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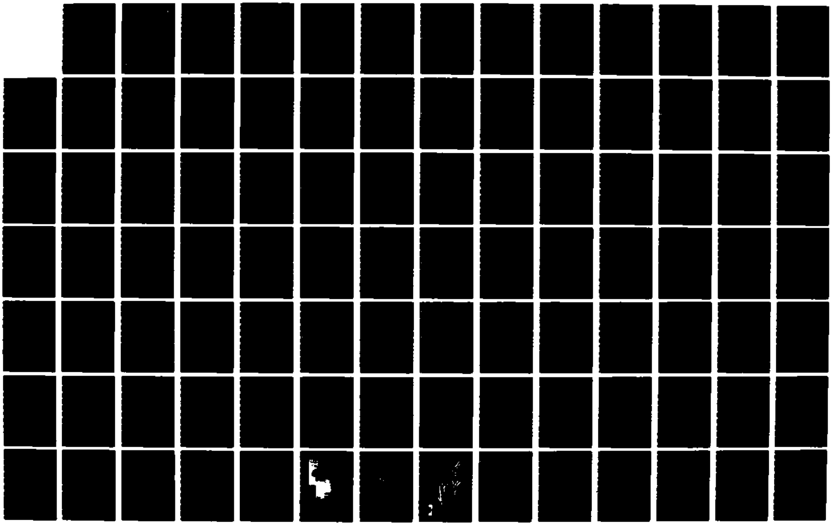

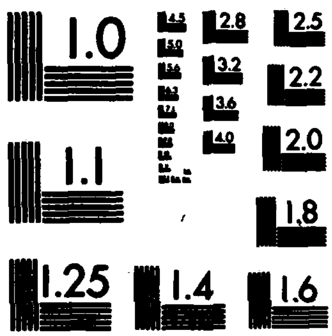

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AD-A135 482

EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: PLAN AND SUMMARY OF 1982 PROGRESS

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M. M. Abromavage

August 1983

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The Department of the Navy completed the ELF Ecological Monitoring Program formulation early in 1982. Scientific studies were funded through a peer-reviewed, competitive bidding process in mid-1982, and studies were initiated at the Wisconsin and Michigan ELF Communications System sites in late summer. Two additional studies will be initiated during 1983 to complete the present complement of projects.

The purpose of the Ecological Monitoring Program is to study ecological and/or biological characteristics of selected biota in an environment that includes natural stresses and low-level ELF electromagnetic fields. Sixteen general types of organisms from three major ecosystems in the System area are being examined. Study sites were selected in 1982, and will be examined further in 1983. Statistical methods of analysis proposed by investigators are identified, and biological and ecological end-points selected for study are described. Data collection began in 1982 and will be continued in 1983 for studies of vegetation, soil animals, pollinating insects, small mammals and birds, wetlands vegetation associations, and aquatic community relationships.

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FOREWORD

This report documents the plans adopted and the accomplishments during 1982 for the Extremely Low Frequency (ELF) Communications Ecological Monitoring Program. The purpose of the Program is to conduct studies recommended to the Naval Electronic Systems Command (NESC) during and subsequent to the ELF Communications Program environmental impact evaluation process, including the scientific review of ELF electromagnetic field effects made by the National Academy of Sciences in 1977.

This document generally describes the Ecological Monitoring Program status as of December 1982. A companion report "Compilation of 1982 Annual Reports of the Navy ELF Communications System Ecological Monitoring Program" (May 1983) provides greater detail on each study element of the Program. All studies are being conducted under subcontract arrangements between IIT Research Institute and study teams (E06516-82-C-10015/40015) via NESC Contract N00039-81-C-0357.

Respectfully submitted
IIT Research Institute

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Engineering Advisor

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INTRODUCTION

EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS PROGRAM

The Department of the Navy has been interested in using extremely low frequency signals for command control communications with submarines since the late 1950's. Communications in the lower portion of the electromagnetic spectrum is especially useful because ELF waves penetrate sea water with very little loss in strength (IEEE, 1974).

The concept of ELF communications was proven by the Navy in tests between an ELF transmitting antenna and submerged submarines in 1963. An experimental transmitter was installed in northwestern Wisconsin in 1968-69 (NESC, 1973) to aid research and development for an operational ELF Communications System. Environmental evaluations have been made concurrently with research and development, and periodically reported (NESC, 1972, 1977).

On October 8, 1981, President Reagan directed the Department of the Navy to proceed with a program for completing an operational ELF Communications System. The experimental transmitter in Northwestern Wisconsin, known as the Wisconsin ELF Facility, is to be upgraded to operational status. A second transmitter and antenna system will be installed in the Upper Peninsula of Michigan. The transmitters can be operated independently of one another, or can be operated synchronously. The Navy's plans for developing the ELF operational capability and conducting necessary environmental protection work have been completed (NESC, 1981). A description of the ELF Communications System is provided in Appendix A.

ELF ELECTROMAGNETIC EFFECTS EVALUATIONS

The evaluation of ELF electromagnetic effects on biological systems commenced with a study of the available scientific literature in 1968-69. The literature at that time included very little research at extremely low frequencies, and particularly at the very low field intensity levels which would be produced by ELF transmitting antennas. Since the literature was sparse, an exploratory series of laboratory tests was initiated to identify the biological areas which were most likely to provide substantive data for assessing the subject, see Table 1. The exploratory research was initiated

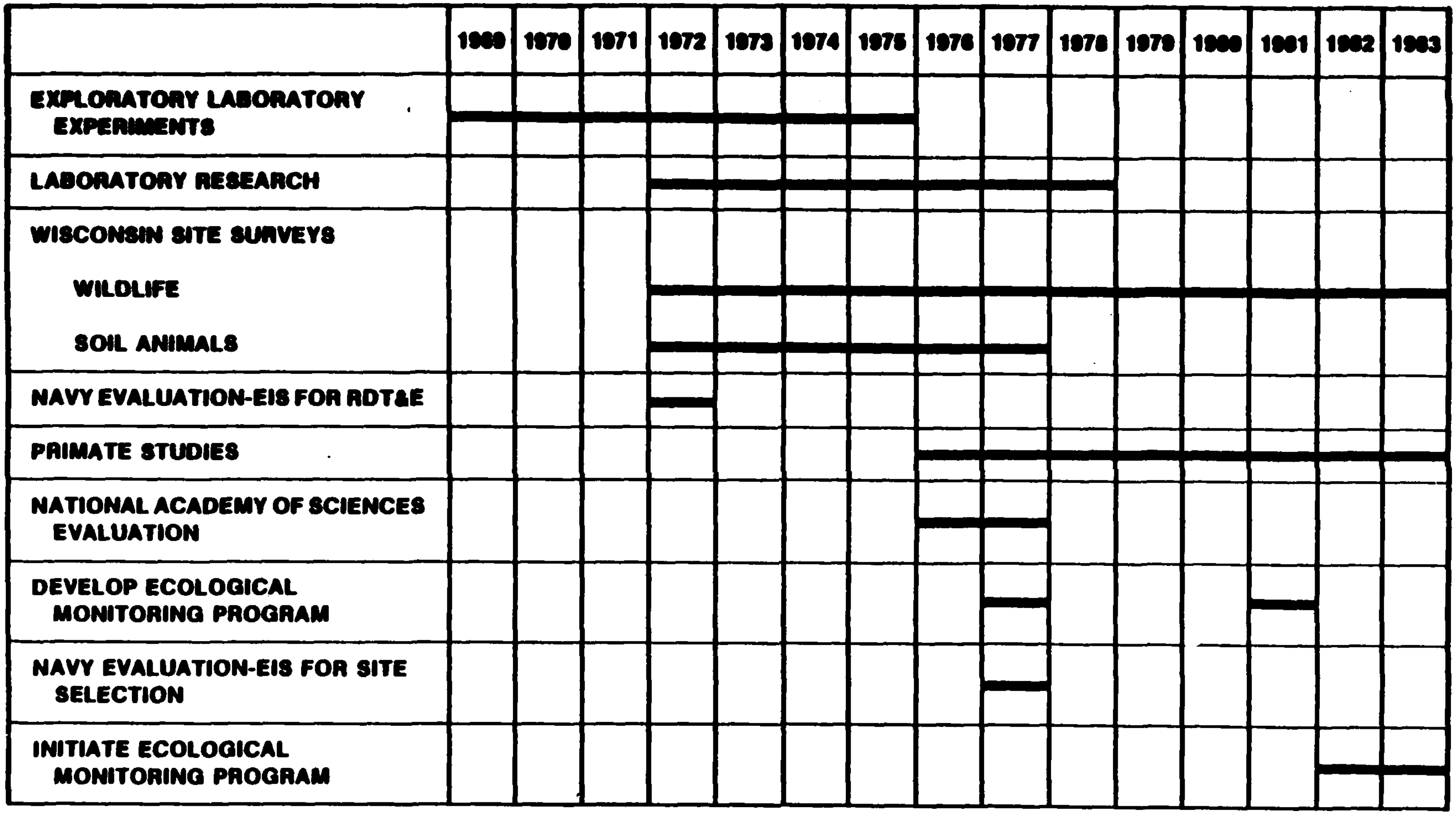

TABLE 1 EVOLUTION OF THE ELF COMMUNICATIONS ECOLOGICAL MONITORING PROGRAM

in 1969, was first evaluated in 1971-72 (NESC, 1972), and was continued until about 1975.

Sufficient information was obtained by 1972 that it was possible to develop a more disciplined line of inquiry to investigate ELF electromagnetic influences on biota with the assistance of an advisory committee selected by the American Institute of Biological Sciences. A program of laboratory investigations was initiated at universities throughout the country (see NESC, 1972 and 1977). Many different species were used to study influences on physiology, genetics, behavior, growth and development, and the like. A series of wildlife surveys also was initiated by the U.S. Forest Service in the region around the Wisconsin ELF Facility, and the Navy also funded a number of ecological surveys there on soil animals. Soil animals were selected for the latter because of their large numbers (a prerequisite for statistical interpretation of results) and the fact that many generations could be studied in short periods of time.

The Navy evaluated the findings reported by university investigators in 1977 (NESC, 1977, Appendix E), and concluded that the very low electromagnetic field levels produced by ELF antennas were unlikely to result in adverse biological or ecological effects. The National Academy of Sciences (NAS), in an independent evaluation of Navy-sponsored research and the available scientific literature, reached a similar conclusion (NAS, 1977). Moreover, the NAS committee concurred with the Navy's plan to essentially terminate laboratory research and proceed with a new program of site-specific ecological monitoring. The Academy recommended that certain physiological indicators should be considered by the Navy along with the planned site-specific ecological monitoring program.

PURPOSE OF ECOLOGICAL MONITORING

Neither the results of exploratory tests, Navy-sponsored laboratory studies nor the scientific literature suggest that very low field intensities at extremely low frequencies are likely to adversely impact the environment. Wildlife and other surveys conducted in Wisconsin infer that adverse effects are unlikely. The few laboratory results that indicated ELF electromagnetic fields might be an important stressor, were obtained in experiments in which field intensities hundreds of times higher than would be produced by ELF antennas were used. Electric power systems produce electromagnetic fields much like those produced by ELF antennas (some power systems produce much higher field intensities), and there is no unequivocal evidence that these low level fields have caused biological or ecological effects after many years of operation. An ecological monitoring program is the next logical step of inquiry.

The Ecological Monitoring Program is intended to provide data on representative species to determine if the low level ELF electromagnetic fields, alone or in combination with other factors of the natural environment (such as cold or heat), will influence biota or ecological relationships over the long term.

WILDLIFE SURVEYS

As noted earlier, wildlife and other surveys conducted in previous years in Wisconsin infer that adverse effects of ELF electromagnetic fields are unlikely. The U.S. Forest Service is continuing to monitor deer, bald eagle and ruffed grouse activities near the Wisconsin ELF Facility. Although not an integral part of the competitively bid ELF Ecological Monitoring Progam, this work by the U.S. Forest Service is an important complement to the Program. The most recent results of this work are therefore summarized in Appendix B of this report.

DEVELOPMENT OF THE ELF ECOLOGICAL MONITORING PROGRAM

INITIAL PLANNING

The Navy outlined plans in its 1977 environmental impact statement for conducting an ecological monitoring program at approved ELF Communications sites. The initial plan was developed from results of laboratory research, inputs from state agencies, and recommendations made by the National Academy of Sciences for long-term environmental monitoring. The elements of the plan were refined from comments submitted by agencies and the public on the 1977 environmental impact statement. The Navy noted its intention to initiate ecological monitoring at the ELF Communications sites in Wisconsin and Michigan in its 1981 report following the approval of the ELF Communications Program by the President and the Congress.

REQUEST FOR PROPOSALS

IIT Research Institute (IITRI), in its role as the Navy's ELF environmental protection contractor, serves as coordinator for the ELF Ecological Monitoring Program. Early in 1982, a competitive process was initiated to select subcontractors to participate in the program. The request for proposals included guidance for developing proposals for ecological studies (see Appendix C). Additionally, bidders were encouraged to submit proposals for study alternatives to those outlined which in their view might be preferable in investigating ecosystems in ELF electromagnetic environments. Bidders also were encouraged to integrate studies into logical sets to enhance the scope of studies and their data interpretation. An example is an aquatics study which includes the three basic trophic levels (periphyton, aquatic insects and fish).

The request for proposals noted that studies in Michigan were to commence with the compilation of a pre-operation data base of representative species or communities. That is, information would be collected before the ELF Communications System in Michigan contributed to the ELF electromagnetic environment. The data base would subsequently be used to compare characteristics of species or communities observed in years following the initiation of system operations.

Studies in the Clam Lake, Wisconsin region are limited to some extent by the absence of a data base representing conditions of representative species or communities prior to the operation of the ELF Communications System in that area. This limitation was noted in the 1982 request for proposals, and prospective bidders were required to address this limitation in proposing studies for the Wisconsin site area.

A total of 121 task proposals was received by IITRI from prospective bidders. Many of the tasks were combined into logical, integrated sets. Eight of the task proposals were non-responsive, either addressing laboratory research only, or studies of stresses other than electromagnetic. Only 16 proposals were received for studies at the Wisconsin site.

QUALITY CONTROL

Scientific quality is being stressed throughout the ELF Ecological Monitoring Program, and commenced with the review of proposals received in 1982. Bidders were advised in the request for proposals that submissions would be scored on a competitive basis according to the following criteria:

	Points
Scientific Approach and Responsiveness	45
Professional Credentials and Similar Experience	15
Local Expertise	15
Cost	15
Project Management and Organization	10
TOTAL	100 points

Bidders were also advised that proposals would be evaluated for scientific merit by independent peer reviewers. The reviewers were selected after all proposals were submitted and remained anonymous to the bidders and to each other. Each reviewer had completed academic training to the doctorate level in the sciences with their degrees conferred by 11 different universities. As a group, the reviewers represented 307 cumulative years of professional experience and authored 698 scientific articles and books (an average of 15 years and 50 publications each).

The independent merit reviewers were assigned to five separate panels and received proposals according to their individual expertise in one of five categories:

Group A - Soil Habitat
Group B - Terrestrial Habitat
Group C - Aquatic Habitat
Group D - Avian Studies
Group E - Vegetation Studies

Three reviewers assigned to each group evaluated each proposal according to the first three criteria listed above. Cost, project management, and organizational information were not provided to merit reviewers. One of the three reviewers on each panel was the major reviewer for each proposal. For example, Group C included an expert in aquatic algae, an expert in aquatic insects, and an expert on fish studies. The algae expert was the major reviewer for proposals on algae, and the remaining two were minor reviewers. The insect expert was the major reviewer for proposals on aquatic insects, and the others became the minor reviewers. This arrangement was used for all groups except for Avian Studies, where two experts in that particular area comprised Group D.

The evaluations returned by the reviewers were scored by summing the three reviewers' evaluations, counting the major reviewer's evaluation twice, and taking the average. A minimum score of 75 percent of the available 75 points (56 points) was the threshold for acceptable scientific merit.

