Statistical/Epidemiological Study of Bovine Performance Associated with the CPA/UPA DC Power Line in Minnesota

September 1983

[MINNE]SOTA ENVIRONMENTAL QUALITY BOARD
MEQB PPSP
POWER PLANT SITING PROGRAM

PREFACE

This report was prepared by the College of Veterinary Medicine, University of Minnesota for the Minnesota Environmental Quality Board. It examines producer records from the Minnesota Dairy Herd Improvement Association to determine if any changes in dairy cattle productivity and health could be associated with proximity to the Cooperative Power Association/United Power Association ± 400 kV dc power line.

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FINAL REPORT

A Statistical/Epidemiological Study of Bovine Performance Associated with the CPA/UPA DC Power Line in Minnesota

by

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September, 1983

Table of Contents

List of Figures

List of Tables

Abbreviations

ac	-	Alternating Current
CPA	-	Cooperative Power Association, Eden Prairie, Minnesota
DHIA	-	Dairy Herd Improvement Association
dc	-	Direct Current
DRPC	-	Dairy Records Processing Center
FCM	-	Fat Corrected Milk
kV	-	Kilovolts
UPA	-	United Power Association, Elk River, Minnesota
305 2xME	-	305 Day Mature Equivalent Records
MEQB	-	Minnesota Environmental Quality Board
GASP	-	General Assembly to Stop the Power Line

Executive Summary

A

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Introduction

There has been considerable controversey over both the routing and possible health effects of the +/-400 kilovolt (kV) direct current (dc) power line that runs from North Dakota across Western and Central Minnesota.

Some Minnesota livestock producers believed that they have observed signs in their animals attributable to power line exposure. The veterinary medical community servicing the power line area however were less convinced of the possible deleterious effects of the line, but at the same time felt that there were insufficient scientific data available to evaluate the question. In 1981, the Minnesota Environmental Quality Board (MEQB) asked the College of Veterinary Medicine, University of Minnesota to determine if a study of livestock, particularly dairy cattle, could be undertaken to evaluate if biological effects were associated with exposure to the power line environment. The College proposed to determine if any effects on dairy cattle productivity and health could be detected through an examination of producer records from the Minnesota Dairy Herd Improvement Association (DHIA). The proposal was approved by the MEQB and funded in late spring, 1982. The purpose of this study therefore was to attempt to determine if any effects on dairy cattle productivity and health could be detected by examination of producer records from DHIA.

DHIA records stored in computer files at the University of Minnesota College of Agriculture contain a wealth of diverse information on the production and reproduction efficiency of both whole herds and individual cows. In so far as this data is gathered at the producers' expense and for their specific benefit in achieving herd improvement, this study presumes that the data is free from biases effecting its outcome. Thus the DHIA records presented an opportunity to investigate an association between dairy herd efficiency and exposure to the Cooperative Power Association and the United Power Association (CPA/UPA) +/-400 kV dc power line as measured by proximity of herds to the line.

During the summer months of 1982 efforts were concentrated on locating and soliciting the cooperation of DHIA members within a corridor 10 miles either side of the 176 mile length of the line in Minnesota from the North Dakota border in Traverse County to the terminus near Rockford, Minnesota. Subsequently the records needed for the study were identified and assembled from storage tapes containing data from the entire state. The statistical analysis began in September at the St. Paul Campus Computer Center.

The Scope of the Study

This study was restricted to an examination of the stored written record. Strict anonymity of the data was required by agreements made with producers when asking permission to use their records. Six years accumulated data from mid 1976 to September 1982 were prepared on 500 herds representing approximately 24,000 milking cows per year. The data mass actually used in this study contained over a quarter of a million lengthy records.

The variables studies include 305 day milk production per cow, DHIA rolling herd average of milk production, herd size, cow age and lactation, parity number, somatic cell counts on test milk, intercalving intervals, the status termination codes of a lactation cycle which include a code for abortion, and the daily rate of decline in milk production during the later part of a lactation cycle.

The Study Plan

The study sought to determine if an association between proximity to the power line and the behavior of any of the above mentioned variables existed. The 500 herds were grouped by the study into six zones or strata. Stratum 1 included farms within a quarter mile of the power line while stratum 6 included farms six to ten miles from the line. The outer strata, particularly stratum 6, were considered control areas that were unexposed to effects from the power line.

The study utilized the data from several years before the line was energized to establish base line behavior for herds in each of the 6 strata. The line was first energized in October of 1978, and was in continuous operation by the fall of 1979. The behavior of the study variables was tracked through the energizing phase of the line, and in subsequent years to September, 1982.

The study sought to observe any changes in overall performance near the power line which did not have parallels in the strata farther removed from the line. If such a change, either beneficial or detrimental, was so large or consistent among cows near to the line that it could not be reasonably attributed to chance, then the study would infer that there is a statistically significant association between the performance variable and proximity to the power line. The amount of data available and the statistical procedures used offer the almost certain assurance that relative differences between strata of 5% would be found to be statistically significant. In so far as they were available in the DHIA record, certain possible confounding variables which might indirectly induce or obscure a significant association were taken into account. Other potential confounders such as management practices which were not recorded in DHIA records were not addressed in this study.

Some Inferences and Findings

Comparison of 305 day lactation milk production was made among cow populations in the 6 defined strata. No significant association between milk production and proximity to the power line was found prior to energizing or in either of two subsequent years.

The rolling herd average in herds remaining on DHIA increased by approximately 800 pounds of milk from May of 1979 to September of 1982. This increase was approximately parallel in all 6 strata and the herds in stratum 1 (0-1/4 mile) showed an increase close to 1,000 pounds in milk. During this period herd size showed a modest increase of approximately 4 cows per herd across all strata, there being no significant association between proximity to the line and the increase in size.

Quality and efficiency measures in the DHIA records, such as percent butter fat, ratio of pounds of milk to pounds of grain fed, and somatic cell counts of milk showed no significant association with proximity to the power line.

The intercalving interval for cows having 2 or more calves showed no significant association with proximity to the line in either of the first two years following energizing of the line. The incidence of recorded abortions was no higher in herds near the line (0-1/2 mile) than away from the line (6 to 10 miles) and the data suggest that producers near the line kept more complete records of the reasons for disposal of cows.

After a cow has been milking for approximately 7 weeks, her milk production reaches a peak and begins to decline in a straight line fashion for 7-8 months until she is eventually dried off prior to having another calf. This study sought to determine if there was any significant deviation in the steady decline of milk production which might be associated with acute effects following a date of interest with regard to the energizing of the power line. Three dates were chosen: 10/17/78 when the line was first energized, 5/15/79 when the time of line operation abruptly increased from 6% to about 71%, and 9/3/79 after which date the time of line operation was about 93%. On all three dates no significant effects were found with proximity to the power line.

Some Conclusions and Recommendations

Cooperation among producers granting permission to use their records was truly excellent and the investigators wish to thank them and those groups interested in the project.

The study observed no short or long term effect of the power line on milk production. The study noticed that producers remaining on DHIA in the 0-1/4 mile stratum experienced an acceptable increase (approximately 8%) in rolling herd average from 1979 to 1982. In the DHIA system, rolling herd average is an important herd performance indicator.

Following energizing of the line, intercalving intervals, the rate of culling for reproductive problems, and the incidence of recorded abortions were no higher near the power line than at 6 to 10 miles away.

In this study, distance from the line has been used as a proxy for actual exposure to air ions and electric fields which might be measured by careful and constant on-the farm monitoring. The investigators concluded either that the degree of exposure generally prevelant within 1/4 mile of the line is not enough to noticably affect production and reproduction, or that exposure is quite uneven within the 0-1/4 mile strata and only a very few farmsteads are effectively exposed. If substantial exposure to air ion and electric fields is present on a very few farms then this study could not have statistically observed power line effects. Any resolution of this particular issue is well beyond the scope of this study.

In both the near and far strata it is possible to locate a small proportion of farmsteads having serious "difficulty" as measured by production decreases or reproductive problems. Similarly it was observed that farms both near to and far from the line has excellent production increases over the time frame studied.

The data used in this study was collected for DHIA purposes and not as part of a planned experiment designed to test for power line effects. It therefore does not necessarily contain the most useful measures which a planned independent experiment might propose, particularly for the purposes of observing acute effects. The investigators do, however, believe that the data utilized from the DHIA is both informative and unbiased and supports the stated conclusions.

The investigators also believe that maximum use has been made of these historical DHIA records. If it is considered that further studies are required, then an obvious area of succession would be to determine whether the reasons for farmsteads having either production or reproduction problems under or near the power line are similar to those at a greater distance from the line.

Other areas of investigation might also involve a detailed prospective study of dairy herd health in relation to the power line, or controlled experimental studies of exposure of air ions and electric fields. Both of these latter proposals however are likely to be very expensive and time consuming.

I. INTRODUCTION

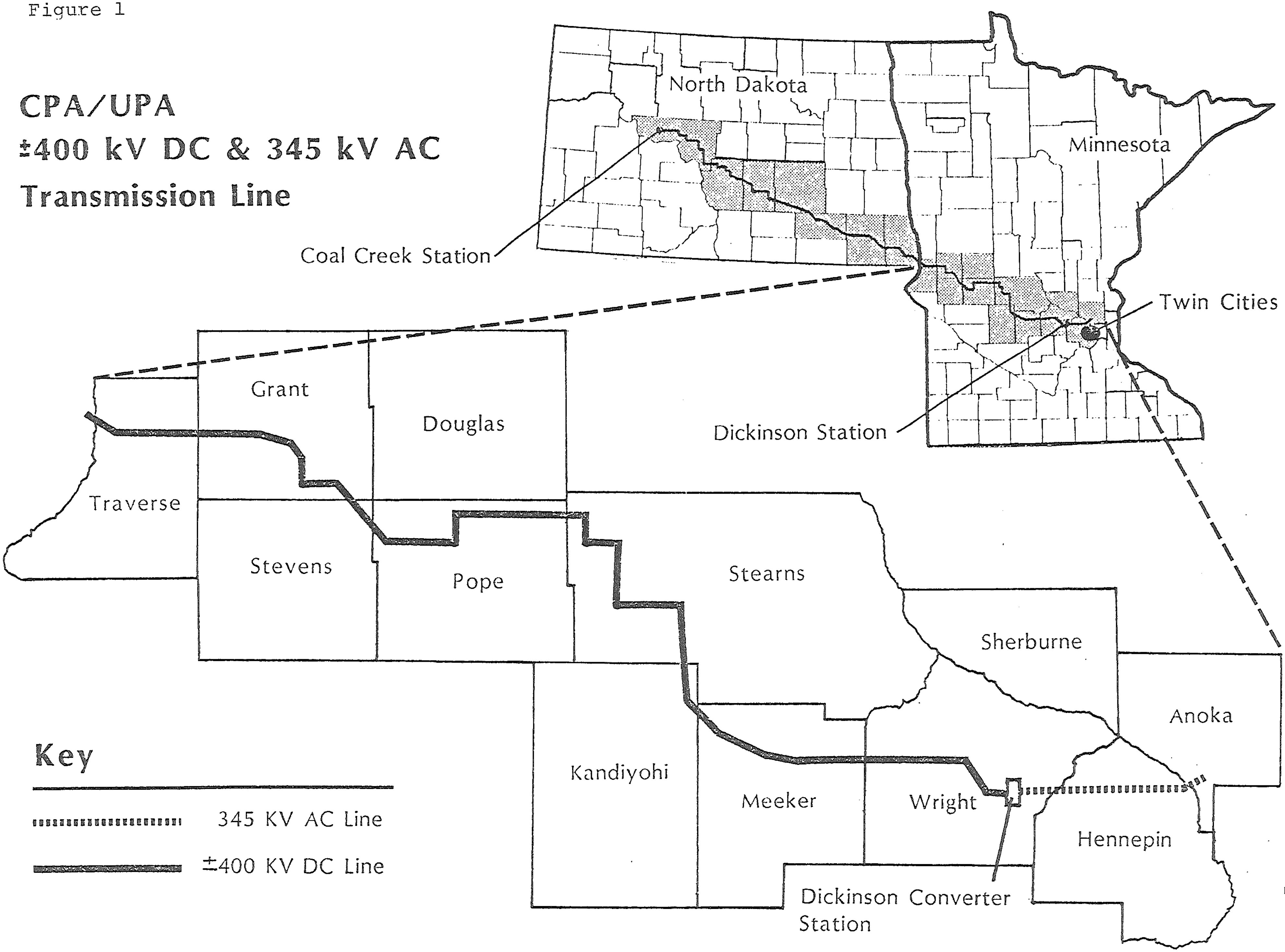
The controversy over the Cooperative Power Association (CPA)/United Power Association (UPA) +/- 400 kilovolt (kV) direct current (dc) power line has a long history of public concern and conflict extending from 1973 to the present. It has been summarized previously many times; each from a differing point of view (U.S. General Accounting Office, 1979; UPA, 1979; Dean 1981; Casper and Wellstone, 1981). The 437 mile power line connects the Coal Creek, minemouth power generating plant near Underwood, North Dakota with the Dickinson convertor station on the western edge of the Minneapolis/ St. Paul metropolitan area. Approximately 176 miles of the power line pass through eight rural counties of west central Minnesota (figure 1). For a detailed description of the power line see appendix VI. A permit to allow construction and operation of the power line was issued to CPA/UPA by the Minnesota Environmental Quality Board (MEQB) on June 3, 1976 and was followed by legal challenges to halt construction and/or modify operation of the line. Conflicts between landowners and utilities involved many questions ranging from the need for the power line and disruption of agricultural land to effects on human and animal health. However, since the power line was first energized in October 1978, the dominant public issue has been the effects on human and animal health.

The literature on the possible biologic effects of dc electric and magnetic fields and of air ions is growing, although it is not as extensive as that of alternating current fields. Much of the literature on fields and air ions is summarized in the the two reports, "Biological Effects and Physical Characteristics of Fields, Ions and Shock" (Dow Associates, 1980) and the report of the Science Advisors to the Minnesota Environmental Quality Board, "A Health and Safety Evaluation of the +/- 400 kV dc Powerline" (MEQB 1982a). While both the fields and the ions have been shown to generate biologic responses to laboratory exposures, extrapolations to adverse biologic effects for either humans or livestock by actual exposure to the power line environment are difficult to substantiate.

Many Minnesota livestock producers believe that they have observed signs in their livestock attributable to power line exposure. In the "Perceptions of Landowners about the Effects of the UPA/CPA Powerline on Human and Animal Health in West Central Minnesota" (Genereux and Genereux 1980), nineteen percent of the dairy producers believed they observed breeding problems; eighteen percent, congential abnormalities; sixteen percent, stress; and twelve percent believed that a change in milk production could be attributed to the power line. However the MEQB Science Advisors reviewed this study and found that the survey had several crucial flaws. These include the failure to enumerate or to acquire reliable lists of the defined study population, the improper suggestion of symptions, and the lack of exposure information, consistent administration, and a control population. Thus the study was regarded as not valid and the percentages reported can not be interpeted (MEQB, 1982a).

In 1980, 16 veterinarians, whose practices in 7 counties contained livestock within the general area of the power line were contacted by telephone and asked if they had heard farmers expressing health concerns of their animals that were believed to be related to the power line (Hendricks,

Figure 1


CPA/UPA
±400 kV DC & 345 kV AC
Transmission Line
North Dakota
Minnesota
Coal Creek Station
Twin Cities
Dickinson Station
Grant
Douglas
Traverse
Stevens
Pope
Stearns
Sherburne
Anoka
Kandiyohi
Meeker
Wright
Hennepin
Dickinson Converter
Station
Key
345 KV AC Line
±400 KV DC Line

1980). Eight veterinarians indicated that they were aware of a few complaints. These included reproduction problems, premature births, abortions, malformed calves, infertility, non-specific health problems, mastitis, as well as behavioral problems with dairy cattle. On further questioning about the purported effects of the power line, 12 were of the opinion that no effects were observable while the other 4 indicated that it was too early to make any judgement.

Six veterinarians also made written submissions to the MEQB (1981a) in which they expressed support for further animal health investigations in relation to the power line. The basis for their concerns were a range of animal disease problems seen in herds in close proximity to the power line for which there appeared to be no reasonable explanation.

The Field Services Division, College of Veterinary Medicine, University of Minnesota has made several field trips to farms with health problems that owners had been unable to resolve satisfactorily which were attributed to the power line. In one instance there was evidence of acute bovine virus diarrhea infection in the herd and in another there was evidence of a nutritional problem related to Vitamin D toxicity (Olson, 1981 - personal communication).

Thus although the veterinary medical community serving the power line area in West Central Minnesota generally did not feel that the power line per se had any obivous deleterious effects on the current health of livestock, individual veterinarians did indicate that there was insufficient data to scientifically evaluate the question. Therefore they did not rule out the possibility of adverse biological effects in livestock exposed to one or more physical components of the dc power line electrical environment. A few veterinarians also expressed concern that health conditions for which there were recognized control and preventive measures available were being erroneously attributed to power line effects by some farmers.

In view of the limited applicable data and lack of consensus in the scientific and veterinary medical communities about the possible animal health effects of dc power line exposure, and in view of the concerns expressed by livestock producers about the perceived effects on their animals and the potential personal and state economic consequences, it appeared prudent to evaluate whether observable biologic effects could be demonstrated in livestock.

The College of Veterinary Medicine, University of Minnesota responded to a request from the Minnesota Environmental Quality Board in 1981 to determine if an epidemiologic study of livestock, particularly dairy cattle, could be undertaken in order to evaluate the hypothesis that high voltage dc power line exposure was associated with demonstrable biological effects.
It was believed that it might be possible to use existing records of the Dairy Herd Improvement Association (DHIA) as a data base on which to evaluate potential exposure effects on milk production, reproduction, and general health. Accordingly, a meeting was held April 28, 1981 attended by several private and State veterinarians, County Extension Agents in areas traversed by the line, University Faculty representing Departments of Electrical Engineering, Agricultural Engineering, Applied Statistics, Epidemiology, College of Veterinary Medicine, and Agricultural Extension Service, Minnesota

Department of Health, and MEQB personnel. As a result of this meeting several groups were formed to look at the possibility of developing three types of study:

(a) A statistical and epidemiolgic analysis of dairy cattle production in relation to power line exposure using historical DHIA records (referred to as the historical study).

(b) A prospective analysis of dairy and swine health on selected farms in relation to power line exposure (referred to as the prospective study).

(c) Experimental studies of high voltage dc power line exposure on livestock health and productivity. To date no definitive protocol has been developed for this type of study although several high voltage ac power line exposures of swine have been carried out (referred to briefly in the literature review).

Protocols and budgets were developed for both the historical and the prospective studies. The historical study was primarily designed by Dr. Alan Bender, Chief, Chronic Disease, Epidemiology Section, Minnesota Department of Health, Dr. Frank Martin, Department of Applied Statistics, Dr. Jerry Steurnagel, Agricultural Extension Service and Dr. Ashley Robinson, Department of Large Animal Clinical Sciences, College of Veterinary Medicine. The protocol was also reviewed by other Faculty members. Two public meetings were held at Litchfield and St. Cloud, Minnesota to describe the proposed study to farmers. In addition, one meeting was held with farmer members of General Assembly to Stop the Power Line (GASP) on the St. Paul Campus. Finally, the protocol was reviewed in detail by several Science Advisors to the MEQB, and with minor suggested changes they recommended approval to the MEQB. In April, 1982 the MEQB contracted with the College of Veterinary Medicine to carry out the historical study.

No further action has been taken on the prospective study, either to modify it in the light of the present study or to seek funding for its development. A synopsis of the prospective study is included as appendix VII.

Throughout this report the term "power line" or "line" should be taken to by synonymous with the Cooperative Power Association/United Power Association +/- 400 kV dc power line.

II. RATIONALE AND BACKGROUND

This section is intended to provide a common understanding of the statistical and epidemiologic principles, bovine biology and data sources used in the historical study. Detailed methodologic considerations are included in the methods section.

The purpose of the historical study was to evaluate whether there were significant measureable effects in the body of accessible data (i.e. DHIA records) which could be associated with "exposure" to the ambient electric environment produced by the dc power line.

To our knowledge this was the first study to attempt to evaluate the existence of biologic effects in a large mammalian population exposed to the field environment of a dc power line. The existence or non-existence of biologic effects due to exposure must be known before assessment of a possible health hazard could be made.

The keys to this investigation were the evaluation of "exposure", the control of confounding variables in the evaluation of associated risk factors, and the use of statistical and epidemiologic methods. The great difficulties of evaluating the actual power line environment have been commented on by the Science Advisors to the MEQB (MEQB, 1982a). The chemical composition of ionized air molecules in the power line environment is not known for this power line nor for any other transmission line. Very few measurements of the electrical environment for other dc transmission lines have been reported in the literature, particularly measurements off the right of way. Fortunately, the Minnesota Department of Health and the MEQB have been conducting an electrical environment monitoring program on this power line for two years. With the information gained from this program (Minnesota Department of Health, 1982; MEQB, 1981b; MEQB, 1982b) a proxy for exposure was developed.

A major source of variability encountered in analyzing data from dairy animals is the between-herd variability. Depending on the biochemical or physiologic parameter being measured, up to 60% of the total variability is accounted for by the herd variable (Appendix I). This source of variability probably reflects differences in management practices (DHIA, 1978). To minimize the effect of this covariate it was necessary to use animals or herds as their own "control" in order to measure baseline departures after the energizing of the power line.

In addition to management variables there are other potential confounding variables that need to be included in the analyses. In the context of this study, infectious disease could be a classic confounder. An infectious disease could occur near the power line and not occur several miles from the power line. Using milk production as an indicator of biologic effect, the infection could result in decreased production. Thus lacking knowledge about the infection, the drop in milk production near the line could be mistakenly attributed to power line exposure.

Another problem that has been causing dairymen concern in recent years is the effects of stray or transient voltage on cattle. This may result in animals showing signs of uneven milk-out, extreme nervousness while milking, reluctance to enter the milk parlor, to feed, or to drink, and lowered milk production. These voltages may be caused by poor or faulty wiring, damaged equipment, or improper grounding. One estimate has been made that up to 20% of all milking parlors or stall barns are affected in varying degrees (Cloud, Appleman, and Gustafson, 1980). This type of problem can usually be corrected but it is cited as an example of a source of variability which again could confound any study of the power line and its hypothesized effects.

A. TYPES OF EPIDEMIOLOGIC STUDIES CONSIDERED

Many considerations must be reviewed before a final decision is made as to what type of epidemiologic study should be undertaken to evaluate a hypothesized effect or risk factor(s) for any specific disease. For most situations, it is possible to divide a population on the basis of those showing abnormal signs or symptoms, lesions or other clinical abnormalities indicative of a disease state and those lacking the above. In essence, a natural distinction can be made between "cases" and "controls". However, in the evaluation of any hypothesized effects of the power line there is no clear indication as to exactly what type of effects could be expected in dairy cattle and thus case and control can not be determined in the design stage of a study.

Another problem is the definition of exposure to the power line. This is an exceedingly complex problem involving consideration of the operating characteristics of the line, the route of the line, the surrounding terain, weather conditions, the properties of electrical and magnetic fields and air ions, the location of the animals and the length of time exposed. Therefore as described later the simplest and most reproducible proxy of exposure was the perpendicular distance from the line.

Finally the DHIA data base, consisting primarily of measurements of production, reproduction and milk quality does dictate to a very large extent what type of studies could be undertaken.

Two types of epidemiologic studies were considered potentially appropriate for the available DHIA data base. These were the retrospective study and the historical prospective study.

The classical retrospective study would attempt to compare prior exposure to the power line among dairy cattle determined to have shown some observable or quantificable effects to those animals not showing any effects. If there were biological effects from the power line, one would expect to find that exposure was greater among the "cases" than among the "controls".

The other type of study considered was the non-concurrent cohort (or historical prospective) study in which a population of cattle are followed from a given point in time until a specified study endpoint. Various degrees of "exposure" to the line would be developed and the outcome responses in cattle to varying levels of exposure would be evaluated. In this type of study it is important to note that no a priori definition of a disease case could be made but rather subdivisions into "cases" and "control" would be arbitrarily chosen or made by statistical comparison of the available data.

The control of bias associated with the use of the DHIA data base was reviewed. From the outset it was realized that there was some selection bias in restricting analyses only to DHIA participants in that these tend to represent the more progressive type of farmer. However, this bias was far outweighed by the fact that DHIA data on dairy cattle production and reproduction was collected both before and during the energizing of the power line, with little thought that it might be used in any study to evaluate the effects of the power line. Observational bias was also not considered a problem since persons involved in the analyses would not have visited the farmers nor have any prior knowledge regarding their personal feelings towards the power line. Finally assuming that the great majority of DHIA members could be persuaded to release their records for analyses there were no reasons to be concerned about sampling bias.

Therefore, reviewing all of the above considerations it appeared that the latter non-concurrent cohort study would be the most rewarding and also the type of study most amenable to statistical analyses. Furthermore, it would to some extent overcome the difficulties of confounding factors such as disease or management by aggregating a large amount of data from many farmsteads. The epidemiological and statistical techniques used in this study precluded the determination of any causal effects of the power line on biological activity. At best, the study may reveal association (postive or negative) between the power line and biological effects. These could then form the basis of hypotheses as to cause and effect which would need to be confirmed or disproved by experimental studies.

B. MEASURES OF BIOLOGIC EFFECTS

Milk production is one of the more sensitive indicators of any adverse effects that may be occurring in a dairy herd. Generally, a drop in milk production accompanies most clinically obvious and sub-clinical disease (Blood and Henderson 1974, Schwabe 1977). Other factors such as changes in feed quality or quantity, environment, movement from barn to pasture, or alterations in normal daily routines can also result in decreased milk production. Consequently, changes in milk production are not specific.

Another measure of biologic effect is reproductive efficiency. The efficiency of reproduction in domestic livestock depends upon many factors including the frequency and detection of estrus, number of ovulations, length of gestation, age at puberty and duration of the reproductive period in an animal´s life. Thus, reproductive efficiency can change as a result of managerial, seasonal, genetic, nutritional, hormonal or other pathologic factors resulting in partial or complete reproductive failure. Reproduction is also closedly linked with milk production so that on a herd basis any agent that causes an effect on one may well result in indirect effects on the other. As with milk production, reproductive efficiency is a sensitive but non-specific indicator of bovine physiologic integrity.

All biologic effects are not of themselves representative of pathologic changes. For example, an "exposure" to temporary water withholding will cause a biologic effect of decreased urinary volume. This is not a pathologic change but rather a physiologic response, consistent with normal homeostasis. Changes in production and reproductive efficiency may be part of a homeostatic mechanism. Their existence impacts directly upon the livelihood of the dairymen in whose herds the changes of performance occur and therefore provide a meaningful end point for study.

C. BOVINE LACTATION CYCLE

The dairy cow becomes sexually mature between nine months and one year of age. Her estrus cycle averages about 21 days between ovulations. She is normally bred at about 18-19 months of age. The average gestation period is about 280 days at which time she starts her first lactation.

The normal lactation curve for milk production is given in figure 2. The portion of the curve from the start of lactation to the maximum production at 6-8 weeks is extremely variable among cows (McDaniel et al 1967). After the time of maximum milk production, the next 7 to 8 months of production are represented by straight line linear descent to the lowest production levels (Illinois 1981).

In routine dairy practice the dairy cow is bred again between 60 and 120 days after calving. Forty to seventy days prior to the next expected calving she is "dried-off". This means that the current lactation is terminated. Usually the drying-off occurs during very low levels of milk production (figure 2). This period serves as a resting period to allow the cow to gain the energy and the physiologic conditioning required to support the next lactation effort. This cycle is repeated as long as the cow maintains productivity. To put into perspective the metabolic demand of lactation, an average dairy cow reproduces her body weight in milk ten or more times during the course of each of her lactations.

The sequence of events in the bovine lacatation cycle is summarized in figure 3.

D. DAIRY HERD IMPROVEMENT ASSOCIATION DATA BASE

The DHIA program is a national dairy record keeping plan. Its purpose is to provide each dairyman a data base of management information about his herd, in addition to performance documention and genetic evaluation. Additional participants in the program include University extension and computer staff as well as state and federal agencies. The data upon which this study of bovine performance was based were derived from the Minnesota DHIA records. The data from the DHIA records are of high quality, consistent, and considered comparable among various geographic regions. The DHIA data base has been used by other researchers to evaluate dairy herd health problems. For example Mercer et. al. (1976) examined the milk production record of herds of Michigan cattle both exposed and not exposed to low levels of polybrominated biphenl. No significant differences were detected. Hird and Robinson (1982) examined the records of 50 DHIA farms in relation to well water quality. Again no significant differences in milk or milk fat production were demonstrated.

There are two major testing plans in the DHIA program. In Minnesota the individual county associations hire a DHIA Supervisor to make unannounced monthly farm visits to collect data. In this "official plan" the supervisor

FIGURE 2. Milk production during typical bovine lactation.

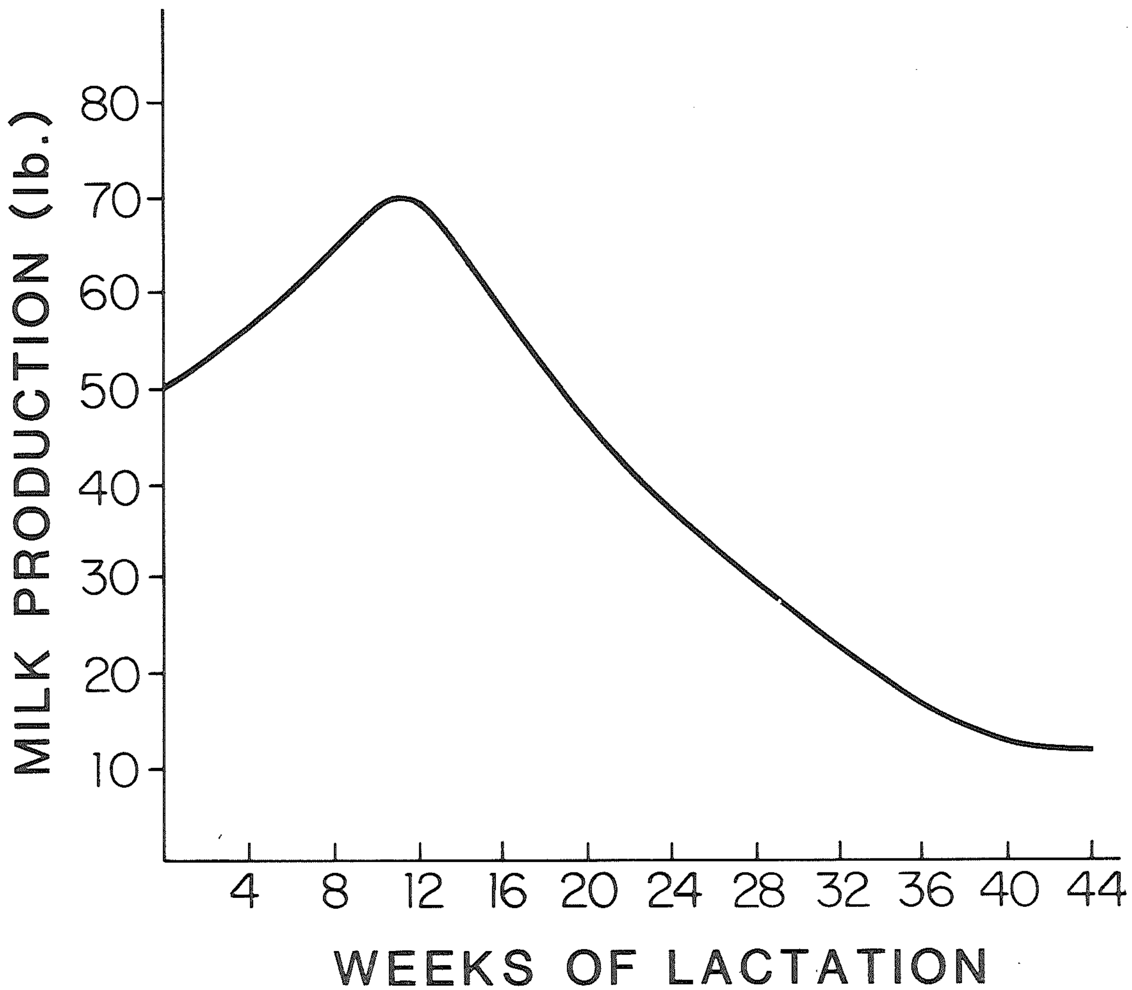
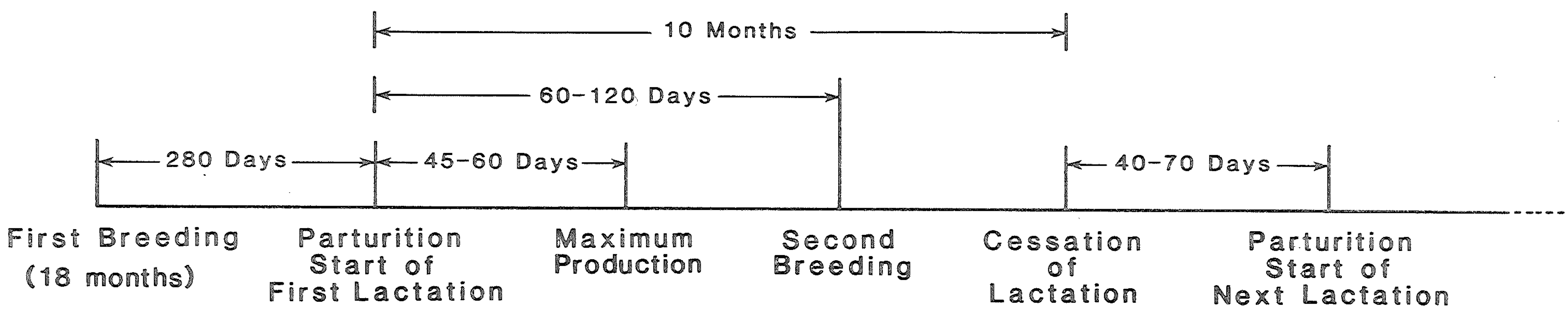


FIGURE 3. Events in normal bovine lactation cycle.



watches the milking operation, weighs the milk and takes a sample from each cow. The other plan is called "owner-sampler" and the dairyman is responsible for weighing the milk and taking his own milk samples. This is not considered as "official" data and is used for within herd management purposes only.

