SAMPLE SIZE DETERMINATION FOR AN IRRIGATION BASELINE STUDY

by

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INTRODUCTION

Water issues in Kansas are currently a much-debated topic, and will continue to be so from this point in time forward. Water policies need to be developed which equitably distribute the available water among its many users. Regardless of how effective the intent of a given water plan may be, it is nevertheless only as good as the the information upon which the plan is based.

Therefore, this research project was initiated to gather data from the irrigation sector of the many users of the water resources of Kansas. To obtain some indication of the trends in irrigation usage, there needs to be some set point from which to measure. A survey of irrigation farmers in a well defined irrigation region, a groundwater management district, was initiated.

This thesis examines the most efficient methodologies for undertaking such a data-gathering project. Its objective is to find the fastest and least expensive manner in which to obtain the most accurate and widest ranging information.

The success of the study depended upon finding a unique group of irrigators, a population which was strictly identifiable. There are five Groundwater Management Districts in Kansas. A map of the districts is located in Appendix C. They all fit these qualifications. Characteristics of groundwater formations vary throughout the state; there are distinct regions present. The Groundwater Management Districts address local groundwater problems with state expertise, with the solutions and policies being initiated and administered by the local users (Hay and Pope, 1974). Therefore, irrigation characteristics will vary less between irrigators within a district than they will vary between irigators of different groundwater districts.

The Equus Beds Groundwater Management District #2 (Equus Beds GMD2) in south-central Kansas was chosen for the study. This choice was made for three main reasons. First, for economic reasons, it was closest to Manhattan, the location of the investigators of the study. Second, it is the smallest of the five districts, and therefore requires the smallest sample size to achieve the desired accuracy. Third, more irrigator cooperation was anticipated from this district than any of the others. The reason behind this theory is that there is probably less controversy over water problems in this district than in any of the other districts. Western Kansas uses approximately fourteen times as much water as it replenishes, while the water table in south-central Kansas is essentially stable (Sloan, 1979). When farmers, irrigators, and those working in agribusiness in southwestern Kansas were asked, "Has groundwater depletion affected you?", over one-half replied positively (Kromm and White, 1981). Two areas of greater concern in south-central Kansas than that of groundwater depletion are water quality problems due to salt water intrusion, and the vast quantities of water which are being pumped for the City of Wichita.

The Equus Beds Groundwater Management District #2 covers about 500,000 acres in McPherson, Reno, Sedgwick, and Harvey Counties, of which about 50,000 are irrigated (Sloan, 1979). The Equus Beds Formation is composed of reworked sands, gravels, silts, and clays. Approximately half of the water pumped out of the Equus Beds is used for municipal purposes, serving a population of about 300,000 residents, including the city of Wichita. Rainfall in the district is about 28-30 inches per year (Soil Surveys of Reno County, 1966, Harvey County, 1974, and Sedgwick County, 1979). The topography is basically gently rolling and sloping, and the soil type ranges from silt loams and silty clay loams to sandy loams.

REVIEW OF LITERATURE

The goal of this paper is to discover the most efficient method for conducting an irrigation baseline study, more specifically, to find the correct sample size for such an undertaking. The optimum sample size is the one which is large enough to estimate the population characteristics with a desired degree of precision, yet small enough to be cost effective without achieving an unnecessarily high accuracy rate. Or, as Parten (1950) phrased it, "The most efficient sample is commonly considered to be the one which provides the most useful information per dollar rather than per case."

Steps to be considered when planning a survey or census are (Yates, 1981):

(1) Specifying what the survey is to accomplish.

(2) Specifying the population and the areas of information to research.

(3) Defining the type of data to be collected.

(4) Deciding upon the method by which the data will be collected.

(5) Choosing the sample size, selection method, and type of sample.

(6) Deciding whether or not the survey will ever be repeated.

The selection of an appropriate sample size can follow six basic steps (Cochran, 1977). They are:

(1) Selection of the desired limits of error.

(2) Choice of the correct sample size determination equation (depends on the type of sampling and how the desired precision is expressed).

(3) Estimation of some population parameters (such as sample proportions

and sample standard deviations).

(4) If the population is made up of various subdivisions, a sample size may be calculated for each subdivision (possibly using different error limits for each subdivision), the total sample size being the sum of the subdivision sample sizes.

(5) If the data from a survey are wide-ranging the information desired to be found has to be broken down into categories. Therefore, a sample size needs to be calculated for each important category. It is very possible that the various sample sizes will not agree with each other. The differences must be resolved and a uniform sample size agreed upon.

(6) The cost of obtaining a sample must be measured against the resources available. If the available resources are too small to complete the survey to the desired extent the survey either has to be abandoned until ample resources can be found or the desired precision can be reduced, therefore making the sample size smaller.

Analysis of the data to calculate the sample size depends upon the type of data and the sampling procedure chosen. Random sampling consists of simply choosing units to be analyzed at random from the population. It is the simplest type of sampling and serves as the basis for most of the complicated sampling schemes (Yates, 1981).

Cluster sampling is also a popular technique. It consists of dividing the elements to be evaluated into groups and randomly selecting from the groups, or clusters. Then either all of the elements within a cluster are chosen for analysis or a sample of the elements within each cluster are chosen, a case which is more specifically called multi-stage sampling. The cluster sampling method is often used because it can many times give a more t=t-value

r=relative error

(also referred to as degree of precision)

p= one proportion

q=1-p

For equations (1) and (2), if the ratio of the first approximation of the sample size to population size is appreciable, usually 5%, then a correction process must take place. The corrected sample size becomes:

$$n = \frac{n_o}{1+\frac{n_o}{N}} \quad [3]$$

where: n=final approximation of sample size

N=population size

Of course, there will be questions that will have more than two answers. This situation will be handled in one of two ways, depending upon the situation (Cochran, 1977). The data can be split up into two distinct classes or the two classes with the most answers can be considered, with the other classes being discarded.

Calculation of the sample size for continuous data using the cluster sampling technique requires the need of, among other parameters, estimates of the mean and standard deviation. The case of using the simple random sampling technique provides no special problem in calculating these estimates as the formulas are well known. The cluster sampling technique is not as simple, however. The data points cannot be simply added up and divided to obtain an precise estimate of the population. This technique is often used because it can drastically cut the sampling cost (Sampford, 1962).

Formulas for computing the sample size for continuous and proportional data using the random sampling technique are given by Cochran (1977). There are two basic equations which will be applied to calculate the required sample sizes. The two different situations which need different approaches are continuous data and proportional data. Continuous data consists of answers which have a wide range and can vary greatly. There many be no one answer which is common to another. Proportional data can be divided into distinct classes, there may be only three possible answers to a question. It is common to divide the data up into two classes. The formula for sample size of continuous data is (Cochran, 1977):

$$n_o = (\frac{ts}{ry})^2 \qquad [1]$$

where: n_o=first approximation sample size

t=t-value

s=sample standard deviation

r=relative error

y=sample mean

The formula for sample size for proportional data is (Cochran, 1977):

$$n_o = pq(\frac{t}{r})^2 \qquad [2]$$

where: n_o=first approximation of sample size estimate of the mean because these data points were not chosen at random, but the clusters were. Therefore, other methods must be used. There are three techniques for handling this situation (Sampford, 1962). First, each cluster can be averaged, and the average of these can be used for an overall average. Second, a weighted average can be used. That is, the sum of the products of each cluster average and cluster size are divided by the sum of the cluster sizes. Third, if the cluster sizes are known throughout the population, the sum of the products of each cluster average and cluster size are divided by the product of the average cluster size and number of clusters. The standard deviation can be computed by using each cluster average as a data point and utilizing the same method of cluster mean computation as was chosen to calculate the overall mean.

Selection of the proper method for the particular case at hand requires review of the data. Considering the means first, the first method may be seriously biased if large values of cluster averages tend to be associated with large or small clusters, the second method will also be biased, but not seriously if the sample size is fairly large, and the third method contains no bias. Considering the variations, method number two has a larger variation than method number one, while method number three typically has a much larger variation than either of the other two methods. Therefore, the first method is to be considered first. If the large clusters do not have above-average or below-average means, this is the method to use. If bias is felt to be a problem, method two should be used, though the variance will increase by a small amount. Method three is generally not used because of its large variance.

When the sample mean and sample standard deviation are calculated, the sample size can then be computed using the same formulas which were used for the random sampling technique.

Sample size determination for proportional data using the cluster sampling technique is similar to the calculation of sample size for the random sampling technique. The same formulas are used. The difference is that an average proportion is used for each cluster and the average of the cluster averages is the proportion which is used in the formula (Cochran, 1977).