Bidders submitting proposals that scored at least 56 points were invited to submit best and final offers for funding. The final proposals submitted by the bidders were then scored for the last two criteria listed above. Contracts were awarded for those proposals that scored the highest and offered to perform proposed studies at reasonable cost.

The Navy has established an Environmental Review Committee to assist its Program Manager in ensuring a scientifically-meaningful program. The Committee includes representatives of the Chief of Naval Operations, the Naval Electronic Systems Command, the Naval Facilities Engineering Command, and the Naval Medical Research and Development Command. Consultants are available to the Committee from other Naval organizations. Representatives from the U.S. Forest Service and States of Wisconsin and Michigan monitor the activities of the Committee to ensure that their interests are considered. The Environmental Review Committee meets quarterly.

Investigators participating in the Ecological Monitoring Program attend a yearly symposium to describe and explain study procedures and results. The symposium provides a means for useful interchange among scientists, engineers and managers. The first symposium was conducted in November 1982 in Wisconsin. The 1983 symposium will be held in Michigan.

Investigators are required to submit yearly reports of their activities and findings. Commencing in 1983, each yearly report will be reviewed by four scientific peers prior to being published. Two of the four peers will be selected by the reporting investigator, and the other two will be selected by IITRI. The Navy will neither approve nor disapprove the selections.

The Navy also is encouraging investigators to publish their findings in scientific and professional journals. Doing so would result in additional peer review and availability of findings.

GENERAL DESIGN

The Ecological Monitoring Program is designed to follow accepted approaches for quantifying and comparing biological and ecological conditions to differing levels of electromagnetic field intensities as produced at varying distances by the ELF Communications System. Ecological studies are of fundamental importance because they represent an integration of the condition of many resident biota. The objective of ecological monitoring in general is to identify changes in group characteristics, such as abundance and productivity. Biological studies emphasize individual organism characteristics. The Program emphasizes ecological studies but also includes investigations for possible basic biological effects.

Multi-year studies, commencing before communications operations begin and continuing thereafter, will be made in Michigan. These studies will be augmented by other studies in northwestern Wisconsin, where an ELF Communications System has been operating experimentally since 1969. Both temporal and spatial comparisons will be made in Michigan. Temporal changes in conditions are represented by the pre-operational and operational phases of the program. Spatial comparisons are made by obtaining data relatively close to ELF transmitting antenna systems (test plots) and at greater distances (control plots). The test-control plot arrangement thereby accounts for the diminishing intensity of electromagentic fields as a function of distance, and provides the necessary differences in stress. Since the System has been experimentally operated in Wisconsin, only spatial comparisons are possible there.

Two important decisions in the design of ecological monitoring (Hinds et al., 1982) are the selection of:

(1) appropriate organisms for study; and,

(2) analytical methods that provide a high degree of certainty in data interpretation

As noted earlier, comments and recommendations from experts were used to provide guidance for interested bidders. A general design for the program was outlined in the Request for Proposals (RFP) (see Appendix C). Selection of specific organisms and methods was by the competitive proposal process which included independent peer review (see page 6).

The general types of organisms to be studied were selected on the basis of ecological significance and the likelihood of being perturbed by electromagnetic fields, irrespective of intensity or frequency (see Table 2). The principal criterion for selecting specific biota was their presence in sufficient numbers to ensure meaningful statistical comparisons. The general types of organisms included in the studies are used throughout the report as an organizing element for describing other aspects of the Program.

If low-level ELF electromagnetic fields influence organisms and higher levels of biotic organization (populations, communities), the effect, based on previous research, is expected to be small relative to the effect of other factors. Ambient factors, site factors (slope, exposure, etc.) and temporal factors (season-to-season, year-to-year) could cause variations in measured biotic conditions. Variability (variance) is the degree to which observations or other measures tend to spread around some average value, and is a possible source of confusion in comparing data sets. Thus variability could make it difficult to detect changes due to ELF electromagnetic fields. Long-term monitoring, matching of sites and proper selection of parameters and methodologies minimize variance. Appropriate replications (numbers of measures) and statistical methods will account for the remaining variance.

TABLE 2

SUMMARY OF STUDY RATIONALE AND LEVELS OF ORGANIZATION

ORGANISM	RATIONALE FOR STUDIES	LEVEL OF ORGANIZATION		
		Organism	Population	Community
Terrestrial Ecosystem	Dominant biota in system area			
	Exert strong influence on other organisms			
	Coupled to electric fields by both above- and below-ground biomass			
Herbs	Sensitive to site disturbance	X	X	X
Trees	Deeply rooted/long lived	X	X	X
Fungi and Bacteria	Important agents of organic matter decomposition		X	X
	Population and litter decomposition are sensitive to environmental perturbations			
Soil Amoebae	Role in soil minearlization, possible regulators of soil bacteria	X	X	
	Various species required in diet of higher soil organisms			
	Structurally similar to slime molds			
Slime Molds	Laboratory exposures indicate electromagnetic sensitivity	X		
Soil Arthropods and Earthworms	Active in the breakdown of organic matter by comminution and partial digestion		X	X
	Earthworms mix soil and increase non-capillary pore space			
	Earthworms are sensitive to high electric current			

TABLE 2 (continued)

Summary of Study Rationale and Levels of Organization

ORGANISM	RATIONALE FOR STUDIES	LEVEL OF ORGANIZATION		
		Organism	Population	Community
Native Bees	Important pollinator of flowering plants and have co-evolved with area plants	X	X	X
	Magnetic sensitive materials have been reported in some species			
	High electric fields affect nesting behavior			
Small Mammals and Nesting Birds	Small mammals/birds are intermediate components of the food chain and serve in dispersal of other biota	X	X	
	Home ranges (mice, 200M; nesting birds, 2-4 Km) are intermediate between other fauna being studied (i.e., soil organisms and migrating birds)			
	Magnetic-sensitive materials have been reported in some species			
	Magnetic fields may affect orientation			
	High electric fields affect nesting behavior			
Migrating Birds	Birds are important components in the food chain and some serve in the dispersal of other biota	X	X	
	Magnetic-sensitive materials have been reported in some species			
	Electromagnetic fields may influence migratory behavior			
Wetland Ecosystem				
Trees, Herbs and Decomposers	Cell membranes of flora and decomposers may be affected by electromagnetic fields of some types	X	X	
	A natural resource of particular environmental concern			

TABLE 2 (continued)

Summary of Study Rationale and Levels of Organization

ORGANISM	RATIONALE FOR STUDIES	LEVEL OF ORGANIZATION		
		Organism	Population	Community
Aquatic Ecosystem				
	ELF System area in headwaters of major drainage systems			
Periphyton	Stabilizing element in food chain Preferred food source for life stages of some consumer organisms Micro-organisms are known to change motion and orientation in some electromagnetic fields	X	X	X
Invertebrates	Intermediate trophic level, feeding on periphyton and allochthonous inputs Primary food source for fish May be susceptible to electromagnetic effects noted for other insects (see bees above)	X	X	X
Fish	Secondary consumer trophic level Some species perceive weak electric fields. This sensitivity may be used in prey capture and orientation	X	X	X

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STUDY DESIGN

The impact of an environmental perturbation can be assessed at several levels of organization, ranging from individual (biological) responses to responses at the population, community or ecosystem level. Assessments of potential environmental damage should include several levels of organization. An examination of characteristics of individuals (e.g., behavior, physiology) is a very sensitive method of assessment. This approach, most appropriate for examining subtle or small effects, was generally followed prior to 1982 for the ELF Communications Program.

Ecology is concerned largely with the higher levels of organization, i.e., populations, communities and ecosystems. Commencing in 1982, the higher levels of organization are being examined to study potential effects among many species. This approach utilizes the higher organization's ability to integrate conditions occurring at lower organizational levels.

The concept of the ecosystem is a broad one, its main function in ecological thought being to emphasize relationships. One of the universal features of all ecosystems is the interaction of the producer and consumer components. For example, photosynthesis (buildup of organic compounds) predominates in the canopy of a forest ecosystem. A small portion of these compounds is immediately and directly used by the producer and by some consumers (herbivores and parasites) which feed on foliage and new wood. Much of the synthesized material stored in leaves, wood, seeds and roots eventually reaches the litter and soil. Most of the utilization, rearrangements and decomposition of the synthesized material takes place here (Odum, 1971). In turn, various consumer activities in soil release compounds for producer synthesis. Thus, the ecosystem is characterized by the integrated and largely self-maintained functioning of a diverse community of organisms (Swift et al., 1979).

The limits of ecosystems, and therefore what constitutes an ecosystem study, are sometimes a cause for argument: as for example, what constitutes a self-contained area in terms of primary productivity and nutrient cycling. Transfer of nutrients from land to water by drainage may be significant, in which case the appropriate ecosystem boundary is the watershed. Studies of total watersheds have been few in number; the most extensive and well known have been at the Hubbard Brook Experimental Forest in New Hampshire (Swift, et al., 1979).

Whether there are significant nutrient transfers from land to water in the Michigan area where ELF aquatic studies are being done has yet to be ascertained. In general, most of the area is covered by forest with sandy, coarsely-textured soils. Thus, there may be relatively little transfer of nutrients and organic material between land and water at study sites. The ELF Communications System is primarily located in headwater areas, and the antennas traverse several watersheds. Electromagnetic exposure criteria, locations of biotic population of sufficient size, and other criteria for matching test and control plots require study sites to be located in close proximity (about 15 miles) to ELF antennas. Thus a watershed study integrated like the Hubbard Brooks concept is inappropriate to the purpose of the ELF Communications Program. This may also be true for commercial power systems serving the region, other public utilities such as pipeline transmission and distribution systems, and the regional highway transportation network.

An ecosystem also can be analyzed in terms of:

(1) food chains;
(2) nutrient (biogeochemical) cycling;
(3) energy circuit;
(4) diversity patterns in time and space;
(5) development and evolution; and,
(6) control (cybernetics). (Odum, 1971)

Functional aspects such as food chains, nutrient cycling and diversity patterns form the basis for integration of the ELF Ecological Monitoring Program.

Monitoring studies will be performed at both the Michigan and Wisconsin sites. One advantage of study at Michigan sites is the opportunity to collect a pre-operational data base. The Wisconsin facility has been operated on a part-time basis since 1969. The presence or absence of an effect and the ecological/biological significance of results at either site is transferable to the other. Ecological results and principles elaborated in Europe have been routinely applied to assessments of environmental perturbations in the United States and Canada. For example, acid rain and its effects are studied in Scandinavian countries and the results are used by researchers in North America. Basic research on the physiology of one species is routinely used in developing assumptions for other appropriate species. The Michigan and Wisconsin ELF study sites are separated by about 150 miles. The biota and ecology of the two regions is sufficiently similar that one can infer conclusions about ELF Communications System effects in either region from data obtained in the other.

Study objectives, methods and end-points for each element of the Ecological Monitoring Program are given in Tables 3, 4, and 5. Each element is summarized on following pages.

TABLE 3

TERRESTRIAL ECOSYSTEM - FLORA AND SOIL BIOTA: STUDY OBJECTIVES, METHODS AND END-POINTS

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Herbs	Phenological Events	Observation and dating of vegetative emergence, growth, initiation of flowering, fruit formation, seed dispersal and senescence
	Annual Growth	Measurements of main stems, branches, leaves, flowers and fruit
	Species Dominance	Percentage of ground cover and frequency of occurrence
	Biomass	Dry weight estimate by clipped material taken from areas adjacent to study plots
Trees	Phenological Events	Observation by dating of bud burst, leaf out, flowering, fruiting, leaf coloration, leaf fall and cambial activity
	Tree Productivity	Productivity estimated by measurements of diameter increment, tree height increment and mortality, past patterns of diameter growth by cores
	Foliar Nutrients	Foliar samples from lower, mid and upper crown positions before leaf coloration. Analyzed for N, P, K, Ca and Mg
	Litter Production	Litter separated by species of leaf, twigs, etc; dried and weighed by litter trap method
	Disease	Incidence of heartrot and root diseases on the basis of decay and decay fruiting structures (Anderson and Schipper, 1978) and tree crown condition (Parmeter et al., 1976)
	Insect Infestations	Incidence and severity of defoliating and wood boring insects
	Root Condition	Relate weight and number of short roots (mycorrhizal and non-mycorrhizal) to total root weight and/or seedling weight

TABLE 3 (continued)

Terrestrial Ecosystem - Flora and Soil Biota: Study Objectives, Methods and End-Points

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Mycorrhizal Fungi	Population Characteristics	Isolation of mycorrhizae present on root systems and their characterization by density and evenness (Williams, 1977)
Fungi and Bacteria	Population Characteristics	Rhizoplane isolates characterized by richness, abundance, frequency and evenness (Williams, 1977). Species diversity for actinomycetes (Lloyd et al., 1968)
	Litter Decomposition	Nylon mesh envelopes retrieved after snow melt and one year later. Litter decomposition of paper birch quantified as percent change over time in biomass and nutrients
	Nitrogen Mineralization	Trenched plot technique (Gosz, 1980) used in root-free areas. Nitrogen release patterns of ammonium and nitrate determinations obtained on collected litter using automated colorometric techniques
	Nitrogen Fixation	Fixation rates estimated using an adaptation of the acetylene reduction technique (described by Hardy et al., 1973)
Soil Amoebae	Spatial Distribution	Quadrant sampling (Morisita, 1959; Pielou, 1969; Hairston et al., 1971)
	Species and Population Characterization	Species and strains identified using morphological and physiological characteristics (growth properties, net surface charge density, isoeneymes, mitochondrial DNA). Subsequently, ratios of vegetative to dormant amoebae, to species and strain, to spatial distribution and ambient conditions determined
	Cropping Efficiency and Growth	Amoebae and food bacterium (soil isolate) cultured in chambers. Counts of amoebae and bacteria periodically made (Danso and Alexander, 1975)

TABLE 3 (continued)

Terrestrial Ecosystem - Flora and Soil Biota: Study Objectives, Methods and End-Points

ORGANISM	OBJECTIVE	METHODS/END POINTS
Soil Amoebae (continued)		
	Cell Cycle	Amoebae buried in culture chambers. Cycle determined by: tritiated thymidine incorporation followed by autoradiographic analysis of metaphase chromosomes (Band and Mohrlok, 1973) and phase contrast microscopy
Slime Molds	Mitotic Cell Cycle and Oxygen Consumption	Field and laboratory studies on cultured organisms. Length of mitotic cycle determined by microscopic examination; oxygen consumption determined using an oxygen analyzer
Surface-Active Arthropods	Population Characteristics	Collection by pitfall trapping in maple-dominated forest. Diurnal and nocturnal samples collected. Combine data with soil-litter faunal data (immediately below) to determine relationship between activity and density
Soil Arthropods and Earthworms	Population Characteristics	Stratified random sampling procedures (Southwood, 1978; Blower, 1970). Frames used to collect surface litter and humus layers. Soil samples taken by core to a depth of 15 cm. Extraction by Tulgren (heat) extraction. Standard methods of sorting faunal material to various taxonomic levels. Counts provide a basis for dominance, abundance, diversity and other population analyses. Biomass estimates derived from size-weight calculations
	Litter Decomposition	Foliar samples analyzed for nutrients (automated colorometric techniques) prior to and after abcission. Abcissed leaves placed in litter bags and sub-samples retrieved. Contents Tulgren-extracted for fauna, dried, weighed for biomass, and analyzed for nutrients and trace metals (P, K, Ca, Mg, Mn, Fe, Cu, Zn, Al, Mo)

