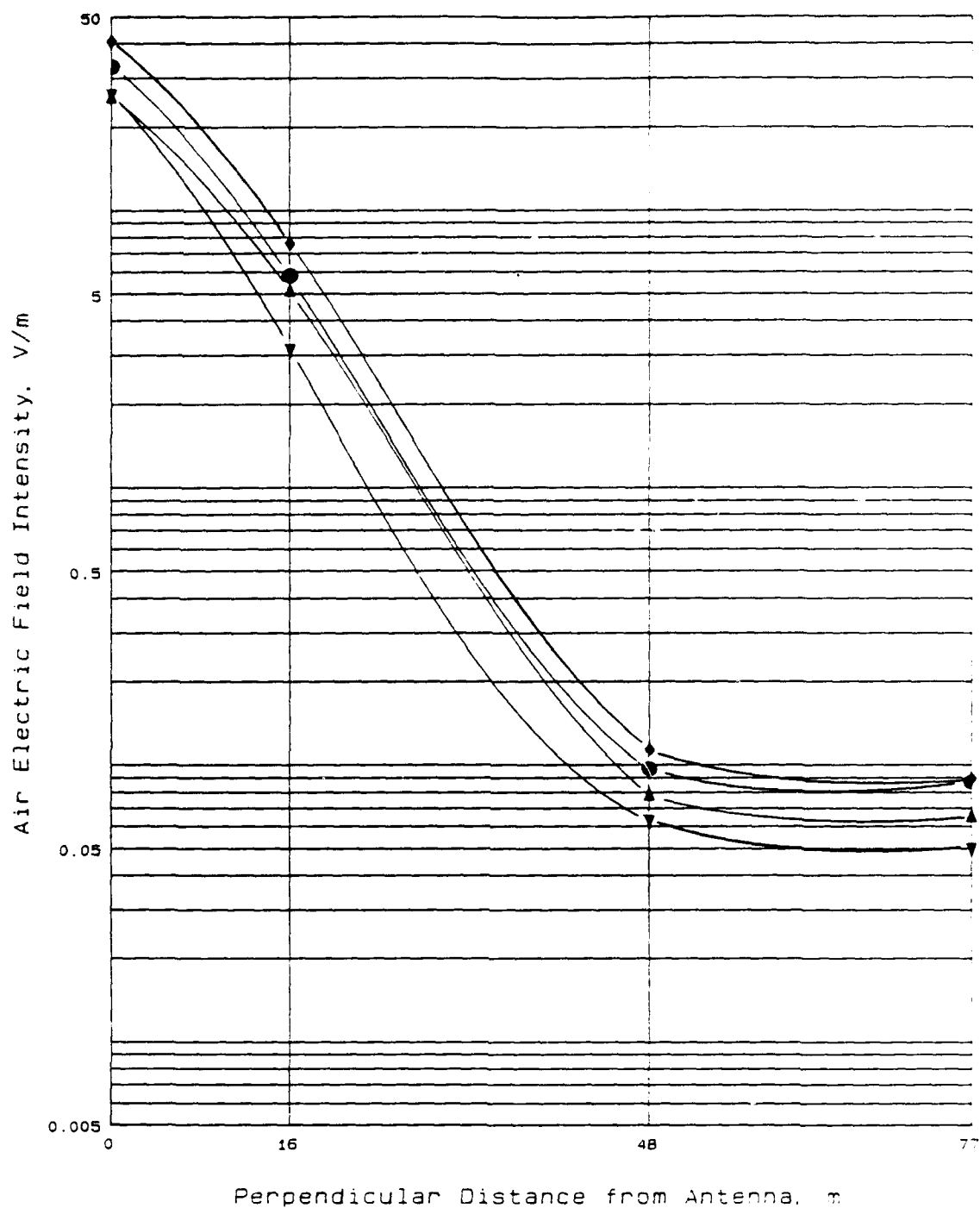


FIGURE A-28. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER NORTH;
1T5-1, 7, 8, 4.

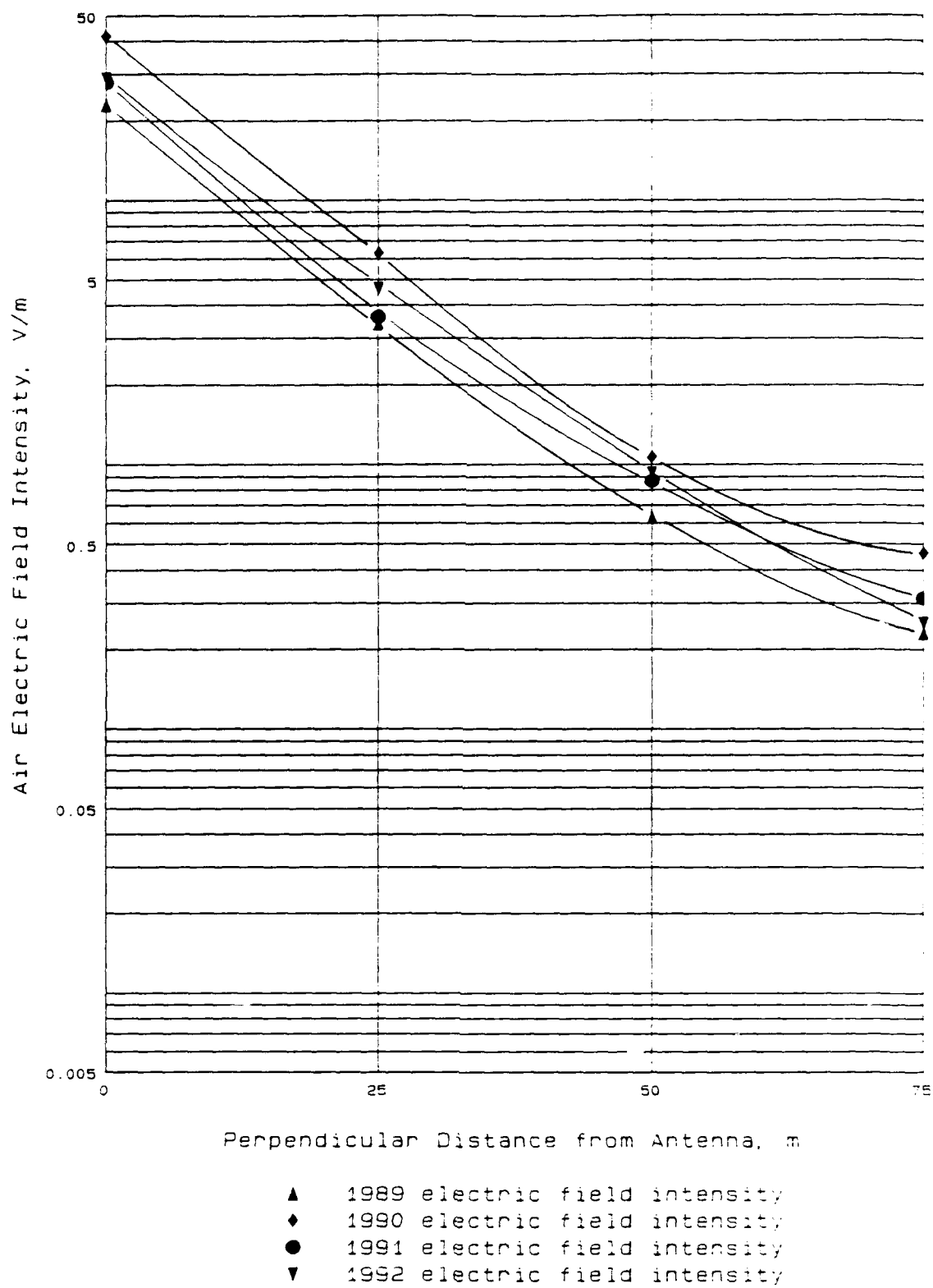


FIGURE A-29. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER NORTH;
1T5-2, 9, 10, 6.

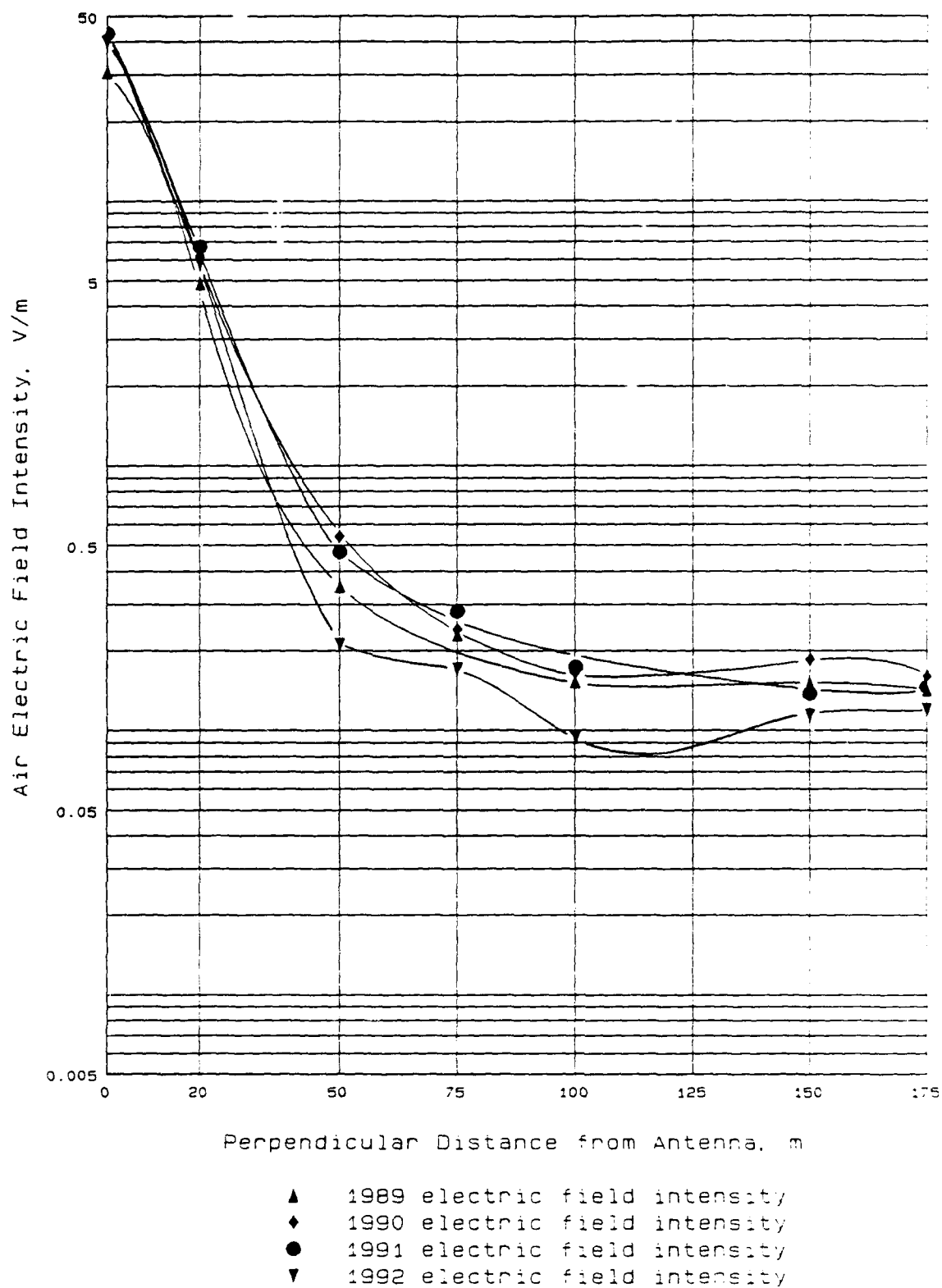
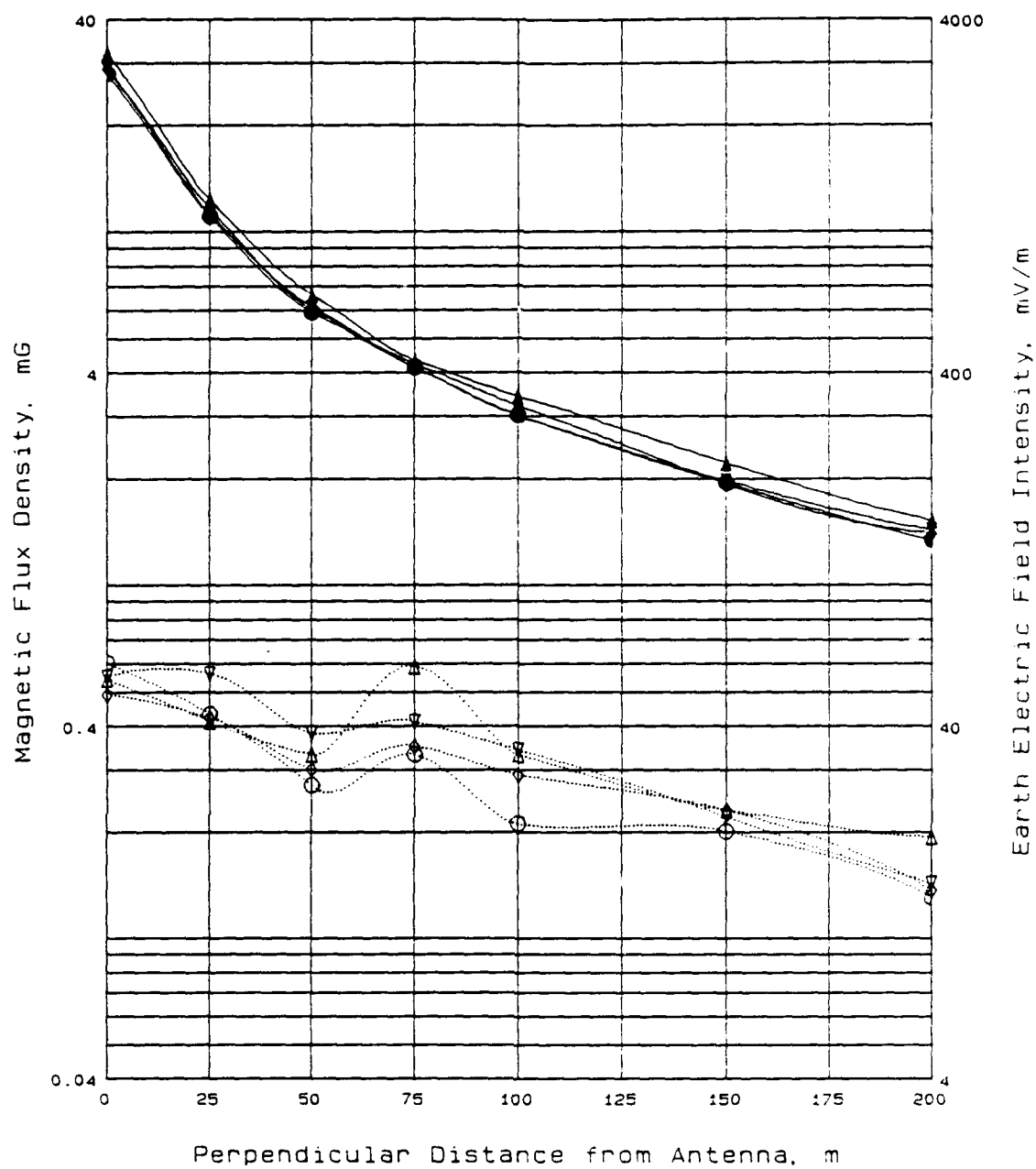


**FIGURE A-30. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER SOUTH;
1T6-2, 1, 3, 4, 5, 6, 7.**



- ▲ 1989 magnetic flux density
- Δ 1989 electric field intensity
- ◆ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- 1991 magnetic flux density
- 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity

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

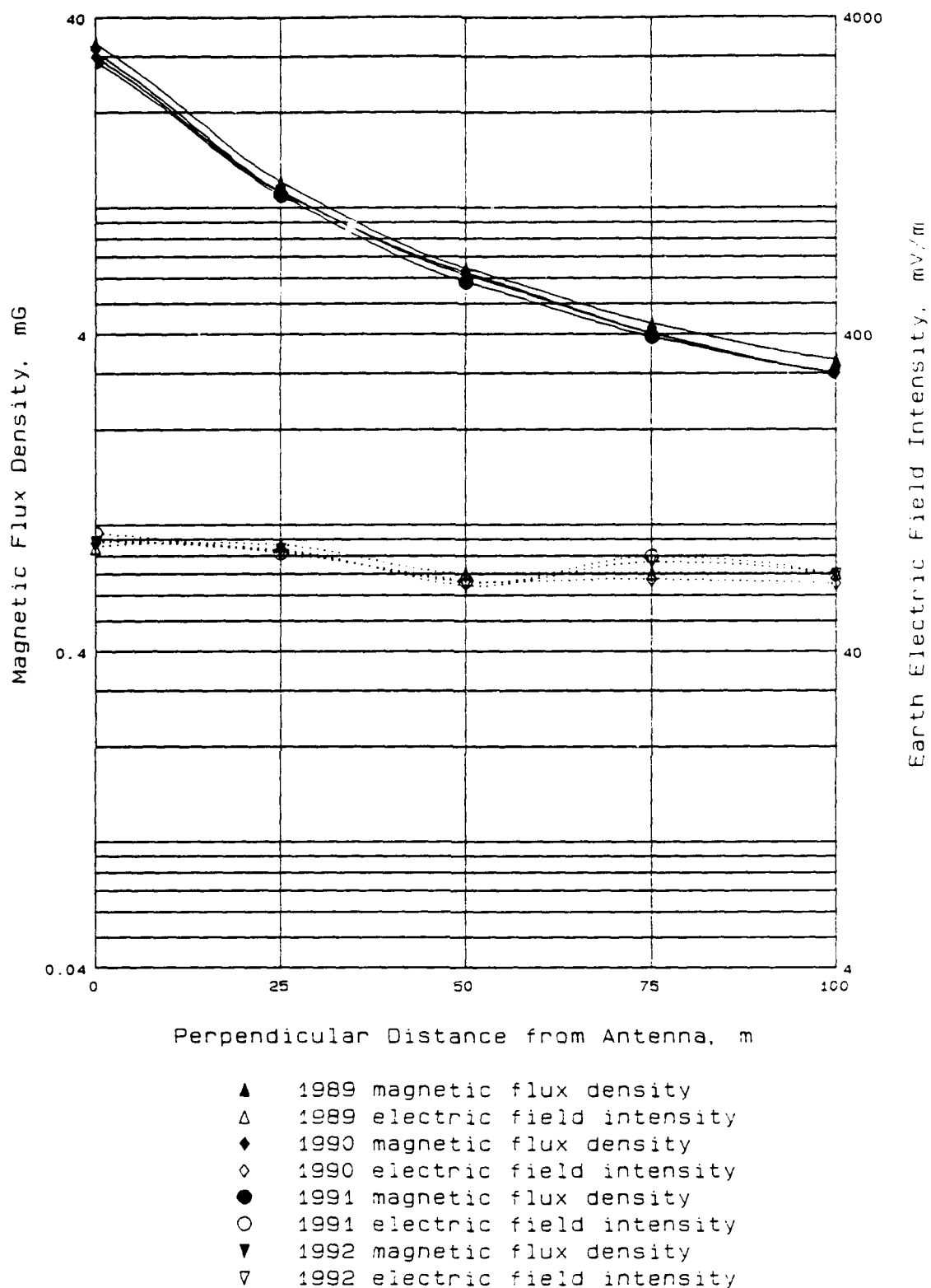
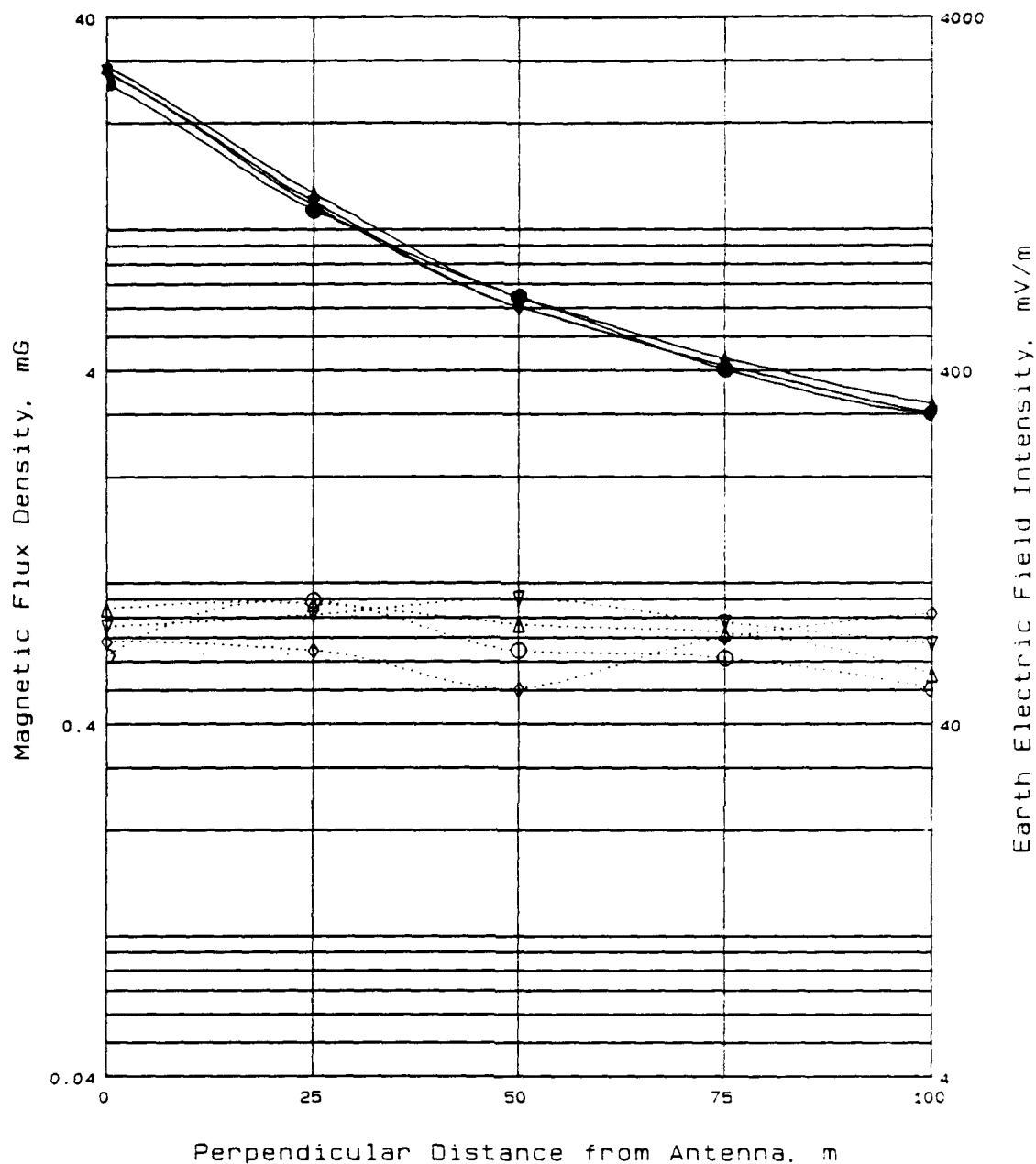
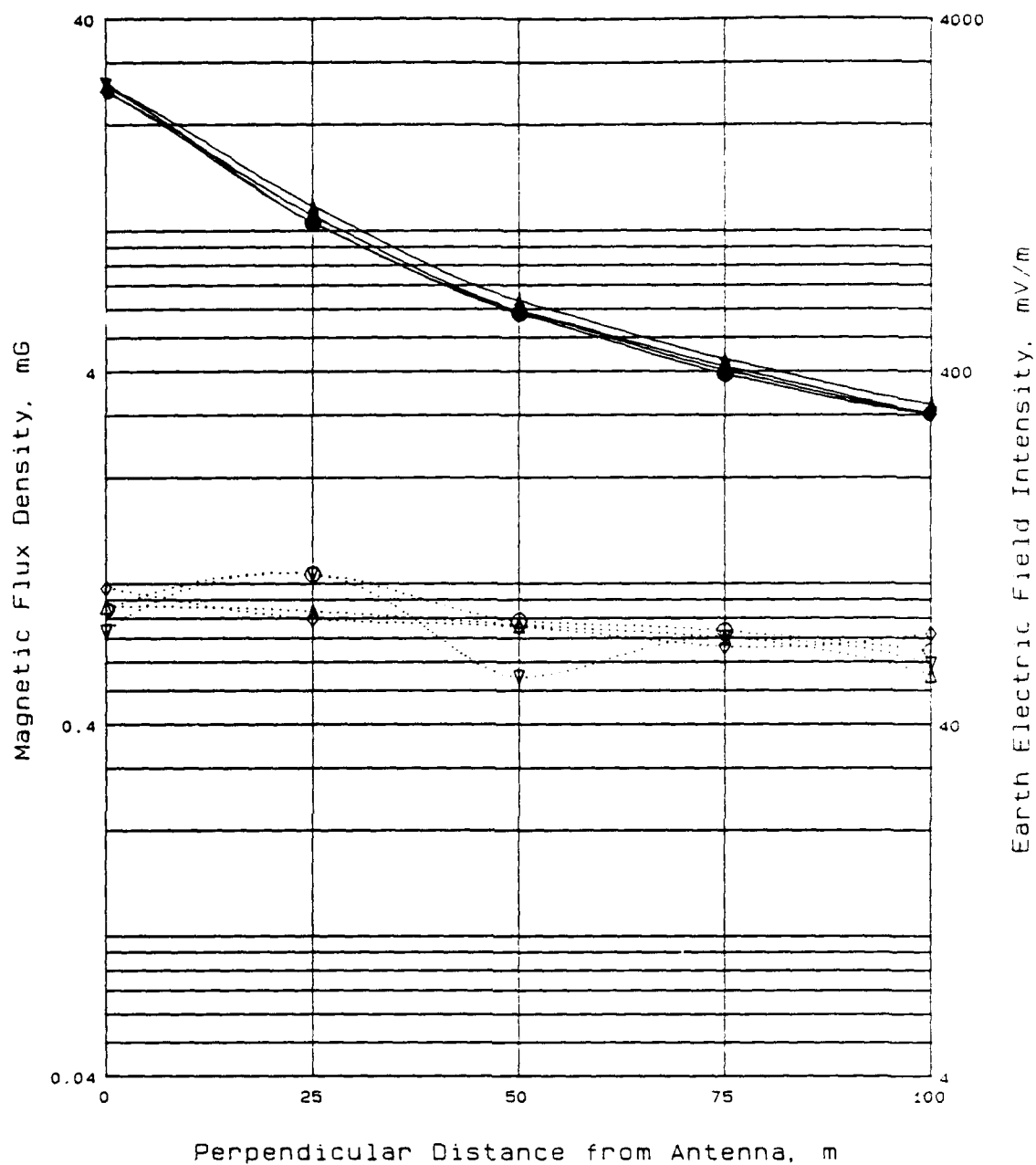


FIGURE A-32. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.



- ▲ 1989 magnetic flux density
- △ 1989 electric field intensity
- ◆ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- 1991 magnetic flux density
- 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity

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



- ▲ 1989 magnetic flux density
- △ 1989 electric field intensity
- ◆ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- 1991 magnetic flux density
- 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity

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

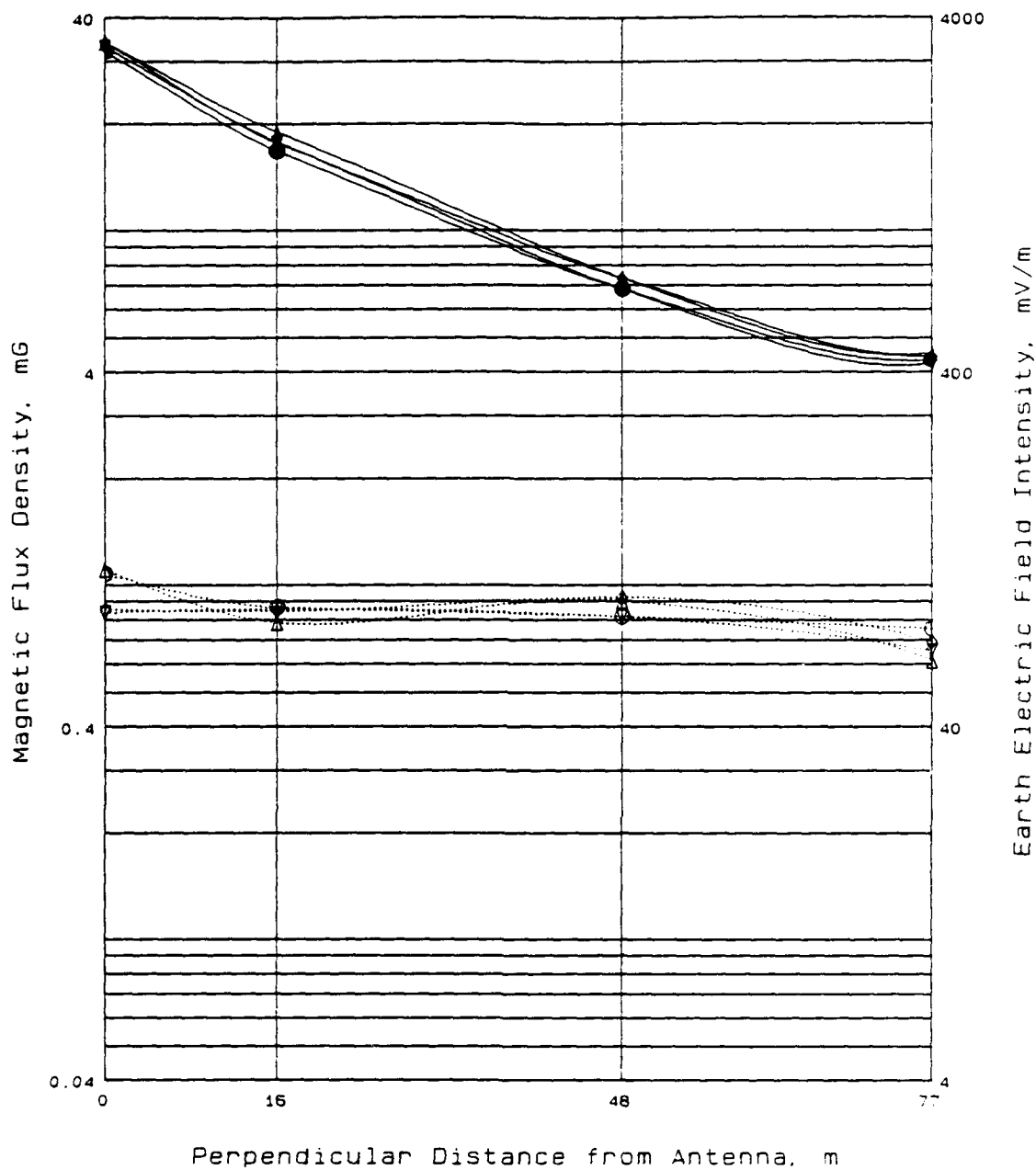
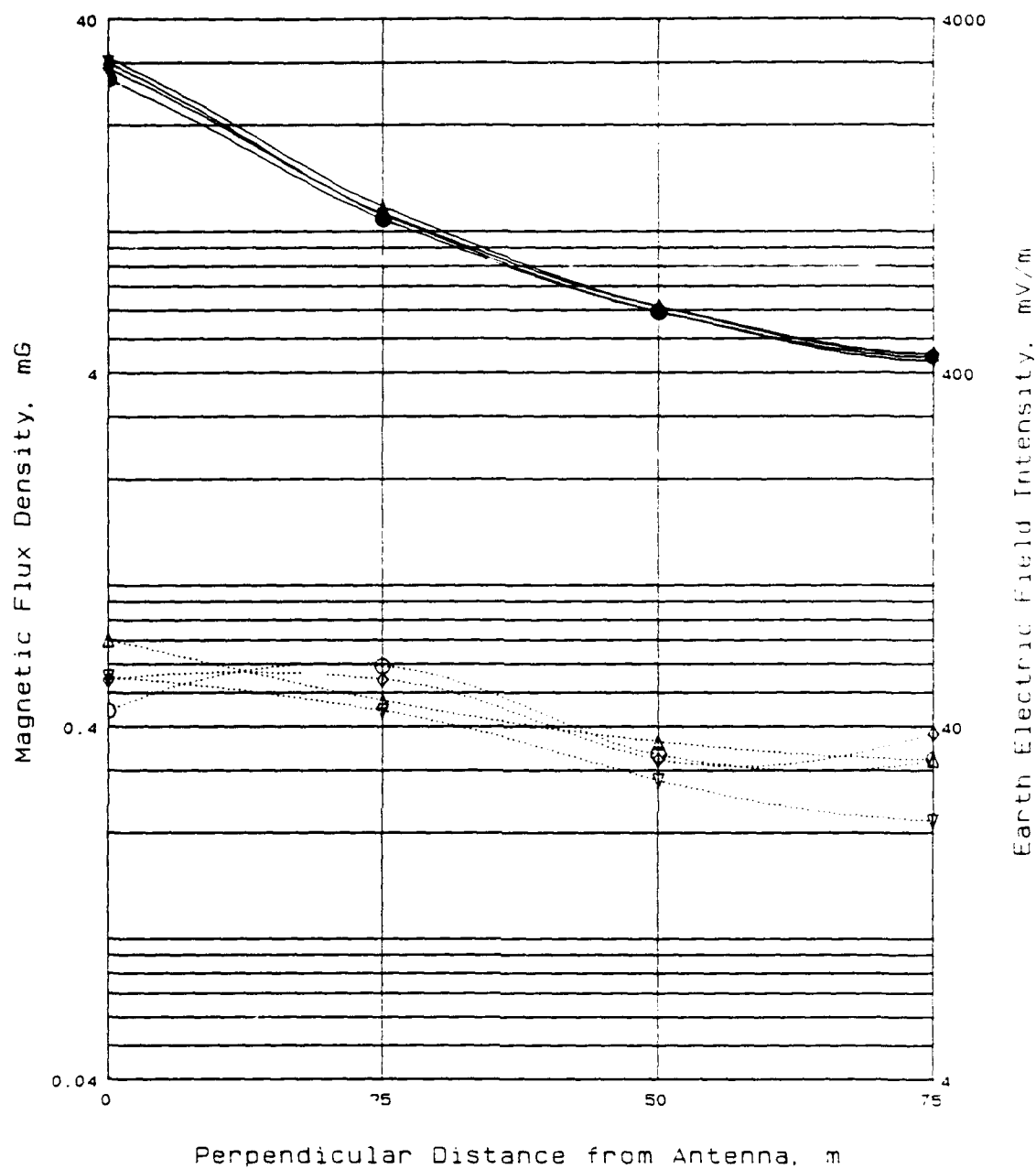


FIGURE A-35. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH;
1T5-1, 7, 8, 4.



- ▲ 1989 magnetic flux density
- △ 1989 electric field intensity
- ◆ 1990 magnetic flux density
- ◇ 1990 electric field intensity
- 1991 magnetic flux density
- 1991 electric field intensity
- ▼ 1992 magnetic flux density
- ▽ 1992 electric field intensity

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

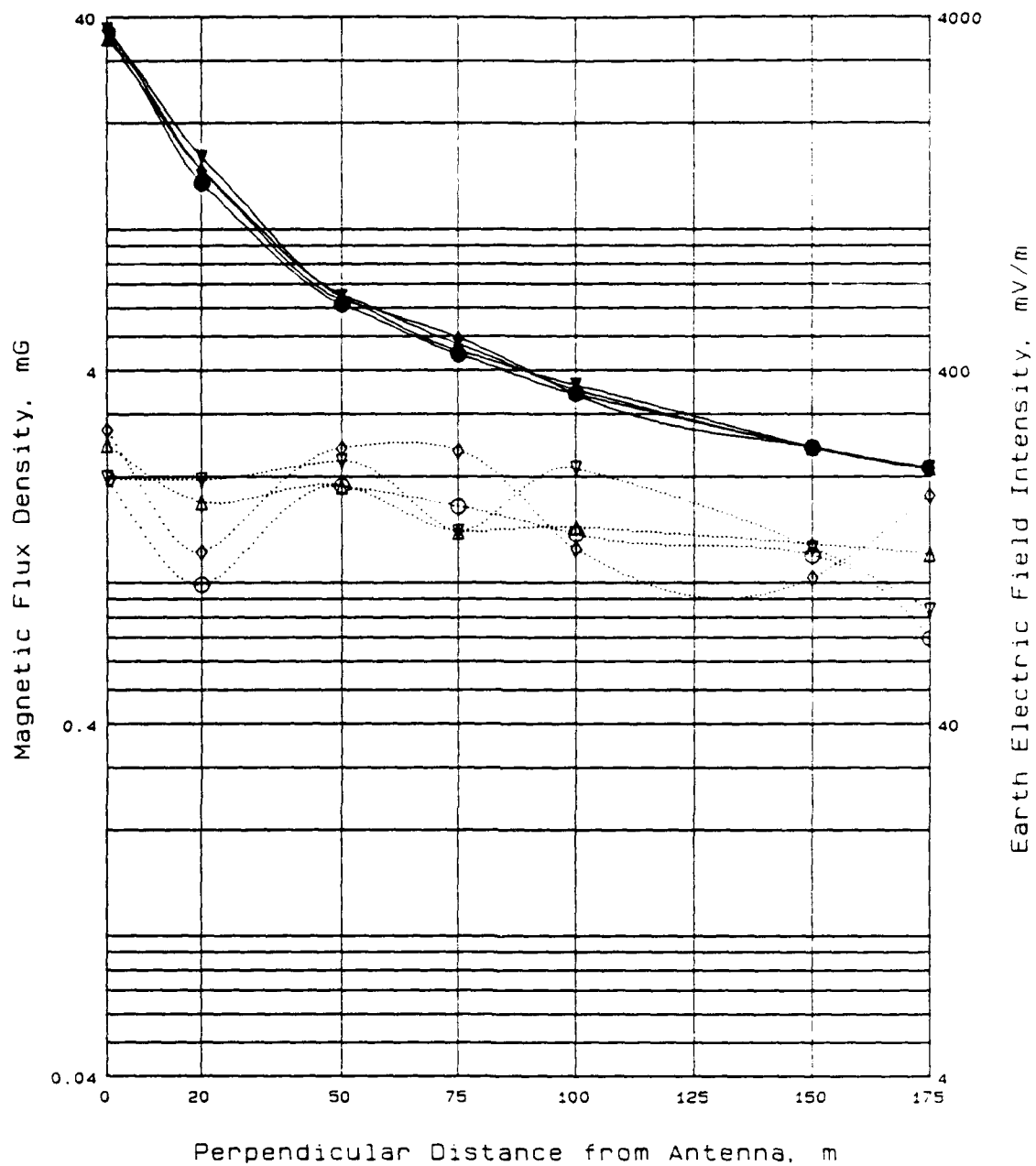


FIGURE A-37. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T6-2, 1, 3, 4, 5, 6, 7.

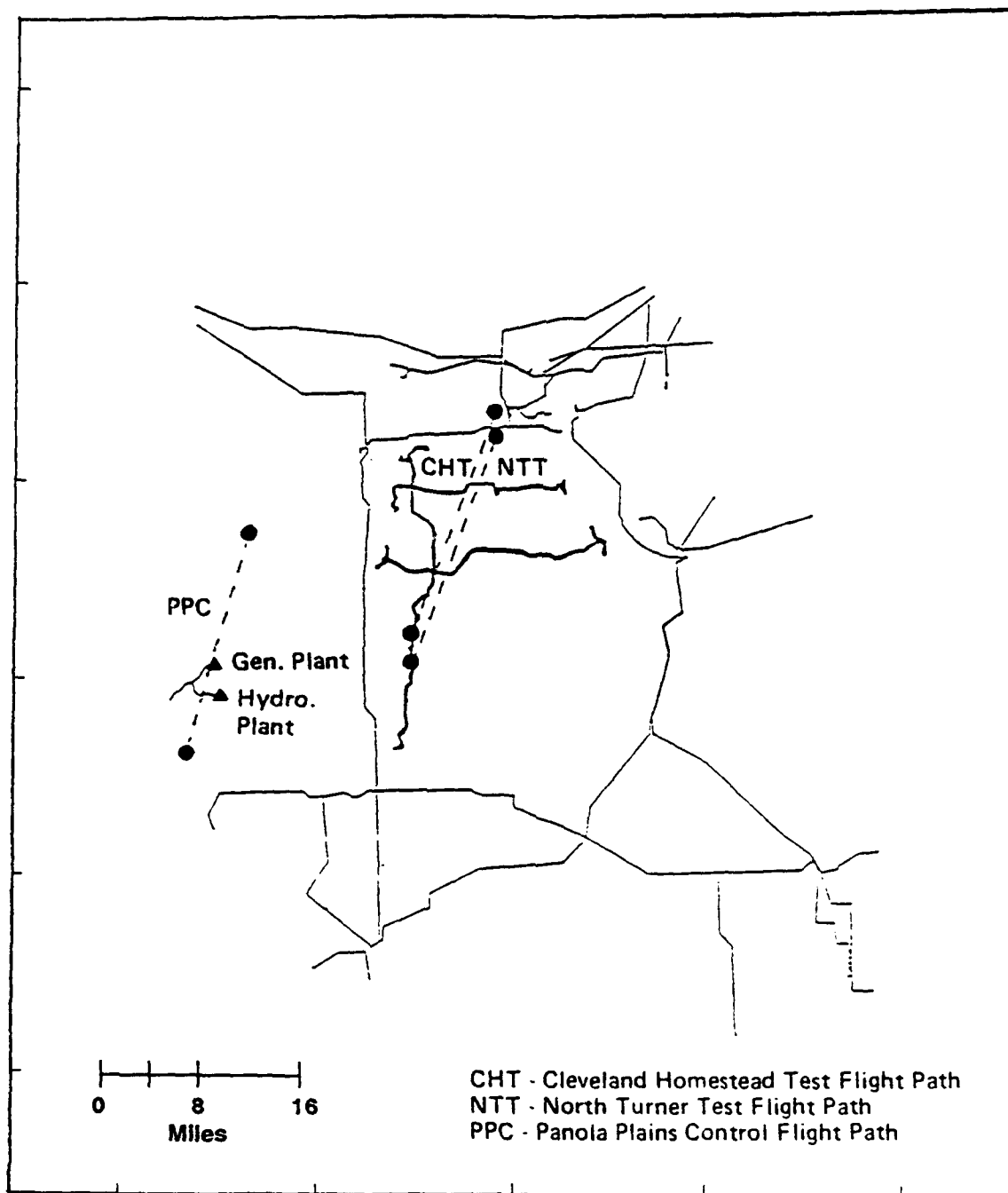


FIGURE A-38. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH-VOLTAGE 60 Hz TRANSMISSION LINES.

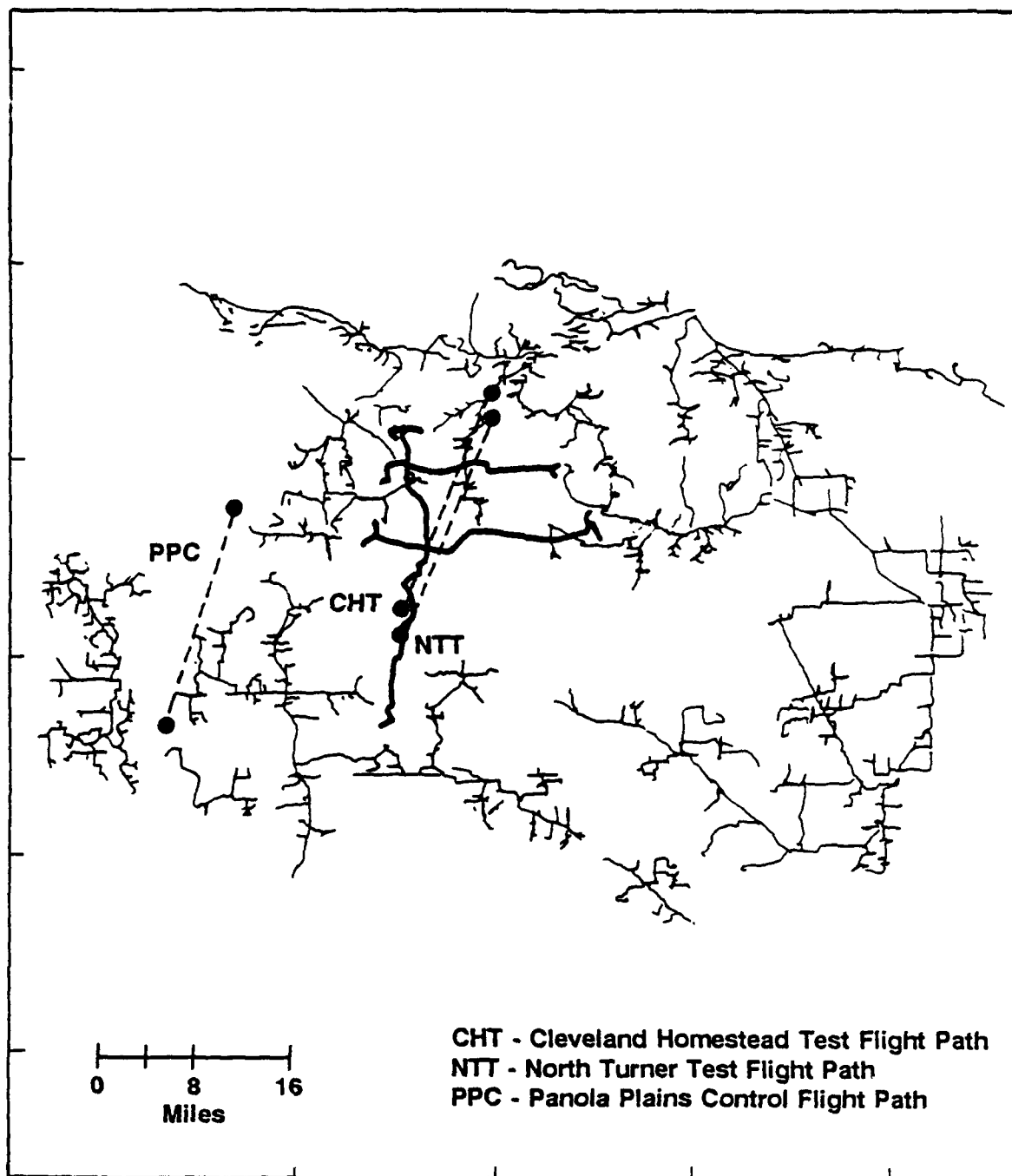


FIGURE A-39. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

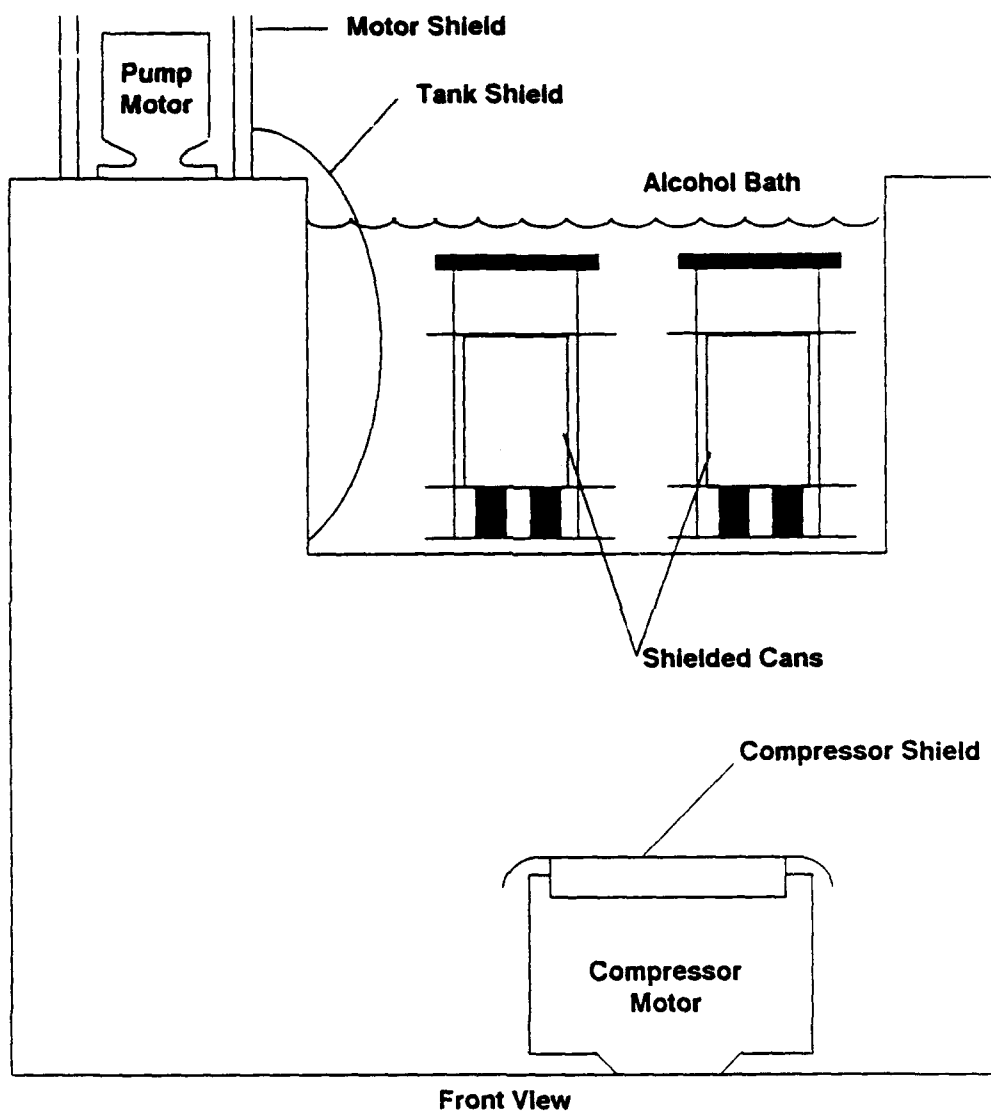


FIGURE A-40. MAGNETIC SHIELD LOCATIONS AT THE METABOLIC COOLING BATH.