In both plans the supervisor collects information on feeding, reproduction, animal identification, and other factors that may affect herd management. The data is coded on a "Barnsheet" and sent along with the milk samples to a milk testing laboratory. At the laboratory the percent milk fat and somatic cell count for each cow is added to the data. The "Barnsheets" are then sent to the Dairy Record Processing Center on the St. Paul Campus, University of Minnesota.

At the University the records are key punched and checked for errors. The computer files are updated and management reports are sent to each dairyman. The computer records include individual cow records as well as herd records.

The herd summary report (Appendix II) contains rolling herd averages for production parameters and other summaries including feed, costs, current mastitis evaluations and reproduction records.

The most important phenotype of a dairy cow is her milk yield. Individual cows are compared on the basis of milk production up to 305 days of lactation. When cows milk longer than 305 days, their yield for the first 305 days is taken as the lactation yield. Milk production varies with both the age of the cow and the month of calving. The 305-day record is traditionally standardized to a Mature Equivalent (ME) basis. The correct interpretation of an ME record is: the amount of milk or components such as milk fat that the same cow would have produced if she had calved in an environmentally average month and been of mature age. The age and month of calving adjustment factors were developed from a national set of DHIA lactation records using statistical procedures that estimated the effects of both age and month of the year at calving on the amount of milk and milk fat that cows produce (Norman 1974).

The individual cow report (Appendix III) contains sample day data, date of last calving, lactation number, days dry, lactation to date summaries, projected 305 2xME records, reproduction, 305 day and completed records, and indications of reasons for infertility, poor production or removal from the herd that will be useful in this study.

DHIA estimates of monthly milk production are based upon two milkings over a 24 hour period once a month. A review of 60 research reports dealing with the estimation of lactation yields from samples taken at various intervals has shown that at least 90% of milk yields estimated from a single day's yield once a month are within +/- 5% of actual measured production (McDaniel, 1969).

III. METHODS

The purpose of this section is to describe the methods that were used to evaluate the presence or absence of associations between power line exposure and observable biologic effects in dairy cattle. The analyses used both the individual animal and the entire herd as observational units.

A. EXPOSURE

The determination of a cow's exposure to the electrical environment of the power line is complex. The magnitudes of the magnetic field and of the electric field due to the voltage impressed on the conductor are calculable. They are greatest near the power line, and decrease rapidly with increasing distance. However the concentration of air ions and the magnitude of ion associated electric field vary considerably with meteoreology, particularly with wind. Significant downwind enhancements of the small ion concentrations and the electric field have been measured up to one quarter mile and one half mile, respectively, from the power line (MEQB, 1981b and 1982b). Exposure is also dependent on the amount of time the power line is energized. Exact measurements at each farm are not now nor were they historically available. Therefore for this study, exposure was estimated by the proxy variable, perpendicular distance of the farmstead from the line.

1. Distance Strata

Of all the constructs available distance is the easiest to measure. Distance is also interpretable in a biologic context. If there is an effect of power line exposure then a dose-response relationship could be expected. Thus the existence of a distance-response association could be interpreted as consistent with a dose-response relationship.

Since most Minnesota dairy farmers practice a fairly confined operation of their dairy herds, it was assumed that the perpendicular distance measured from the farmstead to the power line approximated the average distance of milking cattle from the line. It was realized however, that particularly during the summer and fall some cattle might be grazing at varying distances from the line.

Six individual strata, which were further divided into north and south, were defined for the study as follows:

Stratum	Distance of Farmstead to Powerline
1	0 - 1/4 miles
2	1/4 - 1/2 miles
3	1/2 - 1 mile
4	1 - 3 miles
5	3 - 6 miles
6	6 - 10 miles

Stratum 1 (closest to power line) represented the maximum exposure potential to the power line and stratum 6 (farthest from power line) the control where virtually no biological effects were likely to occur. Subsequent information on air ion monitoring by MEQB staff suggested that these assumptions were consistent with their results (MEQB 1981b, 1982b).

The role of prevailing winds in relation to potential air ion exposure was examined (for example see Appendix IV) and it appeared that there was no great variation throughout a calendar year. Therefore herds were identifed only by position as to north or south of the power line. Although the power line generally runs from northwest to southeast, it does not run in a straight line as there are several turns of 90 degrees or less. The term north was used to indicate north or east of the power line (see figure 1) which was the side carrying the positively charged conductor. The term south was used to indicate south or west of the power line which was the side carrying the negatively charged conductor. In most instances the results were reported in tables both by stratum and side of the line while in the figures, results are drawn using north and south strata combined. This was done because when the two sides in strata 1 and 2 were compared no significant differences were detected and because the outer strata were assumed to be unexposed and therefore uniformly combinable.

2. Power Line Operation

Although the power line was first energized on October 17, 1978, it did not operate on a continuous basis for some time. This was due to testing procedures and vandlism. The MEQB supplied the investigators with a chart (table 1) showing the operational summary of the line from October 17, 1978 to December 31, 1980.

Review of the power line operation shows four time periods which have the potential for quite different exposures and are therefore of epidemiologic interest.

1) Prior to October 17, 1978 no exposure was possible because the power line was not energized.

2) From October 17, 1978 to May 15, 1979 (30 weeks) the power line was test operated for about 6% of the time.

3) From May 15, 1979 to September 3, 1979 (16 weeks) operation of the power line increased to 71% of the time.

4) After September 3, 1979 the power line was in operation a high percentage of the time. (September 3 through December 31, 1979, 17 weeks - 93%; all of 1980 - 86%; all of 1981 - 98%; January through September, 1982 - 99.8%).

Table 1

OPERATIONAL SUMMARY
OF THE
CU ± 400 KV DC POWERLINE
OCTOBER 1978 - DECEMBER 1980

This table presents a summary of the time the Cooperative Power Association/United Power Association ± 400 kV dc powerline was energized at 300 kilovolts (kV) or greater. Each day is represented by six spaces, each of which represents a four hour period. The number (1, 2, 3, or 4) appearing in a space is the number of hours during that four hour period that the powerline was energized. The operation could be bipolar or monopolar. A blank space means the powerline was off during the whole four hour period.

M	T	W	T	F	S	S	M	T	W	T	F	S	S
1978													
10/16	10/17 2	10/18 1 41	10/19	10/20 11 4	10/21	10/22	10/23	10/24 212	10/25 21	10/26	10/27 241	10/28 32	10/29
10/30 441	10/31 442	11/01 442	11/02 444	11/03 441	11/04	11/05	11/06 44	11/07 441	11/08 441	11/09 441	11/10	11/11	11/12
11/13	11/14	11/15	11/16 34	11/17	11/18	11/19	11/20	11/21	11/22 22	11/23	11/24	11/25	11/26
11/27	11/28 3	11/29 2 3	11/30 23	12/01 2	12/02 22	12/03	12/04	12/05 1	12/06	12/07	12/08	12/09	12/10
12/11	12/12 34	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24
12/25	12/26	12/27	12/28	12/29	12/30	12/31	01/01	01/02	01/03	01/04	01/05	01/06	01/07
1979													
01/08	01/09	01/10	01/11	01/12	01/13	01/14	01/15	01/16	01/17	01/18	01/19	01/20	01/21
01/22	01/23	01/24	01/25 3	01/26 3	01/27	01/28	01/29	01/30 41 1	01/31 41	02/01 41	02/02 42	02/03	02/04
02/05 1	02/06 42	02/07 42	02/08 43	02/09 42	02/10	02/11	02/12	02/13	02/14	02/15	02/16	02/17	02/18
02/19	02/20 1	02/21	02/22	02/23	02/24	02/25	02/26	02/27 42 1	02/28 42 2	03/01 42	03/02	03/03	03/04
03/05	03/06	03/07	03/08	03/09	03/10	03/11	03/12 2	03/13 41 4	03/14 2 244	03/15 2 24	03/16 1	03/17 1	03/18
03/19	03/20	03/21 31	03/22 2	03/23	03/24	03/25	03/26	03/27	03/28	03/29	03/30	03/31	04/01
04/02	04/03	04/04	04/05	04/06	04/07	04/08	04/09	04/10	04/11	04/12	04/13	04/14	04/15
04/16	04/17	04/18	04/19	04/20	04/21	04/22	04/23	04/24	04/25	04/26	04/27	04/28	04/29

1979

M	T	W	T	F	S	S	M	T	W	T	F	S	S
04/30	05/01	05/02	05/03 212 1	05/04 42 1	05/05 42 2	05/06 42 1	05/07 42	05/08 1	05/09 42	05/10 22 1	05/11 31	05/12	05/13 41
05/14	05/15 44	05/16 1 4	05/17 44 3 4	05/18 443434	05/19 342444	05/20 44 13	05/21 444444	05/22 444444	05/23 444444	05/24 444444	05/25 442344	05/26 224344	05/27 422434
05/28 444444	05/29 44 34	05/30 42 44	05/31 44	06/01 14	06/02 214243	06/03 444424	06/04 43 14	06/05 44 24	06/06 43 344	06/07 444444	06/08 44 34	06/09 444444	06/10 444444
06/11 444444	06/12 444444	06/13 43 34	06/14 44 2	06/15	06/16	06/17	06/18	06/19	06/20	06/21	06/22	06/23	06/24 2
06/25 44 34	06/26 44 3	06/27 444444	06/28 444344	06/29 441434	06/30 444444	07/01 444444	07/02 44 4	07/03 444444	07/04 444444	07/05 444444	07/06 444444	07/07 444444	07/08 444444
07/09 444444	07/10 444444	07/11 444444	07/12 444444	07/13 444444	07/14 444444	07/15 444444	07/16 444444	07/17 444444	07/18 444444	07/19 444444	07/20 444444	07/21 444444	07/22 444444
07/23 444444	07/24 444444	07/25 444444	07/26 444	07/27 444444	07/28 444444	07/29 444444	07/30 444444	07/31 444444	08/01 444444	08/02 444444	08/03 444444	08/04 421444	08/05 444444
08/06 444444	08/07 444444	08/08 444444	08/09 444444	08/10 444444	08/11 444444	08/12 444444	08/13 41 444	08/14 444444	08/15 444444	08/16 444444	08/17 444444	08/18 444444	08/19 444444
08/20 444444	08/21 444444	08/22 444444	08/23 4	08/24	08/25	08/26	08/27	08/28	08/29	08/30	08/31	09/01	09/02
09/03 3	09/04 444444	09/05 444444	09/06 124444	09/07 444444	09/08 444444	09/09 444444	09/10 444444	09/11 444444	09/12 444444	09/13 444444	09/14 444444	09/15 444444	09/16 444442
09/17 444444	09/18 444444	09/19 444444	09/20 444444	09/21 444444	09/22 444444	09/23 444444	09/24 444444	09/25 444444	09/26 444444	09/27 444444	09/28 444444	09/20 444444	09/30 444444
10/01 444444	10/02 444444	10/03 344444	10/04 444444	10/05 444444	10/06 444444	10/07 444444	10/08 444444	10/09 444444	10/10 444444	10/11 444444	10/12 443444	10/13 444444	10/14 444444
10/15 444444	10/16 444444	10/17 444444	10/18 444444	10/19 444444	10/20 444444	10/21 444444	10/22 444444	10/23 444444	10/24 444432	10/25 444444	10/26 444444	10/27 444444	10/28 444444
10/29 444444	10/30 444444	10/31 44443	11/01 344	11/02 444444	11/03 444444	11/04 444442	11/05	11/06	11/07	11/08	11/09	11/10 24	11/11 444444
11/12 444444	11/13 444444	11/14 444444	11/15 444444	11/16 444444	11/17 444444	11/18 444444	11/19 444444	11/20 444444	11/21 444443	11/22 244	11/23 444444	11/24 444444	11/25 444444
11/26 444444	11/27 444344	11/28 444444	11/29 444344	11/30 444444	12/01 444444	12/02 444444	12/03 444444	12/04 444444	12/05 444444	12/06 444444	12/07 444444	12/08 444444	12/09 444444
12/10 444444	12/11 444444	12/12 444444	12/13 444444	12/14 444444	12/15 444444	12/16 444444	12/17 444444	12/18 444444	12/19 444444	12/20 444444	12/21 444444	12/22 444444	12/23 444444
12/24 444444	12/25 444234	12/26 444244	12/27 444444	12/28 444443	12/29 442444	12/30 444444	12/31 444244	1980 01/01 443414	01/02 444444	01/03 444444	01/04 444444	01/05 443444	01/06 444444

1980

M	T	W	T	F	S	S	M	T	W	T	F	S	S
01/07	01/08	01/09	01/10	01/11	01/12	01/13	01/14	01/15	01/16	01/17	01/18	01/19	01/20
434442	44444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444
01/21	01/22	01/23	01/24	01/25	01/26	01/27	01/28	01/29	01/30	01/31	02/01	02/02	02/03
444444	444444	444444	444444	444444	444444	443444	444444	444444	444444	444444	444444	444444	444444
02/04	02/05	02/06	02/07	02/08	02/09	02/10	02/11	02/12	02/13	02/14	02/15	02/16	02/17
444444	444444	444444	444444	444444	444444	43 4	444444	444444	444444	444444	444444	444444	444444
02/18	02/19	02/20	02/21	02/22	02/23	02/24	02/25	02/26	02/27	02/28	02/29	03/01	03/02
444444	444444	322244	244444	444444	444444	44 44	444444	44443	444444	444444	444444	444444	444444
03/03	03/04	03/05	03/06	03/07	03/08	03/09	03/10	03/11	03/12	03/13	03/14	03/15	03/16
444444	444444	444444	444444	444444	444444	444444	444444	444444	1				
03/17	03/18	03/19	03/20	03/21	03/22	03/23	03/24	03/25	03/26	03/27	03/28	03/29	03/30
		3	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444
03/31	04/01	04/02	04/03	04/04	04/05	04/06	04/07	04/08	04/09	04/10	04/11	04/12	04/13
444444	444444	444444	444444	444444	444443	244444	444444	444444	444444	444444	444443		
04/14	04/15	04/16	04/17	04/18	04/19	04/20	04/21	04/22	04/23	04/24	04/25	04/26	04/27
04/28	04/29	04/30	05/01	05/02	05/03	05/04	05/05	05/06	05/07	05/08	05/09	05/10	05/11
											3	1	
05/12	05/13	05/14	05/15	05/16	05/17	05/18	05/19	05/20	05/21	05/22	05/23	05/24	05/25
	3444	4444	2444	442244	441444	444441	344444	444444	444444	444444	444444	444444	444444
05/26	05/27	05/28	05/29	05/30	05/31	06/01	06/02	06/03	06/04	06/05	06/06	06/07	06/08
444444	444444	444444	444444	444444	444444	444444	444444	444444	444443	444444	444444	444444	444444
06/09	06/10	06/11	06/12	06/13	06/14	06/15	06/16	06/17	06/18	06/19	06/20	06/21	06/22
444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444
06/23	06/24	06/25	06/26	06/27	06/28	06/29	06/30	07/01	07/02	07/03	07/04	07/05	07/06
444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	124444	444444
07/07	07/08	07/09	07/10	07/11	07/12	07/13	07/14	07/15	07/16	07/17	07/18	07/19	07/20
444444	444444	44444	444444	444443	344444	444444	444444	444444	444444	444444	444444	444444	444444
07/21	07/22	07/23	07/24	07/25	07/26	07/27	07/28	07/29	07/30	07/31	08/01	08/02	08/03
444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	444444
08/04	08/05	08/06	08/07	08/08	08/09	08/10	08/11	08/12	08/13	08/14	08/15	08/16	08/17
444444	444444	444444	444444	444444	444444	444444	444444	442444	444444	444444	444444	444444	444444
08/18	08/19	08/20	08/21	08/22	08/23	08/24	08/25	08/26	08/27	08/28	08/29	08/30	08/31
444444	444444	444444	444444	444444	444444	444444	444444	444444	444444	1		44	444444
09/01	09/02	09/03	09/04	09/05	09/06	09/07	09/08	09/09	09/10	09/11	09/12	09/13	09/14
444444	444444	444444					14	444444	444444	444444	444444	444444	444444

M	T	W	T	F	S	S	M	T	W	T	F	S	S
1980													
09/15	09/16	09/17	09/18	09/19	09/20	09/21	09/22	09/23	09/24	09/25	09/26	09/27	09/28
444444	444444	444444	444444	424444	444444	444444	44444	4444444	444444	444444	444444	444444	444414
09/29	09/30	10/01	10/02	10/03	10/04	10/05	10/06	10/07	10/08	10/09	10/10	10/11	10/12
444444	444444	444444	444444	444444	444444	444444	44444	4444444	444444	444444	444444	444444	444444
10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25	10/26
444444	444444	444444	444444	444444	444444	444444	44444	4444444	444444	444444	444444	444444	444444
10/27	10/28	10/29	10/30	10/31	11/01	11/02	11/03	11/04	11/05	11/06	11/07	11/08	11/09
444444	444444	444444	444444	444444	444444	444444	44444	4444444	444444	444444	444444	444444	444444
11/10	11/11	11/12	11/13	11/14	11/15	11/16	11/17	11/18	11/19	11/20	11/21	11/22	11/23
444444	444444	444444	444444	444444	444444	444444	44444	4444444	444444	444444	444444	444444	444444
11/24	11/25	11/26	11/27	11/28	11/29	11/30	12/01	12/02	12/03	12/04	12/05	12/06	12/07
444444	444444	444444	444444	444444	444444	444444	44444	4444444	444444	444444	444444	444444	444444
12/08	12/09	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21
444444	444444	444444	444444	444444	444444	444444	44444	4444444	444444	444444	444444	444444	444444
12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	12/30	12/31				
444444	444444	444444	444444	444444	444444	444444	44444	4444442					

B. DHIA DATA BASE

1. General Herd Qualifications

General qualifications were established for inclusion of a dairy herd in any part of this study. The herd must have been:

1) On DHIA test at least from July 1, 1978 through the end of 1979;

2) Located within 10 miles of the power line;

3) A Holstein herd;

4) On a twice-a-day milking schedule; and

5) The owner or herdsman must have signed a release granting permission to use their DHIA records.

Since the DHIA data had already been collected and was accessible at a very low marginal cost, the sample size for the various sections of the study was determined to be all of the qualifying herds and animals.

Permission was sought and approval granted from the University of Minnesota Committee on the Use of Human Subjects in Research (Secondary use of data category) in so far as the producers themselves were at least marginally involved and permission to use their individual records had to be obtained (see Appendix V).

2. Identification of Qualified Herds

A field veterinarian was assigned to identify qualified herds and to act as liaison between the study investigators and the herd owners. The power line alignment was superimposed on the individual townships maps in the land ownership directories (or plat books) of the eleven counties involved in the 20 mile corridor (figure 4). Wilkin, Douglas and Todd counties were added to the originial 8 because of the 20 mile corridor. A large composite map of the eleven counties was also assembled and the locations of the qualifying herds and the six strata were identified on it.

An initial listing of 1700 herds in the eleven counties was prepared from the DHIA records. The information on each herd was reviewed to determine if it met the general qualifications with the exception of having the release. With the use of the DHIA information and the plat books, most of the qualifying herds were identified.

To locate the remaining herds, the field veterinarian visited each county and utilized information sources such as county extension agents, local veterinarians, farm service centers, more extensive platbooks, and knowledgeable farmers (including representatives from the GASP organization). Tables 2 and 3 show the DHIA herds located by strata and by county location. Their location either south or north of the power line is also indicated.

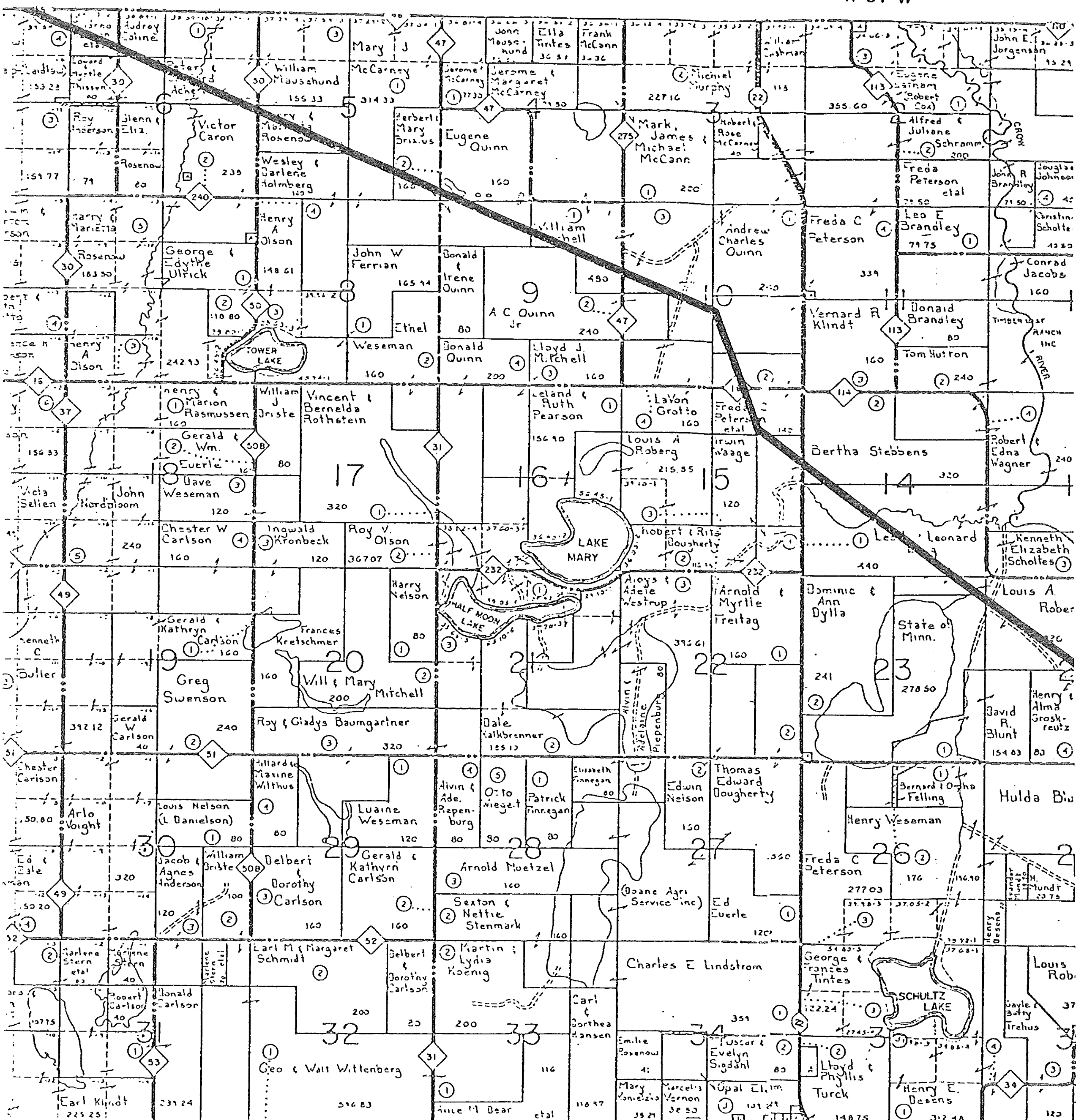
CPA–UPA
COAL CREEK–DICKINSON
±400KV DC LINE

Figure 4

Example of Plat Book and Power Line Routing.

T-120-N

R-31-W



MEEKER COUNTY
HARVEY TWP

TABLE 2

Distribution of Qualified DHIA

Holstein Herds by County

County	Herds	County	Herds
Douglas	23	Stevens	3
Grant	22	Todd	14
Kandiyohi	13	Traverse	5
Meeker	98	Wright	113
Pope	45	Wilkin	1
Stearns	179		

TABLE 3

Distribution of Qualified DHIA

Holstein Herds by Strata

Stratum		North	South	Total
1	(0-1/4 mile)	11	16	27
2	(1/4-1/2 mile)	9	11	20
3	(1/2-1 mile)	9	11	20
4	(1-3 miles)	73	51	124
5	(3-6 miles)	77	66	143
6	(6-10 miles)	101	81	182
		280	236	516

3. Permission to Use DHIA Records

A letter explaining the study and requesting permission to use their DHIA records (Appendix VIII) was sent to the owner or herdsman of the qualifying herds. They were asked to sign release forms granting permission to use their DHIA records on the understanding that strict individual confidentially would be maintained throughout the study.

Information on the study was provided to county extension agents, veterinarians, radio stations, and newspapers serving the power line area. In addition a meeting was held with representatives of GASP to explain the study, answer their questions and to request their support on obtaining signed releases.

A follow up letter was sent about three weeks after the initial request letter. Eighty eight percent of the release forms sent out were returned granting permission following the two mail solicitations.

Since the three strata closest (within one mile) to the power line were the smallest strata, they contained fewer herds than the others. To ensure these strata having the maximum number of herds for statistical purposes, the field veterinarian personally contacted the dairymen who did not respond to the mailings. As a result, release was obtained from all the dairymen in the first three strata.

4. Organization and Retrieval of Stored DHIA Records

The individual cow and herd data of qualifying herds were identified and assembled into a common data base from magnetic storage tapes containing DHIA records for all of Minnesota. The study was restricted to analysis of these records and strict anonymity of the data in relation to an individual farm was maintained.

It was possible to retrieve six years of accumulated data from mid 1976 to September 1982 on 500 of the 516 qualifying herds representing approximately 24,000 milking cows per year. The data base assembled contained over a quarter of a million lengthy records.

For each analysis, a search of the assembled records was run to sort out the data fitting the various definitions of time and strata location for the variable being analyzed. Undecipherable records or those with mistakes in coding were excluded. Since the DHIA records are user audited on a monthly basis the error rate in the data was very low.

C. ANALYTIC METHODS

The design of the study attempted to detect temporal changes in aggregate dairy cattle performance in strata near the power line which do not have parallels in the strata far removed from the power line. If such a change either beneficial or detrimental is so large or consistent among the aggregate of cows near to the power line that it could not be reasonably attributed to chance, the inference can be made that there is a statistically significant association between the performance variable and proximity to the power line. The amount of data available and the statistical procedures used offer the almost certain assurance that relative differences between strata of 5% would be found to be statistically significant.

Profiles of cow or herd performance were drawn over a number of years before and after the power line was energized. Comparisons were made between the different levels of "exposure" using each cow or herd as its own control. No attempt was made in these studies to determine the potential role of confounding factors such as infectious disease or level or type of management indices. This would have necessitated breaking the anonymity codes in order to visit participating farms to assess management practices and to take samples for laboratory examinations. All participants in the study agreed that this was outside the scope of the present undertaking, particularly as any current information obtained may not necessarily reflect what occurred some years earlier.

The specific analyses that were carried out related to milk production, reproduction, and the stated reasons for culling animals from the dairy herd.

1. Milk Production

This study consisted of two parts: one involving "within lactation" comparisons and the other "between lactation" comparisons. The former attempted to detect the more acute effects of any potential exposure on a lactation in progress while the latter looked for any longer term effects between lactations. Both portions of this milk production analysis used individual cow as well as herd records.

a) Within Lactation Analysis:

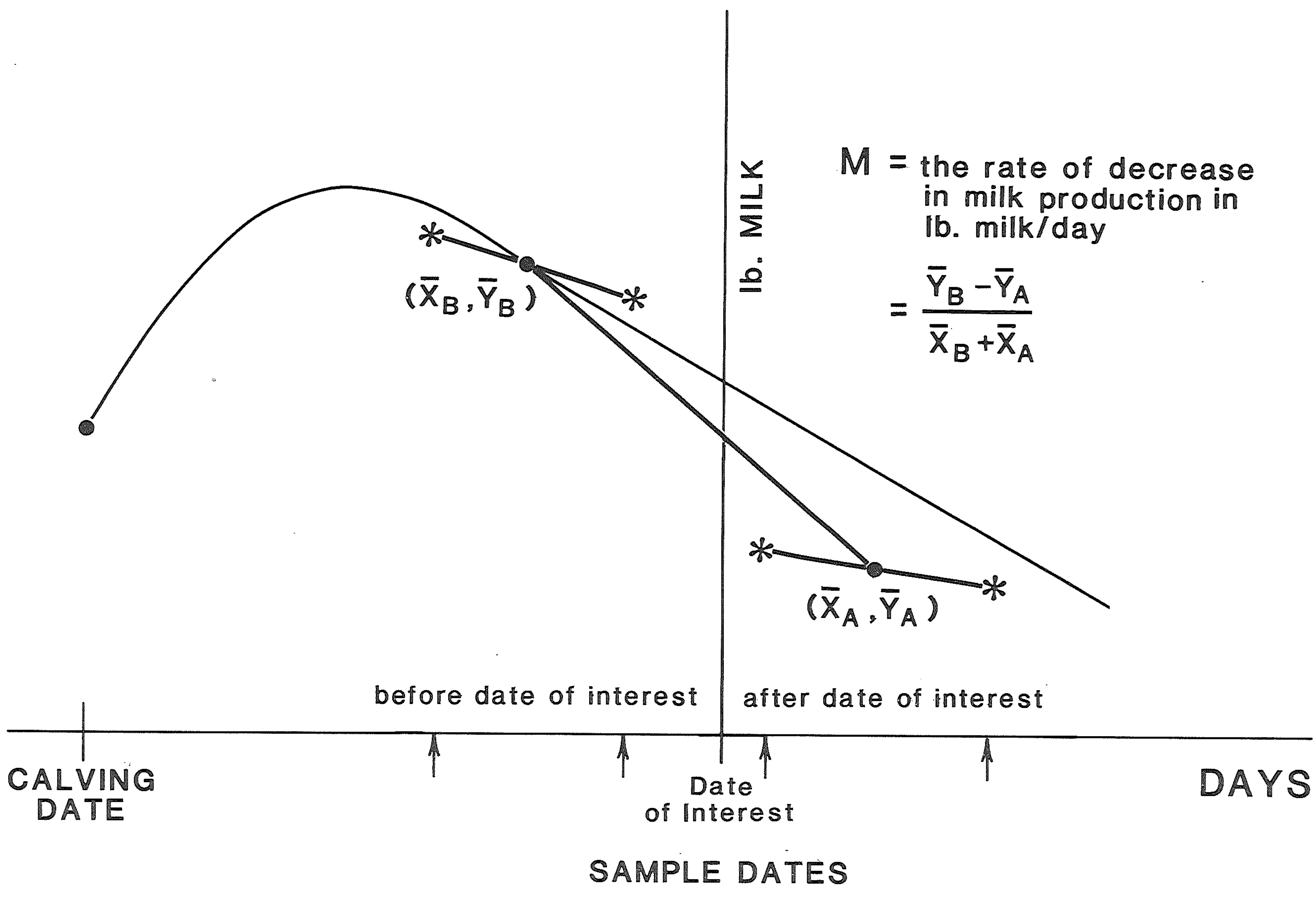
The "within lactation" analysis examines a cow's rate of change in milk production per day across a predetermined date of interest during the 7 to 8 months of lactation following the time of maximum milk production. The individual cow is used as its own control, which is one of the most discriminating techniques available to test for a suspected effect. To be used in this analysis the cow had to be in the portion of her lactation cycle after her peak milk production and had to have at least two useable test days before and after any of the three dates of interest (figure 5). On the test day, Y is defined as the amount of milk produced (in lbs) and X is defined as the amount of time (in days) from the test day to the date of interest regardless of whether the test day was before or after the date of interest.

The rate of decrease in milk production (M) in lbs of milk per day is defined as:

$$M = \frac{\overline{Y}_B - \overline{Y}_A}{\overline{X}_B + \overline{X}_A}$$

Where $\overline{Y}$ is the average of test milkings (B = before, A = after the date of interest) and $\overline{X}$ is the average number of days from the date of interest on which these test milkings took place.

FIGURE 5. Schematic diagram of the calculation of the drop in milk production (M) across a bench mark date for a single "useable" lactation.



The overall average of M for cows in the entire study was determined to be approximately 0.15 lbs/day which is considered within the acceptable range for Holstein cows under Minnesota conditions (G. Steurnagel - personal communication).

Values of M were calculated for three selected dates of interest:

(i) 10/17/78 representing transition from zero to minimial exposure (power line energized 6% of the time).

(ii) 5/15/79 representing transition from minimal to higher exposure (power line energized 71% of the time).

(iii) 9/3/79 representing transition from 71% to approximately 93% power line utilization.

Five separate analyses were made utilizing decrease in milk production per day (i.e. M).

(a) The average M's across exposure strata were compared.

(b) Two definitions of "case" animals were made showing higher than average decrease in production per day i.e. either >0.2 or >0.25 lbs./day. The "case" animals across exposure strata were compared.

(c) "High prevalence" herds were defined as those having at least 50% of the lactation records showing M>0.20 or M>0.25 lbs./day decreases in production. The distribution of "high prevalence" herds was compared across exposure strata.

(d) The distribution of "case" cows (i.e. >.20 lb./day decrease) was compared by strata in relation to whether herds were on the supervisor (i.e. official) testing plan or the owner sampler testing plan.