TABLE 4

TERRESTRIAL ECOSYSTEM - RANGING FAUNA: STUDY OBJECTIVES, METHODS AND END-POINTS

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Native Bees	Nesting Cycle	Trap nesting to observe behavioral and developmental characteristics
		Nests monitored for pollen provision trips, building material trips, etc.
	Development	Nests opened upon completion to ascertain period of egg enclosion, developmental rate of larvae, molt interval, stage of development at close of season. Opened nests stored in glass tubes and opened daily to trace development
	Survival	Over-wintering nests opened to ascertain survival
Small Mammals	Population Characteristics	Circulation of density utilizing mark and recapture techniques (O'Farrell et al., 1977)
	Homing and Activity Patterns	Mice fitted with radio transmitters (Madison, 1977; Mineau and Madison, 1977; Murphy and Gidner, 1982) released at point of capture and monitored to determine home range. Subsequently, mice displaced 200 M from the center of their range and elapsed time to return measured. Space use patterns based on movement frequencies and movement distances determined (Herman, 1977; Webster and Brooks, 1981; Murphy and Gidner, 1982). Activities inferred from location and other parameters such as habitat
	Parental and Nesting Behavior, Maturation and Fecundity	Temporal patterns of nest visitation by pregnant or lactating females determined using a continously recording passive identification system (CPRID). Nest temperature determined by thermal probe
		Litters in nest boxes monitored for litter size, weight, age at eye opening, age at opening of the auditory meatus, age at eruption of lower incisors and survivorship through weaning

TABLE 4 (continued)

Terrestrial Ecosystem - Ranging Fauna: Study Objectives, Methods and End-Points

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Small Mammals (continued)	Metabolic Physiology	Ability to resist extreme cold in metabolic chamber. Aerobic heat production calculated from oxygen consumption (Brown and Brengleman, 1965) and fat content determined (Kodama and Pace, 1963).
Nesting Birds	Population Characteristics	Population densities and the statistics of dispersion recorded (Ralph and Scott, 1981). Census procedures by spot-map method as modified by Franzreb (1981)
	Homing and Activity Patterns	Female birds, banded and fitted with tuned coil (to CRPID) taken from nest boxes. Birds released 2 - 4 Km in each cardinal direction from center of plot. Elapsed time to return to nest box recorded
		Adults and nestlings banded. Average distance between nesting locations from year to year recorded to determine site fidelity
	Developmental Biology	Temperature recorder used to document onset of development (incubation). Embryos of known age obtained from nests, and examination in laboratory
	Parental and Brooding Behavior, Maturation and Fecundity	Incubation and breeding studied in pairs of birds. Nests equipped with artificial eggs containing thermocouples. Elevated temperatures recorded (Hill and Beaver, in press)
		Each sex fitted with CRPID to estimate the rate of feeding by frequency of adult visits
		Intervals of egg laying, egg weight of nestlings, growth of wings and legs, day of eye opening, and success of fledglings recorded (Barth, 1955; Flegg and Cox, 1977; Huggins, 1941; O'Connor, 1975; Paynter, 1954; Ricklefs, 1968; Royama, 1966; Stoner, 1945)

TABLE 4 (continued)

Terrestrial Ecosystem - Ranging Fauna: Study Objectives, Methods and End-Points

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Migrating Birds	Numbers and Species Composition	Ducks and geese surveyed over fixed circuit of water bodies within and beyond antenna system. Smaller birds surveyed using mist-netting. Total numbers estimated using vertical stationary mode radar (Larkin and Eisenberg, 1978; Larkin, in press) and ceiliometer techniques
	Behavior	Navigation, altitude and departure times studied using radio-tracking (Cochran, 1980), vertical stationary mode radar, and tracking radar (Larkin and Sutherland, 1977)

TABLE 5

AQUATIC AND WETLAND ECOSYSTEMS: STUDY OBJECTIVES, METHODS AND END-POINTS

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Wetland Ecosystem		
Flora	Stomatal Resistance	Stomatal resistance, relative humidity, leaf temperature, and photosynthetically active solar radiation measured directly and concurrently
	Foliar Cations	Cations (K, Ca, Mg) extracted from leaf tissue and measured by atomic absorption spectometry (Van der Driessche, 1974)
Decomposers	Decomposition	Pure cellulose sheets placed in nylon mesh bags. Bags randomly selected and harvested (Lahde, 1974; Ulehlova, 1978; Hundt and Unger, 1968; Golley, 1960; Ratliff, 1980)
Acquatic Ecosystem		
Periphytic Algae	Population and Community Characteristics	Diatomer techniques (Patrick, 1973; Bamforth, 1982) used for species identification, species counts, estimates of cell volume; determination of chlorophyll a and phaeophytin, ash-free dry weight and oven-dry weight (APHA, 1976). Community productivity and biomass (Sladecek and Saldeckova, 1964; King and Ball, 1966; Burton and King, in press)
		Periphyton from rocks, sediment and wood taken for comparative purposes

TABLE 5 (continued)

Aquatic and Wetland Ecosystems: Study Objectives, Methods and End-Points

ORGANISM	OBJECTIVE	METHODS/END-POINTS
Aquatic Ecosystem (continued)		
Invertebrates	Leaf Litter Processing	Leaf pack bioassay procedures (Merritt et al, 1979) by preweighed (dry) amounts of leaves (predominant riparian species) bound in packs to bricks placed at study sites. Changes in dry weight/leaf area ratio (Stout, 1981), ash and caloric content determined
	Colonization, Feeding and Processing	Invertebrates on leaf packs removed, identified, counted, measured and weighed. Biomass, species richness, evenness, individual abundances and species diversity calculated (Stout and Cooper, submitted). Major grazing macroinvertebrates identified and feeding strategies and resource partitioning followed. Caged leaf packs containing major shredding organisms placed on site, and leaf degradation rates followed.
	Benthic Invertebrate Characterization	Stream community sampled using artificial substrates (plastic baskets with pebble substrates) and quantitative samplers (Surber samplers, removal of macrophytes enclosed by plankton nets, coring or by dredge). Invertebrates identified, counted, measured and weighed. Biomass, species, richness, and evenness determined (Stout and Cooper, in press; Crowder and Cooper, in press)
	Drift	Drift nets (Elliott, 1970) used to collect invertebrates in water column. Invertebrates extracted from other debris using a modified Ladell apparatus (Lawson and Merritt, 1979). Organisms identified, counted, and biomass determinations made from preserved material (Smock, 1980). Diel periodicities, species composition, size distribution and production determined
	Migration	Movement patterns of select invertebrates followed by means of mark and recapture techniques (Elliot, 1971; Brusven, 1970; Stout, 1978, 1982)

TABLE 5 (continued)

Aquatic and Wetland Ecosystems: Study Objectives, Methods and End-Points

ORGANISM	OBJECTIVE	METHODS/END POINTS
Aquatic Ecosystem (continued)		
Fish	Community Characteristics	Seines and hoop nets primary means of collection
		Species composition, relative abundance, and habitat preference recorded
	Vital Statistics	Population abundance through mark and recapture (Seber, 1973) in conjunction with catch per unit of effort analysis (Ricker, 1975); length, weight, age and condition factors (Bagenal, 1978); growth rate; fecundity estimated using volumetric analysis of oocytes prior to spawning
	Development	Development pattern determined by using emergent fry traps (Philips and Koski, 1969). Embryological stages identified using descriptions of Ballard (1973) and others. Percentage of deformed and infertile eggs determined
	Food Habits	Stomach pump employed to obtain samples. Consumption rate and daily ration determined (Staples, 1975). Feeding preference assessed by comparing insect drift with stomach contents
	Parasites and Pathogens	Distribution, abundance and pathology of infectious agents in three species determined (McDaniel, 1979). Infection rates, prevalance, and mean number of parasites compared by season

TERRESTRIAL ECOSYSTEM STUDIES

TREES, HERBS, FUNGI AND BACTERIA

Forest vegetation is the dominant biota in the Michigan ELF System area and exerts a strong influence on other organisms within both the terrestrial and aquatic ecosystems. Vegetation modifies the microclimate and exerts influence on soil organisms, particularly in the rhizosphere (area surrounding roots). Vegetation influences soil development and fertility through nutrient cycling, and is the primary source of energy inputs to the headwaters of streams. Indeed, organic matter turnover and distribution can be regarded as a major determinant of ecosystem structure.

Trees, herbs, fungi and bacteria form a natural assemblage and will be examined in an integrated set of studies at the same experimental sites. Study sites will be located in aspen-birch dominated stands (most prevalent vegetation) and in areas planted with red pine. The major theme of the study is the functional and structural aspects of organic material cycling. Objectives pertinent to organic cycling are: tree productivity, root growth, litter production, litter decomposition and population characteristics. Optimal root growth and development are essential in maintaining forest productivity. In turn, the symbiotic plant root/fungal relationship (mycorhizae) is considered essential to satisfactory growth of nearly all tree species.

Litter production and subsequent decomposition are important in the transfer of nutrients and energy from producers to consumers. Knowledge of litter biomass production and nutrient content serves as the basis for studying decomposition. Litter decomposition is a complex process involving a variety of organisms engaged in the degredation of organic compounds. The primary agents of decomposition are fungi and bacteria. Thus, this theme integrates the major activities of the producer and decomposer (detritivore) communities.

Herbaceous plants and phenological events are monitored as sensitive indicators at the populational and organismal levels. Insect infestation and plant disease will also be noted as stressors of trees. All of the objectives have been shown to be measurably affected by environmental perturbation, such as air pollution, acid rain, heavy metal decomposition and ionizing radiation.

SOIL AMOEBAE

Soil amoebae are one general type of protozoa that occur in soil and are commonly found in large numbers at study sites. Protozoa numbers are frequently correlated with root growth and thus with soil nutrient status. Their main ecological role is believed to be as predators on bacteria. Bacteria are important organisms involved in litter decomposition and nutrient cycling. The bacterial cropping efficiency of soil amoebae will be studied through the use of in situ culture chambers. Although smaller in size, amoebae have structural and functional characteristics similar to slime molds. Effects on the cell cycle reported for slime molds (Goodman et al., 1976 and 1979) will likewise be examined in this study. Spatial distribution and population characteristics will be determined. Study sites in Michigan will be located in mixed hardwood stands with a dominance of maple trees.

SLIME MOLDS

Although slime molds are not of major ecological significance, they are found in terrestrial habitats in Michigan and Wisconsin. Based on previously reported effects (Goodman et al., 1976 and 1979) the slime mold *Physarum polycephalum* is being examined further as a possible biological indicator of ELF electromagnetic effects. Physiological aspects of cultured slime molds are being examined at both the Wisconsin ELF Facility and in the laboratory at the University of Wisconsin (Parkside). The main objective of the study is to determine if previously reported ELF electromagnetic effects obtained in a controlled laboratory environment are also observed under system operating conditions in the field.

SOIL/SURFACE ARTHROPODS AND EARTHWORMS

Soil surface fauna consist of the large litter-feeding arthropods such as the millipedes, isopods, amphipods, insects, as well as molluscs and the larger earthworms. These animals are responsible for the initial shredding of plant remains and its redistribution within decomposer habitats. Their presence can significantly affect decomposition pathways and contributes directly to the structure of the soil. Soil organisms are the smaller arthropods such as mites, springtails (*Collembola*) and the smaller worms (*Enchytraeidae*). Most members of this group can attack plant litter but their decomposition processes are in regulating microbial populations and reworking the faeces of macrofauna (Swift et al., 1979).

Previous studies at the Wisconsin ELF Facility included monitoring soil arthropod populations for several consecutive years. Based on the relative abundance of individuals in four broad taxa, Greenberg (1976) concluded that six years of electromagnetic exposure had not affected this abundance. This study takes a broader, more integrated approach and keys on the decomposition subsystem. Process-oriented monitoring of organic matter and nutrient cycling and a more specific characterization of the subsystem's invertebrate communities which act as process regulators will be accomplished. Studies will be performed on plots in maple-dominant, mixed hardwood stands in Michigan.

NATIVE BEES

Bees are important pollinators of flowering plants and are therefore important in the continued reproductive success of plants. Native bees will be studied as they have co-evolved with resident plants and survive winters in the site area. This latter attribute is important in examining possible synergism between ELF electromagnetic fields and severe temperature conditions. Magnetic-sensitive structures have been reported in the abdomens of bees, and fluctuations in the strength of the earth's magnetic field have been cited as affecting bee communications.

This study emphasizes behavioral aspects at the organismal level, particularly as it relates to the nesting cycle. Plant preference for nesting material and pollen also will be determined. Site selection, homing, larval development and survival will be studied. Study sites will be in open areas adjacent to the Michigan ELF Facility antenna routes.

SMALL MAMMALS AND NESTING BIRDS

Small mammals and nesting birds represent an ecological level intermediate between plants and strict carnivores. Small mammals undoubtedly have an effect on soils and vegetation. They mix soil through burrowing activities and fertilize it with excreta. Both birds and mammals disperse seeds, and many consume insects. Behavioral experiments have indicated that some species may be able to sense weak electromagnetic fields. Magnetic-sensitive structures have been reported in the heads and necks of both birds and mammals. The effects of electromagnetic fields on both birds and mammals have been extensively studied in the laboratory by many investigators (NAS, 1977).

Small mammals and nesting birds constitute a single, logical category of small, homeothermic vertebrates. As such, they are amenable to a unified program of investigation. Many aspects of their biology (such as parental behavior, fecundity and reproductive success, growth and development of progeny, homing ability) can be investigated with similar techniques. These studies emphasize behavioral and behavioral-based aspects at the organismal level. Thermoregulation will be examined in small mammals to assess possible synergism between ELF electromagentic fields and cold stress. Population studies are being performed concommitantly, so that potential organismal effects can be assessed at this higher level, and/or to detect potential effects not perceived at the organismal level. Study sites are to be located in Michigan in mixed hardwood stands.

MIGRATING BIRDS

Many species of birds migrate from a nesting range to an overwintering area and back again -- in some cases, a total of several thousand kilometers. Successful migratory movement requires a mechanism (among other things) that permits judgment of direction, in order to arrive at the appropriate end point (NAS, 1977). Many experiments have indicated that birds are sensitive to magnetic cues and use such cues along with others for orientation and migration. Williams and Williams (1976) conducted observations at the Wisconsin

ELF Facility during the fall migration seasons of 1974 and 1975. They found neither evidence of aggregation near, nor avoidance of the antenna in any mode of antenna operation. Radar tracks showed no indication of disorientation. The associated study of Larkin and Sutherland (1977) suggested a slight deviant nonlinear course in some tracks taken at night as the birds moved away from the antenna.

Current studies will address possible change in direction and altitude of birds passing over the antenna in Michigan and Wisconsin. Birds will be tracked over short distances (3 kilometers) by radar and over longer distances (up to 150 kilometers) by radio tracking techniques. Possible long-term effects, as evidenced by changes in the number of species migrating through the System area, will be determined by such conventional techniques as visual surveys, netting and ceilometer methods.

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WETLAND FLORA AND DECOMPOSERS

Wetlands play a valuable role in supporting diverse types of food chains, providing fish and wildlife resources, and maintaining natural hydrologic systems. Water stored in wetlands reduces flood peaks in rivers and much of the sediment carried into them are retained. Under some conditions, the groundwater system may receive recharge from them. Wetlands are very sensitive ecosystems and are easily modified by environmental perturbations. The most important and dominant biota in wetlands are its vegetation. Although several laboratory studies have not demonstrated an ELF electromagentic effect on plants (at System frequencies and intensity), the possibility of perturbation to transport processes across biological membranes has been noted (NAS, 1977). Effects to transport mechanisms may lead to altered water and/or ion uptake by plants.

Current studies will examine the competitive ability of three types of wetland plants (herbs, shrubs and trees) by examining the organismal characteristics of leaf diffusion and cation transport. The functional operation of the decomposer community also will be assessed by studying the decomposition rate of standardized cellulose material. These studies will be performed in the Wisconsin ELF Facility region where there are numerous bushy bogs. The absence of a preoperational data base will be addressed by using an electromagnetic gradient plot arrangement and placement of standardized cellulose material at each of the study sites.

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AQUATIC ECOSYSTEM STUDIES

The ELF System area in Michigan is located in the headwater areas of three watersheds, i.e., the Michigamme, Escanaba and Ford Rivers. Aside from laboratory studies on fish orientation in electric fields, no field studies on aquatic biota have been noted.

This current study takes an integrated approach -- combining studies on the major trophic components of a riverine system: periphytic algae (producers); aquatic insects (primary consumers); and fish (secondary consumers). Organismal behavior, sensitive life history events and community processes critical to the basic structure and function of a stream ecosystem will be monitored. All studies will be performed in the same stream segment.