The irrigation baseline determination will include the computation of some confidence intervals. Some common symbols which will be used in these formulas are:

x = overall average

t = t-value (1.96 for 95% confidence interval)

Sx = standard deviation of the sample mean

S = sample standard deviation

n = sample size

N = population size

Sp = standard deviation of the proportion

i = ith cluster

mi = number of elements in the ith cluster

p = a proportion

q = 1-p

C.I. = confidence interval

Snedecor and Cochran (1980) give the formula for calculating confidence intervals for continuous data using the random sampling technique:

$$C.I. = x \pm t(Sx) \quad [4]$$

where:

$$Sx = \frac{S}{\sqrt{n}} \sqrt{1-\frac{n}{N}} \quad [5]$$

Confidence interval calculations for proportional data using the random sampling technique are given by Snedecor and Cochran (1980):

$$C.I. = p \pm t(Sp) \quad [6]$$

where:

$$Sp = \sqrt{\frac{pq}{n}} \sqrt{1-\frac{n}{N}} \quad [7]$$

Formulas for calculating confidence intervals for continuous data using the cluster sampling technique are given by Sukhatme and Sukhatme (1970):

$$C.I. = x \pm t(Sx) \quad [8]$$

where:

$$Sx = \sqrt{(\frac{1}{n}-\frac{1}{N})S} \sqrt{1-\frac{n}{N}} \quad [9]$$

Snedecor and Cochran (1980) give formulas for computing confidence intervals for proportional data using the cluster sampling technique:

$$C.I. = p \pm t(Sp) \qquad [10]$$

where:

$$Sp = \frac{S}{\sqrt{n}} \sqrt{1-\frac{n}{N}} \qquad [11]$$

$$p_i = \frac{(\bar{\Sigma}\, p)_i}{mi} \qquad [12]$$

$$S = \sqrt{\frac{\left(\bar{\Sigma}\, p_i^2 - \frac{\bar{\Sigma}\, p_i^2}{n} \right)}{n-1}} \qquad [13]$$

There are two basic data collection methods which may be used for an agricultural survey such as the one which was undertaken with this research project. One approach is that of a census. This entails attempting to contact 100% of the population. The other common approach is that of a sample survey. A sample of the population only are contacted. The results of the sample are used to approximate the characteristics of the whole population.

There are advantages and disadvantages to both methods. The census method will have no sampling error, though its systematic error may be larger than that of a sample survey (Raj, 1972). Analysis of sample survey data will include some margin of error, therefore confidence intervals can be computed.

This is not possible with a census. If an interview method is used to collect data for a census, more interviewer error is probable, since a greater number of qualified interviewers need to be found. More detailed information can be compiled with a sample survey of limited duration as time considerations would permit more questions to be asked if fewer elements would be contacted. The cost may be much less for a sample survey. If undertaking a national information-gathering project the cost of a sample survey would be approximately one-fifteenth to one-twentieth that of a census (Raj, 1972). Overall, according to Finney (1972), a well run sample survey is far more effective than a poorly conducted census.

The actual procedure of gathering the data also has two basic options to choose from. The element to be surveyed can be contacted by mailing the questionnaire to him/her, or the element may be interviewed in person. The aspects which favor mailing the questionnaire is that it is faster, cheaper, more open to asking personal questions, and also may be more efficient if the respondent has to do some research to answer some of the questions. However, the personal interview method also offers many advantages. It permits asking more detailed questions, whereas with a mail questionnaire, the more detailed the questions, obviously the smaller the response rate. If the answer given to a question is unclear to the interviewer further questioning is possible, while this is not possible with the mail questionnaire. If an opinion of one person is desired as a response it may occur that many people's input will result from a mail questionnaire, while this would not occur with a personal interview. Cross-checking, that is, asking a certain question multiple times for verification, is possible with the personal interview. There is a much higher response rate for personal interviews over mail questionnaires. A common initial response rate for a mail questionnaire is 40%. Through gifts, call-backs, and reminders, this rate may be increased to 70% (Raj,1972). Kromm and White (1981) conducted a survey which measured the attitudes of residents of southwestern Kansas towards the groundwater depletion problem in that area. A questionnaire was mailed to 1500 residents chosen at random. After two weeks 18.2% of the questionnaires were returned, at which point a follow-up letter and survey was sent out to those residents which had not returned the questionnaire. After another two week period, an additional 14.3% of the sample responded, at which point another follow-up letter and survey letter was sent out, where necessary. This second follow-up letter resulted in another 4.5% responses, for a total response of 37.1%. It should be noted that the questionnaire was ten pages long, which is fairly long for a mail-out questionnaire.

Past irrigation or water management surveys have mainly been conducted by the mail-out questionnaire method. Kansas conducts an irrigation survey every four years (Thomas, 1982). Information is gathered county by county by contacting the respective county agents. The county agents give estimates about irrigated acreage, irrigation system types, and energy sources for the systems in their respective counties. The most comprehensive irrigation survey is undertaken by the Bureau of the Census every five years (Bureau of the Census, 1982). This survey gathers information on number of farms irrigated, acres irrigated, crops irrigated, land use in general, water use, water measurement, cost of operation and management, and capital investments. Personal interviews were used in a water management survey in Idaho (Brockway, 1971). Sixty-two farmers were interviewed with questions concerning enterprise types, soil types, and irrigation and water management methods and procedures.

The construction of the questionnaire can play a major role in the response rate of the survey as well as the accuracy of the results (Parten, 1950). The type of questions asked as well as the physical appearance of the questionnaire itself are affected a great deal by whether the questionnaire is mailed or administered in person. If the questionnaire is to be mailed it is imperative that the questions be clear, concise, and be kept to a minimum. If the data are to be recorded by an interviewer, the questionnaire should be made up as close to a check list as possible. Interviewer interpretation of an answer should be kept to a minimum. Other considerations include the brevity of data recording, whether or not the form will be used in the future (make it as easy as possible to compare results), and the physical presentation of the questionnaire form. It should be professional looking, and as easy to handle as possible.

OBJECTIVES

The main objective of the research leading to this paper was to establish an efficient and effective procedure for carrying out an irrigation study to determine a base from which to measure future irrigation development. Basically, given some population of irrigators, the proper size of a sample chosen from the population to accurately determine the irrigation characteristics of the region were found.

A second objective of the research project was to actually determine the baseline previously mentioned. With a baseline accurately determined, future irrigation trends in this region, and in the entire State of Kansas, can be monitored. This objective, however, will not be strictly addressed in this paper, though the survey results are presented in Appendix B.

PROCEDURES

The first step of the irrigation study was to decide exactly what information would be needed. The county agents of the relevant area, the Manager of Groundwater Management District #2, and all principle investigators of the research project were contacted for ideas. The irrigation parameters which were desired to be identified were broken down into categories. A preliminary questionnaire was developed. It was placed on the Agricultural Engineering's graphics terminal. This method provided two basic advantages: a professional appearance was achieved, and changes in the questionnaire could be made with a minimum of difficulty. Four question categories were decided upon: irrigator information, enterprise information, water management information, and individual field information. The categories of irrigator information, enterprise information, and water management information were placed on one sheet (front and back). These questions were kept together because they would only have to be asked each irrigator once, regardless of how many irrigaton systems the irrigator may operate. Another sheet carried the individual field information on the front, and a field sketch on the back. The number of these sheets which would be filled out depended upon the number of irrigaton systems that the farmer operated. A copy of the questionnaire used in the survey is included in Appendix A.

Before the data collection process began, the study was publicized as much as possible, as it was felt that this could only increase irrigator cooperation. The respective county agents were notified, and a press release was sent to the local newspapers explaining the procedures of the survey and its purposes.

The survey began when the questionnaire was basically in its final form. A list of all well permit holders (for irrigation and groundwater purposes only) in The Equus Beds Groundwater Management District # 2 was obtained from the Division of Water Resources, State Board of Agriculture. All multiple permits were thrown out, that is, each irrigator was listed only once, regardless of the number of wells he or she operated. A simple random sampling technique was decided upon for the analysis of the information regarding the irrigator, enterprise, and water management practices. A cluster sampling technique analysis was used for the individual field information data. The use of these two techniques was the practical way to approach the problem. A list of wells for each irrigator was available. To take a random sample from both the irrigator population and the well population would have been too time consuming and costly. Therefore, though the cluster sampling technique is often used to increase the accuracy of the population estimates, in this case it was used because of necessity and practicality. The entire population of irrigators was randomly ordered, as it was not immediately known what the sample size would be. The bigger the sample size got, the more names were selected from the list. Also, the number of irrigators who were contacted about the survey increased over the original sample size chosen because some irrigators refused to participate in the study and others simply could not be contacted for various reasons.

The irrigators who were to be interviewed were sent a copy of the questionnaire along with a letter stating the objectives of the survey and why they were chosen to participate. After a minimum of seven days time, the irrigator was contacted by phone to set an appointment to be interviewed. If he was simply too busy at the time he would be contacted at a later date.

A trial run was initially conducted. The purpose was to evaluate the interviewing process and the questionnaire for clarity and timeliness. Some minor questionnaire changes were made, along with some procedural changes.

When the final interviewing process was perfected, interviewing began in earnest. It began in late April, and continued through late July, with certain time periods having more being accomplished than others, due to factors such as wheat harvest.

Once the interviewing was complete, pump tests were performed on some of the pumping plants. Basically they consisted of a flow measurement of the well at its normal pumping rate. These were performed to obtain a measure of the accuracy of the data received and to improve the credibility of the research project results.

Computer techniques were used to compile data. To make use of Equations (1), (2), and (3) to determine sample size, certain components of the equations had to be determined. The allowable error limits were chosen. Information concerning categories of information such as water management practices, irrigation methods, and well pumping rates leave themselves open to the possibility of substantial error. However, information concerning parameters such as irrigation equipment, well construction, field size, and years of irrigation experience would be expected to achieve a high degree of precision. Therefore, one relative error limit could not be chosen and be considered adequate for every parameter. Sample means, sample standard deviations, sample proportions, and confidence limits of 95% were used to calculate sample sizes. Three sample sizes were calculated for each irrigation parameter using relative error limits of 5, 10, and 15%, respectively. The distinction must be made between error limits and confidence limits. For a confidence limit of 95% and an error limit of 5%, the calculated value will be within 5% of the true value 95% of the time.