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
1C1-2	<	<	<	-	-	-	-	-	-	-
1C1-3	-	-	<	<	<	<	<	<	<	<
1C1-4	-	-	-	<	<	<	<	<	<	<
1C3-1	<	<	<	<	<	<	<	<	<	<
1C3-2	<	<	-	-	-	-	-	-	-	-
1C3-3	-	-	-	<	<	<	<	<	<	<
1C4-1	-	0.001	<	<	<	<	<	<	<	<
1C4-2	-	<0.001	<	-	-	-	-	-	-	-
1C4-3	-	<0.001	<	<	-	-	-	-	-	-
1C4-4	-	-	<	<	<	<	<	<	<	<
1C4-5	-	-	-	-	<	<	<	<	<	<
1D3-1	-	-	-	<	<	<	<	<	<	<
1C6-1	-	0.001	<	<	<	<	<	<	<	<
1C6-3	-	-	<	<	<	<	<	<	<	<
1C6-4	-	-	<	<	<	<	<	<	<	<
1L4-1	-	-	-	-	-	<	<	<	<	<

^a = antennas not constructed.

^b = antennas off, grounded at transmitter.

^c = antennas off, connected to transmitter.

^d = antennas on, 150 A current.

- = measurement point not established.

- = measurement point dropped.

/ = measurement not taken.

= measurement precluded by antenna operation.

< = measurement est. <0.001 V/m based on earth E-field.

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
1T1-1	0.001	<	<	-	-	-	-	-	-	-
1T1-3	-	<	<	-	-	-	-	-	-	-
1T1-4	-	<	<	-	-	-	-	-	-	-
1T1-10	-	<	<	-	-	-	-	-	-	-
1T1-12	-	-	<	-	-	-	-	-	-	-
1T1-13	-	-	<	-	-	-	-	-	-	-
1T1-14	-	-	-	<	<	<	<	<	<	<
1T1-15	-	-	-	<	<	<	#	<	<	<
1T1-16	-	-	-	<	<	<	#	<	<	<
1T1-17	-	-	-	<	<	<	#	<	<	/
1T1-18	-	-	-	<	<	<	#	<	<	/
1T1-19	-	-	-	<	<	<	#	<	<	/
1T1-20	-	-	-	<	<	<	#	<	<	/
1T1-28	-	-	-	-	-	<	#	<	<	/
1T1-29	-	-	-	-	-	<	#	<	<	/
1T1-30	-	-	-	-	-	<	#	<	<	/
1T1-31	-	-	-	-	-	<	#	<	<	/
1T1-21	-	-	-	<	0.086	0.49	0.109	0.076 ^b	/	0.050 ^b
1T1-22	-	-	-	<	<0.001	<	<0.001	<0.001 ^b	/	<0.001 ^b
1T1-23	-	-	-	<	<	<	<0.001	<	/	<0.001 ^b
1T1-24	-	-	-	<	<	<	<	<	/	<
1T1-25	-	-	-	<	<	<	<	<	/	<
1T1-26	-	-	-	<	<	<	<	<	/	<
1T1-27	-	-	-	<	<	<	<	<	/	<

a = not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A current.

- = measurement point not established.

/ = measurement point dropped.

= measurement not taken.

< = measurement precluded by antenna operation.

< = measurement est. <0.001 V/m based on earth E-field.

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 ^c	1991	1992
1T2-1	<0.001	0.001	<	<	-	-	-	-	-	-
1T2-2	-	-	-	<	-	-	-	-	-	-
1T2-3	-	-	-	<	-	-	-	-	-	-
1T2-4	-	-	-	<	-	-	-	-	-	-
1T2-5	-	-	-	-	0.198	0.053	0.016	0.070 ^c	0.119 ^c	0.030 ^b
1T2-6	-	-	-	-	0.024	0.007	0.002	0.010 ^c	0.013 ^c	0.004 ^b
1T2-7	-	-	-	-	0.005	<	<	0.002 ^c	0.003 ^c	<0.001 ^b
1T2-8	-	-	-	-	0.002	<	<	0.001 ^c	0.001 ^c	< ^b
1T2-9	-	-	-	-	<0.001	<	<	<0.001 ^c	< ^b	< ^b
1D1-1	-	-	-	2.5	2.0	9.2	0.74	1.35 ^d	2.5 ^d	8.8 ^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
1T4-6	-	-	-	<	0.014	0.014	0.003	0.037 ^c	0.045 ^b	0.011 ^b
1T4-7	-	-	-	<	0.004	0.002	<0.001	0.007 ^c	0.008 ^b	0.005 ^b
1T4-8	-	-	-	<	<0.001	<0.001	<	0.002 ^c	0.002 ^b	0.001 ^b
1T4-9	-	-	-	<	<	<	<	<0.001 ^c	< ^b	< ^b
1T4-10	-	-	-	-	0.062	0.041	0.009	0.078 ^c	0.103 ^c	0.040 ^b
1T4-11	-	-	-	-	0.014	0.006	0.002	0.020 ^c	0.018 ^c	0.008 ^b
1T4-12	-	-	-	-	0.004	0.003	<	0.005 ^c	0.006 ^c	0.002 ^b
1T4-13	-	-	-	-	0.002	0.002	<	0.003 ^c	0.003 ^c	0.001 ^b
1T4-14	-	-	-	-	0.001	0.001	<	0.001 ^c	0.002 ^c	<0.001 ^b

^a = not constructed.
^b = antennas off, grounded at transmitter.
^c = antennas off, connected to transmitter.
^d = antennas on, 150 A current.
 - = measurement point not established.
 / = measurement point dropped.
 # = measurement not taken.
 < = measurement precluded by antenna operation.
 < = measurement est. <0.001 V/m based on earth E-field.

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
1D2-1	-	-	-	<	<	<	0.004	0.005 ^d	0.007 ^d	0.013 ^d
1T5-1	-	<0.001	<	<	0.118	0.157	#	0.29 ^c	0.20 ^b	0.055 ^b
1T5-7	-	-	-	-	0.019	0.019	#	0.067 ^c	0.042 ^b	0.010 ^b
1T5-8	-	-	-	-	<0.001	<	#	<0.001 ^c	/	<0.001 ^b
1T5-4	-	-	-	<	<	<	#	<0.001 ^c	/	< ^b
1T5-2	<0.001	<0.001	<	<	0.074	0.130	#	0.043 ^b	0.20 ^b	0.048 ^b
1T5-9	-	-	-	-	0.014	0.017	#	0.006 ^b	0.025 ^b	0.009 ^b
1T5-10	-	-	-	-	0.002	0.004	#	0.001 ^b	0.007 ^b	0.002 ^b
1T5-6	-	-	-	<	<0.001	<	#	<0.001 ^b	0.002 ^b	0.001 ^b
1T5-3	-	-	-	<	-	-	-	-	-	-
1T5-5	-	-	-	<	<0.001	0.001	#	<0.001 ^b	0.002 ^b	0.003 ^b
1T6-2	-	<0.001, 0.001	<	<	0.162	0.46	#	0.141 ^b , 0.30 ^c	/	0.073 ^b
1T6-1	<0.001	<0.001, 0.001	<	<	0.024	0.079	#	0.024 ^b , 0.048 ^c	/	0.014 ^b
1T6-3	-	-	-	-	0.003	0.003	#	<0.001 ^{b,c}	/	< ^b
1T6-4	-	-	-	-	0.001	0.003	#	< ^{b,c}	/	< ^b
1T6-5	-	-	-	-	0.001	0.002	#	< ^{b,c}	/	< ^b
1T6-6	-	-	-	-	0.001	<0.001	#	< ^b	/	< ^b
1T6-7	-	-	-	-	<0.001	<0.001	#	< ^b	/	< ^b

^a = not constructed.

^b = antennas off, grounded at transmitter.

^c = antennas off, connected to transmitter.

^d = antennas on, 150 A current.

- = measurement point not established.

: = measurement point dropped.

/ = measurement not taken.

= measurement precluded by antenna operation.

< = measurement est. <0.001 V/m based on earth E-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
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
1C1-4	-	-	-	0.117	0.114	0.085	0.22	0.066 ^d	0.079 ^d	0.115 ^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	0.061 ^d	0.27 ^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
1C4-5	-	-	-	-	0.037	0.046	0.021	0.018 ^d	0.036 ^d	0.112 ^d
1D3-1	-	-	-	0.052	0.156	0.053	0.29	0.26 ^d	0.103 ^d	0.039 ^d
1C6-1	-	0.072	0.095	0.088	0.106	0.057	0.102	0.103 ^d	0.101 ^d	0.064 ^d
1C6-3	-	-	0.123	0.109	0.141	0.053	0.122	0.075 ^d	0.069 ^d	0.066 ^d
1C6-4	-	-	0.038	0.007	0.020	0.013	0.013	0.021 ^d	0.017 ^d	0.012 ^d
1L4-1	-	-	-	-	-	0.019	0.013	0.022 ^d	0.015 ^d	0.008 ^d

a = not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A current.

- = measurement point not established.

/ = measurement point dropped.

= measurement not taken.

= measurement precluded by antenna operation.

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
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	-	-	-	-	-	-	-
1T1-14	-	-	-	0.102	0.058	0.29	0.071	0.071 ^b	0.036 ^c	0.026 ^b
1T1-15	-	-	-	0.040	0.029	0.064	#	0.025 ^b	0.016 ^c	0.019 ^b
1T1-16	-	-	-	0.115	0.102	0.40	#	0.179 ^b	0.045 ^c	0.034 ^b
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
1T1-22	-	-	-	0.050	0.047	0.40	0.086	0.049 ^b	0.090 ^b	0.042 ^b
1T1-23	-	-	-	0.037	0.037	0.31	0.068	0.024 ^b	0.090 ^b	0.031 ^b
1T1-24	-	-	-	0.042	0.058	0.23	0.126	0.040 ^b	0.070 ^b	0.034 ^b
1T1-25	-	-	-	0.033	0.035	0.26	0.070	0.034 ^b	0.075 ^b	0.024 ^b
1T1-26	-	-	-	0.022	0.025	0.20	0.052	0.023 ^b	0.045 ^b	0.018 ^b
1T1-27	-	-	-	0.014	0.021	0.094	0.056	0.015 ^b	0.032 ^b	0.013 ^b

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

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

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
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
1T2-6	-	-	-	-	0.069	0.087	0.064	0.064 ^c	0.065 ^b	0.066 ^b
1T2-7	-	-	-	-	0.047	0.062	0.040	0.044 ^c	0.049 ^b	0.049 ^b
1T2-8	-	-	-	-	0.051	0.067	0.055	0.047 ^c	0.047 ^b	0.050 ^b
1T2-9	-	-	-	-	0.055	0.087	0.031	0.044 ^c	0.048 ^b	0.057 ^b
1D1-1	-	-	-	9.6	2.4	1.15	2.7	1.96 ^d	2.5 ^d	3.9 ^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
1T4-6	-	-	-	0.104	0.066	0.128	0.039	0.106 ^c	0.163 ^b	0.065 ^b
1T4-7	-	-	-	0.102	0.090	0.128	0.036	0.126 ^c	0.121 ^b	0.117 ^b
1T4-8	-	-	-	0.082	0.078	0.096	0.032	0.186 ^c	0.113 ^b	0.146 ^b
1T4-9	-	-	-	0.088	0.063	0.098	0.032	0.200 ^c	0.139 ^b	0.137 ^b
1T4-10	-	-	-	-	0.135	0.124	0.126	0.22 ^c	0.090 ^c	0.082 ^b
1T4-11	-	-	-	-	0.071	0.089	0.047	0.191 ^c	0.116 ^c	0.063 ^b
1T4-12	-	-	-	-	0.071	0.100	0.041	0.181 ^c	0.068 ^c	0.049 ^b
1T4-13	-	-	-	-	0.063	0.083	0.037	0.161 ^c	0.064 ^c	0.043 ^b
1T4-14	-	-	-	-	0.068	0.121	0.037	0.148 ^c	0.064 ^c	0.046 ^b

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

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

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
1D2-1	-	-	-	0.47	0.160	0.28	0.69	0.59 ^d	0.58 ^d	0.65 ^d
1T5-1	-	0.24, 0.42	0.25	0.115	0.128	0.34	#	0.41 ^c	0.21 ^b	0.087 ^b
1T5-7	-	-	-	-	0.107	0.33	#	0.37 ^c	0.154 ^b	0.073 ^b
1T5-8	-	-	-	-	0.099	0.23	#	0.37 ^c	0.138 ^b	0.061 ^b
1T5-4	-	-	-	0.061	0.073	0.166	#	0.26 ^c	0.106 ^b	0.048 ^b
1T5-2	0.23	0.26	0.22	0.042	0.092	0.108	#	0.062 ^b	0.135 ^b	0.085 ^b
1T5-9	-	-	-	-	0.080	0.089	#	0.054 ^b	0.100 ^b	0.058 ^b
1T5-10	-	-	-	-	0.036	0.056	#	0.030 ^b	0.055 ^b	0.045 ^b
1T5-6	-	-	-	0.051	0.034	0.053	#	0.024 ^b	0.064 ^b	0.046 ^b
1T5-3	-	-	-	0.125	-	-	-	-	-	-
1T5-5	-	-	-	0.077	0.051	0.059	#	0.052 ^b	0.28 ^c	0.051 ^b
1T6-2	-	-	-	-	0.48	1.52	#	0.29 ^b , 0.70 ^c	0.31 ^b , 0.23 ^c	0.164 ^b
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
1T6-3	-	-	-	-	0.32	1.54	#	0.31 ^b , 0.83 ^c	0.29 ^b , 0.148 ^c	0.124 ^b
1T6-4	-	-	-	-	0.25	1.32	#	0.25 ^b , 0.44 ^c	0.181 ^b , 0.167 ^c	0.103 ^b
1T6-5	-	-	-	-	0.21	1.19	#	0.21 ^b , 0.63 ^c	0.29 ^c	0.134 ^b
1T6-6	-	-	-	-	0.178	0.90	#	0.169 ^b	0.33 ^c	0.073 ^b
1T6-7	-	-	-	-	0.100	1.31	#	0.20 ^b	0.76 ^b	0.119 ^b

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A 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
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
1C1-4	-	-	-	0.001	0.001	0.001	0.001	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
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
1C4-5	-	-	-	-	0.001	0.002	0.001	0.002 ^d	0.001 ^d	0.002 ^d
1D3-1	-	-	-	0.003	0.002	0.002	0.013	0.009 ^d	0.009 ^d	0.009 ^d
1C6-1	-	0.003	0.003	0.002	<0.001	0.002	0.003	0.002 ^d	0.002 ^d	0.002 ^d
1C6-3	-	-	0.003	0.003	0.003	0.002	0.002	0.003 ^d	0.002 ^d	0.002 ^d
1C6-4	-	-	0.003	0.003	0.004	0.003	0.003	0.004 ^d	0.003 ^d	0.002 ^d
1L4-1	-	-	-	-	-	0.003	0.002	0.002 ^d	0.002 ^d	0.001 ^d

a = not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A 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 2 of 4)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
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	-	-	-	-	-	-	-
1T1-14	-	-	-	0.004	0.003	0.014	0.003	0.002 ^b	0.003 ^c	0.002 ^b
1T1-15	-	-	-	0.004	0.004	0.009	#	0.003 ^b	0.001 ^c	0.001 ^b
1T1-16	-	-	-	0.009	0.006	0.22	#	0.009 ^b	0.002 ^c	0.003 ^b
1T1-17	-	-	-	0.007	0.009	0.031	#	0.007 ^b	0.008 ^b	/
1T1-18	-	-	-	0.006	0.008	0.028	#	0.006 ^b	0.007 ^b	/
1T1-19	-	-	-	0.001	0.009	0.032	#	0.007 ^b	0.007 ^b	/
1T1-20	-	-	-	0.008	0.011	0.034	#	0.008 ^b	0.008 ^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	0.081 ^b	0.027 ^b
1T1-22	-	-	-	0.012	0.018	0.108	0.029	0.014 ^b	0.032 ^b	0.009 ^b
1T1-23	-	-	-	0.008	0.011	0.060	0.015	0.006 ^b	0.017 ^b	0.005 ^b
1T1-24	-	-	-	0.005	0.008	0.041	0.008	0.006 ^b	0.013 ^b	0.003 ^b
1T1-25	-	-	-	0.005	0.005	0.030	0.007	0.004 ^b	0.009 ^b	0.003 ^b
1T1-26	-	-	-	0.003	0.004	0.021	0.005	0.003 ^b	0.006 ^b	0.002 ^b
1T1-27	-	-	-	0.002	0.003	0.014	0.004	0.002 ^b	0.005 ^b	0.001 ^b

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

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 -- = 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 3 of 4)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
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
1T2-6	-	-	-	-	0.018	0.011	0.006	0.019 ^c	0.020 ^b	0.012 ^b
1T2-7	-	-	-	-	0.009	0.007	0.003	0.010 ^c	0.010 ^b	0.006 ^b
1T2-8	-	-	-	-	0.006	0.005	0.002	0.007 ^c	0.006 ^b	0.004 ^b
1T2-9	-	-	-	-	0.005	0.006	0.002	0.005 ^c	0.005 ^b	0.002 ^b
1D1-1	-	-	-	0.109	0.154	0.040	0.151	0.141 ^d	0.25 ^d	0.28 ^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
1T4-6	-	-	-	0.019	0.024	0.017	0.004	0.038 ^c	0.046 ^b	0.012 ^b
1T4-7	-	-	-	0.011	0.013	0.010	0.003	0.020 ^c	0.023 ^b	0.006 ^b
1T4-8	-	-	-	0.006	0.008	0.005	0.001	0.014 ^c	0.015 ^b	0.011 ^b
1T4-9	-	-	-	0.004	0.006	0.004	0.001	0.009 ^c	0.012 ^b	0.007 ^b
1T4-10	-	-	-	-	0.051	0.041	0.039	0.081 ^c	0.060 ^c	0.031 ^b
1T4-11	-	-	-	-	0.023	0.013	0.004	0.035 ^c	0.026 ^c	0.013 ^b
1T4-12	-	-	-	-	0.013	0.010	0.002	0.019 ^c	0.013 ^c	0.006 ^b
1T4-13	-	-	-	-	0.009	0.007	0.001	0.013 ^c	0.009 ^c	0.005 ^b
1T4-14	-	-	-	-	0.007	0.007	0.001	0.009 ^c	0.006 ^c	0.004 ^b

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A 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 4 of 4)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
1D2-1	-	-	-	0.004	0.006	0.005	0.005	0.005 ^d	0.009 ^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
1T5-7	-	-	-	-	0.039	0.077	#	0.087 ^c	0.058 ^b	0.020 ^b
1T5-8	-	-	-	-	0.016	0.025	#	0.035 ^c	0.024 ^b	0.007 ^b
1T5-4	-	-	-	0.006	0.008	0.016	#	0.020 ^c	0.014 ^b	0.005 ^b
1T5-2	0.001	0.002	0.001	0.038	0.042	0.075	#	0.020 ^b	0.112 ^b	0.039 ^b
1T5-9	-	-	-	-	0.019	0.028	#	0.010 ^b	0.032 ^b	0.014 ^b
1T5-10	-	-	-	-	0.011	0.017	#	0.005 ^b	0.023 ^b	0.007 ^b
1T5-6	-	-	-	0.004	0.008	0.012	#	0.004 ^b	0.018 ^b	0.005 ^b
1T5-3	-	-	-	0.007	-	-	-	-	-	-
1T5-5	-	-	-	0.005	0.019	0.018	#	0.004 ^b	0.042 ^c	0.013 ^b
1T6-2	-	-	-	-	0.111	0.34	#	0.087 ^b , 0.177 ^c	0.103, 0.043 ^{b,c}	0.057 ^b
1T6-1	0.002	0.001	0.001	0.020	0.058	0.134	#	0.033 ^b , 0.070 ^c	0.041, 0.020 ^{b,c}	0.024 ^b
1T6-3	-	-	-	-	0.020	0.061	#	0.014 ^b , 0.031 ^c	0.019, 0.009 ^{b,c}	0.011 ^b
1T6-4	-	-	-	-	0.014	0.044	#	0.011 ^b , 0.021 ^c	0.012, 0.006 ^{b,c}	0.008 ^b
1T6-5	-	-	-	-	0.011	0.033	#	0.008 ^b , 0.013 ^c	0.311 ^c	0.006 ^b
1T6-6	-	-	-	-	0.008	0.023	#	0.005 ^b	0.008 ^c	0.004 ^b
1T6-7	-	-	-	-	0.008	0.022	#	0.004 ^b	0.006 ^b , 0.007 ^c	0.004 ^b

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A 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
	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
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
1T1-15	<	<	<	*	0.001	<	0.007	<	0.015	0.021	0.015	0.022
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	<	0.025	<	0.057	0.058	0.046	/

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.
A = amperes.

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

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				1987		1988		1989	1990	1991	1992
	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
1T1-28	-	-	-	-	-	-	0.016	<	0.043	0.044	0.051	/
1T1-29	-	-	-	-	-	-	0.013	<	0.032	0.036	0.036	/
1T1-30	-	-	-	-	-	-	0.017	<	0.037	0.042	0.036	/
1T1-31	-	-	-	-	-	-	0.016	<	0.035	0.035	0.046	/
1T1-21	1.08	<	<	*	3.6	0.005	15.7	0.054	32	35	35	40
1T1-22	0.002	<	<	*	0.005	<0.001	0.024	<	0.049	0.049	0.048	0.040
1T1-23	<	<	<	*	0.008	<	0.033	<	0.053	0.073	0.067	0.054
1T1-24	<	<	<	*	0.013	<	0.045	<	0.150	0.091	0.129	0.072
1T1-25	<	<	<	*	0.019	<	0.059	<	0.160	0.135	0.126	0.120
1T1-26	<	<	<	*	0.012	<	0.044	<	0.092	0.102	0.099	0.083
1T1-27	<	<	<	*	0.008	<	0.032	<	0.060	0.068	0.065	0.051
1T2-5	-	-	-	-	1.28	0.014	7.3	0.100	11.1	12.2	10.7	46
1T2-6	-	-	-	-	0.169	0.002	0.84	0.013	1.17	1.33	1.29	6.9
1T2-7	-	-	-	-	0.034	<0.001	0.29	0.004	0.25	0.34	0.27	1.41
1T2-8	-	-	-	-	0.014	<	0.084	0.004	0.104	0.142	0.109	0.56
1T2-9	-	-	-	-	0.008	<	0.035	0.004	0.077	0.082	0.066	0.21
1D1-1	<	<	<	*	<	<	<	<	0.007	0.010	0.009	0.009
1T4-5	0.58	<	<	*	2.1	0.003	8.7	0.044	17.6	18.4	21	14.0
1T4-6	0.091	<	<	*	0.31	<0.001	1.76	0.009	4.2	4.6	4.0	2.9
1T4-7	0.022	<	<	*	0.089	<	0.35	0.003	0.69	0.86	0.76	0.52
1T4-8	0.005	<	<	*	0.014	<	0.054	0.002	0.093	0.091	0.112	0.078
1T4-9	0.002	<	<	*	0.008	<	0.045	0.002	0.081	0.081	0.106	0.058

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.
A = amperes.

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

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				1987		1988		1989	1990	1991	1992
	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
1T4-10	-	-	-	-	1.30	0.001	6.4	0.033	12.3	15.1	17.4	16.8
1T4-11	-	-	-	-	0.30	<0.001	1.48	0.008	2.4	3.1	4.7	2.7
1T4-12	-	-	-	-	0.090	<0.001	0.39	0.003	0.69	1.02	0.90	0.60
1T4-13	-	-	-	-	0.033	<0.001	0.115	0.002	0.33	0.36	0.37	0.24
1T4-14	-	-	-	-	0.015	<0.001	0.066	0.002	0.128	0.120	0.133	0.103
1D2-1	<	<	<	*	<	0.003	0.001	0.001	0.011	0.013	0.019	0.030
1T5-1	0.81	<	<	*	3.1	0.005	12.4	0.040	26	41	33	26
1T5-7	-	-	-	-	0.54	0.001	1.78	0.005	5.2	7.6	5.8	3.1
1T5-8	-	-	-	-	0.008	<0.001	0.039	<	0.079	0.113	0.096	0.062
1T5-4	0.002	<	<	*	0.007	<	0.039	<	0.066	0.089	0.086	0.049
1T5-2	0.59	<	<	*	2.9	0.003	15.8	0.056	23	42	28	29
1T5-9	-	-	-	-	0.44	<0.001	1.95	0.007	3.4	6.3	3.6	4.6
1T5-10	-	-	-	-	0.076	<	0.29	0.001	0.63	1.06	0.86	0.92
1T5-6	0.009	<	<	*	0.022	<	0.135	<	0.23	0.46	0.31	0.25
1T5-5	0.005	<	<	*	0.019	<	0.095	0.001	0.178	0.40	0.23	0.260
1T6-2	-	-	-	-	3.2	0.005	14.3	0.054	31	42	43	40
1T6-1	0.182	<	<	*	0.48	<	2.4	0.010	4.9	6.2	6.7	5.8
1T6-3	-	-	-	-	0.042	<0.001	0.121	<0.001	0.35	0.54	0.47	0.21
1T6-4	-	-	-	-	0.029	<0.001	0.122	<0.001	0.23	0.24	0.28	0.169
1T6-5	-	-	-	-	0.021	<0.001	0.107	<0.001	0.153	0.164	0.172	0.093
1T6-6	-	-	-	-	0.019	<0.001	0.075	<0.001	0.151	0.185	0.137	0.114
1T6-7	-	-	-	-	0.015	<0.001	0.079	0.001	0.142	0.159	0.145	0.119

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.
A = amperes.

- = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-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)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
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
1C1-4	/	/	/	/	0.087	0.033	0.42	0.185	1.70	1.33	1.23	1.62
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
1C4-4	<0.001	<0.001	<0.001	*	0.002	0.002	0.005	0.005	0.030	0.023	0.030	0.029
1C4-5	-	-	-	-	0.003	0.002	0.012	0.008	0.037	0.035	0.044	0.036
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
1C6-1	/	/	/	/	0.004	0.003	0.017	0.017	0.083	0.100	0.069	0.067
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
1C6-4	/	/	/	/	0.003	0.002	0.017	0.009	0.045	0.043	0.043	0.051
1L4-1	-	-	-	-	-	-	0.006	0.002	0.013	0.020	0.010	0.010
1T1-14	0.86	0.026	0.021	0.035	3.1	0.069	18.1	0.21	34	40	39	37
1T1-15	0.43	0.013	0.015	0.025	1.60	0.051	9.2	0.21	13.6	14.1	23	32
1T1-16	1.11	0.035	0.035	0.058	4.6	0.133	24	0.61	47	50	46	48
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	/

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.

A = amperes.

- = measurement point not established.

/ = measurement not taken.

* = data cannot be extrapolated.

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

Site No., Meas. Pt.	1986				1987			1988		1989	1990	1991	1992
	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
1T1-28	-	-	-	-	-	-	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	/	/
1T1-21	1.45	0.044	0.009	0.015	7.4	0.026	31	0.133	54	49	60	55	55
1T1-22	1.50	0.042	0.009	0.015	4.2	0.021	25	0.62	41	42	43	56	56
1T1-23	0.96	0.030	0.003	0.005	2.9	0.017	16.7	0.109	33	30	27	38	38
1T1-24	1.15	0.036	0.010	0.017	4.7	0.020	14.8	0.117	59	35	33	41	41
1T1-25	0.87	0.027	0.062	0.103	2.9	0.019	15.6	0.079	33	29	21	34	34
1T1-26	0.56	0.017	0.004	0.007	2.0	0.014	12.3	0.082	23	23	20	22	22
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	14.3
1T2-5	-	-	-	-	8.7	0.77	39	3.1	85	88	94	88	88
1T2-6	-	-	-	-	8.5	0.86	41	4.6	86	82	81	83	83
1T2-7	-	-	-	-	7.0	0.56	31	2.7	70	66	66	64	64
1T2-8	-	-	-	-	7.1	0.66	31	3.6	70	67	79	76	76
1T2-9	-	-	-	-	6.2	0.79	31	3.6	70	65	69	69	69
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	7.6
1T4-5	2.1	0.062	0.054	0.090	6.4	0.191	34	0.76	84	68	62	75	75
1T4-6	2.5	0.076	0.103	0.172	6.3	0.29	45	1.35	87	64	89	81	81
1T4-7	2.2	0.067	0.092	0.153	8.7	0.30	37	1.40	76	50	64	90	90
1T4-8	1.91	0.061	0.123	0.21	7.7	0.31	32	1.59	72	70	61	77	77
1T4-9	2.1	0.062	0.126	0.21	6.2	0.34	35	1.74	55	82	50	67	67

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.

A = amperes.

- = measurement point not established.

/ = measurement not taken.

* = data cannot be extrapolated.

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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
1T4-10	-	-	-	-	12.4	0.29	47	1.30	86	97	84	73
1T4-11	-	-	-	-	6.4	0.27	34	1.26	83	79	106	106
1T4-12	-	-	-	-	7.4	0.38	39	1.31	76	75	78	54
1T4-13	-	-	-	-	5.7	0.33	29	1.60	70	66	73	70
1T4-14	-	-	-	-	6.7	0.33	31	1.56	55	72	64	59
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
1T5-1	2.6	0.079	0.074	0.123	9.7	0.21	47	0.94	110	85	107	83
1T5-7	-	-	-	-	8.4	0.21	48	1.01	78	84	86	85
1T5-8	-	-	-	-	8.2	0.20	38	0.87	90	92	81	81
1T5-4	1.39	0.042	0.061	0.102	5.8	0.21	29	0.98	61	69	75	65
1T5-2	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77	70	54	44	55
1T5-9	-	-	-	-	7.2	0.29	19.5	0.84	47	54	59	44
1T5-10	-	-	-	-	3.4	0.170	14.4	1.00	36	32	33	28
1T5-6	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98	32	38	32	22
1T5-5	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40	45	53	54	63
1T6-2	-	-	-	-	27.	0.24	71	0.79	250	270	196	198
1T6-1	5.4	0.159	0.086	0.143	32.	0.25	102	1.03	169	122	98	195
1T6-3	-	-	-	-	21.	0.144	97	0.67	187	240	188	220
1T6-4	-	-	-	-	16.3	0.122	87	0.61	139	236	164	139
1T6-5	-	-	-	-	15.3	0.22	80	1.27	143	124	137	210
1T6-6	-	-	-	-	11.6	0.132	63	0.66	128	103	119	125
1T6-7	-	-	-	-	6.0	0.178	87	1.41	120	177	69	83

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.

A = anapores

- = measurement point not established.

/ = measurement not taken.

* = data cannot be extrapolated.

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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
1C1-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007	0.007	0.007	0.008
1C1-4	/	/	/	/	0.001	<0.001	0.003	0.001	0.006	0.006	0.007	0.006
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
1C4-4	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	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
1D3-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.002	0.008	0.008	0.004	0.011
1C6-1	/	/	/	/	<0.001	<0.001	0.001	0.001	0.004	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
1C6-4	/	/	/	/	<0.001	<0.001	0.002	0.001	0.005	0.005	0.003	0.005
1L4-1	-	-	-	-	-	-	<0.001	<0.001	0.002	0.002	0.002	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
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
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
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	/

- = measurement point not established.

/ = measurement not taken.

* = data cannot be extrapolated.

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

A = amperes.

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

Site No., Meas. Pt.	1986					1987		1988		1989	1990	1991	1992
	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
1T1-28	-	-	-	-	-	-	1.25	0.015	2.4	2.4	2.4	2.4	/
1T1-29	-	-	-	-	-	-	1.10	0.015	2.1	2.2	2.1	2.1	/
1T1-30	-	-	-	-	-	-	1.12	0.015	2.3	2.3	2.1	2.1	/
1T1-31	-	-	-	-	-	-	1.00	0.015	2.1	2.1	1.91	1.91	/
1T1-21	0.78	0.024	0.004	0.007	2.9	0.005	13.8	0.043	32	29	28	29	29
1T1-22	0.31	0.010	0.002	0.003	1.16	0.016	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	6.1
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	4.1
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	1.96
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	1.42
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	11.2
1T2-7	-	-	-	-	0.64	0.002	3.1	0.023	6.4	6.2	5.8	6.1	6.1
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	0.097
1T4-5	0.70	0.022	0.004	0.007	2.9	0.004	13.4	0.047	29	28	26	28	28
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	11.9
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	4.1
1T4-9	0.085	0.003	0.001	0.002	0.34	0.002	1.55	0.012	3.2	3.0	3.0	3.0	3.0

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.
A = amperes.

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

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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
1T4-10	-	-	-	-	2.7	0.004	16.5	0.042	26	25	25	26
1T4-11	-	-	-	-	0.87	0.003	5.3	0.015	11.7	11	10.5	10.5
1T4-12	-	-	-	-	0.64	0.002	2.9	0.008	6.3	5.9	5.8	5.9
1T4-13	-	-	-	-	0.43	0.002	2.0	0.007	4.3	4.0	3.9	4.1
1T4-14	-	-	-	-	0.32	0.002	1.55	0.006	3.2	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
1T5-1	0.89	0.029	0.005	0.008	3.6	0.005	17.0	0.059	34	34	32	33
1T5-7	-	-	-	-	1.93	0.002	8.9	0.035	18.9	17.6	16.7	17.7
1T5-8	-	-	-	-	0.75	0.001	3.5	0.017	7.3	7.3	6.8	6.8
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
1T5-2	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31	29	27	30
1T5-9	-	-	-	-	1.18	0.003	5.6	0.017	11.7	11.2	10.8	11.1
1T5-10	-	-	-	-	0.67	0.002	3.2	0.009	6.1	6.1	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
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
1T6-2	-	-	-	-	3.9	0.006	17.8	0.061	35	37	36	37
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
1T6-3	-	-	-	-	0.65	0.002	3.2	0.008	6.5	6.3	6.1	6.4
1T6-4	-	-	-	-	0.44	0.002	2.1	0.006	4.7	4.9	4.4	4.5
1T6-5	-	-	-	-	0.34	0.002	1.70	0.004	3.5	3.4	3.4	3.6
1T6-6	-	-	-	-	0.24	0.016	1.17	0.004	2.4	2.4	2.4	2.4
1T6-7	-	-	-	-	0.22	0.002	1.05	0.005	2.1	2.1	2.1	2.1

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.
A = amperes.

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

TABLE A-9. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies Laboratory

Site No., Meas. Pt.	1986	1987	1988	1989	1990	
					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-10. 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 21 ^b	5.2 ^c 0.62 ^d 0.077 ^e
1L1-6	-	-	-	3.2 ^a 44 ^b	2.4 ^c 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 an open, unshielded can, submerged to its rim.

b = measurement made above the 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.

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. Those results are presented in Section 4.3.1 of this report; documentation of previous measurements and EM field shielding activities at the old Marquette Street laboratory is included in this appendix. 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.

The positions of the six 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-8.

**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	

**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

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.

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.

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, and the ratios of 60 Hz EM fields between matched treatment and control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1992 were made with 150 ampere 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 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes 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. Use of the Faraday cages continued at the new Crystal Avenue laboratory. The performance of the cages in shielding the air electric field was measured at the Marquette Street laboratory only, and is presented here with other historic data for this laboratory. All data measured in 1992 for the new Crystal Avenue laboratory appear in Section 4.3.1 of this report.

Air electric field shielding at the Marquette Street laboratory was also discussed in the report referenced above.* Table B-9 presents 60 Hz air electric field data before and after shielding was implemented in the Marquette Street laboratory. It can be seen from this table that the shields provided a nominal factor of 100 reduction in the air electric field exposure at the laboratory work areas.

The 60 Hz magnetic flux densities measured at the Marquette Street laboratory appear in Table B-10. The 1990 magnetic flux density levels were similar to those measured in 1989. They were typically at least a factor of 10 lower than the 76 Hz magnetic flux densities measured at the treatment sites during full-power antenna operation. Shielding of the magnetic fields was not considered for this laboratory.

* 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.

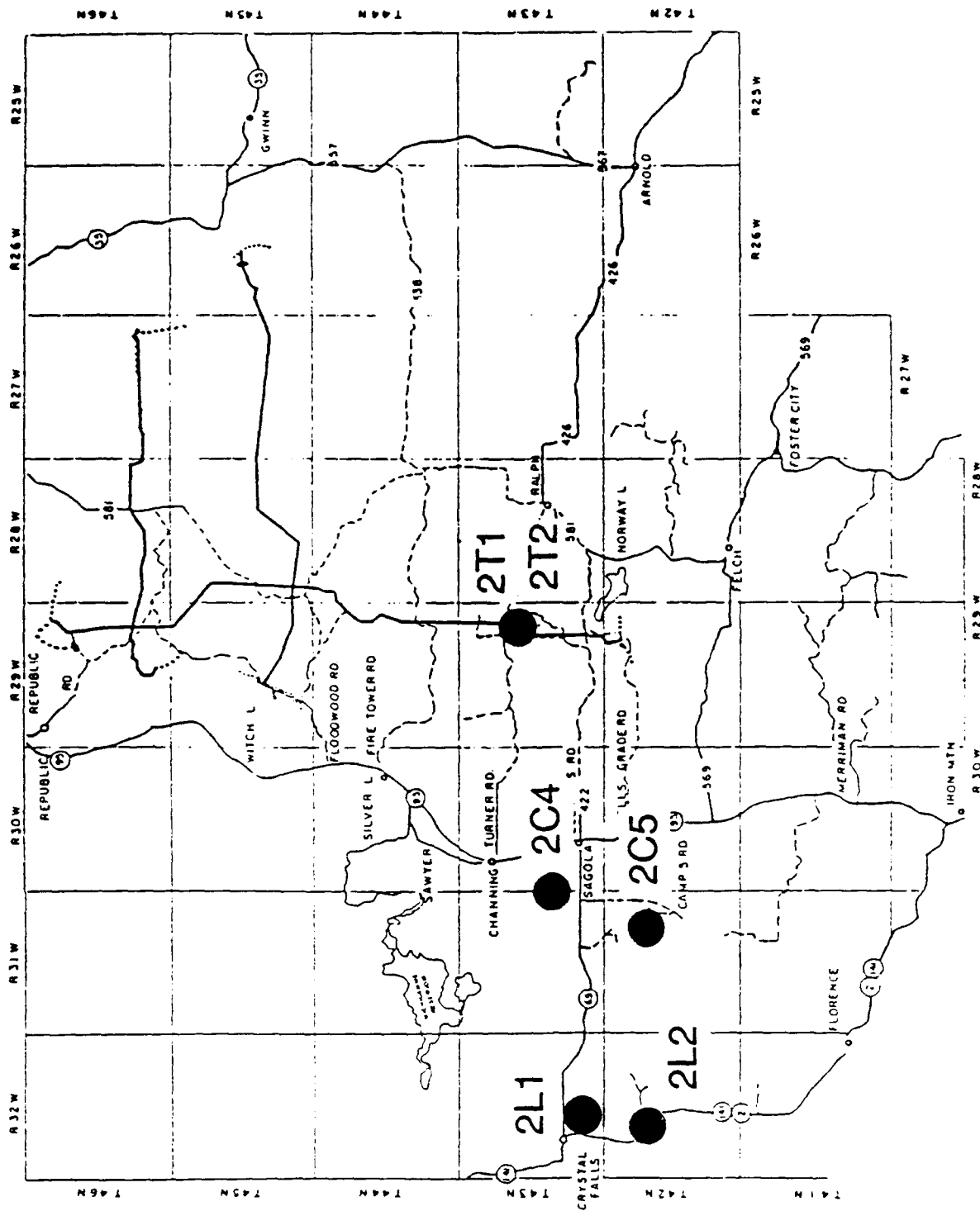
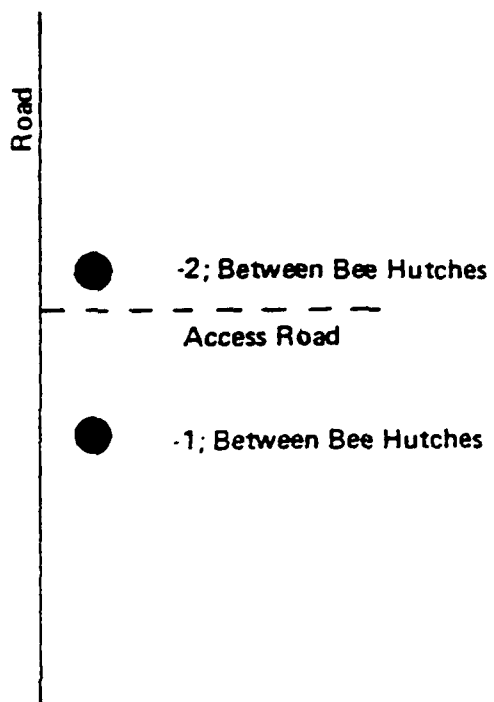
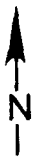


FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.



Not to Scale

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

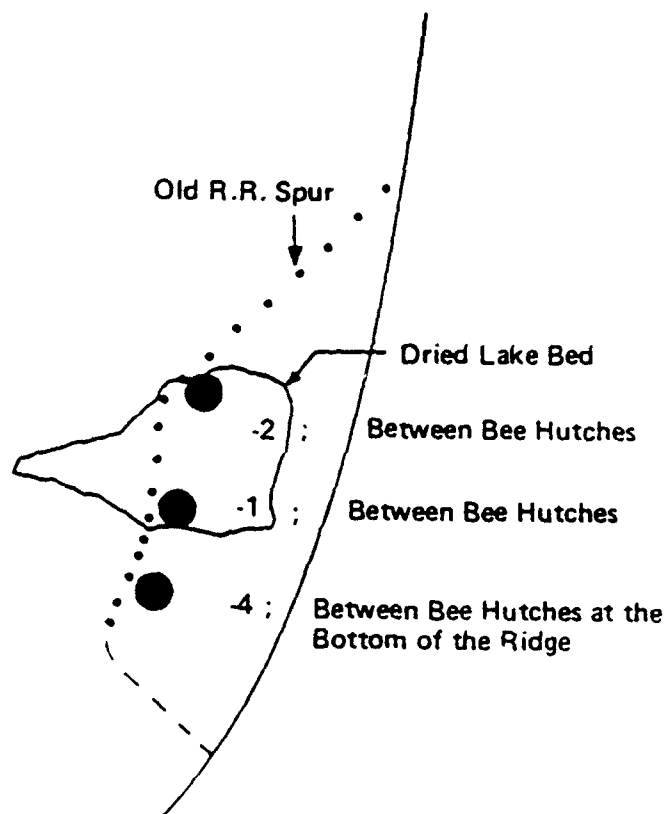
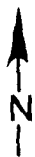


FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5); 2C5-1, 2, 4.

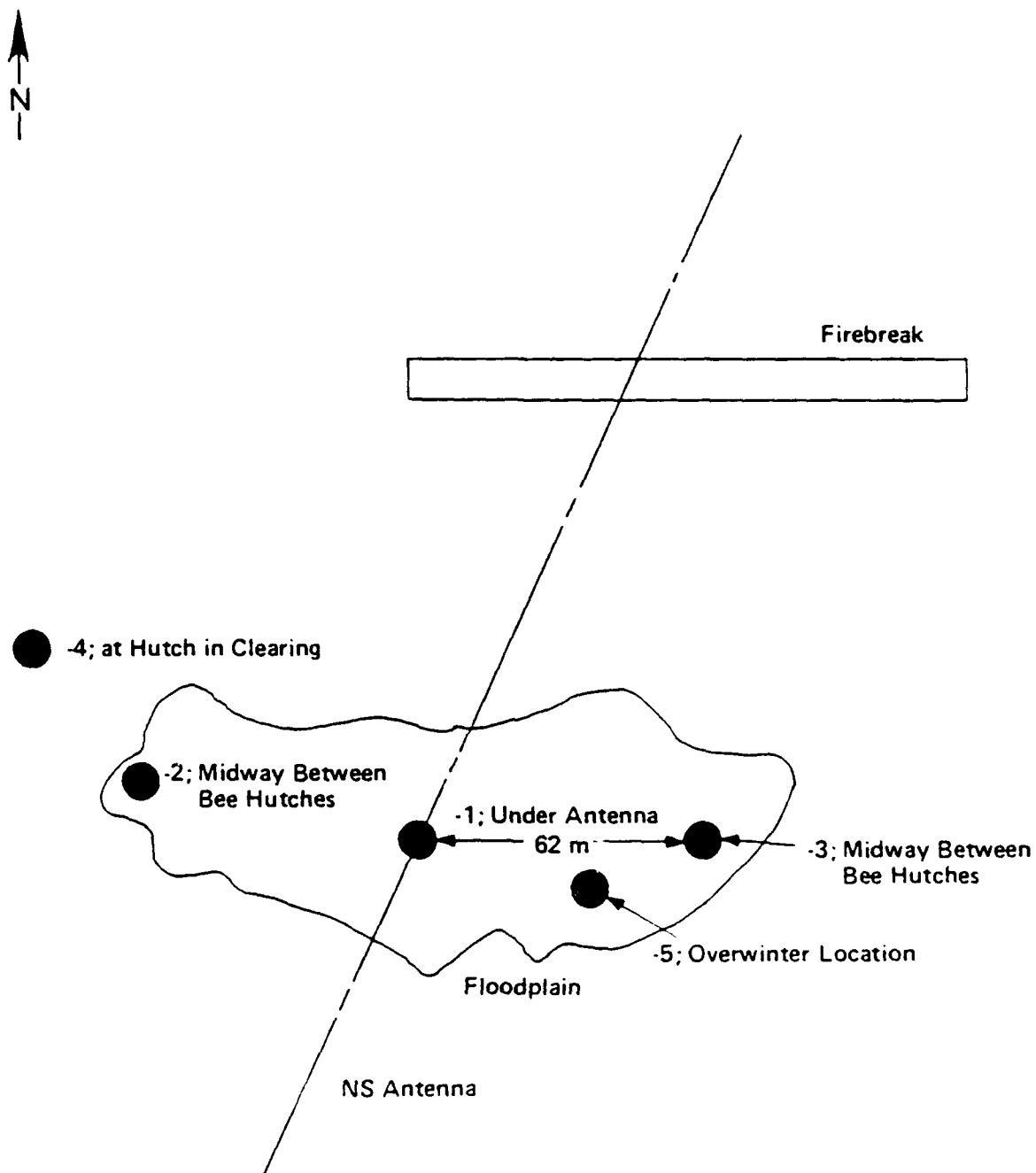


FIGURE B-4. MEASUREMENT POINTS AT FORD 1 (F1); 2T1-1, 2, 3, 4, 5.