Several levels of organization (organisms through communities) will be examined. The principal investigators have shown that such an approach is a sensitive indicator of perturbations to aquatic ecosystems. Study objectives include periphyton and stream invertebrate colonization, migration, diversity, and trophic level changes in density and biomass. Productivity, organic matter (leaves) processing by macroinvertebrates, dynamics of fish population growth, reproduction and survival also will be studied. Additionally, fish behavior including movement patterns of homing and migration, and fish pathogen and parasite loads will be monitored.

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MONITORING OF NATURAL AMBIENT CONDITIONS

Ambient environmental conditions as used here are those natural physico-chemical factors that may significantly affect biota. Factors such as soil conditions and precipitation are conditions to which biota respond. It is important to determine the type and range of responses produced by changing ambient conditions so they can be separated from reactions due to electromagnetic fields, if the latter occur.

Temporal changes in ambient conditions occur to some degree every day. An example is the hourly difference in temperature. More prominent changes occur seasonally, and differing climatic conditions between years also can be substantial. Spatial differences also are common even over distances of only several miles. There can be substantial differences in temperature and precipitation between hill crests and valleys, for example. Matched study plots must be several miles apart for statistically meaningful differences between electromagnetic field intensities at test and control plots. Exact duplication of all environmental factors is improbable, and differences must be identified and ultimately considered in data interpretation. Therefore it is necessary to monitor ambient environmental factors at each plot.

Those ambient parameters which are being measured at the ecological study plots are listed in Table 6. Measurement intervals vary because some parameters change more quickly than others. Automatic recording on digital tape is being used when pertinent.

Relationships between ambient conditions and biological and ecological responses will be determined statistically at each study plot prior to operating the ELF Communications System in Michigan. These relationships will thereby account for the portion of variability in biotic measurements due to changing ambient conditions at test and control plots in the absence of electromagnetic fields produced by the ELF Communications System. Other ELF electromagnetic field intensities, produced principally by 60 Hz electric power transmission and distribution systems, also are being characterized (see following section of this report).

TABLE 6

AMBIENT MONITORING PARAMETERS

ORGANISM	PARAMETER
Trees, Herbs, Fungi and Bacteria	<u>Meteorological</u> Temperature Precipitation Relative Humidity Wind Speed Wind Direction Barometric Pressure Solar Radiation <u>Precipitation Analysis</u> pH Ca, Mg, Na, K, NH_4, NO_3 <u>Edaphic (Litter, Soil and Subsoil)</u> Temperature Moisture Moisture Retention Particle Size Bulk Density Cation Exchange Capacity Extractable Acidity Ca, Mg, Na, K, NH_4, NO_3, Fe, Al
Soil Amoebae	<u>Meteorological</u> Temperature Precipitation Relative Humidity Wind Speed Solar Radiation <u>Edaphic (Soil)</u> Temperature Moisture Suction Horizon Description Classification pH P, K, Ca, Mg, Mn, Zn, Cu, Fe, Na, Cl, Total N, NO_3 % Organic Matter
Slime Molds	None

Table 6 (continued)
Ambient Monitoring Parameters

ORGANISM	PARAMETER
Soil Arthropods and Earthworms	Meteorological: Temperature, Precipitation, Relative Humidity, Wind Speed, Wind Direction, Solar Radiation
	Edaphic (Litter, Soil and Subsoil): Temperature, Moisture, Classification, pH, P, K, Ca, Mg, C(organic) NH_4, NO_3, NO_2, Total N (Kjeldahl), % Organic
Native Bees	Meteorological: Temperature, Precipitation, Relative Humidity, Barometric Pressure, Solar Radiation
Small Mammals and Nesting Birds	Meteorological: Temperature, Precipitation, Relative Humidity, Wind Speed, Solar Radiation
	Edaphic: Temperature
Migrating Birds	Meteorological (Ground and Aloft): Wind Speed, Wind Direction
Wetland Biota	Meteorological: Relative Humidity, Photosynthetically Active Radiation

Table 6 (continued)
Ambient Monitoring Parameters

ORGANISM	PARAMETER
Wetland Biota - continued	Edaphic Temperature Moisture Content pH EH (Redox potential) Aqueous Temperature Specific Conductance Cations
Aquatic Biota	Meteorological Temperature Relative Humidity Solar Radiation Aqueous Stream Velocity/Discharge Temperature Solar Radiation pH Dissolved Oxygen Specific Conductance Turbidity Suspended Solids Dissolved Solids NO_2, NO_3, NH_4, Total N (Kjeldahl), Reactive P Dissolved Silica, Chloride, Alkalinity, Total Organic C, Dissolved Organic C

ELF ELECTROMAGNETIC EXPOSURE CONDITIONS

The ELF Communications System produces electromagnetic fields which can be described in terms of several components. They are:

1. a magnetic field which is the same in air and earth;
2. an electric field in earth, called the longitudinal electric field;
3. an electric field in air, called the transverse electric field; and,
4. an electric field in soil near ground wires buried at the ends of the ELF antennas.

These components also describe electromagnetic fields produced by electric power transmission and distribution lines. It is therefore important to account for electromagnetic fields produced by commercial power systems in ecological studies conducted for the Navy.

MAGNETIC Flux Density

The magnetic flux density near an ELF antenna and away from its ends can be approximated from the following:

$$B = \frac{\mu_0 I}{2\pi r} \times 10^4 \text{ gauss} \qquad (1)$$

$\mu_0 = 4\pi \times 10^{-7}$ henry/meter, permeability of free space

I = antenna current, in amperes

r = distance from antenna, in meters

Magnetic flux density inversely varies with distance from the antenna, and is directly proportional to the antenna current.

LONGITUDINAL ELECTRIC FIELD

The electric field in earth is longitudinal (parallel to the antenna), and horizontal at the surface. It is relatively weak (low intensity), and is affected by the electrical conductivity of the earth. The intensity of the field at the surface is proportional to the antenna current, and decreases logarithmically with the distance from the antenna.

The longitudinal electric field produced by an ELF antenna can be calculated as (Sunde, 1968; Bannister, 1968):

$$E = \frac{-j\omega\mu_o I}{2\pi} \left\{ \ln\left(\frac{1.85}{|\gamma r|} + \frac{h\sqrt{2}}{3}|\gamma| - j\left(\frac{\pi}{4} - \frac{h\sqrt{2}}{3}|\gamma|\right)\right\} \text{ volts/meter} \quad (2)$$

for practical antenna heights, and distances consistent with the expression:

$$|\gamma r| \leq 0.25$$

where

γ = propagation constant $(j\omega_o\sigma)^{1/2}$

ω = $2\pi f$

f = frequency in hertz

h = heigth of antenna in meters

σ = near surface earth conductivity, in Siemens/meter

σ = near surface earth conductivity, in Siemens/meter

and other terms are as defined for Equation 1.

The longitudinal electric field intensity is a logarithmic function of distance, so antenna height has little effect except very near to the cable. The intensity is much more influenced by operating frequency and current. Near surface earth conductivity also is a factor.

TRANSVERSE ELECTRIC FIELD

The transverse electric field in air is produced by voltage on a conductor, and lies in a plane transverse (at right angles) to the direction of an ELF antenna. It is stronger near the surface of the earth than the longitudinal electric field, and does not penetrate the earth to any significant extent. The field has a horizontal component and a vertical component. At the earth's surface it is essentially vertical. The horizontal component has a significant amplitude only at heights close to the cable.

The magnitude of the transverse vertical electric field in air depends upon cable construction details. It can be approximated at the earth's surface for an ELF communications antenna from the expression:

$$|E| = \frac{2V}{h\ln\left(\frac{2h}{a}\right)} \left[\frac{1}{1 + \left(\frac{x}{h}\right)^2}\right] \text{ volts/meter} \quad (3)$$

where

V = antenna voltage, in volts

h = antenna height, in meters

a = antenna cable diameter, in meters

x = horizontal distance from antenna centerline, in meters

The antenna voltage and height of the antenna influence the intensity of the field, while other factors, including the conductivity of the earth, do not. The intensity of the transverse electric field is a function of distance from an ELF antenna, and diminishes very rapidly.

ELECTRIC FIELDS NEAR GROUND TERMINALS

The electric field in soil produced near ground terminals is a localized field which diminishes rapidly as a function of distance.

Several cables are used to construct each ELF ground terminal in order to divide the antenna current and thereby prevent high fields at the surface. The intensity, E, from a single cable away from its ends can be estimated from the expression:

$$E = \frac{I}{\pi \ell \sigma} \frac{x}{x^2 + d^2} \quad \text{volts/meter} \qquad (4)$$

where:

I = current in buried cable of interest, in amperes

ℓ = length of cable of interest, in meters

σ = effective earth conductivity, Siemens/meter

x = lateral distance to point of interest, in meters

d = cable burial depth, in meters

Nearby cables may contribute to the field level at any point, and local variations in earth conductivity also influence its value.

ELECTROMAGNETIC EXPOSURE CRITERIA

Since ELF antennas and commercial power lines produce similar electromagnetic fields, it is necessary to establish some preferable exposure conditions for ecological studies. Criteria were established in March 1982 to assist offerors in preparing proposals (see Appendix C).

Test plots will be located as close as possible to antennas and ground terminals where electromagnetic fields produced in soil near the earth's surface have the following design values:

Wisconsin Antenna System	Michigan Antenna System
0.14 volt per meter (electric)	0.07 volt per meter (electric)
0.06 Gauss (magnetic)	0.03 Gauss (magnetic)
Wisconsin Ground Terminals	**Michigan Ground Terminals**
1.5 volts per meter (electric)	1.5 volts per meter (electric)
< 0.06 Gauss (magnetic)	< 0.03 Gauss (magnetic)

Control plots will be located where electric fields in soil near the surface of the earth produced by the ELF system are on the average one order of magnitude and preferably two orders of magnitude less than those at paired test plots. The same relationship exists for magnetic field components between test and control plots. Electric and magnetic fields in air and earth produced by other ELF sources (e.g., power lines) generally will not differ by more than one order of magnitude between paired test and control plots, and at test plots are about one order of magnitude below the fields produced by the ELF system.

These criteria take on varying degrees of importance, depending upon the particular type of study being conducted.. For example, magnetic and electric fields in soil may be the most important factor in studying soil organisms. Biologically-matched test and control plots need only be separated by about 80 meters to obtain an order of magnitude difference in magnetic field intensity. However, an order of magnitude difference in longitudinal electric field intensity in soil requires much greater separation. In other cases, such as that of migrating birds in flight, fields in soil may not be relevant and only fields in air need be considered.

The components which describe ELF electromagnetic fields will be measured in 1983 at all test and control study plots selected by ecology investigators. Measurements will be made at system operating frequencies and at 60 Hz, with measurements recorded at other extremely low frequencies (such as power line harmonic frequencies). The measurements will be repeated periodically to develop to develop representative ELF electromagnetic profiles at each ecology study plot. These profiles will define electromagnetic exposure conditions for those biota being examined.

STUDY SITES

As suggested in the 1982 Request for Proposals, most principal investigators have developed ecological studies that utilize "paired plot" designs. Their current plot arrangements are listed in Table 7.

Paired plots have essentially similar biotic and abiotic characteristics. Careful matching of study plots reduces inter-plot variability an. replication requirements, and thereby enhances meaningful comparison of da. Plots are being matched for other factors (see Monitoring of Natural Ambient Conditions) that could significantly affect biological end points of the studies. The number of plots, their locations, and their final design are unique to each study. Plot pairing will be an important factor in the peer review process for the 1983 reports on ecological studies.

The bordered area in Figure 1 depicts the region in which most study plots will be located in Michigan. Wetlands studies in Wisconsin are located in the southeast quadrant defined by the ELF antennas (see Appendix A, Figure A-2). Slime mold study plots in Wisconsin are located near the two antenna elements and at a control plot about 10 miles east of the antenna system.

The precise locations of ecological study plots will be established during 1983, and reported in the next yearly program report. At this time, it is expected that test plots will be located close to, but not within, planned antenna rights-of-way. Plots within rights-of-way will be avoided because opening the forests by clearing antenna lanes changes natural habitat for some species, and would confound data interpretation. Control plots will generally be several miles from test plots, so that orders of magnitude differences in ELF field intensities will exist. "Sham" rights-of-way will be used for those few studies in which new forest openings are expected to influence their biotic data. A sham right-of-way is an opening created at about the same time that antenna rights-of-way are cleared.

TABLE 7

ELF ECOLOGICAL MONITORING PROGRAM STUDY PLOT ARRANGEMENTS

Biological Indicators	Antenna Test	Ground Terminal Test	Control Plots
Trees, Herbs, Fungi and Bacteria	6	3	6
Soil Amoebae	1	1	1-2
Slime Molds	1	1	1
Soil Arthropods and Earthworms	1	1	1
Native Bees	1	1	4
Small Mammals and Nesting Birds	3	-	3
Migrating Birds in Flight	Paired Plot Arrangement Not Applicable		
*Wetland Biota**	3	3	6
Aquatic Biota	1	-	2

* Six additional plots, at field intensities of intermediate value relative to test and control plots will also be used.

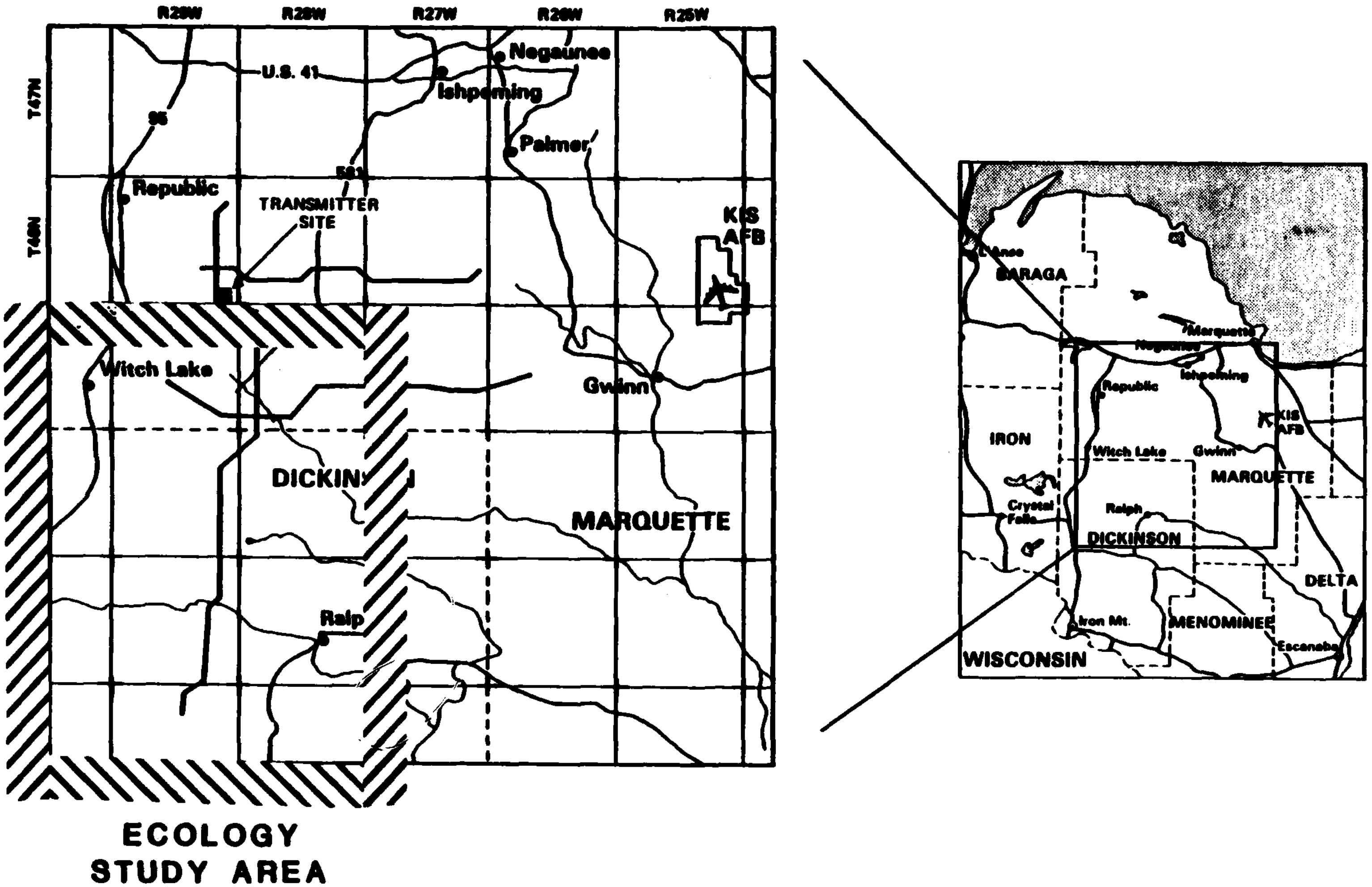

FIGURE 1 LOCATION OF ELF ECOLOGICAL MONITORING STUDY AREA IN MICHIGAN

TERRESTRIAL VEGETATION STUDY SITES

Trees, herbs, fungi and bacteria will be studied at test plots located at ground and antennal locations; these will be matched to control plots. All of the electromagnetic fields are of interest.

Red pine seedlings will be planted in a 3 to 4 acre plot at one of the six planned ground terminals. Three 0.2 acre sub-plots will be delineated after the ground terminal design is established to ensure no damage occurs during system installation. Aerial photographs and information available from the Michigan Department of Natural Resources (stand examination data) will be used to match control plots to the test plots.

Six test plots will be selected in vegetation stands located about 20 meters from antenna rights-of-way. Three 0.2 acre plots will include pole-sized aspen and birch. Three others of the same size will be planted with red pine seedlings in an area of about two acres. The information noted above will be used to select appropriately matched control plots. A sham right-of-way will be cleared at the control plots.

SOIL AMOEBAE STUDY SITES

An antenna test plot and a ground terminal test plot will be selected about 10 meters from rights-of-way established for these system components. Initially, data will be taken by examining 10 one-meter-square sub-plots, but the plots will be selected so that at least an acre is available at each location for long-term studies. A control plot matched to both test plots will be identified in 1983. Two control plots will be used if a common control cannot be identified.

Intensities in soil are the most important electromagnetic factor in the study. Matching criteria also will be determined by exploratory cluster analysis, population estimates and ambient factors.

SLIME MOLD STUDY SITES

The slime mold studies are supplementary to laboratory research completed several years ago. While slime molds may be naturally present in the northwest Wisconsin environment, it would be impractical to search out sufficient numbers living in opportune places (places where electromagnetic intensities satisfy study criteria). As a practical matter, the species will be cultured in buried chambers and strategically placed in appropriate habitat at an antenna test plot, a ground terminal test plot, and a control plot.

Measurements of electromagnetic fields in earth were completed late in 1982 at several candidate study locations near Clam Lake. One selected test plot is near the edge of the right-of-way for the north ground terminal. The antenna test plot is located near a highway where the north antenna crosses underground. The control site is about 16 kilometers (10 miles) east of the north antenna.

SOIL ARTHROPODS AND EARTHWORM STUDY SITES

A system of 15-meter-square grids will be established at antenna test and ground terminal test plots for this study. Each row of squares will be separated by one-meter wide walkways. From 40 to 50 squares will be delineated and examined at each test plot, so each will be about 2.5 acres in extent. One matched control plot with a similar grid arrangement is planned. Electromagnetic field intensities in soil are the possible stress factors to be examined in these studies.

NATIVE BEE STUDY SITES

Pollinating insects require relatively open areas conducive to the growth of flowering plants. Test plots will be established adjacent to an antenna right-of-way that passes through relatively open forest areas, and another will be established in clearings made to accommodate ground terminal installation.

Four control plots will be matched to the test plots. Two will be about 1.6 kilometers from the transmitting antenna system, and the remaining two will be about 16 kilometers further away. Fields in air are the most important electromagnetic factor in this study.

SMALL MAMMALS AND NESTING BIRD STUDY SITES

Three antenna test plots will be selected in 1983 for these studies. Each plot will be about 75 acres in extent, and generally rectangular in shape. The size of the plots represents a practical maximum for paired plot studies, given the multiple sustained-use concept of managing public forests. Each of the plots will be located in mature forests. Vegetation species, density and maturity, soil type, drainage, exposure to sunlight, and the type and amount of standing or flowing water are important factors in selecting the three test plots.

Three control plots will be selected according to similar environmental conditions, and matched as three pairs to the control plots. One pair (T_1 - C_1) will be used to study behavior, growth and development. Minimal live trapping will be employed. The second pair (T_2 - C_2) will be used to monitor population density and examine selected physiological factors of species. Live trapping will be used to study mammals, and bird populations will be censused. The third pair of matched plots (T_3 - C_3) will be used to study homing and prenatal development. Animals will be removed from these plots and examined in a locally-established laboratory. Fields in soil and near the surface are the principal electromagnetic field components of interest in this study. A sham right-of-way is expected to be used to account for opening effects at control sites.

MIGRATING BIRD STUDIES

Certain species of birds use flyways that cross over the ELF communications sites in Wisconsin and Michigan when migrating south for the winter, and returning north in the spring. Deflections in their flight paths over the sites will be identified (if they occur) by tracking individuals and/or flocks with a specialized mobile radar system and radio telemetry. Paired plots are unnecessary for this study.

The tracking equipment will be located conveniently close to the ELF sites in the spring and fall of the year. The equipment location in Wisconsin will be near the intersection of the two antennas. In Michigan, where it is possible to obtain a pre-operational data base, the monitoring equipment will be placed either east or west of the transmitting antenna array. Electromagnetic field intensities at flight altitudes are the principal design stresses of interest in these studies.

WETLAND BIOTA STUDY SITES

A wetland biota study will be initiated as an exploratory investigation at the Wisconsin ELF Facility. Wisconsin was selected as the study site because wetlands are larger and more common than at the Michigan site.

A series of matched plots will be so located that an electromagnetic field gradient is defined. Test plots will be close to the ELF antennas and grounds. Control plots will be distant from the antennas. Study plots at distances intermediate between the test and control plots will define desired field gradient characteristics. The principal matching factors will be species similarity, likeness of vegetation, density, and ambient characteristics. Electromagnetic fields in air and soil are of interest.

AQUATIC BIOTA STUDY SITES

A test site immediately upstream of an antenna river crossing will be established for this study. The site will be located so that the antenna right-of-way opening is not a factor. The Ford River crossing for the north-south antenna in Michigan is preferred. Electromagnetic fields in water (equivalent to soil) are important. Water depth, width and flow rates, substrate composition, habitat type and riparian vegetation are the principal plot matching factors. Control plots will be selected several miles upstream and downstream of the test plot. All three sites will consist of riffle and pool segments.

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STATISTICAL DESIGNS

Statistical methods are planned for analyzing data and interpreting the results of ecological studies. For the most part, standard methods will be used in analyses (Sokal and Rolf, 1981; Zar, 1974; Johnson, 1978; Batschelet, 1981), with appropriate statistical applications to the unique design of each study. Most studies employ a paired plot design, but several studies will use a modified arrangement. Gradients will be examined in wetlands studies by selecting test, intermediate and control plots which provide a more-or-less linearly decreasing electromagnetic field intensity profile. Migration studies will not employ paired plots. Study designs, including planned statistical methods were critiqued in the proposal selection process. Planned statistical methods will be emphasized in preparing 1983 study reports, and again peer-reviewed.

Analysis of variance (ANOVA) will be the primary technique used in comparing biological parameters between electromagnetic treatments (test vs. control, pre-operational vs. post-operational field intensities). Several ANOVA types (covariance, two-way, nested) will be used to account for factors that might confound comparisons between treatments, whether they are biotic, ambient, or temporal. Principal component analyses will be made to identify important confounding factors. This method employs regressions and correlations to account for variability in biological parameters due to factors other than ELF electromagnetic fields.

The proper use of ANOVA techniques requires appropriate randomization of samples, equal variance and a normal distribution of the biological factor of interest. If data do not satisfy normality and variance requirements, one can use logarithmic, arc sine, square root or reciprocal transforms. Non-parametric analyses also may be appropriate for selected parameters lacking a normal distribution. Some data can be reduced to indices such as diversity, evenness or dominance, and examined as individual statistics. Currently planned statistical analyses, transform and indices are summarized in Table 8.

TABLE 8

PLANNED STATISTICAL METHODS, TRANSFORMS AND INDICES FOR ECOLOGICAL MONITORING STUDIES

ORGANISM/ STATISTICAL METHODS AND TRANSFORMS	INDICES
Trees, Herbs, Fungi and Bacteria	
Principal Component Analysis	Shannon's Diversity
Bartlett's Test for Homogeneity	Simberloff Rarification
Transforms (Logarithmic, Arc Sine Square Root or Reciprocal)	Evenness
Analysis of Variance	
Analysis of Covariance	
Soil Amoebae	
Most Probable Number Analysis	Morisita's Index of Dispersion
Paried T-Test	
Wilcoxon Signed Rank Test	
Multiple Regression Analysis	
Nested Analysis of Variance	
Slime Molds	
Correlations with other analyses to be determined by data trends	
Soil Arthropods and Earthworms	
Principal Component Analysis	Pielou's Diversity
Transforms	Berger-Parker Dominance
Multiple Regression Analysis	Lloyd-Ghelardi Equitablity
Nested Analysis of Variance	Shannon-Weaver Diversity
Covariance Analysis	Sorensen's Coefficient of Similarity
Chi Square Methods	Bray-Curtis Coefficient of Community Similarity
	Cole's Coefficient for Degree of Association
Native Bees	
T-Test	Dominance
Rank Correlation	Co-occurrence
Correlation	
One-Way Analysis of Variance	
Nested Analysis of Variance	
Multiple Regression	
Cannonical Correlation	

Table 8 (continued)

ORGANISM/ STATISTICAL METHODS AND TRANSFORMS	INDICES
Small Mammals and Nesting Birds	
One-Way Analysis of Variance	-
Two-Way Analysis of Variance	
Hotelling's T^2 Test	
Chi-Square Analysis	
Factorial Techniques	
Migrating Birds	
Analysis of Variance	-
Circular Statistics	
Least Squares Techniques	
Mann-Whitney U-Tests	
Standard Error of Straight Line Fits	
Multiple Regression Analysis	
Wetland	
One-Way Analysis of Variance	
Two-Way Analysis of Variance	
Periphyton, Aquatic Insects and Fish	
Two-Way Analysis of Variance	Diversity
Transformations	Redundancy
Analysis of Associations	Evenness
Correlation Matrices	
Regression Analysis	
Student's T-Test	
Mann-Whitney U-Test	

Regardless of techniques now planned for analysis, determining the number of replicates necessary for each monitored biological factor will be the most important design decision of 1983 for each study. Initial estimates of the inherent variability of parameters of interest will be based on 1983 field data, and refined in subsequent years. Initial estimates will form the basis for determining the number of replicates necessary for specific levels of precision and power. Peer reviewers of 1983 reports will be requested especially to critique the appropriateness of study design to treatment comparison based in part on measures of parameter variability reported in 1983.

DATA MANAGEMENT

A very substantial amount of ambient and biological data will be collected during this program, and it is expected that others will find uses for the information. Since the amount can be as high as the megabyte per annum range, a data management program is essential to assure efficient and complete data handling, transfer and analysis. A data management program also provides the means for compiling and maintaining a quality archive for use over the years. Planned data management activities are listed in Table 9.

Some data will be collected manually, and others automatically. Several parameters must be continuously monitored, while others can be measured at predetermined intervals or continually sensed. Generally, meteorological and other abiotic parameters (such as soil moisture and temperature) will be sensed and logged electronically. Biotic parameters and results of laboratory analyses will be recorded in hard copy (data sheets) where automated direct entry is impractical. Micro- and mini-computers will be used extensively in most studies for direct data entry, validation and preliminary evaluation. Mainframe computers at each institution will be used to perform the more complex statistical evaluations.

TABLE 9

PLANNED DATA MANAGEMENT ACTIVITIES

ORGANISM	DATA	ENTRY	PROCESSING
Trees, Herbs, Fungi and Bacteria	Manual field measurements recorded on digital tape	Direct transfer to microcomputer	Preliminary error checking
	Laboratory analyses	Manual entry to microcomputer	Preliminary error checking
	Electronically sensed ambient monitoring - digital electronic data	Telemetry communication to National Earth Satellite Service, then transfer by telephone line to minicomputer	Preliminary error checking
		Data will be transferred from micro- and minicomputers to Mainframe Computer via telephone line	Data base will be used to store, retrieve and analyze data. Data will be periodically transferred to tape
Slime Molds	Laboratory and field data collected in machine readable form	Direct transfer to Mainframe Computer	Validation and analysis via interactive computer programs
Soil Amoebae, Soil Arthropods, Earthworms, Bees, Periphyton, Aquatic Insects and Fish	Manually collected field data and laboratory analysis	Manual entry to microcomputer from field sheets, facilitated by menu-driven interactive programs	Manual and automatically-sensed data printed in tabular form for manual checking. Programs for statistics (parametric and non-parametric) trace, scatter, and histogram output used for preliminary data evaluation. Data in the microcomputer periodically copied onto magnetic diskettes
	Electronically-sensed ambient data recorded on integrated circuit memory chip	Direct entry to microcomputer	

TABLE 9 (continued)

Planned Data Management Activities

ORGANISM	DATA	ENTRY	PROCESSING
Soil Amoebae, Soil Arthropods, Earthworms, Bees Periphyton, Aquatic Insects and Fish (continued)		Data from magnetic diskettes transferred to Mainframe Computer via telephone lines	Mainframe Computer provides a flexible format interactive data base management system and statistical analysis package. Data periodically transferred from disk to tape archival record. Diskettes and field sheets retained
Small Mammals and Nesting Birds	Manually collected field data on mark-sense forms or into menu-programmed data loggers (cassette tape)	Data from mark-sense forms read by machine directly into microcomputer	Data indexed by software entered so that relevant data subsets easily assembled for statistical analysis. Preliminary data analysis achieved through system of checks. Data examined through running and seasonal means and variances. Summary reports and analyses compiled on a periodic basis
	Laboratory analyses recorded on mark-sense forms	Data from data loggers (magnetic tape) read directly into microcomputer	
	Electronically sensed data recorded on magnetic cassette tape	Data from microcomputer transferred to Mainframe Computer via telephone line	Mainframe computer provides a flexible format interactive data base management system and statistical analysis package. Data periodically transferred from disk to tape archival record. Diskettes and field sheets retained
Migrating Birds	Data Management Plan Has Not Yet Been Completed		
Wetland Biota	Data Management Plan Has Not Yet Been Completed		

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PROGRAM RESOURCES

Resources for the Ecological Monitoring Program for a 16-month period commencing late in Fiscal Year 1982 and continuing through Fiscal Year 1983 are listed in Table 10. Resources expanded from about 10 staff-years during 1982 to more than 34 staff-years in 1983, and are expected to remain at about that level.

The principal investigators for each ecological task hold PhD's and have published extensively in their respective scientific areas of expertise. They represent 283 university teaching years, and have published more than 400 scientific books, papers and articles. Each principal investigator is assisted by other professors, post-doctoral candidates, and/or graduate research assistants. Staffing is completed by technicians, specialists, undergraduate students and subcontractors with special expertise, totalling 78 people. Additionally, IIT Research Institute provides approximately eight people and three staff years of effort to the Ecological Monitoring Program each fiscal year for program coordination and electromagnetics engineering support.