The population size parameter (N) in Equation (3) was varied to develop a series of curves which planners of future irrigation surveys can use to obtain estimates of sample sizes necessary to identify certain irrigation characteristics.

RESULTS

There were 1059 well permits on file with the Division of Water Resources, Kansas State Board of Agriculture, in The Equus Beds Groundwater Management District #2 as of December,1983, for irrigation from groundwater. Due to various irrigators holding multiple permits, there were 537 different names possessing these permits. This amounts to an average of 2.0 wells per irrigator. The study was set up to contact 20% of the population, which would be equal to 108 irrigators. To attain this figure, 155 initial letters were sent out. Of this number, 131 actual contacts by phone were made. The remainder of the irrigators who received letters were either not contacted because the selected sample size had already been obtained, or because correct addresses or phone numbers were unavailable. Of the 131 actual contacts made by phone with the irrigator, 97 (74.0%) actual interviews took place. Six (4.6%) of the well permit holders had the well operated by another irrigator who was named elsewhere in the survey, so data for both well permit holders were obtained from the one irrigator. Five (3.8%) did not operate the wells in 1983. Eight (6.1%) were not interested in divulging any information about the irrigation practices. Finally, fifteen (11.5%) said that they were simply too busy at that time of season to participate, but may be willing to assist at some other time. It should be noted that repeated calls were made to each irrigator if they gave a certain time frame upon which they may be called back. If they persisted upon another time still, calls were continued to be placed until, of course, the time period of the survey had run its course. Therefore, if the number of actual interviews were summed with the number of irrigators who did not operate their well in 1983 and the irrigators who operated wells whose permits were listed under two separate names in the original random selection of well permit holders, a total of 108 well permit holders of the original 537 are accounted for. Also, it can be stated that of the 131 actual calls made to irrigators, 82.4% positive responses were obtained.

The data from the pump tests that were performed show that the average irrigator is pumping at a rate of 88% of what he thinks he is pumping at, using a weighted average. Applying well certification test data obtained from The Kansas State Board of Agriculture, Division of Water Resources to irrigators chosen for this study shows that they are pumping at a rate of 98% of what they think. This indicates that the irrigators who do have a well certified are aware of the results of the test.

Summary of data is presented in Tables 1 and 2. Included are means, 95% confidence intervals of the means, breakdown of the data into various groups, and proportions of some of the more important question categories.

Table 1. Irrigation Parameters of a Continuous Data Nature.

Parameter	Mean	# of Answers	95% Confidence Limits Lower	Upper	Data Breakdown Category	#	Percent
Irrigator Age (years)	51.9	94	49.5	54.4	11-20	2.	2.1
					21-30	1.	1.1
					31-40	14.	14.9
					41-50	22.	23.4
					51-60	31.	33.0
					61-70	20.	21.3
					71-80	3.	3.2
					81-90	1.	1.1
Farmer Experience (years)	32.7	94	30.3	35.1	0-10	6.	6.4
					11-20	16.	17.0
					21-30	18.	19.1
					31-40	28.	29.8
					41-50	23.	24.5
					51-60	2.	2.1
					61-70	1.	1.1
Irrigation Experience (years)	14.2	92	12.6	15.9	0-5	17.	18.5
					6-10	26.	28.3
					11-15	18.	19.6
					16-20	8.	8.7
					21-25	5.	5.4
					26-30	15.	16.3
					31-35	3.	3.3
Total Acres Operated	674.0	96	568.9	779.1	0-250	27.	28.1
					251-500	22.	22.9
					501-750	15.	15.6
					751-1000	14.	14.6
					1001-1250	5.	5.2
					1251-1500	4.	4.2
					1501-1750	1.	1.0
					1751-2000	5.	5.2
					2001-2250	2.	2.1
					greater than 2251	1.	1.0

Table 1. Irrigation Parameters of a Continuous Data Nature (continued).

Parameter	Mean	# of Answers	95% Confidence Limits Lower	Upper	Data Breakdown Category	#	Percent
Irrigated Field Size (Acres)	89.2	97	81.1	97.3	0-20	14.	8.0
					21-40	17.	9.7
					41-60	16.	9.1
					61-80	35.	20.0
					81-100	9.	5.1
					101-120	18.	10.3
					121-140	54.	30.9
					141-160	8.	4.6
					161-180	2.	1.1
					greater than 181	2.	1.1
Irrigation System Age (years)	9.9	82	8.4	11.3	0-5	46.	31.5
					6-10	53.	36.3
					11-15	24.	16.4
					16-20	10.	6.8
					21-25	3.	2.1
					26-30	8.	5.5
					31-35	2.	1.4
Water Usage (inches)	11.4	78	8.2	14.7	0-2	12.	9.1
					3-4	10.	7.6
					5-6	17.	12.9
					7-8	18.	13.6
					9-10	15.	11.4
					11-12	20.	15.2
					13-14	11.	8.3
					15-16	14.	10.6
					17-18	4.	3.0
					greater than 18	11.	8.3
Well Yield (gallons per minute)	798.2	87	745.6	850.8	0-200	4.	2.4
					201-400	18.	10.6
					401-600	19.	11.2
					601-800	44.	25.9
					801-1000	56.	32.9
					1001-1200	27.	15.9
					1201-1400	1.	0.6
					greater than 1400	1.	0.6

Table 2. Irrigation Parameters of a Proportional Data Nature.

Parameter	Answer	Response (%)	Number of Answers	Error (+ or -)
Irrigation Training?	Yes	29.5	95	8.5
	No	70.5		
Water Application	Farmer Experience	74	96	8
	Private Firm	26		
Water Quality Ever Tested?	Yes	60	96	8.5
	No	40		
Irrigation System Type	Center Pivot	39	83	8.5
	Gated Pipe	61		
Well flow Estimated or Metered?	Estimated	67	90	7.5
	Metered	33		
Pump Type	Turbine	83	87	6.5
	Centrifugal	17		

The survey results provided some interesting indications of the present state of the irrigation industry in The Equus Beds Groundwater Management District #2. The average age of the irrigator is 51.9 years, and 59% of the population is over 50 years of age (Table 1). This would seem to indicate that a turnover in irrigators to a new generation may be in the near future, which will probably mean some changes in the operation of irrigation systems. As shown in Table 1, 94% of the irrigators have been farming over ten years, but only 53% have been irrigating for more than ten years, which indicates that many of the irrigators started irrigating at a rather advanced age. An interesting statistic is that there is a significant (16%) portion of irrigators who began irrigating in the period from 1953-1957, with most of the rest (66%) beginning after 1967 (Table 1). The most variable data recorded were the total size of the farming operation, as 51% of the irrigators operated less than 500 acres, while the rest of the irrigators operated enterprises ranging in size from 500 to more than 2500 acres (Table 1). Only 26% of the farmers used private irrigation consulting services to monitor and advise on water application procedures and amounts (Table 2).

The irrigated field size was bunched mainly into two categories, 61 to 80 acres (20%) and 121 to 140 acres (31%) (Table 1). This is due to center pivots of 130 acres and gated pipe systems of 80 acres being common to the area. Concerning irrigation systems, 38% were center pivot systems, 54% were gated pipe, and 8% were other types of systems (Appendix B). The average age of the irrigation systems was 9.9 years, with 68% of the systems being under ten years of age (Table 1). This corresponds with the formation of the Equus Beds Groundwater Management District #2 in 1976. Many of the irrigators expressed that the formation of the district and the fear that the granting of water rights could at any time be cut off, with no more wells being drilled from that time forward was a factor in their decision to drill a well.

Reported well pumping rates were generally in the range of 600 to 1000 gallons per minute (59%), with virtually no wells pumping over 1200 gallons per minute (Table 1). This contrasts with Western Kansas, where pumping rates of over 1200 gallons per minute are far more common. As shown in Table 1, one-third of the wells had meters on them. This figure may rise rapidly in the future, as a policy of meters being required on all wells is being considered by the district. Seventeen percent of the pumps were centrifugal, with the rest being turbine (Table 2). This relatively large percentage of centrifugal pumps is due to the high water table in some southern portions of the district attributed to recharge from Arkansas and Little Arkansas Rivers which flow perennially.

The average water applied per crop is shown in Table 3. Gross irrigation requirements are also shown for instances of rainfall amounts which would occur 50% of the time and 80% of the time, both at an irrigation efficiency of 65%.

Table 3. Water Applied Per Crop, 1983, and Gross Irrigation Requirements at 65% Efficiency.

Crop	Water Applied (inches)	Gross Irrigation Requirements (inches)	
		80% rainfall chance	50% rainfall chance
Grain Sorghum	10.0	16.0	12.3
Corn	11.1	20.3	16.6
Soybeans	12.1	14.9	10.8
Wheat	6.1	13.1	9.1
Alfalfa	8.3	32.0	26.2
Sorghum Silage	8.2	—	—
Double Crop			
Grain Sorghum	7.7	—	—
Soybeans	12.0	—	—

Soybeans was the crop upon which the most water was applied, with 12.1 inches. Corn was next with 11.1 inches, then grain sorghum with 10 inches. All other crops had less than 10 inches of water applied to them.

The remainder of the survey data is presented in Appendix B.

Fourteen specific questions were selected which were felt to encompass irrigation characteristics. Questions were of a general nature and for which estimates may be available in an irrigation region where a survey is being planned. These questions include information about irrigator age, farmer experience, irrigation experience, irrigator's degree of training, total acres operated, methods of determining water application procedures, water quality testing, irrigated field size, type of irrigation system, age of irrigation system, water usage, well yield, well metering, and pump type. Sample sizes were calculated for The Equus Beds Groundwater Management District #2 for error limits of 5, 10 and 15%, respectively, using the sample proportions, sample means, and sample standard deviations which were calulated from the data (Table 4).