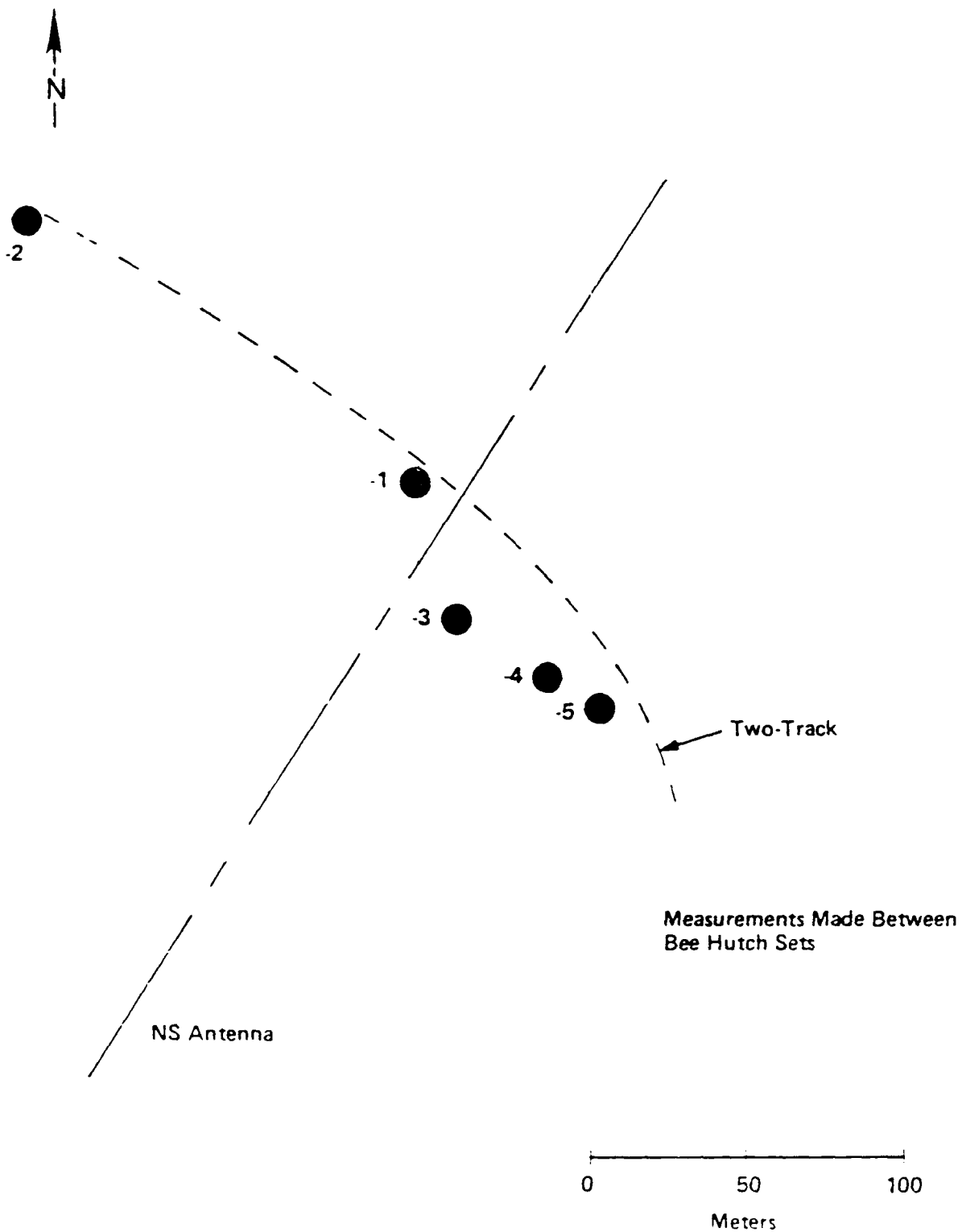


FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2); 2T2-1 THROUGH 5.

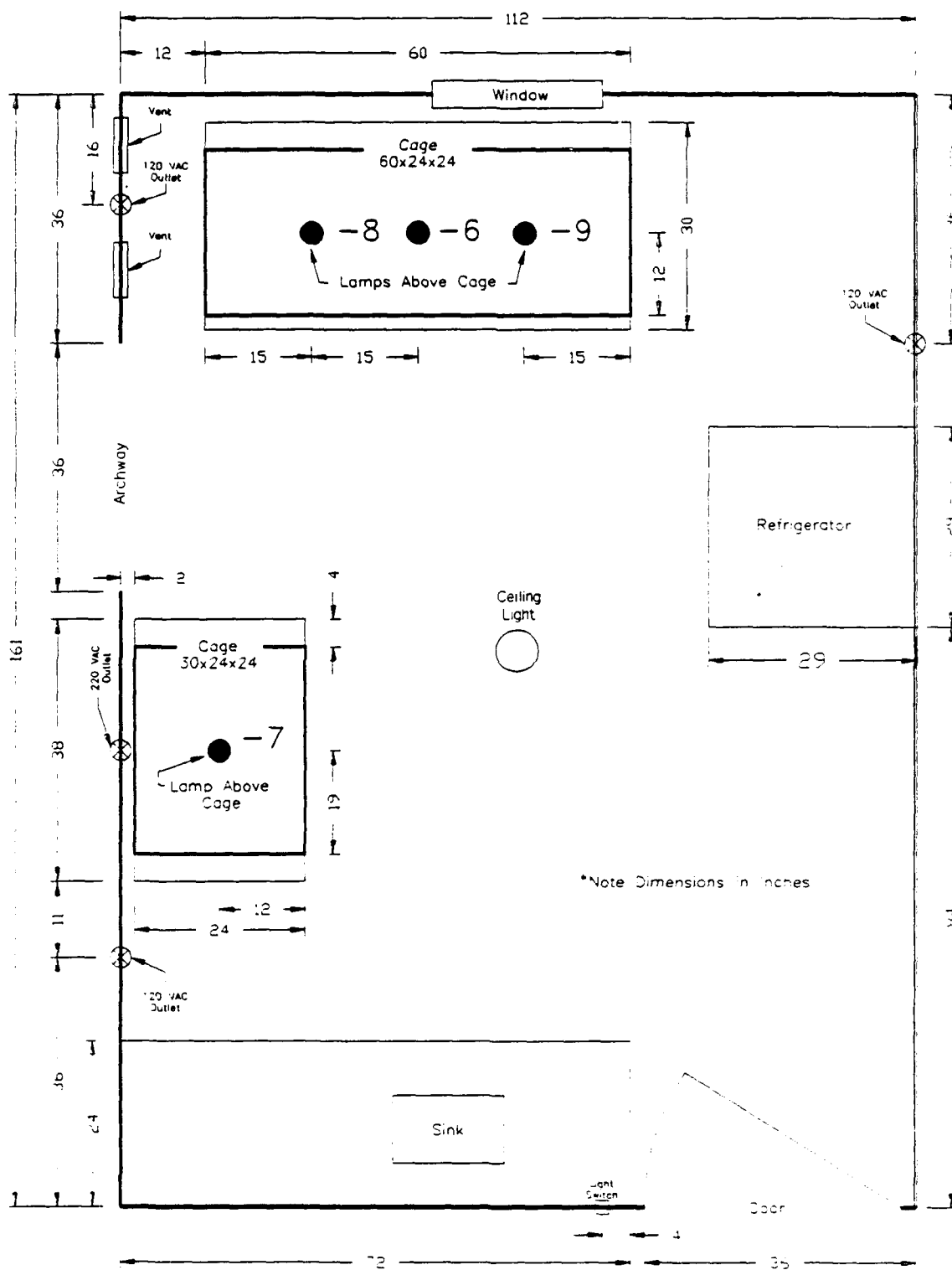


FIGURE B-6. MEASUREMENT POINTS AT CRYSTAL FALLS LABORATORY, 2ND FLOOR WORK AREA; 2L1-6 THROUGH 9.

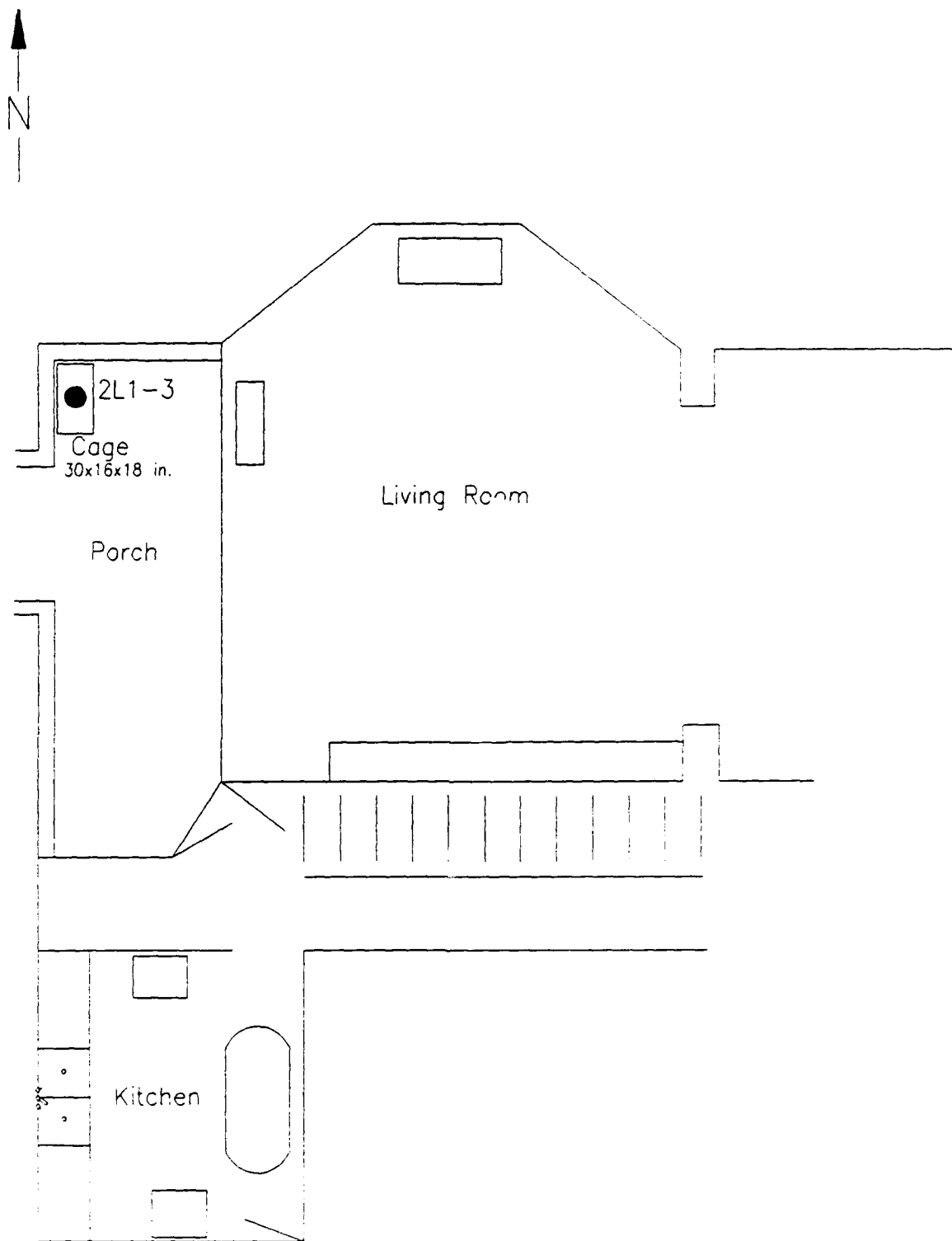


FIGURE B-7. MEASUREMENT POINT AT CRYSTAL FALLS LABORATORY, GROUND LEVEL; 2L1-3.

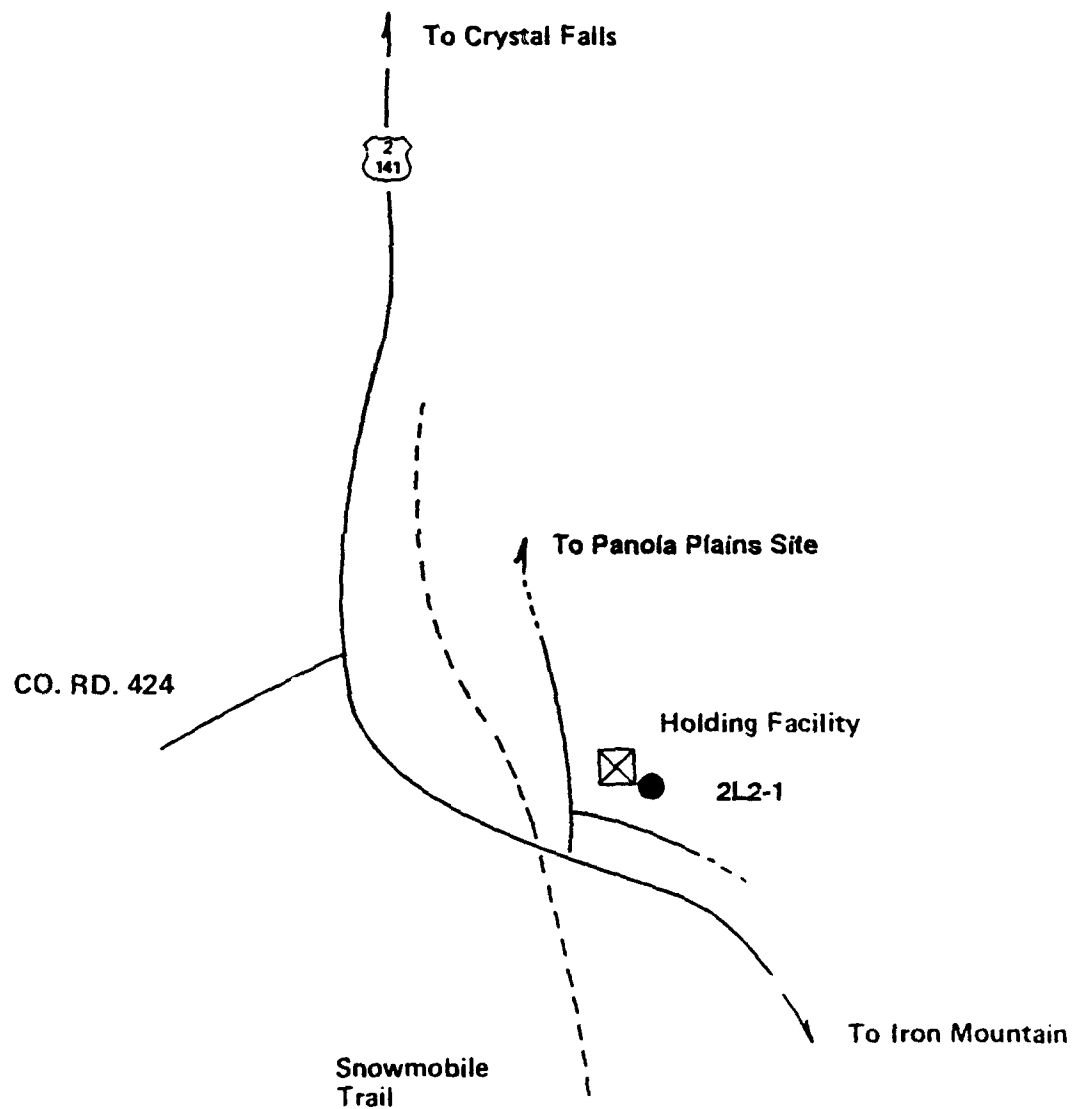
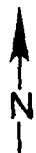


FIGURE B-8. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 2L2-1.

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	0.008 ^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 A current.

, = measurement point not established.

= measurement precluded by antenna operation.

< = measurement est. <0.001 V/m based on earth E-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	1987	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	0.066 ^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 A 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 A 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., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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	0.25	0.32	0.36	0.30

1bNS = 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 est. <0.001 V/m based on earth E-field.

* = data cannot be extrapolated.

A = amperes.

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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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	0.050	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.

A = amperes.

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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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	/	/	/	*	0.001	<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	4.6

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.

A = amperes.

TABLE B-9. 60 Hz AIR ELECTRIC FIELD INTENSITIES
Native Bees Studies Laboratory

Measurement Point Identification	1988	1989	1990			
	E-Field (V/m)	E-Field (V/m)	Hatches	Lamps	Workers	E-Field (V/m)
2L1-1	79	31	N/A	N/A	N/A	--
2L1-2	22	19.5	N/A	N/A	N/A	--
2L1-3	0.25	0.45	Closed	N/A	N/A	0.001
			Open	N/A	N/A	0.023
2L1-4	-	12.5	N/A	N/A	N/A	--
2L1-5	-	18.2	N/A	N/A	N/A	--
2L1-6	-	5.3	N/A	On	None	14.9
2L1-7	-	-	N/A	N/A	N/A	22
(no cage)						
2L1-7 (no cage)	-	-	Closed	On	None	0.039
			Open	On	None	1.14
			Open	On	2-Not grounded to cage	15.7
2L1-8	-	-	Open	On	1-Grounded to cage	0.122-0.198
			Closed	On	None	0.039
			Open	On	None	0.84
2L1-9	-	-	Open	On	2-Grounded to cage	0.122-0.198
			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.

TABLE B-10. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies 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.

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 1992, IITRI field crews made ELF EM field measurements at 12 measurement points within the treatment site, control site, and two candidate species collection sites for the soil arthropods and earthworms studies. The measurement regime differed from 1991 in that one sample collection measurement site/point (3S1-1) was dropped because it was not used, and five of seven measurement points along the treatment site worm incubation bag line (3T2-8 through 12) were dropped because the level of detail necessary for the setup of this study was no longer needed. Measurement dates for 1992 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-5.

EM field measurements for 1992 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.

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	

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
3S1	Merriman Truck Road	T41N	R29W	22
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 1992 (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 1992 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, and the ratios of 60 Hz EM fields between the treatment and control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1992 were made with 150 ampere 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 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989 through 1992. The 1992 measurements made during operation of both antennas are consistent with the measurements made in 1989 through 1991 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, data were first 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. This result was predicted last year* based on 1988 measurements during individual operation of the two antennas. Comparison of measurements made at the control site in 1991* with data for 1989 and 1990 indicated only a slight (20 percent) decrease in magnetic flux density during the EW shutdown, and no apparent change in the electric field intensities. The 1992 data indicate a 15- to 18-percent reduction in the earth electric field intensity, and about a 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.

* Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1991. IIT Research Institute, Technical Report D06200-4, 81 pp. plus appendixes, 1992.

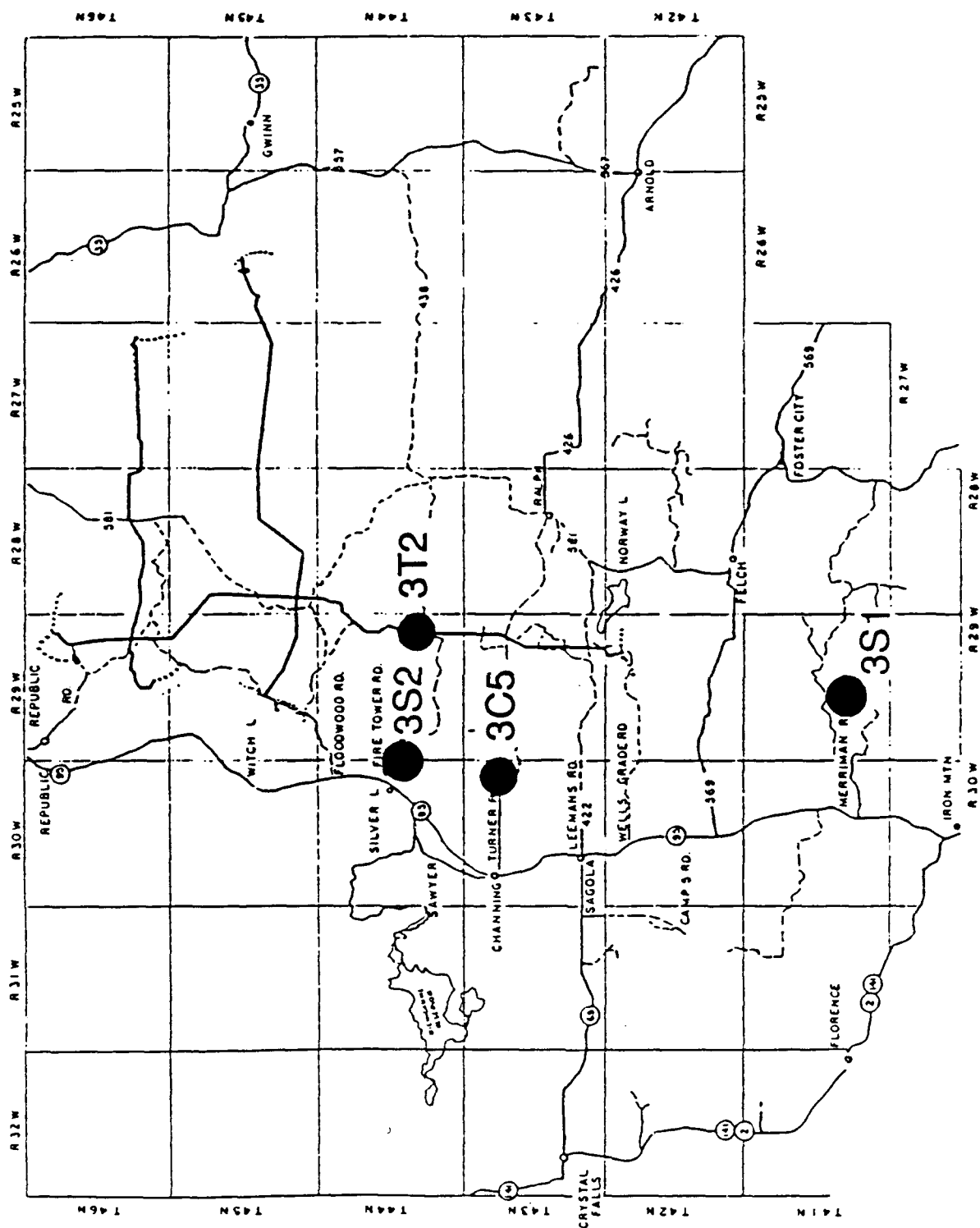


FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

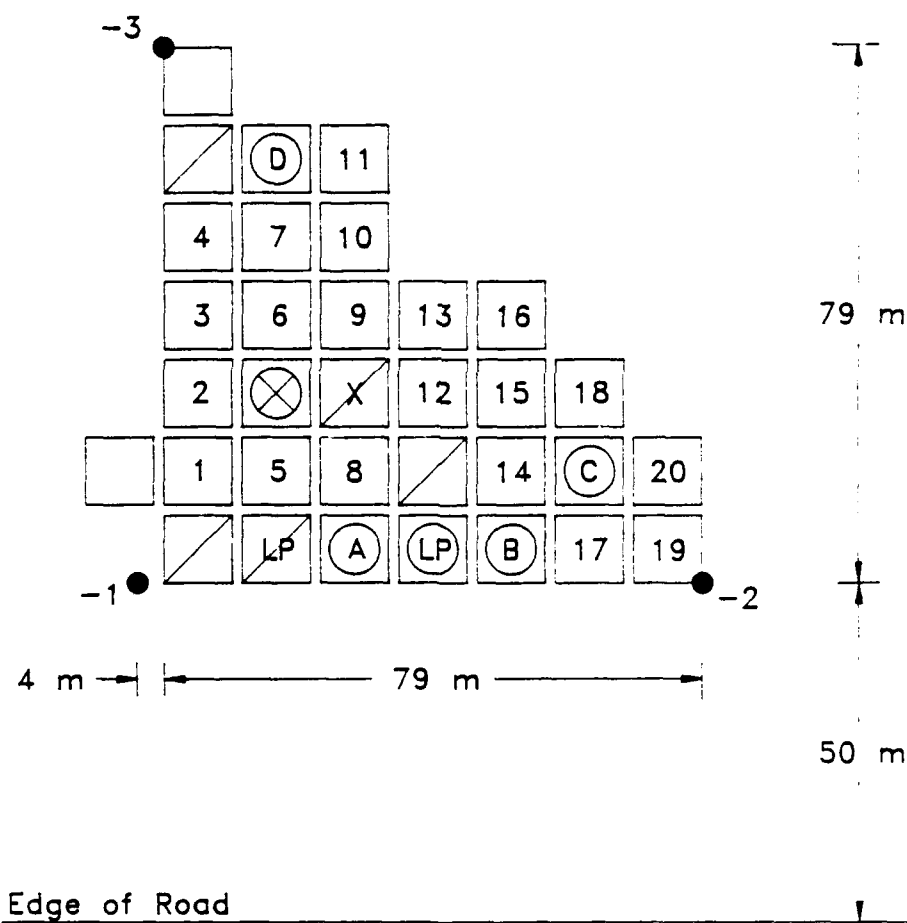
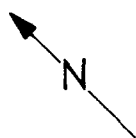


FIGURE C-2. MEASUREMENT POINTS AT TURNER ROAD; 3C5-1 THROUGH 3.

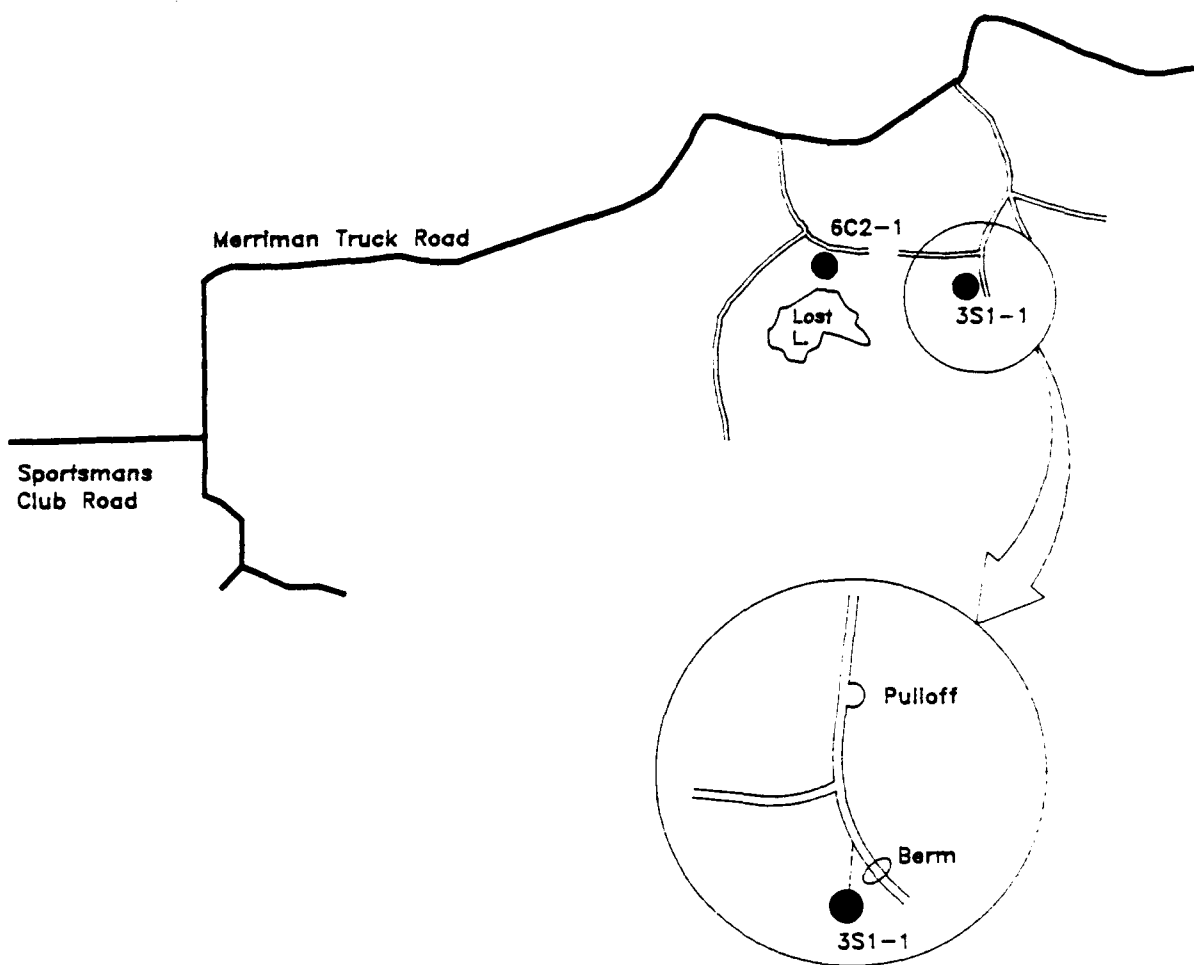


FIGURE C-4. MEASUREMENT POINT AT MERRIMAN TRUCK ROAD WORM COLLECTION SITE; 3S1-1.

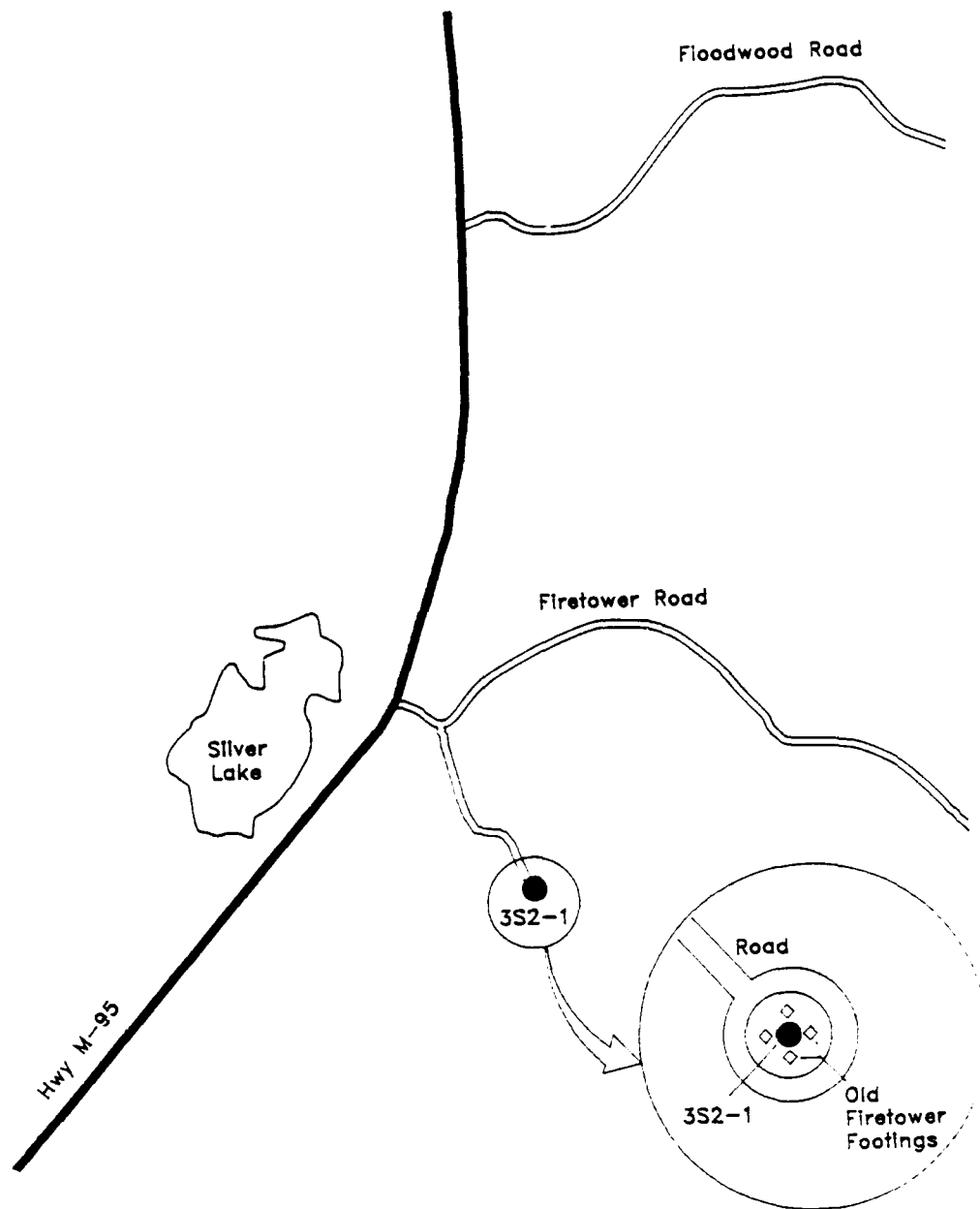


FIGURE C-5. MEASUREMENT POINT AT FIRETOWER ROAD WORM COLLECTION SITE; 3S2-1.

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
3C5-1	<0.001	<0.001	<	<	<	<	<	< ^d	< ^d	< ^d
3C5-2	-	-	-	<	<	<	<	< ^d	< ^d	< ^d
3C5-3	-	-	-	-	-	-	-	-	< ^d	< ^d
3T2-1	<0.001	<0.001	<	<	<	<	<0.001	<0.001 ^c	< ^c	< ^b
3T2-2	-	-	-	<	<	<	<	<0.001 ^c	< ^c	< ^b
3T2-3	-	-	-	<	<	<	<	< ^c	< ^c	< ^b
3T2-4	-	-	-	<	<	<	<	< ^c	< ^c	< ^b
3T2-5	-	-	-	<	<	<	<	< ^c	< ^c	< ^b
3T2-6	-	-	-	<	<	<	<	< ^c	< ^c	< ^b
3T2-7	-	-	-	-	-	-	-	-	/	/
3T2-8	-	-	-	-	-	-	-	-	/	/
3T2-9	-	-	-	-	-	-	-	-	/	/
3T2-10	-	-	-	-	-	-	-	-	/	/
3T2-11	-	-	-	-	-	-	-	-	/	/
3T2-12	-	-	-	-	-	-	-	-	/	/
3T2-13	-	-	-	-	-	-	-	-	/	< ^b
3S1-1	-	-	-	-	-	-	-	-	< ^c	/
3S2-1	-	-	-	-	-	-	-	-	< ^c	< ^b

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

. = measurement point not established.
 < = measurement est. <0.001 V/m based on earth E-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
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
3C5-2	-	-	-	0.027	0.071	0.085	0.182	0.116 ^d	0.098 ^d	0.086 ^d
3C5-3	-	-	-	-	-	-	-	-	0.120 ^d	0.077 ^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
3T2-2	-	-	-	0.068	0.049	0.093	0.049	0.043 ^c	0.063 ^c	0.053 ^b
3T2-3	-	-	-	0.038	0.043	0.084	0.035	0.047 ^c	0.041 ^c	0.074 ^b
3T2-4	-	-	-	0.045	0.039	0.087	0.068	0.040 ^c	0.176 ^c	0.076 ^b
3T2-5	-	-	-	0.044	0.045	0.084	0.053	0.047 ^c	0.047 ^c	0.065 ^b
3T2-6	-	-	-	0.048	0.033	0.087	0.041	0.042 ^c	0.043 ^c	0.065 ^b
3T2-7	-	-	-	-	-	-	-	-	/	0.073 ^b
3T2-8	-	-	-	-	-	-	-	-	/	/
3T2-9	-	-	-	-	-	-	-	-	/	/
3T2-10	-	-	-	-	-	-	-	-	/	/
3T2-11	-	-	-	-	-	-	-	-	/	/
3T2-12	-	-	-	-	-	-	-	-	/	/
3T2-13	-	-	-	-	-	-	-	-	/	0.055 ^b
3S1-1	-	-	-	-	-	-	-	-	0.62 ^c	/
3S2-1	-	-	-	-	-	-	-	-	0.45 ^c	0.084 ^b

^a = antennas not constructed.

^b = antennas off, grounded at transmitter.

^c = antennas off, connected to transmitter.

^d = antennas on, 150 A 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
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
3C5-2	-	-	-	<0.001	0.001	0.001	0.002	0.001 ^d	0.001 ^d	0.001 ^d
3C5-3	-	-	-	-	-	-	-	-	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
3T2-2	-	-	-	0.006	0.003	0.006	0.002	0.004 ^c	0.006 ^c	0.003 ^b
3T2-3	-	-	-	0.004	0.003	0.003	0.001	0.003 ^c	0.005 ^c	0.003 ^b
3T2-4	-	-	-	0.005	0.003	0.005	0.002	0.004 ^c	0.010 ^c	0.003 ^b
3T2-5	-	-	-	0.005	0.003	0.004	0.002	0.004 ^c	0.005 ^c	0.003 ^b
3T2-6	-	-	-	0.004	0.003	0.003	0.001	0.004 ^c	0.006 ^c	0.002 ^b
3T2-7	-	-	-	-	-	-	-	-	/	0.004 ^b
3T2-8	-	-	-	-	-	-	-	-	/	/
3T2-9	-	-	-	-	-	-	-	-	/	/
3T2-10	-	-	-	-	-	-	-	-	/	/
3T2-11	-	-	-	-	-	-	-	-	/	/
3T2-12	-	-	-	-	-	-	-	-	/	/
3T2-13	-	-	-	-	-	-	-	-	/	0.004 ^b
3S1-1	-	-	-	-	-	-	-	-	0.006 ^c	/
3S2-1	-	-	-	-	-	-	-	-	0.004 ^c	0.002 ^b

a = antennas not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A 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				1987		1988		1989	1990	1991	1992
	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
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
3T2-2	0.002	<	<	*	0.006	<	0.024	0.003	0.070	0.068	0.064	0.062
3T2-3	0.002	<	<	*	0.006	<	0.028	0.003	0.048	0.067	0.061	0.061
3T2-4	0.002	<	<	*	0.006	<	0.026	0.003	0.055	0.061	0.054	0.059
3T2-5	0.002	<	<	*	0.006	<	0.029	0.005	0.061	0.056	0.097	0.065
3T2-6	0.002	<	<	*	0.006	<	0.027	0.002	0.048	0.055	0.053	0.050
3T2-7	-	-	-	-	-	-	-	-	-	-	/	0.090
3T2-8	-	-	-	-	-	-	-	-	-	-	/	/
3T2-9	-	-	-	-	-	-	-	-	-	-	/	/
3T2-10	-	-	-	-	-	-	-	-	-	-	/	/
3T2-11	-	-	-	-	-	-	-	-	-	-	/	/
3T2-12	-	-	-	-	-	-	-	-	-	-	/	/
3T2-13	-	-	-	-	-	-	-	-	-	-	/	0.075
3S1-1	-	-	-	-	-	-	-	-	-	-	/	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/	/

NS = north-south antenna.

EW = east-west antenna.

NEW = northern EW antenna element.

SEW = southern EW antenna element.

B = NS + EW antennas

EX = extrapolated data.

A = amperes.

< = measurement est. < 0.001 V/m based on earth E-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., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
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
3C5-2	0.009	0.001	0.003	0.005	0.034	0.009	0.170	0.021	0.38	0.29	0.31, NS	0.38
3C5-3	-	-	-	-	-	-	-	-	-	-	0.27, NS	0.33
3T2-1	1.33	0.057	0.186	0.31	5.4	0.54	27	2.6	58	55	59	64
3T2-2	1.46	0.064	0.24	0.40	6.3	0.71	26	3.0	60	53	55	59
3T2-3	1.19	0.047	0.149	0.25	5.3	0.60	27	2.7	49	56	58	60
3T2-4	1.47	0.060	0.20	0.33	5.6	0.47	29	2.6	62	50	54	56
3T2-5	1.56	0.070	0.23	0.38	5.7	0.61	27	2.8	52	59	62	62
3T2-6	1.20	0.056	0.180	0.30	5.5	0.54	27	2.4	49	49	55	48
3T2-7	-	-	-	-	-	-	-	-	-	-	74, NS	85
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
3S1-1	-	-	-	-	-	-	-	-	-	-	/	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/	3.9

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

- = 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				1987		1988		1989	1990	1991	1992
	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
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
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
3C5-3	-	-	-	-	-	-	-	-	-	-	0.012, NS	0.018
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
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
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
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
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
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
3T2-7	-	-	-	-	-	-	-	-	-	-	2.5, NS	2.9
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
3S1-1	-	-	-	-	-	-	-	-	-	-	/	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/	0.051

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

* = data cannot be extrapolated.

- = measurement point not established.

/ = measurement not taken.

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 streptomyces) 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. Because the electric field in the air can be greatly distorted and shielded by trees or plants on a study plot, special care was taken in characterizing the air electric field intensities to avoid such perturbations.

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 1992, IITRI field crews made ELF EM field measurements at 50 historic measurement points within the two treatment sites, one control site, and three foliage collection points. The study sites and measurement points within those study sites were unchanged from 1991. Annual EM field measurement dates for 1992 and previous years appear in Table D-1.

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	

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

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 1992 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 corresponding operating current of the NRTF-Republic for each year.

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 at treatment sites in 1986 through 1992 (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 these sites from the antennas. Until 1992, the 60 Hz field values at the control site were about as variable as those at the treatment sites. In 1992, however, values at the control site were found

to be more than 100 times greater than those measured in previous years. To determine the temporal scope of the increased 60 Hz values, IITRI will contact Wisconsin Electric Power Company for loading data on one of its transmission lines, which is believed to be the primary source of 60 Hz fields at the control site.

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 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. Because of the increase in 60 Hz EM field intensities at the control site, however, the ratios of 60 Hz EM fields between matched treatment and control sites now fail to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1992 were made with 150 ampere 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 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989 through 1992. The 1992 measurement values for full-power operation with both antennas are consistent with those obtained in 1989 through 1991 under the same antenna conditions.

The extended shutdown of the EW antenna for repairs 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 1993, EM field measurements could not be made during this period because of weather restrictions. Also, comprehensive data collected during 1992 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 are still being 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 1992 are presented in Tables D-9 through D-14. 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. Discussion of these data may be found in a previous report.* In 1991 and 1992, 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. The 1990 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.

* Haradem, D. P.; Gauger, J. R.; Zapalá, 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.