TABLE 10

FY 82-83 ECOLOGICAL MONITORING PROGRAM RESOURCES

Study	Subcontractor	Principal Investigator and Staff	Professional Staff - Hours
Trees, Herbs, Fungi and Bacteria	Department of Forestry Michigan Technological University	M. F. Jurgensen, Ph.D. 17 persons	13,800
Soil Microflora and Litter Decomposition	Department of Forestry Michigan Technological University	J. N. Bruhn, Ph.D. 8 persons	4,500
Soil Amoebae	Department of Zoology Michigan State University	R. N. Band, Ph.D. 3 persons	4,700
Soil Arthropods and Earthworms	Department of Zoology Michigan State University	R. J. Snider, Ph.D. R. M. Snider, Ph.D. 10 persons	15,500
Native Bees	Deparment of Entomology Michigan State University	R. L. Fischer, Ph.D. 5 persons	6,700
Small Mammals and Nesting Birds	Department of Zoology Michigan State University	D. L. Beaver, Ph.D. 9 persons	11,300
Periphytic Algae	Department of Zoology Michigan State University	T. M. Burton, Ph.D.	18,800
Aquatic Insects		R. W. Merritt, Ph.D. R. J. Stout, Ph.D.	
Fish		W. W. Taylor,Ph.D. 9 Persons	

Table 10 (continued)

FY 82-83 Ecological Monitoring Program Resources

Study	Subcontractor	Principal Investigator and Staff	Professional Staff - Hours
Wetland Flora	Department of Botany University of Wisconsin (Milwaukee)	F. Stearns, Ph.D. 5 persons	2,500
Migrating Birds	Illinois State Natural History Survey (University of Wisconsin--Madison)	R. P. Larkin, Ph.D. (S. Temple, Ph.D.) 7 persons	4,100
Slime Molds	Biomedical Research Institute University of Wisconsin (Parkside)	E. M. Goodman, Ph.D. 5 persons	4,200
Program Integration and Electromagnetics Engineering	IIT Research Institute	J. E. Zapotosky, Ph.D. 8 persons	6,900

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ACHIEVEMENTS IN 1982

The ELF Communications Ecological Monitoring Program, conceptually developed by the Navy in 1977, was funded and initiated soon after the President and the Congress approved the development and installation of the system in Wisconsin and Michigan late in 1981. Several achievements in 1982 provide the foundation for a multi-year ecological study.

Many experts contributed to the development of the 1982 Request for Proposals issued by IIT Research Institute. Certain species and biological end-points were recommended by scientists familiar with research on electromagnetics effects. The perspectives of resource management, local familiarity and field ecology were identified and recommended by others. The proposals submitted by interested bidders helped focus the studies and integration of efforts.

The studies funded in 1982 were reviewed and judged scientifically meritorious by independent peers prior to being initiated. Moreover, the peer review process will be continued. Peer reviews will be conducted annually before yearly reports are published, and one-half of the reviewers (2 of 4) for each study will be selected by the principal investigators. The remaining two will be selected by IIT Research Institute. The Navy will neither approve nor reject the peer reviewers selected by either party.

The first yearly symposium involving principal investigators, IIT Research Institute, state monitors and the Navy was conducted in Wisconsin in 1982. The symposia are intended to foster better understanding of individual objectives and requirements, promote integration of studies, and provide the means for a participatory appraisal of each study and the program as a whole.

Investigators were funded and most initiated exploratory field work in 1982 in Wisconsin and Michigan. This permitted investigators to target candidate study areas, collect preliminary data, and arrange necessary logistics for field investigations during 1983.

PROJECTIONS FOR 1983

Emphasis in 1983 will be placed on preparing and distributing the first yearly compilation of study reports. This will be followed by the selection of study plots by Principal Investigators and electromagnetic verification of plots by IIT Research Institute. The first inputs to the pre-operational data base in Michigan will be compiled, as will data collected in Wisconsin. Preliminary analysis of results will be initiated in the Fall of 1983.

The second yearly symposium will be conducted in Michigan in 1983, and the second yearly compilation of study reports will be distributed. The peer review process will emphasize the matching of study plots and the statistical basis of analysis to be used by investigators. A summary report of progress, plans and findings for 1983 will be prepared by IIT Research Institute.

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APPENDIX A

BRIEF DESCRIPTION OF THE ELF COMMUNICATIONS SYSTEM

ELF COMMUNICATIONS SYSTEM DESCRIPTION

OPERATIONAL REQUIREMENTS

The primary purpose of the ELF Communications System is to provide the capability to communicate with submarines at operational depths and speeds to enhance their operational flexibility by minimizing communications constraints. The ELF Communications System will complement other Navy submarine communications systems by alerting submarines to receive long messages from these other systems. The ELF system will transmit short messages to single, multiple, or all submarines.

All information flow within the ELF Communications System will be protected against unauthorized access, traffic analysis and spoofing. The ELF link will have antijam protection.

SYSTEM DESCRIPTION

The purpose of the ELF Communications System is to deliver short messages from operating authorities in the Continental United States to submarines operating at best mission speeds and depths. The unique feature of ELF is its ability to penetrate ocean depths to several hundred feet with little signal loss. This penetrating ability will allow submarines and their receiving antennas to be operated well below the immediate surface, which will enhance submarine survivability by making detection difficult.

The fundamental operating concept for the ELF system is straightforward. Submarines will maintain contact with command authorities by receiving ELF transmissions while operating at best mission speeds and depths. Many messages may be transmitted, including one which may alert submarines to "copy traffic" on higher data rate communication systems for which a more exposed receiving posture is required.

The Transmitter Segment consists of the two sites shown in Figure A-1: the Wisconsin Transmitter Facility (WTF) located in the Chequamegon National

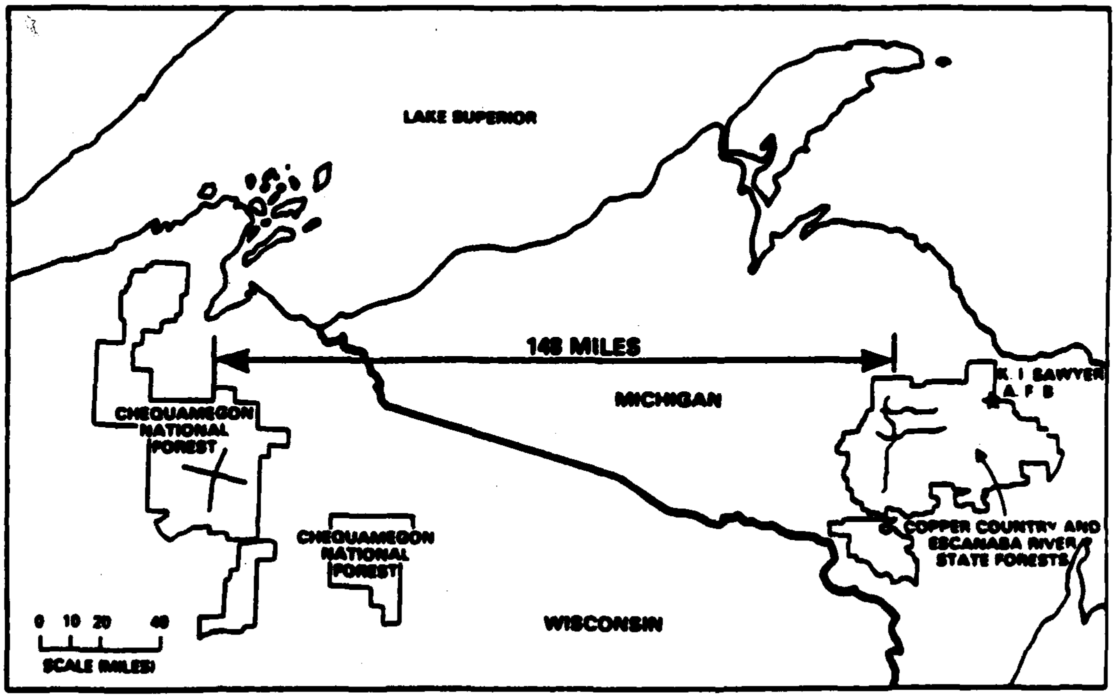

FIGURE A-1 ELF TRANSMITTER SEGMENT LOCATIONS IN WISCONSIN AND MICHIGAN

Forest near Clam Lake, Wisconsin and the Michigan Transmitter Facility (MTF) which will be located in the Escanaba River and Copper Country State Forests near Republic in the Upper Peninsula of Michigan. The two transmitter facilities can broacast the ELF signal either synchronously or independently. The Receiver Segment on the submarines receives the signal and processes and displays the message.

FUNCTIONAL DESCRIPTION

Broadcast Control Authority

The Broadcast Control Authority, Norfolk, VA, has the necessary message and cryptographic equipment for placing ELF messages in the system. The ELF message is entered from a computer connected to the transmitter. Data entry includes the message and the number of times the message is to be transmitted. Messages may also originate at K.I. Sawyer AFB.

Transmitter Segment

The transmitter receives the message, processes it, and broadcasts it to the receiver. It consists of two transmitter facilities; one located at the existing WTF to be known as the Naval Radio Transmitting Station Clam Lake, and the second, the MTF in the Upper Peninsula of Michigan to be known as the Naval Radio Transmitting Station Republic. The WTF has one north-south antenna and one east-west antenna, as shown in Figure A-2. The MTF will have one north-south and two east-west antennas, as shown in Figure A-3. The antennas are long overhead wires like those shown in Figure A-4, and are grounded at each end. Each antenna is driven by one power amplifier. The antennas at WTF have a total length of 45 kilometers. The antennas at MTF will have a total length of 90 kilometers.

The power amplifier output current has a nominal amplitude of 300 amperes at the WTF and 150 amperes at the MTF.

Cryptographic equipment provides communication security and antijam protection. Electrical power is supplied by local commercial utilities with backup power available if prime power is interrupted.

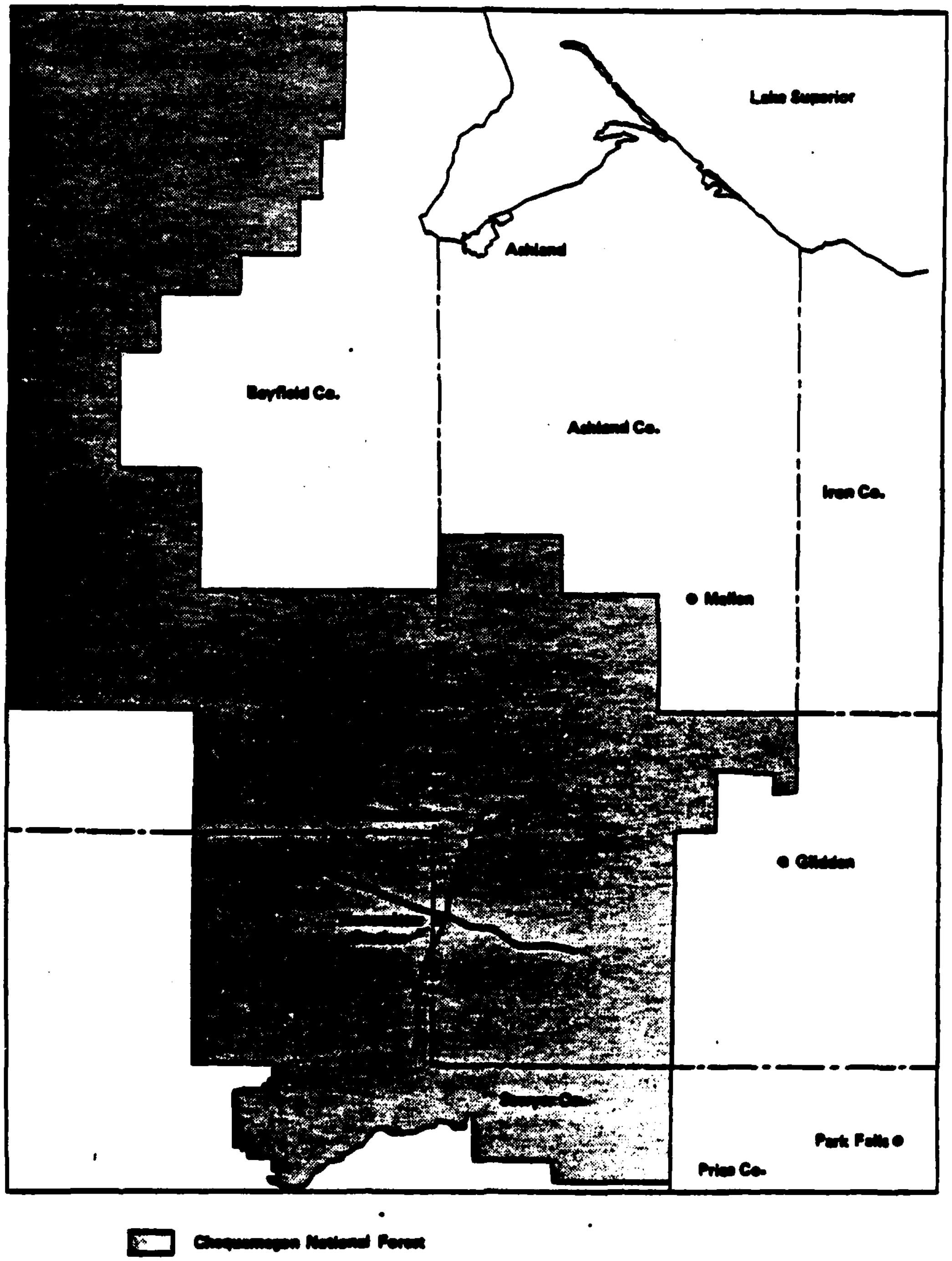

FIGURE A-2 WISCONSIN ELF TRANSMITTER SITE

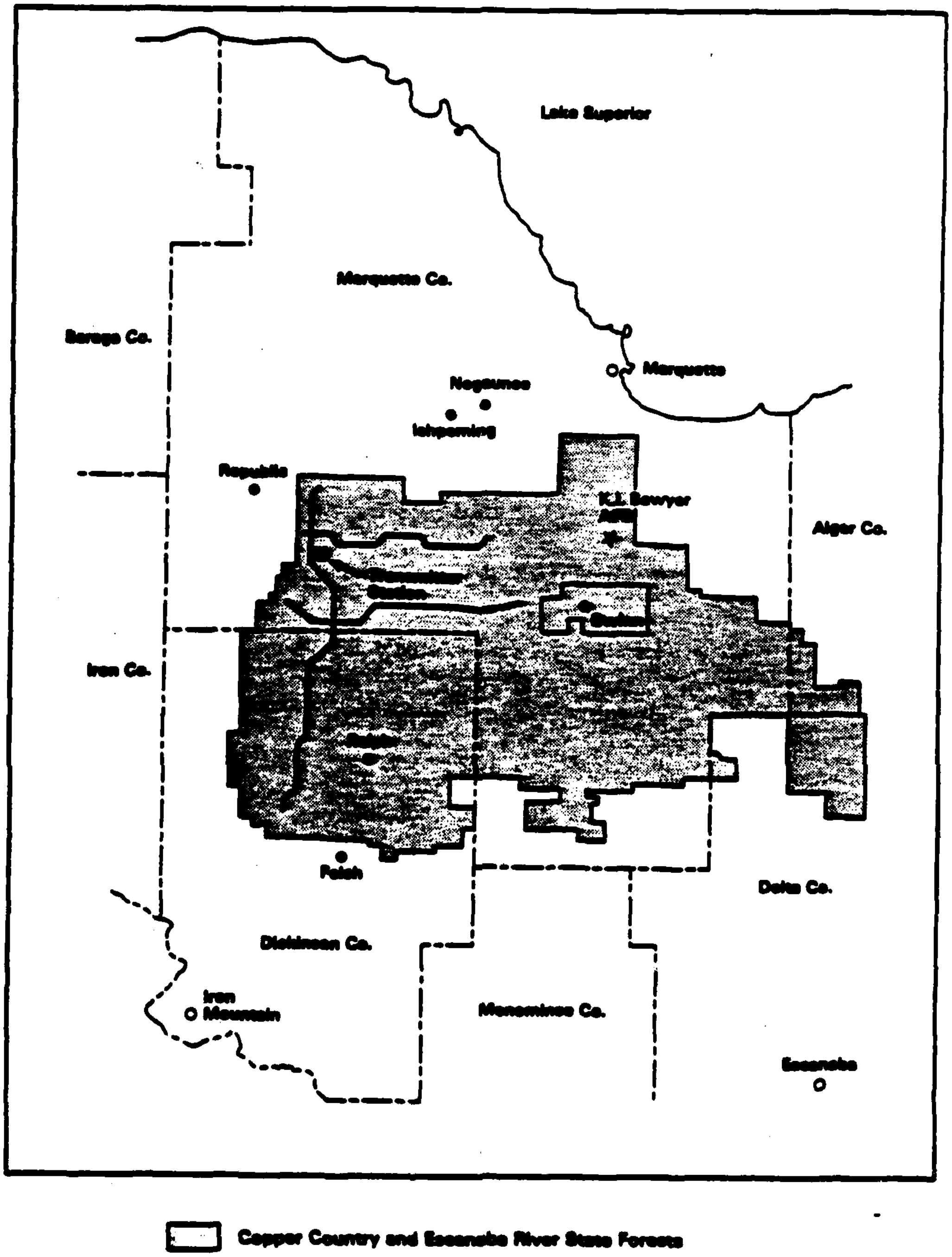

FIGURE A-3 MICHIGAN ELF TRANSMITTER SITE

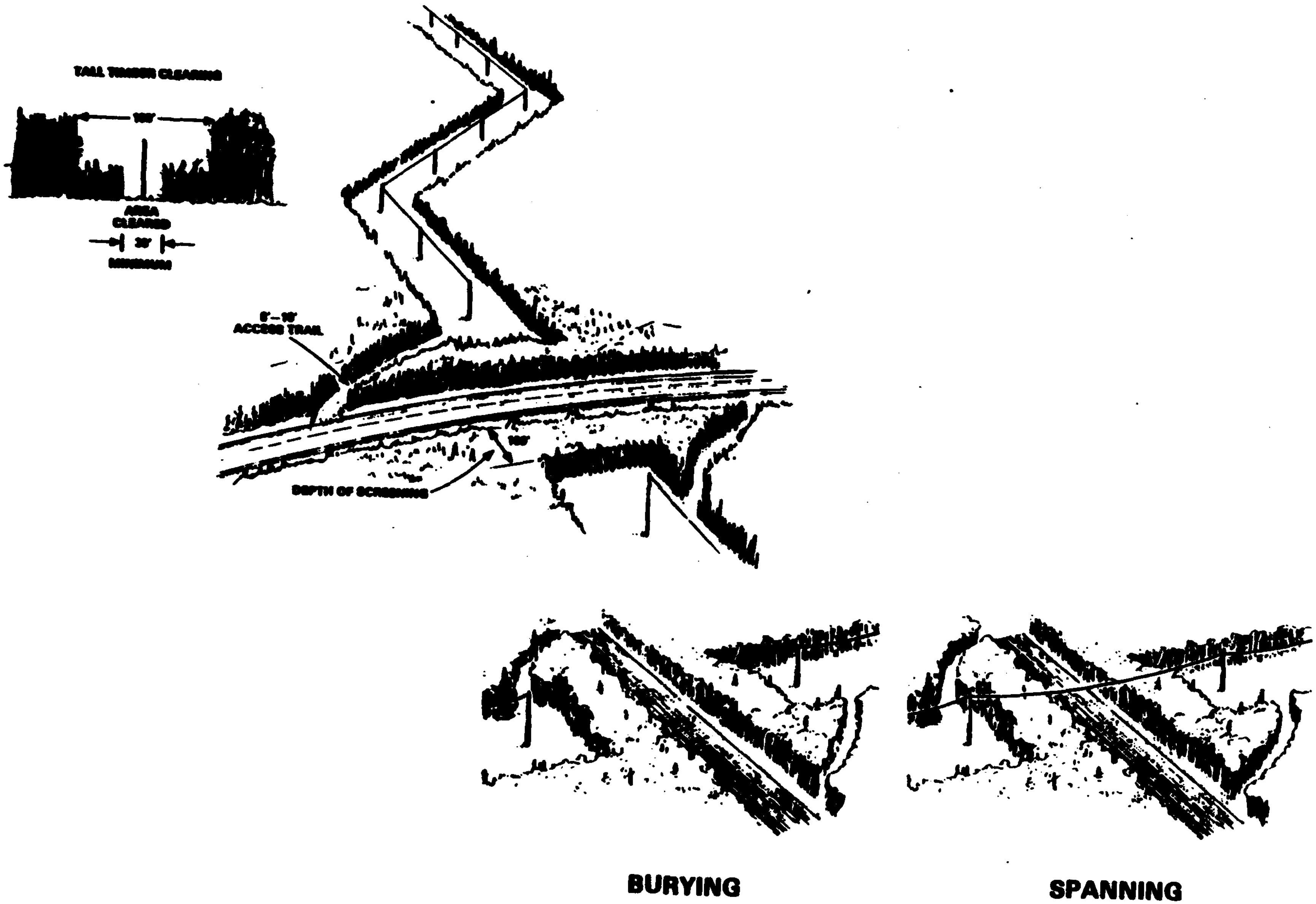

FIGURE A-4 TYPICAL CONSTRUCTION DETAIL FOR ELF TRANSMITTING ANTENNA

Receiver Segment

The receiver is deployed onboard submarines for receiving and decoding ELF messages. A receiver at the Broadcast Control Authority monitors ELF messages. The received message corresponds to a detailed code book message.

The ELF signal is picked up on a receiving antenna that trails from the submarine. A computer processes the signal and prints it out.

Facilities

Each ELF facility will be designed and built according to applicable building codes and environmental regulations. Each transmitter facility is expected to occupy about two acres of land. The public will have access to the antenna and grounds rights-of-way. The transmitter buildings and attendant facilities will be fenced.

PROGRAM SCHEDULE

The objective is to complete upgrading the ELF Communications System in Wisconsin in Fiscal Year 1985. Construction of the MTF will start in 1983 and is due to become operational in Fiscal Year 1986 (see Figure A-5).

The Wisconsin upgrade will be implemented as follows:

a. Antenna terminal grounds will be improved to meet safe current criteria recommended by the National Academy of Sciences for an operational system

b. Antenna and ground fault detection equipment appropriate for an operational system will be installed

c. Standby power will be installed

d. Physical security measures will be implemented at the transmitter station

e. The trasnmitter building will be modified to accommodate new equipment

f. New equipment will be installed in the transmitter building, including new power amplifiers

COMMENCE MICHIGAN SITE SURVEYS	FY 1982
INITIATE ECOLOGICAL MONITORING PROGRAM	FY 1982
COMMENCE WISCONSIN ELF FACILITY UPGRADE	FY 1983
COMMENCE CONSTRUCTION - MICHIGAN	FY 1983
WISCONSIN OPERATIONAL CAPABILITY	FY 1985
COMPLETE MICHIGAN SITE	FY 1986
FULL OPERATIONAL CAPABILITY	FY 1987

FIGURE A-5 ELF COMMUNICATIONS PROGRAM ACQUISITION SCHEDULE

The MTF will be constructed as follows:

a. A transmitter building will be constructed

b. Electrical and electronic equipment will be installed in the transmitter building

c. Overhead transmitting antennas will be constructed

d. Antenna terminal grounds will be constructed to meet safe current criteria

e. Antenna and ground fault detection equipment will be installed

f. Standby power will be installed

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APPENDIX B

WILDLIFE SURVEYS AT CLAM LAKE, WISCONSIN

WILDLIFE SURVEYS AT CLAM LAKE, WISCONSIN

Wildlife surveys have been initiated by the U.S. Forest Service in the Clam Lake region to obtain information about several species to ensure that chronic effects, if produced by the electromagnetic fields there, will be detected. While the surveys do not have the scientific or statistical depth of the studies included in the ecological monitoring program, they provide information helpful to formulating more formal studies in the future if data trends suggest it would be necessary to do so. Recent results submitted by the U.S. Forest Service are summarized in this appendix.

DEER TRACK SURVEY

The U.S. Forest Service established the ELF Deer Management Unit in 1974 in consultation with the Wisconsin Department of Natural Resources Division of Forest Wildlife Research. The purpose of the survey is to measure trends in the deer population in the vicinity of the Navy's Clam Lake ELF Facility in the Chequamegon National Forest.

The survey is made by establishing 16 two-mile long transects along forest roads, distributed among the four quadrants defined by the ELF transmitting antenna system (NE, NW, SW and SE). Each transect is dragged with equipment that leaves a 3-4 foot wide smooth surface on the roadway. Tracks left on the smooth surface of each designated roadway are counted the day after dragging. The survey times correspond to late summer days when air temperature is within 15° F of the long-time average, and no cold front is in or approaching the area. Deer activity is depressed under those weather conditions, but light rain does not affect activity. Half the transects are dragged on one afternoon, and the tracks are counted the following morning. The remaining half are dragged on the second afternoon, and the tracks are counted on the third morning.

The average of the number of tracks per transect counted on two consecutive mornings can vary considerably. The data are rationalized to represent

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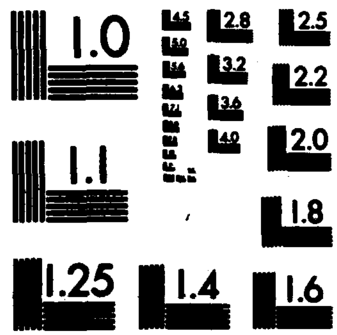

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

the estimated deer population per square mile. The last, previous estimate was made in 1978, and was 14. The estimate obtained from the most recent survey (August, 1982) was also 14. In 1981, the Wisconsin Department of Natural Resources estimated a deer population of 14 per square mile for a much larger geographic area than that surveyed by the U.S. Forest Service. The estimates, independently derived by the U.S. Forest Service for the smaller area and the Wisconsin Department of Natural Resources for the larger area, suggest that the deer population near the ELF Facility is remaining stable and comparable to that for the region at large.

BALD EAGLE NEST PRODUCTION

The U.S. Forest Service has been monitoring the population and nesting activity of bald eagles in an area described by the Chequamegon National Forest boundary plus one mile around the perimeter for a number of years. Monitoring results were most recently obtained during the summer of 1982.

A total of 23 known eagle territories were checked. Seventeen of the 23 showed signs of activity in 1982, and 10 of the 17 produced young. The rate of production was 1.0 eaglet per active territory. This was close to the 1982 average of slightly less than 1.1 for all National forests in the Lake States Region.

Three of the six known eagle territories within 10 miles of the Clam Lake ELF Facility showed activity in 1982. Young were produced in two of the three active territories for a production rate of 1.0 eaglet per active territory. Three new territories have been identified within the 10-mile radius since 1980, and one is now considered abandoned after no activity since 1977.

Bald eagle monitoring by the U.S. Forest Service suggests no activity or inactivity within 10 miles of the ELF Facility different from that observed throughout the Lake States Region.

RUFFED GROUSE DRUMMING TRANSECTS

The U.S. Forest Service has been monitoring the activity of ruffed grouse in the Chequamegon National Forest since 1967. The survey is made by recording the number of drumming male grouse along seven 15-mile-long transects. Five of the transects were established in 1967, and two others were added to the survey in 1974. Four of the seven, including the two most recent transects, are in the immediate vicinity of the ELF Facility.

The average number of drumming birds was nine in 1967, the year before the ELF Facility was initially operated. The average increased gradually to 20 by 1972, with the highest numbers consistently reported from the two transects most closely associated with the ELF Facility. The averages for those two over the six-year period were 18 and 32, while the avergages for the remaining three were 4, 8 and 12.

A gradual reduction in the number of drumming males was recorded from 1972 to 1976. The average per transect dropped from 20 in 1972 to eight in 1976. The highest numbers continued to be made along those transects close to the ELF Facility. For example, the 4-year average (1973-76) for those four transects was 15, and the average for the remaining three over the same period was only five.

The average number of male drumming birds along the seven transects is again exhibiting an increase. It has increased from eight in 1976 to 14 in 1982. The largest numbers continue to be observed along the transects closest to the ELF Facility. The numbers ranged from eight to 29 along the four "ELF" transects in 1982, and were none, six and nine for the remaining three transects.

A consistently higher number of male drumming grouse have been recorded along transects close to the Clam Lake ELF Facility than along other transects in the region since 1967. This trend has been constant over periods when the species population appeared to be increasing generally, and when their population generally decreased.

ELF WILDLIFE HABITAT IMPROVEMENT PROGRAM

The Department of the Navy (Naval Facilities Engineering Command) and the U.S. Forest Service have been cooperating in resource management in the Chequamegon National Forest since the ELF Facility was installed there in 1969. Arrangements were initiated in 1982 for improving wildlife management practiced by the Forest Service by developing additional wildlife openings along the 28 miles of ELF antenna rights-of-way. During the next four years, 29 new upland habitat wildlife openings will be created over 67 acres of land. Another 35 acres of permanent wildlife openings will be developed by clearing and seeding five miles of the rights-of-way.

The ELF antenna rights-of-way have been popular with sportsmen since they were constructed in 1967-68. Resource use and game management will be enhanced by renovating 3.5 miles of the antenna rights-of-way, and constructing another 1.75 miles of hunter walking trails along the antenna routes.

APPENDIX C

ELF COMMUNICATIONS ECOLOGICAL MONITORING PROGRAM

STATEMENT OF WORK

SOLICITATION NO. IITRI-E06516-82-R-00015

ELF COMMUNICATIONS PROGRAM
ENVIRONMENTAL PROTECTION PLAN

STATEMENT OF WORK

ECOLOGICAL MONITORING PROGRAM

18 MARCH 1982

ELF COMMUNICATIONS PROGRAM

ENVIRONMENTAL PROTECTION PLAN

ECOLOGICAL MONITORING PROGRAM

1. PURPOSE

1.1 Scope

The purpose of this work is to determine if low-level, long-term electromagnetic fields and gradients produced by an ELF Communications System affect vegetation and/or wildlife located in and near the system area. The scope of desired studies includes multi-year investigations of ecological compartments of forest environments in the Chequamegon National Forest in northwestern Wisconsin and in the contiguous Michigamme, Escanaba and Ford River State Forests in the Upper Peninsula of Michigan. Post-construction investigations are possible in Wisconsin. Both pre-construction and post-construction studies are desired in Michigan.

2. DEFINITIONS

The following definitions apply for this work:

ELF Communications System	-	The transmitter station and peripheral electrical equipment, the transmitter control center and peripheral electrical equipment, antenna cables, ground terminals and feed lines.
System Area	-	A two-mile boundary extending for one mile on either side of antennas, feed lines and ground terminals, at which boundary electrical fields produced in soil by the ELF Communications System have decreased by approximately one order of magnitude or more relative to values on the surface of the earth directly below an overhead antenna. The system area in Wisconsin is identified in Figures 3, 4, 5 and 6 of Exhibit A. The system area in Michigan will be identified precisely at a later date, and will be within the perimeter of the contiguous Michigamme, Escanaba River and Ford River State Forests depicted in Figure 9 of Exhibit A.
Subcontractors	-	Individuals and/or organizations selected to perform tasks proposed and approved within the scope of this statement of work.
Subcontract Administrator	-	The person representing IIT Research Institute (IITRI) authorizing contractors to perform this work.
Program Coordinator	-	The person authorized by IITRI to provide technical direction to contractors.

3. APPLICABLE DOCUMENTS

Exhibit A - Extremely Low Frequency (ELF) Communications Program in Wisconsin and Michigan; System and Site Definition, Program Plans, Environmental Summary and Supplemental Information; Naval Electronic Systems Command; December 1981;

Exhibit B - Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project SEAFARER; Committee on Biosphere Effects of Extremely Low Frequency Radiation, Assembly of Life Sciences, The National Research Council, National Academy of Sciences; 1977 (pp. 27-54)

Exhibit C - Ecology; From SEAFARER ELF Communications System Draft Environmental Impact Statement for Site Selection and Test Operations; Appendix E, Biological and Ecological Information; Naval Electronic Systems Command; February 1977 (pp. A-96 - A-112).

Exhibit D - Pilot Survey of Small Mammal Populations in the Chequamegon National Forest during 1971 and 1972; IIT Research Institute Technical Report E6357-4 to Naval Electronic Systems Command; August 1976 (pp. 1-37).

4. STATEMENT OF WORK

4.1 General Requirements

Subcontractors shall develop ecological monitoring programs to be initiated on or about 1 July 1982 and continued for a period of 28 months in Wisconsin (31 October 1984 end date) and/or a period of 52 months in Michigan (31 October 1986 end date). Ecological monitoring may continue beyond these end dates through contract renewals or new solicitations.