Table 4. Sample sizes in percent for the Equus Beds Groundwater Management District #2.

Type of Information	Relative Error Limits		
	5%	10%	15%
Irrigator Age	17.6	5.1	2.4
Farmer Experience	34.3	11.5	5.5
Irrigation Experience	56.0	24.1	12.4
Irrigation Training	39.7	14.1	6.8
Acres Operated	70.6	37.5	21.1
Application Procedures	37.9	13.2	6.3
Water Quality Testing	43.1	15.9	7.8
Irrigated Field Size	39.8	14.2	6.8
Irrigation System	43.0	15.9	7.7
System Age	40.4	14.5	7.0
Water Usage	43.7	16.3	8.0
Well Yield	23.8	7.2	3.5
Well Metered?	41.3	14.9	7.2
Pump Type	30.4	9.9	4.9

From these computed sample sizes, it is obvious that determining the given irrigation parameters to within 5% is probably not feasible for most situations, as sample sizes ranged from a low of 17.6% to a high of 70.6%, with the average being 40.1%. Estimating irrigation characteristics to within 10% presents far more reasonable levels, as the high value was 37.5%, the low value was 5.1%, and the average was 15.3%. A given error of 15% gives a high sample size of 21.1%, a low of 2.4%, and a mean value of 7.7%.

Graphs were developed which show, for the error limits previously stated, sample sizes required for various irrigator populations (Figures 1 through 14). These were developed by using Equations (1), (2) and (3) and the irrigation parameters derived from the survey data. The only parameter which was changed was the population size. The purpose of these graphs is to provide a guide to future planners of similar irrigation surveys. Estimates of sample size may be made in the planning stages of the survey, aiding in an economic feasibility study of the proposed project.

Figure 1 shows that irrigator age can be estimated with a relatively small sample size for various populations. In fact, of the question categories chosen to calculate sample size from, it requires the smallest sample size. The largest sample size required is for determining total acres operated (Figure 5). Its curve is not very reliable due to the data not possessing a normal distribution. The rest of the data were fairly similar in the sample size it required, with the exceptions of irrigation experience (Figure 3), which requires a large sample size, and reported well yield (Figure 12), which required a relatively low sample size.

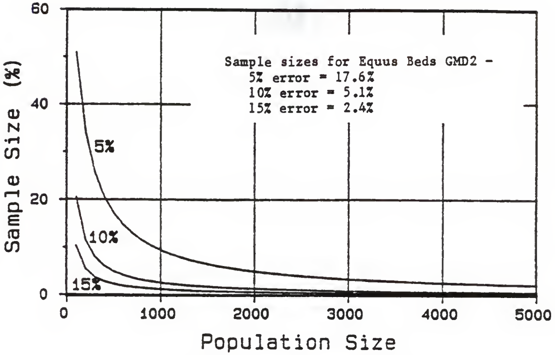

Figure 1. Sample Size Based on Irrigator Age for Various Relative Errors

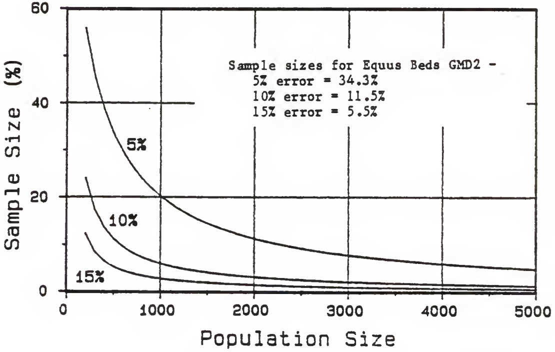

Figure 2. Sample Size Based on Farming Experience for Various Relative Errors

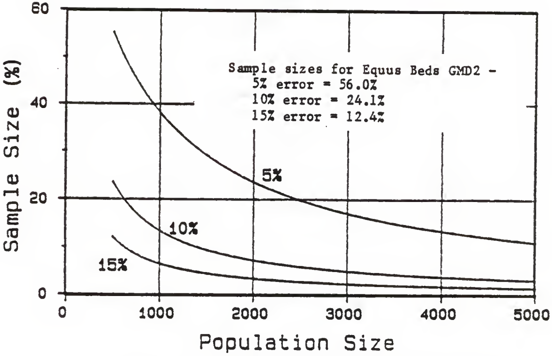

Figure 3. Sample Size Based on Irrigation Experience for Various Relative Errors

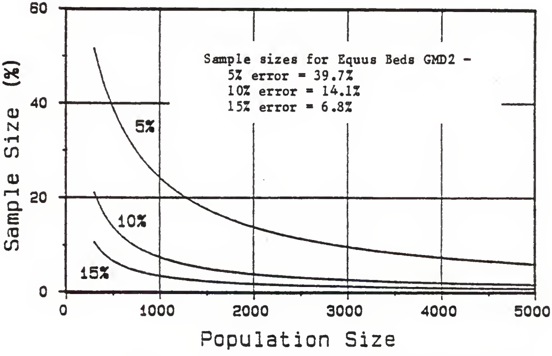

Figure 4. Sample Size Based on Irrigation Training for Various Relative Errors

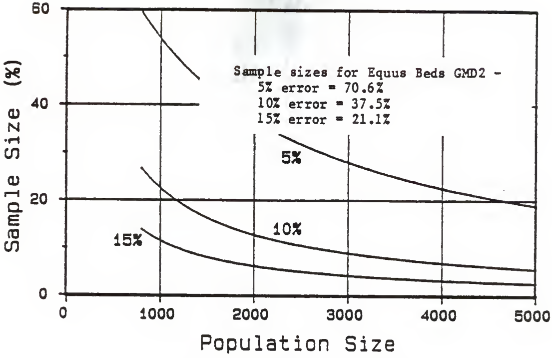

Figure 5. Sample Size Based on Acres Operated for Various Relative Errors

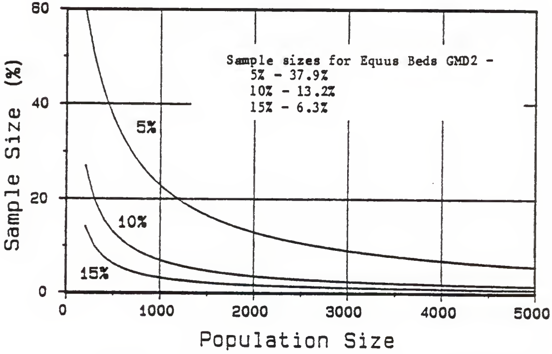

Figure 6. Sample Size Based on Water Application Procedures for Various Relative Errors