(e) The effect of standardization of M to peak milk yield. It was possible that cows with high maximum milk production might decrease at a steeper rate than cows with lower maximum milk production, and therefore variations in M might represent variation in peak milk production. All M values were thus adjusted to a common average value of peak milk using the formula: M (adjusted) = M + 0.0033 (herd average peak milk - 64.88). The coefficents were determined from a regression of M on the herd averages for peak milk. Herd average values were calculated from M and M (adjusted) for each of the 500 herds and a comparison of these two averages was made across strata.

b) Between Lactation Analysis:

For the "between lactation" studies, milk production data were compared both across strata and over time. The milk production parameters available for this study include 305 day milk production, as well as 305 day fat corrected milk (FCM) production and 305 day mature equivalent (ME) production. The 305 day milk production is the basic variable measured for each cow for each lactation. It is the amount of milk she is determined to have produced in a 305 day lactation. If the lactation ended prior to 305 days her total production for the lactation is considered the 305 day milk production. If the lactation exceeded 305 days, only the first 305 days production was used. The 305 FCM is considered a hybrid indicator of both pounds of milk and fat and is one means of adjusting to a common metabolic equivalent (Campbell and

Marshall, 1975). The 305 ME production adjusts for differences in age of cow and month of calving. Statistical analyses of 305 FCM and 305 ME were carried out in parallel to 305 day milk production. The latter measurement was found to be redundantly parallel to the two former measurements. Therefore it was decided to utilize 305 day milk production for reporting of most analyses.

Individual cow production comparisons across exposure strata were made using three separate groups of lactations based upon time of calving. First, animals calving between January 20, 1977 and January 19, 1978 were selected as representing cows which had calved and completed a lactation before the power line was initially energized. The second group included cows that had calved between October 18, 1978 and October 17, 1979 and thus had completed lactations coincident with varying periods of power line operation. The third group included cows that had calved between October 18, 1979 and October 16, 1980 and thus uniformly experienced a complete lactation during a time when the line was operating greater than 90% of the time.

The final portion of the milk production analysis involved using herd data to compare across strata and over time the following three attributes:

(i) DHIA membership attrition from May, 1979 until September, 1982.

(ii) A comparison of the rolling herd averages of 428 herds as of May, 1979 and the same herds in September, 1982.

(iii) A comparison of milk quality (as measured by 12 month rolling herd average % fat), production efficiency (as measured by 12 month rolling herd average milk production per cow to grain consumed ratio) and udder health (as measured by the 12 month rolling average of % of cows showing a somatic milk cell count in excess of 500,000 cells/ml.) This latter test is an optional test and is utilized by approximately half of the DHIA members. Animals with milk cell counts of this magnitude or higher are considered to have inflamed udders usually resulting from bacterial infections. All three comparisons were made using September 1982 data from 428 herds that were participating DHIA members as of May 1979.

2. Reproduction

A cow's ability to produce a calf annually is extremely important to the dairy producer and inability to produce a calf is generally viewed as a "health" problem. The DHIA data base, by its design, will not contain information on cows which have never had a calf. Thus heifers (i.e. first calving cows) which could not have had a first lactation are outside the scope of the present study. Nevertheless the investigators have found no significant biological reasons to believe that sexually mature heifers have greater reproductive susceptibility to air ions or electrical fields than do cows that have had a calf.

The parameters chosen to measure reproductive efficiency were the intercalving interval, rate of occurrence of abortions in relation to normal pregnancies, and the rate of culling animals for reproductive reasons in relation to total culling rates.

The individual intercalving interval is a sensitive but nonspecific indicator of reproductive ability and is measured in days from one parturition to the next. The optimum intercalving interval is generally regarded as 12-12 1/2 months but the actual interval in Minnesota at least is 13 months or longer. Obviously animals to be eligible for this portion of the study had to have had a further calf. Thus this portion of the study omits any calving cows which for whatever reasons were never rebred, conceived nor carried a further calf to full term. Many factors enter into the length of the intercalving interval. These include management practices, such as the breeding program (natural mating vs artificial breeding) and the efficiency of detecting cows in heat, and infectious agents that can cause early fetal death. These variations could not distort any findings unless they are also associated with proximity to the power line. There is no reason to suspect that this was so.

Average and median intercalving intervals were calculated for the first intercalving interval and the second and subsequent intercalving intervals. Comparisons were made by strata and over the 3 already described time periods (see III C. 1. b.) representing pre-exposure, intermittent, and more or less continuous exposure. In addition, the percentage of animals with excessively long intercalving intervals (> 500 days) were also compared over strata and time.

Abortions in both humans and animals have been one of the topics of concern raised during discussion of potential adverse effects of the power line. The DHIA record of lactations shows when an animal aborts a fetus of 150 days or more, or calves prematurely as judged by the farmer. The percentage of abortions in relation to all abnormally ending lactations was compared between strata 1 and 2 combined and stratum 6 for cows calving between December 21, 1976 and December 21, 1977 (i.e. before energizing of the power line) and also between cows calving between April 5, 1979 and April 4, 1980 (i.e. after energizing of the power line).

When farmers cull animals from the herd, one of the reasons may be that the animal does not conceive. A comparison was made between strata 1 and 2 combined and stratum 6 using the percentage of culled animals which were culled for reproductive reasons, both before and after the power line was energized. In both this and the previous analyses, comparisons were made between first lactations and also between second and later lactations.

3. Reasons for Culling Animals

Culling refers to the removal of a live cow from the dairy herd, after which that cow is not generally used for dairy purposes. The observed rate of culling from Minnesota dairy herds is approximately 30% per year.

If a pregnant cow completes her lactation and is dried off prior to the next lactation, her lactation is recorded as having ended "normally". If a cow in lactation is permanently removed from the herd, the owner is expected to identify from an assigned list a reason why the animal left the herd. These reasons include; sold to another farmer for dairy use, sold because of low production, reproductive problems, abortion, injury, disease, death, or no reason given. Obviously there is the possibility of some overlap as for example cows sold because of low production may be affected with mastitis.

All of the above lactations are termed "abnormally ending". Less than 1% of these records were unuseable due to incompleteness.

Two groups of animals were examined in this portion of the study (i) those completing a lactation before the line was energized and (ii) those completing a lactation after the line had been energized. Each group was divided into those having an abnormal termination of the first lactation and those having an abnormal termination of the second or later lactation. Two analyses were carried out. The first involved a comparison by strata of the percentage of abnormally ending lactations in relation to the total number of recorded lactations. The second involved a comparison of the distribution of different reasons for abnormally ending lactations in strata 1 and 2 and stratum 6 respectively.

IV. Results and Discussion

In all figures presented in this section, 95% confidence bounds are included. The confidence bounds are calculated plus or minus 2 standard errors of estimations. The wider intervals near the power line do not suggest that the data are more variable but rather that sample sizes are smaller in the narrow strata. The variance in these populations is the same as in the larger strata. In reading these figures, the most relevant comparison is to examine height of the stratum 1 center point and observe its vertical fluctuation between years and then do the same at the other strata centers. A distinctively different pattern of fluctuation in stratum 1 would have been a signal of interest.

A. DHIA Data Base

As indicated in the methods section, an excellent response to solicitation letters and personal contact was obtained. As a result it was considered by the investigators that an adequate number of cooperating farmers were available and that the quality of the data available was such that it was possible to proceed with the proposed detailed analyses.

B. Milk Production Analyses

1. Within Lactation Analysis

a) Rate of Production Decrease (M)

As indicated in the methods section (see relevant page) M represents the rate of decrease in milk production (lbs. per day) across a predetermined date during the declining 6 or 7 months period of a cow's lactation after the peak milk production has been reached. In tables 4, 5, and 6 and also in figures 6, 7 and 8, strata comparisons of M across the following 3 dates are shown.

-- 10/17/78 representing transition from zero to minimal exposure (power line energized 6% of the time). Table 4 and Figure 6.

-- 5/15/79 representing transition from minimal to higher exposure (power line energized 71% of the time). Table 5 and Figure 7.

-- 9/3/79 representing transition from 71% to approximately 93% power line utilization. Table 6 and Figure 8.

TABLE 4

AVERAGE DROP IN PRODUCTION (M) DURING
A COW'S LACTATION FROM BEFORE TO AFTER 10/17/78

Pounds of Milk Per Day

STRATUM	NORTH		SOUTH		COMBINED	
	M	(n)	M	(n)	M	(n)
1.	.156	(72)	.162	(63)	.159	(135)
2.	.124	(116)	.182	(106)	.152	(222)
3.	.159	(42)	.154	(73)	.156	(115)
4.	.142	(550)	.137	(390)	.140	(940)
5.	.139	(610)	.140	(476)	.140	(1086)
6.	.150	(661)	.150	(606)	.150	(1267)

Pounds of Fat Corrected Milk Per Day

	M	(n)	M	(n)	M	(n)
1.	.123	(72)	.130	(63)	.126	(135)
2.	.091	(116)	.143	(106)	.118	(222)
3.	.125	(42)	.126	(73)	.125	(115)
4.	.110	(550)	.107	(390)	.109	(940)
5.	.107	(610)	.110	(476)	.108	(1086)
6.	.117	(661)	.120	(606)	.118	(1267)

TABLE 5

AVERAGE DROP IN PRODUCTION (M) DURING A COW'S LACTATION FROM BEFORE TO AFTER 5/15/79

Pounds of Milk Per Day

STRATUM	NORTH		SOUTH		COMBINED	
	M	(n)	M	(n)	M	(n)
1.	.137	(179)	.149	(260)	.144	(439)
2.	.117	(125)	.152	(188)	.138	(313)
3.	.158	(196)	.144	(177)	.151	(373)
4.	.148	(1092)	.140	(764)	.145	(1856)
5.	.146	(1161)	.148	(1155)	.147	(2316)
6.	.151	(1372)	.135	(1277)	.143	(2649)

Pounds of Fat Corrected Milk Per Day

	M	(n)	M	(n)	M	(n)
1.	.117	(179)	.127	(260)	.123	(439)
2.	.100	(125)	.129	(188)	.117	(313)
3.	.133	(196)	.130	(177)	.132	(373)
4.	.124	(1092)	.118	(764)	.122	(1856)
5.	.124	(1161)	.126	(1155)	.125	(2316)
6.	.128	(1372)	.114	(1277)	.121	(2649)

TABLE 6

AVERAGE DROP IN PRODUCTION (M) DURING A COW'S LACTATION FROM BEFORE TO AFTER 9/3/79

Pounds of Milk Per Day

STRATUM	NORTH		SOUTH		COMBINED	
	M	(n)	M	(n)	M	(n)
1.	.137	(82)	.144	(128)	.141	(210)
2.	.145	(119)	.215	(95)	.176	(214)
3.	.209	(72)	.128	(119)	.159	(191)
4.	.157	(640)	.157	(455)	.157	(1095)
5.	.167	(727)	.158	(632)	.163	(1359)
6.	.167	(830)	.152	(691)	.160	(1521)

Pounds of Fat Corrected Milk Per Day

	M	(n)	M	(n)	M	(n)
1.	.108	(82)	.118	(128)	.114	(210)
2.	.111	(119)	.171	(95)	.138	(214)
3.	.181	(72)	.096	(119)	.128	(191)
4.	.124	(640)	.125	(455)	.124	(1095)
5.	.132	(727)	.129	(632)	.131	(1359)
6.	.131	(830)	.125	(691)	.128	(1521)

FIGURE 6. Average drop in production per cow before to after 10/17/78 during post peak lactation with 95% confidence bounds.

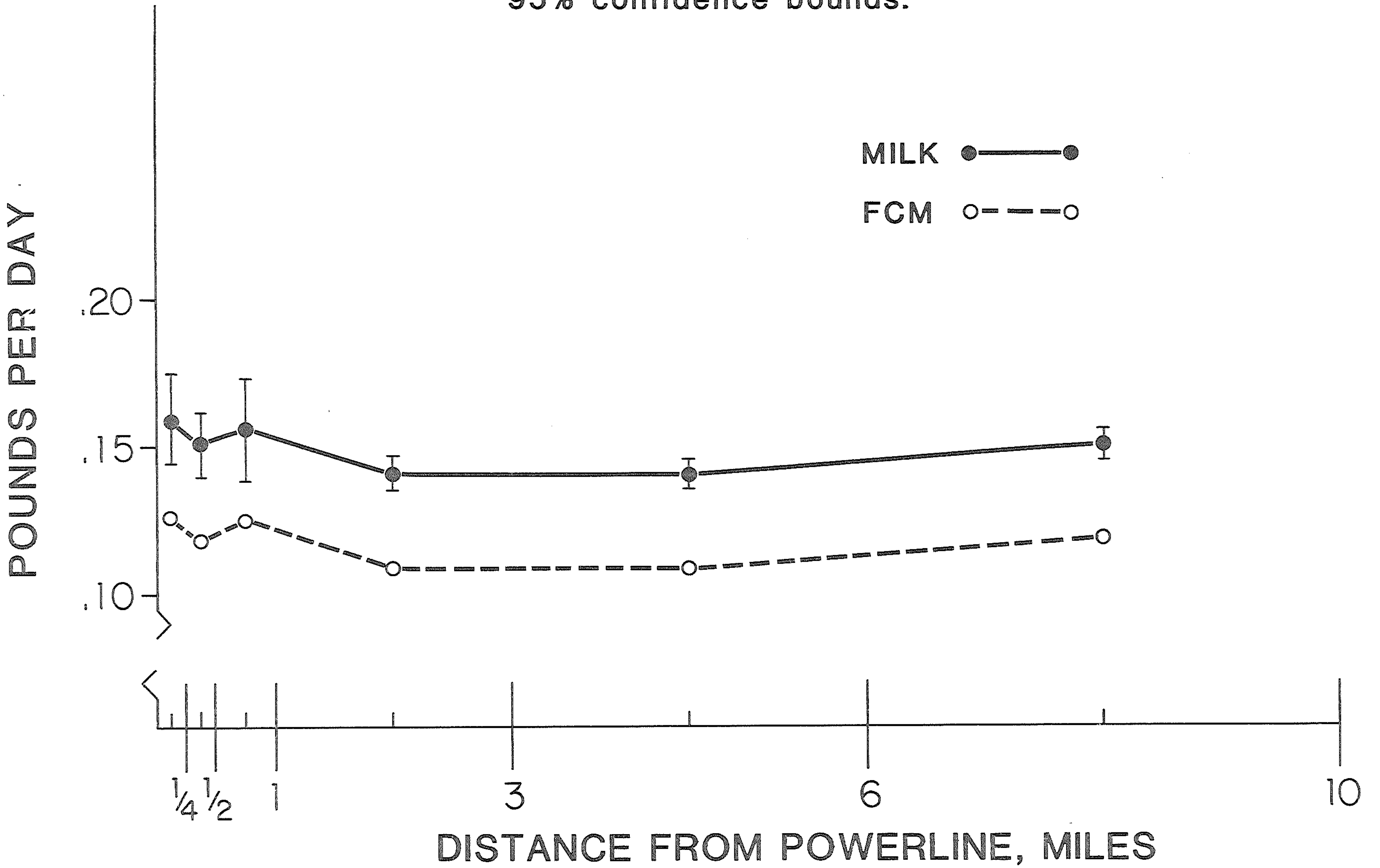


FIGURE 7. Average drop in production per cow before to after 5/15/79 during post peak lactation with 95% confidence bounds.

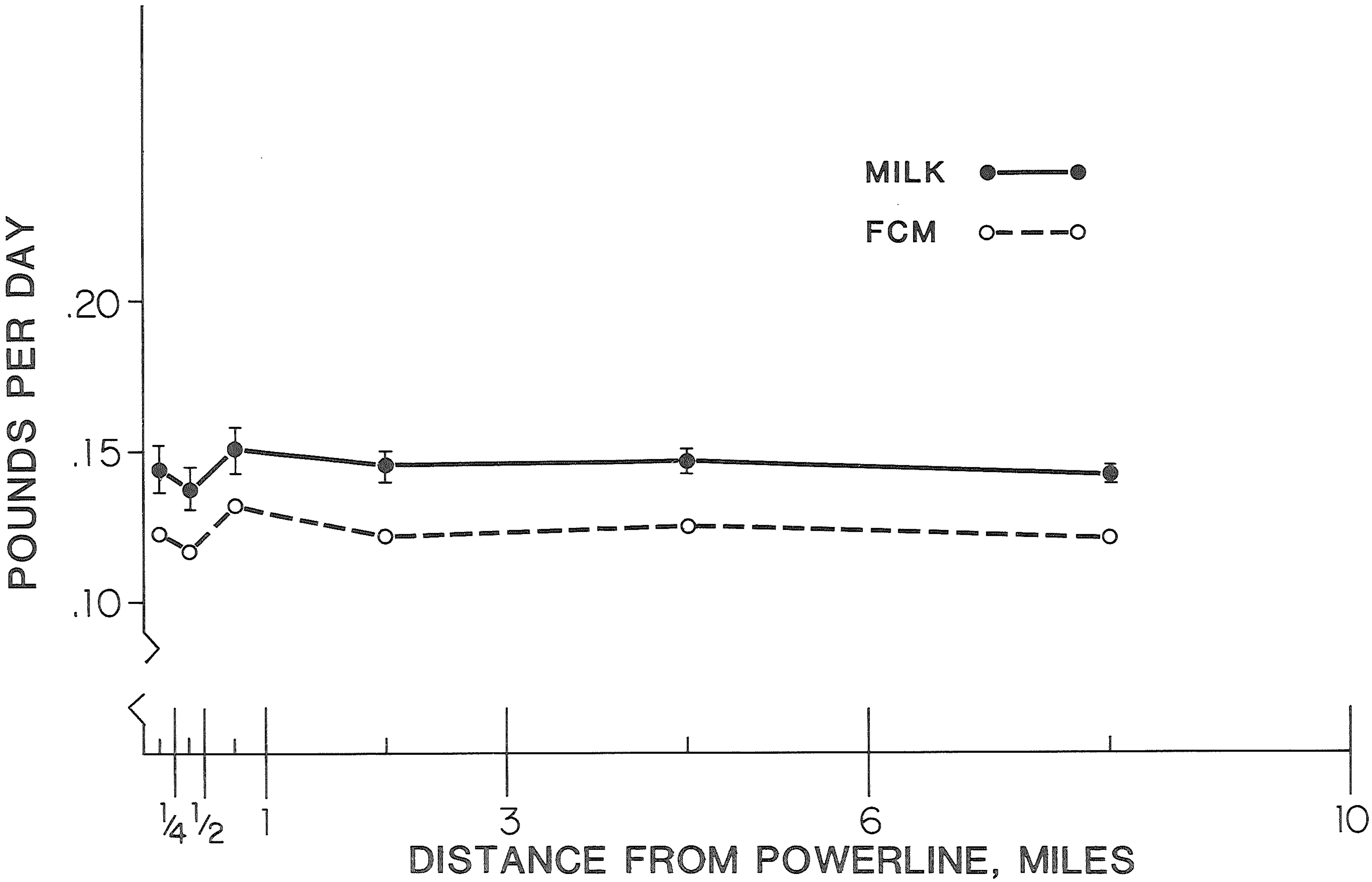
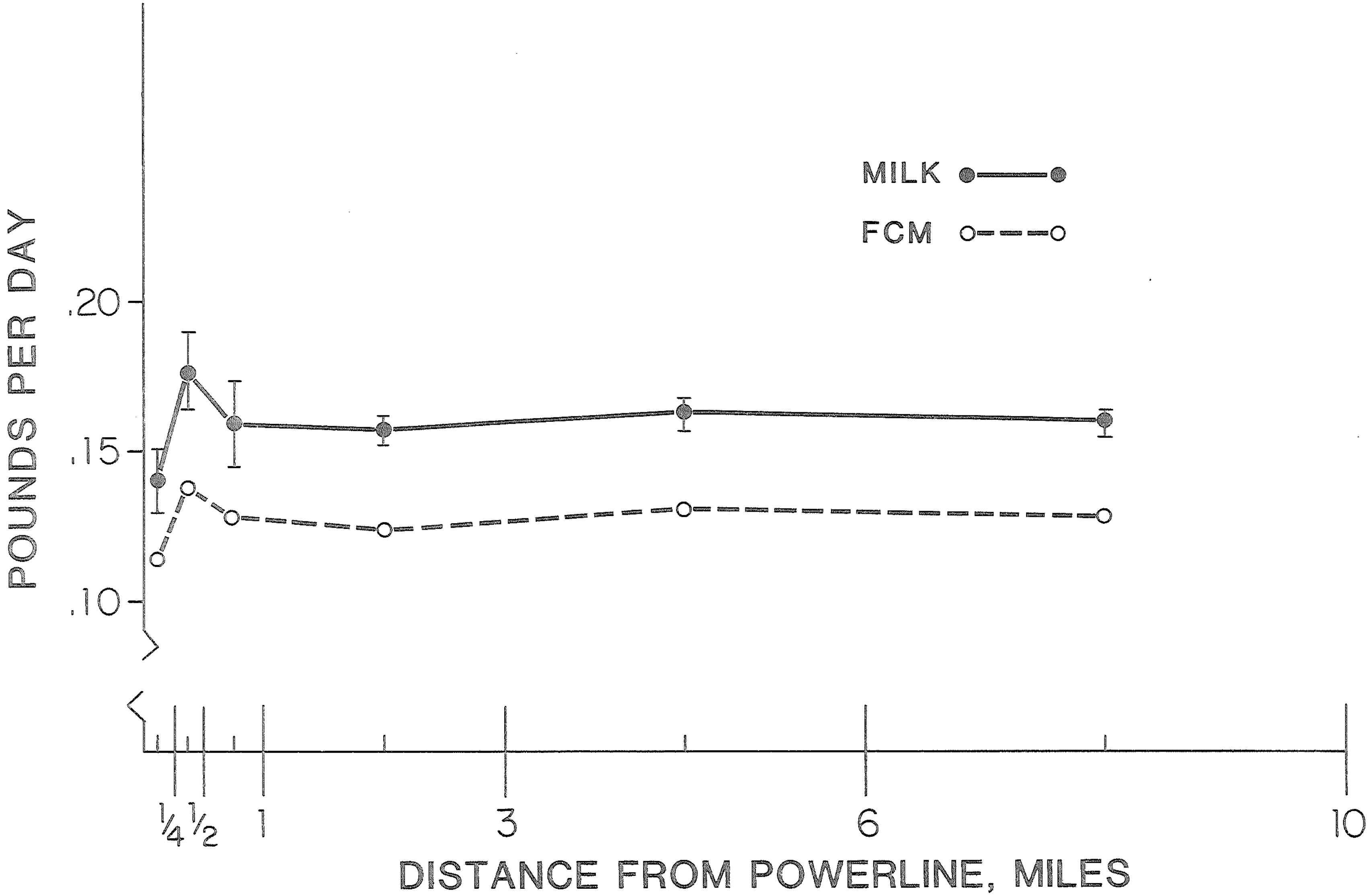


FIGURE 8. Average drop in production per cow before to after 9/3/79 during post peak lactation with 95% confidence bounds.



M was calculated for both pounds of milk per day and lbs of fat corrected milk per day decreases. No association could be found between proximity to the power line (either north or south) and an increased rate of decline in milk production using either measure of production.

b) Distribution of High M Cows

The second analysis of this data involved defining a "case" animal as being one with an elevated value of M. If "case" animals could be shown to have significantly higher exposure "scores" (in this instance proximity to the power line) then an association might be considered causal.

Given that the average M value for all animals in the study is approximately 0.15 lb./day, the criteria for two types of cases were defined as those animals with:

(i) M > 0.20 lb./day (this included about 25% of all useable lactation records).

(ii) M > 0.25 lb/day (this included about 11% of all useable lactation records).

Using both definitions of "cases", the percentage distribution of these cases by strata was calculated and compared. These results are shown in table 7 and also in figures 9, 10 and 11. They are essentially similar to the first comparisons of daily milk production decreases and support the conclusion of no observable association between the percentage of "case" cows (using either definition) and proximity to the power line.

TABLE 7

PERCENTAGES OF "CASE" COWS
DEFINED BY M ON 10/17/78

STRATUM	NUMBER OF COWS	# CASES M>.20	% CASES M>.20	# CASES M>.25	% CASES M>.25
1	135	36	26.7%	15	11.1%
2	222	64	28.8%	36	16.2%
3	115	38	33.0%	15	13.0%
4	940	210	22.3%	101	10.7%
5	1086	235	21.6%	109	10.0%
6	1267	322	25.4%	170	13.4%

PERCENTAGES OF "CASE" COWS
DEFINED BY M ON 5/15/79

STRATUM	NUMBER OF COWS	# CASES M > .20	% CASES M>.20	# CASES M > .25	% CASES M>.25
1	439	102	27.3%	41	9.3%
2	313	58	18.5%	22	7.0%
3	369	87	23.6%	37	10.0%
4	1856	416	22.4%	162	8.7%
5	2316	510	22.0%	222	9.6%
6	2649	546	20.6%	220	8.3%

PERCENTAGES OF "CASE COWS
DEFINED BY M ON 9/3/79

STRATUM	NUMBER OF COWS	# CASES M>.20	% CASES M>.20	# CASES M>.25	% CASES M>.25
1	210	49	23.3%	17	8.1%
2	214	74	34.6%	45	21.0%
3	191	51	26.7%	37	19.4%
4	1095	294	26.8%	153	14.0%
5	1359	393	28.9%	204	15.0%
6	1521	429	28.2%	206	13.5%

FIGURE 9. Percentage of animals showing large production drops (M) from before to after 10/17/82 with 95% confidence bounds.

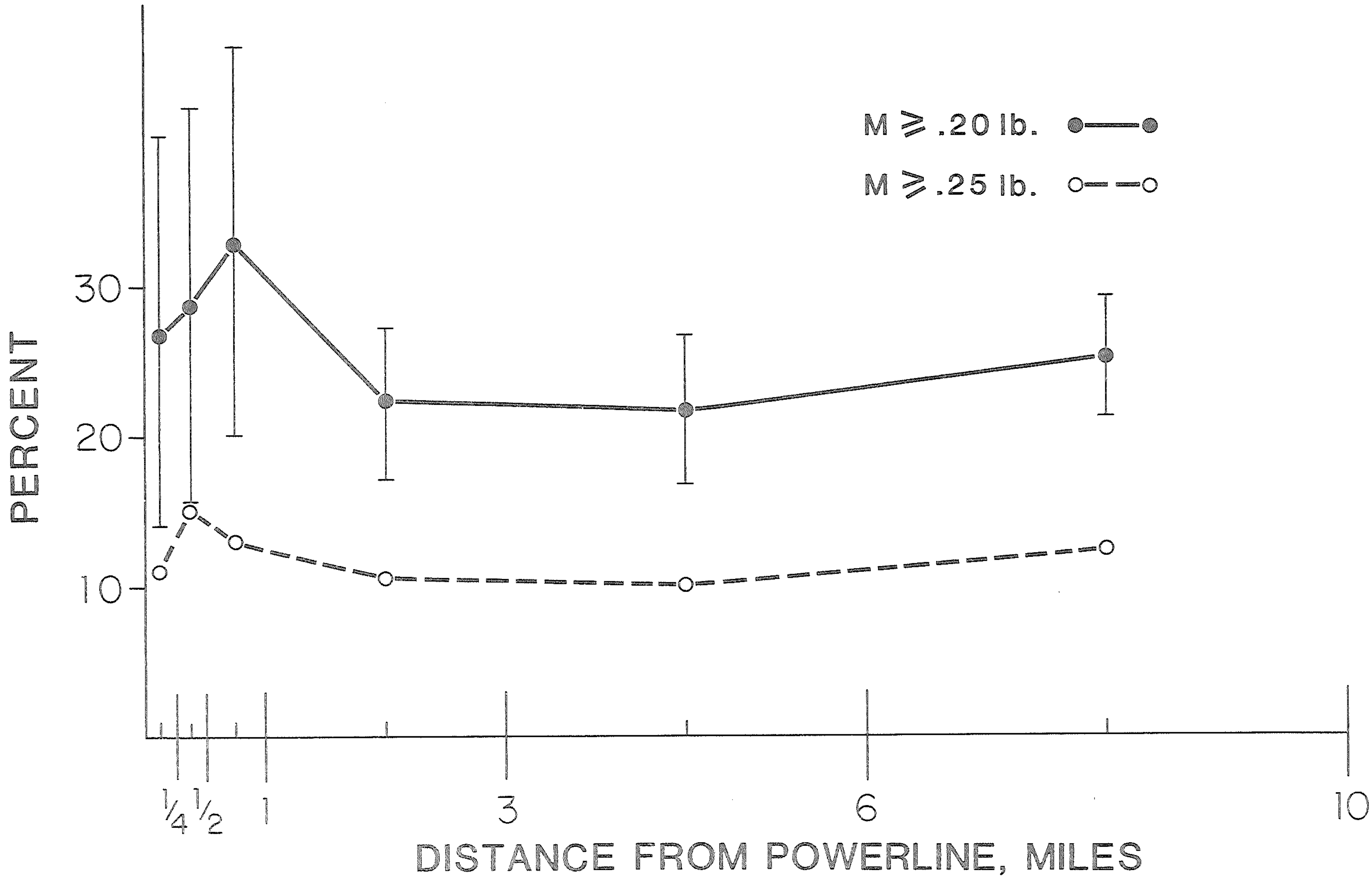


FIGURE 10. Percentage of animals showing large production drops (M) from before to after 5/15/79 with 95% confidence bounds.

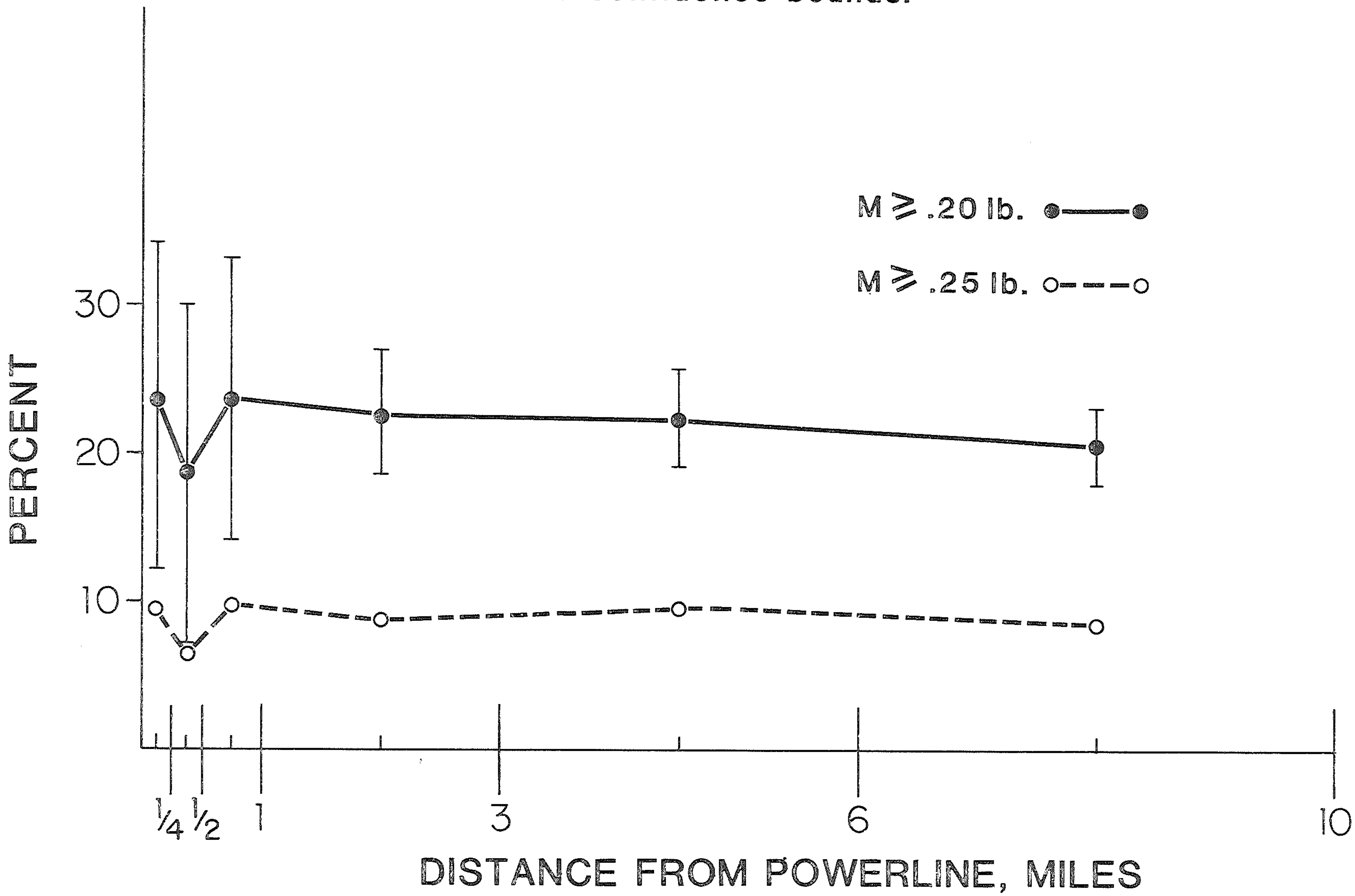
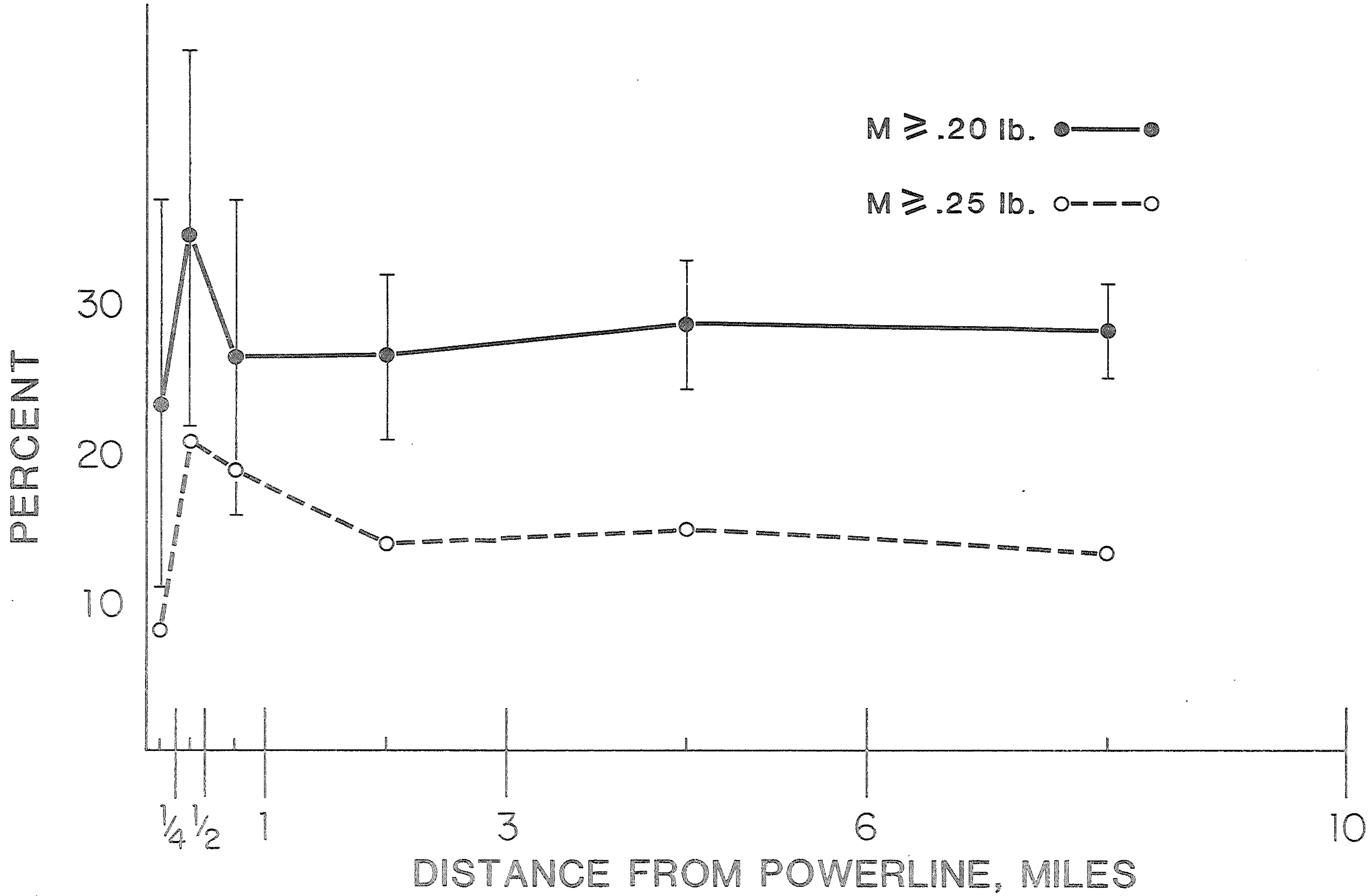


FIGURE 11. Percentage of animals showing large production drops (M) from before to after 9/3/79 with 95% confidence bounds.



c) Distribution of Herds with > 50% High M Value Animals

A "high prevalence" herd was arbitrarily defined as one in which more than 50% of its useable lactation records had M values of >0.20 lbs./day. Since M is related to both management, nutrition and genetic quality of the cattle it was reasonable to expect some consistency within a herd and also some interherd variation. In table 8 a comparison by strata of high vs low (<50%) prevalence herds is made across the 3 dates of interest. Again no obvious associations were observed between strata and the occurrences of high prevalence herds.

d) Owner ("unofficial") vs Supervisor ("official") Sampling

Supervisor tested herds are known to have higher rolling herd production averages than owner tested herds. This could be a confounding factor in any analyses. Rather than a study of the distribution of animals having elevated M values, the study may be of the distribution of supervisor testing. The incidence of high and low prevelance herds is compared between supervisor and owner test herds in table 9. Chi square tests show no assocation between the number of high prevelance herds and type of testing.