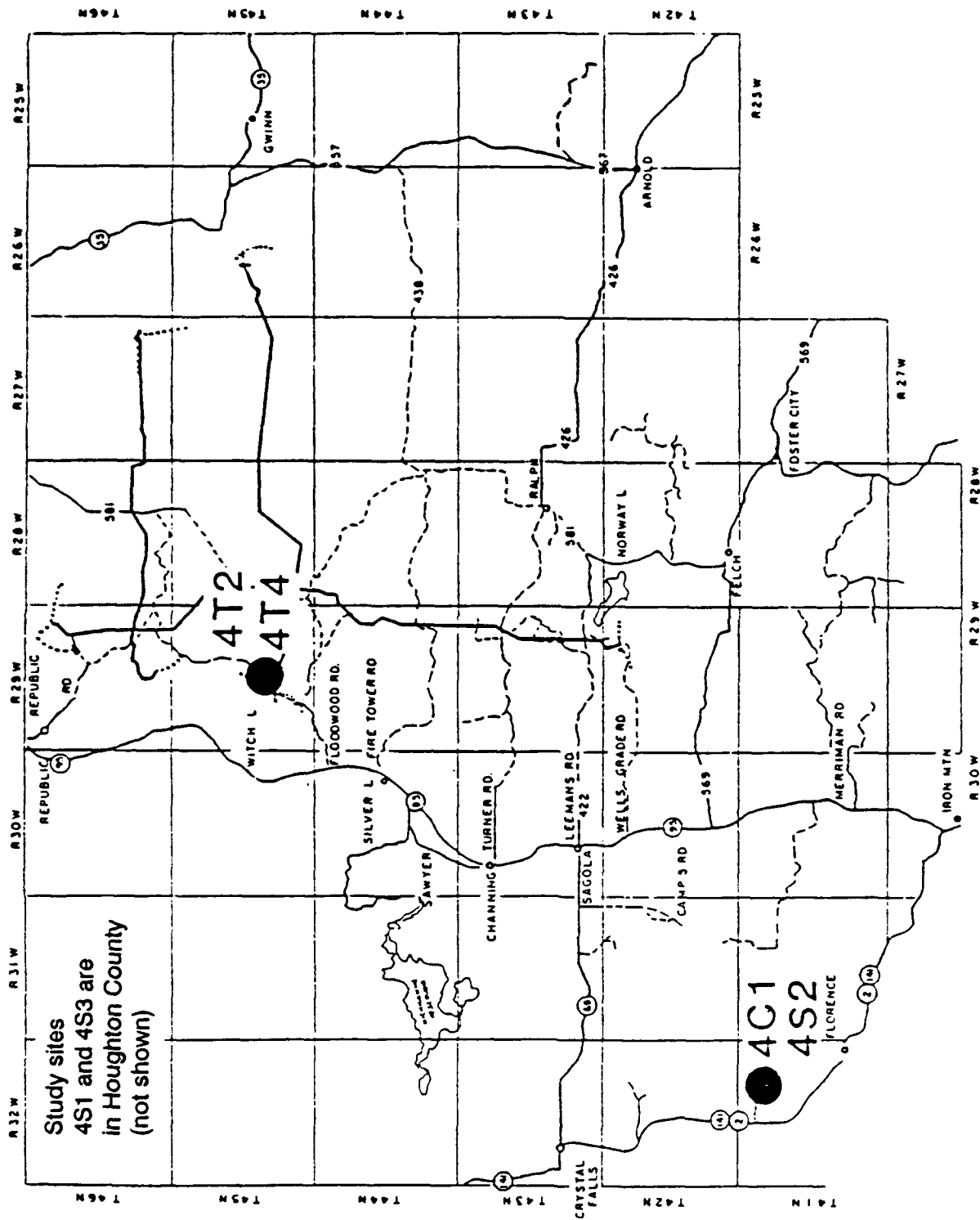


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

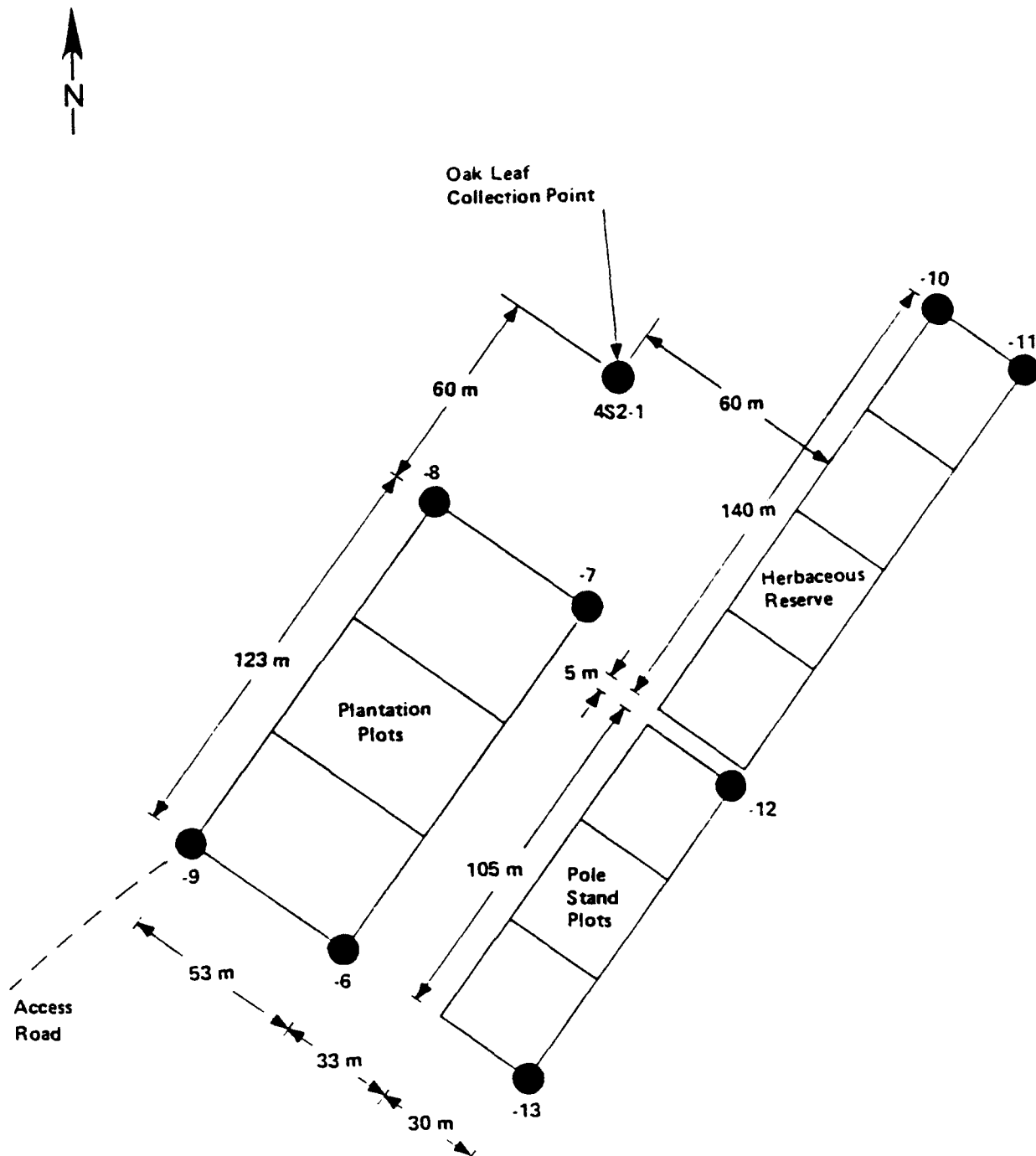


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

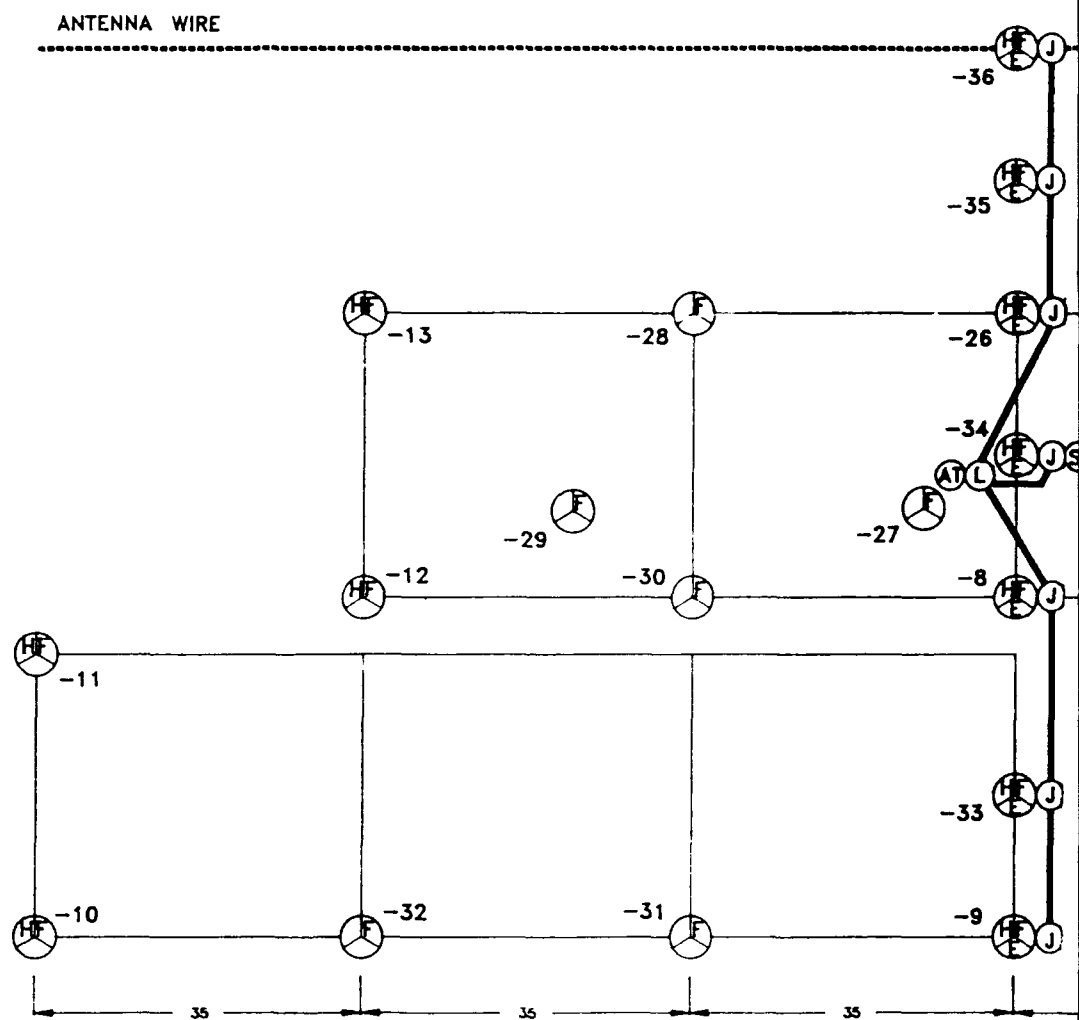
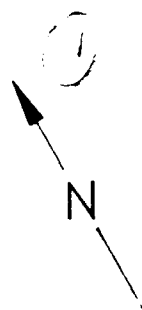
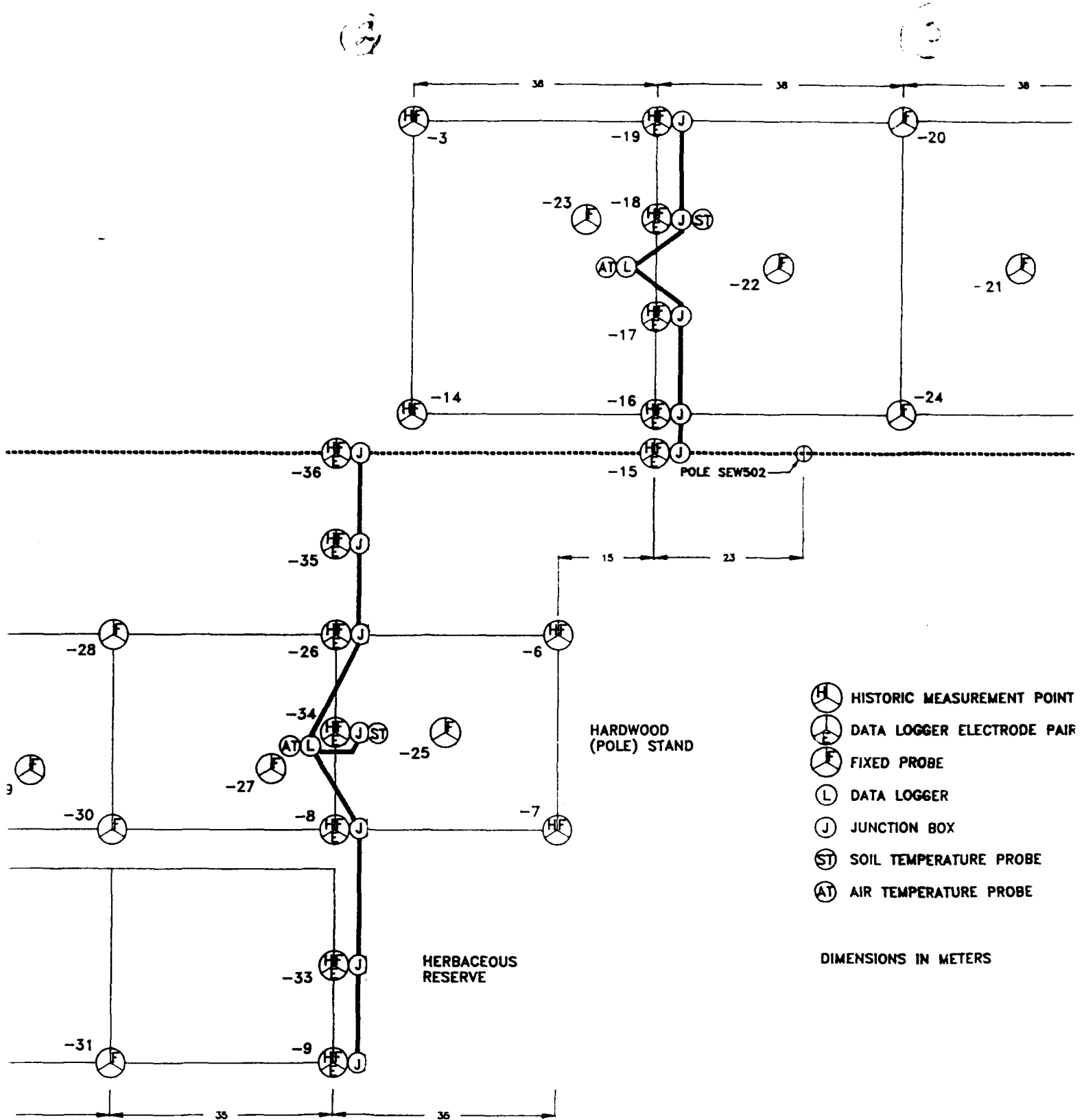
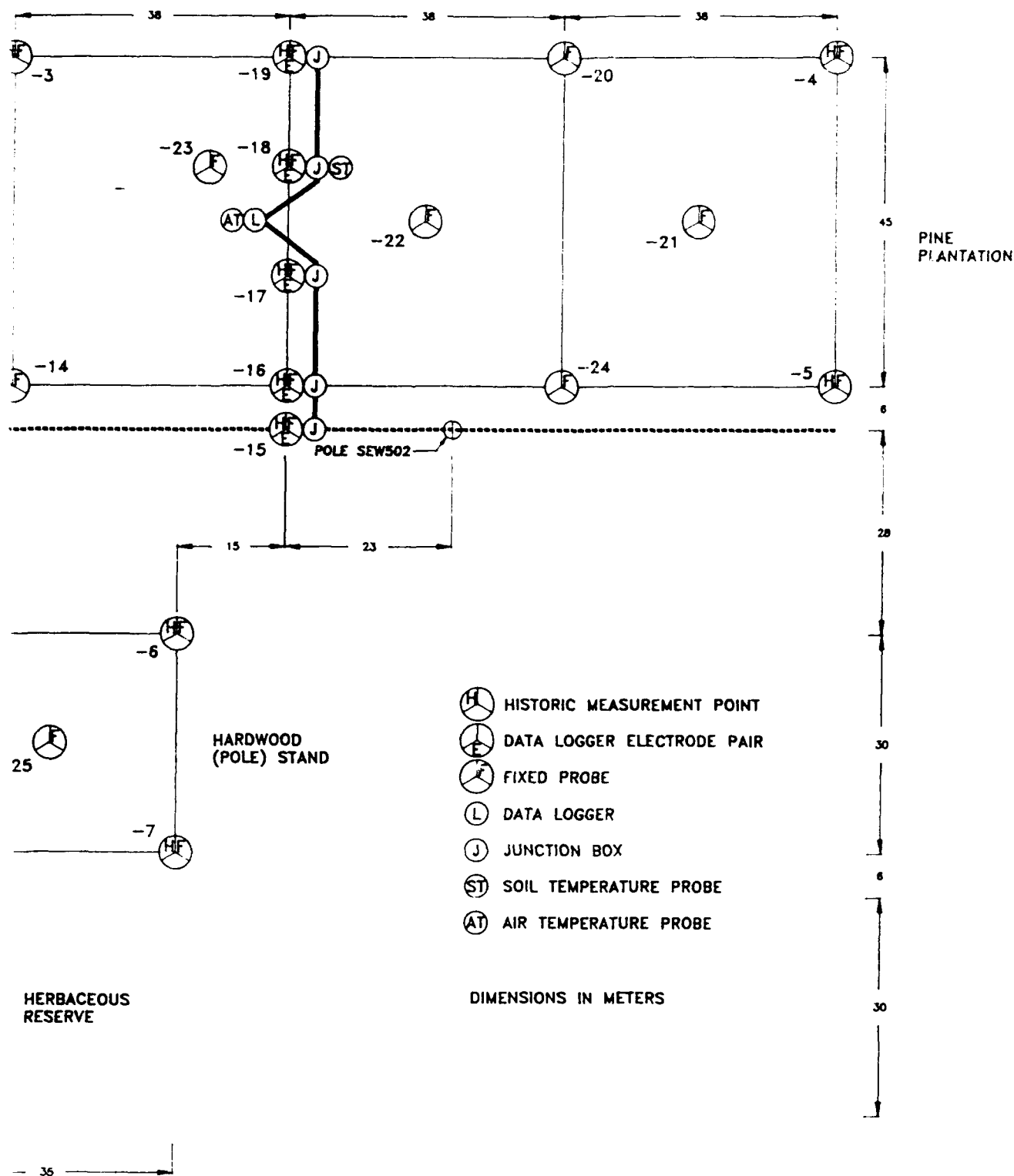


FIGURE D-3. HISTORIC AND FIXED MEASUREMENT POINT



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



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

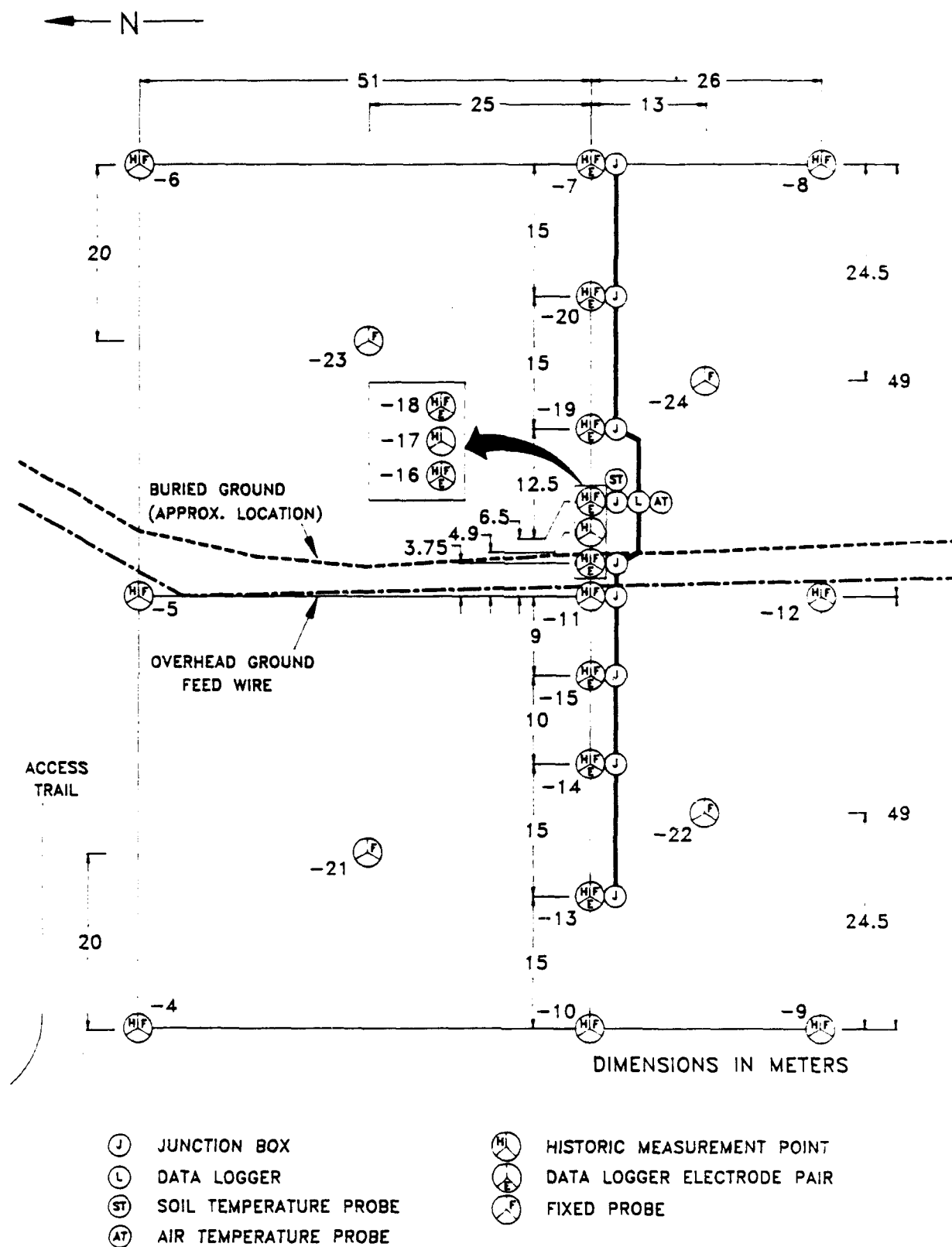


FIGURE D-4. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTELL'S LAKE (BURIED): EP; 4T4-4 THROUGH 24.

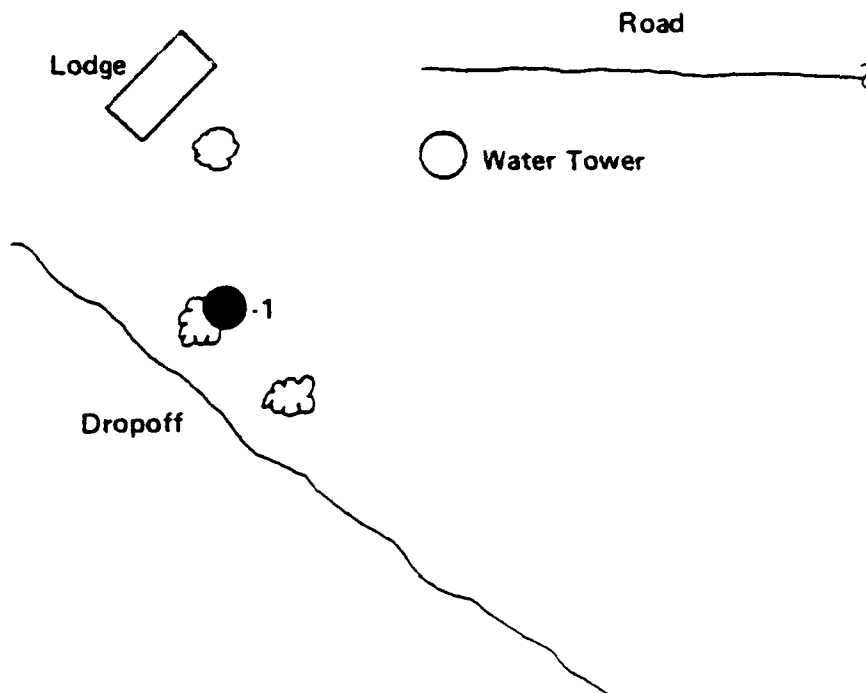
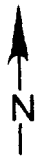


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF COLLECTION SITE; 4S1-1.

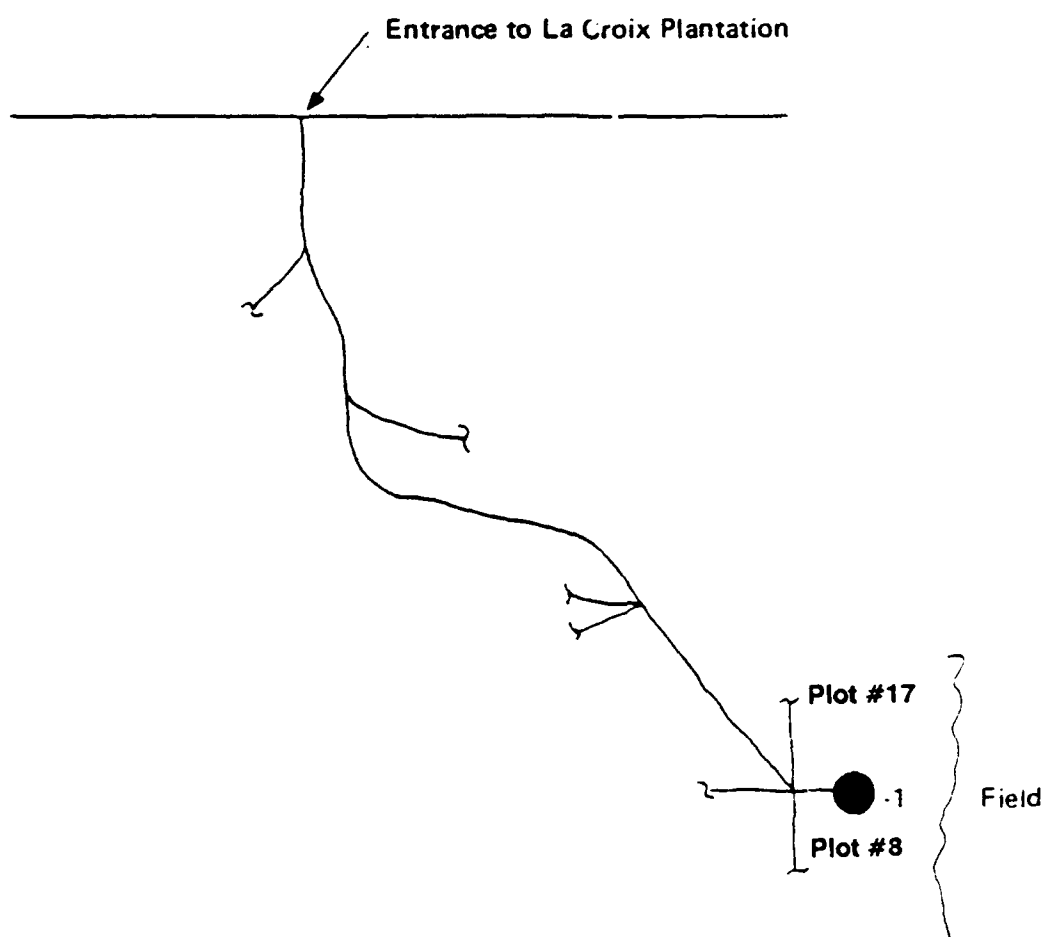


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE COLLECTION SITE; 4S3-1.

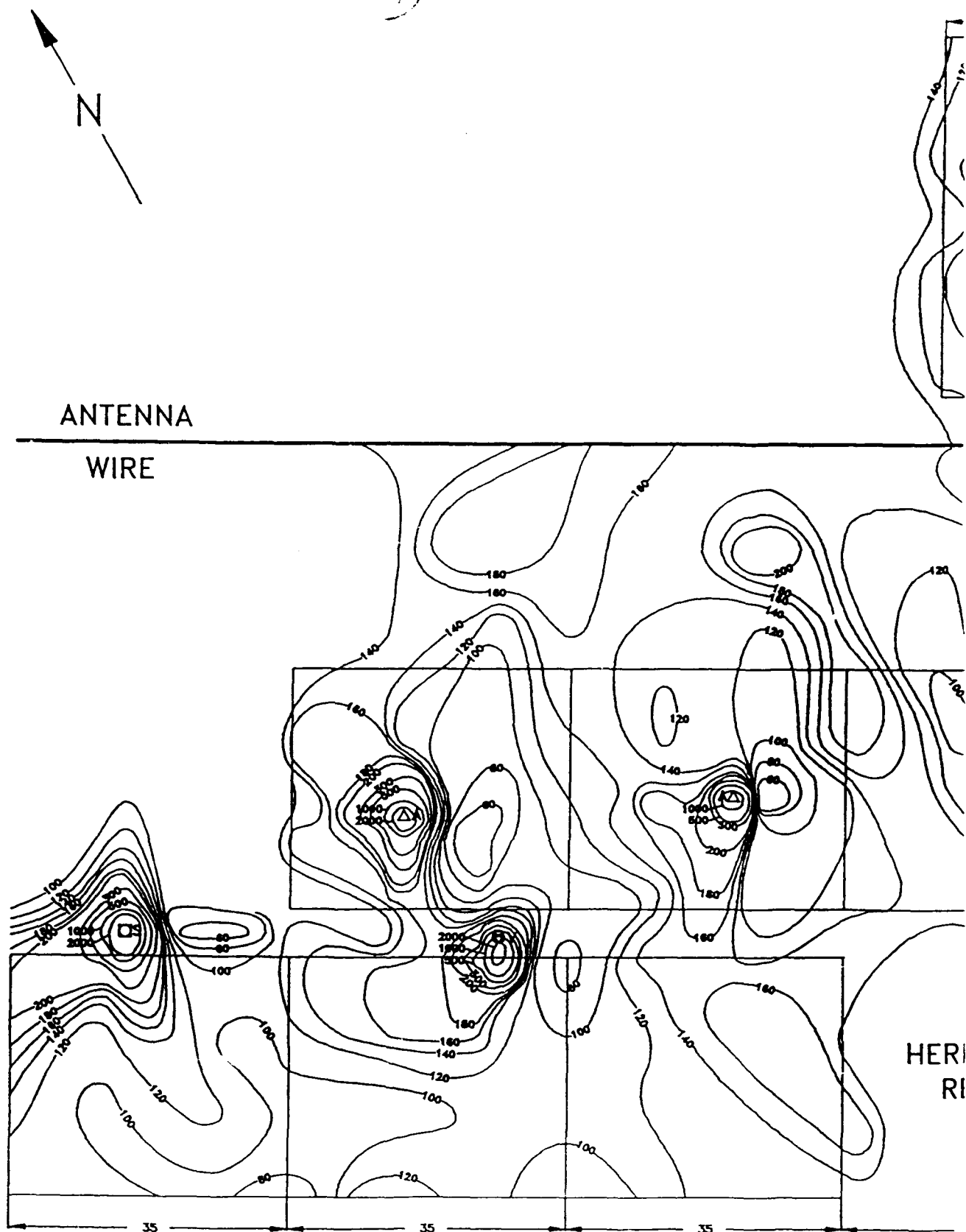


FIGURE D-7. EARTH ELECTRIC FIELD CONTOU

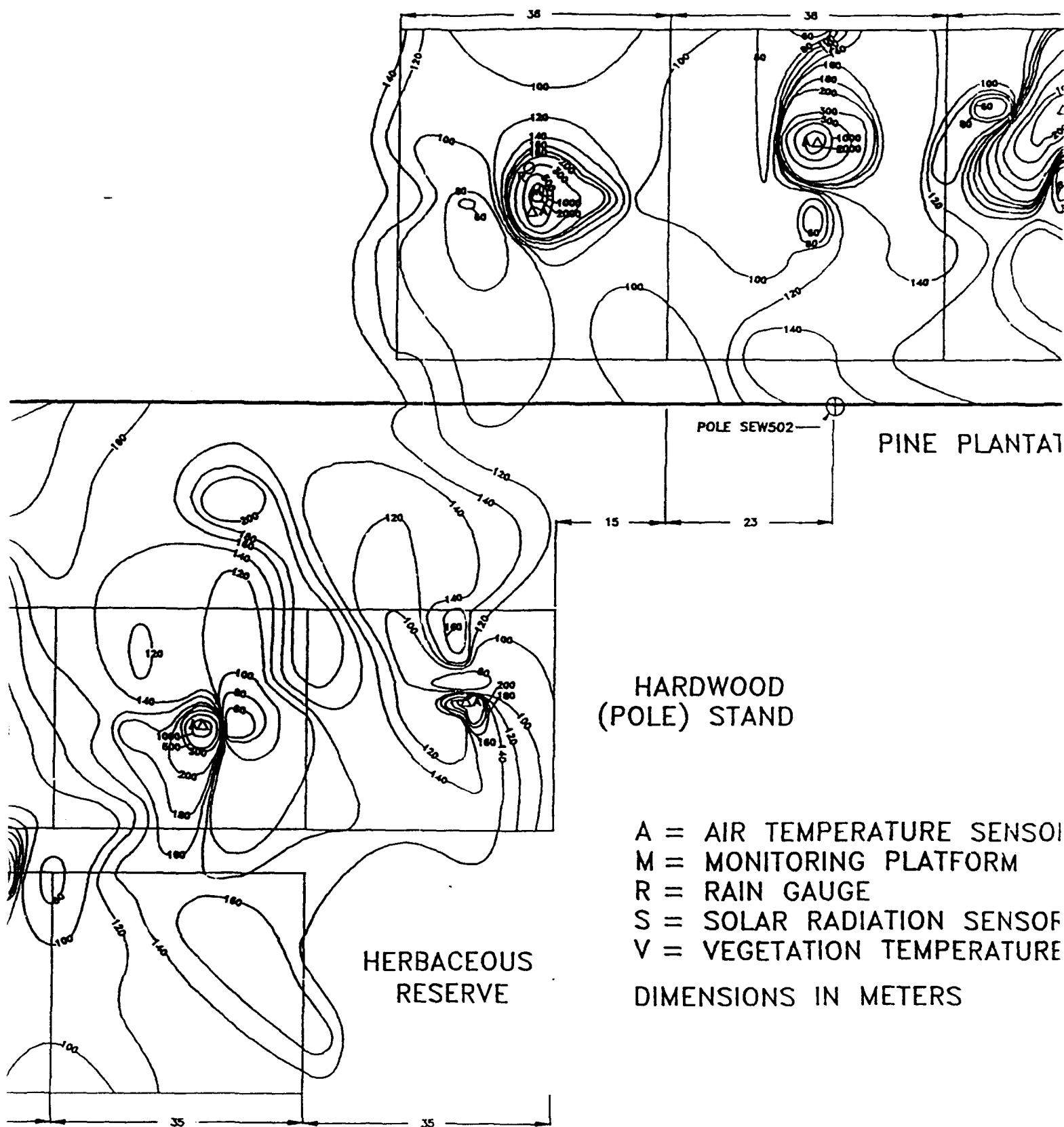


FIGURE D-7. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.

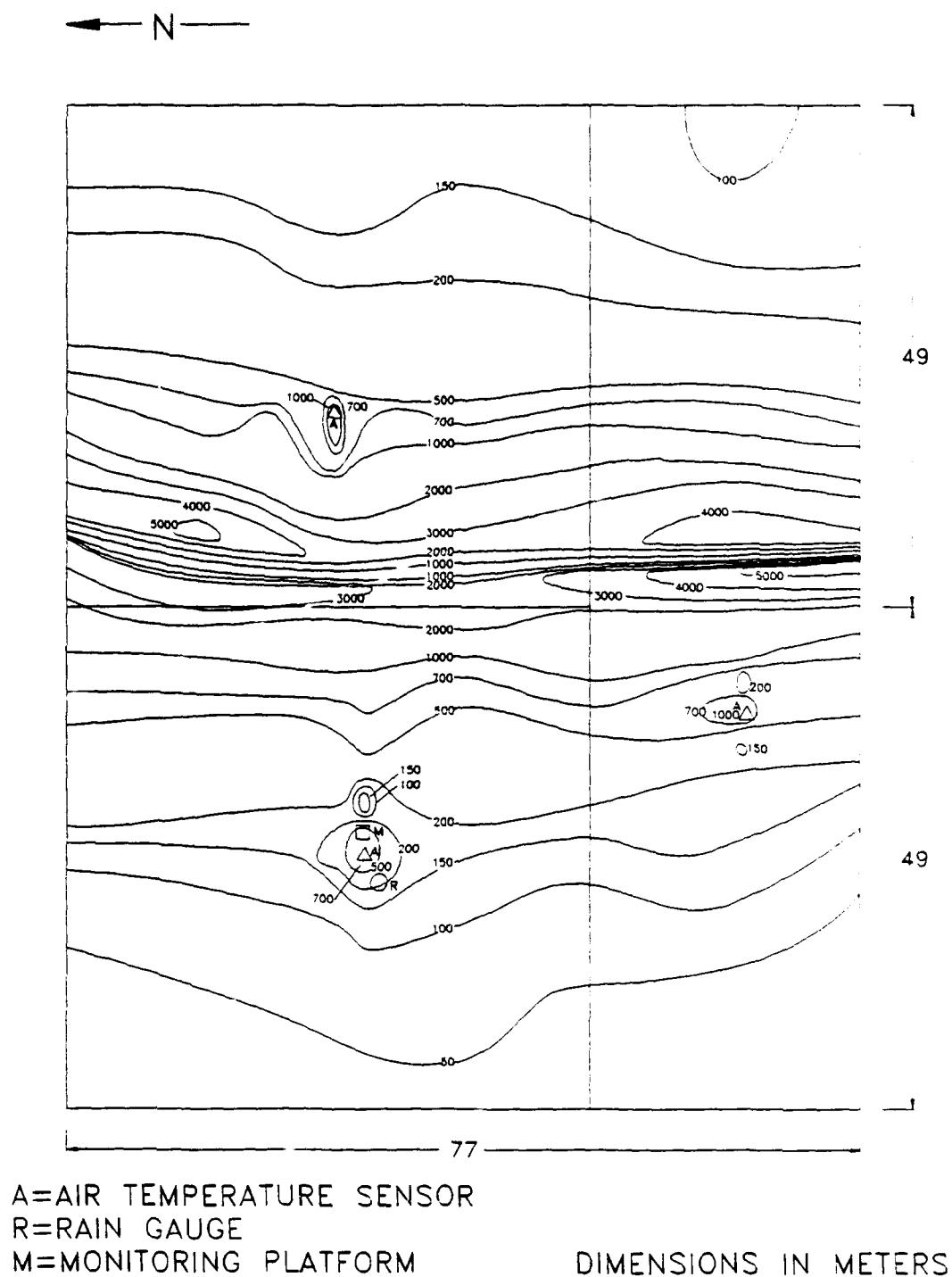


FIGURE D-8. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (BURIED):
EP; JUNE 1990.

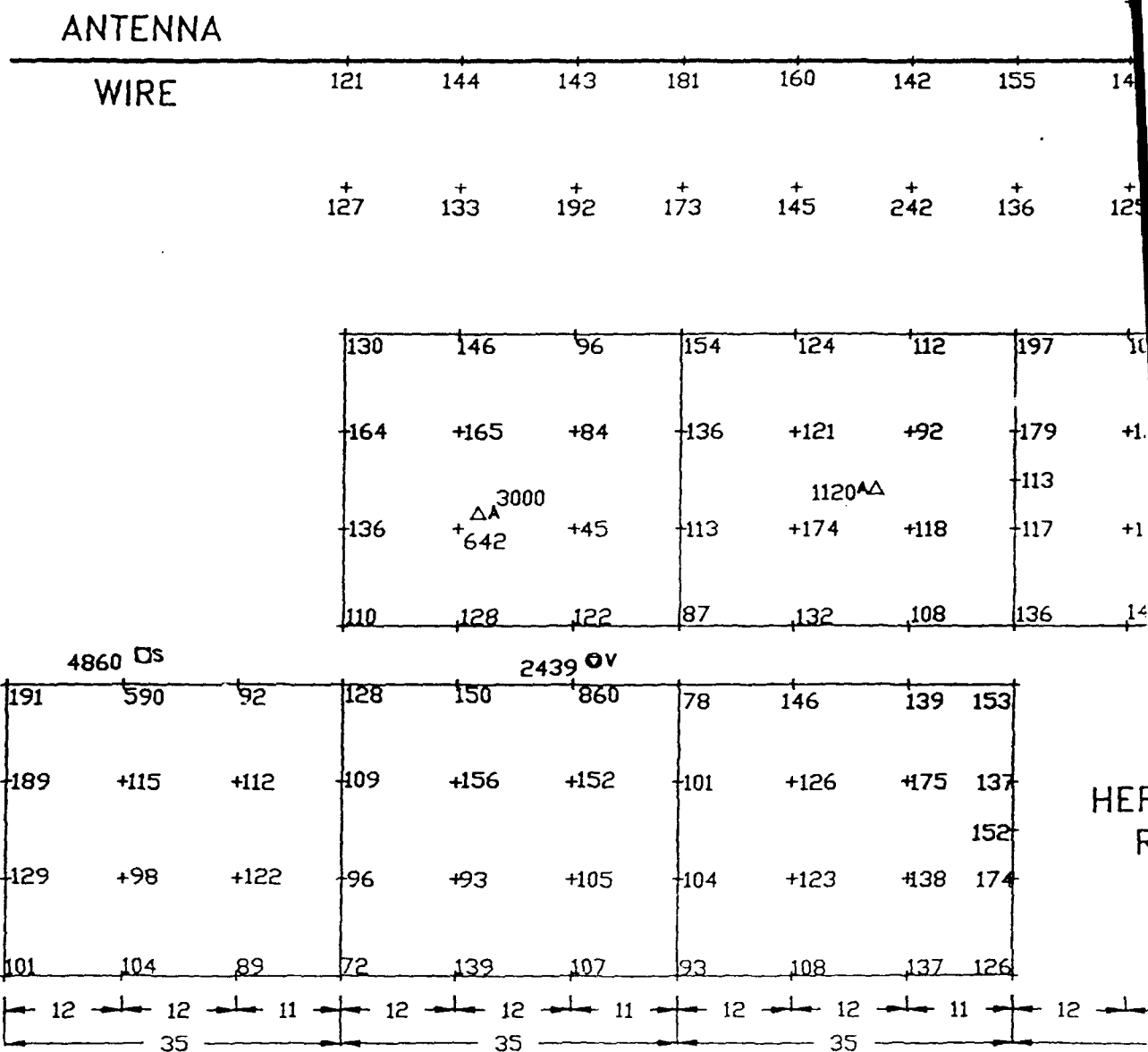
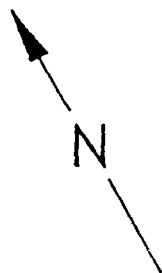


FIGURE D-9. EARTH ELECTRIC FIELD SURV

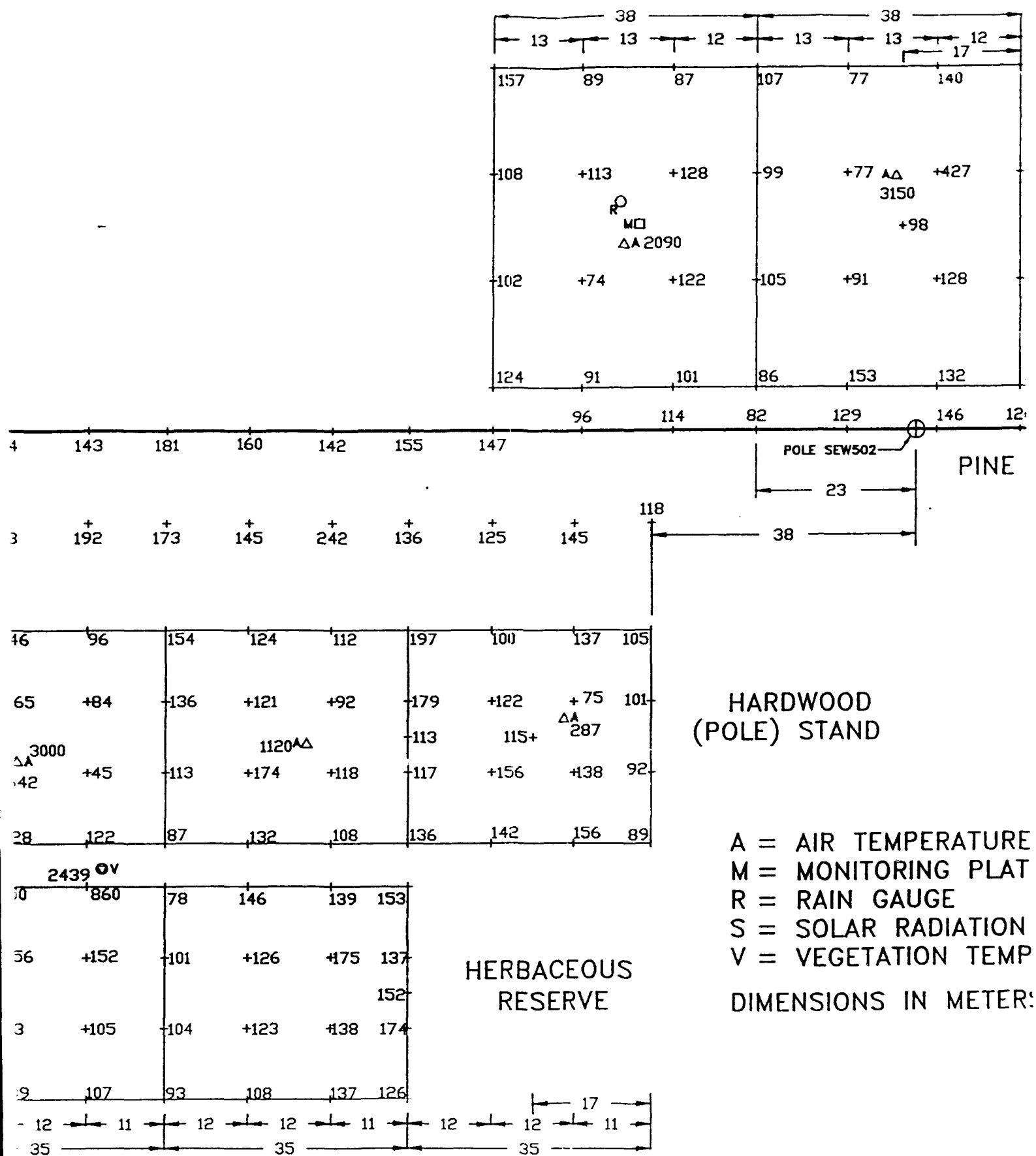
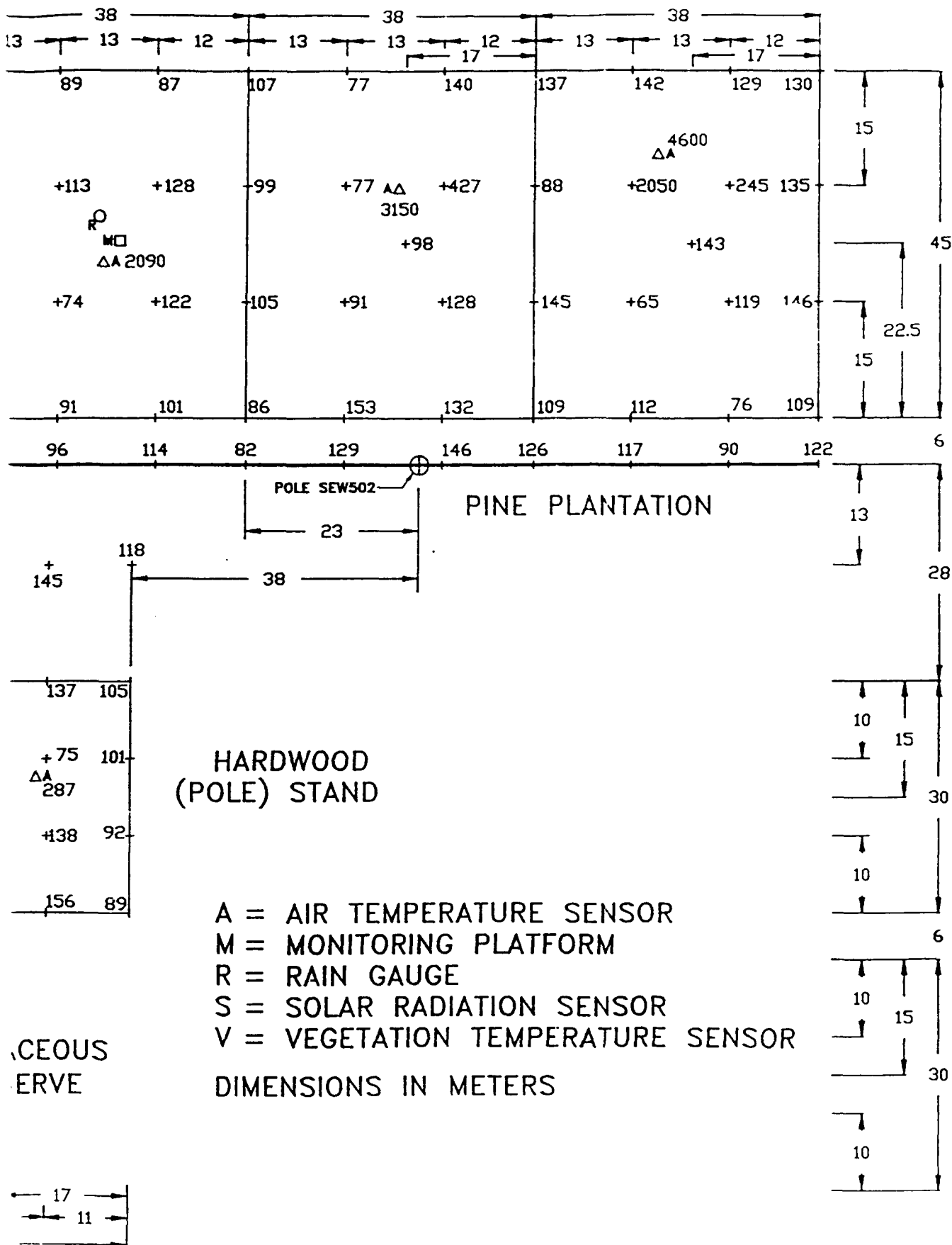
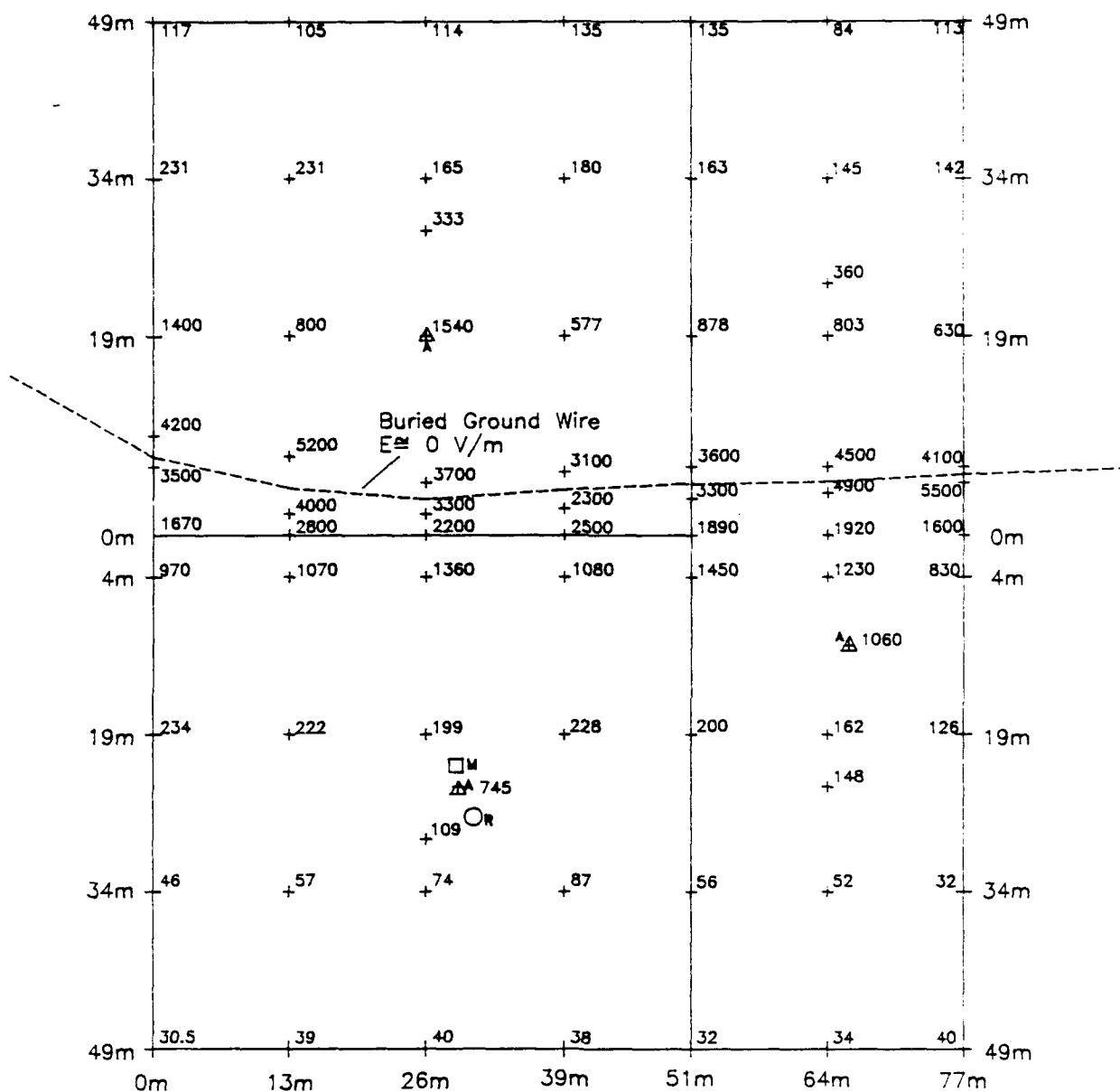


FIGURE D-9. EARTH ELECTRIC FIELD SURVEY (mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.