Subcontractors shall provide all materials, work spaces, analytical tools, and technical and administrative support services necessary to satisfy the requirements of this statement of work. IITRI-furnished materials and information are limited to Exhibits A through D contained herein except for meeting facilities which may be provided by IITRI periodically, electromagnetic field intensity information (a subcontractor option), related ELF Program information, and MSK modulators, if required.

Subcontractors are responsible for obtaining rights-of-entry from cognizant forest managers in order to perform studies proposed within the scope of this statement of work. The cognizant agency in Wisconsin is the U.S. Forest Service, and the Department of Natural Resources is the responsible agency for managing state forests in Michigan.

Subcontractors must coordinate selection of study areas with cognizant government agencies. Arrangements with property owners are the responsibility of subcontractors in the event locations on private land are selected for studies. Monitoring activities must not damage forest resources.

Methods for protecting study areas from intrusion require the prior approval of land managers. Living accommodations on public lands also require prior approval of land managers. Subcontractors will be responsible for inadvertent site damage, restoration and clean-up following studies.

4.2. Program Options

Subcontractors may propose and afterward periodically recommend alternatives to program elements included in this statement of work. Subcontractors must demonstrate that alternatives are scientifically sound, are statistically meaningful, and preferable for discerning whether electromagnetic fields produced in the system area by the ELF Communications System affect flora or fauna. Subcontractors may not implement proposed alternatives and cannot terminate established program elements until authorized in writing by the Subcontract Administrator.

Proposed alternatives may include research conducted in laboratories to support studies conducted in the field. Subcontractors are required to account for appropriate test, ambient and electromagnetic monitoring in proposals including laboratory research.

Subcontractors are responsible for designing, fabricating, testing, evaluating and operating equipment used to generate ELF electromagnetic fields for laboratory research, except that IITRI will provide equipment necessary to simulate ELF Communications System modulation characteristics. IITRI reserves the right to determine by independent measurements that electromagnetic fields produced in laboratory arrangements conform to design requirements. Preliminary electromagnetic design information must accompany proposals.

Subcontractors may elect to conduct all work or only selected portions of work included in this statement. Each proposed work element or alternative will be evaluated independently in selecting subcontractors. Subcontractors are encouraged to group specific tasks into logical sets where such groupings would enhance interpretation of clearly related data. Direct costs of each proposed work element or related sets of work elements are required, and funding may be limited to approved work elements.

4.3 General Design

The Ecological Monitoring Program is intended to determine whether electromagnetic fields produced by the ELF Communications System influence plant and/or animal populations, or otherwise result in community or ecosystem level changes of importance.

Subcontractors must satisfy the following general criteria unless present scientific knowledge or contemporary scientific research practice dictate otherwise:

a. data must be quantitative;

b. statistical methods of analysis must be capable of detecting small changes in measured variables.

c. well-established techniques of data collection and analysis must be used;

d. taxa must be available for observation in reasonable numbers in the system area;

e. naturally-occurring time-dependent and weather-dependent changes must be reasonably accounted for:

f. biologic variables used as end-points must be sufficiently understood to ensure confident interpretation.

g. unless otherwise approved by the IITRI program coordinator, blind scoring must be used in analyzing laboratory results;

h. field studies shall be executed in a manner that produces minimal impact on the forest environment.

4.4 Experimental Design

Subcontractors must demonstrate that each study is designed and will be conducted to produce statistically meaningful results. Validity may be accounted for by numbers of samplings or observations, and/or population sizes.

4.5 Paired Plots

Subcontractors are encouraged to develop studies that maximize the use of paired plots and minimize the use of the same individuals or populations as both test and control subjects. It is recognized that the free-ranging behavior of some species may not permit separation of species and/or habitat into distinctive test and control groups.

Paired study plots that have essentially similar soil types, drainage, exposure to sunlight and vegetation type and density shall be used. Taxa of similar age and of the same class should be identified in analyses to minimize within-group variations.

4.6 Electromagnetic Exposure Levels

Test plots shall be selected at locations where electromagnetic fields produced by ELF antennas and ground terminals in soil near the earth's surface have the following nominal design values:

<u>Wisconsin Antenna System</u>

0.14 volt per meter (electric)
0.06 Gauss (magnetic)

<u>Michigan Antenna System</u>

0.07 volt per meter (electric)
0.03 Gauss (magnetic)

<u>Wisconsin Ground Terminals</u>

1.5 volt per meter (electric)
$<$ 0.06 Gauss (magnetic)

<u>Michigan Ground Terminals</u>

1.5 volt per meter (electric)
$<$ 0.03 Gauss (magnetic)

Electromagnetic field intensities near the intersections of antennas depend upon the relative phase between the currents in the antennas. They could be either higher or lower than nominal values by about a factor of two or less, and depend upon the operating mode of the system. Test locations at antenna intersections may therefore exhibit a range of time-dependent electromagnetic values. Anticipated system operating frequencies range from about 40 to 80 Hz with MSK modulation. For proposal purposes, center frequencies ± 4 Hz may be assumed (e.g., 76 ± 4 Hz).

Overhead ELF antennas in both Wisconsin and in Michigan will produce electric fields of about 150 volts per meter in air near the surface of the earth. Unlike the longitudinal electric fields produced in soil, the fields in air dissipate rapidly as a function of distance in directions normal to the antenna, and are highest near the transmitter feed point.

Control plots shall be selected at locations where electric fields in soil near the surface of the earth produced by the ELF system are on the average at least one order of magnitude and preferably two orders of magnitude less than those at paired test plots. The same relationship shall exist for magnetic field components between test and control plots. Electric and magnetic fields in air and earth produced by other ELF sources (e.g., power lines) shall not differ by more than one order of magnitude between paired test and control plots, and at test plots should be at least one order of magnitude below the fields produced by the ELF system.

Electromagnetic field intensities shall be measured at study plots at intervals sufficient to characterize ELF exposure levels from extraneous sources. Field intensities shall be measured seasonally for studies in which habitats are sensitive to changes in the near-surface electrical conductivity of the earth at extremely low frequencies. Subcontractors may elect to measure ELF field intensity, or may request the data as furnished information. In the former case, measurement methods and equipment are subject to the approval of the IITRI program coordinator. Information will be supplied by IITRI on ELF System modulation characteristics necessary to determine appropriate measurement methods. IITRI reserves the right to verify subcontractor data by independent measurements.

Subcontractors should recognize that power lines may produce measurable ELF field intensities at harmonics of 60 Hz. Therefore, measurements should be made (at least initially) to account for these power harmonics as well as operating frequencies of the ELF Communications System.

4.7 Preconstruction Data Base

Antennas and ground terminals for the ELF Communications System in Wisconsin were installed in 1968-69. Installation of system components in Michigan will not be completed for several years. A preconstruction data base is not available for the Wisconsin system area. A preconstruction data base for the Michigan area is required for proposed work in [illegible]. [illegible] sources of data should be considered in assembling preconstruction data bases. Multiple test and control plots should be established in Wisconsin to account for data limitations at that location.

5. SPECIFIC REQUIREMENTS

5.1 Ambient Monitoring

Ambient atmospheric, terrestrial and aquatic environmental conditions shall be monitored and recorded at or near each location selected for field ecology studies. Standard monitoring and reporting methods shall be used. Subcontractors must propose methodologies for monitoring ambient environmental factors pertinent to their proposed studies.

Important factors that characterize or which may affect soil and aquatic environments shall be monitored. Subcontractors shall investigate whether road salts, agricultural wastes or fertilizers, or industrial or community waste products are present in habitat used in these studies. Stream velocity, discharge, pH, specific conductance, alkalinity, silica, chlorides, total phosphate, nitrate, suspended solids, dissolved solids, total organic carbon, dissolved organic carbon, dissolved oxygen, discharge temperature and turbidity should be monitored. The frequency of measurements must be specified by subcontractors. Shading from nearby vegetation should be documented. Subcontractors are expected to augment this list as appropriate to their proposals.

Subcontractors are required to obtain information on atmospheric environmental conditions. Data may be obtained from established reporting sources, local observations or by direct measure (if appropriate). Temperature, precipitation, humidity, barometric pressure, solar radiation, cloud cover and wind conditions, and other phenomena shall be recorded. As noted above, subcontractors are expected to augment this list as appropriate to their proposals.

5.2 Soil Amoebae

Well-known soil amoebae shall be selected and species number determined by established techniques. Cell cycle analysis shall be performed. The efficiency of cropping bacteria shall be determined.

5.3 Soil and Litter Microfauna

Subcontractors shall obtain estimates of rates of breakdown of natural litter and examine the population dynamics of related species of organisms. Two contrasting ecosystems (e.g., hardwood and conifer forest settings) shall be investigated. Soil/litter characteristics which may be important to species composition, diversity and density shall be identified. The latter may include soil texture and moisture, temperature, pH, calcium, nitrate, ammonia, phosphate, organic carbon, exchangeable cations, chlorides and sulfates.

5.4 Earthworms

Subcontractors shall study earthworm population density and biomass. Soil characteristics identified above for soil microfauna studies shall be recorded. Earthworm casts from test and control plots should be compared with surrounding soil in terms of total nitrogen, organic carbon, exchangeable calcium, exchangeable magnesium, available phosphorous, exchangeable potassium, organic matter, base capacity, pH and moisture equivalent.

Subcontractors shall make seasonal estimates of population patterns and functional capability of earthworms in test and control plots.

5.5. Herpetofauna

Species composition and density changes of reptiles and amphibians shall be determined by using standard techniques for herpetological surveys. Species shall be listed for distinctive habitat in the system area. Mark-recapture methods should be considered for determining populations numbers. Trapping methods should be selected that ensure high survivorship. Species should be classified as common, uncommon or rare.

5.6 Small Mammal Biometric Survey

Subcontractors shall study small mammal species whose natural range is limited, whose abundance is high, and for which there is abundant literature on their ecology and techniques for study.

Population and range data shall be obtained within the ELF Communications System area and beyond the electromagnetic influence of the system. Electromagnetic characteristics noted above for paired plot studies generally apply except for constraints due to ranging of species.

In the event that important differences are noted in either population density or ranging characteristics between system-exposed and reference groups, subcontractors shall investigate possible causes of such changes. Parameters such as biomass, age profiles, fecundity and reproduction condition may be appropriate monitors.

5.7 Large Mammal Studies

Large mammal studies may not be useful in investigating whether ELF Communications System electromagnetic fields affect wildlife because of the free-ranging habitat of many large species. Their habitat generally encompasses ELF electromagnetic fields produced by numerous sources. While it may be possible to identify such sources, a cause-effect relationship probably cannot be established with one particular ELF source from among many sources and many field intensity levels. That is, exposure to ELF antenna electromagnetic fields cannot reliably be distinguished from exposure from other ELF sources. Nevertheless, large mammal studies are not necessarily excluded from this statement of work. If electromagnetic methods of monitoring species activity are proposed, subcontractors must demonstrate that tracking devices would not mask electromagnetic fields produced by the ELF Communications System.

The above notwithstanding, proposals are desired to collect and report data on habitat usage by deer. Information should be obtained on deer browse conditions, population distribution estimates, pellet counts, location and condition of wintering yards, and hunter-kill records. Data available from state Departments of Natural Resources should be used.

5.8 Periphytic Algae

Subcontractors shall select aquatic environments for studying attached algae. The density, number of species and relative abundance of component populations shall be determined. A perennial aquatic moss may be used to determine cumulative effects over a long period of time. Diversity indices shall be developed to describe and compare periphytic community structure and relationships of component species to abiotic factors. The lowest positive taxon shall be identified. Algae production and appropriate physiological and biochemical indices should be determined.

5.9 Aquatic Insects

Subcontractors shall study insect life cycles and other phenomena to detect changes in bethnic community structure and/or function. Representative species of chironomids, may flies, caddisflies and stoneflies shall be studied. Life cycle, body size, growth rate and population density characteristics should be analyzed.

5.10 Fish Studies

Subcontractors shall determine the fecundity, development, feeding and growth and behavioral habitat selection patterns of fish in aquatic environments within and distant from the electromagnetic influence of the ELF Communications System.

Two non-migratory fish species should be selected, one representing a species that feeds predominantly on bethnic invertebrates, and the other representing a species that feeds predominantly on invertebrate drift and adult insects. Parasitic and pathogen infestation should be quantified as indicators of stress.

Subcontractors may also study a species of sport fish if one exists in the system area that exhibits predictable migratory or homing behavior. The relative numbers of fish in a spawning migration shall be determined at selected points. Counts may be made by using non-conductive weirs, but electronic devices cannot be used. Fixed plantings are permissible for these studies.

5.11 Pollinating Insects

Subcontractors shall study colonies of honeybees of known genetic stock in introduced hives close to and distant from ELF Communications System antennas and/or grounds and in reasonable proximity to abundant foraging plants. Behavior, reproduction and population dynamics shall be monitored. Orientation information on nectar sources and swarming activity shall be noted. Egg production, survival and adult population size shall be studied. Comb size, shape and orientation; volume of honey production; and wax production shall be determined.

5.12 Nesting Birds and Migrating Birds in Flight

Subcontractors shall devise methods for studying behavior and populations of resident and migrant birds (including waterfowl) common to the region. Species should include at least one species of winter resident and one transient.

The abundance of selected migrating species shall be noted and their diversity of species described. Any changes from expected migratory behavior shall be reported.

Any abnormal nesting site tenacity expressed by birds near ELF antennas and grounds shall be reported. Any continuing tendency for young reared close to the antenna system to return to their natal area for breeding shall be noted. Behavior by transients shall be distinguished from that exhibited by resident species.

5.13 Herbaceous Plant Cover

Subcontractors shall study representative species of managed vegetation (annual crops and/or forage crops) and non-managed vegetation (sucessional communities and/or mature systems of understory components of forest communities). Developmental and life history stages of selected species should be analyzed throughout seasons of active growth and dispersal.

5.14 Trees

Deciduous and evergreen trees, including both fast-growing and slow-growing species, should be studied. Sample trees within paired plots shall be compared according to species, age, size and dominance class. Principal phenological events shall be recorded and analyzed. Physiological variables affecting growth and mortality may be appropriate monitors.

The productivity of commercially important trees in the region shall be studied. Plots selected for productivity studies shall be free of disease and insect infestation. Methods may include but are not restricted to collecting core samples and correlating annual ring width to climatological and environmental variables, followed by examination of core samples to detect deviations from expected patterns.

6. DELIVERABLES

6.1 Work Plan

Subcontractors shall prepare work plans identifying equipment development, plans, procedures and schedules for satisfying proposed tasks from this statement of work. The plan shall include a list of contributing professional personnel, and shall be submitted to the IITRI program coordinator within 30 days of subcontract award. Work plans shall be revised on a yearly basis or as otherwise necessary to account for changes in plans, staff, etc.

6.2 Monthly Reports

Subcontractors shall submit monthly status reports to the IITRI subcontract administrator with monthly invoices for services within 10 days of completing each month's work.

6.3 Annual Reports

Subcontractors shall prepare annual technical reports on each funded study included in this Program. The 1982 report shall be a summary of proposed work and is due on 30 October 1982. Subsequent yearly reports are due on 30 October of suceeding years.

Voluminous reporting of data and procedures is not desired. The former should be summarized, and appropriate reference should be made to the work plan in the case of the latter. IITRI may exercise the option of receiving complete copies of data for independent analysis.

Each yearly report shall include a brief summary written to be understandable to the knowledgeable layman. The summary shall precede other material included in the report. One reproducible copy and 10 copies of each report shall be delivered.

Annual reports shall receive peer review. Subcontractors will select two reviewers, and IITRI will select two reviewers for each report. At least one reviewer selected by each organization shall represent Federal or state government not associated with the ELF Communications Program. Reviewers' comments on draft reports will be addressed by subcontractors in completing annual reports.

6.4 Yearly Symposium

Subcontractors shall participate in a yearly one-day symposium which will be open to the public. Work plans and study results shall be described. The symposium will be conducted in the fall of each year commencing in 1982. Locations will alternate between Wisconsin and Michigan with the 1982 symposium in Wisconsin.

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