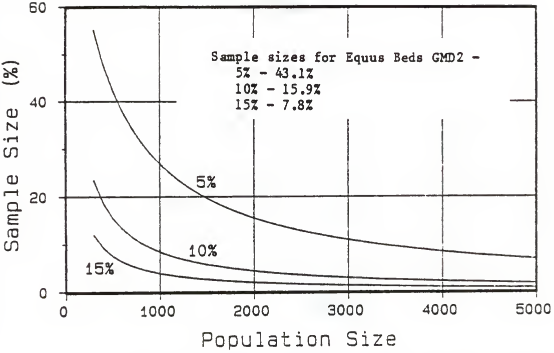

Figure 7. Sample Size Based on Water Quality Testing for Various Relative Errors

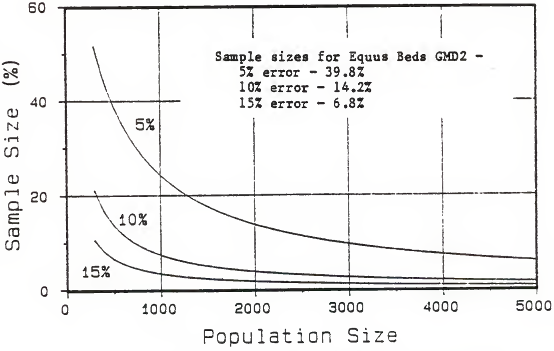

Figure 8. Sample Size Based on Field Size for Various Relative Errors

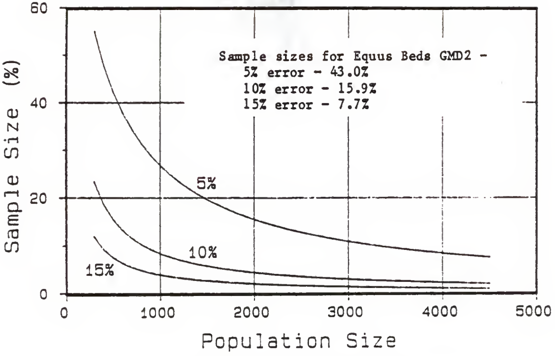

Figure 9. Sample Size Based on System Type for Various Relative Errors

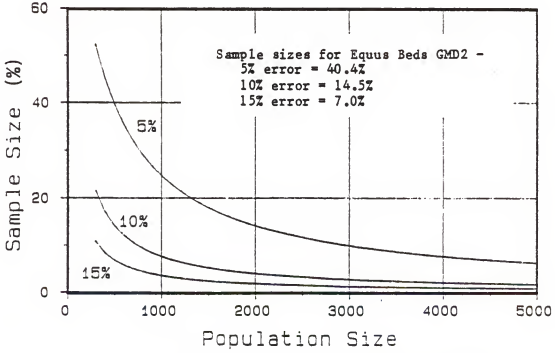

Figure 10. Sample Size Based on System Age for Various Relative Errors

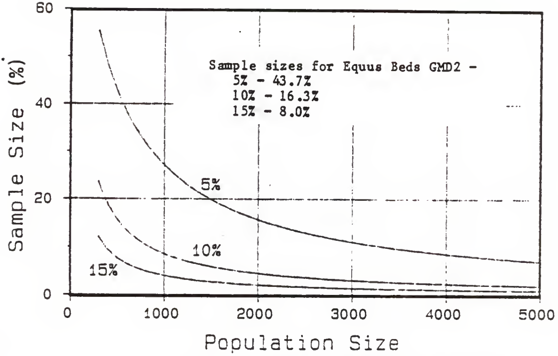

Figure 11. Sample Size Based on Water Usage for Various Relative Errors

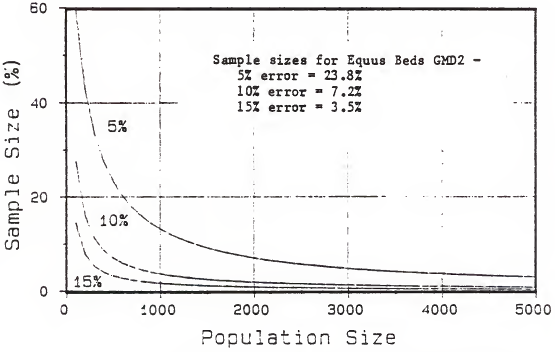

Figure 12. Sample Size Based on Well Yield for Various Relative Errors

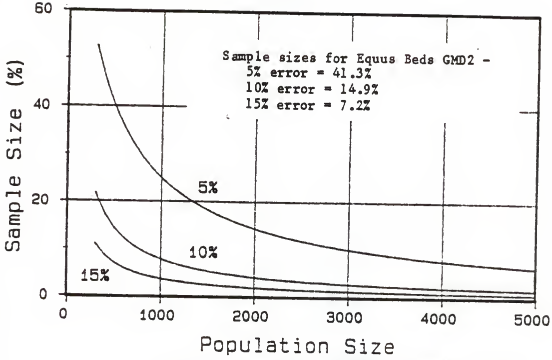

Figure 13. Sample Size Based on Meter Usage for Various Relative Errors

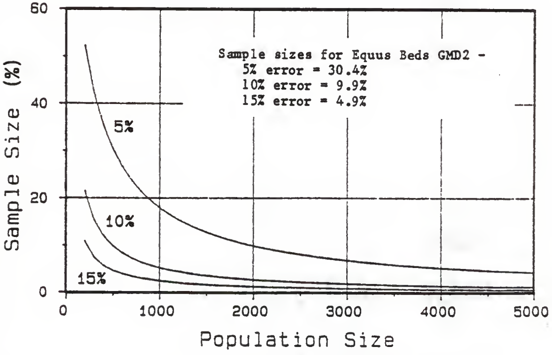

Figure 14. Sample Size Based on Pump Type for Various Relative Errors

DISCUSSION

It is intended that the information presented in the results section of this thesis serve as a guide to planners of irrigation surveys such as the one undertaken with this research project. These results should provide a good deal of direction when concocting what a proposed survey is trying to accomplish, especially in the early stages of planning. Results from The Equus Beds GMD2 Irrigation Study show that the average required sample size for a given error limit of 5% considering the question categories selected was 40.1%. Sample sizes of this magnitude are impractical to be undertaken in a survey. However, to estimate irrigation characteristics within 5% can also be considered an unreasonably low figure when considering information currently available in these areas. An average sample size of 15.3% was found for a given error limit of 10%. This is far more reasonable. For a given error limit of 15%, an average sample size of 7.7% was derived. Therefore, most of the given irrigation parameters can be estimated to within 15% by using a sample size under 10%. It should be noted that the percent sample size decreases appreciably as the population increases.

When planning an irigation survey the desired information and accuracy of this information needs to be determined. A general idea of the required sample size can be identified from the results of this report. A feasibility study can be performed to determine whether the required information can be accurately found within the economic bounds of the proposed project. If resources are not available to accomplish what is desired, a decision can be made to either lower the desired accuracy of the results or to postpone the study until more resources can be obtained to enable the study to be undertaken.

Along with the sample size determination, other suggestions can be made to future planners of a similar type of irrigation survey in hope that the total survey procedure can be improved.

Irrigator cooperation can vary greatly according to the degree of understanding the irrigator has of the study. An irrigation survey of any sort has a specific purpose or some long term goal or goals. Typically it is undertaken to understand just what the state of the irrigation industry is at the time. This information can be merged with data gathered from other water users such as industry, municipal, recreation, hydropower, etc. to develop some water plan for the region. It is imperative that the irrigator understand the purpose of the study and his role in it. Future benefits which the irrigator and the irrigation industry as a whole may receive from the results of the study need to be made clear. Chances are, if the survey is perceived by the irrigator as an attempt by a government agency to monitor what the irrigator is doing, cooperation from the irrigator will be much lower than if it is demonstrated to the irrigator that he will not be restricted in any manner due to the results of the survey, if such is the case. If participation in the survey by the irrigator is voluntary, it should not be so stated when the request is made of the irrigator's time and effort to complete the questionnaire. The irrigator should be approached with the attitude that it is his duty and he will benefit in the long run.

When performing the analysis of data gathered from an irrigation survey, the proper sample size equations must first be decided upon. For data taken using random sampling techniques, the equations are fairly straightforward. When using cluster sampling methods, however, there is no one set equation which works for all cases. The type of data which is to be analyzed must be taken into consideration before the correct equations may be chosen. For the proper equations to be used, estimates of standard deviations and proportions are needed. Estimates may be available for some of the question categories. If not, another method of estimation is a "pilot survey". This consists of a survey of a sample of the sample, that is, a small percentage of the expected sample size is surveyed initially to obtain a measure of the estimates. The pilot survey concept was not used in the Equus Beds GMD2 Irrigation Study.

The various sample sizes which will be calculated will probably not agree with each other. The more important information should have precedence over other information if there is a large discrepency. It must be kept in mind that some data will require a larger error limit than other data, simply because of their nature.

The proposed sample sizes should be balanced against the resources available for an irrigation study to obtain a measure of efficiency. Future studies which may be undertaken can use calculations from this study as a guideline in planning the necessary resources for carrying out a similar study.

CONCLUSIONS

The conclusions drawn from this study should be of interest to future planners of irrigation surveys. They can be divided into two parts: selection of proper sample sizes for various irrigation parameters and proper methods in implementing the survey itself.

1. Selection of a relative error limit of 5% is probably unreasonable, as the average sample size to describe selected common irrigation parameters at that

level for the Equus Beds GMD2 was 40%.

2. Relative error limits of 10 and 15% required average sample sizes of 15 and 8%, respectively, which is far more economically feasible for carrying out an irrigation survey than a relative error limit of 5%.

3. The required sample size in percent for a given relative error limit decreases as irrigator population increases.

4. Cooperation of the irrigator is increased if it is made clear what the purpose of the survey is and how he may be affected in the future by it.

5. A questionnaire with a professional appearance is desireable to increase response rate to the survey.

SUMMARY

An irrigation baseline study was undertaken in a Kansas Groundwater Management District. One objective of the study was to develop an efficient procedure for implementing such an irrigation survey. Another objective was that of establishing an irrigation baseline. That is, present irrigation characteristics were defined so that future irrigation developments in the region can be monitored.

The region chosen for the study was the Equus Beds Groundwater Management District #2 in south-central Kansas, which includes parts of Reno, Sedgwick, Harvey, and McPherson Counties. There are five such districts in Kansas. Each of them consists of a well-defined body of irrigators, with the districts having different irrigation characteristics, but possessing much less characteristic variation within each district than between districts. The Equus

Beds Groundwater Management District #2 was chosen for the study because of its proximity, size (smallest of the five districts), and anticipated least controversy of the five districts.

A sample survey method of personal interviews was chosen as the data collection method. Selecting a sample of the population to collect data from is much more economical than a census type of survey where 100% of the population is contacted. The actual data collection method of personal interviewing was chosen over a method of mail-out questionnaires because the information which was desired was fairly detailed, and it was felt response rate would be much higher with some form of personal contact with the irrigator.

A questionnaire was developed based on the information which was desired. Questions were divided into four basic categories: irrigator information, enterprise information, water management information, and individual field information. The questionnaire was mailed to irrigators in the Equus Beds Groundwater Management District #2 at least one week prior to contact by phone. The purpose of the phone call was to set up an appointment to interview the irrigator in person.

Inteviews took place from late April to early August of 1984. Available resources allowed 20% of the irrigators to be interviewed. Data were compiled using computer techniques.

Sample size determination required the use of different analyses, depending upon the type of data and the sampling method chosen. The two types of data that were gathered were continuous data and proportional data. Continuous data consists of answers that can vary a great deal, there may be no one answer which is common to another. Proportional data answers can be divided into definite classes, usually two of them, and the answers themselves have no numerical value, but are assigned one. The two sampling methods used were random sampling and cluster sampling. The random sampling procedure was used when gathering data on the irrigator, his farming enterprise, and water management information. A cluster sampling technique analysis was used on the individual field information data. This enabled a sample size to be determined from data that was not gathered strictly at random.