TABLE 8

DISTRIBUTION BY STRATA OF 'HIGH PREVALENCE' HERDS HAVING AT LEAST 50% OF REPORTING COWS SHOWING M >.20 lb/DAY

Before to After 10/17/78

STRATUM	1	2	3	4	5	6	
At least 50%	3	4	5	11	9	19	51
Less than 50%	20	14	14	99	128	141	416
Totals	23	18	19	110	137	160	467
% of High Prevalance Herds	13%	22%	26%	10%	7%	12%	

Before to After 5/15/79

STRATUM	1	2	3	4	5	6	
At least 50%	3	0	2	16	13	14	48
Less than 50%	22	19	18	103	128	162	452
Totals	25	19	20	119	141	176	500
% of High Prevalence Herds	21%	0	10%	13%	9%	8%	

Before to After 9/3/79

STRATUM	1	2	3	4	5	6	
At least 50%	2	6	2	16	21	32	79
Less than 50%	22	13	16	99	115	132	399
Totals	24	19	18	117	136	164	478
% of High Prevalence Herds	8%	32%	11%	14%	15%	20%	

TABLE 9

DISTRIBUTION BY TYPE OF TEST OF 'HIGH PREVALENCE' HERDS HAVING 50% OR MORE REPORTING COWS WITH M >.20 LB MILK PER DAY

(OFFICIAL VS NON-OFFICIAL)

M Computed on 10/17/78

	Herds on Supervisor Test	Herds on Owner Test
Herds with 50% or more "cases"	35	12
Herds with less than 50% cases	281	178

$\chi^2 = 3.2$ N.S.

M Computed on 5/15/79

	Herds on Supervior Test	Herds on Owner Test
Herds with 50% or more "cases"	36	13
Herds with less than 50% cases	280	177

$\chi^2 = 2.8$ N.S.

e) Standardization of M for Peak Milk Yield

In table 10 and figure 12, 500 observations of herd averages for M and M adjusted are compared by strata. Although not essential to the overall study, these results do show that if all of the cows in the study had the same peak milk potential then even flatter comparisons across strata would have been observed.

f) Conclusion

Using the change in the rate of decrease in milk production per day (M) as a measure of effect, no assocation was detected between power line events and strata proximity to the line. It must be acknowledged however that M is an imperfect description of production change but nevertheless was the only relevant construct available in the DHIA data base.

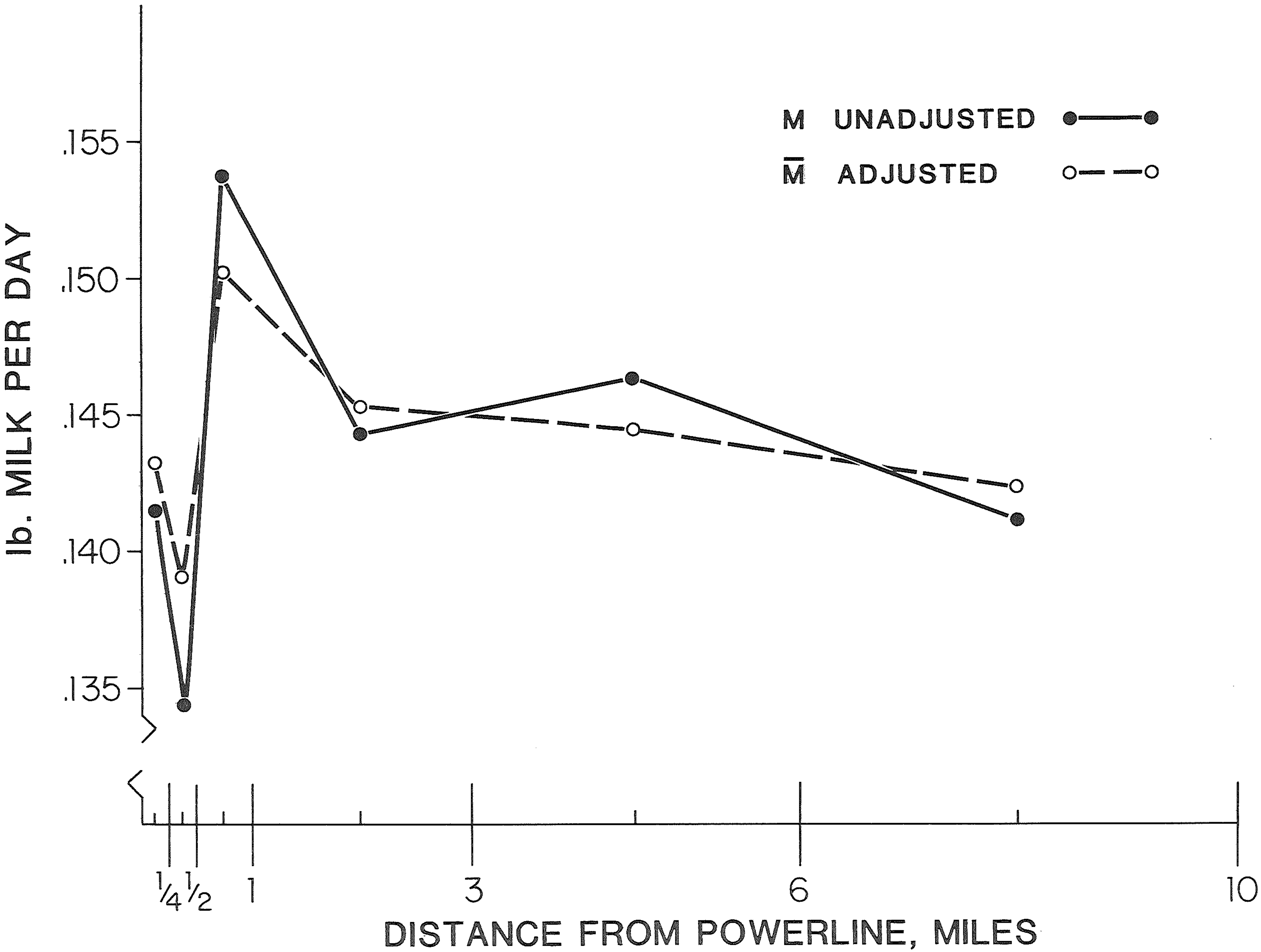
TABLE 10

ADJUSTED VALUES OF $\overline{M}^*$ ON 5/15/79
BASED ON HERD AVERAGES

STRATUM	$\overline{M}$	PEAK MILK lb. per day	$\overline{M}$* (ADJUSTED)
North 1	.1376	62.7	.1448
2	.1163	59.8	.1329
3	.1555	66.4	.1504
4	.1465	65.8	.1434
5	.1453	65.2	.1442
6	.1486	65.0	.1482
South 1	.1445	65.8	.1417
2	.1524	67.2	.1448
3	.1521	65.5	.1501
4	.1420	63.4	.1468
5	.1473	65.7	.1447
6	.1337	64.0	.1365
COMBINED 1	.1411	64.2	.1433
2	.1344	63.5	.1389
3	.1538	66.0	.1503
4	.1443	64.6	.1451
5	.1463	65.4	.1445
6	.1412	64.5	.1424

$\overline{M}$* (Adjusted) = $\overline{M}$ + .0033 (Peak Milk - 64.88)

FIGURE 12. $\bar{M}$ and $\bar{M}$ adjusted for peak milk herd average on 5/15/79.



2. Between Lactation Analyses

a) Individual Cow 305 Day Milk Production

In this portion of the study three separate groups of lactations based on calving times were analysed using 305 day milk production. First, cows calving between January 20, 1977 and January 19, 1978 were selected as representing cows which had calved and completed a lactation before the power line was initially energized. The second group included cows that had calved between October 18, 1978 and October 17, 1979 and thus completed a lactation coincidential with varying periods of line operation. The third group included cows that had calved between October 18, 1979 and October 16, 1980 and thus uniformly experienced a completed lactation during a time when the line was in more or less continuous operation (greater than 90% of the available time).

Tables 11, 12, 13, and 14 show the average 305 day milk production for several hundred cows in the inner strata (1, 2, and 3) and for several thousand cows in the outer strata (4, 5, and 6) for first, second, third and fourth and later lactations. The analysis used each stratum compared to itself from before, during intermittent, and after full energizing of the power line. The study attempted to observe any changes in aggregate performance near the line which did not have parallels in large strata farther removed from the line.

Production, as expected, varied substantially with lactation number. Generally there was an increase in production from the first to the 3rd lactation. The peak production was usually reached by the 3rd lactation and then gradually decreased for additional lactations. Figures 13, 14, 15, and 16 present essentially the same data with 95% confidence limits.

If a before to after change in production of 600-700 lbs of milk were to have occurred consistently near the power line and nowhere else it would have been a statistically significant deviation suggesting that an association between 305 day milk production and proximity to the power line existed. However this change was not found. For example, in figure 13, stratum 1 shows gains almost identical to stratum 6 and it appears as though an apparent depressing effect of energizing the line is in strata 4 and 5 which are centered 2 and 4.5 miles distance from the power line. Stratum 2 shows a decrease in the first year after and rebounds in the 2nd year after. No statistically significant association between the 305 day milk production and proximity to the power line was found prior to energizing nor in either of the two subsequent years.

TABLE 11

AVERAGE PRODUCTION OF FIRST LACTATION COWS MEASURED
AS 305 DAY POUNDS OF MILK AVERAGE PER COW

Stratum	North (N) lb. milk	North (N) (n)	SOUTH (S) lb. milk	SOUTH (S) (n)	N & S lb. milk	N & S (n)
Calved between January 20, 1977 and January 19, 1978						
1.	11836	(138)	11904	(193)	11876	(331)
2.	10669	(98)	12259	(138)	11599	(236)
3.	11748	(118)	11345	(183)	11503	(301)
4.	11933	(993)	11642	(661)	11817	(1654)
5.	11695	(1054)	11802	(964)	11746	(2018)
6.	11392	(1333)	11694	(1143)	11531	(2476)
Calved between October 18, 1978 and October 17, 1979						
1.	12456	(150)	11479	(185)	11916	(335)
2.	10667	(140)	11804	(174)	11296	(314)
3.	11834	(133)	11202	(199)	11455	(332)
4.	11634	(1043)	10925	(773)	11332	(1816)
5.	11658	(1089)	11625	(963)	11643	(2052)
6.	11495	(1404)	11700	(1147)	11587	(2551)
Calved between October 18, 1979 and October 16, 1980						
1.	12235	(121)	12265	(174)	12253	(295)
2.	10980	(130)	12510	(140)	11773	(270)
3.	11614	(133)	11187	(166)	11376	(299)
4.	11360	(1013)	11018	(680)	11227	(1693)
5.	11122	(1144)	11745	(892)	11395	(2036)
6.	11634	(1298)	12132	(1072)	11859	(2370)

n = number of cows

TABLE 12

AVERAGE PRODUCTION OF SECOND LACTATION COWS MEASURED AS 305 DAY POUNDS OF MILK AVERAGE PER COW

Calved between January 20, 1977 and January 19, 1978

	NORTH (N)		SOUTH (S)		N & S	
	lb. milk	(n)	lb. milk	(n)	lb. milk	(n)
Stratum						
1.	12799	(98)	13054	(166)	12959	(264)
2.	11867	(92)	14186	(113)	13145	(205)
3.	13806	(103)	13208	(123)	13480	(226)
4.	13455	(623)	13179	(460)	13338	(1083)
5.	13455	(727)	13292	(681)	13376	(1408)
6.	13183	(892)	13061	(726)	13128	(1618)

Calved between October 18, 1978 and October 17, 1979

1.	13612	(118)	12267	(182)	12796	(300)
2.	12392	(105)	14227	(95)	13263	(200)
3.	13879	(104)	12271	(109)	13056	(213)
4.	13352	(839)	13060	(603)	13230	(1442)
5.	13120	(814)	13107	(781)	13114	(1595)
6.	13098	(1065)	13388	(917)	13232	(1982)

Calved between October 18, 1979 and October 16, 1980

1.	14032	(104)	13399	(154)	13654	(258)
2.	12953	(90)	13633	(122)	13344	(212)
3.	12382	(93)	13748	(160)	13246	(253)
4.	13565	(796)	12886	(550)	13288	(1346)
5.	13319	(827)	13775	(707)	13529	(1534)
6.	13749	(1031)	13964	(871)	13847	(1902)

n = number of cows

TABLE 13

AVERAGE PRODUCTION OF THIRD LACTATION COWS MEASURED AS 305 DAY POUNDS OF MILK AVERAGE PER COW

Calved between January 20, 1977 and January 19, 1978

	NORTH (N)		SOUTH (S)		N & S	
Stratum	lb. milk	(n)	lb. milk	(n)	lb. milk	(n)
1.	13833	(78)	14214	(125)	14068	(203)
2.	13631	(91)	15160	(84)	14365	(175)
3.	13918	(73)	14542	(93)	14268	(166)
4.	13929	(526)	13784	(345)	13871	(871)
5.	13764	(631)	13814	(521)	13787	(1152)
6.	13583	(724)	14022	(577)	13778	(1301)

Calved between October 18, 1978 and October 17, 1979

1.	13575	(77)	14243	(111)	13969	(188)
2.	12350	(82)	15634	(94)	14104	(176)
3.	14913	(64)	12647	(141)	13354	(205)
4.	14163	(541)	13323	(423)	13794	(964)
5.	14055	(632)	13874	(543)	13971	(1175)
6.	13747	(832)	14335	(635)	14001	(1467)

Calved between October 18, 1979 and October 16, 1980

1.	14646	(84)	14193	(112)	14387	(196)
2.	13243	(81)	13982	(82)	13615	(163)
3.	14914	(76)	13310	(83)	14077	(159)
4.	14549	(602)	13670	(442)	14177	(1044)
5.	13825	(572)	14353	(497)	14070	(1069)
6.	14451	(719)	13978	(669)	14223	(1388)

n = number of cows

TABLE 14

AVERAGE PRODUCTION OF FOURTH OR LATER LACTATION COWS MEASURED AS 305 DAY POUNDS OR MILK AVERAGE PER COW

Calved between January 20, 1977 and January 19, 1978

	NORTH (N)		SOUTH (S)		N & S	
Stratum	lb. milk	(n)	lb. milk	(n)	lb. milk	(n)
1.	13415	(109)	13837	(155)	13663	(264)
2.	12866	(152)	14154	(154)	13514	(306)
3.	14100	(131)	13611	(154)	13836	(285)
4.	13829	(924)	13476	(575)	13694	(1499)
5.	13246	(906)	13903	(950)	13582	(1856)
6.	13249	(1284)	13800	(1168)	13511	(2452)

Calved between October 18, 1978 and October 17, 1979

1.	13600	(138)	13369	(210)	13461	(348)
2.	11491	(179)	13992	(187)	12769	(366)
3.	14328	(138)	12984	(171)	13584	(309)
4.	13570	(947)	13155	(653)	13401	(1600)
5.	13030	(1050)	13416	(1010)	13219	(2060)
6.	13396	(1279)	13761	(1143)	13568	(2422)

Calved between October 18, 1979 and October 16, 1980

1.	14624	(130)	14178	(188)	14360	(318)
2.	12027	(125)	12816	(171)	12483	(296)
3.	14565	(145)	12820	(190)	13575	(335)
4.	13690	(884)	13241	(674)	13496	(1558)
5.	13548	(1037)	13841	(869)	13682	(1906)
6.	13738	(1182)	13676	(1097)	13708	(2279)

n = number of cows

FIGURE 13. 305 day milk production for first lactation cows, average per cow.

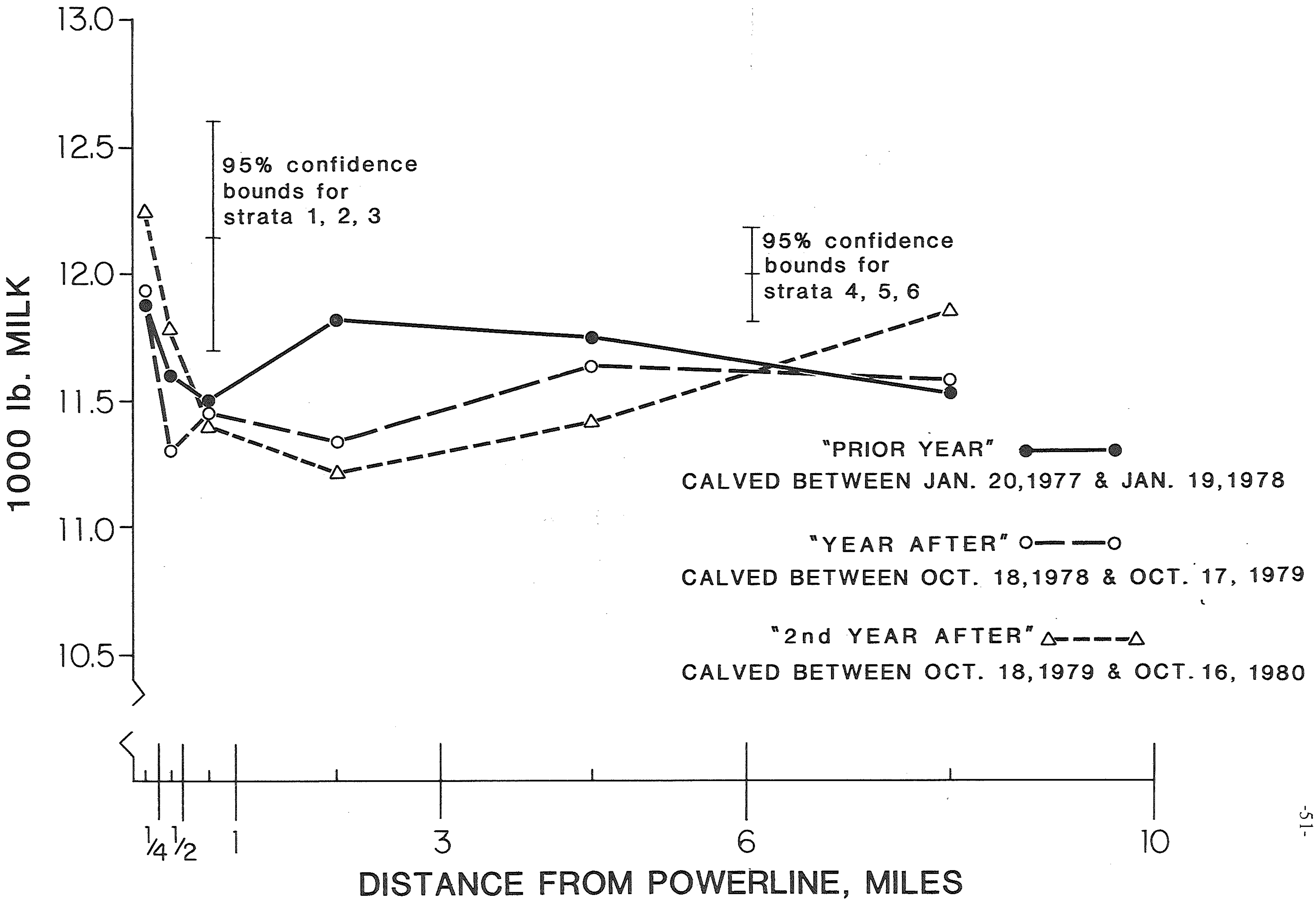


FIGURE 14. 305 day milk production for second lactation cows, average per cow.

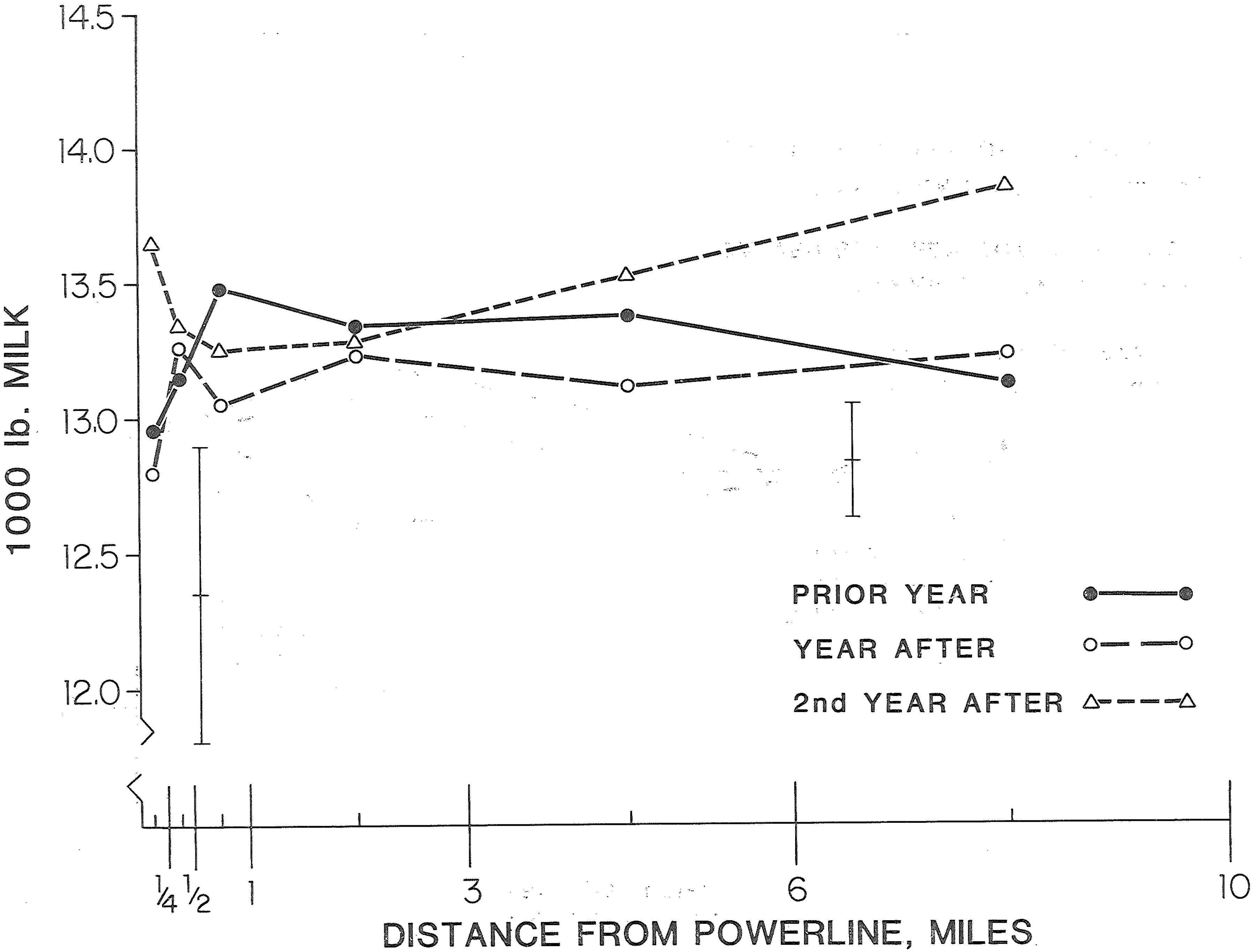


FIGURE 15. 305 day milk production for third lactation cows, average per cow.

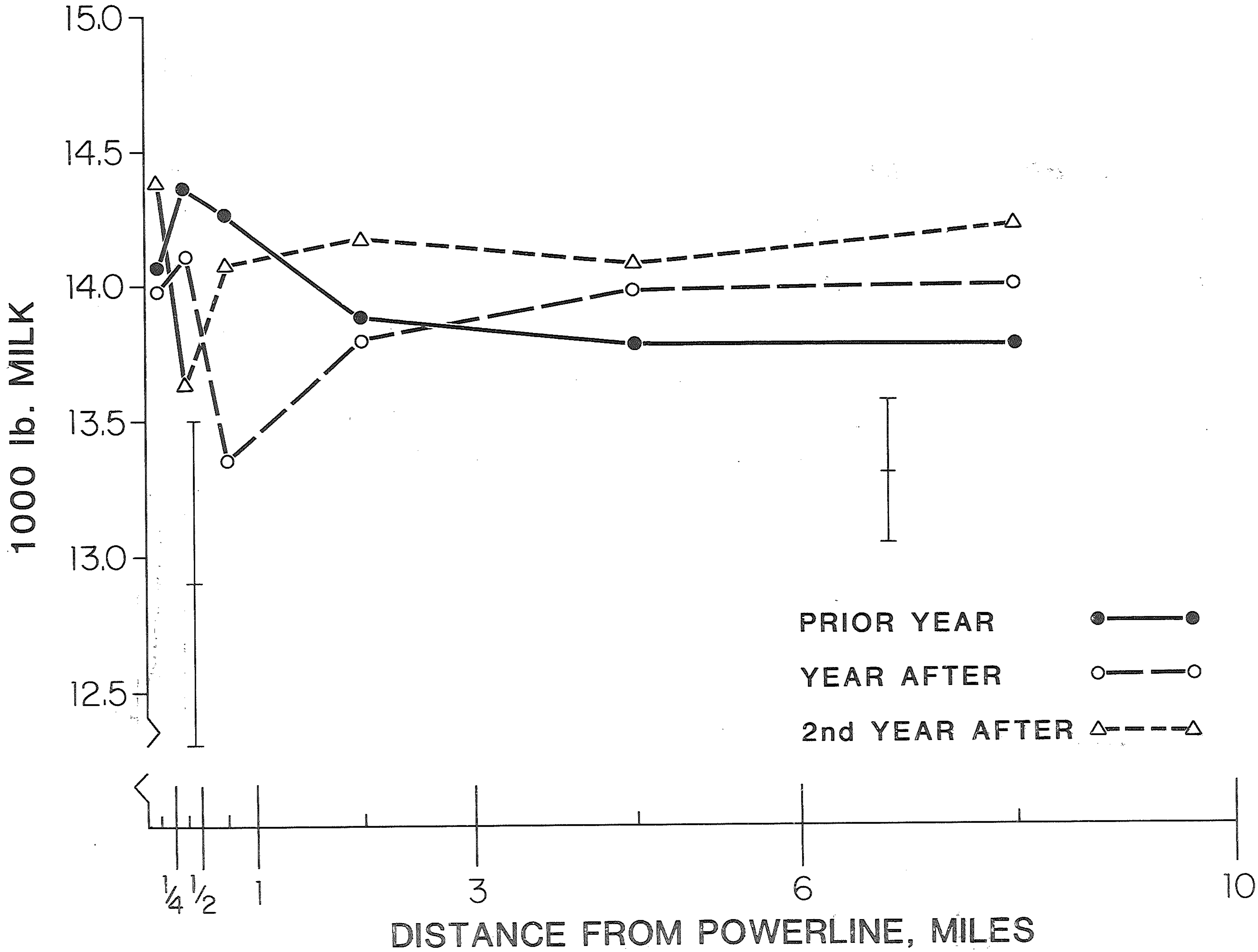
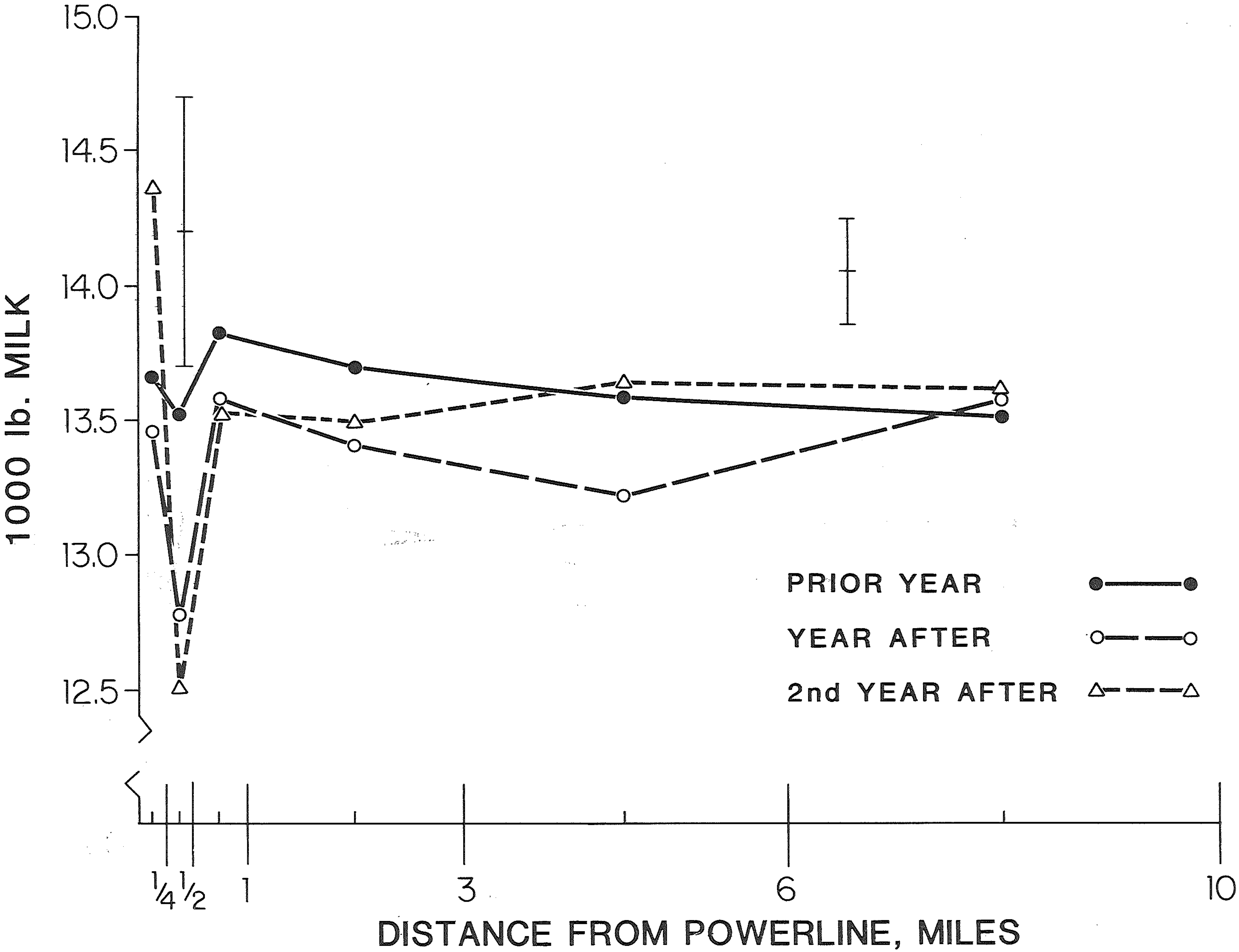


FIGURE 16. 305 day milk production for fourth and later lactaction cows, average per cow.



b) Herd Production Comparison by Strata

The following three analyses used herds which were on DHIA test in May, 1979 and remained on DHIA test as of September 19, 1982. These herds have had at least 3 year histories of potential exposure to any power line effects. Also it should be remembered that the composition of the herds will have changed over this three year period in that some animals will have left the herd and new animals will have joined from herd replacements within the herd or outside purchases.