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
4C1-6	-	0.003	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-7	-	0.006	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-8	-	0.004	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-9	-	0.002	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-10	-	-	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-11	-	-	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-12	-	-	<	<	<	<	< ^d	< ^b	< ^d	/
4C1-13	-	-	<	<	<	<	< ^d	< ^b	< ^d	/
4T2-3	-	0.001	<	<	<	0.002	# ^d	# ^d	/	< ^b
4T2-4	-	-	<	<	<	0.001	# ^d	# ^d	/	< ^b
4T2-5	-	-	<	<	<	0.011	# ^d	# ^d	/	< ^b
4T2-6	-	-	<	<	<	<0.001	# ^d	# ^d	/	< ^b
4T2-7	-	-	<	<	<	<0.001	# ^d	# ^d	/	< ^b
4T2-8	-	-	<	<	<	/	# ^d	# ^d	/	< ^b
4T2-9	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T2-10	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T2-11	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T2-12	-	-	<	<	<	/	# ^d	# ^d	/	< ^b
4T2-13	-	-	<	<	<	<0.001	# ^d	# ^d	/	< ^b
4T2-14	-	-	<	<	<	0.011	# ^d	# ^d	/	<0.001 ^b
4T2-15	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T2-16	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T2-17	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T2-18	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T2-19	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T2-26	-	-	-	-	-	-	-	# ^d	/	< ^b
4T2-33	-	-	-	-	-	-	-	# ^d	/	< ^b
4T2-34	-	-	-	-	-	-	-	# ^d	/	< ^b
4T2-35	-	-	-	-	-	-	-	# ^d	/	< ^b
4T2-36	-	-	-	-	-	-	-	# ^d	/	< ^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
4T4-4	-	0.003	<	<	<0.001	<0.001	# ^d	# ^d	/	< ^b
4T4-5	-	-	<	<	0.006	0.003	# ^d	# ^d	/	< ^b
4T4-6	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T4-7	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T4-8	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T4-9	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T4-10	-	-	<	<	<	<	# ^d	# ^d	/	< ^b
4T4-11	-	-	<	<	0.010	0.009	# ^d	# ^d	/	< ^b
4T4-12	-	-	-	<	0.005	0.007	# ^d	# ^d	/	< ^b
4T4-13	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-14	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-15	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-16	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-17	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-18	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-19	-	-	-	-	-	-	# ^d	# ^d	/	< ^b
4T4-20	-	-	-	-	-	-	# ^d	# ^d	/	< ^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 A current.

* = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation
< = measurement est. <0.001 V/m based on earth 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
4C1-6	-	0.022	0.016	0.005	0.043	0.023	0.016 ^d	0.024 ^b	0.012 ^d	1.51 ^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
4C1-8	-	0.104	0.117	0.077	0.131	0.078	0.018 ^d	0.063 ^b	0.020 ^d	6.1 ^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
4C1-10	-	-	0.090	0.068	0.118	0.106	0.054 ^d	0.041 ^b	0.030 ^d	7.5 ^d
4C1-11	-	-	0.160	0.107	0.132	0.146	0.066 ^d	0.066 ^b	0.048 ^d	9.1 ^d
4C1-12	-	-	0.104	0.101	0.075	0.093	0.042 ^d	0.042 ^b	0.033 ^d	4.2 ^d
4C1-13	-	-	0.040	0.030	0.046	0.065	0.025 ^d	0.039 ^b	0.014 ^d	2.9 ^d
4T2-3	-	0.51	0.39	0.194	0.27	0.28	# ^d	# ^d	0.52 ^b	0.20 ^b
4T2-4	-	-	0.27	0.24	0.30	0.25	# ^d	# ^d	0.59 ^b	0.24 ^b
4T2-5	-	-	0.43	0.32	0.20	0.20	# ^d	# ^d	0.77 ^b	0.25 ^b
4T2-6	-	-	0.66	0.46	0.192	0.22	# ^d	# ^d	0.84 ^b	0.30 ^b
4T2-7	-	-	0.42	0.52	0.197	0.28	# ^d	# ^d	0.71 ^b	0.22 ^b
4T2-8	-	-	0.47	0.190	0.22	/	# ^d	# ^d	0.79 ^b	0.24 ^b
4T2-9	-	-	0.49	0.31	0.183	0.25	# ^d	# ^d	0.62 ^b	0.23 ^b
4T2-10	-	-	0.44	0.32	0.155	0.166	# ^d	# ^d	0.71 ^b	0.25 ^b
4T2-11	-	-	0.51	0.40	0.31	0.43	# ^d	# ^d	0.72 ^b	0.34 ^b
4T2-12	-	-	0.47	0.38	0.24	/	# ^d	# ^d	0.73 ^b	0.28 ^b
4T2-13	-	-	0.76	0.31	0.31	0.25	# ^d	# ^d	0.87 ^b	0.27 ^b
4T2-14	-	-	0.61	0.29	0.35	0.21	# ^d	# ^d	0.78 ^b	0.28 ^b
4T2-15	-	-	-	-	-	-	# ^d	# ^d	1.01 ^b	0.35 ^b
4T2-16	-	-	-	-	-	-	# ^d	# ^d	0.66 ^b	0.23 ^b
4T2-17	-	-	-	-	-	-	# ^d	# ^d	0.93 ^b	0.173 ^b
4T2-18	-	-	-	-	-	-	# ^d	# ^d	0.73 ^b	0.158 ^b
4T2-19	-	-	-	-	-	-	# ^d	# ^d	0.64 ^b	0.25 ^b
4T2-26	-	-	-	-	-	-	-	# ^d	0.61 ^b	0.26 ^b
4T2-33	-	-	-	-	-	-	-	# ^d	0.75 ^b	0.27 ^b
4T2-34	-	-	-	-	-	-	-	# ^d	0.81 ^b	0.28 ^b
4T2-35	-	-	-	-	-	-	-	# ^d	0.73 ^b	0.26 ^b
4T2-36	-	-	-	-	-	-	-	# ^d	0.60 ^b	0.30 ^b

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
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Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989	1990	1991	1992
4T4-4	-	0.72	0.42	0.185	0.56	0.079	# ^d	# ^d	0.40 ^b	0.30 ^b
4T4-5	-	-	0.58	0.58	4.3	1.12	# ^d	# ^d	3.1 ^b	3.2 ^b
4T4-6	-	-	0.22	0.16	0.61	0.188	# ^d	# ^d	0.35 ^b	0.45 ^b
4T4-7	-	-	0.44	0.29	0.64	0.22	# ^d	# ^d	0.28 ^b	0.32 ^b
4T4-8	-	-	0.42	0.193	0.40	0.23	# ^d	# ^d	0.27 ^b	0.28 ^b
4T4-9	-	-	0.50	0.21	0.27	0.073	# ^d	# ^d	0.31 ^b	0.36 ^b
4T4-10	-	-	0.42	0.22	0.29	0.063	# ^d	# ^d	0.23 ^b	0.28 ^b
4T4-11	-	-	0.40	0.60	2.7	1.27	# ^d	# ^d	4.1 ^b	3.8 ^b
4T4-12	-	-	-	0.75	3.4	1.35	# ^d	# ^d	0.34 ^b	2.2 ^b
4T4-13	-	-	-	-	-	-	# ^d	# ^d	0.22 ^b	0.26 ^b
4T4-14	-	-	-	-	-	-	# ^d	# ^d	0.53 ^b	0.78 ^b
4T4-15	-	-	-	-	-	-	# ^d	# ^d	1.29 ^b	1.86 ^b
4T4-16	-	-	-	-	-	-	# ^d	# ^d	4.4 ^b	4.8 ^b
4T4-17	-	-	-	-	-	-	# ^d	# ^d	/	2.1 ^b
4T4-18	-	-	-	-	-	-	# ^d	# ^d	4.6 ^b	4.7 ^b
4T4-19	-	-	-	-	-	-	# ^d	# ^d	1.17 ^b	1.02 ^b
4T4-20	-	-	-	-	-	-	# ^d	# ^d	0.27 ^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 A 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
4C1-6	-	0.003	0.003	0.003	0.002	0.003	0.002 ^d	0.002 ^b	0.001 ^d	0.28 ^d
4C1-7	-	0.003	0.002	0.001	0.003	0.002	0.001 ^d	0.002 ^b	0.001 ^d	0.25 ^d
4C1-8	-	0.003	0.003	0.002	0.003	0.002	0.001 ^d	0.002 ^b	0.002 ^d	0.24 ^d
4C1-9	-	0.003	0.003	0.002	0.001	0.002	0.002 ^d	0.002 ^b	0.001 ^d	0.29 ^d
4C1-10	-	-	0.002	0.002	0.002	0.002	0.002 ^d	0.002 ^b	0.001 ^d	0.22 ^d
4C1-11	-	-	0.002	0.002	0.002	0.002	0.001 ^d	0.002 ^b	0.001 ^d	0.23 ^d
4C1-12	-	-	0.002	0.003	0.001	0.002	0.001 ^d	0.002 ^b	0.001 ^d	0.26 ^d
4C1-13	-	-	0.002	0.003	0.001	0.003	0.002 ^d	0.002 ^b	0.001 ^d	0.30 ^d
4T2-3	-	0.002	0.001	0.001	0.003	0.005	# ^d	# ^d	0.004 ^b	0.002 ^b
4T2-4	-	-	0.001	0.001	0.003	0.006	# ^d	# ^d	0.005 ^b	0.002 ^b
4T2-5	-	-	0.001	0.007	0.017	0.030	# ^d	# ^d	0.029 ^b	0.004 ^b
4T2-6	-	-	0.001	0.006	0.006	0.014	# ^d	# ^d	0.017 ^b	0.001 ^b
4T2-7	-	-	0.001	0.004	0.004	0.007	# ^d	# ^d	0.010 ^b	0.001 ^b
4T2-8	-	-	0.001	0.002	0.004	/	# ^d	# ^d	0.010 ^b	0.001 ^b
4T2-9	-	-	0.001	0.003	0.003	0.005	# ^d	# ^d	0.007 ^b	0.001 ^b
4T2-10	-	-	0.001	0.003	0.003	0.005	# ^d	# ^d	0.007 ^b	0.001 ^b
4T2-11	-	-	0.001	0.004	0.005	0.007	# ^d	# ^d	0.009 ^b	0.002 ^b
4T2-12	-	-	0.002	0.004	0.005	/	# ^d	# ^d	0.010 ^b	0.002 ^b
4T2-13	-	-	0.001	0.005	0.008	0.013	# ^d	# ^d	0.016 ^b	0.002 ^b
4T2-14	-	-	0.002	0.011	0.018	0.029	# ^d	# ^d	0.035 ^b	0.004 ^b
4T2-15	-	-	-	-	-	-	# ^d	# ^d	0.043 ^b	0.005 ^b
4T2-16	-	-	-	-	-	-	# ^d	# ^d	0.033 ^b	0.004 ^b
4T2-17	-	-	-	-	-	-	# ^d	# ^d	0.016 ^b	0.003 ^b
4T2-18	-	-	-	-	-	-	# ^d	# ^d	0.009 ^b	0.002 ^b
4T2-19	-	-	-	-	-	-	# ^d	# ^d	0.004 ^b	0.002 ^b
4T2-26	-	-	-	-	-	-	# ^d	# ^d	0.015 ^b	0.001 ^b
4T2-33	-	-	-	-	-	-	# ^d	# ^d	0.008 ^b	0.001 ^b
4T2-34	-	-	-	-	-	-	# ^d	# ^d	0.012 ^b	0.001 ^b
4T2-35	-	-	-	-	-	-	# ^d	# ^d	0.030 ^b	0.001 ^b
4T2-36	-	-	-	-	-	-	# ^d	# ^d	0.042 ^b	0.003 ^b

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
4T4-4	-	0.004	0.002	0.001	0.003	0.003	# ^d	# ^d	0.003 ^b	0.002 ^b
4T4-5	-	-	0.002	0.006	0.010	0.017	# ^d	# ^d	0.008 ^b	0.008 ^b
4T4-6	-	-	0.002	0.001	0.004	0.007	# ^d	# ^d	0.002 ^b	0.003 ^b
4T4-7	-	-	0.001	0.001	0.004	0.005	# ^d	# ^d	0.002 ^b	0.003 ^b
4T4-8	-	-	0.002	0.001	0.004	0.005	# ^d	# ^d	0.002 ^b	0.003 ^b
4T4-9	-	-	0.002	0.001	0.002	0.003	# ^d	# ^d	0.001 ^b	0.002 ^b
4T4-10	-	-	0.001	0.001	0.002	0.002	# ^d	# ^d	0.001 ^b	0.002 ^b
4T4-11	-	-	0.002	0.002	0.002	0.019	# ^d	# ^d	0.008 ^b	0.010 ^b
4T4-12	-	-	-	0.002	0.010	0.016	# ^d	# ^d	0.006 ^b	0.008 ^b
4T4-13	-	-	-	-	-	-	# ^d	# ^d	0.001 ^b	0.002 ^b
4T4-14	-	-	-	-	-	-	# ^d	# ^d	0.001 ^b	0.003 ^b
4T4-15	-	-	-	-	-	-	# ^d	# ^d	0.003 ^b	0.005 ^b
4T4-16	-	-	-	-	-	-	# ^d	# ^d	0.012 ^b	0.015 ^b
4T4-17	-	-	-	-	-	-	# ^d	# ^d	0.013 ^b	0.016 ^b
4T4-18	-	-	-	-	-	-	# ^d	# ^d	0.009 ^b	0.011 ^b
4T4-19	-	-	-	-	-	-	# ^d	# ^d	0.003 ^b	0.005 ^b
4T4-20	-	-	-	-	-	-	# ^d	# ^d	0.002 ^b	0.004 ^b
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 = antenna off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A 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., Meas. Pt.	1986					1987		1988		1989	1990		1991		1992
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	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	0.007	0.002	0.014	0.006	0.125	0.142	0.110	0.047	0.122	0.195	0.23
4T2-4	<	<	0.005	0.008	0.008	0.001	0.014	0.017	0.113	0.149	0.122	0.041	0.095	0.23	0.23
4T2-5	0.018	<	0.092	0.153	0.153	0.003	0.23	0.033	2.6	1.31	1.16	0.30	1.08	3.5	3.5
4T2-6	<	<	0.005	0.008	0.008	0.003	0.013	0.014	0.142	0.138	0.148	0.051	0.123	0.23	0.23
4T2-7	<	<	0.007	0.012	0.012	0.001	0.018	0.020	0.165	0.173	0.177	0.044	0.150	0.20	0.20
4T2-8	<	<	0.004	0.007	0.007	0.002	0.012	/	/	0.124	0.112	0.045	0.103	0.123	0.123
4T2-9	<	<	0.005	0.008	0.008	0.002	0.010	0.019	0.137	0.116	0.119	0.031	0.110	0.128	0.128
4T2-10	<	<	0.004	0.007	0.007	0.002	0.011	0.020	0.112	0.113	0.076	0.034	0.112	0.189	0.189
4T2-11	<	<	0.003	0.005	0.005	0.002	0.012	0.010	0.130	0.22	0.180	0.042	0.132	0.28	0.28
4T2-12	<	<	0.002	0.003	0.003	0.002	0.014	/	/	0.095	0.096	0.041	0.086	0.105	0.105
4T2-13	<	<	0.005	0.008	0.008	0.002	0.012	0.010	0.121	0.125	0.130	0.036	0.125	0.21	0.21
4T2-14	0.030	<	0.155	0.26	0.26	0.003	0.166	0.026	2.5	1.66	1.94	0.23	1.68	3.7	3.7
4T2-15	-	-	-	-	-	-	-	-	-	2.3	1.67	0.32	0.58	1.82	1.82
4T2-16	-	-	-	-	-	-	-	-	-	1.92	1.84	0.46	1.17	0.89	0.89
4T2-17	-	-	-	-	-	-	-	-	-	0.69	0.59	0.075	0.27	0.73	0.73
4T2-18	-	-	-	-	-	-	-	-	-	0.28	0.21	0.039	0.152	0.24	0.24
4T2-19	-	-	-	-	-	-	-	-	-	0.107	0.105	0.029	0.092	0.20	0.20
4T2-26	-	-	-	-	-	-	-	-	-	-	0.182	0.059	0.136	0.23	0.23
4T2-33	-	-	-	-	-	-	-	-	-	-	0.141	0.042	0.146	0.23	0.23
4T2-34	-	-	-	-	-	-	-	-	-	-	0.144	0.041	0.129	0.22	0.22
4T2-35	-	-	-	-	-	-	-	-	-	-	0.24	0.101	0.38	1.82	1.82
4T2-36	-	-	-	-	-	-	-	-	-	-	4.7	0.94	4.7	8.1	8.1

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

Site No., Meas. Pt.	1986						1987		1988		1989	1990		1991		1992
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	EW 15 A	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A	NS 150 A	B 150 A	B 150 A	B 150 A
4T4-4	<	<	0.006	0.010	0.005	0.002	0.005	0.008	0.028	0.067	0.058	0.015	0.015	0.071	0.127	0.127
4T4-5	0.033	0.008	0.20	0.33	0.27	0.019	0.27	0.089	1.31	4.8	3.8	1.37	1.37	4.4	11	11
4T4-6	0.005	<	0.023	0.038	0.021	0.002	0.021	0.011	0.064	0.175	0.117	0.040	0.040	0.186	0.24	0.24
4T4-7	<	<	0.006	0.010	0.015	0.002	0.015	0.008	0.090	0.133	0.129	0.026	0.026	0.33	0.33	0.33
4T4-8	<	<	0.008	0.013	0.016	0.002	0.016	0.007	0.083	0.145	0.145	0.032	0.032	0.130	0.090	0.090
4T4-9	<	<	0.009	0.015	0.008	0.001	0.008	0.009	0.047	0.095	0.072	0.017	0.017	0.130	0.22	0.22
4T4-10	<	<	0.007	0.012	0.001	0.001	0.001	0.011	0.057	0.112	0.085	0.026	0.026	0.107	0.21	0.21
4T4-11	<	0.005	0.38	0.63	0.43	0.025	0.43	0.20	4.4	5.0	4.6	1.37	1.37	4.8	10.0	10.0
4T4-12	0.055	0.005	0.43	0.72	0.30	0.017	0.30	0.150	2.1	4.5	3.8	1.26	1.26	4.6	10.7	10.7
4T4-13	-	-	-	-	-	-	-	-	-	0.26	0.21	0.042	0.042	0.28	0.40	0.40
4T4-14	-	-	-	-	-	-	-	-	-	0.88	0.84	0.194	0.194	0.90	1.57	1.57
4T4-15	-	-	-	-	-	-	-	-	-	2.7	2.6	0.51	0.51	2.8	4.0	4.0
4T4-16	-	-	-	-	-	-	-	-	-	5.9	5.4	1.68	1.68	6.7	9.7	9.7
4T4-17	-	-	-	-	-	-	-	-	-	4.5	4.3	1.28	1.28	5.7	12.7	12.7
4T4-18	-	-	-	-	-	-	-	-	-	4.8	3.8	1.24	1.24	4.9	6.9	6.9
4T4-19	-	-	-	-	-	-	-	-	-	1.16	0.96	0.25	0.25	1.15	1.25	1.25
4T4-20	-	-	-	-	-	-	-	-	-	0.32	0.183	0.067	0.067	0.47	0.59	0.59
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.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
< = measurement est. <0.001 V/m based on earth E-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., Meas. Pt.	1986					1987			1988			1989		1990		1991		1992	
	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	NS 150 A	B 150 A	NS 150 A	B 150 A	NS 150 A	B 150 A	NS 150 A	B 150 A	NS 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	/	0.026	/	0.029
4C1-7	<0.001	<0.001	<0.001	*	0.005	0.006	0.024	0.023	0.091	/	0.085	/	0.079	/	0.096	/	0.079	/	0.096
4C1-8	<0.001	<0.001	<0.001	*	0.004	0.004	0.017	0.016	0.076	/	0.067	/	0.069	/	0.085	/	0.069	/	0.085
4C1-9	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.006	0.030	/	0.022	/	0.028	/	0.021	/	0.028	/	0.021
4C1-10	<0.001	<0.001	<0.001	*	0.005	0.004	0.026	0.023	0.087	/	0.079	/	0.089	/	0.095	/	0.089	/	0.095
4C1-11	<0.001	<0.001	<0.001	*	0.006	0.005	0.028	0.028	0.113	/	0.103	/	0.101	/	0.108	/	0.101	/	0.108
4C1-12	<0.001	<0.001	<0.001	*	0.004	0.003	0.016	0.016	0.068	/	0.072	/	0.053	/	0.063	/	0.053	/	0.063
4C1-13	<0.001	<0.001	<0.001	*	0.002	0.002	0.012	0.011	0.051	/	0.044	/	0.037	/	0.047	/	0.037	/	0.047
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2	7.7	76	131	22	140	22	126	44	142	22	126	44	142
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7	6.2	68	135	44	129	44	134	44	151	44	134	44	151
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7	8.2	62	86	41	105	41	123	41	142	41	123	41	142
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4	10.4	56	105	39	101	39	114	39	112	39	114	39	112
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7	8.8	71	90	28	89	28	94	28	89	28	94	28	89
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8	/	/	141	40	135	40	139	40	133	40	139	40	133
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7	7.1	63	119	40	125	40	121	40	133	40	121	40	133
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5	8.1	50	96	35	91	35	98	35	101	35	98	35	101
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7	9.6	122	182	38	170	38	155	38	178	38	155	38	178
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5	/	/	99	45	114	45	119	45	113	45	119	45	113
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9	8.2	71	138	36	144	36	142	36	145	36	142	36	145
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3	6.6	56	124	42	121	42	138	42	133	42	138	42	133
4T2-15	-	-	-	-	-	-	-	-	73	32	82	32	82	32	87	32	82	32	87
4T2-16	-	-	-	-	-	-	-	-	88	33	86	33	92	33	103	33	92	33	103
4T2-17	-	-	-	-	-	-	-	-	104	29	105	29	107	29	106	29	107	29	106
4T2-18	-	-	-	-	-	-	-	-	95	29	99	29	124	29	108	29	124	29	108
4T2-19	-	-	-	-	-	-	-	-	107	31	107	31	103	31	111	31	103	31	111
4T2-26	-	-	-	-	-	-	-	-	-	57	210	57	189	57	220	57	189	57	220
4T2-33	-	-	-	-	-	-	-	-	-	41	113	41	130	41	126	41	130	41	126
4T2-34	-	-	-	-	-	-	-	-	-	36	152	36	127	36	140	36	127	36	140
4T2-35	-	-	-	-	-	-	-	-	-	45	136	45	137	45	169	45	137	45	169
4T2-36	-	-	-	-	-	-	-	-	-	44	155	44	133	44	125	44	133	44	125

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

Site No., Meas. Pt.	1986						1987		1988		1989	1990		1991		1992
	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	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	2100	31	1670	10.2	25	1790	28
4T4-5	13.6	2.0	81.	135.	14.0	194.	68	910	2100	1670	1670	1740	510	1790	1740	1740
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9	10.3	62	140	117	117	152	29	141	152	152
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1	9.1	62	119	135	135	153	30	101	153	153
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7	6.8	65	106	113	113	113	31	111	113	113
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0	7.5	18.1	47	42	42	21	4.5	18	21	21
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9	5.1	16.0	39	43	43	29	8.1	30	29	29
4T4-11	0.59	1.82	89.	148.	10.7	178.	50	850	1870	1890	1890	2100	630	2200	2100	2100
4T4-12	21.	2.2	118.	197.	13.8	260.	40	760	1950	1600	1600	1550	380	1380	1550	1550
4T4-13	-	-	-	-	-	-	-	-	64	56	56	66	15.2	59	66	66
4T4-14	-	-	-	-	-	-	-	-	220	200	200	290	59	320	290	290
4T4-15	-	-	-	-	-	-	-	-	760	760	760	880	220	820	880	880
4T4-16	-	-	-	-	-	-	-	-	3000	3800	3800	3000	690	3300	3000	3000
4T4-17	-	-	-	-	-	-	-	-	130	30	30	0	/	/	0	0
4T4-18	-	-	-	-	-	-	-	-	3200	3600	3600	3400	1000	4100	3400	3400
4T4-19	-	-	-	-	-	-	-	-	750	880	880	930	196	880	930	930
4T4-20	-	-	-	-	-	-	-	-	200	163	163	210	49	200	210	210
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	/	/	/	/	/	/	/	/
4S2-1	-	-	-	-	0.005	0.005	0.026	0.026	0.126	0.103	0.103	0.096	/	0.097	0.096	0.096
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	/	/	/	/	/	/	/	/

- = measurement point not established.

/ = measurement not taken.

* = data cannot be extrapolated.

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.

A = amperes.

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

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

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

Site No., Meas. Pt.	1986					1987			1988			1989		1990		1991		1992	
	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	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			
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			
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			
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			
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			
4T4-9	0.025	0.21	0.118	0.197		0.005	0.29		0.027	1.41	2.8	2.7		0.79	2.8	3.0			
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			
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			
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			
4T4-13	-	-	-	-		-	-		-	-	2.7	3.8		1.12	4.0	4.1			
4T4-14	-	-	-	-		-	-		-	-	7.0	7.0		2.0	7.4	7.0			
4T4-15	-	-	-	-		-	-		-	-	11.9	12.0		3.4	11.5	12.1			
4T4-16	-	-	-	-		-	-		-	-	18	14.6		5.2	14.7	15.8			
4T4-17	-	-	-	-		-	-		-	-	14.3	13.6		4.3	13.8	14.9			
4T4-18	-	-	-	-		-	-		-	-	16.8	15.7		5.0	15.8	16.3			
4T4-19	-	-	-	-		-	-		-	-	9.8	9.1		2.8	9.7	10.3			
4T4-20	-	-	-	-		-	-		-	-	5.9	5.4		1.76	5.9	6.0			
4S1-1	-	-	-	-		<0.001	<0.001		<0.001	<0.001	/	/		/	/	/			
4S2-1	-	-	-	-		<0.001	<0.001		0.001	<0.001	0.002	0.001		/	0.002	0.002			
4S3-1	-	-	-	-		<0.001	<0.001		<0.001	<0.001	/	/		/	/	/			

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.

A = amperes.

- = measurement point not established.

/ = measurement not taken.

* = data cannot be extrapolated.

TABLE D-9. 1990 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points

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	135	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 LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Ground Site Fixed Test Points

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.
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 LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points

Test Point	Measurement Date															Summary Statistics*		
	NS Antenna Only															Mean	SD	Coeff. of Variab.
	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	
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	164	140	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	60	65	66	64	65	63	59	63 2.9 0.046
4T2-16	81	85	87	100	101	33	34			99	92	108	118	114	120		100	101 13.1 0.129
4T2-17										118	116	112	108	110	110	111	100	106 7.0 0.066
4T2-18												107	116	101	108	124	103	111 4.3 0.039
4T2-19	98	103	99	106	104	33	33					112	112	112	114	113	106	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

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

TABLE D-12. 1991 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Ground Site Fixed Test Points

Test Point	Measurement Date																	Summary Statistics*		
	NS Antenna Only																	Coeff. of Variab.		
	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/13	9/30	10/10	10/23	11/6	12/6	Mean	SD	
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	0.185
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	760	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-13. 1992 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points

Test Point	Measurement Date																Summary Statistics*		
	NS Antenna Only																Mean	SD	Coef. of Variab.
	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			
4T2-3	45	40	40	132	153	162	156	155	156	149	148	142	154	150	136	130	148	9.6	0.65
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

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

TABLE D-14. 1992 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Ground Site Fixed Test Points

Test Point	Measurement Date																	Summary Statistics*		
	NS Antenna Only																	Mean		Coeff. of Variab.
	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				
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	8.6	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	720	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	76		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.

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 1992, IITRI field crews made ELF electromagnetic (EM) field measurements at 16 measurement points within four treatment and five control sites for the aquatic ecosystems studies. The study sites and measurement points within those study sites were unchanged from 1991. Annual EM field measurement dates for 1992 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

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.

EM field measurements for 1992 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.

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

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 1992 (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 site.

Overall, the 60 Hz EM fields measured at both treatment and control study sites in 1992 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, and the ratios of 60 Hz EM fields between the treatment and control sites continue to meet exposure criteria guidelines established at the beginning of the study. One exception to this is the T-line crossing for the fish movement study, where the 60 Hz EM fields dominate the 76 Hz EM fields. Study protocol modifications to account for this inevitable EM field disparity were implemented in 1990 and are described in a previous report.*

The 76 Hz EM field measurements in 1992 were made with 150 ampere 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 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989 through 1992. 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 years during operation of both antennas. This period of single-antenna operation can therefore be treated as a full-exposure operation period.

* 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.

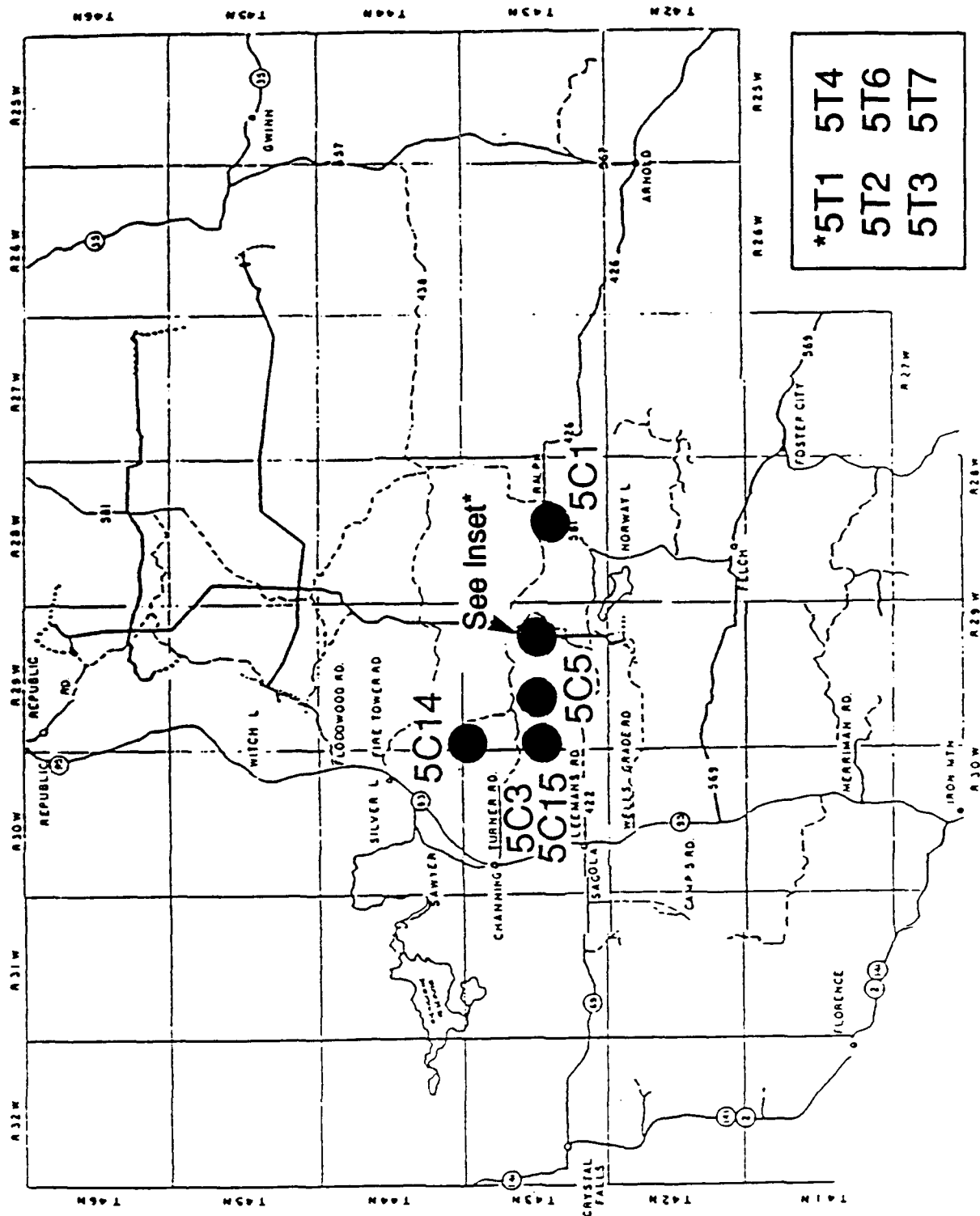


FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

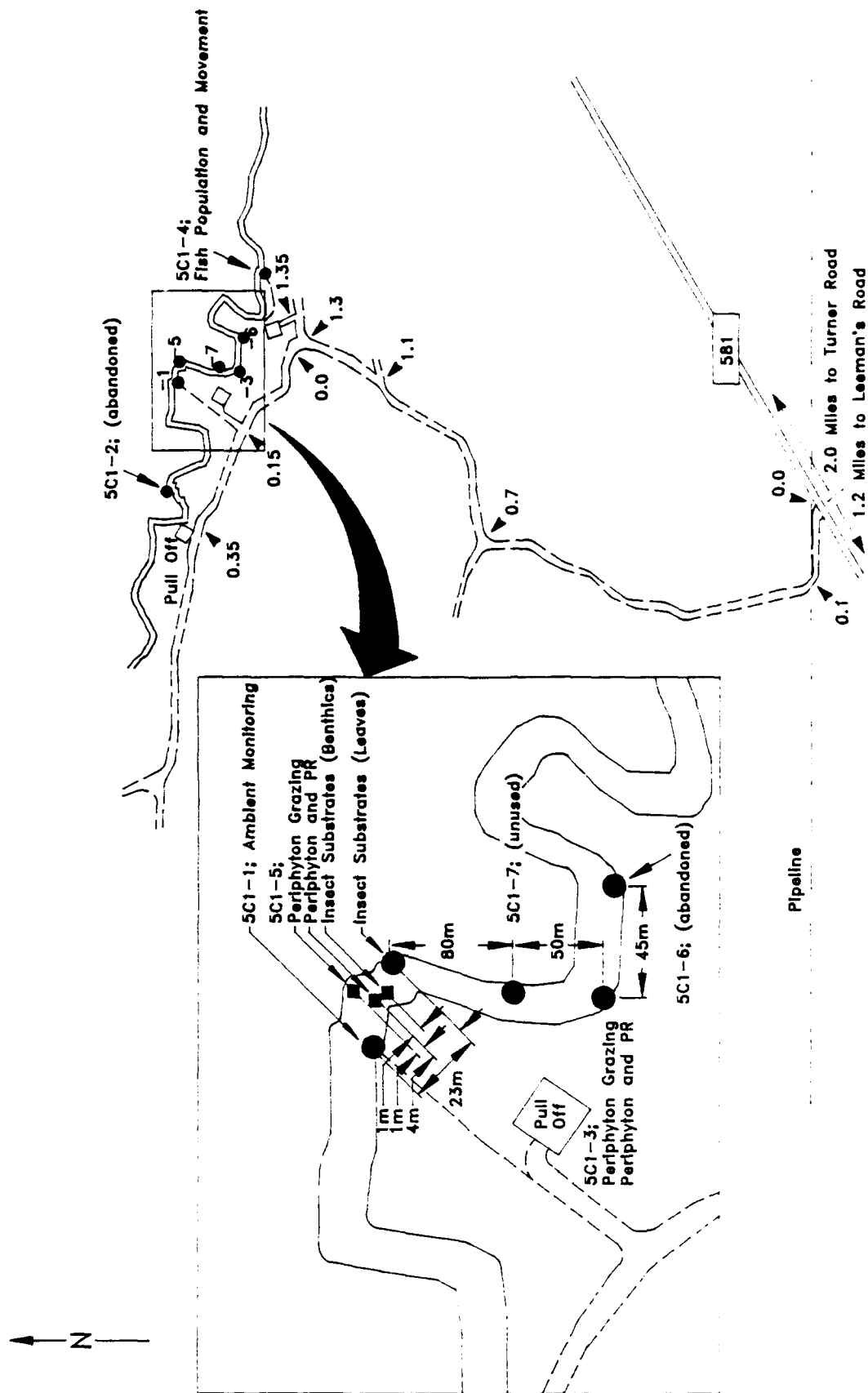
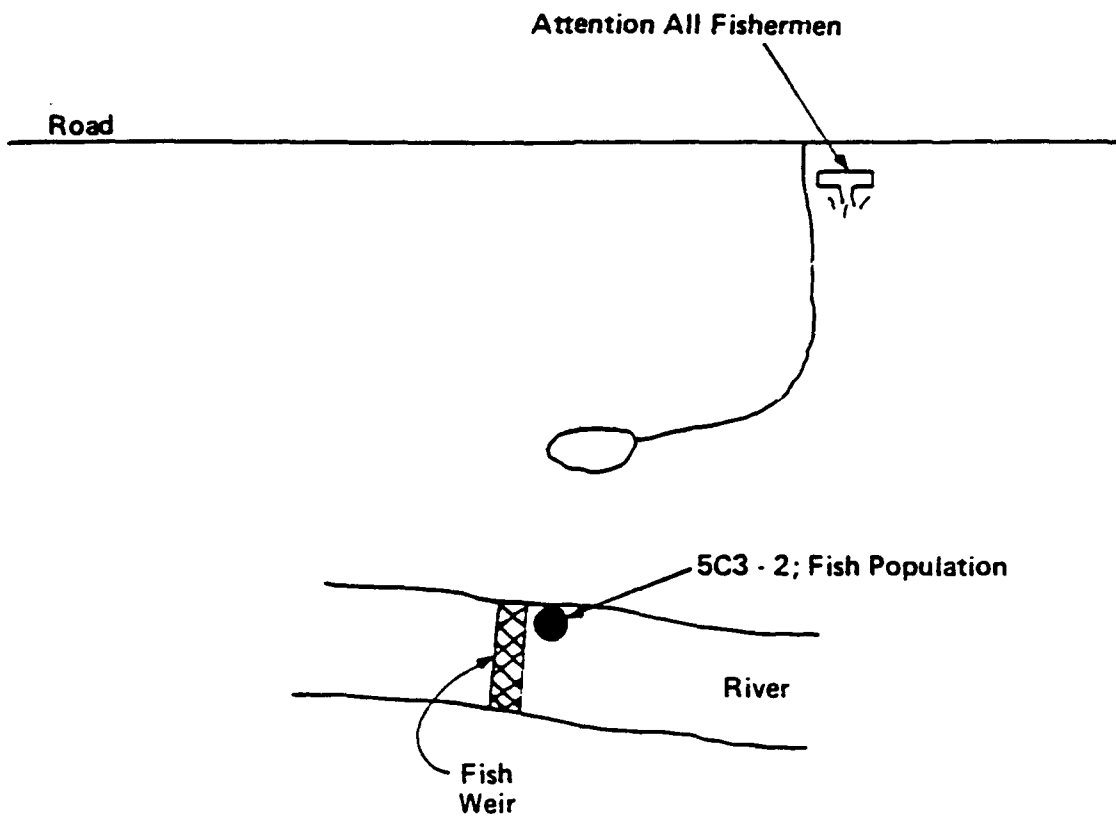
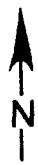
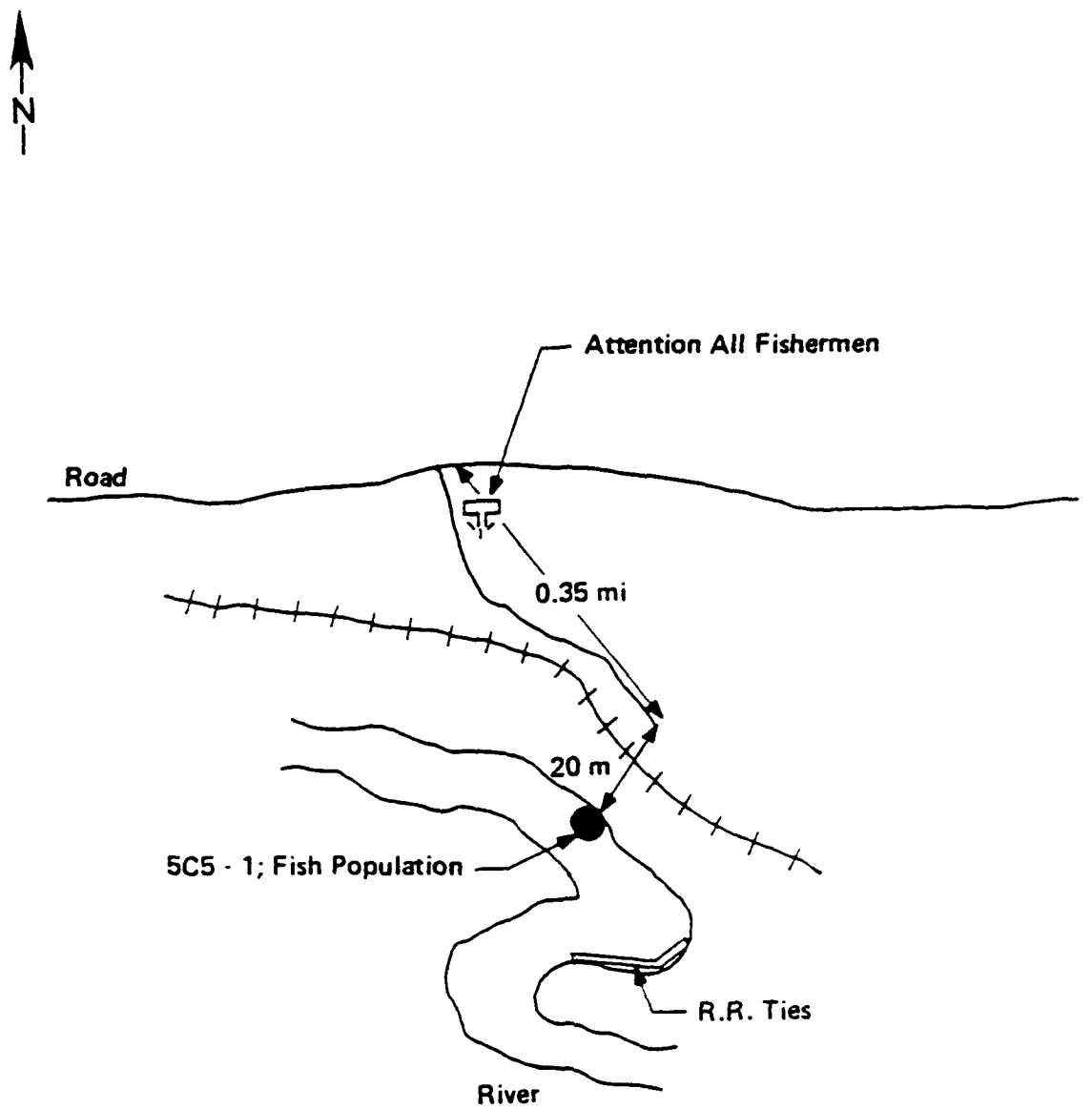


FIGURE E-2. MEASUREMENT POINTS AT FCD; SC1-1 THROUGH 7.



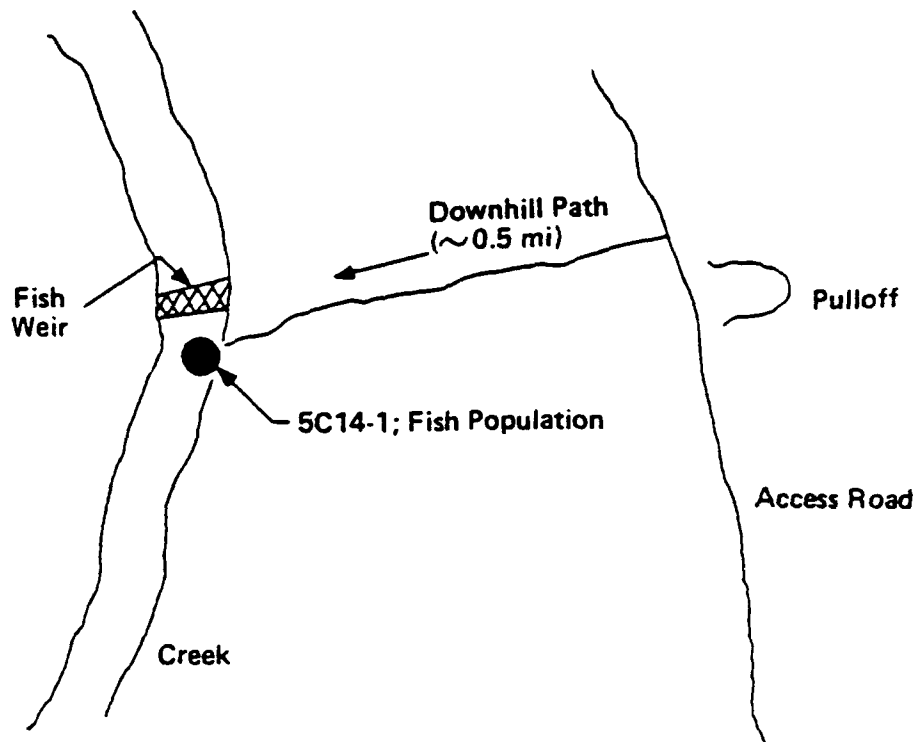
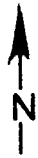
Not to Scale

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



Not to Scale

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



Not to Scale

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

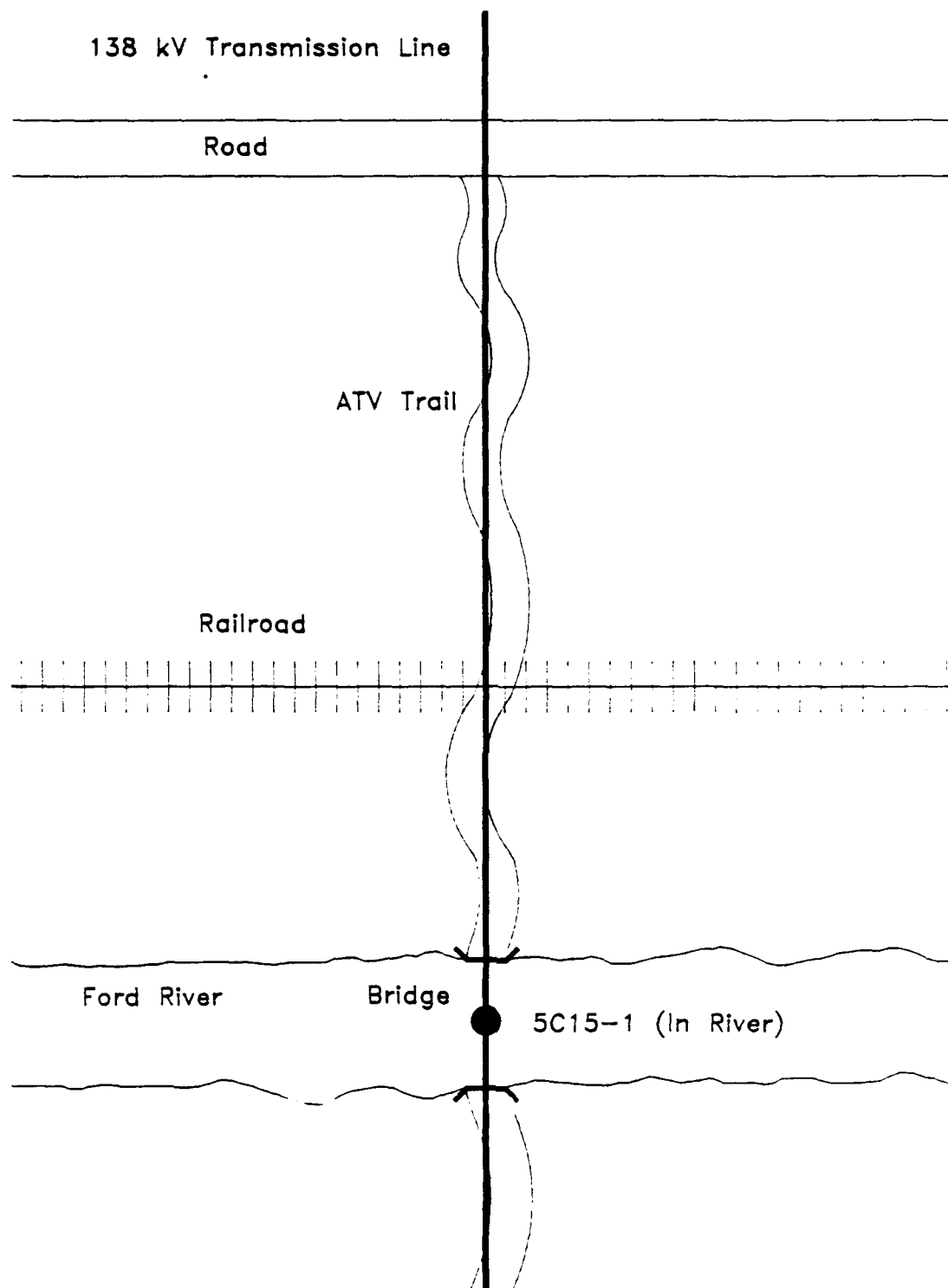


FIGURE E-6. MEASUREMENT POINT AT TRANSMISSION LINE; 5C15-1.

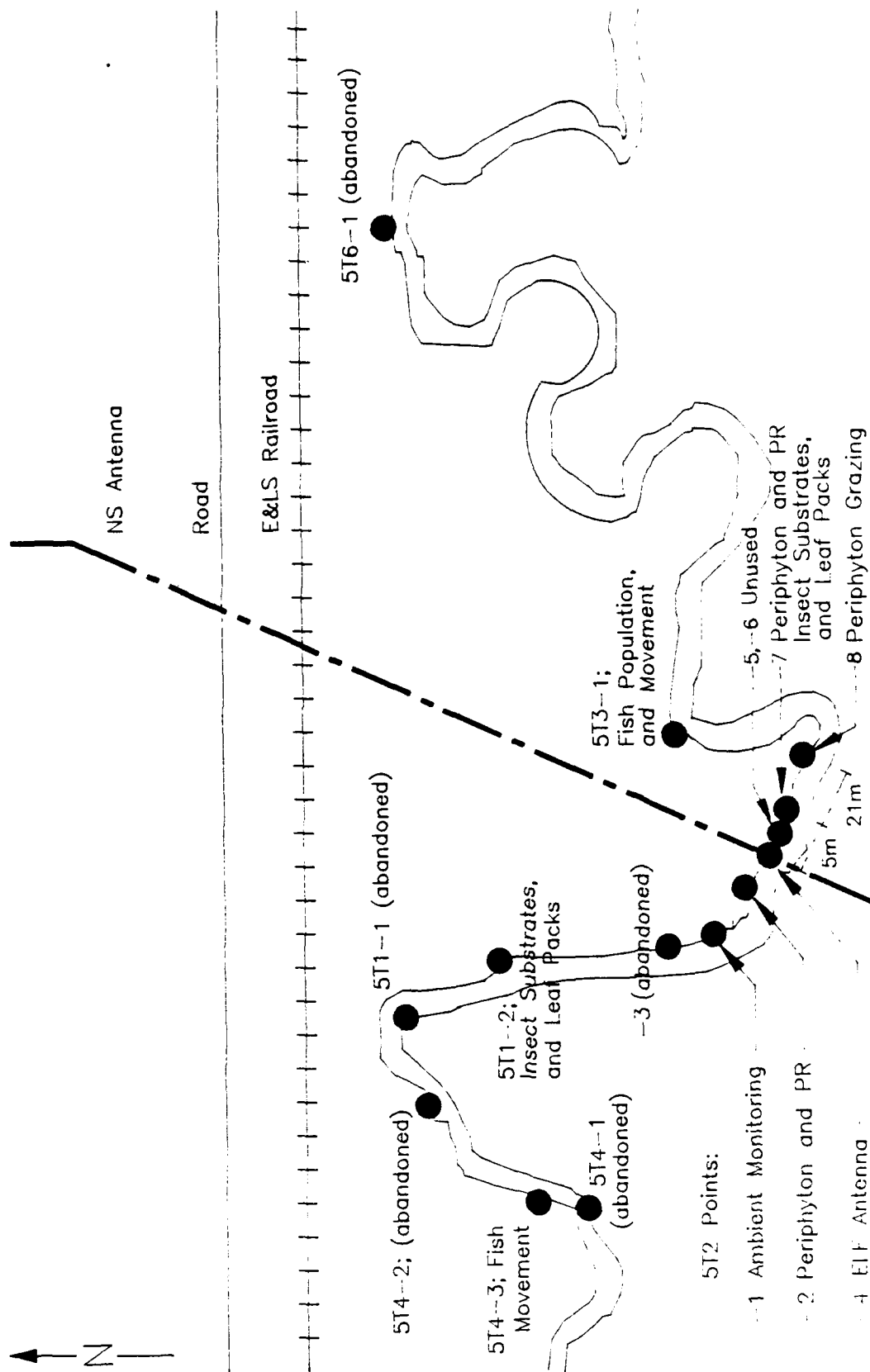
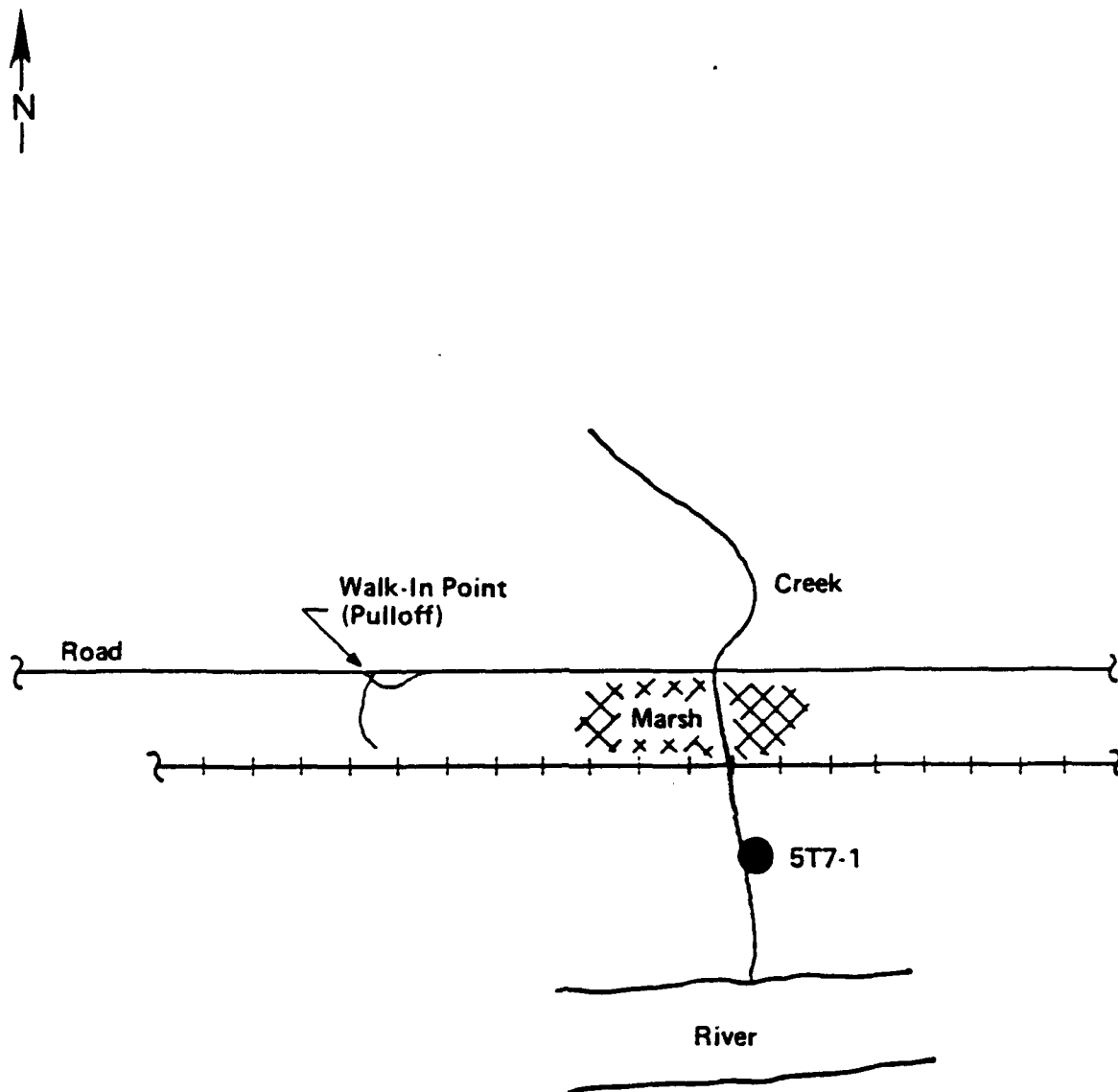


FIGURE E-7. MEASUREMENT POINTS AT FEX; 5T1-1, 2; 5T2-1 THROUGH 8; 5T3-1; 5T4-1, 2; 5T6-1.



Not to Scale

FIGURE E-8. MEASUREMENT POINT AT FEX 7; 5T7-1.

TABLE E-3. 60 HZ AIR ELECTRIC FIELD INTENSITIES (V/M)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990 ^d	1991 ^b	1992
5C1-1	0.002	<0.001	<	<	<	<	<	#	<	< ^b
5C1-2	<0.001	/	/	<	<	<	<	#	-	-
5C1-3	<0.001	/	/	<	<	<	<	#	<	< ^b
5C1-4	.	<0.001	<	<	<	<	<	#	<	< ^b
5C1-5	.	.	.	.	.	<	<	#	<	< ^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
5T2-1	.	<	<	<	<	<	<0.001	#	<0.001	< ^b
5T2-2	.	<	<	<	<0.001	0.002	<0.001	#	0.019	<0.001 ^b
5T2-3	.	.	.	<	<	<0.001	<	#	-	-
5T2-4	.	.	.	.	.	.	.	#	0.065	0.010 ^b
5T2-5	.	.	.	.	.	.	.	#	-	-
5T2-6	.	.	.	.	.	.	.	#	-	-
5T2-7	.	.	.	.	.	.	.	#	0.037	0.005 ^b
5T2-8	.	.	.	.	.	.	.	#	0.017	0.003 ^b
5T3-1	.	<	<	<	0.001	<0.001	/	#	<	< ^b
5T4-1	.	<	/	<	<	<	<	#	-	-
5T4-2	.	.	.	<	<	<	-	#	-	-
5T4-3	.	.	.	.	.	.	.	.	<	< ^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 A current.

.

- = measurement point not established.

/ = measurement point dropped.

= measurement not taken.

< = measurement precluded by antenna operation.

< = measurement est. <0.001 V/m based on earth E-field.

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

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990 ^d	1991 ^b	1992
5C1-1	1.47, 1.73	2.7	2.6	0.22	0.26	0.32	0.27	#	0.50	0.182 ^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
5C1-4	-	2.5, 2.7	2.2	0.174	0.25	0.21	0.44	#	0.085	0.119 ^b
5C1-5	-	-	-	-	-	0.27	0.33	#	0.43	0.151 ^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	0.187	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
5T2-1	-	0.22, 0.31	0.23	0.057	0.061	0.126	0.037	#	0.166	0.074 ^b
5T2-2	-	0.26	0.165	0.082	0.076	0.198	0.040	#	0.194	0.077 ^b
5T2-3	-	-	-	0.050	0.056	0.063	0.033	#	--	--
5T2-4	-	-	-	-	-	-	-	#	0.26	0.076 ^b
5T2-5	-	-	-	-	-	-	-	#	--	--
5T2-6	-	-	-	-	-	-	-	#	--	--
5T2-7	-	-	-	-	-	-	-	#	0.26	0.083 ^b
5T2-8	-	-	-	-	-	-	-	#	0.179	0.104 ^b
5T3-1	-	0.22, 0.26	0.23	0.046	0.053	0.115	/	#	0.114	0.064 ^b
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
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 A 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

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
5C1-1	0.008	0.008	0.003	0.001	0.001	0.001	0.001	#	0.001	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
5C1-4	-	0.007, 0.008	0.007	0.001	0.001	0.001	0.002	#	0.001	0.001 ^b
5C1-5	-	-	-	-	-	<0.001	0.001	#	0.003	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
5T2-1	-	0.001, 0.002	0.001	0.005	0.009	0.015	0.003	#	0.037	0.006 ^b
5T2-2	-	0.002	0.001	0.014	0.021	0.047	0.009	#	0.103	0.011 ^b
5T2-3	-	-	-	0.004	0.007	0.007	0.003	#	--	--
5T2-4	-	-	-	-	-	-	-	#	0.157	0.024 ^b
5T2-5	-	-	-	-	-	-	-	#	--	--
5T2-6	-	-	-	-	-	-	-	#	--	--
5T2-7	-	-	-	-	-	-	-	#	0.133	0.022 ^b
5T2-8	-	-	-	-	-	-	-	#	0.083	0.014 ^b
5T3-1	-	0.001, 0.002	0.001	0.005	0.009	0.021	/	#	0.031	0.006 ^b
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
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 A 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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
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
5T2-1	0.001	<	<	*	0.005	<	0.026	0.002	0.062	/	0.046	0.058
5T2-2	0.011	<	<	*	0.022	<0.001	0.130	<0.001	0.54	0.27	1.02	0.29
5T2-3	<	<	<	*	0.005	<	0.030	<0.001	0.049	-	-	-
5T2-4	-	-	-	-	-	-	-	-	-	9.8	4.0	6.1
5T2-5	-	-	-	-	-	-	-	-	-	8.3	-	-
5T2-6	-	-	-	-	-	-	-	-	-	8.3	-	-
5T2-7	-	-	-	-	-	-	-	-	-	6.7	2.8	5.6
5T2-8	-	-	-	-	-	-	-	-	-	1.06	1.51	1.11
5T3-1	0.008	<	<	*	0.020	<	0.104	<0.001	0.175	0.24	0.165	0.161
5T4-1	<	<	<	*	0.003	<	0.014	<0.001	0.036	-	-	-
5T4-2	<	<	<	*	0.007	<	0.054	<0.001	-	0.088	-	-
5T4-3	-	-	-	-	-	-	-	-	-	-	0.033	0.062
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.
A = amperes.

- = measurement point not established.
/ = measurement point dropped.
= measurement not taken.
< = measurement est. <0.001 based on earth E-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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
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
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
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
5C1-5	-	-	-	-	-	-	7.1	0.83	11.9	12.3	11.5	10.3
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
5T2-1	1.33	0.045	0.077	0.128	5.4	0.22	25	1.16	47	48	45	51
5T2-2	1.62	0.052	0.067	0.112	6.1	0.184	31	0.100	65	61	55	66
5T2-3	1.17	0.042	0.079	0.132	4.9	0.23	21	1.18	40	--	--	--
5T2-4	-	-	-	-	-	-	-	-	-	59	64	69
5T2-5	-	-	-	-	-	-	-	-	-	61	--	--
5T2-6	-	-	-	-	-	-	-	-	-	73	--	--
5T2-7	-	-	-	-	-	-	-	-	-	85	71	79
5T2-8	-	-	-	-	-	-	-	-	-	95	77	104
5T3-1	1.22	0.045	0.082	0.137	4.8	0.27	18.8	1.07	45	42	48	40
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
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.
A = amperes.
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

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
5C1-1	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.039	0.036	0.042	0.038
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
5C1-4	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.040	0.037	0.043	0.039
5C1-5	-	-	-	-	-	-	0.022	0.005	0.038	0.035	0.045	0.037
5C1-6	-	-	-	-	-	-	-	-	0.038	--	--	--
5C1-7	-	-	-	-	-	-	-	-	0.035	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
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
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
5T2-3	0.110	0.003	<0.001	*	0.41	0.002	1.90	0.007	3.7	--	--	--
5T2-4	-	-	-	-	-	-	-	-	-	22	21	22
5T2-5	-	-	-	-	-	-	-	-	-	22	--	--
5T2-6	-	-	-	-	-	-	-	-	-	22	--	--
5T2-7	-	-	-	-	-	-	-	-	-	21	19.9	21
5T2-8	-	-	-	-	-	-	-	-	-	12	14	12.3
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
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
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.
A = amperes.
EX = extrapolated data.
- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.
* = data cannot be extrapolated.
= measurement precluded by ambient 60 Hz fields.

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 1992, 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 1991. Measurement dates for 1992 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

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 1992 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 operating currents of the NRTF-Republic for each year.

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.

Soil amoeba growth chambers were not used during the 1992 field season. Data logger monitoring systems were left on the study sites, however, to monitor climatological parameters in 1992. Figure F-17 shows climatological data collected in 1992. Included are daily high and low air temperatures, soil temperature, and rainfall. Temperatures at the three sites are similar throughout the field season. Rainfall events are also similar, as might be expected, but the rainfall levels differ considerably. Unfortunately, because all of the sites are in hardwood tree stands, it is not possible to conclude whether differences in rainfall levels are actual or simply the effect of differences in the placement of the rain gauges relative to canopy openings.

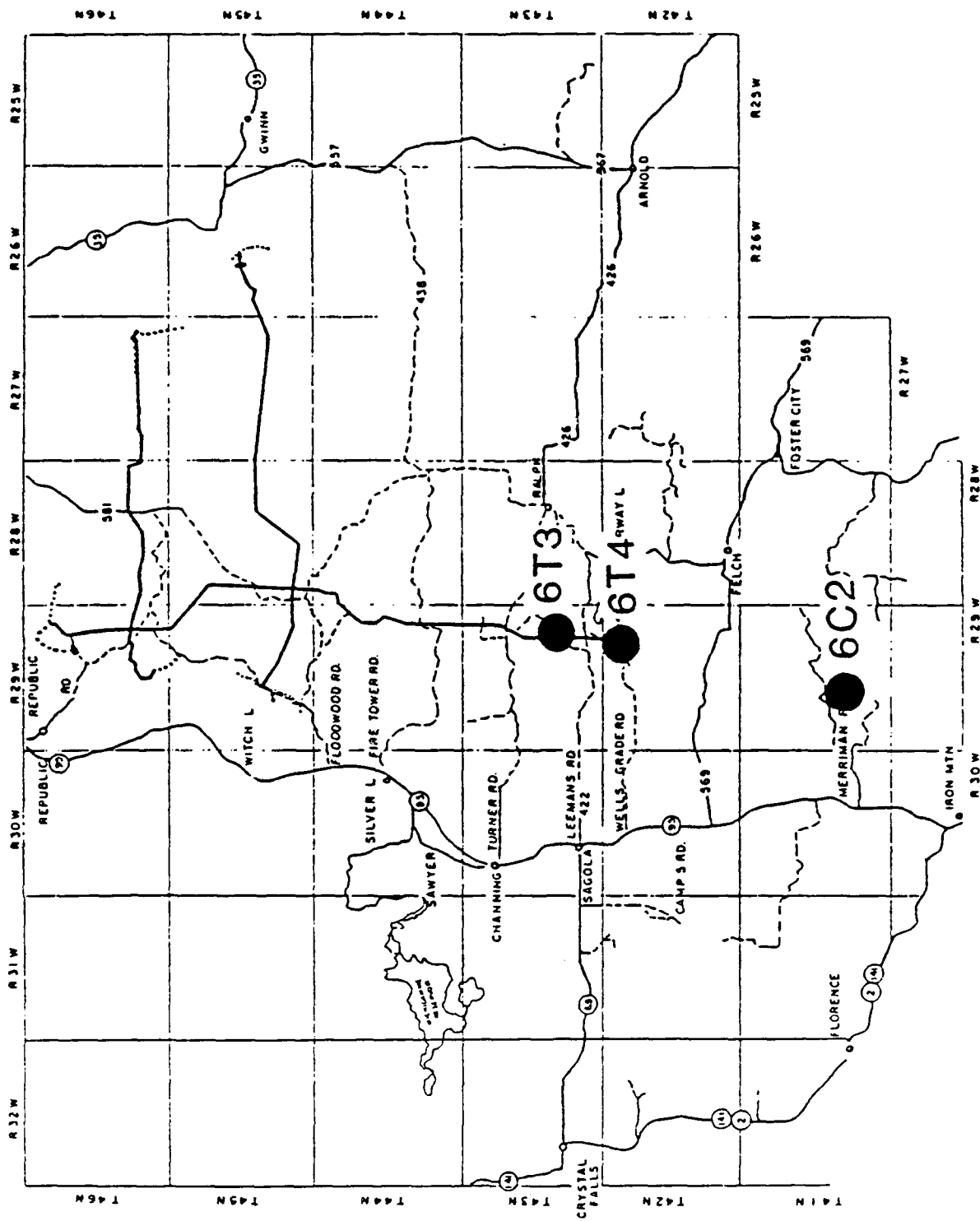


FIGURE F-1. POSITIONS OF SOIL AMOEBA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

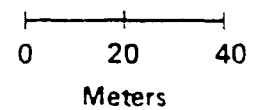
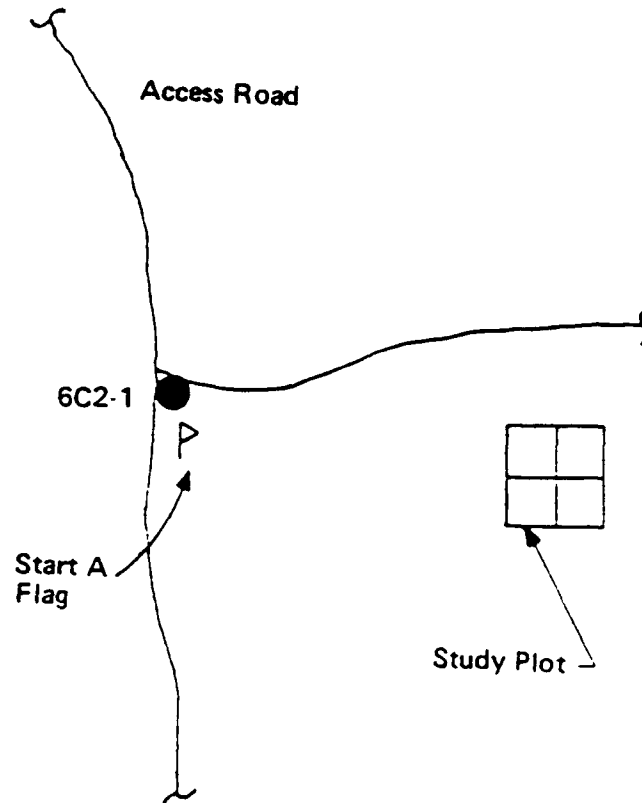
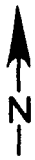


FIGURE F-2. MEASUREMENT POINT AT MERRIMAN TRUCK ROAD CONTROL; 6C2-1.

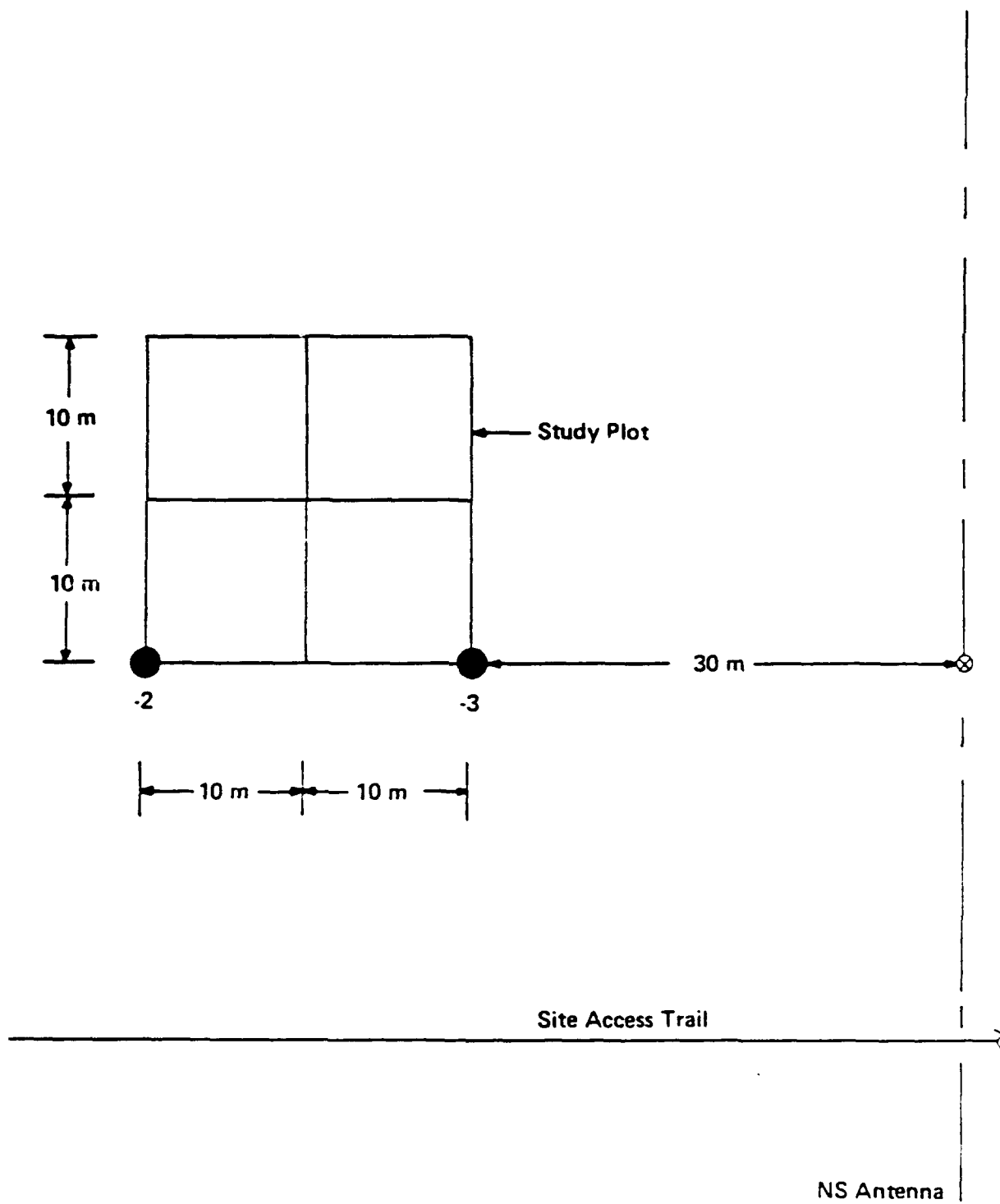
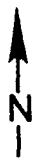


FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD; 6T3-2, 3.

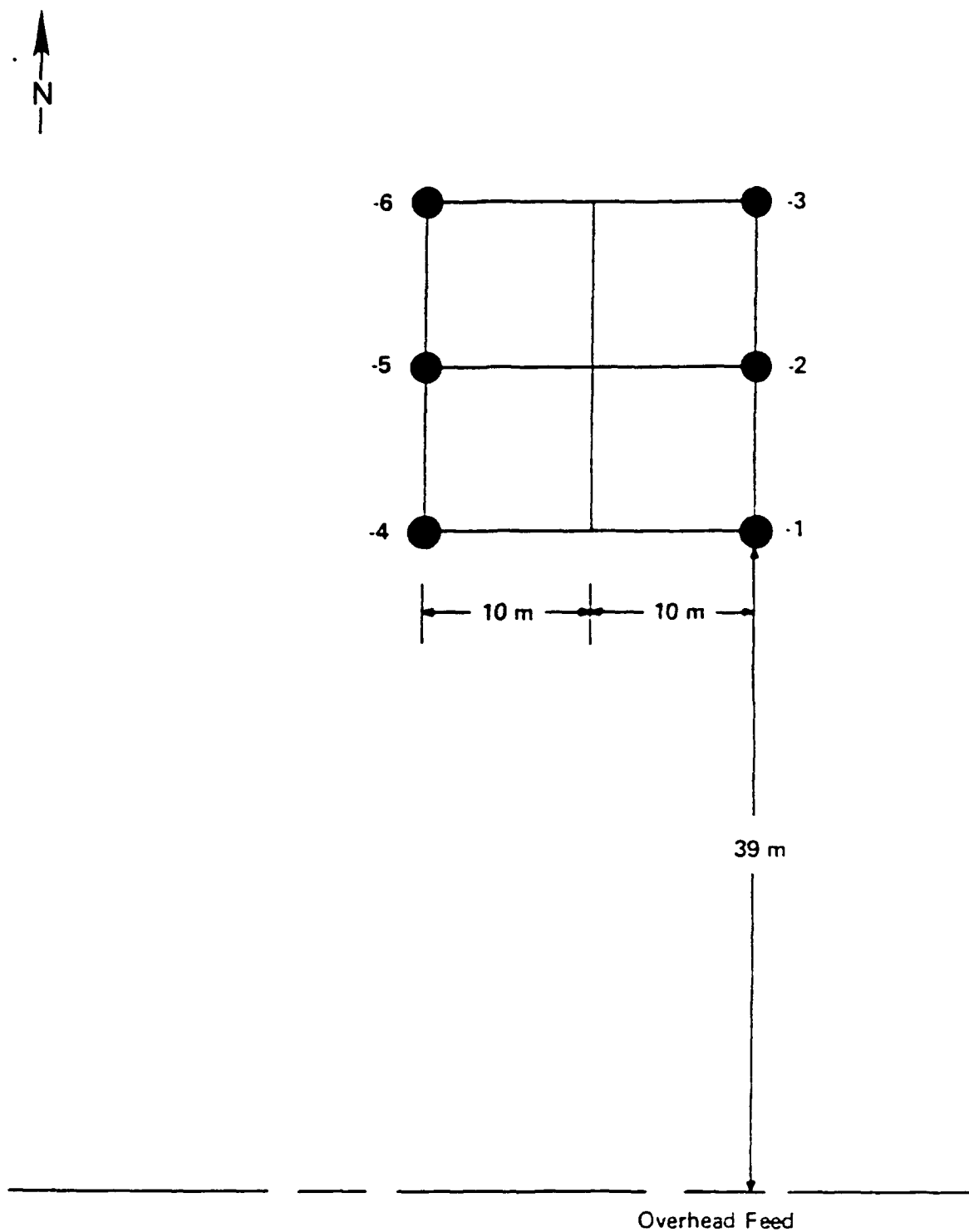


FIGURE F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND; 6T4-1 THROUGH 6.

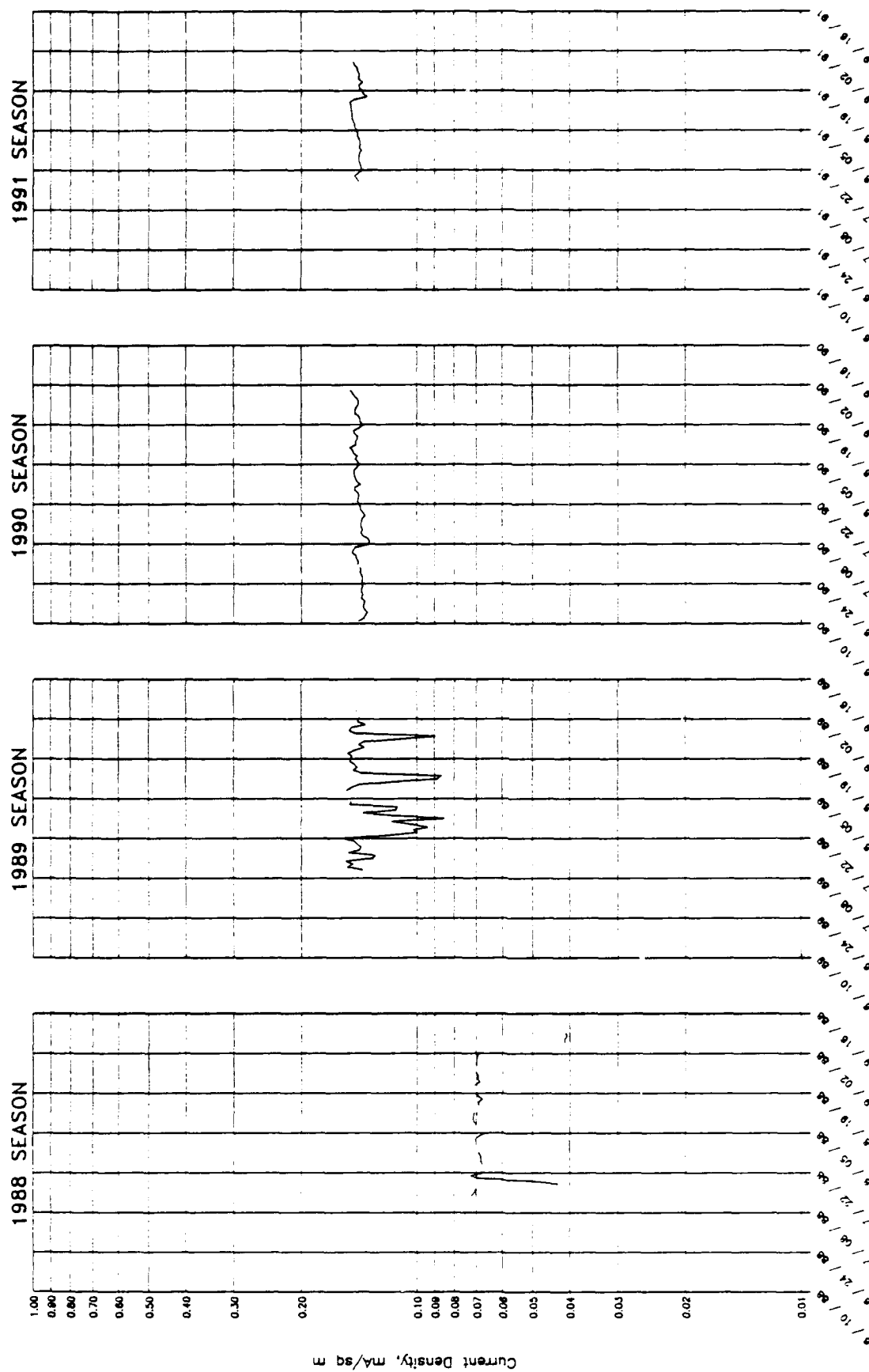


FIGURE F-5. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 1 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

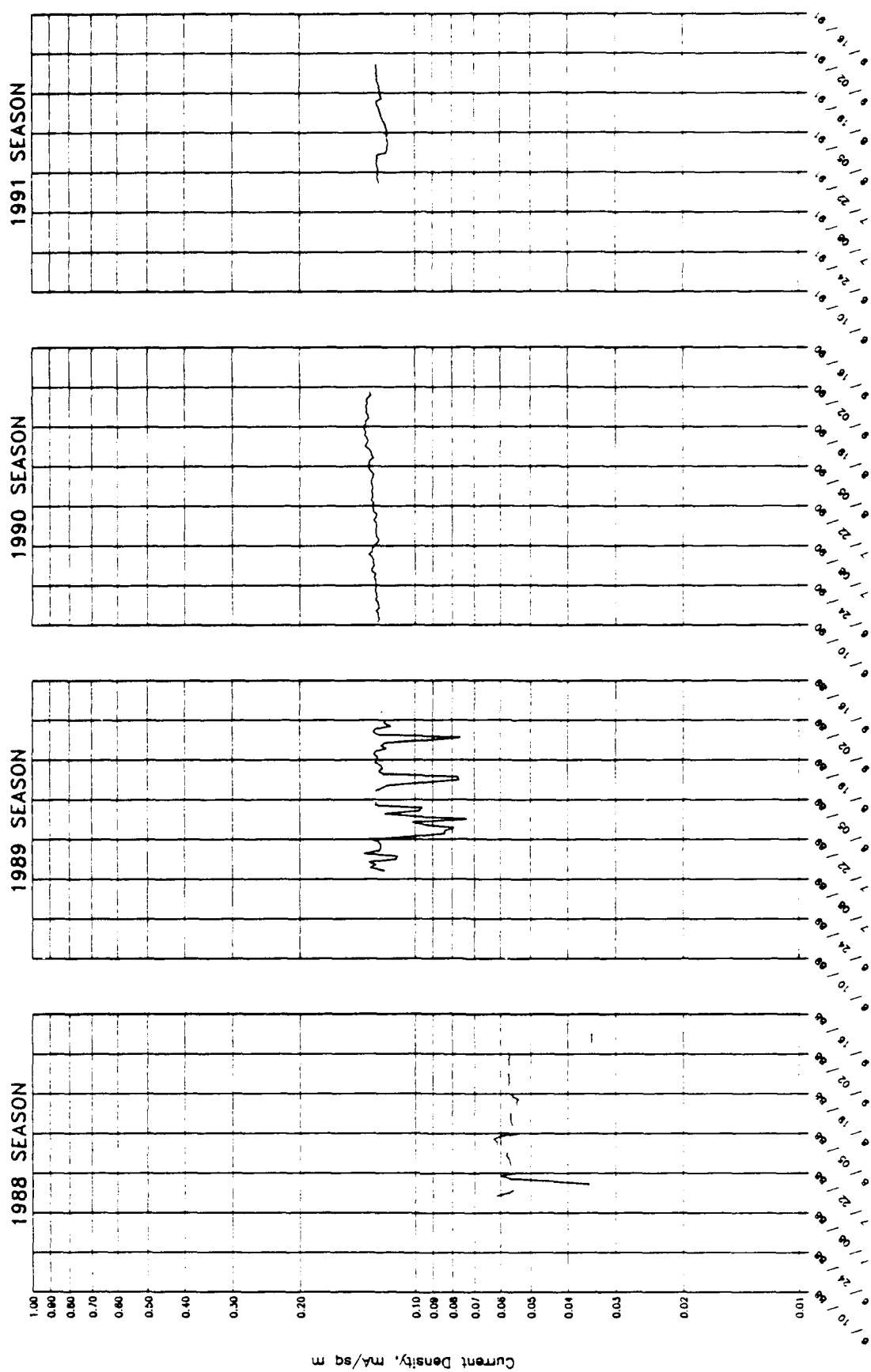


FIGURE F-6. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 2 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

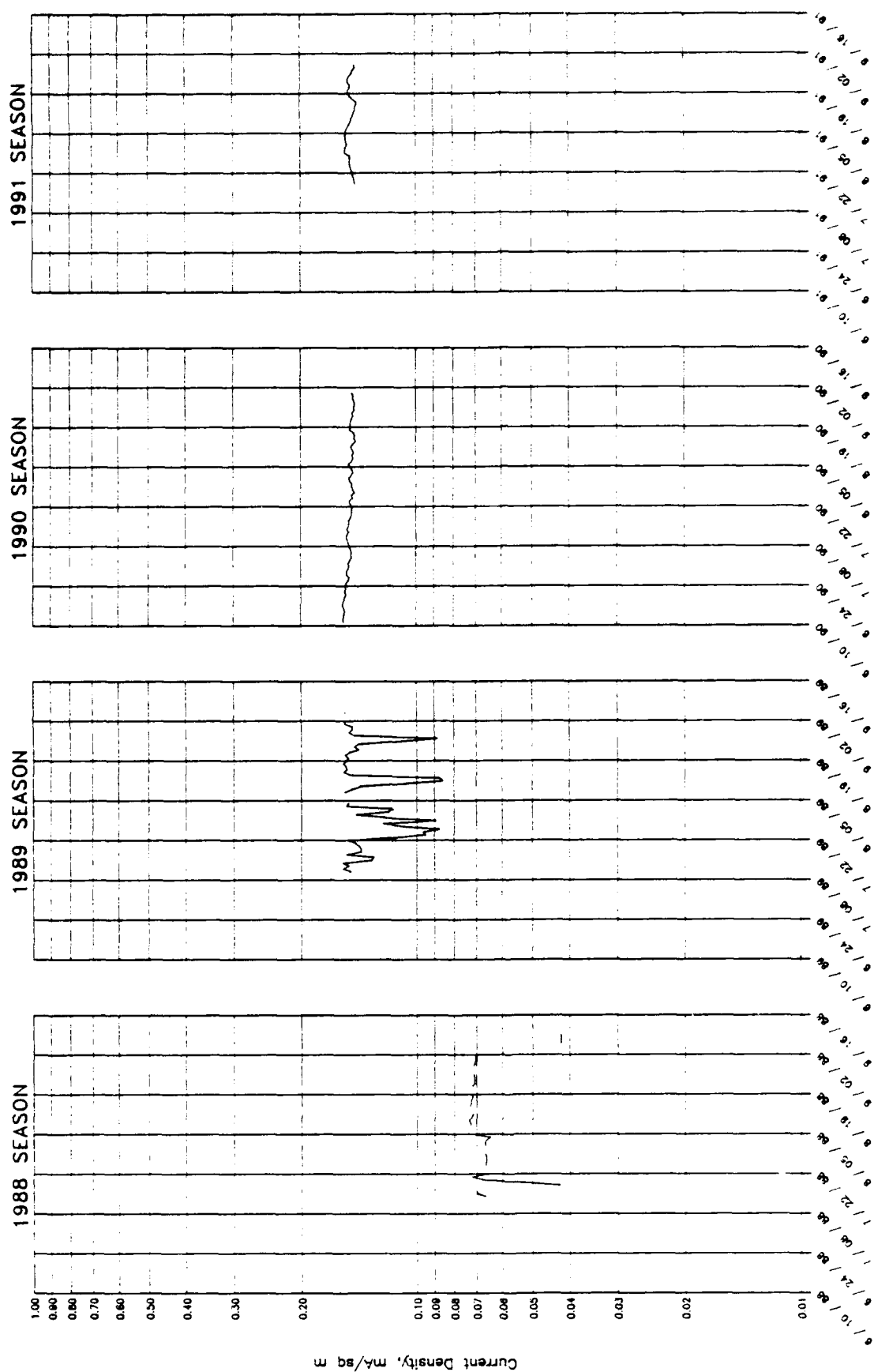


FIGURE F-7. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 3 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

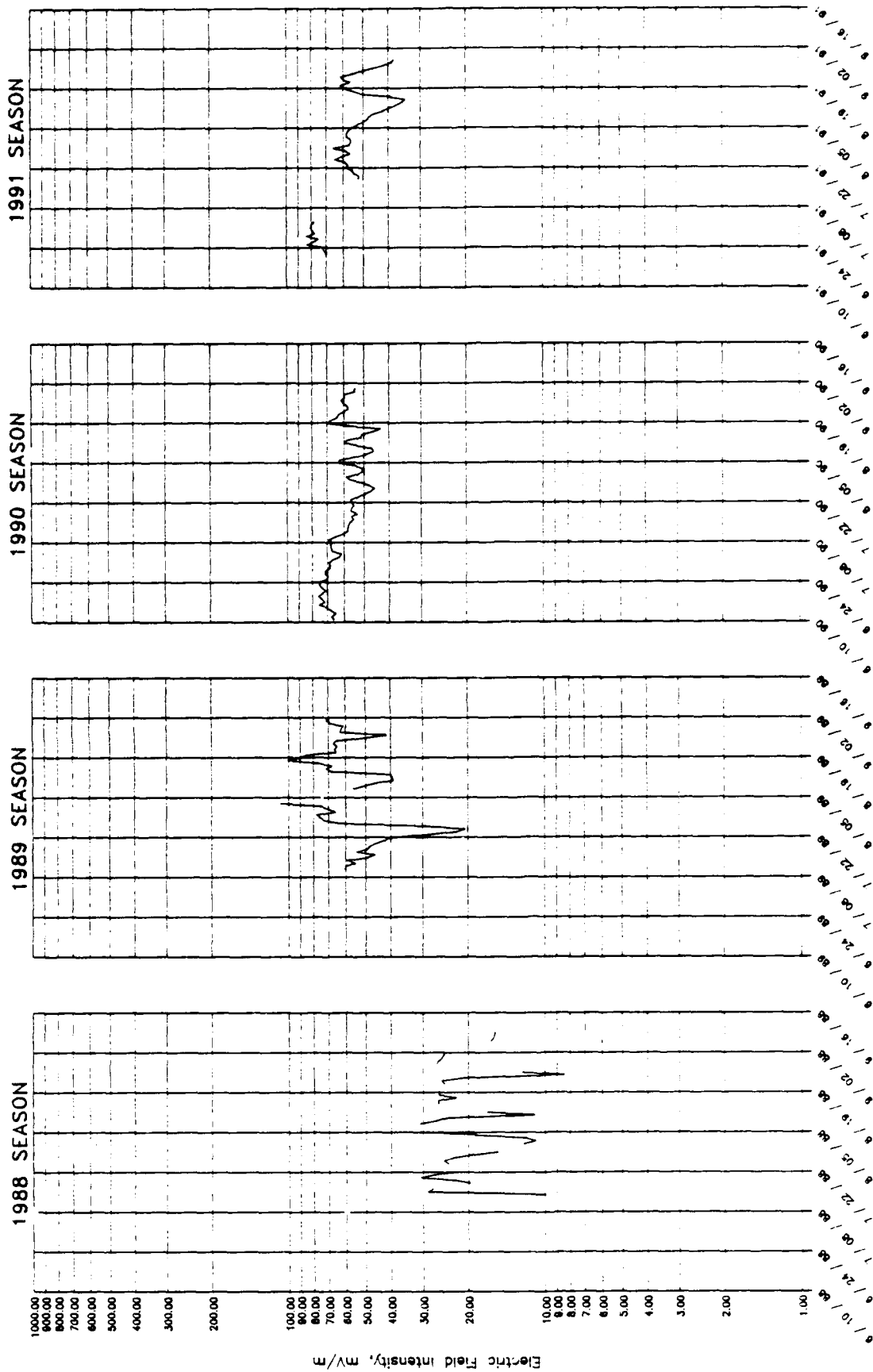


FIGURE F-8. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 4 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

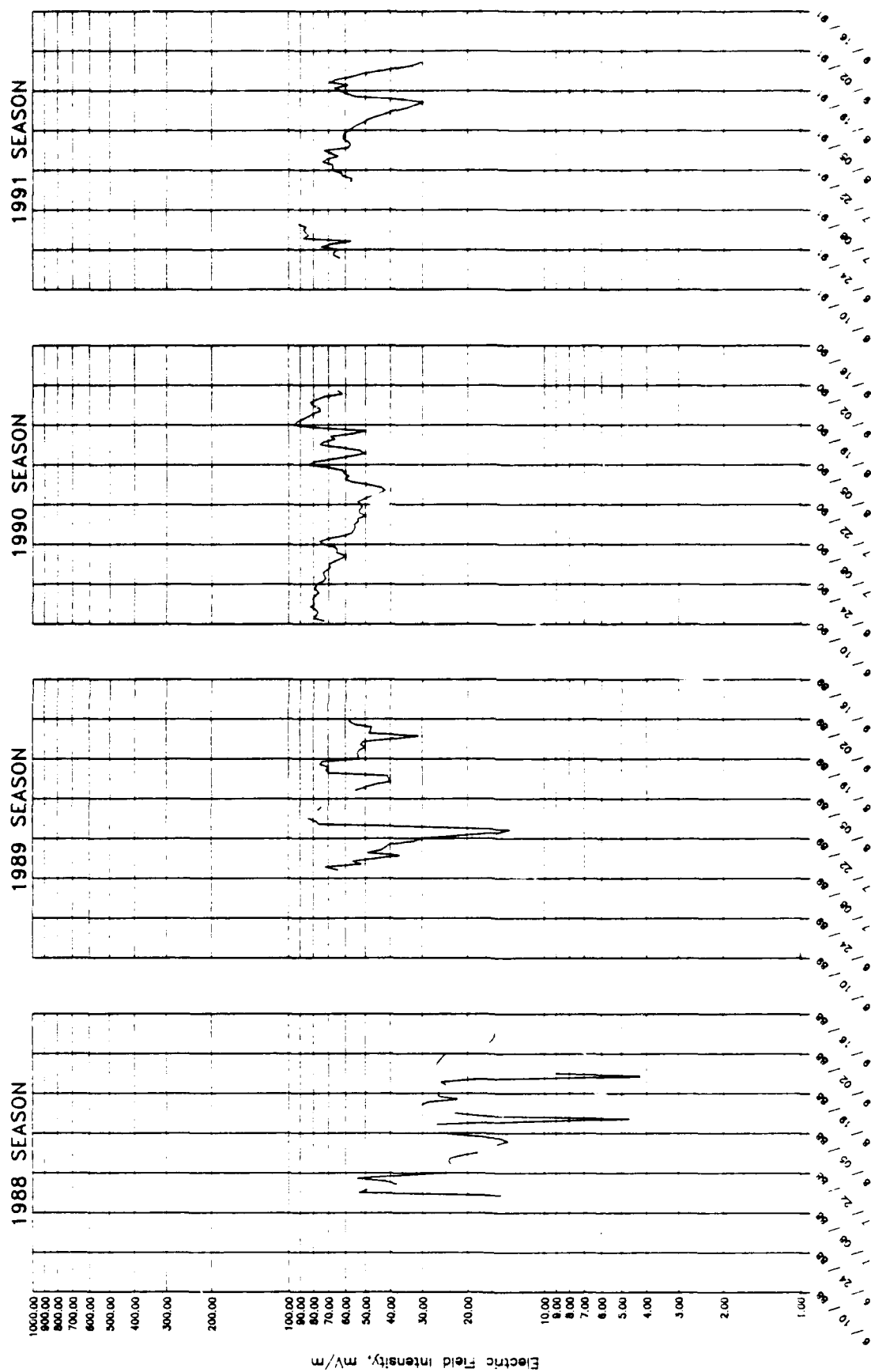


FIGURE F-9. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 5 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