Sample means, sample standard deviations, and sample proportions were calculated for some of the more important question categories. These computations were used to calculate confidence intervals and necessary sample sizes for different error limits for the population given. Fourteen question categories were selected for sample size calculations. These categories of information were of a general nature and categories for which estimates may be available in some areas. Included were irrigator age, farmer experience, irrigation experience, irrigation training, acres operated, water applicaton procedures, water quality testing, irrigated field size, irrigation system type, irrigation system age, water usage, well yield, well metering, and pump type. Sample sizes for a 5% accuracy level ranged from 17.6% to 70.6%, with an average of 40.1%. For an error of 10% sample sizes ranged from 5.1% to 37.5%, the mean being 15.3%. A 15% error gave an average sample size of 7.7%, with a range of 2.4% to 21.1% The sample sizes for a 5% error are too high to be practically considered when conducting an irrigation survey to estimate the irrigation parameters chosen. However, since very little data are currently available about these parameters, estimating within 5% is unreasonable. The sample sizes based on an error of 10% are far more feasible to undertake in an irrigation survey. If the allowable error limits are increased to 15%, however, the sample size is cut in half over that of the figures for a 10% error. This shows that a reasonable estimate of most irrigation parameters can be found for an economical sample size of well under 10%. Also, this applies to an irrigation region the size of the Equus Beds Groundwater Management District #2, and the percent sample size would decrease as the irrigation population increases.

A series of graphs were developed which show, for an area of irrigators with the same irrigation characteristics which are possessed by The Equus Beds Groundwater Management District #2, necessary sample sizes for various population sizes. The purpose of these graphs is to provide a guide when planning an irrigation survey. An idea of the sample size can be balanced against the desired accuracy of the results to see if the available resouces are adequate.

SUGGESTIONS FOR FUTURE RESEARCH

Possibly the main avenue towards which future energies should be directed for an irrigation survey such as the one undertaken by this study is not the collection of more information, but the further analysis of data already gathered. Hypotheses can be drawn in the area of identifying what type of irrigators are using what kinds of water management techniques. Information is available about ages, education, labor supplies, irrigation and farming experience, and water management techniques of the irrigators. Trends could be identified in these areas.

Typically a survey is unable to contact 100% of the sample chosen, and therefore a doubt remains whether the elements of the survey accurately describe the population. In other words, if all the elements chosen for the study agreed to participate, would the results be different than the more common case of where only some of the elements participated? Further research using data from this study may provide an answer. The irrigators who refused to participate in this study are identifiable by location and well discharge records currently available. Through the use of such aids as state records and aerial photographs, much of the information gathered in the survey can be accurately identified or estimated. The small population who refused to participate in the study could then be compared to the much larger population who did agree to participate to see if there are major or minor differences between the two populations.

One goal of this study was to provide data for use in establishing water policy in Kansas. Further direction could be provided by undertaking a study aimed more towards the attitude of irrigators in considering various possibilities of future water policies. Certainly more cooperation could be expected from the irrigators in implementing a water plan if their input was gathered before the plan took affect rather than hearing their complaints after it has already been implemented.

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APPENDIX A

Survey Questionnaire

1984 KANSAS STATE UNIVERSITY IRRIGATION SURVEY OF EQUUS BEDS GROUNDWATER MANAGEMENT DISTRICT #2

Name________________________ Date__________

Address________________________ Time__________

________________________ Zip________ Phone__________

I. IRRIGATOR INFORMATION

Sex______ | Age______ | Farming Experience______years

Irrigation Experience:
Years Total______

System Type	Years
______	____
______	____
______	____
______	____
______	____

Irrigation Training:
Workshops? ______
Irrigation Associations? ______

Labor Supply:
Self ______
Family ______
Hired ______

Education:
Grade School ______
High School ______
Technical School ______
Junior College ______
College ______
Other (specify) ______

Off-Farm Employment:
None ______
Full-time ______
Part-time ______hrs/week

II. ENTERPRISE INFORMATION

Acres Owned ______
Acres Rented ______
Total Acres ______

Grain______
Livestock______
Mixed______

Crop Type	Acres Per Crop: Irrigated	Non-Irrigated
Corn	______	______
Milo	______	______
Soybeans	______	______
______	______	______
______	______	______
______	______	______

III. WATER MANAGEMENT

WATER APPLICATION:

How is time of and amount of water applied determined?
Farmer Experience________
Private Consulting Firm________ (name________________)

SOIL MOISTURE:

Is soil moisture measured?
Yes______ No______
How?
Tensiometer______
Resistance Blocks______
Other (Specify) ______

Who installed these?____________

RAINFALL:

Is rainfall measured?
Yes______ No______

Rain Gage Type________________

# of Gages______

WELL OUTPUT:

How is pumping rate determined?
Manufacturer's Values______
Meter______
Meter Type__________
Meter Size__________
Meter Model #__________
Pump Test______
Frequency of Test______year (s)
Who performs test?__________
Test Method__________
____

WATER QUALITY:

Is water quality tested?
Yes______ No______

Who takes samples?
Self______
Other______
(name________________)
Lab which does analysis-
____
Frequency________year (s)

TAILWATER:

Pit-
Sur. Area____ac.
Depth____feet
Pump-
Energy________
Capacity____gpm
Manufacturer__________

Pipe
Length____feet
Size____in.
Material________

System-
Age____years
Running Time__________
Frequency of Test__________

MISCELLANEOUS:

Farm Management Association Member?
Yes______ No____
Allow access to records?
Yes______
No______

Surveyor Identification:
____

IV. INDIVIDUAL FIELD INFORMATION

Field #_____

SIZE: _____acres

SOIL TYPE: ____________________

CROP DATA:

Type-
1983 Crop__________
1982 Crop__________

Yield-
______bu/acre

Fertilizer-
Amount and Type__________
____
____

Weed Control-
Chemicals______
Cultivation______

Cultural Practices-
Conventional______
Chisel______
No-till______
Disk______
Other (Specify)________
____

IRRIGATION DATA:

System Operation-
# of Irrigations_____
Time to Irr._____
Water Applied_____in.
Tailwater Used?_____

System Data-
Type________
Manufacturer________
Age_____years
Capacity_____gpm

System Changes-
Previous____________
____
____

Future (5 years)__________
____
____

Cost of Future Changes______
Future Yearly Savings______

Delivery Pipe-
Length_____feet
Size_____inches
Age_____years

Buried_______
or
Surface?_______
Material_________

WELL DATA:

Yield______ gpm est._____ metered_____

Age______years

Size-
Bore Hole_____in.
Casing_____in.
Depth_____feet

Depth to Water-
Before Season_____feet
After Season_____feet
Drawdown_____feet

Construction-
Well Screen? No_____
Yes_____
Screen Length_____feet
Screen Type_____
Depth to Screen_____feet
Below Screen_____feet
Gravel Pack? Yes_____
No_____

Pump- Type________
Rated Capacity______gpm
# of Bowls______
Manufacturer________
Age_____years
Annual Use_____hours
Pressure_____psi
Speed______rpm
Column Size_____inches
Service History________
____
____

Power Source-
Energy Source________
Annual Use______hours
Manufacturer____________
Service History____________
____
____

Age______years
Size______hp

Drive-
Ratio________
Manufacturer________
Service History____________
____
____

Driller__________________

FIELD SKETCH

APPENDIX B

Additional Survey Data

Irrigator information: Data collected about the actual person who does the irrigating.

Sex -
Male: 96 (100.0%)
# of answers 96

Gated pipe experience-
Average = 14.1 years
# of answers = 62

Center pivot experience -
Average = 7.0 years
# of answers= 44

Labor Supply -

Self:	14	(14.7%)
Self & Family:	56	(58.9%)
Self & Hired:	9	(9.5%)
Self, Family, & Hired:	16	(16.8%)

# of answers 95

Education -

Grade School:	11	(11.7%)
High School:	40	(42.6%)
Junior College:	5	(5.3%)
Technical School:	4	(4.3%)
Some College:	18	(19.1%)
College Degree:	15	(16.0%)
Advanced College:	1	(1.1%)

# of answers 94

Off-Farm Employment -

None:	59	(63.4%)
Full Time:	17	(18.3%)
Part Time:	17	(18.3%)

# of answers 93

Enterprise information: Data regarding the total farming operation of the irrigator.

Acres owned -	Acres rented -
Average = 311.5	Average =351.0
# of answers= 95	# of answers = 95

Crop by crop breakdown -

Irrigated -

Crop: Corn	4271.	acres	(7.3%)
Crop: Grain Sorghum	5596.	acres	(9.5%)
Crop: Soybeans	3863.	acres	(6.6%)
Crop: Wheat	970.	acres	(1.7%)
Crop: Alfalfa	452.	acres	(0.8%)
Crop: Sorghum Silage	364.	acres	(0.6%)
Crop: Double Crop Milo	671.	acres	(1.1%)
Crop: Double Crop Soybeans	115.	acres	(0.2%)
Crop: Double Crop Alfalfa	100.	acres	(0.2%)
Crop: Other	65.	acres	(0.1%)

Non-irrigated -

Crop: Corn	30.	acres	(0.1%)
Crop: Milo	8787.	acres	(15.0%)
Crop: Soybeans	884.	acres	(1.5%)
Crop: Wheat	21158.	acres	(36.0%)
Crop: Alfalfa	1312.	acres	(2.2%)
Crop: Pasture	6583.	acres	(11.2%)
Crop: PIK	3236.	acres	(5.5%)
Crop: Sorghum Silage	106.	acres	(0.2%)
Crop: Oats	50.	acres	(0.1%)
Crop: Fallow	130.	acres	(0.2%)
Total # of farmers answering:	97		

Total Acres: 58738.

Enterprise type -

Grain only:	50	(52.1%)
Livestock only:	6	(6.3%)
Livestock and grain:	40	(41.7%)
# of answers	96	

Water management information: This data reflects the procedures by which the irrigator manages his water resources.

Soil moisture measured?
Yes: 33 (34.4%)
No: 63 (65.6%)
# of answers 96

Rainfall measured?
Yes: 72 (75.0%)
No: 24 (25.0%)
# of answers 96

# of Tailwater Pits = 82
Average = 0.8 pits per irrigator

# of pits which recycle water = 64
78% of tailwater pits recycle the water

Tailwater pump energy -

Electric:	22	(59.5%)
PTO:	3	(8.1%)
Natural Gas:	6	(16.2%)
Propane:	4	(10.8%)
LP Gas:	2	(5.4%)
# of answers	37	

Tailwater pumping rate (gpm) -
Average = 534.4 gpm
# of answers 32

Who takes water quality samples?

Self:	17	(36.2%)
State:	9	(19.1%)
GWMD #2:	10	(21.3%)
Servitech:	7	(14.9%)
Other:	4	(8.5%)
# of answers	47	

Lab Used -

Peterson Labs:	12	(33.3%)
State:	7	(19.4%)
Servitech:	8	(22.2%)
GWMD #2:	6	(16.7%)
General Labs:	1	(2.8%)
A & L:	1	(2.8%)
Means Lab:	1	(2.8%)
# of answers	36	

Frequency of Sampling -

Once:	11	(30.6%)
Every Year:	6	(16.7%)
Every other year:	6	(16.7%)
Other:	13	(36.1%)
# of answers	36	

Tailwater pit surface area -
Average = 0.55 acres

Tailwater pit depth -
Average = 8.3 feet

Pipe Length -
Average = 1115 feet

Pipe Diameter -

4 inches:	3	(8.6%)
5 inches:	2	(5.7%)
6 inches:	19	(54.3%)
8 inches:	9	(25.7%)
16 inches:	2	(5.7%)
# of answers	35	

Pipe Material -

Aluminum:	12	(41.4%)
Plastic:	16	(55.2%)
Steel:	1	(3.4%)
# of answers	29	

Tailwater Pump Manufacturer -

Berkeley:	18	(60.0%)
Western Landroller:	6	(20.0%)
Denver-Gardner:	2	(6.7%)
Pacific:	1	(3.3%)
Red Jacket:	1	(3.3%)
Goulds:	1	(3.3%)
Layne & Bowler:	1	(3.3%)
# of answers	30	

Tailwater pit age -
Average = 9.3 years

Farm Management Association Member?
Yes: 9 (9.4%)
No: 87 (90.6%)
# of answers 96

Individual field information: Refers to data gathered about each field with an irrigation system on it. There are three separate categories presented: crop information, irrigation information, and well information.

Crop information:

Soil type -

Sandy loam:	71	(52.6%)
Silt loam:	10	(7.4%)
Heavy:	18	(13.3%)
Clay loam:	13	(9.6%)
Loam:	12	(8.9%)
Clay:	2	(1.5%)
Alkali:	7	(5.2%)
Gumbo:	1	(0.7%)
# of answers	135	

Crop yields -

Soybeans	Ave. Yield = 43.9	bushels/acre
Grain sorghum	Ave. Yield = 113.7	bushels/acre
Corn	Ave. Yield = 124.0	bushels/acre
Alfalfa	Ave. Yield = 3.8	tons/acre
Sorghum silage	Ave. Yield = 28.2	tons/acre
Wheat	Ave. Yield = 45.3	bushels/acre
Double-crop grain sorghum	Ave. Yield = 89.0	bushels/acre

Fertilizer application -

Average 18-46-0 applied = 88.2 lbs./acre
Average units N applied = 146.6 lbs./acre
Average anhydrous ammonia applied = 138.3 lbs./acre
(Note: Averages apply only to farmers who used these fertilizers.)

Weed control methods -

Chemicals and cultivation:	96	(67.6%)
Chemicals only:	40	(28.2%)
Cultivation only:	6	(4.2%)
# of answers	142	

Cultural practices -

Chisel and disk:	127	(78.4%)
Moldboard plow:	14	(8.6%)
Field cultivator:	5	(3.1%)
Disk only:	9	(5.6%)
Chisel only:	5	(3.1%)
Minimum tillage:	2	(1.2%)

Irrigation information:

Average size of irrigation system -

Center Pivot	Average System Size = 121.9 acres
Gated Pipe	Average System Size = 76.5 acres
Sideroll	Average System Size = 78.0 acres
Tractor Move	Average System Size = 80.0 acres
Handmove	Average System Size = 80.0 acres
Big Gun	Average System Size = 52.5 acres
Ditches	Average System Size = 10.0 acres
Solid Set	Average System Size = 2.0 acres

Number of irrigations per season -
Average = 5.9 times
Breakdown -

1 time:	6	(6.2%)
2 times:	10	(10.3%)
3 times:	10	(10.3%)
4 times:	14	(14.4%)
5 times:	14	(14.4%)
6 times:	11	(11.3%)
7 times:	10	(10.3%)
8 times:	6	(6.2%)
Greater than 8 times:	16	(16.3%)

Time per irrigation -
Average = 107.3 hours
Breakdown -

0-20 hours =	0.	(0.0%)
21-40 hours =	10.	(11.9%)
41-60 hours =	9.	(10.7%)
61-80 hours =	11.	(13.1%)
81-100 hours =	20.	(23.8%)
101-120 hours =	0.	(0.0%)
121-140 hours =	3.	(3.6%)
141-160 hours =	5.	(6.0%)
161-180 hours =	12.	(14.3%)
Greater than 180 hours =	14	(16.7%)

Irrigation system type -
Breakdown of all systems -

Center pivot:	66	(37.7%)
Gated pipe:	94	(53.7%)
Sideroll:	3	(1.7%)
Tractor move:	1	(0.6%)
Handmove:	3	(1.7%)
Big gun:	5	(2.9%)
Ditches:	1	(0.6%)
Drip:	1	(0.6%)
Solid set:	1	(0.6%)

Irrigation system manufacturer -

Valley:	33	(41.3%)
Zimmatic:	19	(23.8%)
T and L:	5	(6.3%)
Rain Bird:	2	(2.5%)
Olson:	11	(13.8%)
Doud:	2	(2.5%)
Hygromatic:	3	(3.8%)
E-Z Rain:	2	(2.5%)
A and M:	2	(2.5%)
Lindsey:	1	(1.3%)
# of answers	80	

Capacity of irrigation system -
Average = 751.3 gpm

Delivery pipe from well to system?
(Does water have to be pumped to the system?)
Yes: 53%
No: 47%

Length of delivery pipe -
Average = 1620 feet

Size of delivery pipe -

2 inches:	1	(1.3%)
4 inches:	3	(4.0%)
6 inches:	18	(24.0%)
7 inches:	4	(5.3%)
8 inches:	34	(45.3%)
10 inches:	13	(17.3%)
12 inches:	2	(2.7%)
# of answers	75	

Age of delivery pipe -
Average = 9.6 years

Is delivery pipe buried or surface?
Buried: 47%
Surface: 53%

Delivery pipe material -

Aluminum:	33	(45.2%)
Plastic:	29	(39.7%)
Steel:	11	(15.1%)
# of answers	73	

Breakdown of previous and future irrigation system changes -

	Previous		Future	
Install tailwater pit:			7	(23.3%)
Switch to center pivot:	6	(21.4%)	2	(6.7%)
Switch to low pressure:	2	(7.1%)	4	(13.3%)
Switch to flood system:	3	(10.7%)	1	(3.3%)
Install new motor or pump:	4	(14.3%)	2	(6.7%)
Switch to sideroll system:	1	(3.6%)	1	(3.3%)
Increase acreage:	2	(7.1%)	2	(6.7%)
Smaller engine:	1	(3.6%)	1	(3.3%)
Siphon to gated pipe:	1	(3.6%)		
Level land:			5	(16.7%)
New nozzles:	1	(3.6%)		
Drill new well:	1	(3.6%)		
Install tailwater pumps:			3	(10.0%)
Install new pivot:	2	(7.1%)	1	(3.3%)
Switch to electric motor:	3	(10.7%)		
Switch to diesel engine:			1	(3.3%)
Lower the well:	1	(3.6%)		

Well information:

Age of well -
Average = 10.1 years
Breakdown -

0-5 years	56.	(35.2%)
6-10 years	53.	(33.3%)
11-15 years	24.	(15.1%)
16-20 years	12.	(7.5%)
21-25 years	3.	(1.9%)
26-30 years	10.	(6.3%)
Greater than 30 years	1.	(0.6%)

Depth of well -
Average = 117.4 feet
Breakdown -

0-20 feet	10.	(6.5%)
21-40 feet	12.	(7.8%)
41-60 feet	23.	(14.9%)
61-80 feet	21.	(13.6%)
81-100 feet	17.	(11.0%)
101-120 feet	18.	(11.7%)
121-140 feet	14.	(9.1%)
141-160 feet	8.	(5.2%)
161-180 feet	6.	(3.9%)
Greater than 180 feet	25.	(16.2%)

Static water level -
Average = 39.8 feet
Breakdown -

0-10 feet	23.	(14.0%)
11-20 feet	39.	(23.8%)
21-30 feet	26.	(15.9%)
31-40 feet	22.	(13.4%)
41-50 feet	12.	(7.3%)
51-60 feet	9.	(5.5%)
61-70 feet	3.	(1.8%)
71-80 feet	6.	(3.7%)
81-90 feet	5.	(3.0%)
Greater than 90 feet	19.	(11.6%)

Drawdown during pumping -
Average = 36.1 feet
Breakdown -

0-10 feet	0.	(0.0%)
11-20 feet	1.	(11.1%)
21-30 feet	3.	(33.3%)
31-40 feet	5.	(55.5%)

Total time of pumping in 1983 -
Average = 626 hours
Breakdown -

0-150 hours	21.	(16.2%)
151-300 hours	18.	(13.8%)
301-450 hours	16.	(12.3%)
451-600 hours	19.	(14.6%)
601-750 hours	7.	(5.4%)
751-900 hours	18.	(13.8%)
901-1050 hours	19.	(14.6%)
1051-1200 hours	5.	(3.8%)
1201-1350 hours	3.	(2.3%)
Greater than 1350 hours	4.	(3.1%)

Energy source -

Electric:	60	(33.7%)
LP Gas:	11	(6.2%)
Propane:	29	(16.3%)
Diesel:	39	(21.9%)
Natural Gas:	31	(17.4%)
Butane:	4	(2.2%)
Gasoline:	4	(2.2%)
# of answers	178	

Bore hole size -
Average = 26.7 inches

Well casing size -
Average = 15.0 inches

Well screen length -
Average = 39.4 feet

Depth to well screen -
Average = 67.9 feet

Depth below well screen -
Average = 44.0 feet

Well screen type -

Perforated casing:	45	(36.6%)
Transite:	31	(25.2%)
Steel:	15	(12.2%)
Concrete:	15	(12.2%)
Plastic:	14	(11.4%)
Wire:	2	(1.6%)
Slots:	1	(0.8%)

# of answers 123

Gravel pack in well?
Yes: 95%
No: 5%

Capacity of pump -
Average = 831.1 gpm

Number of pump bowls -
Breakdown -

1 bowl:	2	(1.8%)
2 bowls:	37	(33.9%)
3 bowls:	36	(33.0%)
4 bowls:	14	(12.8%)
5 bowls:	16	(14.7%)
6 bowls:	3	(2.8%)
7 bowls:	1	(0.9%)

# of answers 109

Pump manufacturer -

Western Landroller:	80	(52.3%)
Berkeley:	20	(13.1%)
Amarillo:	6	(3.9%)
Layne-Bowler:	8	(5.2%)
Emerson:	1	(0.7%)
Peerless:	20	(13.1%)
Valley:	1	(0.7%)
Simmons:	1	(0.7%)
Jacuzzi:	3	(2.0%)
Denver-Gardner:	4	(2.6%)
Hastings:	1	(0.7%)
Meyer:	1	(0.7%)
Randolph:	2	(1.3%)
Layne-Western:	2	(1.3%)
American:	1	(0.7%)
AERmotor:	1	(0.7%)
Aurora:	1	(0.7%)

# of answers 153

Age of pump -
Average = 11.1 years

System operating pressure -
Average = 45.2 psi

Pump operating speed -
Average = 1696 rpm

Pump column size -
Breakdown -

3 inches:	3	(2.2%)
4 inches:	12	(8.9%)
5 inches:	1	(0.7%)
6 inches:	29	(21.5%)
8 inches:	86	(63.7%)
10 inches:	4	(3.0%)

# of answers 135

Pump service history -

No problems:	149	(98.0%)
Adjust bowls:	2	(1.3%)
Bearings:	1	(0.7%)

# of answers 152

Power unit manufacturer-

John Deere:	6	(4.8%)
International:	14	(11.1%)
Minneapolis Moline:	17	(13.5%)
U. S. Motor:	10	(7.9%)
Ford:	28	(22.2%)
Perkins:	6	(4.8%)
Emerson:	1	(0.8%)
Chevrolet:	1	(0.8%)
AMC:	1	(0.8%)
Cummings:	2	(1.6%)
General Electric:	9	(7.1%)
Chrysler:	10	(7.9%)
Jacuzzi:	1	(0.8%)
Belarus:	3	(2.4%)
Allis Chalmers:	10	(7.9%)
Continental:	1	(0.8%)
Waukesha:	1	(0.8%)
Detroit:	2	(1.6%)
JEEP:	1	(0.8%)
Marathon:	1	(0.8%)
Hercules:	1	(0.8%)

# of answers 126

Power unit service history -

No Problems:	128	(88.9%)
Driller Mistake:	2	(1.4%)
Rewound Motor:	4	(2.8%)
Bearings:	1	(0.7%)
Overhauled:	6	(4.2%)
Cracked Block:	1	(0.7%)
Engine Cooling Problems:	1	(0.7%)
Rewired:	1	(0.7%)

# of answers 144

Age of power unit -
Average = 10.2 years

Power unit size -
Average = 50.9 horsepower

Driller -

Peterson:	59	(36.0%)
Harp:	16	(9.8%)
Darling:	37	(22.6%)
Theissen:	4	(2.4%)
Johnson:	2	(1.2%)
Weninger:	29	(17.7%)
Paul´s:	2	(1.2%)
Pratt Well Service:	1	(0.6%)
Anderson:	1	(0.6%)
Layne-Western:	2	(1.2%)
Henderson:	1	(0.6%)
Rosencrantz & Beemus:	2	(1.2%)
Owner of Well:	3	(1.8%)
Clark:	3	(1.8%)
Del Wells:	2	(1.2%)

# of answers 164

Drive Ratio -

1:1	45
6:5	9
7:4	1
2:1	1
5:6	2
11:10	2
5:4	2
4:3	2
3:4	3
1:1.2	1
4:1	2
2.5:1	1
3:2	1
1:3	1
2:3	1
Belt Driven	1

Drive Manufacturer -

Amarillo:	9	(60.0%)
General Electric:	1	(6.7%)
General Motors:	1	(6.7%)
Western Landroller:	2	(13.3%)
U. S. Motor:	1	(6.7%)
Randolph:	1	(6.7%)

# of answers 15

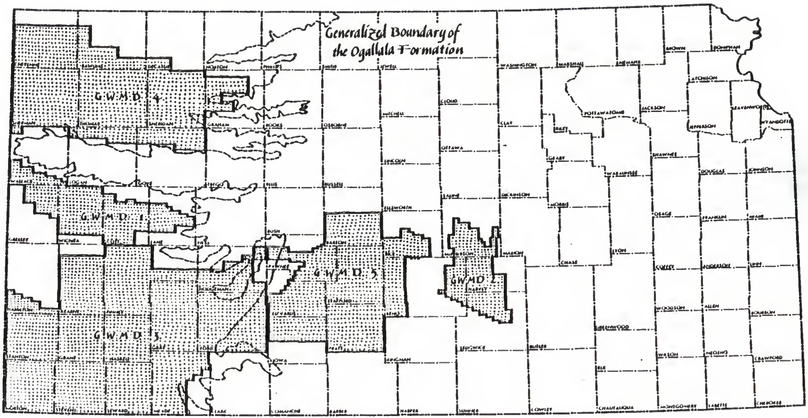
Drive Service History -

No Problems:	47	(94.0%)
New Bearings:	3	(6.0%)

# of answers 50

APPENDIX C

Groundwater Management Districts in Kansas



Groundwater Management Districts in Kansas

KANSAS WATER RESOURCES BOARD

SAMPLE SIZE DETERMINATION FOR AN IRRIGATION BASELINE STUDY

by

THOMAS ALAN KIRKEENG

B.S., University of Wisconsin-Platteville, 1982

An ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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KANSAS STATE UNIVERSITY
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1984

An irrigation baseline study was undertaken in a Kansas Groundwater Management District. There were two main objectives to the study. One was to develop an efficient procedure for carrying out an irrigation baseline study. Central to this objective was determining the proper sample size. The other objective was to establsh an irrigation baseline for comparing future irrigation developments.

A Kansas Groundwater Management District was chosen for the study because each district possesses similar irrigation characteristics within its region. The Equus Beds Groundwater Management District #2 in south-central Kansas was selected for the survey because it is the smallest of the five districts in Kansas, it is the closest to Manhattan, and has a minimum of water problems.

A method of personal interviews was used to collect data. Basically, questions were broken into four categories: irrigator informaton, farming enterprise information, water management information, and individual field information. Information was gathered from 20% of the irrigator population, the names being selected at random.

Statistical parameters such as sample means, sample standard deviations, and sample proportions were used, along with error limits of 5, 10, and 15%, respectively, to estimate the sample size required to determine various irrigation characteristics within given error limits.

Sample sizes were calculated for fourteen different question categories. Included were irrigator age, farmer experience, irrigation experience, irrigation training, acres operated, water applicaton procedures, water quality testing, irrigated field size, irrigation system type, irrigation system age, water usage, well yield, well metering, and pump type. The sample sizes for a

5% error averaged 40%, which is too high to be practically considered when conducting an irrigation survey to estimate the irrigation parameters chosen. For a given relative error limit of 10%, an average sample size of 15% was found to be necessary. If the allowable error limits are increased to 15% the average sample size is 7%, or half of that required for a 10% error. This shows that a reasonable estimate of most irrigation parameters can be found for an economical sample size of well under 10%. Also, when applying these results to an irrigation region larger than that of The Equus Beds Groundwater Management District #2, the percent sample size would decrease as population increased.

Along with determining sample size for an irrigation survey, this study exhibited that a professional-looking questionnaire and good understanding of the purposes of the survey by the irrigators aids in irrigator cooperation.