(i) DHIA Membership Attrition:

Table 15 shows the number of original dairy farms studied as of May, 1979 and their rate of attrition as of September 1982. In all strata, owner samplers were likely to drop out at a rate 3 times that of supervisor samplers. There was a statistically significant ($p < .05$) difference in the rate at which the original farms in stratum 1 have remained in the DHIA program. Obviously farmers leave the DHIA program for a number of reasons. Attempts to determine these reasons could not have been made without effectively violating the anonymity agreement with participants.

TABLE 15

NUMBER OF STUDIED FARMS REMAINING
ON THE DHIA PROGRAM AS OF SEPT. 1982

STRATUM	NORTH		SOUTH		TOTAL		% REMAINING
1	8	(2)*	9	(6)	17	(8)	68%
2	8	(1)	9	(1)	17	(2)	89%
3	7	(2)	10	(1)	17	(3)	89%
4	59	(9)	43	(8)	102	(17)	86%
5	66	(9)	55	(11)	121	(20)	86%
6	87	(9)	67	(13)	154	(22)	87%
	235	(32)	193	(40)	428	(72)	86%

* numbers in parenthesis ( ) indicate farms discontinuing DHIA participation

(ii) Rolling Herd Average Comparisons (May, 1979 vs September, 1982)

Table 16 and figure 17 show the 12 month rolling herd averages (lbs. of milk per cow) for 428 herds in May 1979 and for the same herds in September 1982. All herds had production increases over this time period and this was typical for DHIA farms in Minnesota. The increases per cow for the 17 herds in stratum 1 (978 lb) was higher than the mean increase for all strata (842 lb).

Table 17 contains the average herd size among these farms on May, 1979 and September, 1982. Overall it can be seen that apart from a slight decrease in stratum 2 (north) the strata showed increases in milking cows per herd. It is likely that the increase in stratum 1 was associated with the higher attrition rate of DHIA members over this time period.

TABLE 16

AVERAGE VALUES OF ROLLING HERD AVERAGE (LB. OF MILK, $\overline{X}$) FOR DHIA FARMS RETAINED IN SEPTEMBER 1982 COMPARED WITH MAY 1979.

STRATUM	AS OF MAY 1979 $\overline{X}$	(n)	AS OF SEPT. 1982 $\overline{X}$	(n)	INCREMENT
	NORTH		NORTH		NORTH
1	14700	(8)	15622	(8)	922
2	13038	(8)	13788	(8)	750
3	14772	(7)	15409	(7)	637
4	14398	(59)	15590	(59)	1192
5	14344	(66)	14794	(66)	450
6	14188	(87)	15047	(87)	859
	SOUTH		SOUTH		SOUTH
1	15037	(9)	16065	(9)	1028
2	14769	(9)	15268	(9)	499
3	13846	(10)	14966	(10)	1120
4	14101	(43)	15024	(43)	923
5	14514	(55)	15125	(55)	611
6	14215	(67)	15236	(67)	1021
	COMBINED		COMBINED		COMBINED
1	14878	(17)	15856	(17)	978
2	13954	(17)	14572	(17)	618
3	14227	(17)	15148	(17)	921
4	14264	(102)	15351	(102)	1087
5	14423	(121)	14944	(121)	521
6	14200	(154)	15129	(154)	929

FIGURE 17. Comparison of rolling herd average from 5/15/79 to 9/1/82. Average values per farm.

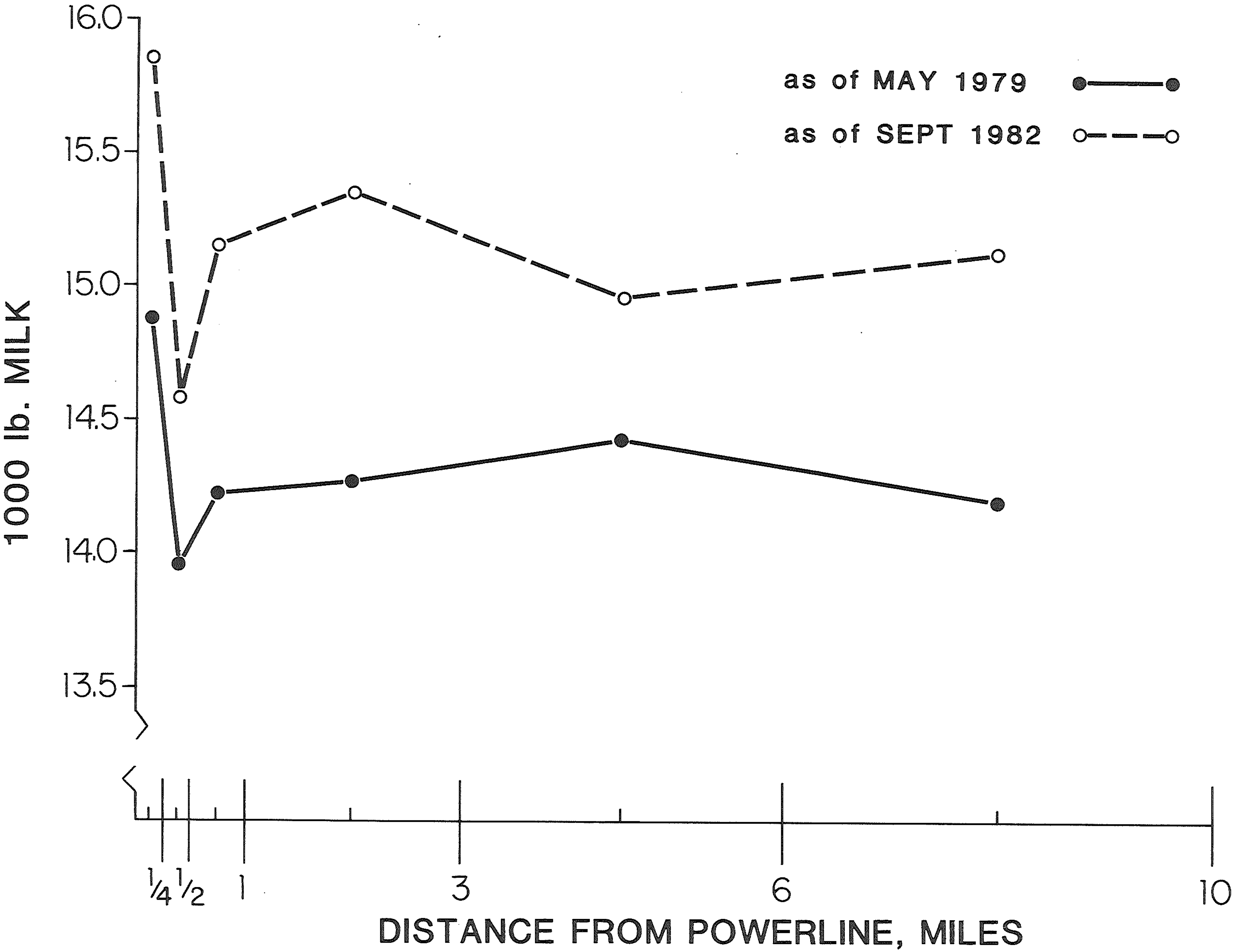


TABLE 17

AVERAGE HERD SIZE AMONG FARMS
RETAINED ON DHIA IN SEPT. 1982
COMPARED WITH MAY 1979

	AS OF MAY 1979	AS OF SEPT 1982	INCREMENT
STRATUM	NORTH	NORTH	NORTH
1	47.5	47.6	0.1
2	55.1	55	−0.1
3	45	48.7	3.7
4	44.6	51.3	6.7
5	46	51.7	5.7
6	42.8	48	5.2
	SOUTH	SOUTH	SOUTH
1	43	51.1	8.1
2	50.2	51.7	1.5
3	51.8	54.0	2.2
4	44.6	49.0	4.4
5	47.5	48.9	1.4
6	46.2	51.4	5.2

(iii) Comparisons of Milk Quality and Production Efficiency

To determine if there were any other obvious production problems associated with proximity to the power line after more than three years exposure, all herds remaining on test as of 9/1/82 from the original herds were examined for current condition on three parameters:

(a) a measure of milk quality i.e. 12 month rolling herd average % fat.

(b) a measure of production efficiency i.e. 12 month rolling herd average milk production per cow to grain ratio.

(c) a measure of health i.e. 12 month rolling average (%) of cows in the herd showing a somatic milk cell count above the threshold value of 500,000 cells/ml. This is an optional test and approximately half (217/428) of DHIA members used this measurement.

The results of these analyses are presented in Table 18. Although the number of herds in strata 1, 2, and 3 were much smaller than in the remaining strata, the overall conclusion was that in terms of milk quality, production efficency and udder health, there did not appear to be any significant variation by strata.

c) Conclusions

Both individual lactation records and herd averages indicated that the dairymen remaining on DHIA in 1982 close to the power line were not experiencing significant production changes that were not observable in herds far from the power line.

C. REPRODUCTION ANALYSES

1. Intercalving Intervals

Tables 19 and 20 contain the average and median intercalving intervals for animals calving during the three exposure periods grouped by strata and direction from the power line. Data for the first intercalving interval (table 19) are presented separately from the later intercalving intervals (table 20). Figures 18, 19, 20 and 21 are graphs of these relationships, drawn on an expanded scale so that the three time lines could be distinguished. No significant association with proximity to the power line was detected.

Table 21 and figures 22 and 23 show the percentage of intercalving intervals that could be considered excessive i.e. greater than 500 days. An intercalving interval of this length may be the result of a management decision particularly if an animal is a high producer. Again there was no significant differences in the percentages among the 6 strata.

Finally table 22 contains the average values of the DHIA calculated intercalving intervals by strata for the 428 herds remaining on DHIA as of September 1, 1982. Again there was no association with proximity to the power line in these data, nor did they differ significantly from the Minnesota state average i.e. 12.8 months.

TABLE 18

STRATA AVERAGES OF GIVEN DHIA
HERD AVERAGE MEASURES ASSOCIATED WITH THE
QUALITY OF MILK PRODUCTION RECORDED ON
9/1/82 AMONG 428 RETAINED FARMS

	Rolling Herd Average % Fat		Rolling Herd Average Milk To Grain Ratio lb/lb	
STRATUM	NORTH	SOUTH	NORTH	SOUTH
1	3.63	3.77	2.90	3.00
2	3.66	3.67	2.54	2.82
3	3.83	3.80	3.25	3.61
4	3.68	3.70	2.81	2.85
5	3.73	3.69	2.94	2.97
6	3.69	3.68	3.11	2.85

ROLLING AVERAGE FOR THOSE HERDS
REQUESTING THE OPTION (N) OF THE PERCENTAGE
OF COWS SHOWING A SOMATIC MILK CELL COUNT
ABOVE THRESHOLD VALUE. (i.e. > 500,000 cells/ml)
ON 9/1/82

STRATUM	Rolling Ave. % $\overline{X}$	Herd Numbers (n)	Rolling Ave. % $\overline{X}$	Herd Numbers (n)
1	14.5	(4)	21.7	(3)
2	22.5	(2)	13.5	(4)
3	15.7	(6)	13.2	(6)
4	15.4	(32)	19.9	(24)
5	16.9	(38)	19.3	(27)
6	18.4	(42)	22.0	(29)

TABLE 19

FIRST INTERCALVING INTERVAL

AVERAGE AND MEDIAN INTERCALVING INTERVALS FROM FIRST TO SECOND CALF

STRATUM		Calved Between Oct. 17, 1977 & Oct. 16, 1978			Calved Between August 14, 1979 & August 12, 1980			Calved Between Aug. 13, 1980 & Aug. 12, 1981		
		AVE.	(n)	Median	AVE.	(n)	Median	AVE.	(n)	Median
NORTH	1	394	(99)	367	391	(100)	377	395	(86)	387
	2	391	(86)	375	389	(89)	366	391	(78)	374
	3	375	(70)	365	382	(97)	368	402	(72)	372
	4	381	(624)	368	391	(753)	372	388	(597)	374
	5	392	(767)	372	398	(821)	378	384	(683)	368
	6	382	(967)	370	390	(1018)	370	391	(789)	375
SOUTH	1	382	(133)	372	385	(138)	372	393	(117)	376
	2	384	(107)	374	386	(113)	368	398	(88)	381
	3	385	(160)	369	389	(145)	376	383	(117)	364
	4	389	(411)	372	391	(540)	373	387	(367)	372
	5	380	(658)	366	390	(698)	377	389	(543)	370
	6	383	(754)	370	388	(857)	375	393	(626)	377
Combined										
	1	387	(232)	371	388	(238)	374	394	(203)	382
	2	387	(193)	374	387	(202)	367	395	(166)	378
	3	382	(230)	368	386	(242)	372	390	(189)	368
	4	384	(1035)	370	391	(1293)	372	388	(964)	373
	5	386	(1425)	369	394	(1519)	378	386	(1226)	369
	6	382	(1721)	370	389	(1875)	372	392	(1415)	376

TABLE 20

SECOND AND SUBSEQUENT INTERCALVING INTERVALS

AVERAGE AND MEDIAN INTERCALVING INTERVALS
FOR COWS HAVING A 3rd OR LATER CALF

		Calved Between October 17, 1977 & October 16, 1978			Calved Between August 14, 1979 & August 12, 1980			Calved Between August 13, 1980 & August 14, 1981		
STRATUM		AVE.	(n)	Median	AVE.	(n)	Median	AVE.	(n)	Median
NORTH	1	370	(188)	359	374	(205)	362	379	(168)	367
	2	377	(182)	367	391	(217)	375	400	(167)	385
	3	367	(177)	361	383	(217)	369	381	(161)	371
	4	384	(1295)	371	386	(1445)	372	390	(1145)	373
	5	390	(1467)	374	394	(1560)	375	388	(1290)	371
	6	384	(1823)	369	387	(1979)	372	388	(1610)	374
SOUTH	1	382	(259)	366	399	(283)	382	393	(220)	378
	2	386	(231)	372	393	(243)	379	386	(192)	374
	3	386	(211)	365	383	(267)	368	383	(213)	366
	4	382	(740)	371	387	(1090)	371	386	(850)	374
	5	381	(1420)	368	387	(1417)	371	387	(1082)	372
	6	386	(1598)	371	388	(1750)	378	392	(1336)	375
Combined										
	1	377	(447)	363	388	(488)	372	387	(388)	372
	2	382	(413)	370	392	(460)	377	392	(359)	379
	3	377	(388)	363	383	(484)	368	382	(374)	369
	4	383	(2035)	370	386	(2535)	372	388	(1995)	373
	5	386	(2887)	371	390	(2977)	373	388	(2372)	371
	6	385	(3421)	370	387	(3729)	375	390	(2946)	374

FIGURE 18. Average intercalving interval per cow, for cows having a second calf.

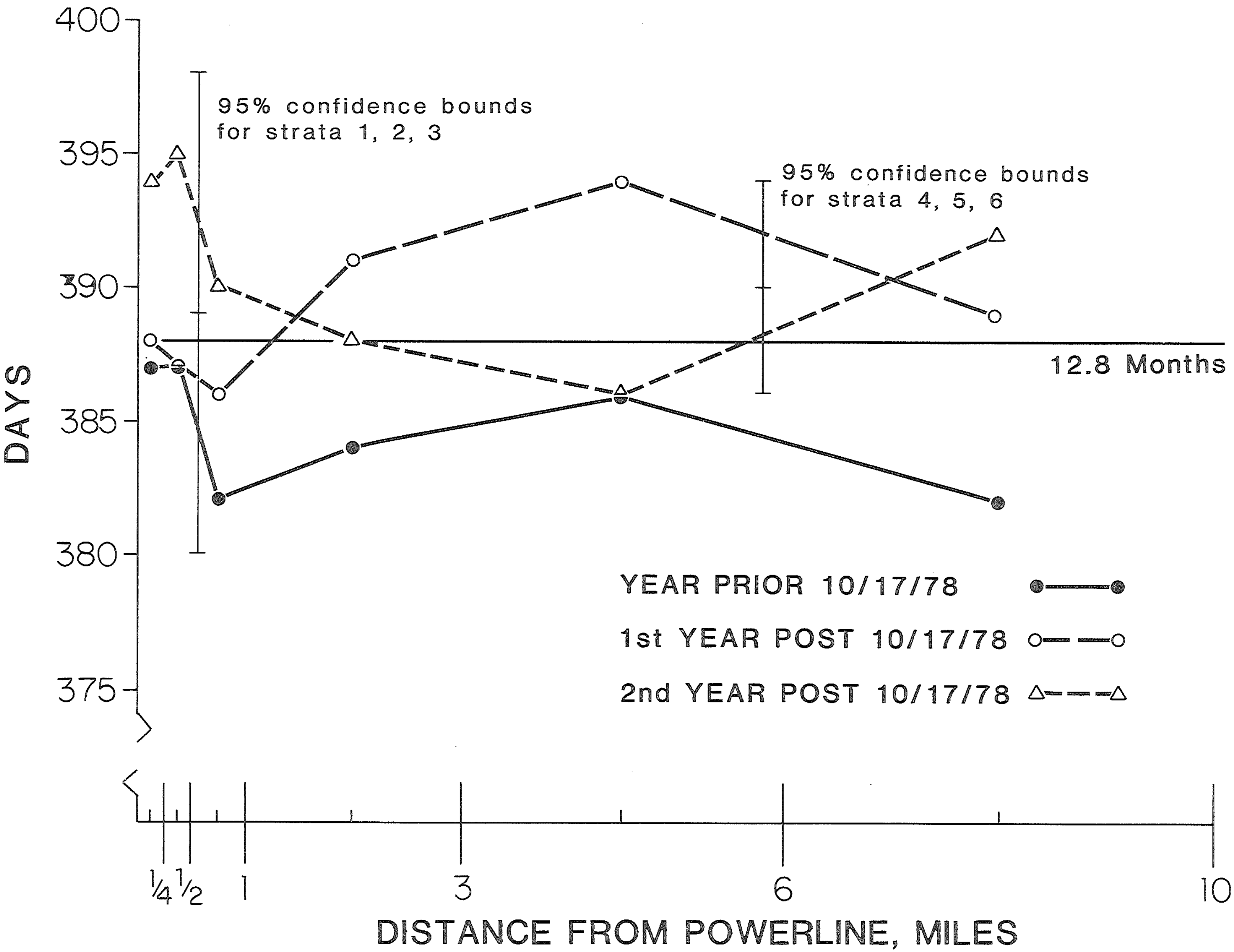


FIGURE 19. Median intercalving intervals for cows having a second calf.

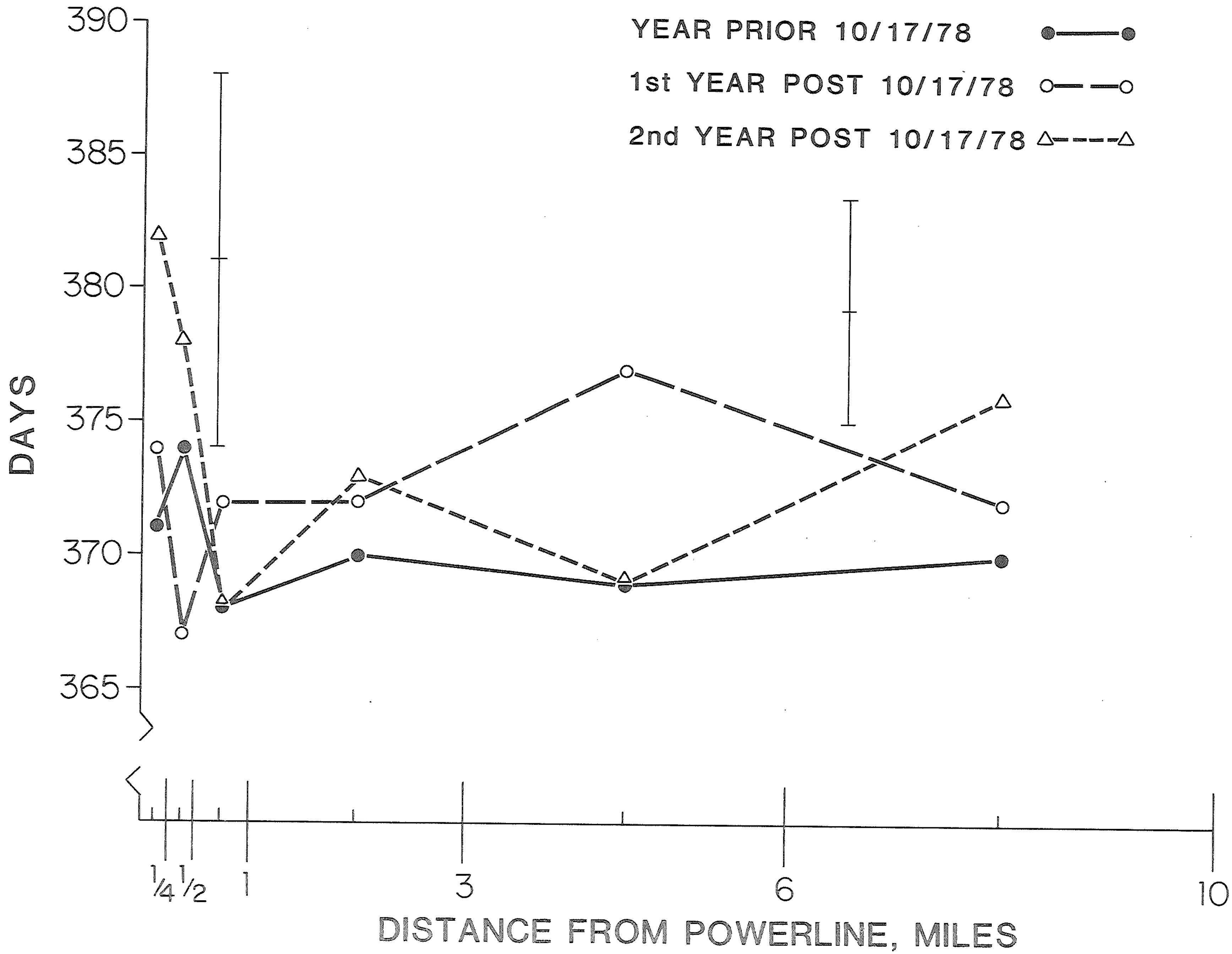


FIGURE 20. Average intercalving interval for those cows having a third or later calf.

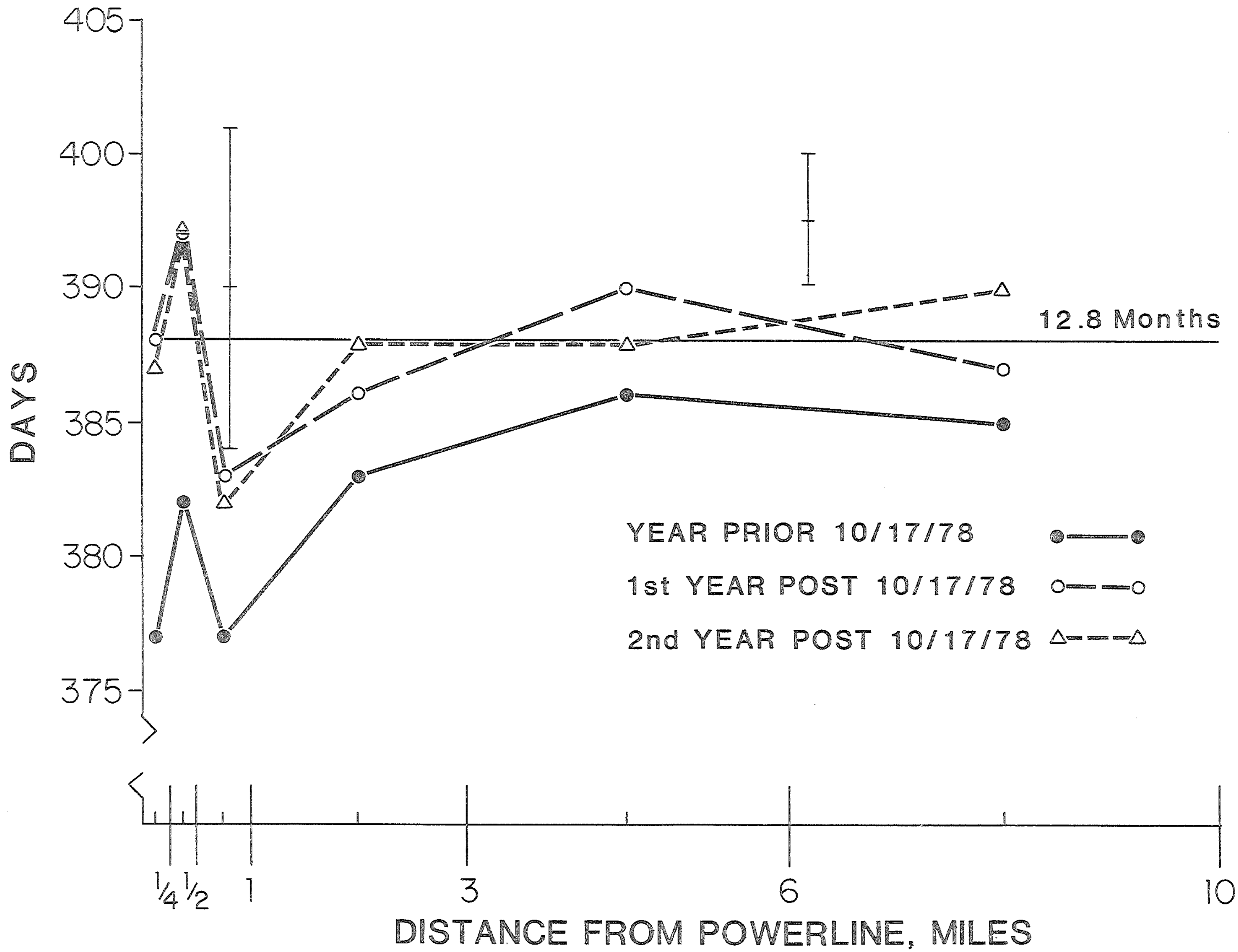


FIGURE 21. Median intercalving interval for those cows having a third or later calf.

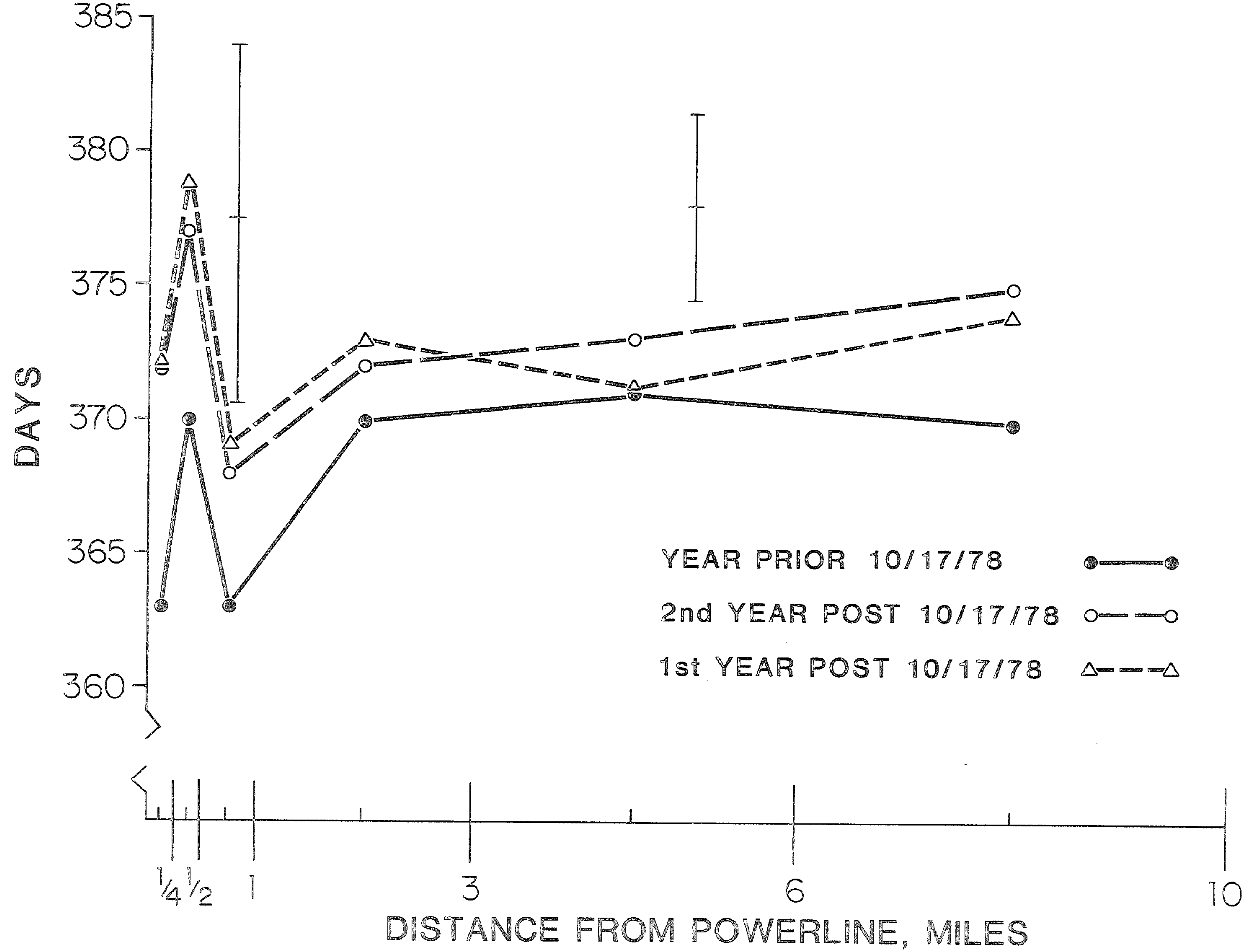


TABLE 21

PERCENTAGE OF COWS HAVING INTERCALVING INTERVAL GREATER THAN 500 DAYS

		1st-2nd calving interval	2nd-3rd and later calvings intervals
Calving Between October 17, 1977 & October 16, 1978			
STRATUM	1	6.5%	4.9%
	2	6.2%	4.4%
	3	3.9%	4.1%
	4	5.1%	4.6%
	5	6.9%	4.8%
	6	5.2%	5.4%
Calving Between August 14, 1979 & August 12, 1980			
STRATUM	1	8.2%	5.0%
	2	6.6%	7.3%
	3	4.3%	4.3%
	4	7.8%	5.0%
	5	7.3%	6.8%
	6	6.3%	5.7%
Calving Between August 13, 1980 & August 12, 1981			
STRATUM	1	6.9%	5.2%
	2	8.4%	6.4%
	3	7.9%	2.7%
	4	4.3%	5.2%
	5	5.9%	5.4%
	6	6.9%	6.1%

FIGURE 22. Percentage of first intercalving intervals greater than 500 days.