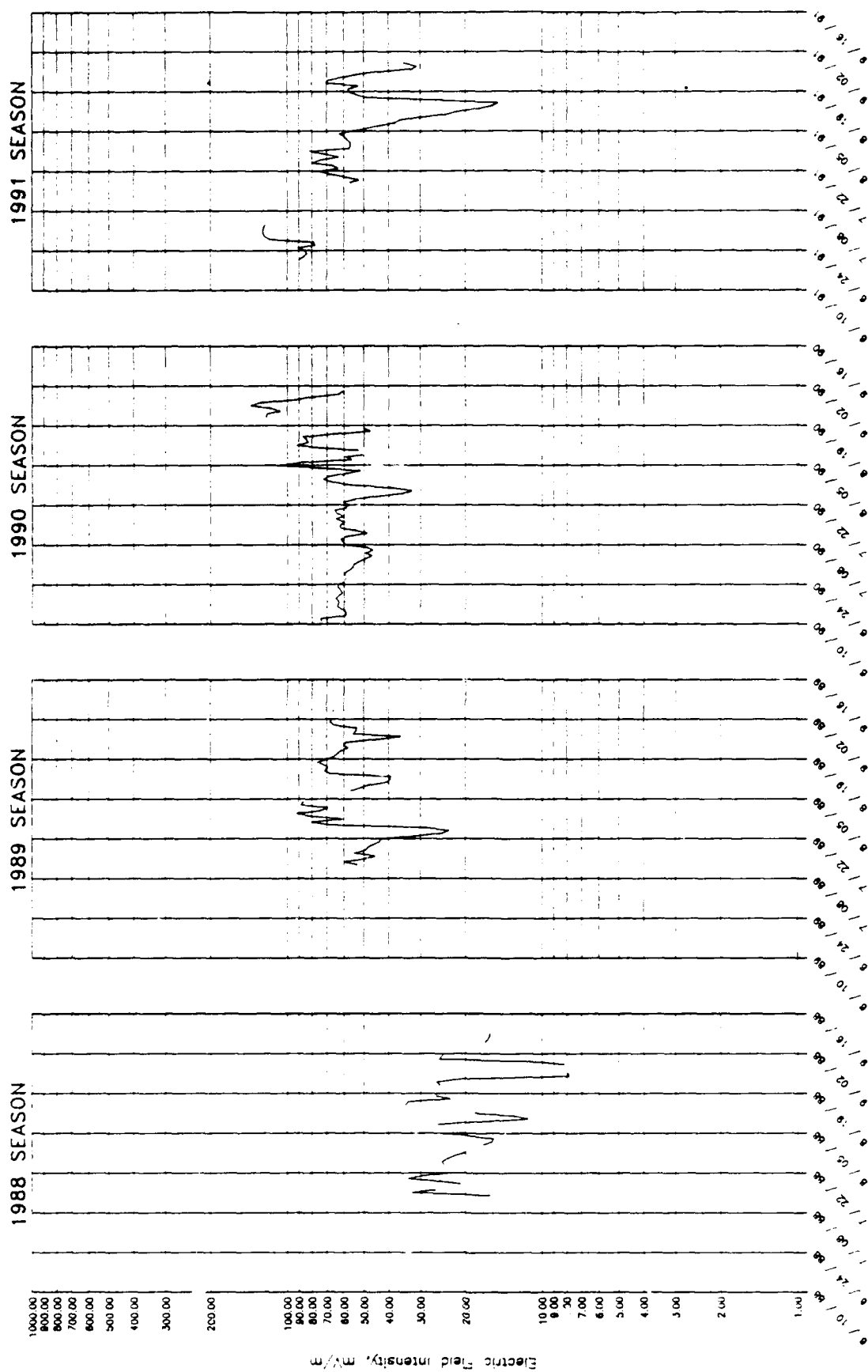


FIGURE F-10. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 6 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

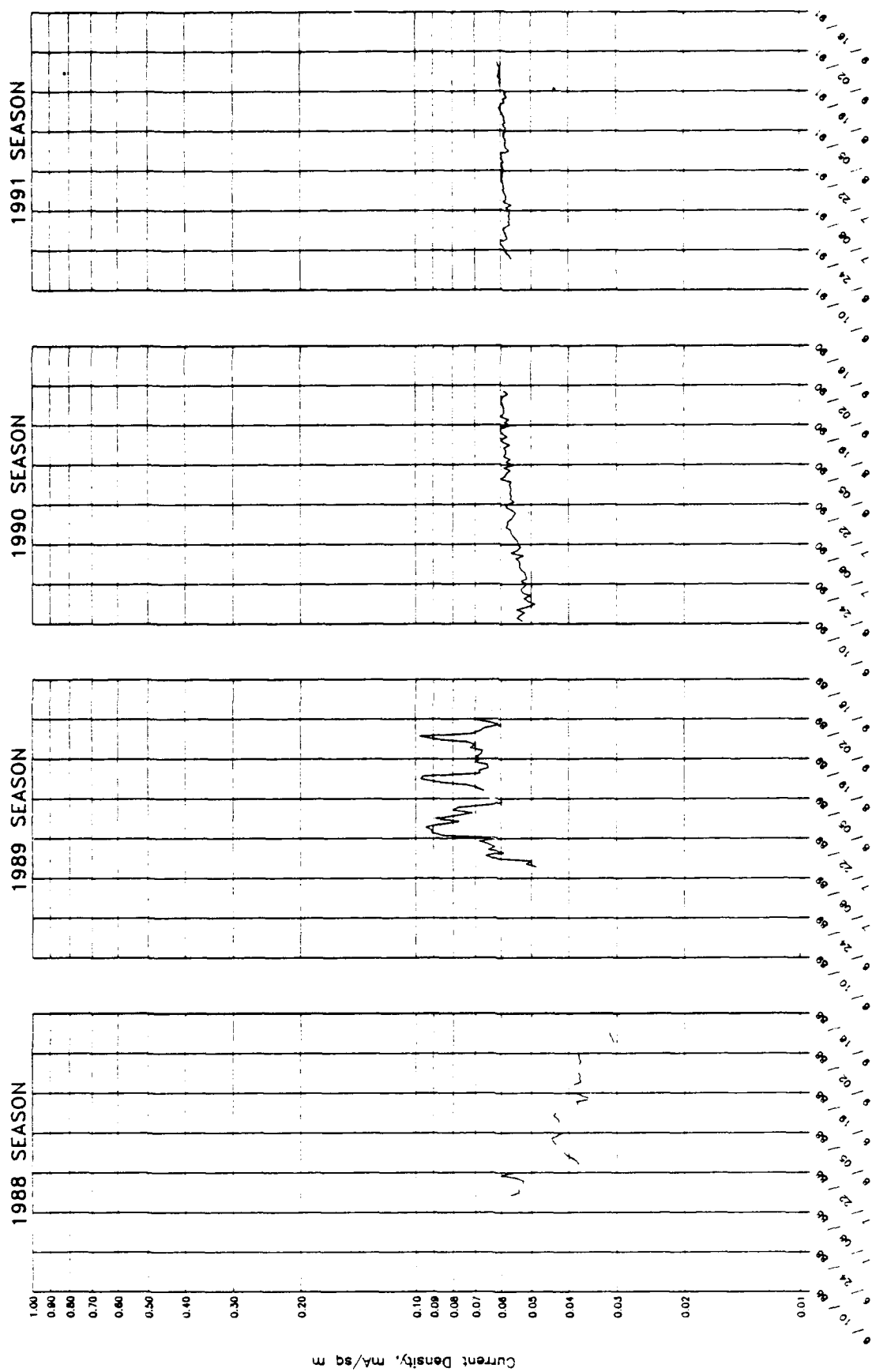


FIGURE F-11. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 1 AT THE SOIL AMOEBA GROUND STUDY SITE.

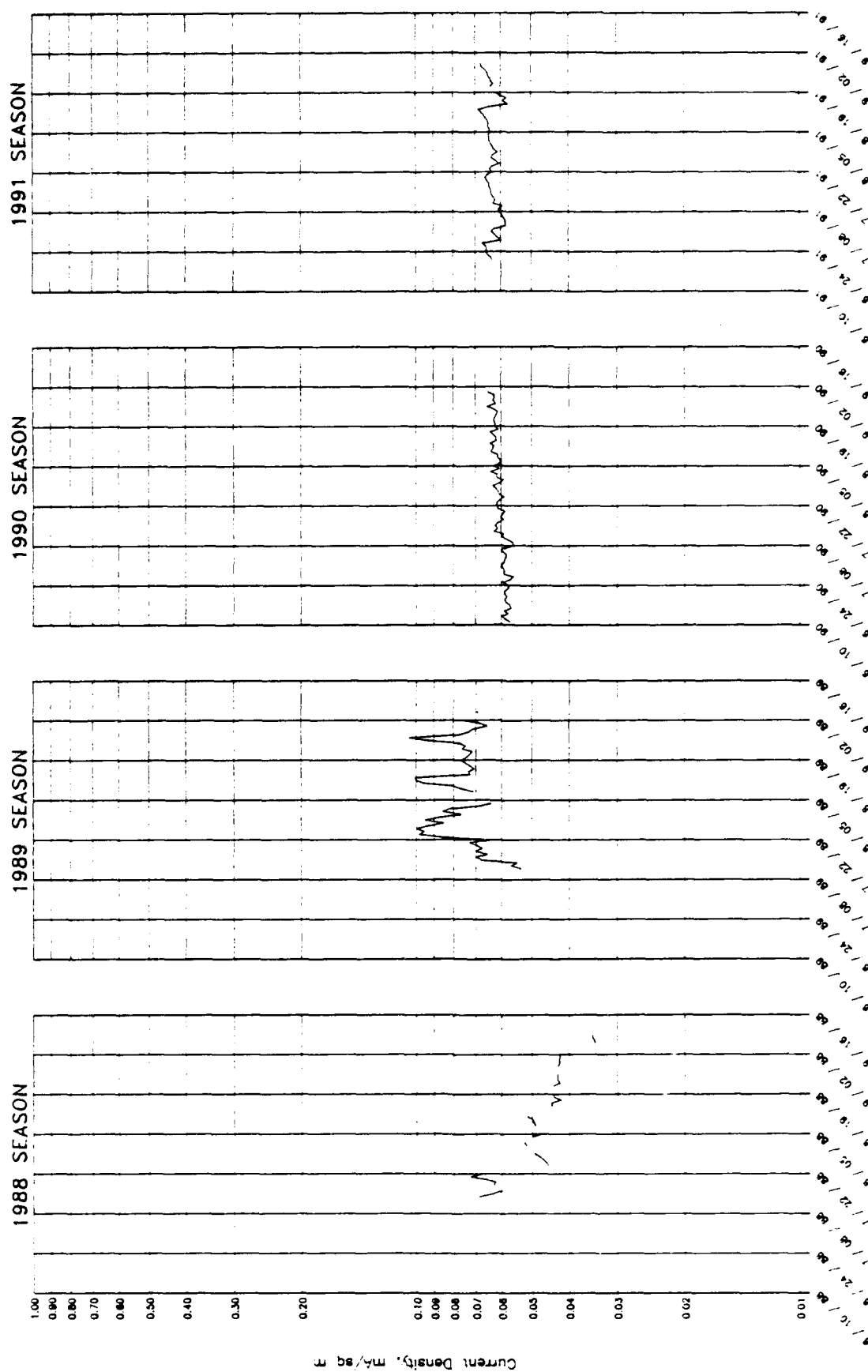


FIGURE F-13. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 3 AT THE SOIL AMOEBA GROUND STUDY SITE.

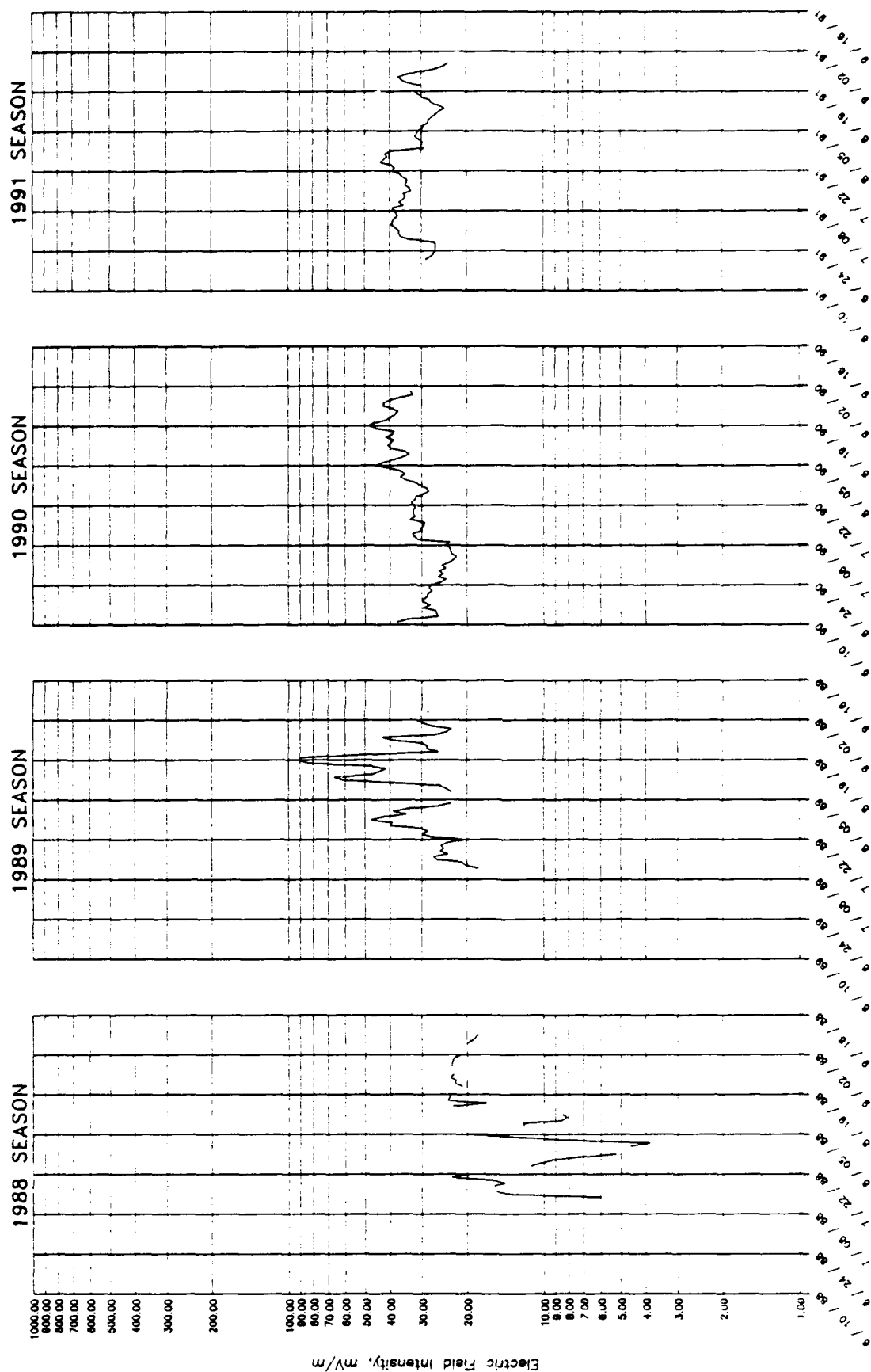


FIGURE F-14. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 4 AT THE SOIL AMOEBA GROUND STUDY SITE.

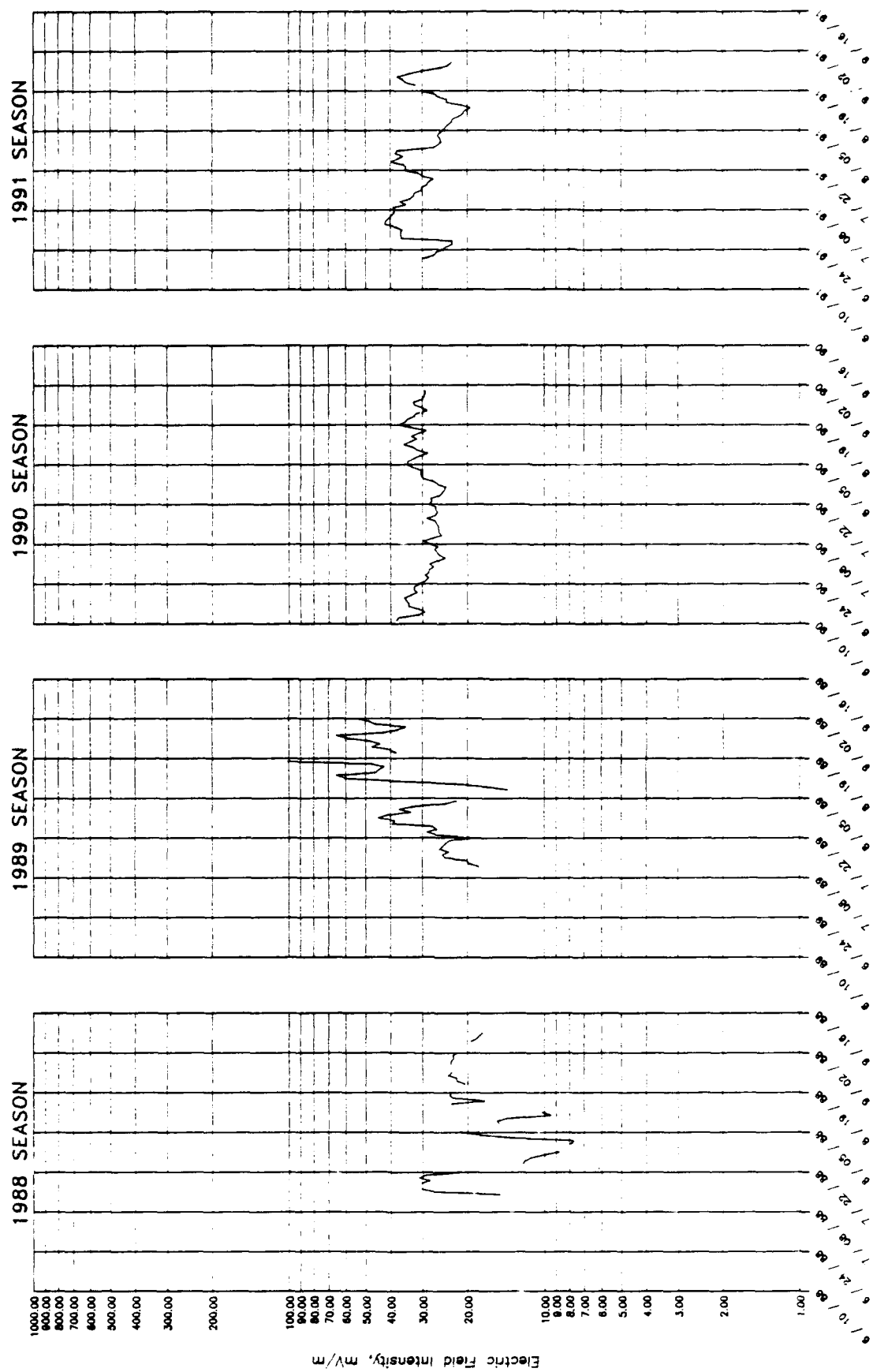


FIGURE F-15. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 5 AT THE SOIL AMOEBA GROUND STUDY SITE.

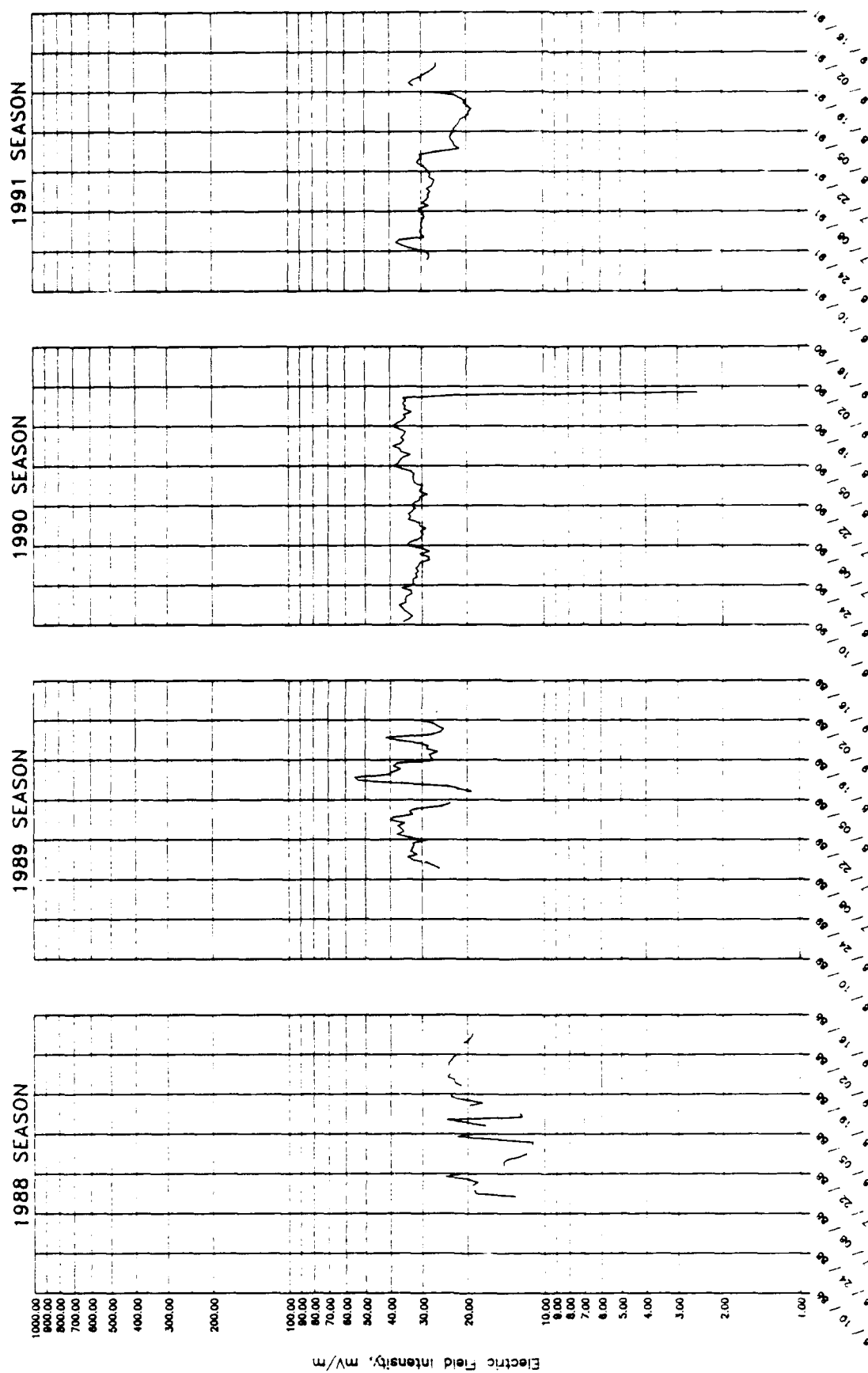


FIGURE F-16. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 6 AT THE SOIL AMOEBA GROUND STUDY SITE.

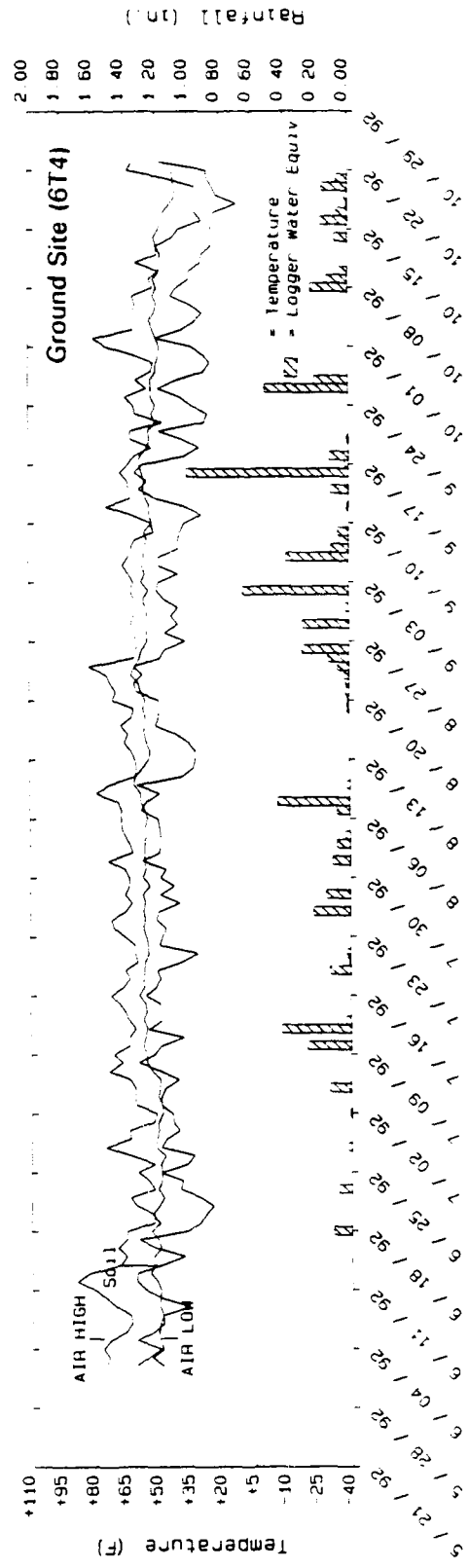
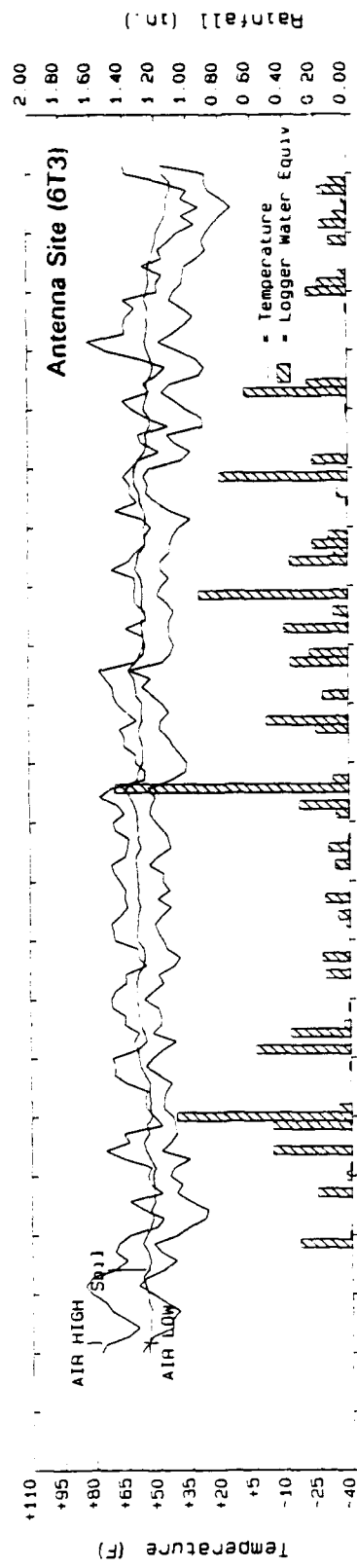
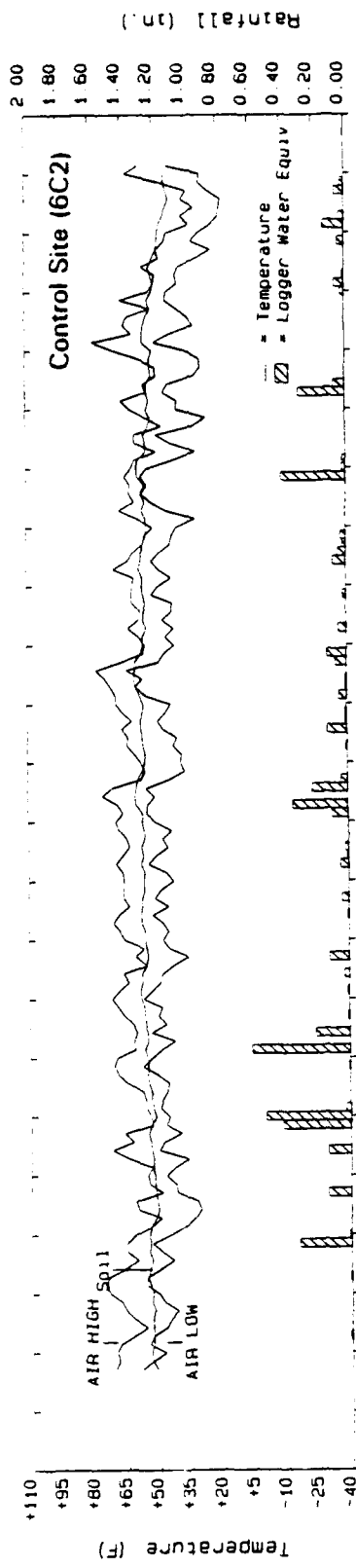


FIGURE F-17. CLIMATOLOGICAL DATA COLLECTED AT SOIL AMOEBA STUDY SITES.

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
6C2-1	<0.001	<	<	<	<	<	<	< ^d	< ^d	< ^d
6T3-2	.	<	<	<	<	<	<	<0.001 ^c	< ^c	< ^b
6T3-3	.	.	.	<	<	<	<	< ^c	< ^c	< ^b
6T4-1	.	<	<	<	<	<	<0.001	< ^b	< ^c	< ^b
6T4-2	.	.	.	<	<	<0.001	<	< ^b	< ^c	< ^b
6T4-3	.	.	.	<	<	<	<	< ^b	< ^c	< ^b
6T4-4	.	.	.	<	<	<	<	< ^b	< ^c	< ^b
6T4-5	.	.	.	<	<	<	<	< ^b	< ^c	< ^b
6T4-6	.	.	.	<	<	<	<	< ^b	< ^c	< ^b

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

. = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-field.

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

Site No., Meas. Pt.	1983 ^d	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
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
6T3-2	0.087	0.130	0.134	0.078	0.130	0.41	#	0.193 ^c	0.056 ^c	0.056 ^b
6T3-3	-	-	-	0.085	0.125	0.35	#	0.186 ^c	0.060 ^c	0.053 ^b
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
6T4-2	-	-	-	0.046	0.162	0.145	0.30	0.048 ^b	0.086 ^c	0.070 ^b
6T4-3	-	-	-	0.065	0.082	0.24	0.34	0.068 ^b	0.106 ^c	0.101 ^b
6T4-4	-	-	-	0.037	0.24	0.27	0.23	0.057 ^b	0.061 ^c	0.048 ^b
6T4-5	-	-	-	0.053	0.182	0.18	0.33	0.049 ^b	0.091 ^c	0.066 ^b
6T4-6	-	-	-	0.098	0.084	0.33	0.34	0.069 ^b	0.120 ^c	0.107 ^b

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A 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
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
6T3-2	-	0.002	0.003	0.013	0.033	0.103	#	0.193 ^c	0.008 ^c	0.015 ^b
6T3-3	-	-	-	0.020	0.023	0.065	#	0.029 ^c	0.013 ^c	0.010 ^b
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
6T4-2	-	-	-	0.005	0.006	0.016	0.009	0.005 ^b	0.005 ^c	0.006 ^b
6T4-3	-	-	-	0.004	0.005	0.014	0.008	0.005 ^b	0.004 ^c	0.005 ^b
6T4-4	-	-	-	0.002	0.006	0.018	0.010	0.006 ^b	0.005 ^c	0.006 ^b
6T4-5	-	-	-	0.003	0.006	0.017	0.009	0.005 ^b	0.004 ^c	0.006 ^b
6T4-6	-	-	-	0.005	0.005	0.015	0.009	0.004 ^b	0.004 ^c	0.005 ^b

a = antennas not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A 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., Meas. Pt.	1986				1987		1988		1989	1990	1991	1992
	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
6C2-1	<	<	<	*	<	<	<	<	<	<	<	<
6T3-2	<	<	<	*	0.005	<	0.028	<	0.061	0.065	0.042	0.038
6T3-3	<	<	<	*	0.005	<	0.027	<	0.058	0.058	0.050	0.038
6T4-1	<	<	<	*	0.020	<	0.047	<	0.036	0.056	0.058	0.037
6T4-2	<	<	<	*	0.007	<	0.022	<0.001	0.030	0.030	0.033	0.042
6T4-3	<	<	<	*	0.004	<	0.030	<	0.045	0.041	0.048	0.022
6T4-4	<	<	<	*	0.014	<	0.035	<	0.028	0.044	0.037	0.056
6T4-5	<	<	<	*	0.007	<	0.036	<0.001	0.047	0.033	0.038	0.031
6T4-6	<	<	<	*	0.004	<	0.043	<	0.050	0.047	0.050	0.075

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.
A = amperes.

< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.

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

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

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.

A = amperes.

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

Site No., Meas. Pt	1986				1987		1988		1989	1990	1991	1992
	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
6C2-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004	0.004	0.002	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
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
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
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
6T4-3	0.071	0.002	<0.001	*	0.26	0.001	1.30	0.005	2.9	2.6	2.5	2.7
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
6T4-5	0.078	0.002	<0.001	*	0.27	<0.001	1.41	0.006	3.4	2.8	2.7	2.8
6T4-6	0.067	0.002	<0.001	*	0.24	0.001	1.22	0.005	2.7	2.4	2.4	2.5

NS = north-south antenna. * = data cannot be extrapolated.

EW = east-west antenna.

NEW = northern EW antenna element.

SEW = southern EW antenna element.

B = NS + EW antennas, standard phasing.

EX = extrapolated data.

A = amperes.

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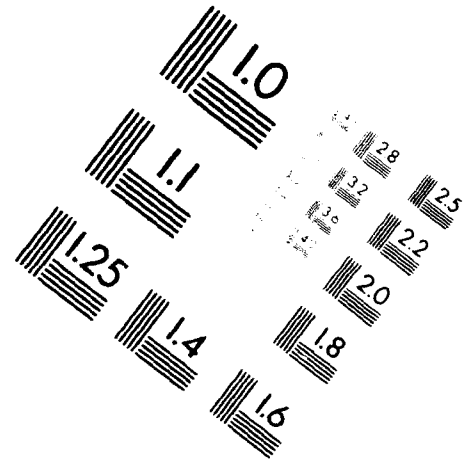
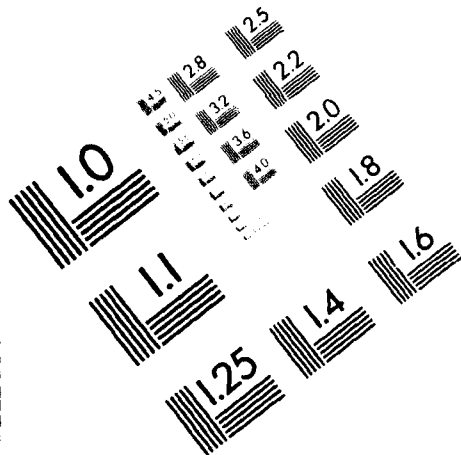


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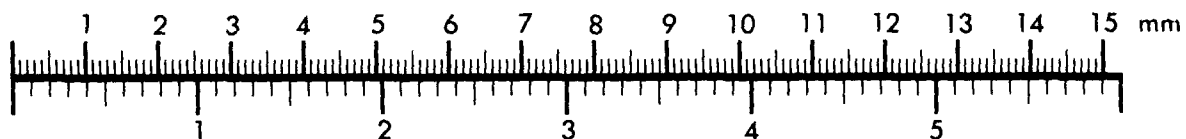
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Silver Spring, Maryland 20910

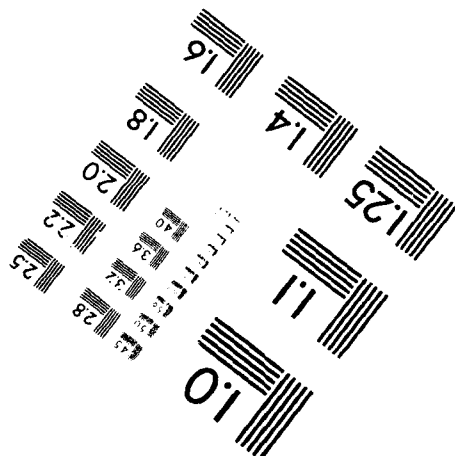
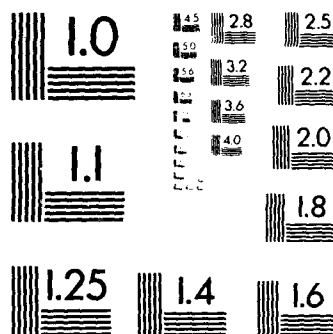
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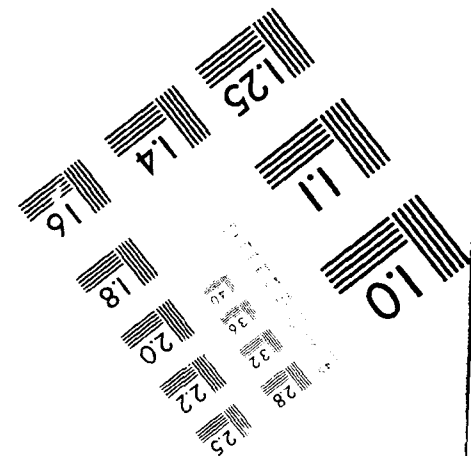
Centimeter



Inches



MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.



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 1992, IITRI field crews made ELF EM field measurements at 23 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 1991. One measurement point (10T4-3), however, was inaccessible because of a washed-out bridge and therefore was not surveyed in 1992. Measurement dates for 1992 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

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 1992 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 corresponding operating currents of the NRTF-Republic.

TABLE G-2. TRANSECT NO. 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

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 1992 (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 1992 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, and the ratios of 60 Hz

EM fields between matched treatment and control transects continue to meet the exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements made in 1992 were made with 150 ampere 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 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989 through 1992. The 1992 measurements are consistent with the measurements made in 1989 and 1990 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 southern EW 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-9. Measurements were made at the start and finish of each transect and at the "X" flags between transect sub-segments. Table G-9 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.*

* 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.

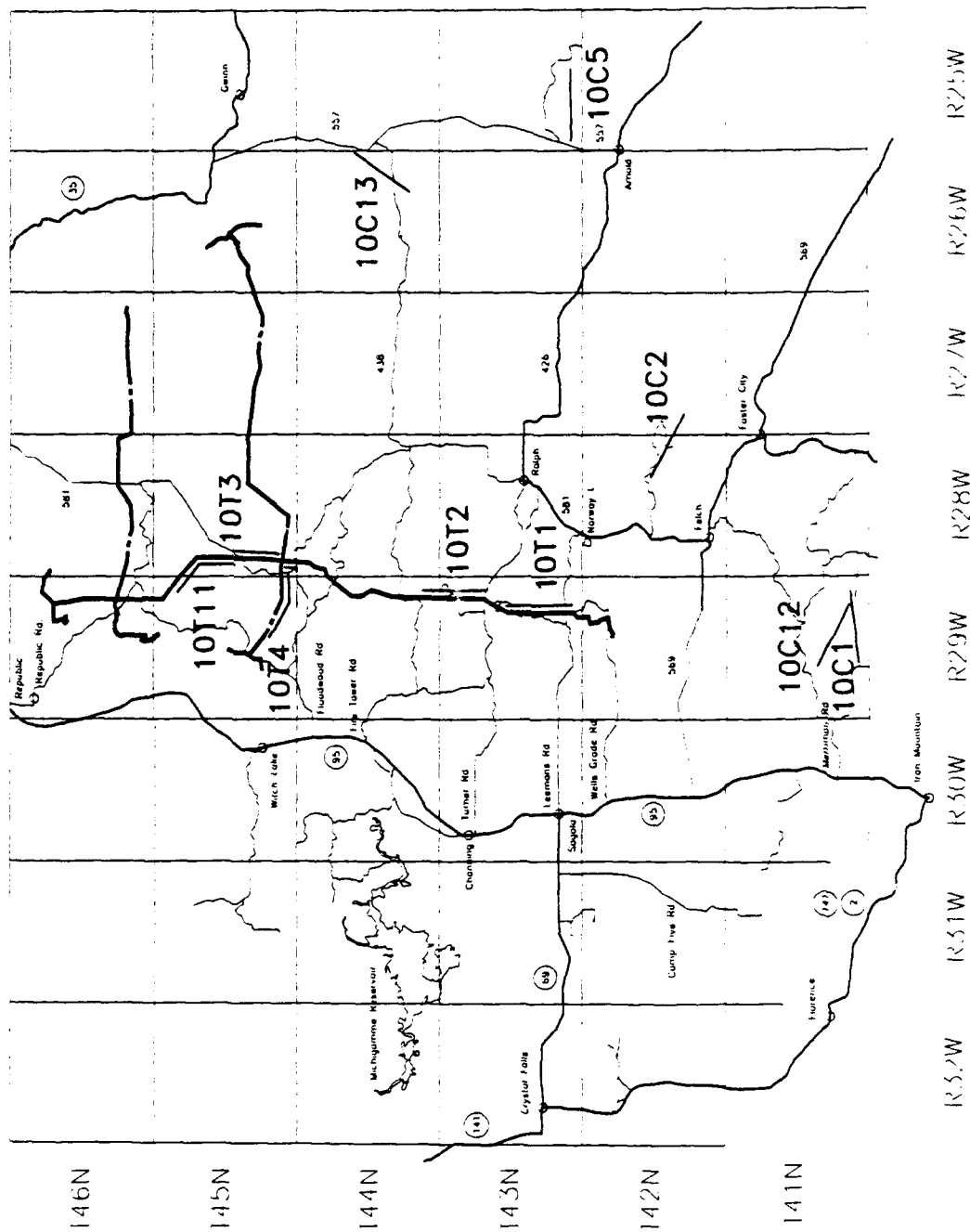


FIGURE G-1. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

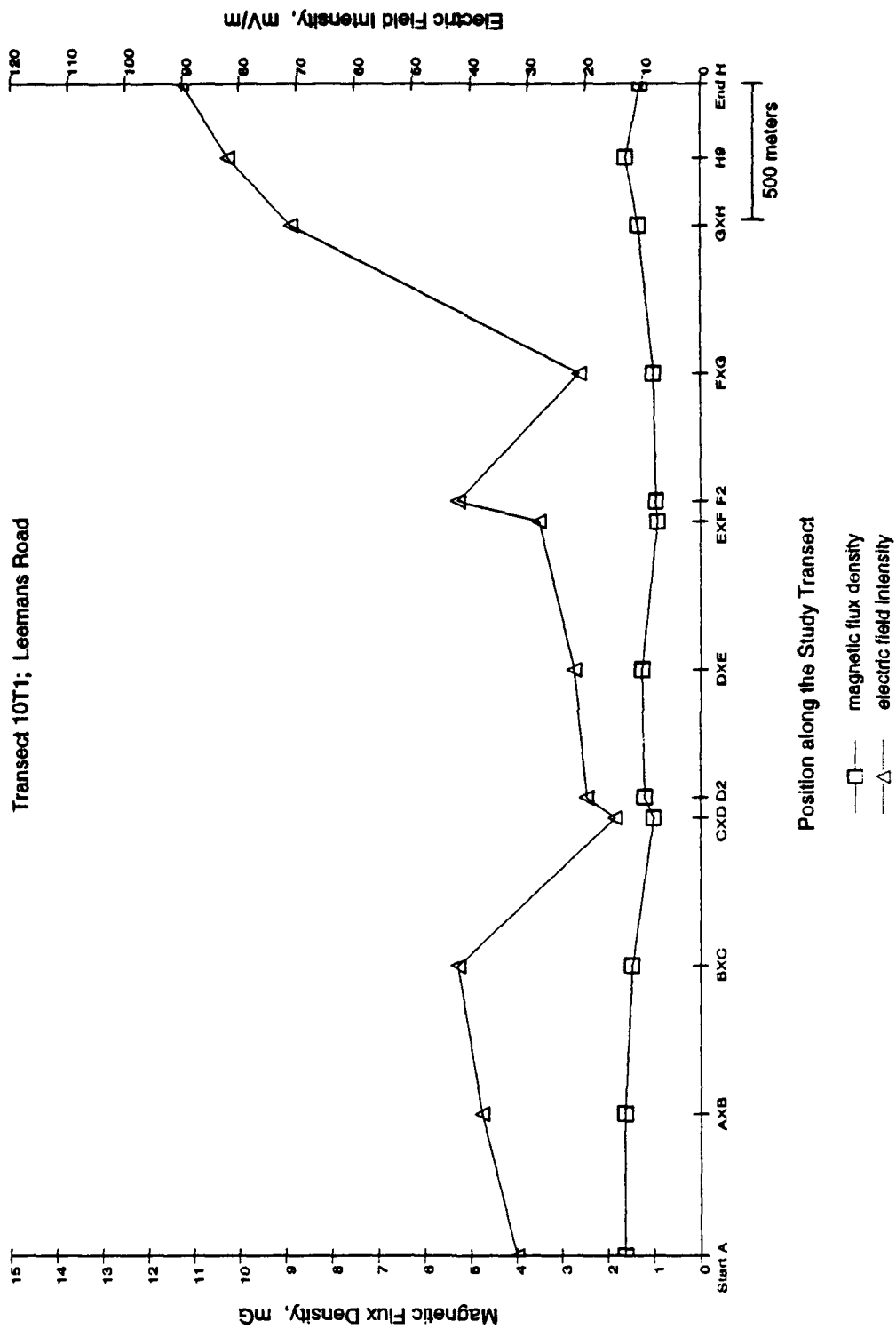


FIGURE G-2. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T1.

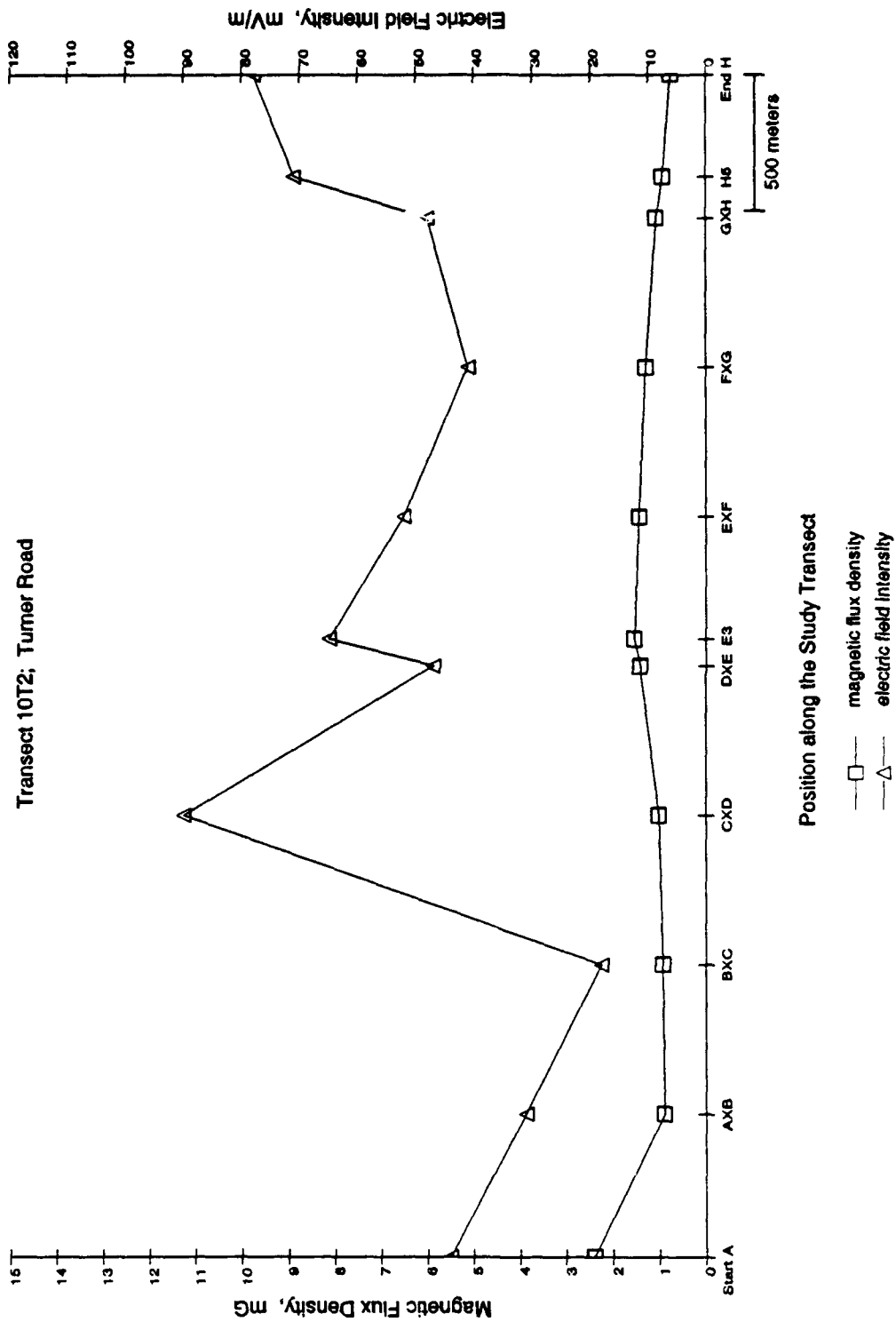


FIGURE G-3. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T2.

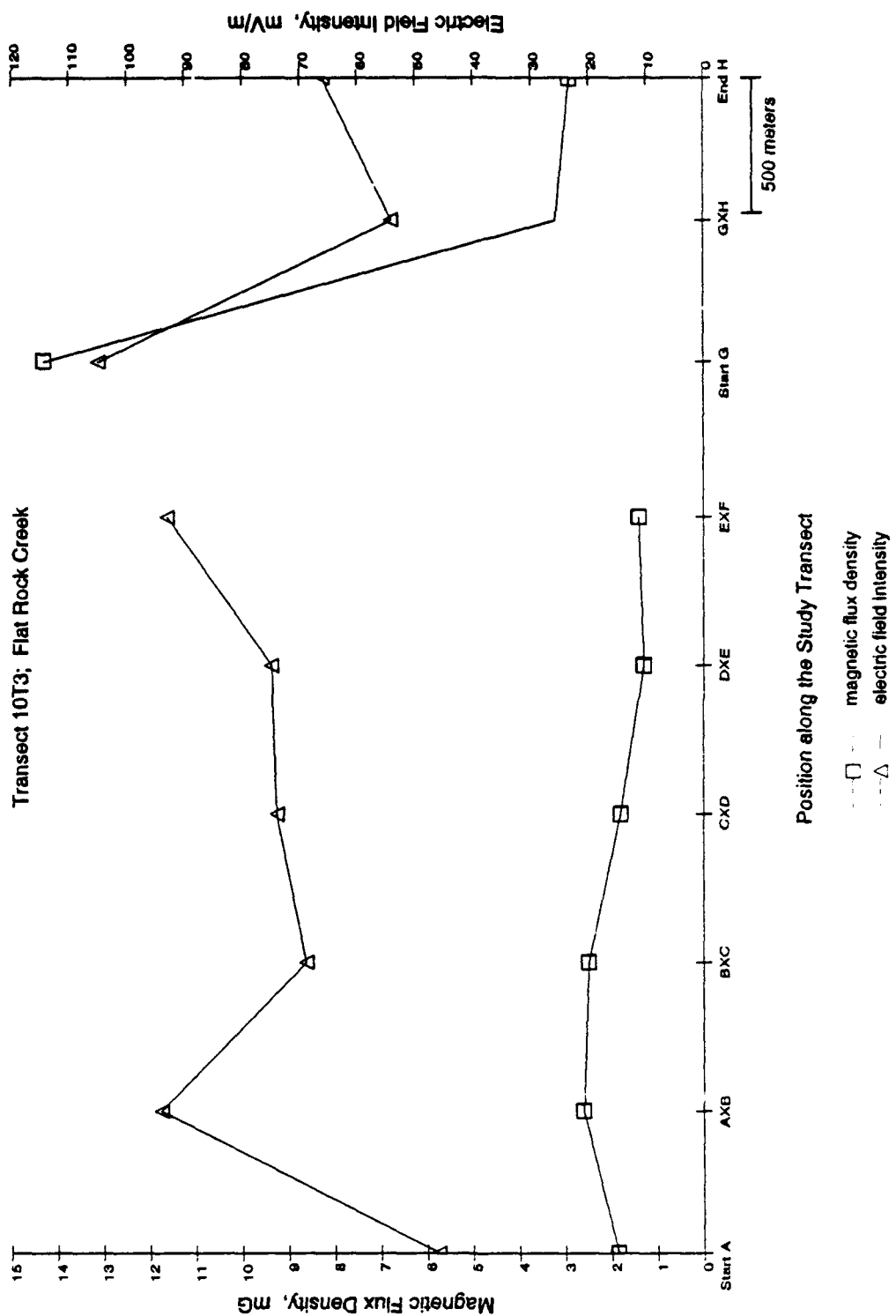


FIGURE G-4. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T3.

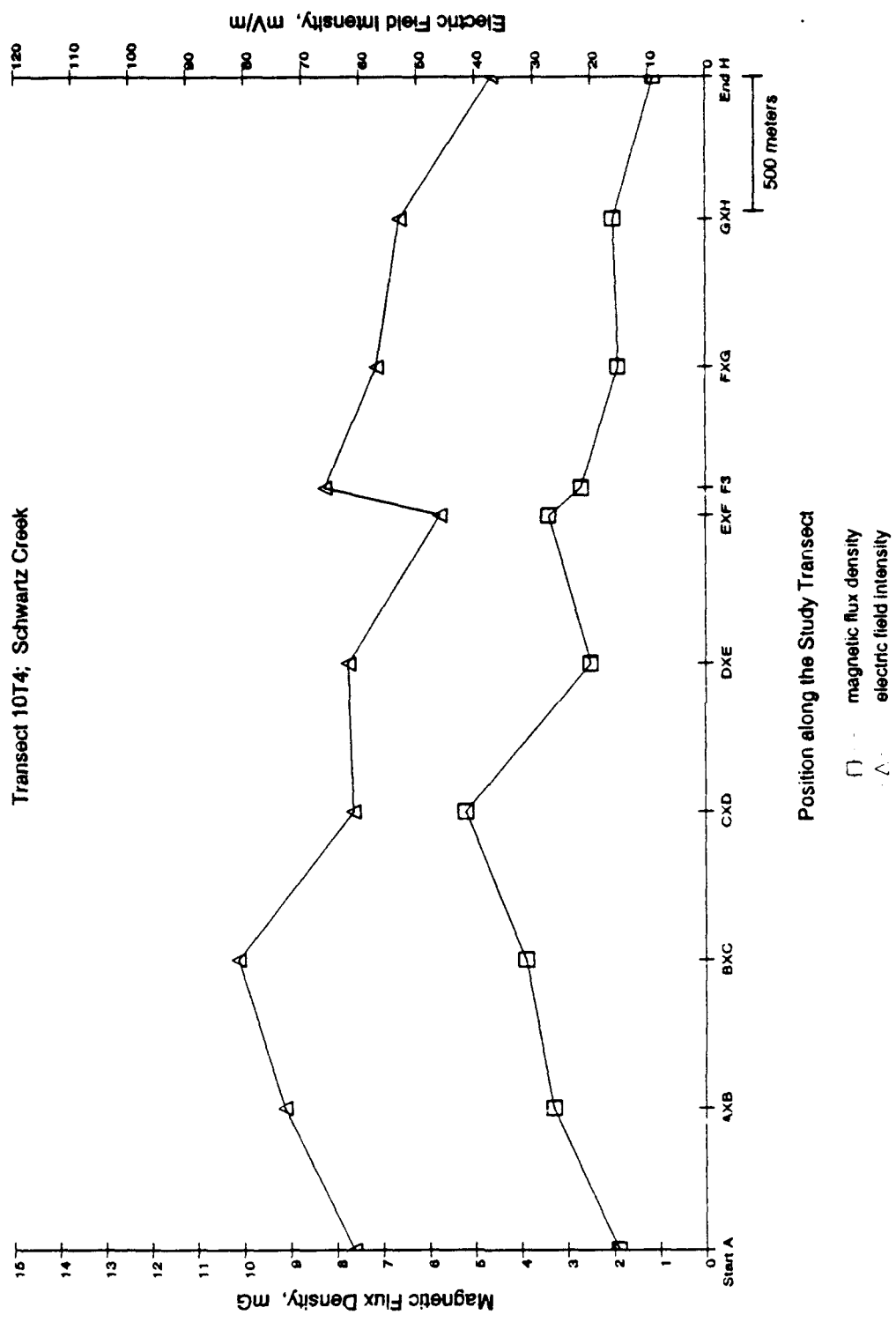


FIGURE G-5. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T4.

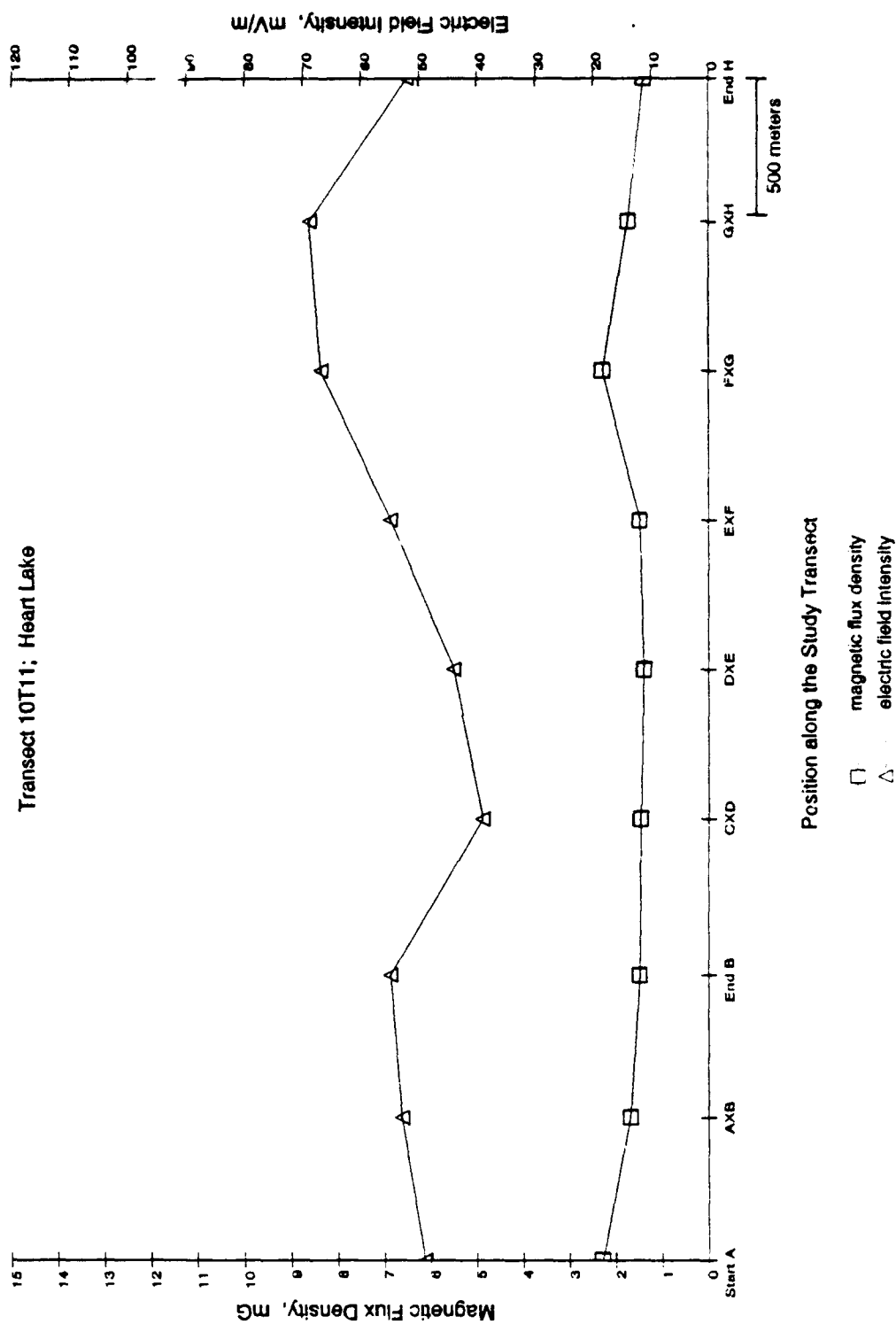


FIGURE G-6. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T11.

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

Site No., Meas Pt	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
10C1-2	-	<	<	<	<	<	<	< ^d	< ^d	< ^d
10C1-3	-	-	<	<	<	<	<	< ^d	< ^d	< ^d
10C2-1	-	<	<	<	<	<	<	< ^d	< ^d	< ^d
10C2-2	-	<	<	<	<	<	<	< ^d	< ^d	< ^d
10C5-2	-	<	<	<	<	<	<	< ^d	< ^d	< ^d
10C5-3	-	<	<	<	<	<	<	< ^d	< ^d	< ^d
10C12-1	-	-	<	<	<	<	<	< ^d	< ^d	< ^d
10C12-2	-	-	<	<	<	<	<	< ^d	< ^d	< ^d
10C13-1	-	-	<	<	<	<	<	< ^d	< ^d	< ^d
10C13-2	-	-	<	<	<	<	<	< ^d	< ^d	< ^d
10T1-1	-	<	<	<	<	<	<0.001	< ^b	< ^c	< ^b
10T1-3	-	-	<	<	<	<	<	< ^b	< ^b	< ^b
10T1-4	-	-	-	<	<	<	<	< ^b	< ^c	< ^b
10T1-5	-	-	-	<	<	<	<0.001	< ^b	< ^c	< ^b
10T2-1	-	<0.001	<	<	<	<	<	< ^c	< ^b	< ^b
10T2-2	-	-	-	<	<	<	<	< ^b	< ^b	< ^b
10T2-4	-	-	<	<	<	0.008	#	< ^b	< ^b	< ^b
10T3-1	-	<	<	<	<	<	<	#	< ^b	< ^b
10T3-2	-	<	<	<	<	<	<	#	< ^c	< ^b
10T3-3	-	-	-	<	<	<0.001	<0.001	#	< ^c	< ^b
10T4-1	-	<	<	<	<	<	<	#	< ^c	< ^b
10T4-3	-	-	-	<	<	<	<	#	< ^c	/
10T11-1	-	-	<	<	<	<0.001	<0.001	#	< ^b	< ^b
10T11-2	-	-	<	<	0.011	<0.001	<0.001	#	< ^b	< ^b

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

-- measurement point not established
- -- measurement precluded by antenna operation
< -- measurement est <0.001 V/m based on earth E field

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

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
10C1-2	-	0.62	0.106, 0.141	0.101	0.059	0.20	0.073	0.27 ^d	0.105 ^d	0.038 ^d
10C1-3	-	-	0.26, 0.27	0.055	0.21	0.32	0.72	0.079 ^d	0.78 ^d	0.50 ^d
10C2-1	-	0.98	0.138	0.041	0.038	0.087	0.080	0.076 ^d	0.076 ^d	0.031 ^d
10C2-2	-	0.35	0.21	0.055	0.048	0.047	0.069	0.076 ^d	0.057 ^d	0.045 ^d
10C5-2	-	0.35	0.45	0.193	0.116	0.23	0.053	0.050 ^d	0.037 ^d	0.44 ^d
10C5-3	-	0.111	0.23	0.25	0.103	0.126	0.050	0.073 ^d	0.160 ^d	0.27 ^d
10C12-1	-	-	0.194, 0.28	0.058	0.256	0.98	1.19	0.22 ^d	1.32 ^d	0.65 ^d
10C12-2	-	-	0.106, 0.141	0.101	0.059	0.20	0.073	0.27 ^d	0.105 ^d	0.098 ^d
10C13-1	-	-	0.34, 0.52	0.30	0.40	0.37	0.78	0.099 ^d	0.156 ^d	0.70 ^d
10C13-2	-	-	0.143, 0.31	0.139	0.157	0.121	0.039	0.074 ^d	0.212 ^d	0.30 ^d
10T1-1	-	0.076	0.061	0.034	0.099	0.21	0.077	0.039 ^b	0.038 ^c	0.056 ^b
10T1-3	-	-	0.38	0.120	0.20	0.51	#	0.106 ^b	0.092 ^b	0.036 ^b
10T1-4	-	-	-	0.111	0.085	0.30	0.076	0.029 ^b	0.040 ^c	0.032 ^b
10T1-5	-	-	-	0.040	0.052	0.116	0.052	0.021 ^b	0.023 ^c	0.030 ^b
10T2-1	-	0.42	0.194	0.050	0.058	0.23	0.034	0.130 ^c	0.123 ^b	0.081 ^b
10T2-2	-	-	-	0.058	0.052	0.24	0.023	0.028 ^b	0.090 ^b	0.046 ^b
10T2-4	-	-	0.158	0.054	0.029	0.166	0.164	0.013 ^b	0.093 ^b	0.038 ^b
10T3-1	-	0.30	0.23	0.145	0.164	0.070	#	#	0.148 ^b	0.170 ^b
10T3-2	-	0.26	0.117	0.069	0.103	0.075	#	#	0.173 ^c	0.091 ^b
10T3-3	-	-	-	0.094	0.120	0.132	0.32	#	0.39 ^c	0.105 ^b
10T4-1	-	0.29	0.132	0.129	0.093	0.087	#	#	0.20 ^c	0.076 ^b
10T4-3	-	-	-	0.112	0.22	0.166	0.087	#	0.21 ^c	/
10T11-1	-	-	0.23	0.172	0.106	0.095	0.25	#	0.145 ^b	0.116 ^b
10T11-2	-	-	0.26, 0.50	0.58	0.45	0.196	0.21	#	0.34 ^b	0.22 ^b

a = antennas not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A current.

= measurement point not established.

- = measurement precluded by antenna operation.

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

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c	1988 ^c	1989 ^d	1990	1991	1992
10C1-2	-	0.001	0.001	<0.001	<0.001	0.001	0.001	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
10C2-1	-	0.005	0.004	<0.001	<0.001	<0.001	0.001	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
10C5-2	-	0.008	0.009	0.006	0.005	0.006	0.002	0.001 ^d	0.008 ^d	0.014 ^d
10C5-3	-	0.001	0.002	0.002	0.001	0.001	0.001	0.001 ^d	0.002 ^d	0.002 ^d
10C12-1	-	-	0.001, 0.003	0.002	0.003	0.011	0.009	0.001 ^d	0.014 ^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
10C13-1	-	-	0.007, 0.010	0.007	0.005	0.003	0.009	0.003 ^d	0.011 ^d	0.017 ^d
10C13-2	-	-	0.001, <0.001	0.001	0.001	0.001	0.001	0.001 ^d	0.001 ^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
10T1-3	-	-	0.002	0.003	0.005	0.017	#	0.003 ^b	0.005 ^b	0.002 ^b
10T1-4	-	-	-	0.003	0.003	0.009	0.002	0.001 ^b	0.002 ^c	0.002 ^b
10T1-5	-	-	-	0.003	0.016	0.012	0.003	0.001 ^b	0.002 ^c	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
10T2-2	-	-	-	<0.001	0.002	0.008	0.001	0.001 ^b	0.006 ^b	0.002 ^b
10T2-4	-	-	0.001	0.002	0.001	0.004	0.001	<0.001 ^b	0.004 ^b	0.001 ^b
10T3-1	-	0.001	0.001	0.006	0.003	0.004	#	#	0.003 ^b	0.002 ^b
10T3-2	-	0.001	<0.001	0.008	0.005	0.004	#	#	0.012 ^c	0.003 ^b
10T3-3	-	-	-	0.012	0.007	0.017	0.010	#	0.030 ^c	0.001 ^b
10T4-1	-	0.001	<0.001	0.002	0.002	0.003	#	#	0.004 ^c	0.001 ^b
10T4-3	-	-	-	0.001	0.003	0.004	0.002	#	0.06 ^c	/
10T11-1	-	-	<0.001	0.006	0.006	0.003	0.003	#	0.003 ^b	0.002 ^b
10T11-2	-	-	0.001, <0.001	0.008	0.005	0.004	<0.001	#	0.006 ^b	0.003 ^b

a = antennas not constructed.

b = antennas off, grounded at transmitter.

c = antennas off, connected to transmitter.

d = antennas on, 150 A current.

= measurement point not established.

= measurement precluded by antenna operation.

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

Site No., Meas. Pt.	1986				1987			1988		1989	1990	1991	1992
	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	0.037	0.032
10T1-3	0.002	<	<	*	0.007	<	0.038	<0.001	0.068	0.081	0.084	0.084	0.055
10T1-4	<	<	<	*	0.004	<	0.024	<	0.036	0.040	0.033	0.033	0.026
10T1-5	<	<	<	*	0.003	<	0.010	<	0.022	0.029	0.022	0.022	0.016
10T2-1	0.002	<	<	*	0.006	<	0.033	<0.001	0.059	0.088	0.072	0.072	0.072
10T2-2	0.002	<	<	*	0.007	<	0.047	0.003	0.062	0.062	0.069	0.069	0.036
10T2-4	0.002	<	<	*	0.007	<	0.028	0.007	0.062	0.060	0.075	0.075	0.039
10T3-1	0.004	<	<	*	0.005	0.003	0.016	0.019	0.040	0.050	0.050	0.050	0.072
10T3-2	0.004	<	0.001	0.002	0.006	0.003	0.048	0.034	0.071	0.070	0.067	0.067	0.134
10T3-3	0.005	<	0.017	0.028	0.005	0.009	0.046	0.120	0.170	0.130	0.125	0.125	0.123
10T4-1	0.002	<	0.003	0.005	0.003	0.006	0.042	0.038	0.049	0.051	0.067	0.067	0.075
10T4-3	<	<	0.003	0.005	0.001	0.008	0.018	0.054	0.078	0.062	0.072	0.072	/
10T11-1	<	<	<	*	0.004	0.002	0.019	0.014	0.051	0.053	0.064	0.064	0.063
10T11-2	<	<	<	*	0.038	0.009	0.059	0.017	0.108	0.27	0.185	0.185	1.32

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

EX = extrapolated data.
* = data cannot be extrapolated.
< = measurement est. <0.001 V/m based on earth E-field.

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

Site No., Meas. Pt.	1986					1987			1988			1989	1990	1991	1992
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	NS 150 A	EW 150 A	NS 150 A	EW 150 A	NS 150 A	EW 150 A
10C1-2	0.004	0.003	0.004	0.007	0.007	0.015	0.012	0.074	0.058	0.153	0.153	0.31	0.31	0.139	0.158
10C1-3	0.013	0.004	0.002	0.003	0.003	0.049	0.011	0.26	0.060	0.41	0.41	0.44	0.44	0.50	0.55
10C2-1	0.017	0.002	0.007	0.012	0.012	0.073	0.021	0.30	0.095	0.78	0.78	0.70	0.70	0.64	0.62
10C2-2	0.011	0.003	0.007	0.012	0.012	0.037	0.020	0.176	0.100	0.33	0.33	0.43	0.43	0.30	0.40
10C5-2	0.001	0.003	0.007	0.012	0.012	0.014	0.023	0.073	0.119	0.26	0.26	0.28	0.28	0.21	0.179
10C5-3	0.005	0.003	0.009	0.015	0.015	0.017	0.027	0.091	0.143	0.30	0.30	0.28	0.28	0.24	0.29
10C12-1	0.028	0.010	0.011	0.018	0.018	0.068	0.028	0.36	0.140	1.37	1.37	0.76	0.76	0.90	0.94
10C12-2	0.004	0.003	0.004	0.007	0.007	0.015	0.012	0.074	0.058	0.153	0.153	0.31	0.31	0.139	0.158
10C13-1	0.024	0.027	0.104	0.173	0.173	0.057	0.24	0.32	1.39	4.8	4.8	4.2	4.2	3.3	3.9
10C13-2	0.024	0.023	0.098	0.163	0.163	0.089	0.29	0.34	1.07	2.1	2.1	2.7	2.7	2.4	2.7
10T1-1	0.85	0.028	0.008	0.013	0.013	2.8	0.015	13.0	0.115	42	42	32	32	41	38
10T1-3	2.2	0.068	0.077	0.128	0.128	7.1	0.147	33	0.86	74	74	82	82	77	76
10T1-4	0.96	0.030	0.031	0.052	0.052	4.1	0.087	19.8	0.46	35	35	42	42	40	43
10T1-5	0.65	0.020	0.006	0.010	0.010	2.3	0.015	10.9	0.098	20	20	19.7	19.7	19.0	21
10T2-1	1.42	0.043	0.077	0.128	0.128	5.3	0.25	31	1.05	48	48	44	44	76	83
10T2-2	1.69	0.056	0.107	0.178	0.178	7.0	0.34	33	1.77	53	53	65	65	67	63
10T2-4	0.59	0.056	0.158	0.26	0.26	5.0	0.49	26	2.6	79	79	71	71	57	74
10T3-1	0.82	0.23	0.60	1.00	1.00	4.9	2.1	26	10.1	47	47	46	46	47	46
10T3-2	1.24	0.133	1.05	1.75	1.75	5.4	2.7	21	31	61	61	66	66	76	78
10T3-3	1.36	(0.35)	3.6	6.0	6.0	4.8	7.5	43	54	111	111	105	105	105	112
10T4-1	0.88	0.137	1.58	2.6	2.6	2.4	4.8	14.5	19.3	62	62	61	61	58	54
10T4-3	0.46	0.139	1.92	3.2	3.2	1.30	8.1	5.4	39	68	68	66	66	67	/
10T11-1	0.67	0.27	0.59	0.98	0.98	3.9	1.97	17.6	8.9	47	47	49	49	47	52
10T11-2	1.38	0.93	0.44	0.73	0.73	7.3	2.9	32	12.6	105	105	86	86	72	77

EX = extrapolated data.

NS = north-south antenna.

EW = east-west antenna.

NEW = northern EW antenna element.

SEW = southern EW antenna element.

B = NS + EW antennas, standard phasing.

A = amperes.

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

Site No., Meas. Pt.	1986					1987		1988		1989	1990	1991	1992
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	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
10C1-2	<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
10C2-1	<0.001	<0.001	<0.001	*	*	0.001	0.001	0.005	0.002	0.009	0.009	0.007	0.006
10C2-2	<0.001	<0.001	<0.001	*	*	0.001	<0.001	0.003	0.002	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
10C5-3	<0.001	<0.001	<0.001	*	*	<0.001	<0.001	0.001	0.001	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
10C12-2	<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
10C13-2	<0.001	<0.001	<0.001	*	*	<0.001	0.001	0.002	0.006	0.015	0.015	0.014	0.013
10T1-1	0.044	0.001	<0.001	*	*	0.179	0.001	0.84	0.005	1.87	1.63	1.60	1.77
10T1-3	0.047	0.001	0.007	0.012	0.012	0.176	0.001	0.84	0.010	1.70	1.62	1.64	1.68
10T1-4	0.026	0.001	0.001	0.002	0.002	0.103	0.002	0.49	0.014	1.02	0.95	0.91	0.94
10T1-5	0.034	0.001	0.001	0.002	0.002	0.49	0.002	0.61	0.008	1.31	1.20	1.19	1.22
10T2-1	0.066	0.002	0.001	0.002	0.002	0.25	0.001	1.21	0.010	2.5	2.4	2.3	2.4
10T2-2	0.043	0.001	0.001	0.002	0.002	0.165	0.002	0.80	0.010	1.61	1.54	1.55	1.60
10T2-4	0.026	0.001	0.001	0.002	0.002	0.097	0.002	0.46	0.005	0.97	0.92	0.91	0.91
10T3-1	0.029	0.003	0.007	0.012	0.012	0.188	0.015	0.96	0.078	1.89	1.87	1.85	1.94
10T3-2	0.081	0.002	0.013	0.022	0.022	0.29	0.031	1.61	0.161	2.9	2.9	2.8	3.0
10T3-3	0.116	(0.040)	0.58	0.97	0.97	0.196	0.89	1.11	7.7	15.0	14.3	14.0	15.0
10T4-1	0.025	0.001	0.081	0.135	0.135	0.038	0.191	0.20	1.00	1.92	1.89	1.90	2.0
10T4-3	0.025	0.001	0.119	0.198	0.198	0.011	0.32	0.051	1.42	2.9	2.7	2.6	/
10T11-1	0.033	0.002	0.006	0.010	0.010	0.24	0.015	1.09	0.072	2.3	2.3	2.0	2.2
10T11-2	0.042	0.003	0.003	0.005	0.005	0.31	0.006	1.42	0.033	2.9	2.8	2.8	3.0

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

EX = extrapolated data.

* = data cannot be extrapolated.

TABLE G-9. 1990 EM FIELD VARIATIONS ALONG MICHIGAN TRANSECTS
Bird Species and Communities Studies

Study Transect	Sub-Transect Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10T1-1	Start A	1.63	32
10T1	AXB	1.64	38
10T1	BXC	1.48	42
10T1	CXD	1.02	14.8
10T1-5	D2	1.20	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
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:

$$T_{(76 \text{ Hz})}/C_{(76 \text{ Hz})} > 10 \quad (1)$$

$$T_{(76 \text{ Hz})}/T_{(60 \text{ Hz})} > 10 \quad (2)$$

$$T_{(76 \text{ Hz})}/C_{(60 \text{ Hz})} > 10 \quad (3)$$

$$0.1 < T_{(60 \text{ Hz})}/C_{(60 \text{ Hz})} < 10 \quad (4)$$

where $T_{(76 \text{ Hz})}$ = treatment site exposure due to ELF Communications System

$T_{(60 \text{ Hz})}$ = treatment site exposure due to power lines

$C_{(76 \text{ Hz})}$ = control site exposure due to ELF Communications System

$C_{(60 \text{ Hz})}$ = 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-meter 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-meter probe.
- (2) Locate collector electrodes in line with maximum electric field, with a separation of 1 meter.
- (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 M Ω).

- (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.

$$V_R = V_{DR} = V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} = 0.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

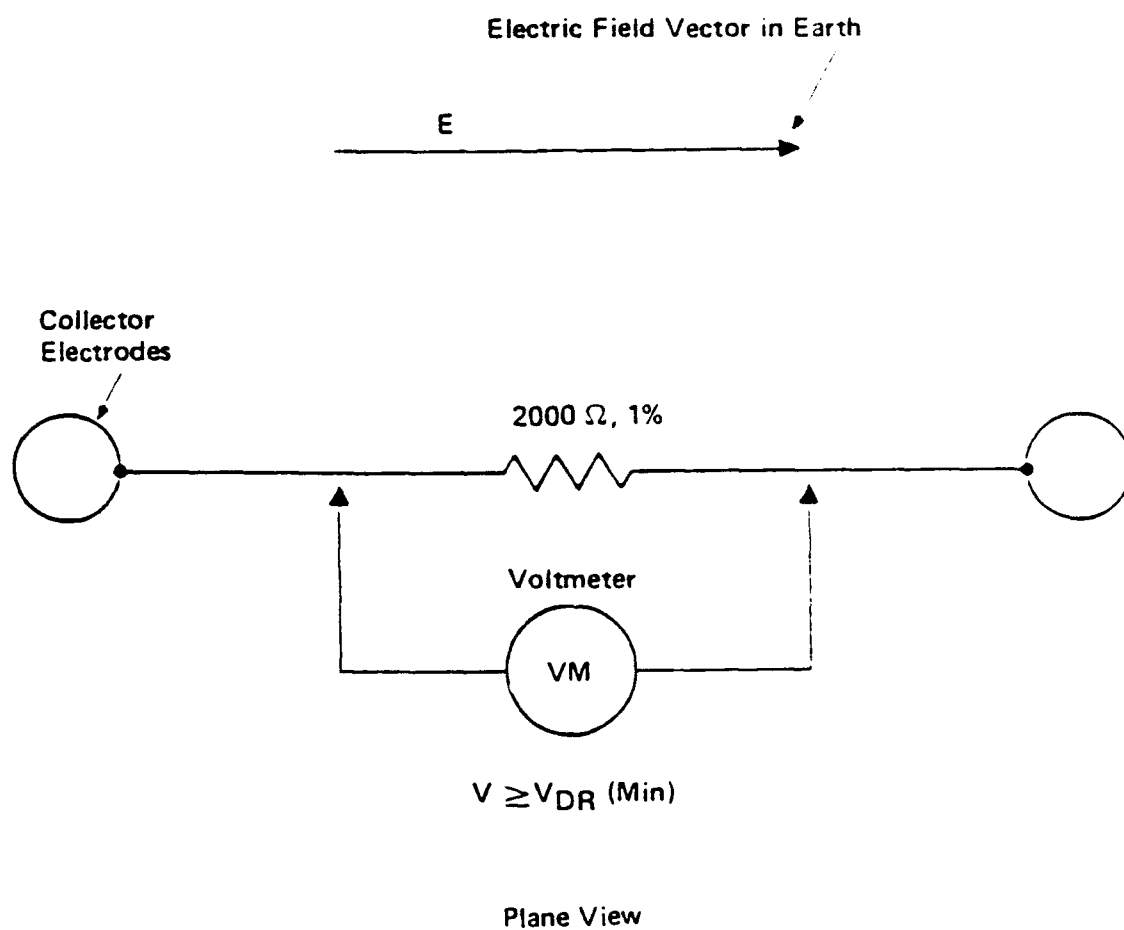
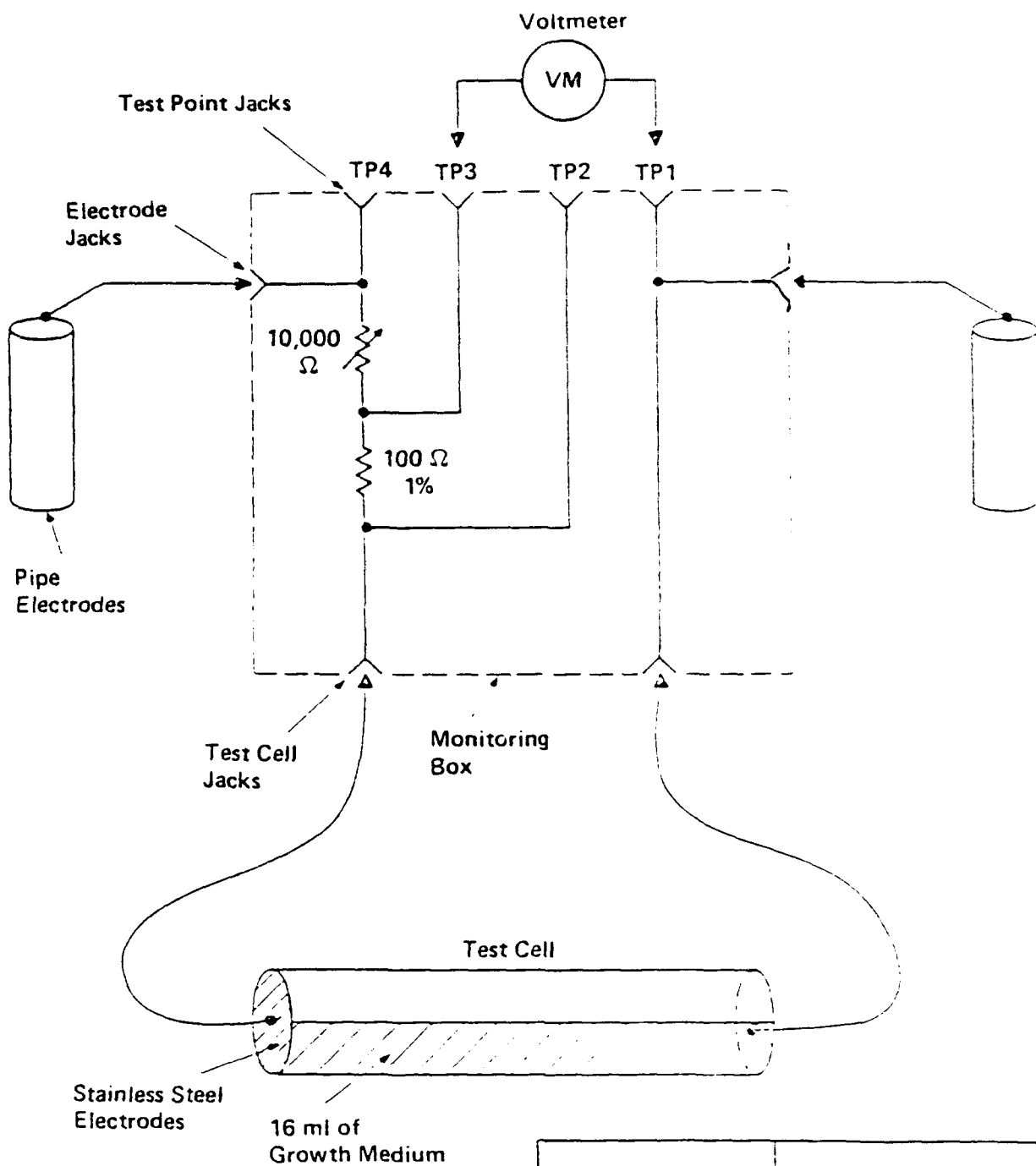


FIGURE I-1. DETERMINATION OF DRIVE VOLTAGE FOR THE SOIL AMOEBA STUDIES
MATCHED ELECTRIC FIELD PROTOCOL.



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.

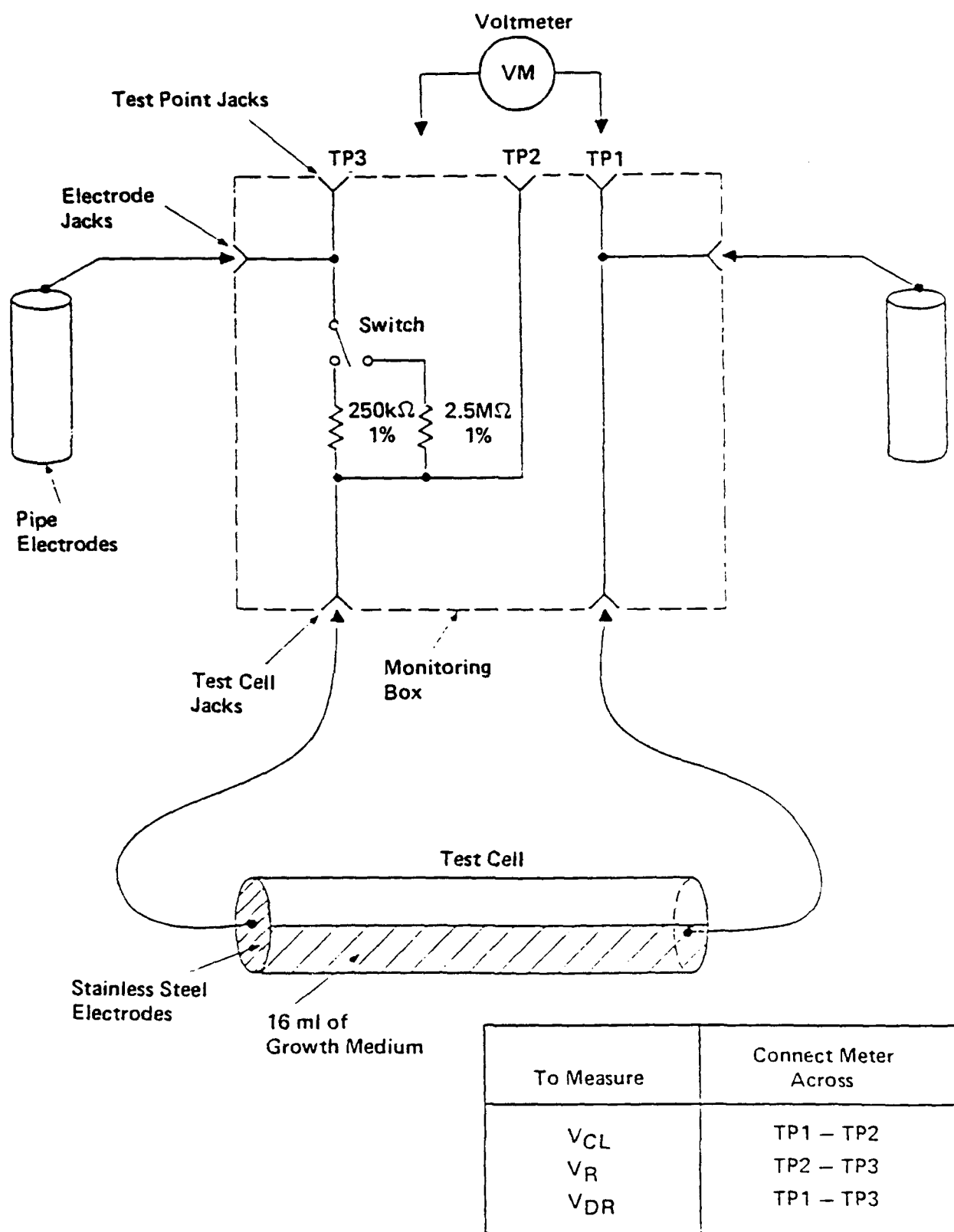


FIGURE I-3. CONTROL BOX CONNECTIONS FOR MATCHED CURRENT DENSITY CHAMBERS.

APPENDIX J

**SUMMARY OF OPERATION,
NRTF-REPUBLIC**

SUMMARY OF OPERATION, NRTF-REPUBLIC

The operations of the NRTF-Republic from 1986 through 1992 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-19 show the number of hours of operation per month in 1989, 1990, 1991, and 1992 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 1992) 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												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal^a</u>													
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: <u>Unmodulated Signal</u>													
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

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes 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												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	0.05	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	0.00	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

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes 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: <u>Modulated Signal</u> ^a													
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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: <u>Unmodulated Signal</u>													
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)	<u>0.00</u>	<u>0.00</u>	<u>3.87</u>	<u>18.64</u>	<u>6.15</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>28.66</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.03</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.03</u>
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

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes 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: <u>Modulated Signal^a</u>													
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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: <u>Unmodulated Signal</u>													
76 (15 Amps)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>44.40</u>	<u>27.59</u>	<u>32.40</u>	<u>38.86</u>	<u>33.08</u>	<u>21.79</u>	<u>0.00</u>	<u>198.12</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.42</u>	<u>0.42</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.84</u>
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

^aFrequency listed refers to the center frequency of operation.

^bDenotes small periods of time at other currents or unmodulated 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	0.00	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

^aFrequency listed refers to the center frequency of operation.

^bDenotes 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: <u>Modulated Signal</u> ^a													
76 (75 Amps)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.27</u>	<u>0.14</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.41</u>
Subtotal	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.27</u>	<u>0.14</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.41</u>
Mode: <u>Unmodulated Signal</u>													
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)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>1.27</u>	<u>0.00</u>	<u>26.16</u>	<u>2.61</u>	<u>31.20</u>	<u>15.68</u>	<u>76.92</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>8.09</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>8.09</u>
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	498.56
Antenna On/Off Cycles	326	316	326	410	495	519	485	714	725	666	526	473	5981

^aFrequency listed refers to the center frequency of operation.

^bDenotes 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												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	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

^aFrequency listed refers to the center frequency of operation.

^bDenotes 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	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal</u> ^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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.32</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.32</u>
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: <u>Unmodulated Signal</u>													
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	0.00	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	8.19	0.30	3.82	0.42	9.19	25.30	3.55	0.00	0.00	0.00	109.46
80	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.38</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.38</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.40</u>	<u>1.24</u>	<u>0.35</u>	<u>0.02</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>2.01</u>
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

^a75 ampere antenna current used in Jan-Mar, 150 ampere antenna current used in Apr-Dec

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
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

^a75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
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

^a75 ampere antenna current used in Jan-Mar, 150 ampere antenna current used in Apr-Dec.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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 ^c													
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

^a150 ampere antenna current used throughout 1990.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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

^a150 ampere antenna current used throughout 1990.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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

^a150 ampere antenna current used throughout 1990.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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

^a150 ampere antenna current used throughout 1991.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal ^p													
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.25</u>	<u>2.01</u>	<u>3.95</u>	<u>0.09</u>	<u>0.00</u>	<u>0.00</u>	<u>9.30</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>1.13</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>2.00</u>	<u>3.13</u>
Totals	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>4.38</u>	<u>2.01</u>	<u>3.95</u>	<u>0.09</u>	<u>0.00</u>	<u>2.00</u>	<u>12.43</u>
Antenna On/Off Cycles	0	0	0	0	0	0	10	4	2	9	0	1	26

^a150 ampere antenna current used throughout 1991.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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

^a150 ampere antenna current used throughout 1991.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal</u> ^b													
76	<u>673.85</u>	<u>648.50</u>	<u>576.74</u>	<u>0.08</u>	<u>0.06</u>	<u>0.00</u>	<u>0.28</u>	<u>9.67</u>	<u>0.15</u>	<u>0.71</u>	<u>0.12</u>	<u>0.00</u>	<u>1910.16</u>
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: <u>Unmodulated Signal</u>													
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
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	<u>0.12</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.12</u>
Totals	<u>673.97</u>	<u>648.50</u>	<u>576.74</u>	<u>0.08</u>	<u>0.06</u>	<u>0.00</u>	<u>0.28</u>	<u>9.67</u>	<u>0.15</u>	<u>0.71</u>	<u>0.12</u>	<u>0.00</u>	<u>1910.28</u>
Antenna On/Off Cycles	10	11	10	2	1	0	4	3	4	3	2	0	50

^a150 ampere antenna current used throughout 1992.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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: <u>Modulated Signal</u> ^b													
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.99</u>	<u>0.00</u>	<u>0.06</u>	<u>5.62</u>	<u>0.23</u>	<u>0.00</u>	<u>0.85</u>	<u>4.28</u>	<u>15.03</u>
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: <u>Unmodulated Signal</u>													
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.36</u>	<u>0.05</u>	<u>0.41</u>
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	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Totals	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>3.99</u>	<u>0.00</u>	<u>0.06</u>	<u>5.62</u>	<u>0.23</u>	<u>0.00</u>	<u>1.21</u>	<u>4.33</u>	<u>15.44</u>
Antenna On/Off Cycles	0	0	0	0	2	0	1	8	5	0	5	2	23

^a150 ampere antenna current used throughout 1992.

^bFrequency listed refers to the center frequency of operation.

^cDenotes 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

^a150 ampere antenna current used throughout 1992.

^bFrequency listed refers to the center frequency of operation.

^cDenotes small periods of time at other currents or undesignated operation.