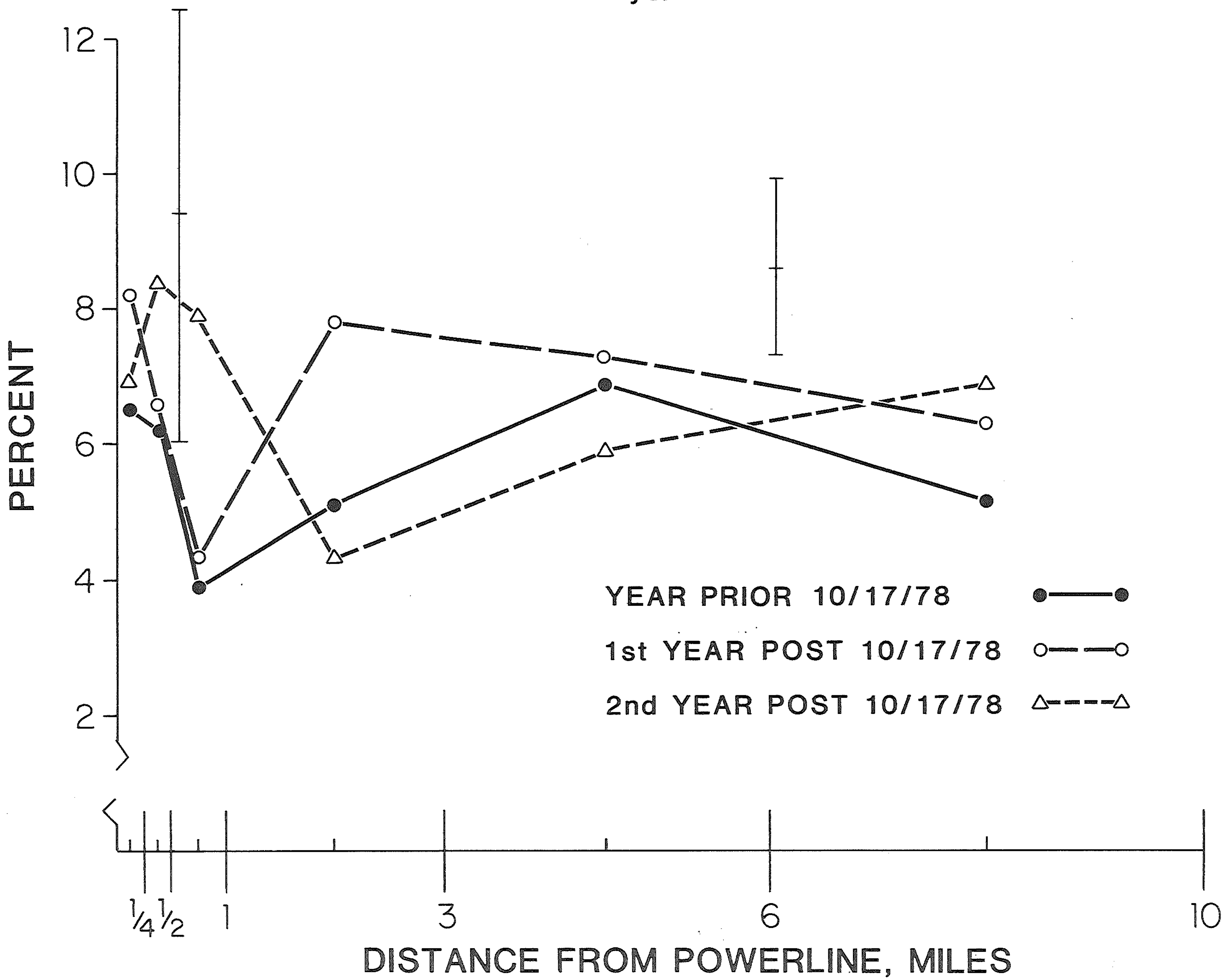


FIGURE 23. Percentage of second or later intercalf intervals greater than 500 days.

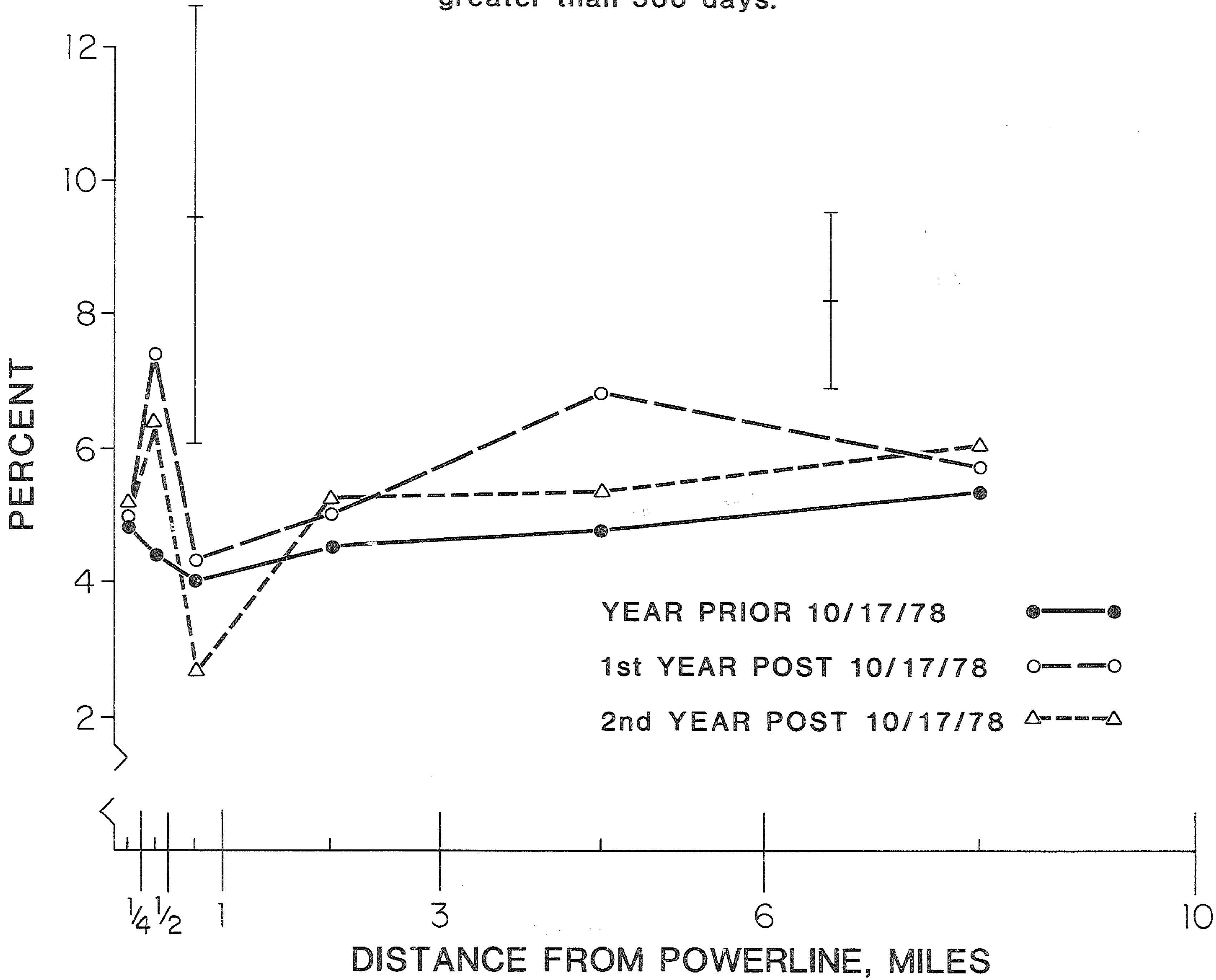


TABLE 22

STRATA AVERAGES OF THE CALCULATED INTERCALFING INTERVAL FOR HERDS ON DHIA ON SEPT. 1, 1982

Intercalving Interval in Months

STRATUM	NORTH	SOUTH
1	12.9	12.9
2	12.8	12.8
3	12.8	12.5
4	12.8	12.9
5	12.9	13.1
6	13.0	12.9

2. Abortions

Table 23 data contains the percentage of abortions in all lactation records and as a percentage of abnormally ending lactation records. Two groups of lactations were defined - those which ended prior to energizing of the power line and those which began after energizing of the power line. In the latter group only animals starting lactations after April 5, 1979 were included so that the cow was bred and carrying a fetus well after the time the power line was in more or less continuous use. Comparisons were also made between first lactation (second gestation) and second or later lactations (third or later gestations). In this analysis strata 1 and 2 combined were compared to stratum 6. In first lactation cows there were no significant differences between these strata in the rate of abortion. The rate of abortion in older cows was lower but this is to be expected as a result of culling animals for reproductive reasons. In the older cows the strata 1 and 2 near the power line showed a significantly lower abortion rate in the year following energizing of the line than did the control stratum 6.

TABLE 23

OCCURRENCE OF ABORTIONS RECORDED AS
THE DHIA CODE ENDING A LACTATION RECORD

FIRST LACTATIONS (2nd Gestation)

	Cows calving between Dec. 21, 1976 & Dec. 21, 1977		Cows calving between April 5, 1979 & April 4, 1980	
	Strata 1 & 2	Stratum 6	Strata 1 & 2	Stratum 6
Number of Lactation Records	651	2448	611	2301
Number of Lactations Ending Abnormally	137	651	161	518
Number of Recorded Abortion Codes	7	29	7	21
Abortions as a % of Lactation Records	1.1%	1.2%	1.1%	0.9%
Abortions as a % of Abnormal Records	5.1%	4.5%	4.3%	4.1%

SECOND OR LATER LACTATIONS (3rd or later Gestations)

	Strata 1 & 2	Stratum 6	Strata 1 & 2	Stratum 6
Number of Lactation Records	1392	5414	1442	5648
Number of Lactations Ending Abnormally	482	1882	474	1884
Number of Recorded Abortion Codes	9	45	1	36
Abortions as a % of Lactations Records	0.6%	0.8%	0.1%	0.6%
Abortions as a % of Abnormal Records	1.9%	2.4%	0.2%	1.9%

3. Culling of Animals for Reproductive Problems

Data on all stated reasons for culling animals from herds are treated in the following section of the report. Animals that were specifically culled for reproductive problems (at least as identified by the farmer) are listed in table 24 for both strata 1 and 2 combined and stratum 6 for 2 time periods - pre-exposure (calved between December 21, 1976 and December 21, 1977) and post-exposure (calved between May 5, 1979 and May 4, 1980). Stratum 6 was utilized as a control population for this portion of the study and animals in strata 1 and 2 were combined to accumulate an adequate number of units for statistical analysis. Once again there were no significant differences in the rate of culling animals among herds close to the power line as opposed to the farthest stratum nor were there any significant differences in these rates between pre-exposure and post-exposure to the power line environment.

Table 24

Animals Sold Off for Reproductive Problems

Calved between December 21, 1976 and December 21, 1977				Calved between May 5, 1979 and May 4, 1980			
Strata 1 & 2		Stratum 6		Strata 1 & 2		Stratum 6	
First Lactation Animals							
n	(%)	n	(%)	n	(%)	n	(%)
28	(20.4)	119	(21.4)	30	(18.6)	87	(16.8)
Second and Later Lactations							
133	(27.6)	403	(21.4)	107	(22.6)	365	(19.4)

D. ANALYSES OF REASONS FOR LEAVING THE DAIRY HERD

Tables 25 and 26 contain data by stratum and line direction for both first lactation animals and second and subsequent lactation animals that terminated that particular lactation "abnormally". Two groups of lactations were compared, those ending prior to energizing of the line and those ending after the line had been in use for some time (i.e. between May 5, 1979 and May 4, 1980).

Overall the proportions were remarkably constant over the two time periods and no obvious differences by strata or line direction were apparent. The percentage of "abnormal" endings for first lactation animals was 25% and approximately 34% for later lactations. These results are consistent with state-wide DHIA data. Figures 24 and 25 also suggest that these percentages are quite consistent across the 6 strata. With the exception of the rarely occurring abortion and the sale of dried off cows the numbers in tables 26 and 27 can be regarded as "culling rates". It can be concluded from these data that the culling rates were nearly constant across strata and over time.

The lower culling rate following the first lactation is to be expected. Younger animals have potential for better production even if their first lactation production was below expectations. The overall culling rate is usually regarded as being related to calving success. A producer with a large number of heifers entering the herd has more opportunity to remove older animals. Thus a high culling rate as defined in these tables may well be an indicator of "success" as well as an indicator of many cows with problems necessitating their removal from the herd.

TABLE 25

DISTRIBUTION OF ABNORMAL TERMINATION OF RECORDS FOR COWS IN FIRST LACTATION

STRATUM	NORTH			SOUTH			COMBINED		
	Abnormal records	# of Records	%	Abnormal records	# of Records	%	Abnormal records	# of Records	%
Calving date Between Dec. 21, 1976 and Dec. 21, 1977									
1	37	136	27.2	39	183	21.3	76	319	23.8
2	23	104	22.1	43	138	31.2	66	242	27.3
3	32	120	26.7	46	192	23.5	78	312	25.0
4	225	969	23.2	168	643	26.1	393	1612	24.4
5	250	1047	23.8	237	954	24.8	487	2001	24.3
6	334	1320	25.3	317	1128	28.1	651	2448	26.6
Calving date Between May 5, 1979 and May 4, 1980									
1	36	137	26.3	39	177	22.0	75	314	23.9
2	29	127	22.8	57	170	33.5	86	297	29.0
3	31	112	27.7	31	168	18.5	62	280	22.1
4	282	1021	27.6	178	673	26.4	460	1694	27.2
5	267	1100	24.3	220	870	25.3	487	1970	24.7
6	285	1251	22.8	233	1050	22.2	518	2301	22.5

TABLE 26

DISTRIBUTION OF ABNORMAL TERMINATION OF RECORDS FOR COWS IN SECOND OR LATER LACTATION

STRATUM	NORTH			SOUTH			COMBINED		
	Abnormal records	# of Records	%	Abnormal records	# of Records	%	Abnormal records	# of Records	%
Calving date Between Dec. 21, 1976 and Dec. 21, 1977									
1	100	285	35.1	157	436	36.0	257	721	35.6
2	119	326	36.5	106	345	30.7	225	671	33.5
3	104	309	33.6	112	355	31.5	216	664	32.5
4	743	2057	36.1	462	1315	35.1	1205	3372	35.7
5	727	2240	32.5	724	2144	33.8	1451	4384	33.1
6	1037	2900	35.8	846	2514	33.7	1883	5414	34.8
Calving date Between May 5, 1979 and May 4, 1980									
1	110	322	34.2	135	420	32.1	245	742	33.0
2	105	332	31.6	124	368	33.7	229	700	32.7
3	94	297	31.6	146	413	35.4	240	710	33.8
4	769	2244	34.3	536	1623	33.0	1305	3867	33.7
5	815	2450	33.3	730	2098	34.8	1545	4548	34.0
6	1044	3048	34.3	840	2600	32.3	1884	5648	33.4

FIGURE 24. Rates of occurance of first lactations having "abnormal" ending codes.

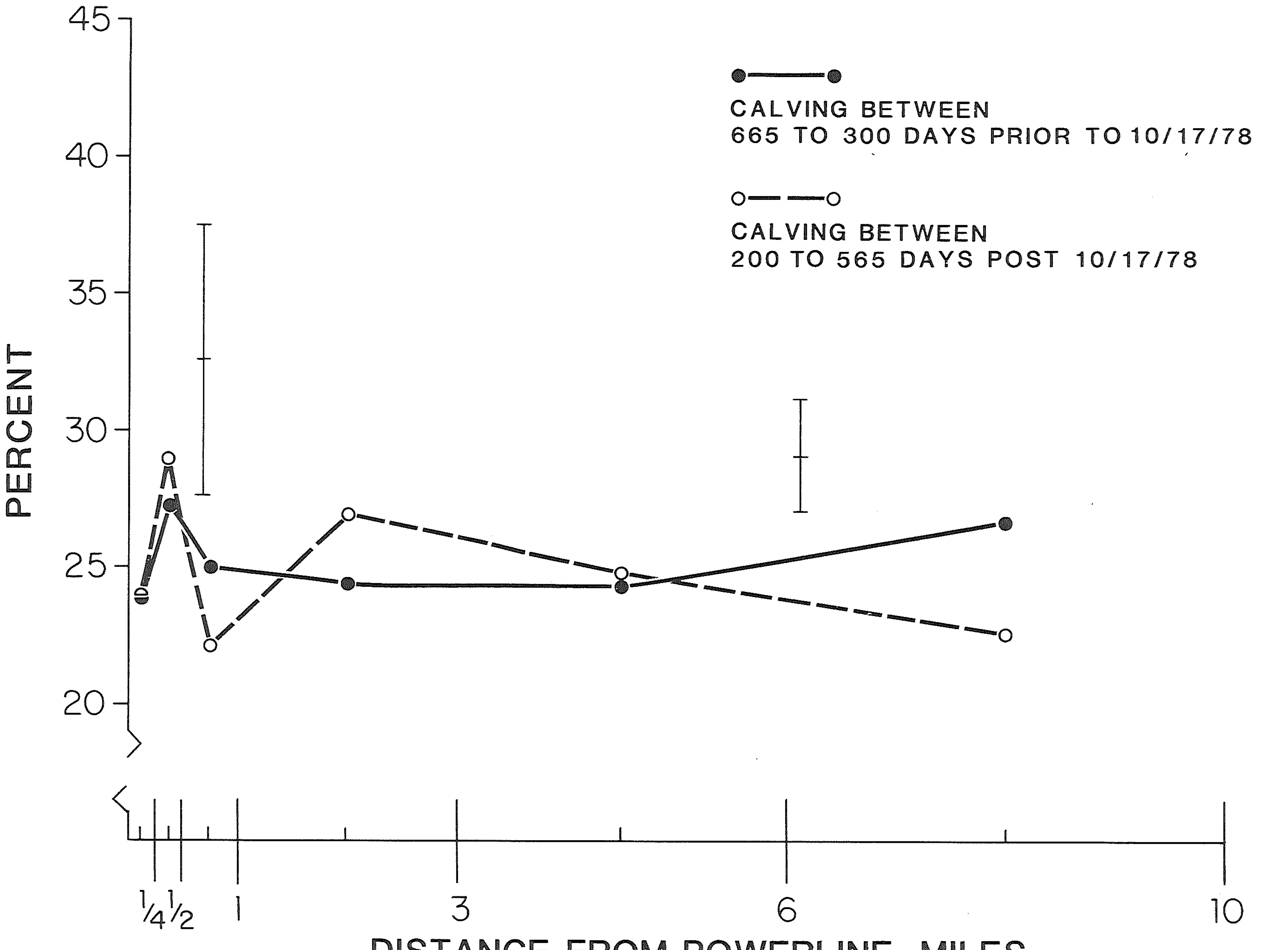
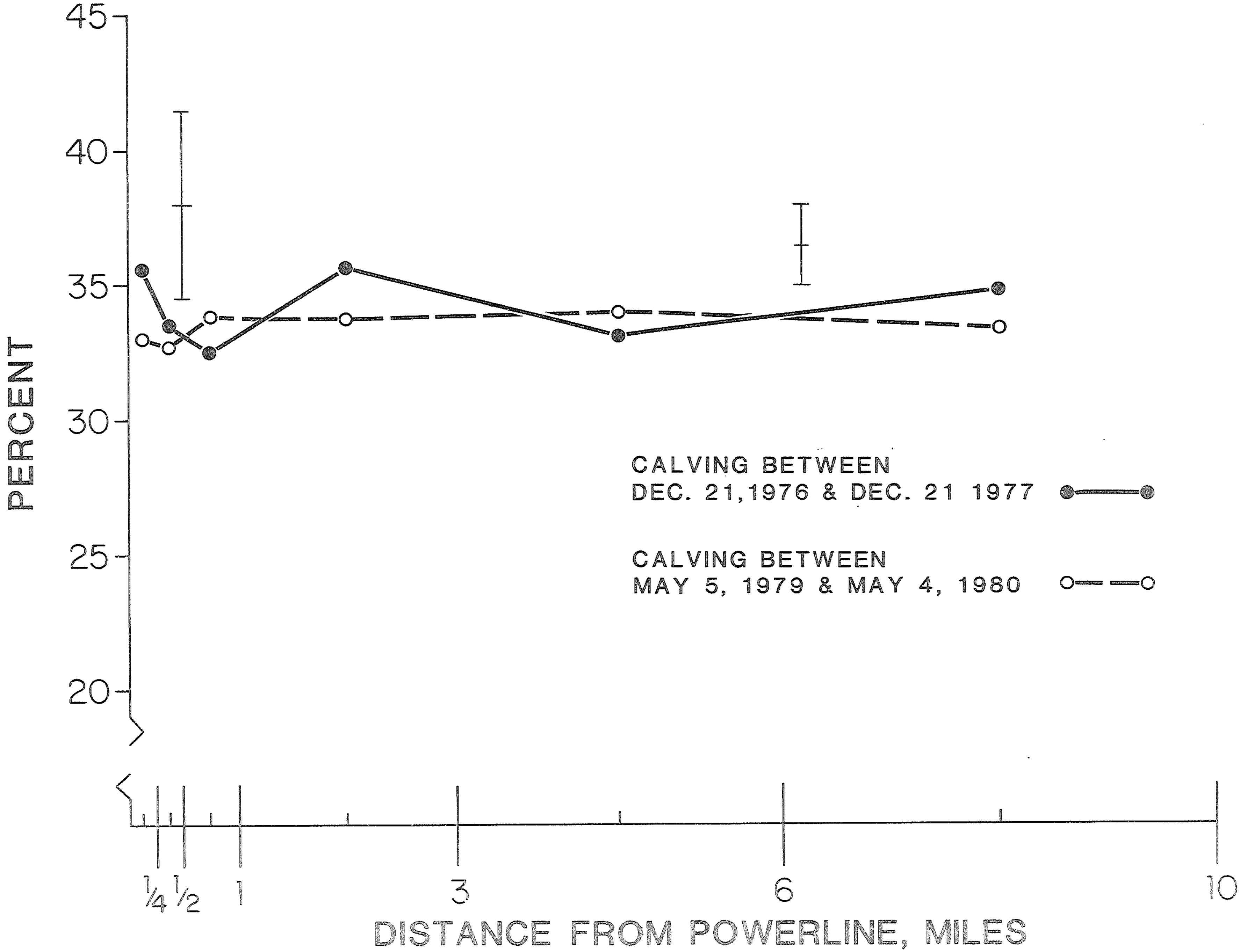


FIGURE 25. Rates of occurance of second and higher later lactations ending in "abnormal" codes.



Reasons given by farmers for removing animals are presented by strata, both before and after energizing of the power line are given in tables 27 and 28. There were statistically significant differences in the distribution of reasons given when farms in strata 1 and 2 were compared to those producers in stratum 6. A some what puzzling difference lies in the fact that producers in stratum 6 were reporting more animals (16.0% and 16.6%) under code 9 (no reason given) in 1979-80 compared to 3.7% and 9.5% by the producers in strata 1 and 2.

The proportion of animals reported as dying (code #6) by strata and over time appeared to be relatively constant. After the power line was fully energized more first lactation animals in strata 1 and 2 were sold off due to injury or disease (24.2% vs 15.4%). There was a suggestion that producers in the inner strata (1 and 2) sold a higher proportion (15.5% vs 10.2%) of first lactation animals for dairy use to other producers. There was no obvious differences in the number of animals culled for mastitis problems. A higher rate of culling for older animals (13-15%) was to be expected as compared to 1st lactation animals (i.e. 5-10%).

TABLE 27

DISTRIBUTION OF ABNORMAL ENDING
LACTATIONS BY REASON FOR FIRST LACTATION ONLY

Calved between Dec. 21, 1976 and Dec. 21, 1977

Code*	Strata 1 & 2 n	Strata 1 & 2 (%)	Stratum 6 n	Stratum 6 (%)
2	17	(12.4)	75	(11.5)
3	45	(32.8)	183	(28.1)
4	28	(20.4)	139	(21.4)
5	21	(15.3)	108	(16.6)
6	7	(5.1)	39	(6.0)
7	7	(5.1)	45	(6.9)
8	7	(5.1)	29	(4.5)
9	5	(3.6)	33	(5.1)

$\chi^2 = 2.4$ N.S.

Calved between May 5, 1979 and May 4, 1980

Code	Strata 1 & 2 n	Strata 1 & 2 (%)	Stratum 6 n	Stratum 6 (%)
2	25	(15.5)	53	(10.2)
3	32	(19.9)	113	(21.8)
4	30	(18.6)	87	(16.8)
5	39	(24.2)	80	(15.4)
6	9	(5.6)	30	(5.8)
7	13	(8.1)	51	(9.8)
8	7	(4.3)	21	(4.1)
9	6	(3.7)	83	(16.0)

$\chi^2 = 23.5$ ($p < .01$)

*Code 2 = Sold for Dairy Use
3 = Sold off for low production
4 = Sold off for reproductive problems
5 = Sold off due to injury or disease
6 = Died
7 = Udder problems
8 = Aborted
9 = Reason not given

TABLE 28

DISTRIBUTION OF ABNORMAL ENDING LACTATION BY REASON FOR SECOND AND LATER LACTATIONS

	Calved between Dec. 21, 1976 and Dec. 21, 1977					Calved between May 5, 1979 and May 4, 1980			
	Strata 1 & 2		Stratum 6			Strata 1 & 2		Stratum 6	
Code*	n	(%)	n	(%)	Code	n	(%)	n	(%)
2	26	(5.4)	120	(6.4)	2	43	(9.1)	100	(5.3)
3	106	(22.0)	472	(25.1)	3	89	(18.8)	358	(19.0)
4	133	(27.6)	403	(21.4)	4	107	(22.6)	365	(19.4)
5	74	(15.4)	314	(16.7)	5	91	(19.2)	315	(16.7)
6	38	(7.9)	134	(7.1)	6	35	(7.4)	113	(6.0)
7	76	(15.8)	259	(13.8)	7	63	(13.3)	285	(15.1)
8	9	(1.9)	45	(2.4)	8	1	(0.2)	36	(1.9)
9	20	(4.1)	136	(7.2)	9	45	(9.5)	312	(16.6)

$\chi^2 = 16.4$ ($p<.01$) $\chi^2 = 33.7$ ($p<.01$)

*Code 2 = Sold for Dairy Use
3 = Sold off for low production
4 = Sold off for reproduction problems
5 = Sold off due to injury or disease
6 = Died
7 = Udder problems
8 = Aborted
9 = Reason not given

V. SUMMARY CONCLUSIONS

This study utilized historical records of the DHIA data base in an attempt to determine if any significant associations could be detected between proximity to the +/-400 kV dc power line and various parameters associated with milk production, reproduction and stated reasons for removal of animals from dairy herds. In this study distance from the power line (measured to the nearest 1/4 mile) was used as a proxy for potential exposure to air ions and electric fields which otherwise could only be measured by on-farm monitoring. Six strata (0-1/4, 1/4-1/2, 1/2-1, 1-3, 3-6, 6-10 miles) were defined: the outermost stratum was considered to be non-exposed and herds in this stratum were used as a control group for some comparisons.

Permission was obtained to use the stored records from 516 farms in the Minnesota counties traversed by the line. Analyses were conducted over 4 time periods; (1) prior to energizing of the line on October 17, 1978; (2) from October 17, 1978 to May 15, 1979 when the line was in operation approximately 6% of the time; (3) from May 15, 1979 to September 3, 1979 when the line was in operation approximately 71% of the time and (4) after September 3, 1979 when the line was essentially in continuous use. It was determined that there were sufficient numbers of animals and thus records, in all strata so that changes could be detected.

No significant effects on individual cow milk production could be detected either during lactations or between lactations at any of the 3 dates of interest. Herds on the 'official' plan (i.e. supervisor tested) were compared with those on the 'unofficial' plan (i.e. owner tested) and no significant differences were found. For the purposes of the study it appeared legitimate not to distinguish these 2 subpopulations.

Herd production increases as denoted by rolling herd averages were determined for 428 herds from May 1979 to September 1982. The herds in the inner stratum showed slightly higher increases than the average for all strata over this time period. However 32% of the herds in stratum 1 discontinued DHIA membership over this period compared with an average of 12.5% for the other 5 strata. Determination of the reasons for this disparity in attrition rates would require personal interviews with the herd owners thus violating the anoymity agreement and this was beyond the scope of this study.

Herds on test during September 1982 did not show any significant differences across strata in milk quality (as measured by % fat), and production efficiency (as measured by milk production per cow to grain ratio). Based on a much more limited data base udder health (as measured by % of cows with elevated somatic milk cell counts) showed no difference across strata.

Analyses of reproductive efficiency as measured by the mean and median intercalving intervals over 3 time periods did not appear to differ significantly by strata, nor was there any evidence of greater frequency of excessively long (>500 day) intercalving intervals in the inner strata as compared to the outermost stratum. No increases in the rate of recorded abortions over the time periods were detected which could be associated with proximity to the line. Nor did it appear that more animals were sold because of reproductive failure in the inner (1 and 2) strata herds as opposed to the outer (6) stratum.

Overall the rate of culling or removing animals from the herds for whatever reasons did not appear to differ between strata 1 and 2 and stratum 6. There did appear to be a clear excess of animals culled in stratum 6 during 1979-80 under the heading 'no reason given' but the reasons for this was not clear. After the power line was energized, more 1st lactation animals in strata 1 and 2 were reported sold because of injuries or disease than in strata 6. However, it was also observed that more 1st lactation animals were sold for dairy use from stratum 1. The data used in these comparisons was collected primarily in the years 1978, 1979 and early 1980. Some of the high strata 1 attrition observed as of September 1982 would have begun to occur in late 1979 but its potential for distoring these comparisons between strata is believed to be limited.

The failure to detect significant changes in production, reproduction and reasons for culling animals from the herd that could be associated with proximity to the power line and thus indirectly exposure to air ions or electric fields could be the result of two situations. Either there were no effects produced or that the techniques used or parameters used for these analyses were insufficiently sensitive or inappropriate to detect any effects. Theoretically it is possible that perhaps only a very few farmsteads in the innermost strata might be effectively exposed to ions or fields. Any resolution of this issue is well beyond the scope of this study.

The factors involved in the significantly lower retention rate of DHIA membership in stratum 1 could not be investigated in the present study without effectively violating the anonymity agreement with participants. This is a subject of some concern, however, and probably should be the subject of a separate investigation.

In both the inner and outer strata it is possible to locate a small proportion of farmsteads having serious difficulties as measured by either production decreases or reproductive problems or both. It was observed that some farms both near and far from the line had excellent production increases and current production over the time frame studied. A further study could perhaps be usefully undertaken to determine the reasons for any past or current problems in a sample of farms both near to and far from the line.

The data used in this study were collected for DHIA purposes and not as part of a planned experiment designed to test for power line effects. It, therefore, does not necessarily contain the most useful measures to test for power line effects. The investigators do however believe that the data utilized from the DHIA records was both informative and unbiased and supports the stated conclusions.

The DHIA data base was also subject to the possible influence of, as yet not well understood, factors which might confound some aspects of the present analyses. The search for the effects of confounding factors has expended the resources of present study, but should not necessarily be viewed as exhaustive. It is difficult to agree on when this point is reached and there is nothing in our present understanding of the problem which suggest such factors could be found, but further work could usefully be done.

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(b) Staff of the County Extension Service

(c) Farmers along the power line who gave permission for the use of their DHIA herd records.

(d) Members of the general assembly to stop the power line.

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(f) Mr. John Hynes and other staff of the Minnesota Environmental Quality Board.

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APPENDICES

APPENDIX I

Intraclass Coefficients* (R^2) of Herd Variable to Total Variability for Various Parameters+

Parameter	R^2(%)
pounds of milk	13.8
percent fat	8.5
packed cell volume	23.7
hemoglobin	22.1
red cell count	25.4
mean corpuscular hemoglobin	44.2
mean corpuscular volume	39.0
mean corpuscular hemoglobin concentration	23.0
white cell count	26.2
lymphocytes	18.1
total neutrophils	18.1
eosinophils	10.8
basophils	7.1
monocytes	22.8
glucose	54.2
blood urea nitrogen	60.0
cholesterol	23.3
sodium	44.0
chloride	26.9
magnesium	39.1
calcium	40.3
phosphorus	40.3
potassium	26.5
alkaline phosphatase	28.4
total serum protein	19.3
albumin	43.4
globulin	21.8
SGOT	38.5
CPK	53.0

*Intraclass coefficients or R^2 are defined as the ratio of between herd's sum of squares to the total sum of squares for that parameter. For example, for BUN, herd sum of square = 30360.62 and sum of squares total = 50562.6313 and the ratio is 0.60. This is interpreted as sixty percent of the total variability in BUN being attributable to the herd variable.

+Data obtained from Metabolic Profile Testing Program of 38 Holstein herds and 1508 animals. Supported by the Minnesota Agricultural Experiment Station Grant No. MN 20-047.

APPENDIX II

Example of DHIA Herd Summary

HERD CODE	TYPE OF RECORD	ASSOC	SUPVR	LAB	CO	% DAY
41-00-0070	OFFICIAL DHI	62	1	1	62	22

TEST INTERVAL	LAB DATE	RECEIVED	MAILED
12-03 01-05	01-06	01-07	01-14-79

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

12-08

REPORT 56

J. WILLIAM MUDGE
EXTENSION DAIRYMAN

OPTIONS
ACTION LISTS
365

JOHN DAIRYMAN
101 HAECKER HALL
ST PAUL
MN 55108

DHI 202
6-76

DAIRY HERD IMPROVEMENT

HERD SUMMARY

SAMPLE DATE	LAB
01-05-79	2.52
NUMBER COWS	COMPUTER
28	7.43
COW-DAYS	TOTAL
	9.95

PRODUCTION, INCOME AND FEED COST SUMMARY

DESCRIPTION	SAMPLE DAY AVG PER COW	DHI ROLLING HERD AVG 12 TESTS
NUMBER COWS	28	30.7
% COWS IN MILK	89	86
MILK LBS	40.0	14059
% FAT	3.93	3.78
FAT LBS	1.57	532
DRY FORAGE LBS	8	100 PCT DM 3049
HAY SILAGE LBS	25	100 PCT DM 3181
CORN SILAGE LBS	18	100 PCT DM 1766
OTHER FORAGE LBS		100 PCT DM 755
GRAIN LBS	14	100 PCT DM 6006
FORAGE DM PER CWT BW	2.0	1.9
ENERGY INDEX	96	115
PROTEIN INDEX	110	119
MILK PER LB GRAIN DM	3.4	2.3
VALUE OF PRODUCT $	4.58	1434
TOTAL FEED COST $	1.29	607
INCOME OVER FEED COST $	3.29	827
FEED COST PER CWT MILK $	3.23	4.32
MILK PRICE PER CWT $	11.45	10.20

MANAGEMENT INFORMATION

SAMPLE DAY FEED	AVG LBS CONSUMED	PCT DM	NET ENERGY	CRUDE PROTEIN	COST $/TON
HAY - - - - - -	8	90	51	15	55
CORN SILAGE - -	18	27	59	9	19
HAY SILAGE - -	25	50	50	16	25
GRAIN INDIV FED	14	84	73	*13	85

* 13% CRUDE PROTEIN RECOMMENDED

SUMMARY OF COWS NOW IN HERD

LACT NO	NUMBER COWS	PROJECTED 305-2X-ME MILK	FAT	INDEX	AVERAGE AGE	% IDENTIFIED SIRE	DAM
1ST	6	13533	493	99	2-05	67	67
OTHER	22	13373	515	99	5-09	77	41
ALL	28	13405	511	99	5-02	75	46

COWS MILKING ON SAMPLE DAY

LACT NO	NUMBER COWS	AVG DAYS IN MILK	AVG LBS MILK	AVG PEAK LBS MILK
1ST	5	93	40	43
OTHER	20	141	46	61
ALL	25	132	45	57

CURRENT MASTITIS EVALUATION

LACT NO	NUMBER COWS	PERCENT COWS NEGATIVE	SUSPECT	POSITIVE	V STRONG
1ST	5	20	20	20	40
OTHER	18	22	22	33	22
ALL	23	22	22	30	26

YEARLY SUMMARY

LACT NO	COWS ENTERING HERD NUMBER	%	COWS LEAVING HERD NUMBER	%
1ST	9	29	4	13
OTHER	7	23	14	45
ALL	16	52	18	59

REPRODUCTIVE SUMMARY

	NUMBER COWS	AVG DAYS SINCE CALVING	NUMBER COWS OPEN < 60 DAYS	60-120 DAYS	> 120 DAYS	NUMBER COWS BRED 1 TIME	2-3 TIMES	4+ TIMES	COWS - BREEDING INTERVAL < 18 DAYS	18-24 DAYS	> 24 DAYS	CALVED TO 1ST BRED DAYS	CALVED TO LAST BRED DAYS	MINIMUM CALVING INTERVAL MONTHS
PREGNANT COWS	7	276		6	1	6	1				1	74	85	12.0
POSSIBLY PREGNANT	11	147	1	7	3	7	2	2		1	3	72	119	13.1
OPEN COWS	10	44	8		1	1								

CONCEPTION RATE = 78%   HEAT DETECTION INDEX = 50%

AVERAGE AI SIRE PREDICTED DIFFERENCE

SIRE	NUMBER	MILK	DOLLAR
SERVICE	16	843	94
1ST LACT	4	729	91
OTHER	15	220	12

COWS DRY BEFORE CALVING

NO COWS	AVG DAYS DRY	< 40 DAYS	40-70 DAYS	> 70 DAYS
18	60	4	9	5

BREED OF HERD	AVERAGE BODY WT
HOL	1230

DAILY HERD TOTALS

MILK SOLD	DHI MILK	GRAIN	INCOME OVER FEED COST
828	1119	392	92

SAMPLE DAY PRODUCTION SAMPLE DATE	TOTAL COWS	% IN MILK	MILKING COWS ONLY AVG DIM	MILK	%	DHI ROLLING HERD AVG ENTIRE HERD MILK	%	FAT
1-05-79	28	89	132	45	3.9	14059	3.8	532
12-02-78	28	75	148	35	3.7	14098	3.8	532
11-07-78	29	72	158	34	3.9	14270	3.8	540
10-12-78	28	86	163	38	3.6	14317	3.8	542
9-16-78	26	96	182	41	3.7	14214	3.8	540
7-22-78	33	85	167	43	3.5	13958	3.8	535
6-13-78	33	97	161	48	3.9	13797	3.8	527
5-17-78	33	89	148	51	3.9	13601	3.8	51[illegible]
4-18-78	32	84	123	51	3.9	13505	3.8	509
3-21-78	33	79	133	53	3.8	13409	3.8	503
2-19-78	31	64	128	49	3.8	13368	3.7	500
1-08-78	30	83	168	43	3.9	13639	3.7	509
12-12-77	29	86	167	44	3.9	13793	3.7	514

APPENDIX III

DHIA Individual Cow Report - Example

JOHN DAIRYMAN — 101 HAECKER HALL — ST PAUL — MN 55108 — 1202

HERD CODE	TYPE OF RECORD	ASSOC	SUPVR	LAB	CO	SC UNIT	TEST INTERVAL		LAB DATE	RECEIVED	MAILED	BREED	MATURE WT	NO COWS	INTERVAL	SAMPLE DATE	RPT	PAGE
41-00-0067	OFFICIAL DHI	62	1	1	62	22	12-03	1-05	1-06	1-07	1-14-79	HOL	1300	28	34	1-05-79	56	1

DAIRY HERD IMPROVEMENT
DHI 200
5-78

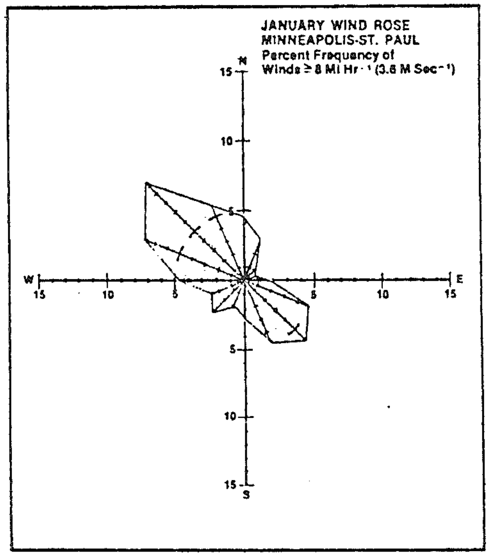
COW REPORT

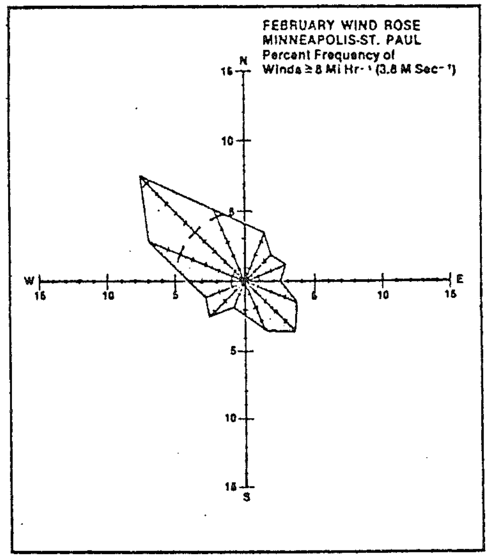
INDEX NUMBER	BREED	PERMANENT IDENTIFICATION OF COW	COW'S SIRE	LAST MILK LBS	SAMPLE DAY DATA MILK LBS	% FAT	INCOME OVER FEED COST $	MASTITIS	LBS TO FEED GRAIN	PROT 44	BARN NAME	DATE CALVED	[illegible]	AGE AT CALVING	DAYS DRY	LACTATION-TO-DATE DAYS IN MILK	MILK LBS	% FAT	FAT LBS	PROJECTED 305-2X-ME MILK LBS	FAT LBS	PROD INDEX	[illegible]	REPRODUCTION DUE DATE	SERVICE SIRE	REMARKS (OVER)
0025	H	41XHI1201	17H260	52	58.1	3.7	4.86	1	21		ANGIE	11-10	4	4-11	54	57	2881	37	106	10985	385	79		OPEN		
0023	H	41XGN5652	29H2296	39	30.4	3.8	2.32	2	9		ARLENE	8-15	4	4-11	45	144	7095	44	315	12622	568	102	1	8-23	21H415	
0062	H	41AZG2357			56.0	3.5	4.43		21		AUGUST	12-20				17	771	39	30							N
0008	H	41XFC8011	29H2346	34	33.8	4.2	2.79	3	11		BETSY	6-29	8	10-00	133	191	7426	38	282	11028	425	80	3	9-08	21H318	
0029	H	41WGG0870	21H232		68.1	3.9	5.85	N	28		BETTY	11-29	3	4-09	72	38	2329	43	100	14873	533	112				
0041	H	41WFG1725	17H348	64	63.3	4.0	5.55	T	24		BLUE	9-28	4	5-08	67	100	6014	40	239	14219	550	107	1	9-14	21H369	
0026	H	41WFW3625	....		FRESH						BONNIE	1-04	4	5-00	93											
0021	H	41AZD3871	17H240	17	49.5	5.2	4.81	N	22		CANDY	2-04	3	4-09	95	336	16316	46	757	15088	694	116	4	9-16	21H417	
0031	H	41WFL1210		24	20.3	3.7	1.36	1	4		CAREY	11-06	3	3-10		51	1326	38	51	4977	181	34	1	9-03	21H266	A
0037	H	41WFP6996	21H232		39.0	4.0	3.17	1	14		CARLA	12-04	3	4-00		33	1133	44	50	8761	320	63				A
0046	H	41WFP6997	21H232		83.5	4.1	7.38	T	36	1	CHRIS	12-03	2	4-01	42	34	2527	45	114	18793	709	152				
0042	H	41WFW3608	21H224	47	59.9	3.9	5.14	T	23		COOKIE	11-03	2	3-07	33	64	3079	38	116	11230	402	82	1	10-08	21H396	
0038	H	41WFL1169	21H206		70.3	3.9	6.06		29		CUTIE	12-19	3	4-04	67	13	1038	42	44	15633	551	118				
0014	H	41XX1568	21H246	39	35.1	3.5	2.66	N	10		DAISY	4-06	4	6-04	50	275	15076	34	517	15815	548	107	1	P 3-31	21H240	D
0052	H	41XHC4949		29	26.4	4.3	2.12	1	7		DARLEN	2-20	5	4-01	7	320	17326	42	722	17260	719	127	5	6-26	21H371	
0057	G	41C135246	21G237	31	25.2	4.7	2.18	3	11		DAWN	10-02	1	2-11		96	2732	44	120	7710	348	60	1	9-15	21H319	
0058	X	41XIE9996		30	26.3	5.1	2.34	1	8		DIANE	9-21	1			107	3439	44	150				1	8-25	21H415	
0057	H	41WGG0363	17H365	46	59.7	3.1	3.83	2	19		DIXIE	8-03	1	2-00		156	7384	30	223	16551	494	113	1	7-09	21H268	
0044	H	41WFG8083	29H2189	50	50.9	3.3	3.96	T	17		DONNA	5-29	6	7-04	86	222	13070	35	453	16119	575	119	1	P 5-17	21H408	
0060	H	41CAH8566	17H240	40	40.1	3.1	2.93	N	15		DORY	10-20	1	2-00		78	2315	36	100	11359	393	81	1	10-06	21H386	
0048	H	41AZD0298			51.5	4.1	4.39		21		DUSTY	12-15	3	4-11	39	22	952	45	43	11227	416	83				A
0007	H	41AVZ3863	21H257	16	16.5	3.9	1.06	2	2		GINGER	3-31	7	8-09	57	281	14109	43	602	14820	645	111	1	P 4-08	21H406	
0061	G	41XR31357	29G775		55.2	3.9	4.67	T	26	1	JULY	12-09	1	2-01		28	1293	43	56	15005	629	123				N
0045	H	41WB09324	29H1895	46	51.4	4.0	4.39	1	19		LIZ	8-07	11	13-01	54	152	7947	38	299	15697	604	120	1	OPEN	21H385	
0006	H	41ACE5728	....	41	38.5	3.4	2.94	3	11		MARCH	9-10	6	7-07	70	118	4619	32	147	9558	303	62	3	9-25	21H256	
0050	H	41AZD1631	17H255		DRY		-.73		0		MELISA	2-10	1	3-03	40	290	15778	36	562	17040	601	116	1	1-16	21H184	
0047	J	41AWZ3658	21J305	19	19.8	5.4	1.78	N	9		PEBLES	1-29	3	5-00	8	342	12489	49	607	11447	542	89	3	3-22	21H385	D
0051	H	41XHB4846	29H2345	28	DRY		-.73	1	0		VIOLET	2-13	2	4-01	23	304	16765	37	617	17100	629	119	1	2-01	17H251	
******		******	******		******		******				305 DAY	AND COMPLETED			RECORDS	******	******		******	******	******	******		******	******	******
0021	H	41AZD3871	17H240								CANDY	2-04	3	4-09	95	305	15240	46	701	15088	694	116		305 DAY		R
0037	H	41WFP6996	21H232								CARLA	5-02	2	3-05	59	216	9745	39	377	13185	509	98		COMPLETE		C
0040	H	41WGI1964									DANDY	8-04	2	3-09	51	140	4803	37	180	9296	348	65		SOLD-PROD		C3
0052	H	41XHC4949									DARLEN	2-20	5	4-01	7	305	16922	42	705	17260	719	127		305 DAY		R
0013	H	41AHY8445									SALLY	10-27	6	7-08	88	339	12688	31	396	12057	373	77		SOLD		C5
0051	H	41XHB4846	29H2345								VIOLET	2-13	2	4-01		304	16765	37	617	17100	629	119		COMPLETE		C

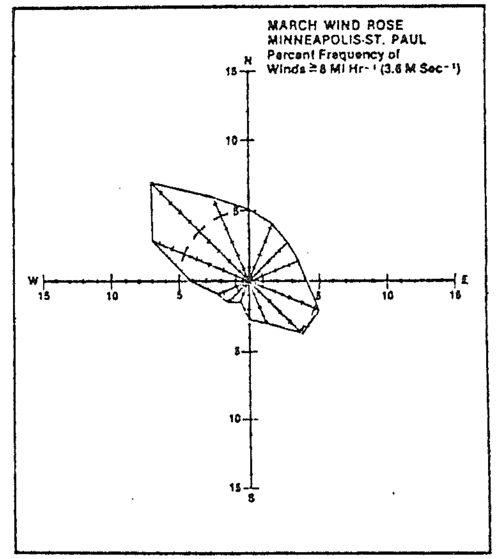
APPENDIX IV

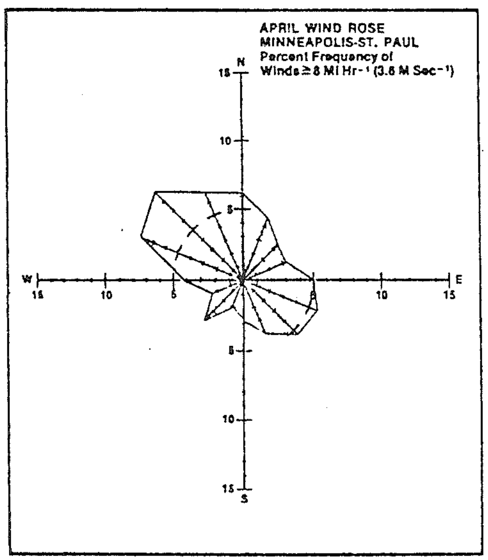
WIND ROSES

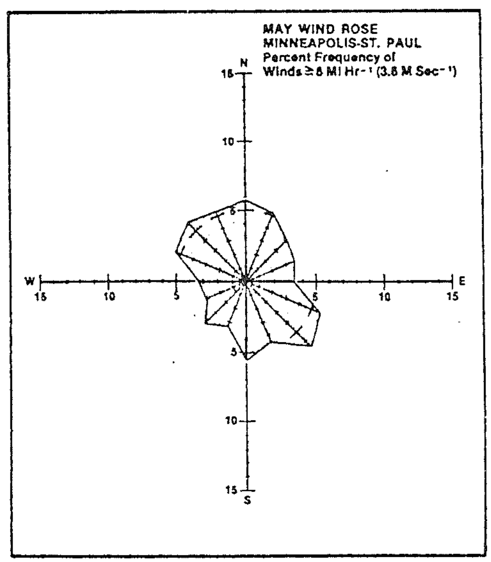
Based on 10 Recent Years

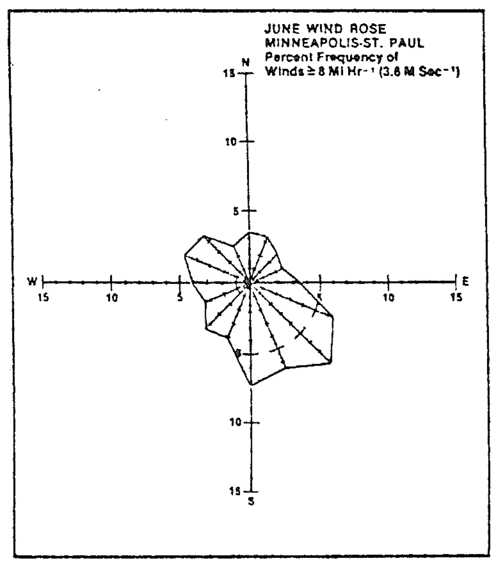

JANUARY WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
E
W
15
10
5

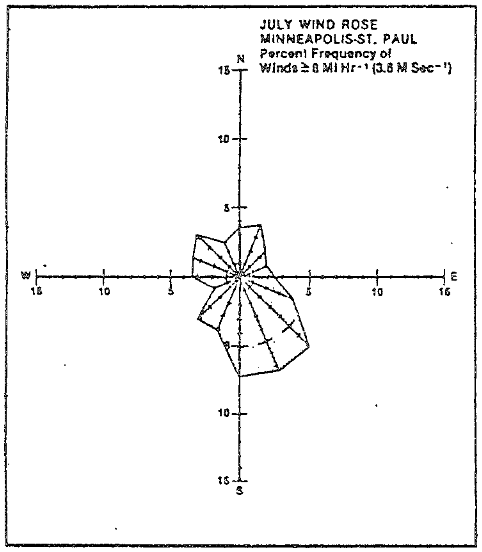

FEBRUARY WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
E
W
15
10
5

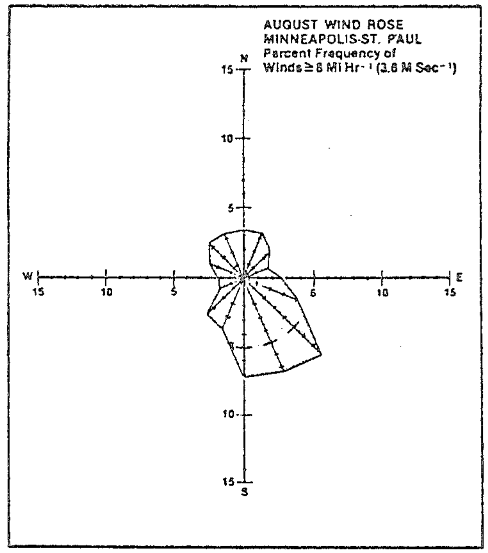

MARCH WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
E
W
15
10
5

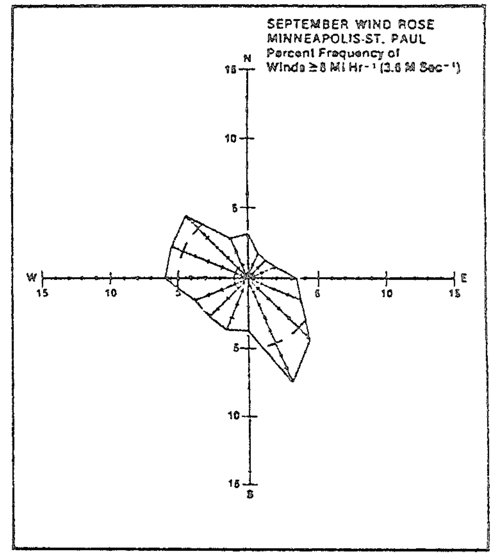

APRIL WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
E
W
15
10
5

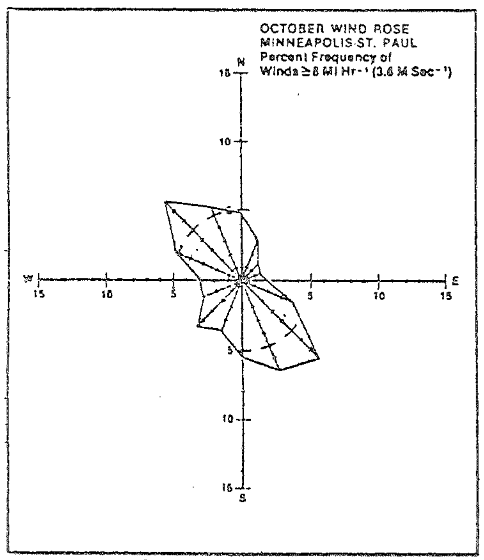

MAY WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
E
W
15
10
5

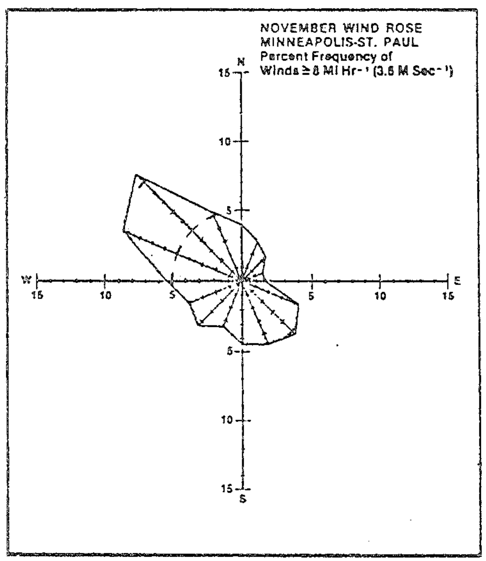

JUNE WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
E
W
15
10
5

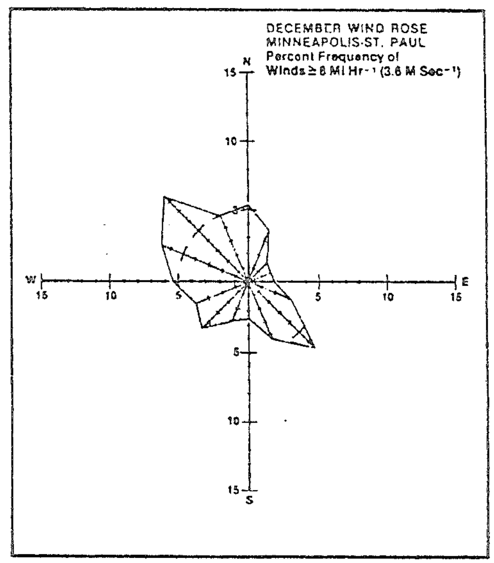

JULY WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

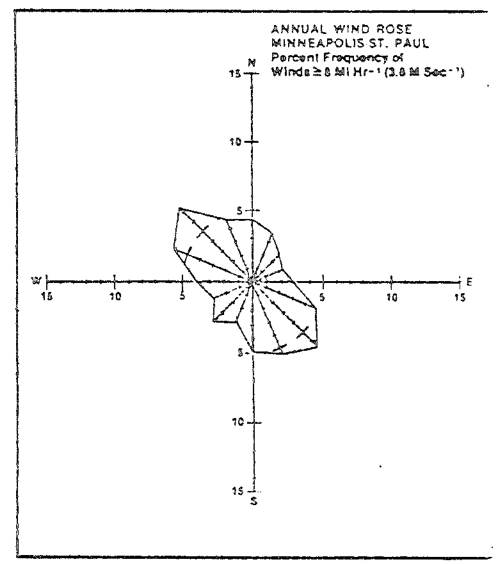

AUGUST WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

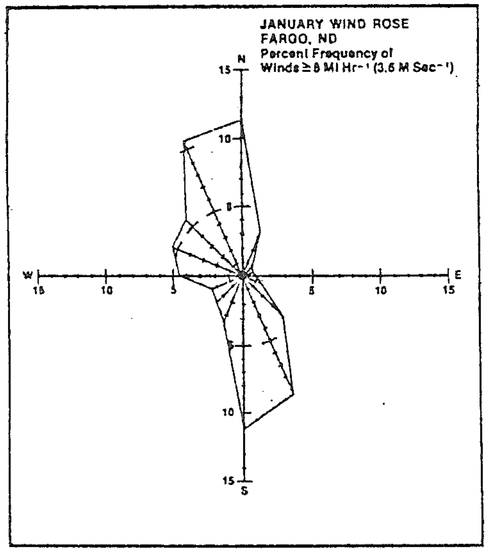

SEPTEMBER WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

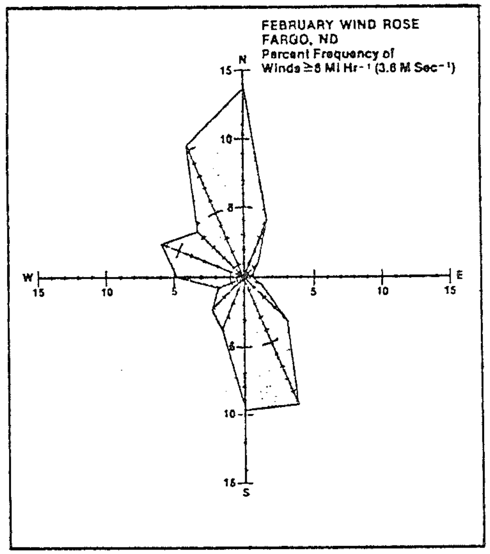

OCTOBER WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

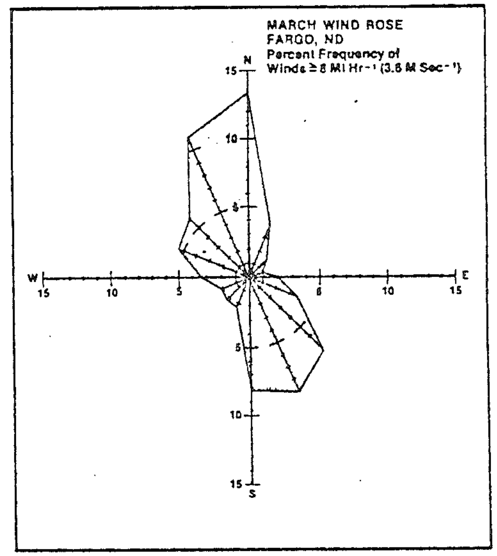

NOVEMBER WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

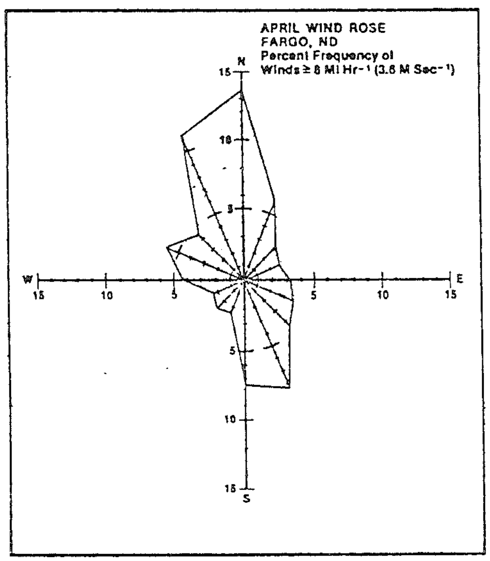

DECEMBER WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

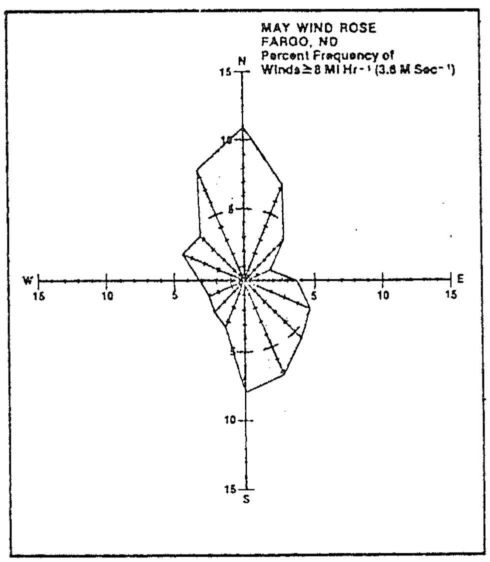

ANNUAL WIND ROSE
MINNEAPOLIS-ST. PAUL
Percent Frequency of
Winds ≥ 8 Mi Hr⁻¹ (3.6 M Sec⁻¹)
N
S
W
E
15
10
5

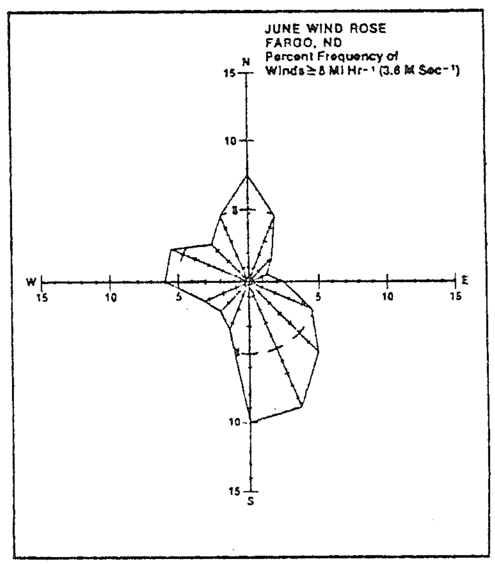

JANUARY WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr⁻¹ (3.6 M Sec⁻¹)

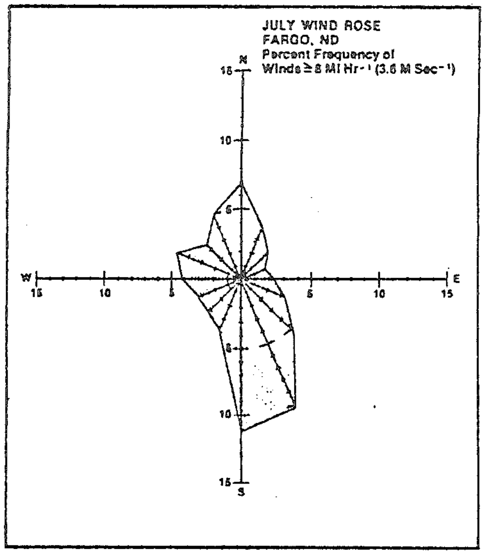

FEBRUARY WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr⁻¹ (3.6 M Sec⁻¹)

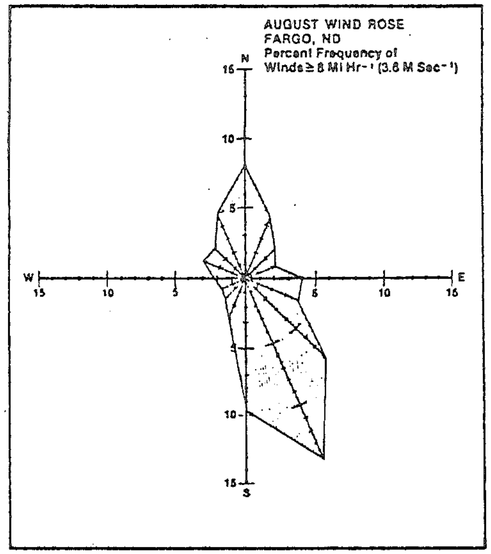

MARCH WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr⁻¹ (3.6 M Sec⁻¹)

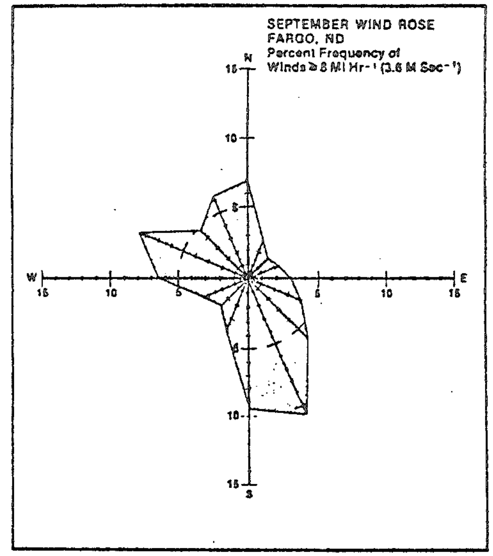

APRIL WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr⁻¹ (3.6 M Sec⁻¹)

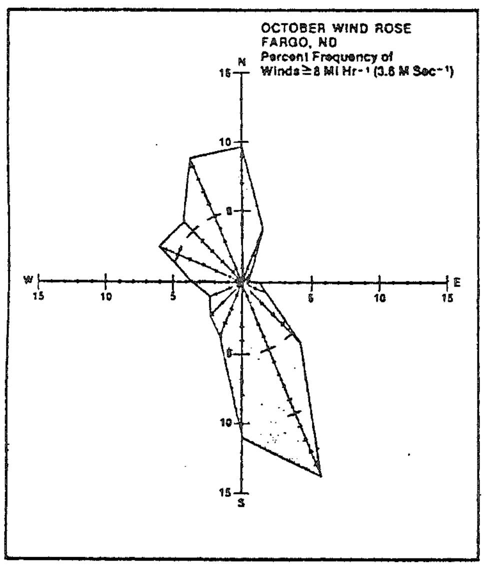

MAY WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr⁻¹ (3.6 M Sec⁻¹)

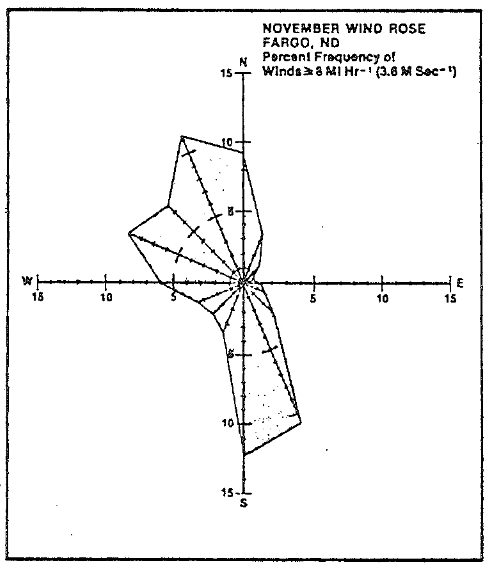

JUNE WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr⁻¹ (3.6 M Sec⁻¹)

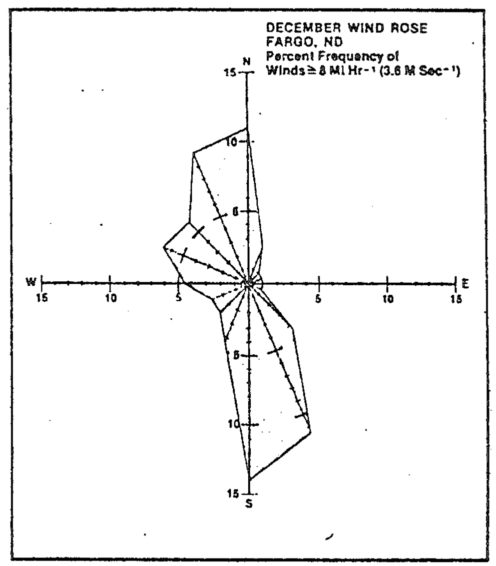

JULY WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

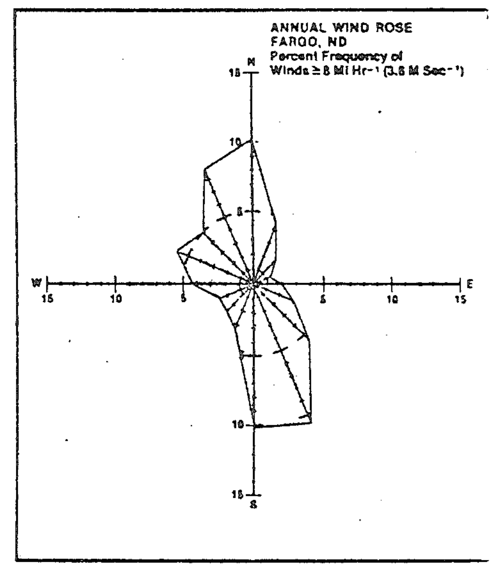

AUGUST WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

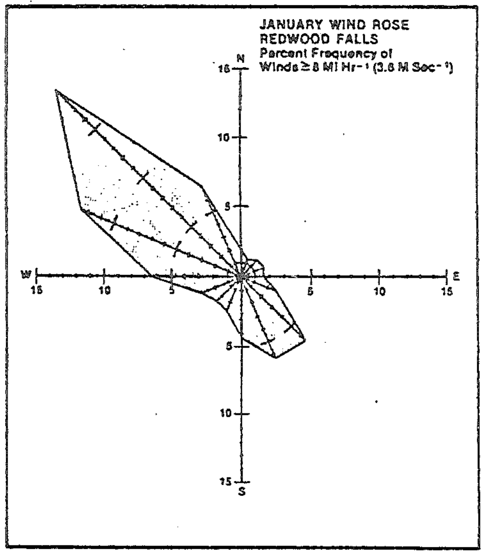

SEPTEMBER WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

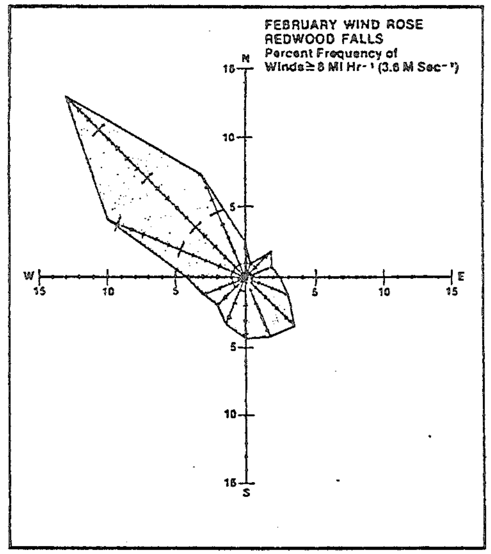

OCTOBER WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

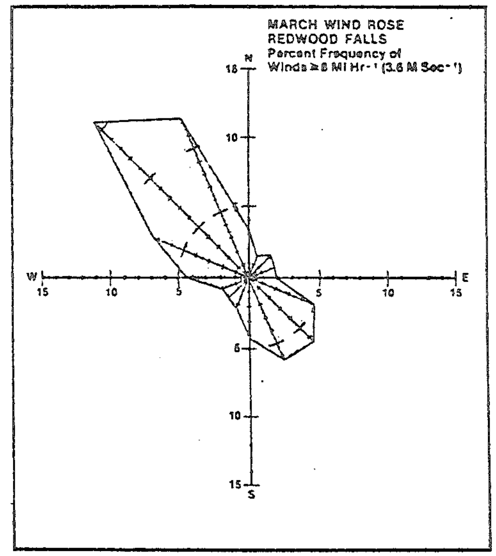

NOVEMBER WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

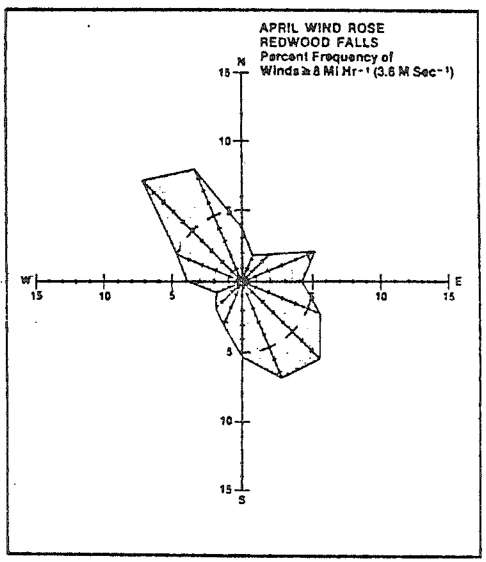

DECEMBER WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

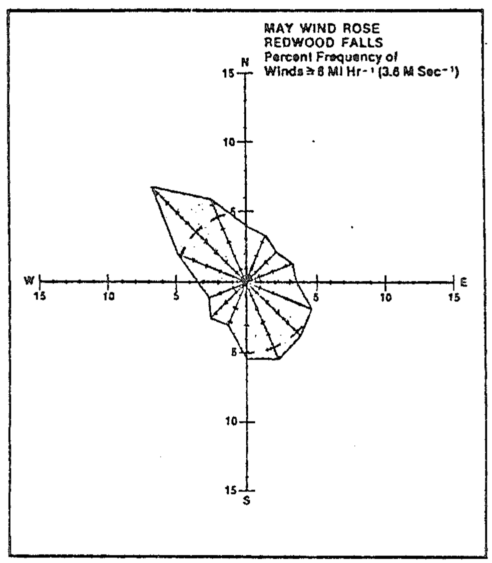

ANNUAL WIND ROSE
FARGO, ND
Percent Frequency of
Winds ≥ 8 MI Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E
15
10
5

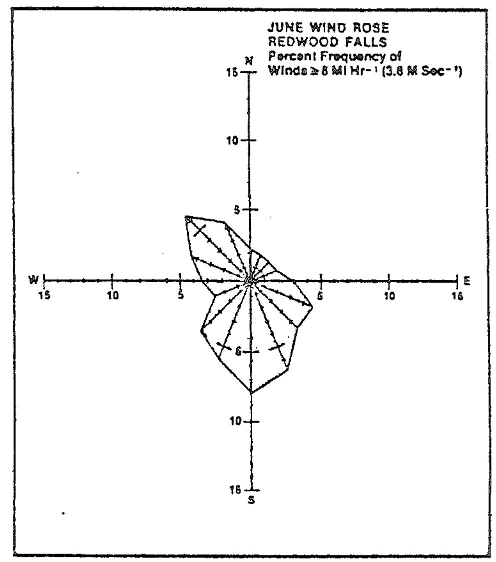

JANUARY WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
E
S
W

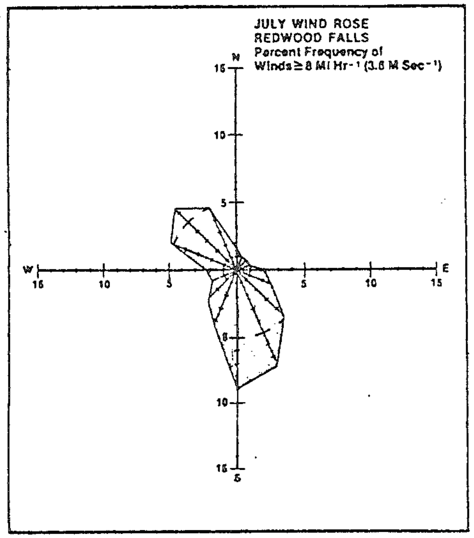

FEBRUARY WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
E
S
W

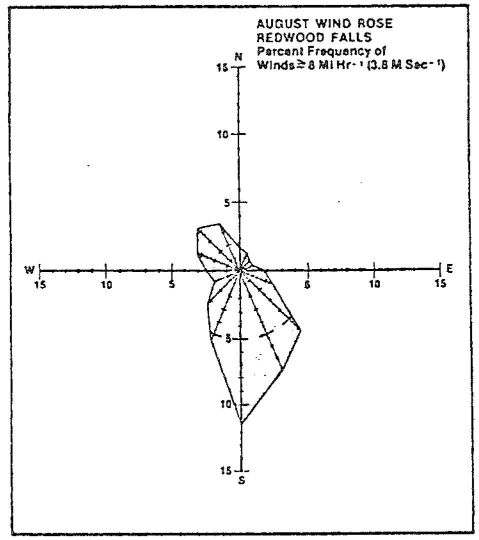

MARCH WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
E
S
W

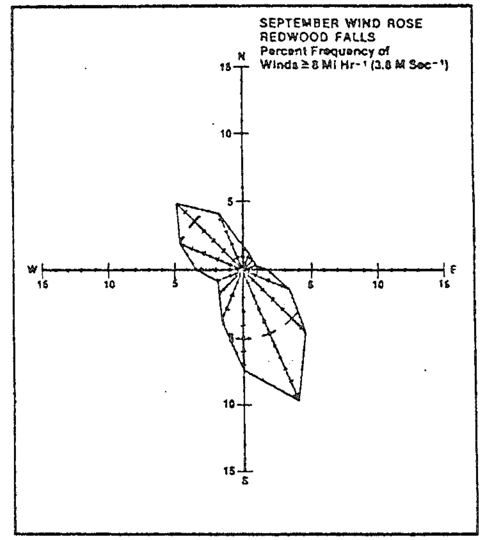

APRIL WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
E
S
W

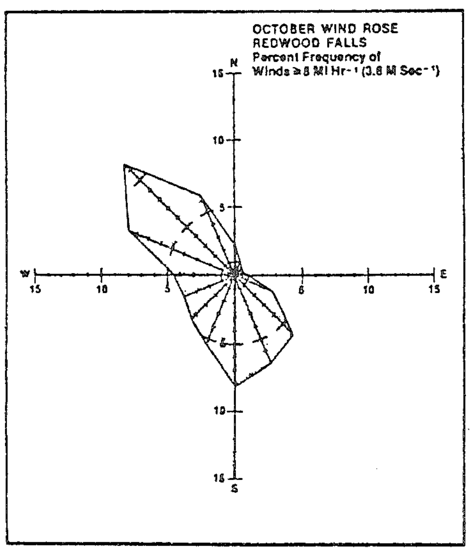

MAY WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
E
S
W

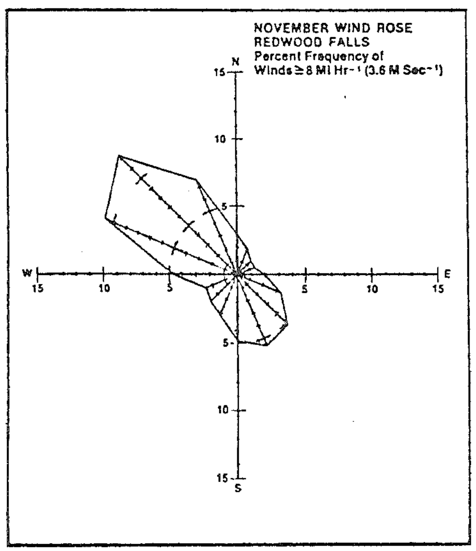

JUNE WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
E
S
W

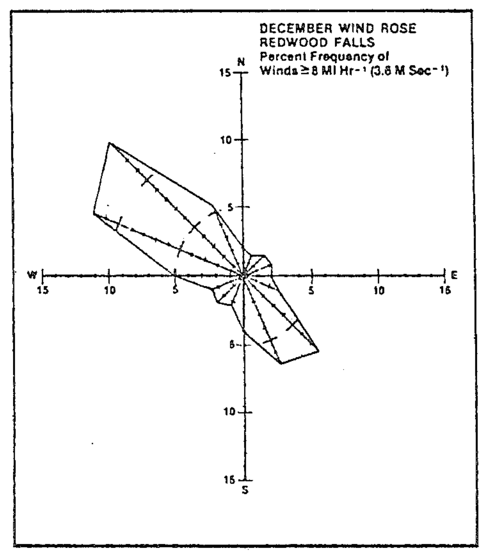

JULY WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E

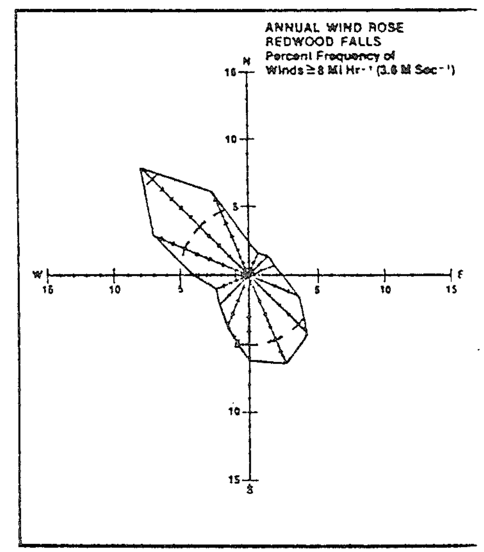

AUGUST WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E


SEPTEMBER WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E


OCTOBER WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E


NOVEMBER WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E


DECEMBER WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E


ANNUAL WIND ROSE
REDWOOD FALLS
Percent Frequency of
Winds ≥ 8 Mi Hr^{-1} (3.6 M Sec^{-1})
N
S
W
E

APPENDIX V

Human Subjects Research Committee Approval for Study

Return this form (please type) with appropriate attachments to: Committee on the Use of Human Subjects in Research, 5th Floor, AdmSvCtr, 1919 University Ave., St. Paul, MN 55104

METHODOLOGICAL PROTOCOL REQUEST FOR APPROVAL FORM

This study is covered under the Methodological Protocol listed below:

______#1: Questionnaires X #4: Secondary Use of Data

______#2: Interviews ______#5: Archival

______#3: Observational Research

Investigator/
Project Director Drs. D.K. Sorensen & R. A. Robinson Phone Number 373-3890 or 373-1124

Project Title Statistical & Epidemiologic Study of Bovine Performance Associated With CPA/UPA High Voltage DC Power Line in West Central Minnesota.

Department College of Veterinary Medicine

Mailing Address 301 Veterinary Science Building

Inclusive Dates of Project June 15 - December 31, 1982

Subject Population: Age Range Adults Number of Subjects Unknown

How are subjects chosen (classes, referral, canvassing, etc., be specific)?

From computerized lists of Dairy Herd Improvement (DHI) Association members in counties of Western Minnesota.

ABSTRACT (Clearly state the purpose of the study in which human subjects will be involved. Specify what will be done to or for the subjects or participants, as applicable to the relevant Methodological Protocol. USE BACK OF PAGE IF NECESSARY.)

Approximately 700 dairy farmers in Western and Central Minnesota will be sent explanatory letters and release forms to obtain their permission to use their archival DHI records. This is a prerequisite to a statistical study of the effects/association of the high voltage DC (UPA/CPA) power line that crosses farms in 11 Minnesota counties. In the accompanying letter and form farmers are guarranteed that no individual identification of their farm data will be possible from the final report.

NOTE: If this research is to be supported by external funding, the Board of Regents' Policy requires that a Request for Approval for Individual Protocols be completed. Please call the Committee Office (373-9895) for further Information.

-OVER-

-102a-

NOTE: A copy of the consent form/statement and supporting information (e.g., proposed interview schedule, questionnaire, approval from officials, etc.) as applicable to the relevant Methodological Protocol under which this study is to be conducted must be attached. NO RESEARCH MAY BEGIN UNTIL YOU HAVE RECEIVED A POSTCARD FROM THIS OFFICE INDICATING APPROVAL.

- -

I hereby certify that I will adhere to the guidelines as described in the Methodological Protocol. I understand that no contact with subjects may begin until I receive approval from the Committee office.

D L Lorens (signature) 6-10-82

Signature of Principal Investigator Date

- -

If student research, the application must be signed by the Faculty Advisor.

Signature of Faculty Advisor Date

If required by department:

Signature of Department Chairman Date

10/78

RE: Methodological Protocol # 4.

Dear Dr. Robinson:

Your Methodological Protocol Request for Approval was received in the Committee office on 6/14/82, and has been administratively approved on 6/14/82 as within the guidelines of the referenced Methodological Protocol.

I would like to remind you that it is the responsibility of the investigator to bring to the attention of the Committee any proposed change in the project or any emergent problems that will affect human subjects.

On behalf of the Committee, I wish you luck with your research.

Sincerely,

Anne Munro (signature)

Anne Munro
Executive Secretary to the
Committee on the Use of Human
Subjects in Research

FOR COMMITTE

Date

APPENDIX VI

Powerline Description

The Cooperative Power Association (CPA)/United Power Association (UPA) $\pm$ 400 kV dc powerline connects the Coal Creek electric generating plant near Underwood, North Dakota with the Dickinson converter station in Wright County near Rockford, Minnesota. Coal Creek is a two unit lignite minemouth plant capable of generating 1060 megawatts (MW) of power. CPA has 594 MW of that capacity and UPA has 466 MW.

The powerline is 437 miles long, with 176 miles passing through eight rural counties of west central Minnesota (Figure 1). The ownership of the Minnesota portion of the line was transferred by CPA/UPA to the United States of America acting through the administrator of the Rural Electrification Administration in September 1980. At the same time the powerline was leased back to CPA/UPA for the purpose of operating and managing it.

The powerline is bipolar, direct current (dc), and normally operates at $\pm$ 400 kilovolts (kV). Each of the two pole conductors is made up of a pair of subconductors, each of which is made up of 47 strands of aluminum wire (for low electrical resistivity) wound over 7 strands of steel wire (for mechanical strength). The subconductor's outside diameter is 3.82 cm (1.504 in.) and the distance between subconductor centers is 45.7 cm (18 in.). The distance between conductors is 12.2 meters (40 feet).

Two, 1.27 cm (0.5 in.) diameter, stranded, galvanized steel, shield wires are suspended above the pole conductors for lightning protection.

The conductors are supported by steel lattice towers at approximately one quarter mile intervals (400 meters). The minimum ground clearance of the conductors is 15.2 meters (50 ft.) in Minnesota and 10.7 meters (35 ft.) in North Dakota. The actual midspan clearance varies a meter or more above the minimum depending on ambient temperature, line current, and ice loading. The height of the conductors at the support towers in Minnesota is typically 30 meters (100 ft.).

The powerline control system regulates line voltage to within 0.625% of $\pm$ 397.5 kV at the North Dakota terminal. At any other point on the line, the voltage will be reduced by the voltage drop between that point and the North Dakota terminal. Since the line resistance is approximately 14 ohms per pole, the voltage at the Minnesota terminal can vary from

$$(397.5 \text{ kV}) \times 1.00625 - (14 \text{ ohms}) \times (125 \text{ Amperes}) = 398 \text{ kV}$$

at minimum load, to

$$(397.5 \text{ kV}) \times 0.99375 - (14 \text{ ohms}) \times (1500 \text{ Amperes}) = 374 \text{ kV}$$

under overload conditions.

A reduced voltage (±300 kV) operating mode is available for use under abnormal conditions such as when the line insulation has not completely failed but cannot withstand full voltage. This permits limited power transmission to continue until repairs can be made.

The powerline is normally operated in the bipolar mode, that is, with current travelling from one converter station to the other through the conductor energized at +400 kV with respect to ground, and returning through the conductor energized at -400 kV. The powerline is capable of transmitting up to one-half rated power through one conductor when the other is disabled. During such monopolar operation, current carried by the operating conductor is returned either through the earth using ground elecrodes near each converter station ("ground return") or through the de-energized conductor ("metallic return"). Because monopolar operation is less efficient and reliable than bipolar operation, it is used primarily for maintainance or repair procedures.

The ac/dc conversion process results in the generation of current harmonics on the ac side and voltage harmonics on the dc side of each converter. The characteristic dc side harmonics occurs at multiples of 12 times the 60 cycles/second (Hz) fundamental frequency (e.g. 720 Hz, 1440 Hz, etc.). Other harmonics are also present, but at much lower amplitudes. Since the harmonic frequencies are in the audible range, they can result in interference if coupled into telephone and other communications networks. For this reason, smoothing reactors and filters are included at each converter station to greatly attenuate the amplitude of the harmonics on the HVDC line.

For example, at rated operating conditions, the characteristic dc voltage harmonics generated by the converters are calculated to be:

Frequency	Harmonic Voltage
(Hz)	(kV)
720	26.6
1440	12.6
2160	8.3

The smoothing reactors and filters reduce the harmonics to:

Frequency	Harmonic Voltage
(Hz)	(kV)
720	3.2
1440	0.97
2160	0.65

The electric fields resulting from the harmonics are small compared to the dc electric field. For example, the maximum ground level electric fields resulting from the harmonic voltages given above with a 10.7 meter clearance are:

Frequency	Electric Field
(Hz)	(kV/m)
720	0.077
1440	0.022
2160	0.016

Fluctuations in the dc electric field resulting from space charge distribution variations are usually many times greater than the fields due to harmonic voltages.

The total electric field, ion current, and ion concentration varies considerably with meteorologic conditions. The Minnesota Department of Health and the Minnesota Environmental Quality Board have monitoring programs to determine total electric field, ion current, and small ion concentration both within the right of way and outside the right of way.

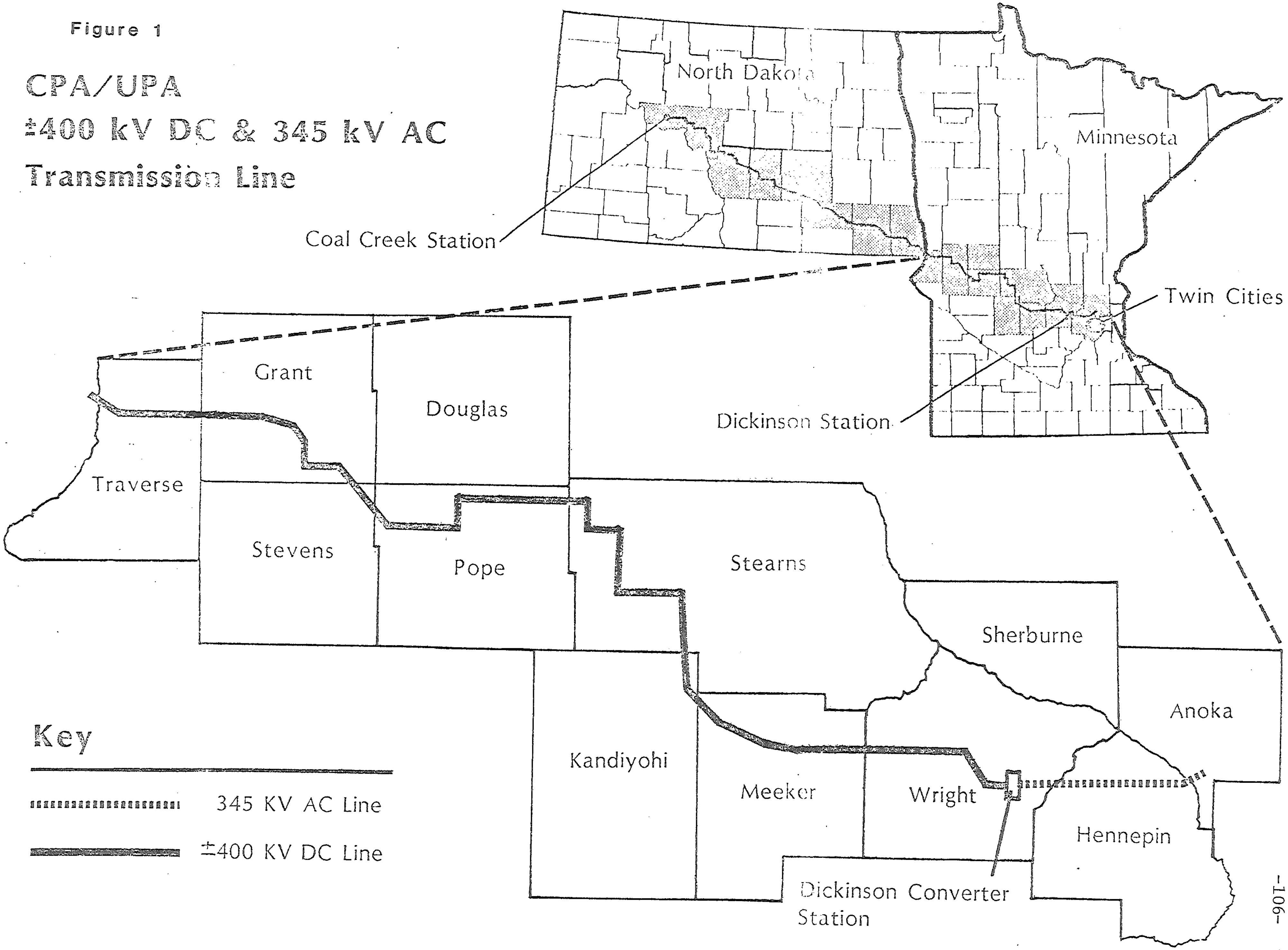
Preliminary results indicate that within the right of way the maximum electric fields at ground level can exceed ±30 kilovolts (kV) per meter (m) with an average value at 12 meters from the centerline of 10-15 kV/m. Ion current can exceed 70 nanoamperes per square meter with an average value at 12 meters of 10 nA/m^2. The ground level small ion concentration can exceed 50,000 ions per cubic centimeter (cm^3).

Outside the right of way, small ion concentrations and electric fields are enhanced on the downwind side of the line. At one quarter mile the half hour averages of the small ion concentration and of the electric field can vary from 100 to 4,000 $ions/cm^3$ and from 0.5 to 4 kV/m, respectively.

The magnetic field resulting from the powerline under normal operating conditions is static and can be calculated. Figure 2 shows the calculated ground level magnetic field profile during bipolar operation at an overload current of 1,500 amperes.

Figure 1

CPA/UPA ±400 kV DC & 345 kV AC Transmission Line



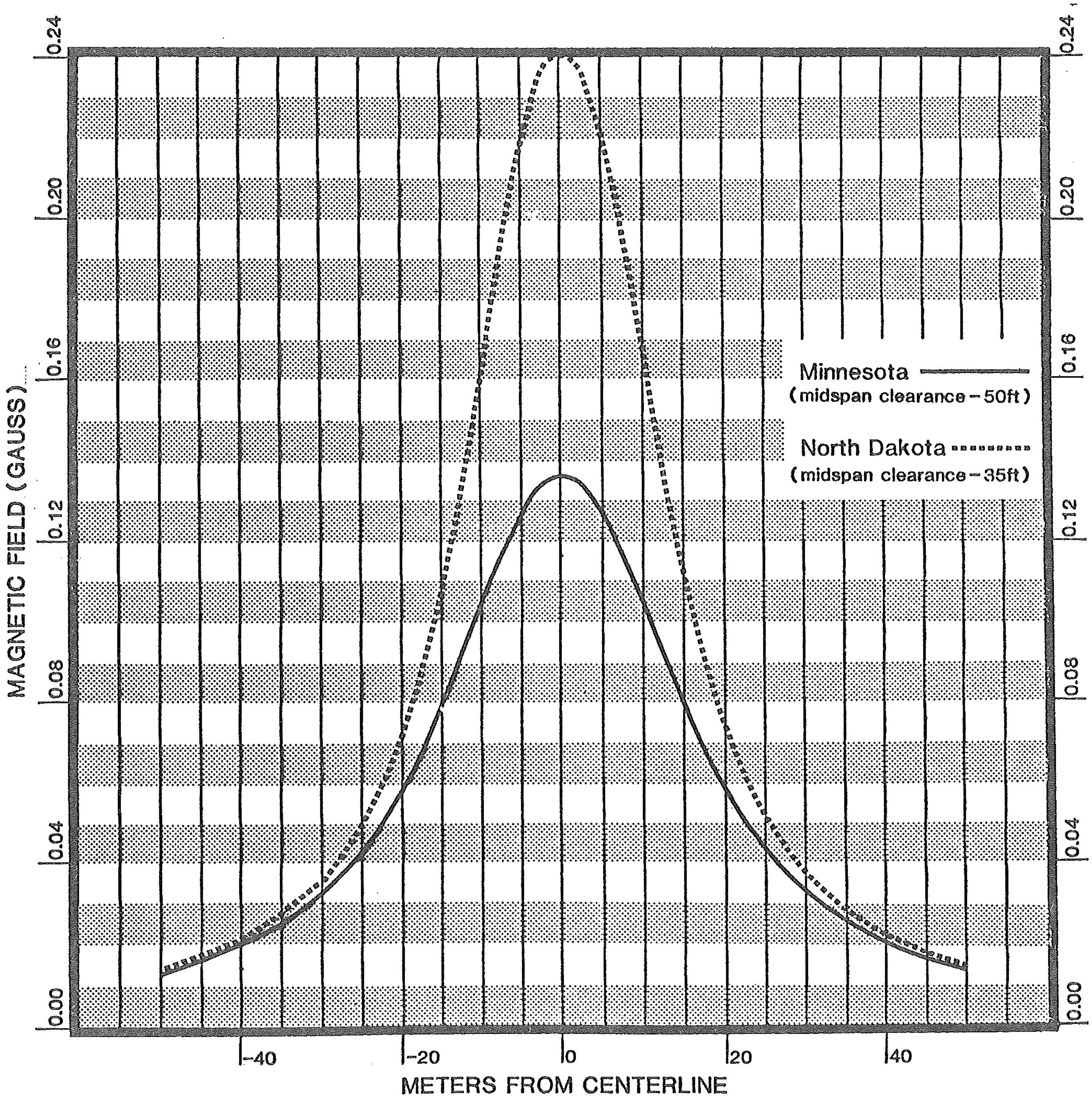


Figure 2. Calculated ground level magnetic field profile (1500 amperes bipolar)

APPENDIX VII

Synopsis of Proposed Phase II Study

If significant associations were shown between production, reproduction and culling of adult animals in the DHIA data based study, a second study was proposed to examine these associations in greater detail. This would attempt to document and measure all aspects of recognizable diseases and its effect on livestock production on farms both exposed and non-exposed to the power line. Specifically this would examine:

-- incidence, prevalence, geographic and seasonal patterns of specific diseases.

-- morbidity and mortality.

-- reproduction.

-- reasons for and rates of disposal of cull animals.

-- cause(s) of inadequate production.

-- non-specific disease syndromes.

-- management.

-- ability of herds to respond to improved management, nutritional or disease control programs and meet specific goals.

An alternative prospective study could also be considered in which selected farms identified in the DHIA study as having problems would be examined in detail to determine if recognized agents or explanations could account for these problems. Both exposed and non-exposed farms would be included in such a study. Any Phase II study would not be anonymous as was the present study.

Appendix VIII

UNIVERSITY OF MINNESOTA
TWIN CITIES

Department of Large Animal Clinical Sciences
College of Veterinary Medicine
C339 Veterinary Hospitals
1352 Boyd Avenue
St. Paul, Minnesota 55108
(612) 373-1810

Herd Code Number

Name (Computer Generated Label)

Address

Town

State Zip

We are writing to ask your assistance in a study being done by the College of Veterinary Medicine, to investigate any changes in the overall performance of dairy cattle herds near the recently constructed and energized CPA/UPA DC power line that crosses western and central Minnesota. This work will be based on a detailed analysis of Dairy Herd Improvement (DHI) Association records. To ensure success of this study, it is crucial that we obtain permission to make use of individual records from as many qualifying DHI herds located within 10 miles either side of the line as possible.

This study, which is being done for the Minnesota Environmental Quality Board, will only make use of DHI records of Holstein dairy herds that date back to 1978, before the line was first energized; to determine if there were any changes in performance in 1978 or in subsequent years. Specifically; we intend to look at lactation and production records of individual cows, rolling herd averages before and after the line was operating, and reported reasons for culling from these herds. This will be a statistical study that is limited to data previously on record, but it may reveal whether further in depth studies of effects on livestock as related to the power line should be undertaken.

Because of your farm location, and the herd sampling before and after the charging of the power line, your previously computerized records do qualify for inclusion in this study. Your County Extension Agency or your local veterinarian are familiar with this study and can answer most questions that you have. In addition, please feel free to contact Dr. Ashley Robinson at the College of Veterinary Medicine (address above) or call him collect at (612) 373-1124 for more information.

If you are willing to allow us to make use of the applicable portions of those archival DHI records (without further solicitation), please then check the box(es), sign, and send back to us by return mail the attached release form in the pre-addressed envelope.

Thanking you in advance for your cooperation.

Sincerely,

D K Sorensen

D. K. Sorensen
Associate Dean
College of Veterinary Medicine
University of Minnesota

J. W. Mudge

J. W. Mudge
Extension Dairyman - DHI
University of Minnesota

UNIVERSITY OF MINNESOTA
Twin Cities

Department of Large Animal Clinical Sciences
College of Veterinary Medicine
C339 Veterinary Hospitals
1352 Boyd Avenue
St. Paul, MN 55108
(612) 373-1810

Release Form

☐ I hereby give permission to the College of Veterinary Medicine, University of Minnesota to utilize my DHI records for a study of the effects of the CPA/UPA High Voltage DC Power Line on dairy cattle performance. I understand that confidentiality will be maintained, and that no individual identification from my coded records will be made in the statistical report to the Minnesota Environmental Quality Board.

(Computer Generated Label)

Signed_______________________________

☐ Please check this box if you would like a summary copy of the final report of the study at the end of 1982.

Room for comments: