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IDENTIFICATION OF FACTORS AFFECTING  
FARMSTEAD WELL WATER QUALITY IN KANSAS

by

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## ABSTRACT

Concern about the extent of contamination of domestic wells on Kansas farmstead with pesticides, volatile organic compounds (VOCs), and minerals led to this study to obtain best estimates of the percent of wells contaminated. A random sampling scheme to draw a sample of one hundred wells from a population of over 40,000 such wells was designed and carried out by sampling each well and analyzing the water for pesticides, VOCs, and minerals. In conjunction with the water sampling, a questionnaire was developed which provided information from residents at the farmsteads about the well, nature of the farming operation, and activities around the farm that might influence the quality of water from the well.

Results of the water analyses ( $\alpha = 0.05$ ) showed that for farmstead wells in Kansas, the percentage of wells with detectable amounts of pesticides is  $9 \pm 6$  percent, for wells with detectable amounts of VOCs it is  $2 \pm 3$  percent, and for wells with inorganic contamination exceeding the Maximum Contaminant Level (MCL) for one or more constituent it is  $38 \pm 9$  percent. Nitrate was the most common source of inorganic contamination occurring in 28 percent of the wells tested. Selenium was next most common with 9 percent showing levels above the MCL.

Various statistical analyses were performed to try to pick out factors that influenced the occurrence of various contaminants in the samples. Because the statistical design was to obtain a random sample, results of testing individual factors were not surprising. No relationships were found that explained the occurrence of pesticides or VOCs. Nitrate and selenium concentrations were related to geographical and precipitation regions of the state. Higher nitrate levels were found in the south central, north central, and northeast regions of the state and in precipitation regions with from 26-35 inches of annual precipitation. Higher selenium concentrations were found in the southwest and north central parts of the state and where annual precipitation is less than 30 inches. A statistically significant multiple regression model to estimate the concentration of nitrate from a well was identified. The model includes the age of the well, land use around the well, and distance to a possible source of organic contamination such as a feedlot or septic tank.

The extent of contamination of farmstead wells with pesticides and VOCs is not of immediate concern in Kansas. The high incidence of nitrate contamination makes it prudent to test a well before it is used as a source of drinking water for infants, pregnant women, or young animals. Additional work using a statistical sampling plan designed to evaluate factors which might affect water quality especially for nitrate, pesticides and VOCs is needed to help assess if a well should be sampled and analyzed for possible contamination. Such a plan could aid in identifying wells that are at risk among the large number of farmstead wells so that the cost of analyses can be kept to a reasonable amount while still assuring the public health of groundwater users on farms in Kansas. Additionally, the results of such a study could be utilized to develop guidelines for siting and protection of farmstead wells from contamination.

### KEYWORDS:

Wells, Groundwater, Domestic water, Pollution, Nitrate, Pesticides,  
Volatile organic compounds, Selenium, Kansas

## INTRODUCTION

Citizens of Kansas are becoming increasingly concerned about water. Topics at the center of the debate are quantity and quality. Water, a resource of great value, is susceptible to degradation from many sources, particularly manmade ones. Groundwater constitutes the major portion of drinking water supplies in Kansas. When this resource becomes contaminated by chemicals, inorganic materials and other pollutants, it loses value that can not be easily restored. In recent years there have been many reports of groundwater contamination throughout the United States and Kansas.

Groundwater forms the cornerstone of Kansas water supply. Nearly ninety percent of rural Kansans rely on groundwater as their source of drinking water. About half of all Kansans are supplied from this source. Groundwater in storage in Kansas has been estimated to equal 385 million acre feet. This amount roughly equals two to seven years of normal precipitation across the state or 35 times the amount stored in all the state's major reservoirs. It becomes readily apparent that Kansas will continue to rely heavily upon groundwater in the future.

Groundwater, in the past, has been assumed pure. Water that normally comes from aquifers is clear compared to surface waters. To many people, the earth's crust acts as a filter, depository and protective layer above the saturated layer in unconfined aquifers. People in the past have relied on this sense of security in their approach to land use practices. Only in the last decade has the ability to detect chemical constituents at very low concentrations been developed. Now this technology is being used to thoroughly analyze all contaminants in water.

Contaminants are considered to be any synthetic chemical at any detectable concentration and naturally-occurring chemicals at concentrations above drinking water standards. Water from nearly all privately-owned wells is not tested on a regular basis. When problems with the water, such as taste and odors, occur it is often too late to stop or reverse the contamination. "In the classic case, people notice that their water smells or tastes bad" (Maranto, 1985).

Agriculture has advanced rapidly because of technology in the last three decades and brought potential pollution problems along with it to farmsteads. Many farming activities can have negative impacts upon groundwater quality. Fertilizers and pesticides commonly used on farms in Kansas are essential if we are to remain efficient and produce needed food. Carbon tetrachloride, a known carcinogen, has been widely used to fumigate grain in storage. Large feedlots have become commonplace, concentrating many animals and their byproducts into relatively small areas. Farmshops use many chemicals including solvents, paint thinners and degreasers that contain chemicals that have not been evaluated for their toxicity when consumed at low levels over long periods of time. Septic tanks may be improperly constructed and/or located too near a water well. Chemicals containing solvents (VOCs) may be added to septic tanks to "improve" the absorption bed.

The water well itself may be a cause of contamination because it can be a direct "conduit" into an aquifer. Private wells may be poorly constructed, have inadequate surface protection or be located unknowingly near contaminant sources. Chemigation, the injection of chemicals

into irrigation systems, was largely unregulated until recently and may have resulted in back-siphoning of agricultural chemicals into wells, tainting aquifers for long periods of time.

The degree of contamination of wells nationwide has been estimated in the range of 2 to 10 percent (Maranto, 1985; Pye and Patrick, 1983). The four pollutants most commonly reported--chloride, nitrate, heavy metals and hydrocarbons--may be a reflection of the monitoring practices prevailing at the time the surveys were conducted (Pye and Patrick, 1983). About 80 per cent of all groundwater pollution problems are caused by chlorinated compounds used in industrial solvents and degreasers; trichloroethylene (TCE) and carbon tetrachloride, for example. TCE reaches groundwater not only through industrial waste disposal, but also through backyard septic tanks because TCE is an ingredient in many septic tank cleaning aids (Tangley, 1984).

The Kansas Department of Health and Environment (KDHE) and United States Geological Survey (USGS) have cooperatively operated a groundwater quality monitoring network since 1976. Approximately 250 network wells have been tested over the ten-year period. Pesticides have been detected in 2 per cent of the samples (Robbins, 1986). Atrazine was the most commonly detected pesticide, followed by 2,4-D.

Volatile Organic Compounds (VOCs) have been detected in groundwater throughout the U.S. Benzene, a component of gasoline, is a prime example of a VOC. A survey of 945 public water supplies (Westrick et al., 1984) showed the percentages of supplies containing at least one VOC ranged from 16.8 percent to 37.3 percent depending upon population size served by the water supply and whether the sample was random or non-random.

How VOCs get into farmstead wells is unknown. VOCs are volatile substances and many are easily degraded in open-air environments. Sources include fuels, solvents, degreasers, and fumigants. Many VOCs, especially fumigants, are much more dense than water and rapidly move downward through soil by gravity.

Pesticides present a dilemma similar to VOCs because most have been tested for their ability to be degraded and dissociate in the environment. These tests, however, have been only in aerobic soil environments not in the anaerobic saturated region found below the rooting zone. Potential to contaminate groundwater was given little consideration when pesticides were being evaluated for registration until very recently. None of the pesticides currently available for use were given significant review for groundwater pollution potential.

While sampling public water supply wells for contamination with VOCs, KDHE sampled private wells in the vicinity to evaluate the extent of the contamination plume. In one case a farmstead well was found to contain carbon tetrachloride, yet all surrounding wells were uncontaminated. This led KDHE to believe the source came from the farmstead itself. The question arose as to how widespread and severe this problem might be. This led to the initiation of this project.

The main purpose of this study was to determine, statistically from a random survey, the extent of contamination of rural Kansas farmstead wells by VOCs, pesticides and inorganic constituents. A second purpose was to determine relationships, if any, between agricultural practices around the wells and water quality from the wells.

## OBJECTIVES

KDHE conducts a sampling and analysis program to determine the extent of pollution of wells used for public water supplies. KDHE decided information was needed for private wells, particularly on farmsteads. In order to make the best possible determination of extent of contamination, Kansas State University was asked to help decide where more effort should be exerted on this project.

The objectives for this project were

- 1) Development of a sampling plan and identification of wells to be sampled which represent the population of farmstead wells.
- 2) Obtaining owner's permission to test the well.
- 3) Development of a questionnaire to obtain information about the well and activities that might be related to water quality from the well.
- 4) Sampling and analyzing the water to determine presence of VOCs, pesticides and other selected chemical constituents.
- 5) Establishment of best estimates of extent of contamination with various constituents.
- 6) Perform statistical analyses on the results of the chemical analysis and questionnaire data to determine if meaningful correlations exist.
- 7) Determine what, if any, additional action is needed protect public health and groundwater quality on Kansas farmsteads.

## PROCEDURE

### Sample Selection

The usual procedure for obtaining an estimate of the characteristics of a population is to collect a random sample from the population. Increasing the number of observational units sampled results in greater accuracy. Because of the high cost of chemical analysis and limited resources, the sample size was limited to about one hundred wells.

A statistically random sample requires two things: (1) a "frame" or list of all members of the target population, and (2) a sampling scheme which will select the desired number of subjects so that each has equal probability of being selected. The sampling scheme used here does not follow the first rule completely. There are over 40,000 farmstead wells in Kansas (1982 Census of Agriculture - County Data). At the present time no list of Kansas water well owners exists. The closest thing available was 1980 and 1982 census data provided by Ott (1985). This list approximates the number of farmstead wells in Kansas by county. This list was used as a frame to select counties from which wells would be sampled.

Given the allowable sample size of  $n=100$  and a list approximating 40,000 wells for the state resulted in using a one in four hundred sampling ratio. A random number between 1 and 400 was selected from a published random number table: the number chosen was 294. To reduce the costs of surveying wells it was decided to choose 2 wells per county

selected instead of one. Hence, increments of 800 were added to the random number generating the series  $284 + 800k$ . The 105 counties in Kansas were assigned a cumulative count of wells by the following formula:

$$F_i = \sum_{i=1}^n f_i$$

where,

$$i = (1, 2, \dots, 105)$$

$f_i$  =  $i$ th county well count  
 $F_i$  =  $i$ th county cumulative well count

A county for which one of the increments  $284 + 800k$  fell between  $F_{i-1}$  and  $F_i$  was selected for sampling. This resulted in two subject farms being selected from 48 counties and four were picked from two counties because of the large numbers of wells in those counties. The counties which were selected are identified on a map (Figure 1) and tend to be clustered more in the central and northern parts of the state. This mirrors the distribution of all farmstead wells across the state.

Because information about the nature of activities around the well and about the well was also needed, four criteria were set forth that had to be met before a well was enrolled in the program.

- 1) The well had to be at a farmstead performing farm operations.
- 2) Residents of the farmstead needed to be familiar with the activities near the well for the past ten years.
- 3) Residents of the farmstead had to be willing to cooperate.
- 4) Residents of the farmstead had to use water from the well in their home.

Since we lacked a list of farmstead well owners in each county, County Extension Agricultural and Home Economics Agents in the selected counties were requested by letter to provide the names of five individuals who they thought met the four criteria stated above. Nearly all county agents replied. One county was dropped from this list because it is now supplied almost entirely with water from rural water districts. Five names could not be supplied in this case. A neighboring county was then chosen as a substitute. In the two counties with a quota of four wells, ten names were requested.

All individuals identified by the extension agents were sent a letter inviting them to participate in the study. The letter explained the other requirements: to fill out a questionnaire and allow KDHE to sample and analyze water from their well in return for the results of the water analysis. The reply rate to this letter was 65 percent, and 90 percent of those responding agreed to participate. In most counties more than two individuals agreed to participate, so a random order was used to select two or four from the group of willing participants.

### Water Collection and Analysis

KDHE district staff collected the water samples. Analytical work to determine presence of contaminants was performed by the KDHE Environmental Laboratory at Topeka. Samples were collected between December

# LEGEND

- Well Sampled
- ☆ Pesticide Detected
- ☆ Volatile Organic Chemical Detected
- ☆ Nitrate Above MCL\*
- ☆ Selenium Above MCL\*
- Fluoride Above MCL\*
- \* Maximum Contaminant Level

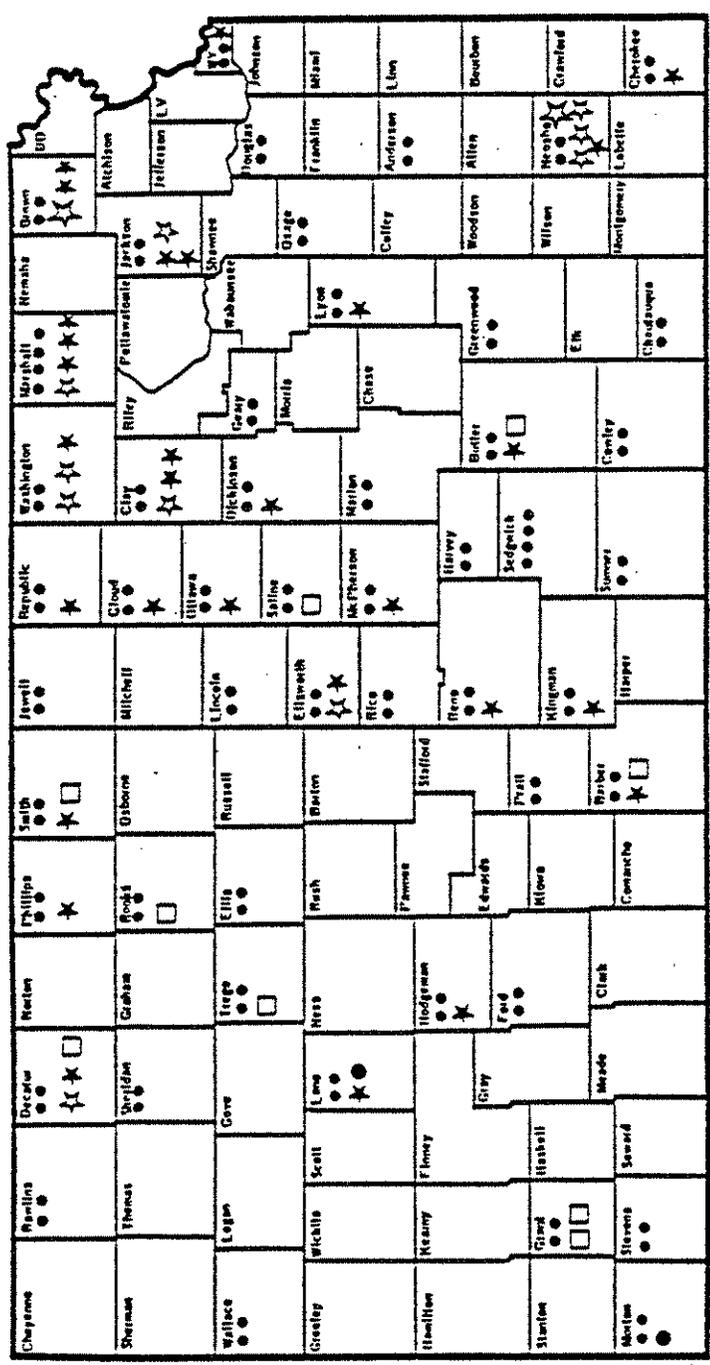


Figure 1. Map showing counties in Kansas in which wells were sampled, wells with detectable amounts of pesticides and VOCs were found, and wells with inorganic chemicals exceeding MCLs for public water supplies were found.

1985 and February 1986. Sampling was done at the outlet nearest from the well to avoid extraneous sources of contamination. Water was not retained until after 5 minutes of release had occurred. Five containers were then filled in order to get a sample for the different tests: purgeable organics, routine pesticides, heavy metals, ammonia and minerals. Bottled samples were kept chilled during transport to the laboratory and while awaiting analysis.

All water samples were analyzed for the contaminants listed in Table 1. Purgeable organics were measured with a combination gas chromatograph and mass spectrometer according to EPA Method 624 (USEPA, 1984b). Organochloride pesticides and PCBs were measured as described in EPA Method 608 (USEPA, 1984a). Chlorophenoxy acid herbicides were measured as described by the EPA (USEPA, 1978). Both tests for pesticides included extraction and preparation followed by gas chromatography and detection by electron capture. All inorganic chemicals (minerals) were measured by EPA approved methods (USEPA, 1982) except those for which no method is prescribed. If there was no EPA-approved method, the procedures described in Standard Methods for the Examination of Water and Wastewater, 16th edition (APHA-AWWA-WPCF, 1985) were used.

### Questionnaire

The questionnaire was designed to gather supporting information about the nature of the farming operations at and originating from the farmsteads, pesticides and VOCs used on the farm, waste disposal practices, characteristics of the well, problems, if any, that were associated with the well, and any other information which the cooperating scientists thought might influence water quality from the wells. Table A1, Appendix A lists the nearly 300 questions that were asked in the questionnaire.

### Data Analyses

Introduction: All data from the questionnaires (See Appendix A) and water quality analyses (See Appendix B) were entered into an electronic spreadsheet on a microcomputer. Output from parts of the spreadsheet were then uploaded into the mainframe computer at Kansas State University for statistical analyses. The data were encoded with "1" meaning a positive response and "0" a negative response for yes/no questions. A "." (period) was used for no response. Multiple answer questions were encoded on a scale with the worst case(s) condition given a low rating and and best case(s) given a high rating. For example, for soil type around the well the following scale was used: Clay - 25, Loamy - 20, Silty - 15, Sandy - 10, Gravel - 5. For other ratings see Table A2 of Appendix A.

Dependent Variables: After examining the data, the dependent (response) variables nitrate, selenium, pesticides, VOCs and chlorides were chosen for further consideration.

Data Grouping: The data were collated into three major groupings for analysis. These groupings were geological water region, geographical region and precipitation region. The subparagraphs that follow describe each of these groupings.

Table 1. Contaminants for which analyses were made in each water sample.

<u>Volatiles organic compounds</u>	Detection limit <u>ug/l</u>	<u>Pesticides</u>	Detection limit <u>ug/l</u>
Benzene	0.4	Alachlor	0.25
Bromodichloromethane	0.5	Aldrin	0.025
Bromoform	1.5	Atrazine	1.2
Bromomethane	1.2	Chlordane	0.25
Chlorobenzene	0.4	Dacthal	0.05
Chloroethane	3.7	Dieldrin	0.05
Cis 1,3-dichloropropene	0.9	Dual	0.25
Chloromethane	5.0	Endrin	0.1
Dibromochloromethane	0.7	Lindane	0.025
Dichloromethane	0.9	Methoxychlor	0.2
Ethylbenzene	0.7	O,P' DDT	0.1
Tetrachloroethylene	1.1	P,P' DDT	0.1
Tetrachloromethane	0.7	Ramrod	0.25
Toluene	0.4	Sencor	0.1
Trans 1,2-dichloroethylene	0.5	Silvex	0.2
Trans 1,3-dichloropropene	0.8	Toxaphene	2.0
Trichloroethylene	0.6	2,4,5-T	0.2
Trichloromethane	0.5	2,4-D	0.4
Vinyl chloride	0.8	Tordon	0.4
1,1,1-trichloroethane	0.7	Heptachlor	0.02
1,1,2,2-tetrachloroethane	0.6	epoxide	
1,1,2-tetrachloroethane	0.6		
1,1-dichloroethane	0.5	<u>Ohter</u>	
1,1-dichloroethylene	0.6		
1,2-dichloroethane	0.6	P.C.B.'s	0.5
1,2-dichloropropane	0.4		
Meta-xylene	0.6		
Ortho &/or para-xylene	1.0		
1,2 &/or 1,4-dichlorobenzene	1.0		

Inorganic chemicals (minerals)

Alkalinity	Potassium
Ammonia	Selenium
Arsenic	Silica
Barium	Silver
Cadmium	Sodium
Chloride	Specific conductance
Chromium	Sulfate
Copper	Total phosphorus
Fluoride	Total dissolved solids
Iron	Total hardness .
Lead	Turbidity
Manganese	Zinc
Mercury	pH
Nitrate	

- 1) Geological Water Regions (Figure 2): To allow water managers to assess possible regional water quality problems within the state, Kansas has been divided into 14 groundwater regions. They are relatively homogeneous with respect to topographical, geological, land use and water use features and are similar to physiographic divisions presented in Schoewe (1953).
- 2) Geographical Regions (Figure 3): The state was divided arbitrarily along county lines into six approximately equal parts of northeast, southeast, north central, south central, northwest and southwest. Counties were not subdivided between regions.
- 3) Precipitation Regions (Figure 4): The division along county lines was based on normal annual precipitation as follows: Region 1 - less than 20 inches, Region 2 - between 20 and 25 inches, Region 3 - between 25 and 30 inches, Region 4 - between 30 and 35 inches and Region 5 - greater than 35 inches. Amounts of annual precipitation were taken from Climatic Data Summary for Kansas (1986) and Hjelmfelt and Cassidy (1975).

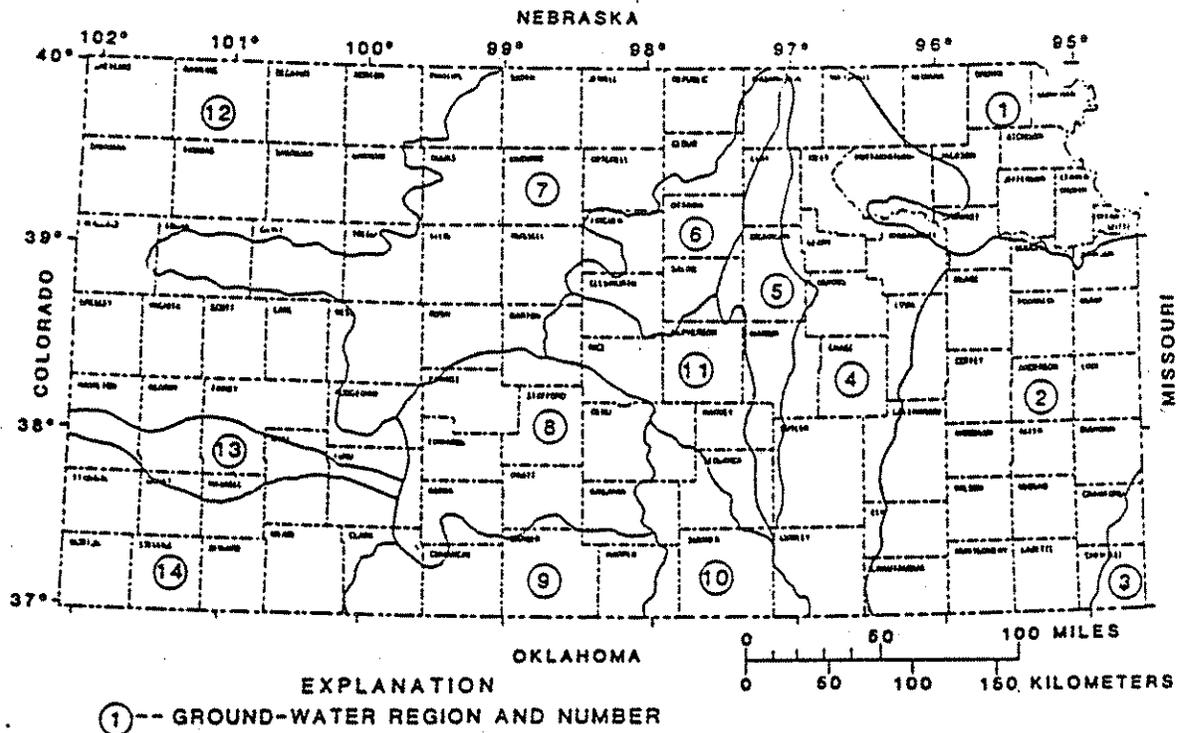


Figure 2. Map showing geological water regions used in statistical analysis models.

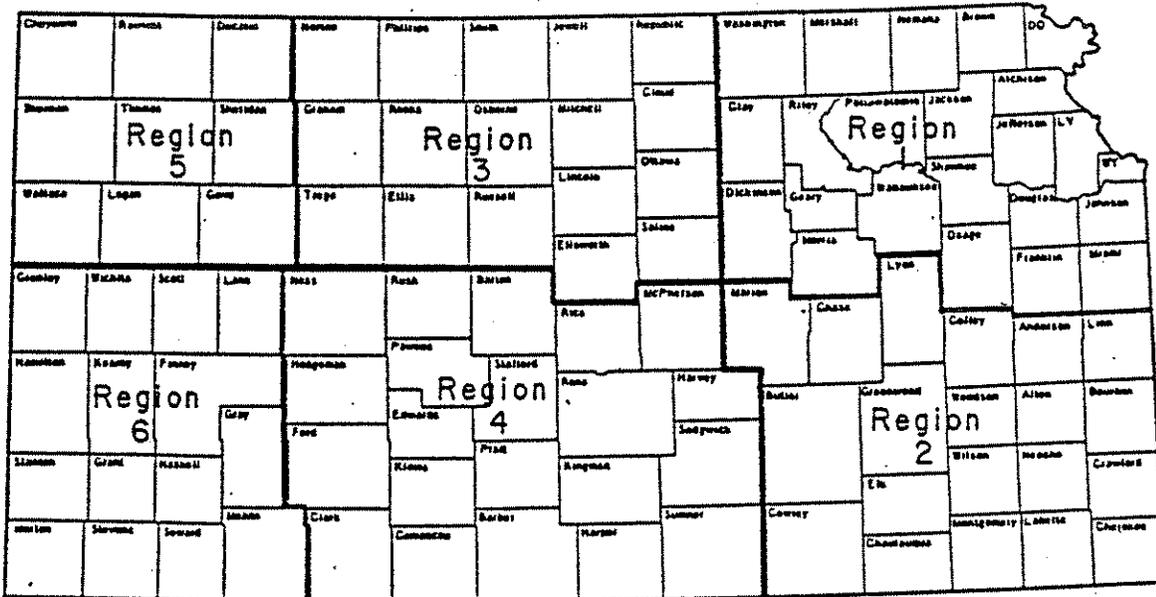


Figure 3. Map of geographical regions used in statistical analysis models.

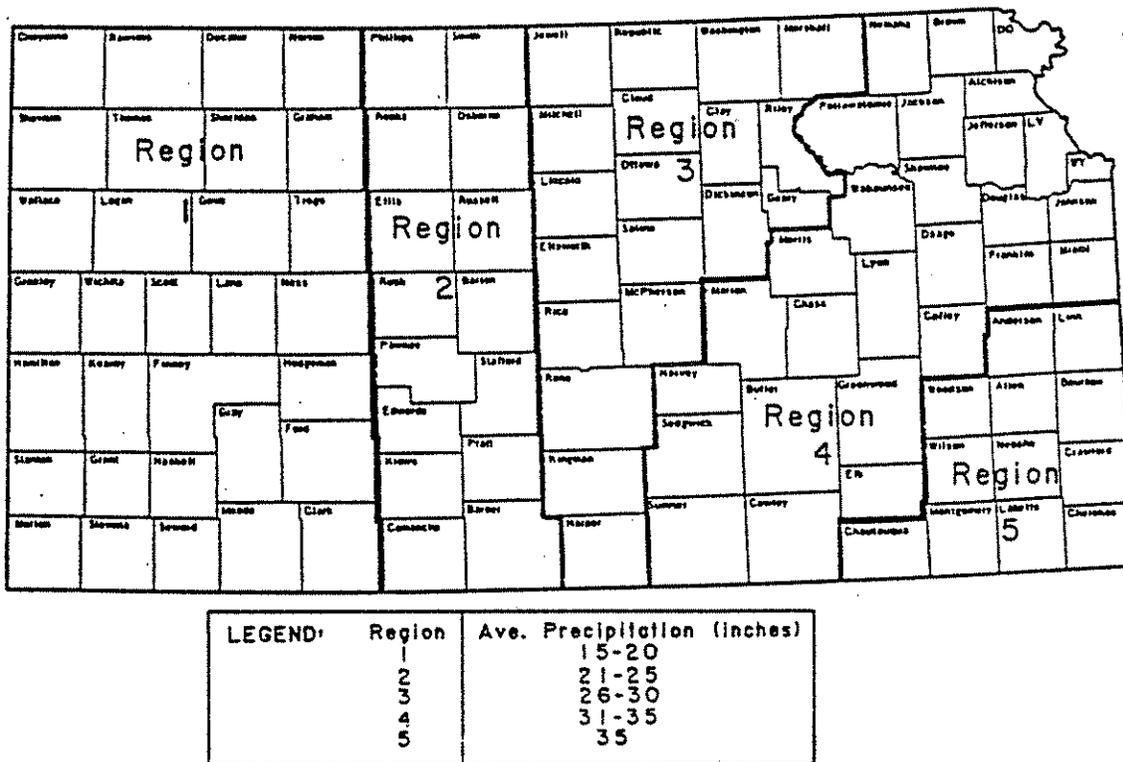


Figure 4. Map of precipitation regions used in statistical analysis models.

## RESULTS

### From the Questionnaires

All data from the questionnaires are contained in Table A3, Appendix A. A few pertinent results are summarized below. The questionnaires contained a wealth of data about farmstead characteristics; topography, soil characteristics, and land use around the well; household wastewater disposal methods; where various activities and facilities are located relative to the well; past disposal practices and events that might affect water quality from the well; use and application of herbicides and pesticides; and additional characteristics of the well. The results of most of these questions are succinctly summarized as part of Table A1 in Appendix A. A complete narrative description of these results is beyond the scope of this report.

**Well Descriptions:** General characteristics of the wells are presented here in the form of figures and a table. Figure 5 is a relative frequency histogram for the age of the wells sampled. Figure 6 summarizes who constructed the wells, methods of well construction, and type of grouting material used. Type of construction for the wells sampled

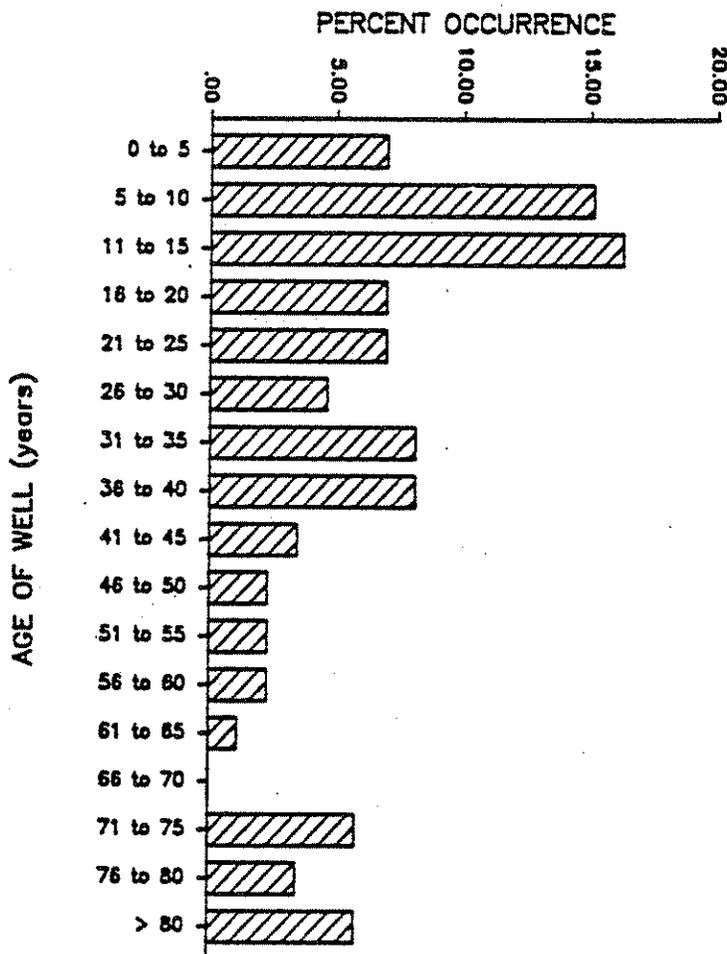


Figure 5. Relative frequency histogram of age of wells.

agreed closely with census data compiled by Ott (1985). The census reported 19 percent were dug while 15 percent of the wells sampled were reported as dug. Figure 7 shows the depths to water table, top of well screen and well bottom. Other facts about the wells are used are presented in Table 2.

Table 2. Miscellaneous facts about the wells.

<u>NUMBER</u>	<u>MIN</u>	<u>MAX</u>	<u>MEAN</u>	<u>STDV</u>
of persons who drink from well	0	13	3.64	2.11
of houses connected to well	0	3	1.10	0.41
of years in use	1	106	31.12	25.20

Additional pertinent descriptive statistics follow: water from 24 percent of the wells was treated in some way before drinking (25 out of 102), users of 24 percent of the wells had experienced difficulty with their septic tanks or lagoons (24 out of 101), and 4 percent of those sampled did not drink from their well (4 out of 103).

Pesticides and VOCs Used: Every farmer reporting used one or more pesticide on the farm. The most widely reported herbicides used were 2,4-D (79 percent), Atrazine (70 percent), Roundup (57 percent), and 2,4,5-T (32 percent). The most commonly used insecticides were Furadan (44 percent) and Sevin (43 percent). By virtue of using fossil fuels on their farms, every farm used one or more VOC.

### Water Quality Results

VOCs and pesticides were detected in several samples as shown in Table 3. Of the 103 wells sampled eight had detectable levels of pesticides present, two had detectable levels of VOCs and 38 had inorganic chemicals exceeding MCLs established by EPA (1984). Figure 1 shows the geographical distribution of wells where the detectable amounts were found. For all but one of the wells sampled which had detectable levels of VOCs or pesticides, concentrations were below the KAL (Kansas Action Level—the level which KDHE considers the water unacceptable for long-term consumption). All participants in the study received a copy of their well water quality analyses accompanied by an interpretation. In cases where KDHE considered the water quality to present a health concern or to be unacceptable as a drinking water supply, the users were so advised.

Detailed results are shown in Table 4. Nitrate was the contaminant most commonly found. Nitrate-N was present in 29 wells at a concentration exceeding the MCL of 10 mg/l. In half of these wells the concentration exceeded 20 mg/l of nitrate-N (See Figure 8). The highest concentration found was 129 mg/l, measured during resampling. Selenium was the next most common contaminant. It exceeded the MCL in 9 wells (See Figure 9). Fluoride concentrations on two wells exceeded the MCL and two wells exceeded the MCL for lead.

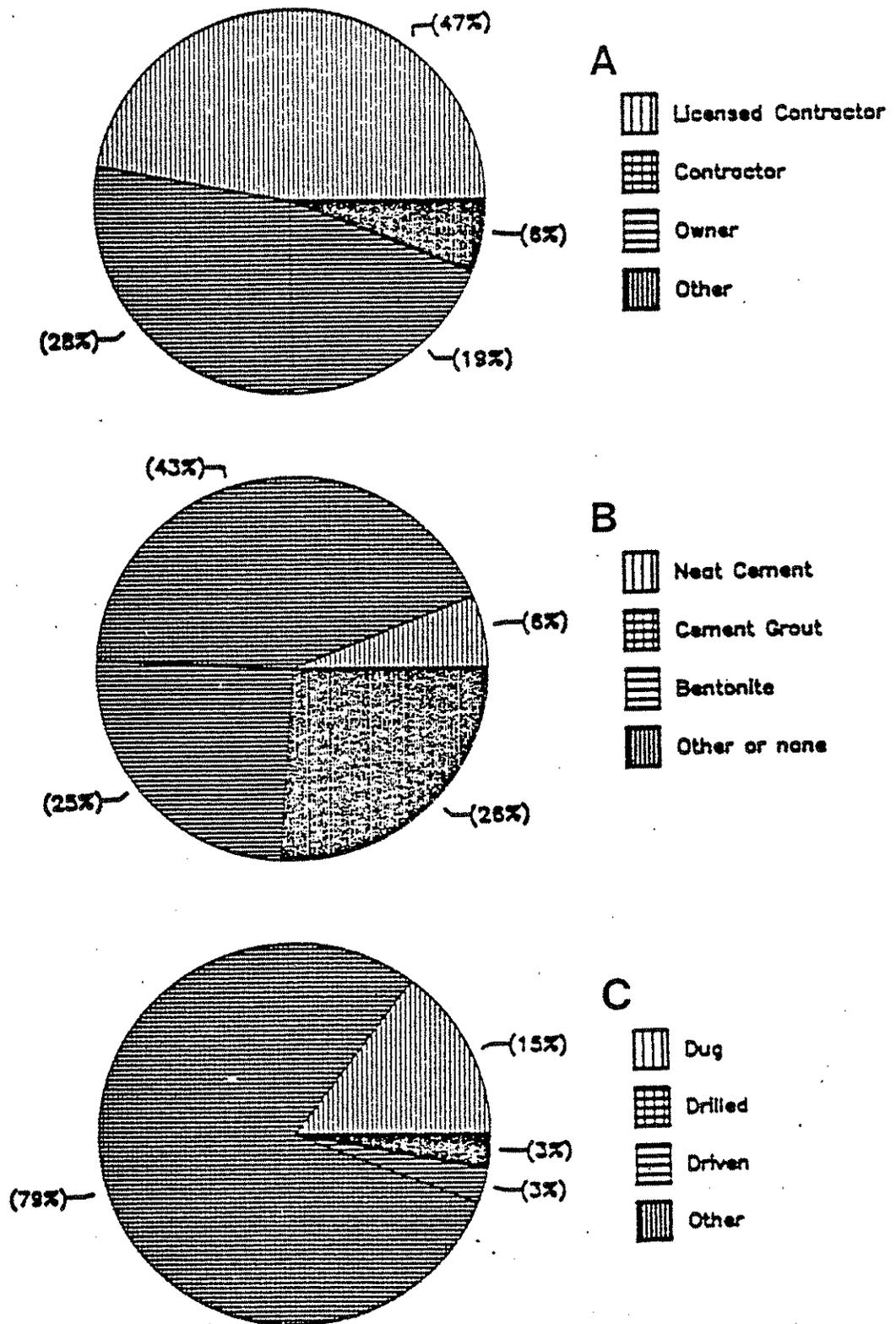


Figure 6. Pie charts for (A) who constructed the wells, (B) type of grouting methods, and (C) methods of well construction.  
 Note: Percent responding were A - 82, B - 64, and C - 99.

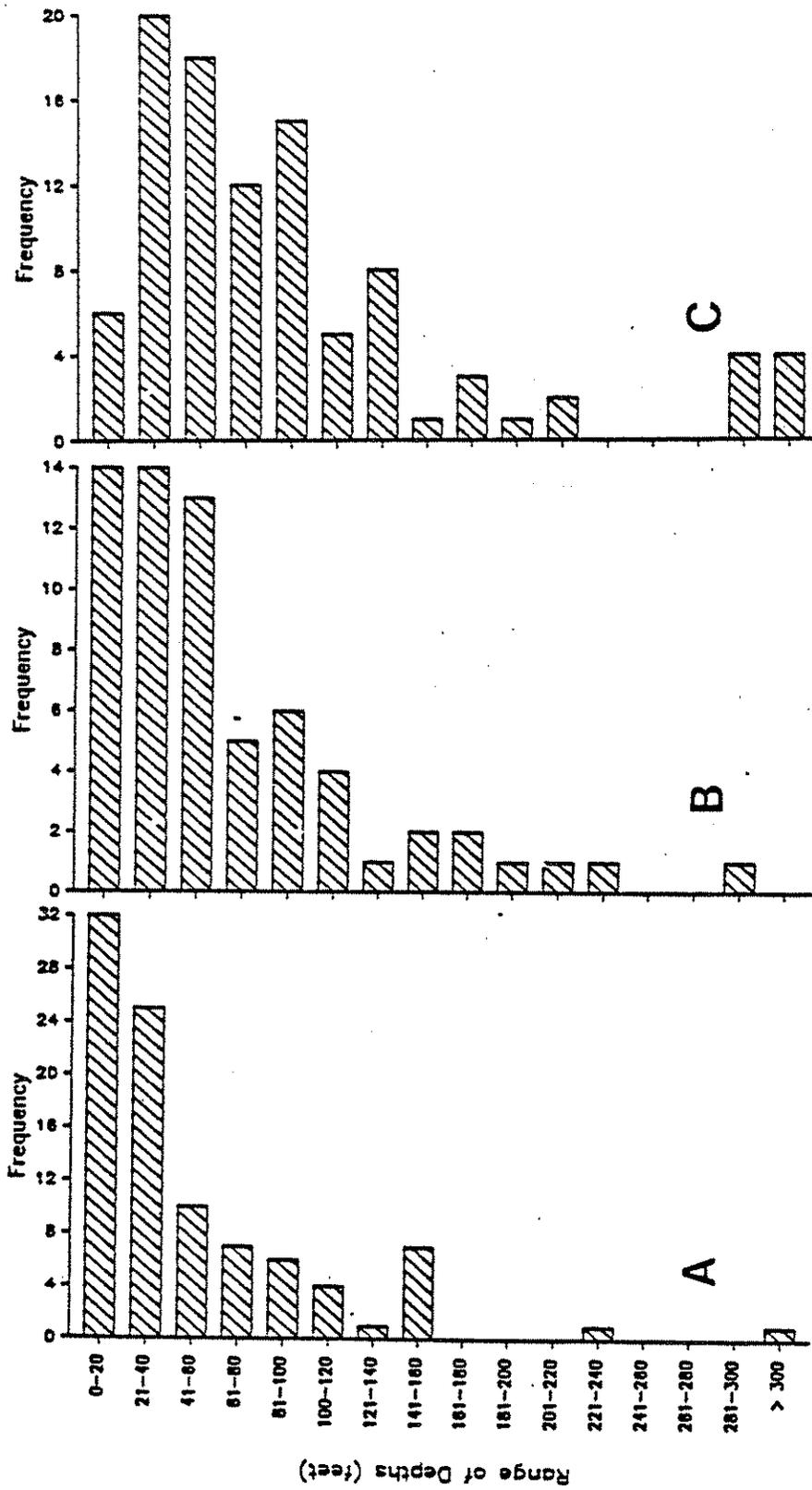


Figure 7. Frequency histograms for (A) depth to bottom of wells, (B) depth to water surface, (C) depth to top of screen.

Table 3. Summary of water quality analyses.

	<u>Number</u>	<u>Percentage, %</u>	<u>Confidence band width<sup>a</sup></u>
Wells sampled	103	100	--
Wells with pesticide	9	9	+6
Wells with VOC	2	2	+3
Wells with inorganic chemicals exceeding MCL <sup>b</sup>	39	37	+9

<sup>a</sup>Confidence band widths determined at alpha = 0.05

<sup>b</sup>Maximum Contaminant Level as established by the National Interim Primary Drinking Water Standards

Table 4. Contaminants found in farmstead wells<sup>a</sup>

<u>Chemical</u>	<u>No. of wells</u>	<u>Concentration</u>		<u>MCL or KAL<sup>b</sup></u>	
		<u>initial</u>	<u>resample</u>		
Nitrate-N (mg/l)	29	high=91	high=129	10	(MCL)
Selenium (mg/l)	9	high=0.056	NR <sup>c</sup>	0.01	(MCL)
Atrazine (µg/l)	4	high=7.4	high=40	150	(KAL)
Fluoride (mg/l)	2	high=2.3	NR	1.8	(MCL)
Lead (µg/l)	2	64	ND <sup>d</sup>	50	(MCL)
2,4-D <sup>e</sup> (µg/l)	1	1.3	f	100	(MCL)
2,4,5-T <sup>e</sup> (µg/l)	1	1.1	f	700	(KAL)
Tordon (µg/l)	1	5.6	3.3	175	(KAL)
Chlordane <sup>g</sup> (µg/l)	1	0.47	0.58	0.22	(KAL)
Heptachlor epoxide <sup>g</sup> (µg/l)	1	0.026	0.023	0.006	(KAL)
Alachlor <sup>h</sup> (µg/l)	1	0.88	1.8	15	(KAL)
1,2-Dichloroethane <sup>h</sup> (µg/l)	1	0.90	1.6	5	(KAL)
Benzene (µg/l)	1	2.3	ND	5	(KAL)
Trichloromethane (µg/l)	1	0.6	ND	100	(MCL)

<sup>a</sup>Contaminants were considered any synthetic chemical at any concentration and naturally-occurring chemicals in concentrations above the MCL<sup>b</sup>.

<sup>b</sup>MCL is the Maximum Contaminant Level established by the National Primary Drinking Water Standards. KAL (Kansas Action Level) is the level at which KDHE considers the water unacceptable for long-term consumption. KALs are established for those chemicals that currently have no MCL.

<sup>c</sup>Not Resampled

<sup>d</sup>Not Detected

<sup>e</sup>2,4-D and 2,4,5-T were found in the same well.

<sup>f</sup>This well could not be resampled because the pump had failed.

<sup>g</sup>Chlordane and heptachlor epoxide were found in the same well.

<sup>h</sup>Alachlor and 1,2-dichloroethane were found in the same well.

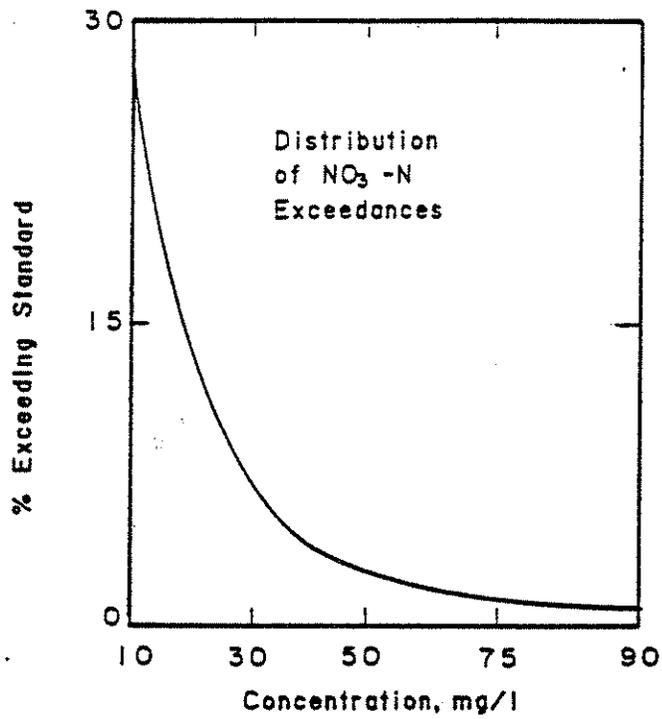


Figure 8. Distribution of nitrate-N concentrations exceeding MCL in wells sampled.

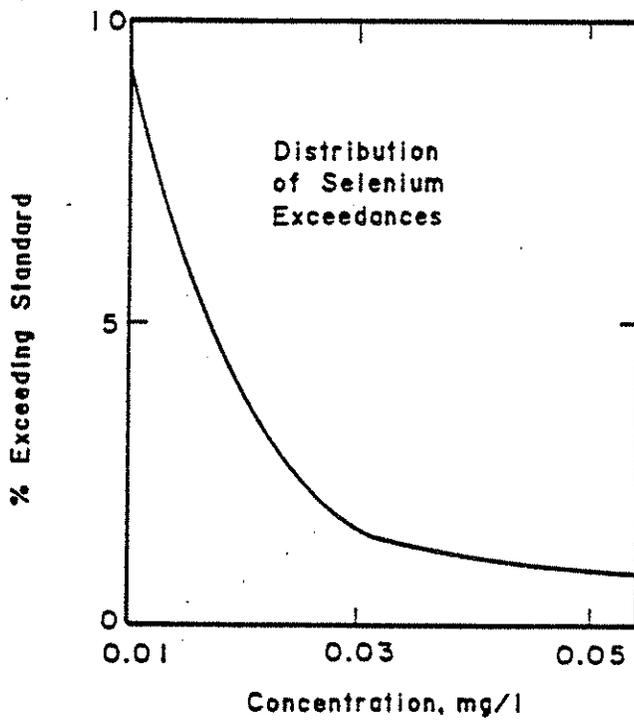


Figure 9. Distribution of selenium concentrations exceeding MCL in wells sampled.

Resampling was done for all wells in which pesticides and VOCs were detected, and where lead was found to be above the MCL. Resampling was done four to five months later. Resampling confirmed the presence of all pesticides in each well with the exception of 2,4-D and 2,4,5-T which had been found in a well that could not be resampled because the pump had failed. Pesticides appear to persist for a relatively long time. According to CAST (1986) atrazine, 2,4-D, 2,4,5-T, and alachlor are thought to be only slightly to moderately mobile in soil. Of particular interest are heptachlor epoxide and chlordane which are considered to be immobile in soil. Chlordane is injected into soil around the foundation of buildings to prevent termite infestations in part because it is so immobile.

The two wells with detectable levels of VOCs, benzene and 1,2-dichloroethane, were resampled and only the presence of 1,2-dichloroethane was confirmed. Fuel spills near both of these wells were noted on the questionnaires, thus both contaminants were considered confirmed. In a third well, trichloromethane was not detected upon resampling. The questionnaire disclosed that this owner chlorinated the well on a regular basis, and trichloromethane is a by-product of chlorination. Therefore, this finding was not considered contamination.

Initially, two wells were found to be contaminated with lead above the MCL. Later discussions with the well users, however, revealed that the water from both wells was highly corrosive and had passed through galvanized piping before reaching the point of sampling. Careful resampling to minimize any effects of piping corrosion revealed no detectable lead in either water sample. Therefore, lead was not considered a contaminant of the well water.

## Statistical Analysis

### Tests of Differences

Homogeneity of Variances: Levine's test for homogeneity of variances (Milliken and Johnson, 1984) was applied for all dependent variables (nitrates, selenium, pesticides, VOCs and chlorides). The purpose of this test was to insure that the equal variance assumption for standard tests of differences was not violated. The Levine's test was chosen because of its robustness and sensitivity for large data sets. All dependent variables variances were found to be heterogeneous. Since the data were collected from a state-wide sample with no attempt to control independent variables, it is not surprising that the assumption of homogeneity did not hold for most comparisons.

Due to the heterogeneous variances, Satterthwaite's Approximation (Snedecor and Cochran, 1980) was used for two-sample comparisons instead of the multiple comparisons normally provided by either analysis of variance (ANOVA) or general linear model (GLM) techniques. To determine the confidence level of these comparisons, Bonferroni's formula was applied to yield a per comparison error rate (Devore, 1982).

Nitrate: Nitrate levels were not significantly different in geological water regions. Significant differences prevailed in geographical and precipitation regions. Tables 5 and 6 show these differences for geographical and precipitation regions. By using a significance level of 0.025 and Bonferroni's inequality for multiple comparisons, one may be at least 63 percent confident for the geographical and

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Table 5. Mean nitrate-N concentration by geographical region, mg/l.  
(underlined values are statistically equivalent)

<u>GR6</u>	<u>GR5</u>	<u>GR2</u>	<u>GR4</u>	<u>GR3</u>	<u>GR1</u>
5.05	5.57	5.75	9.06	11.61	14.98

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Confidence level is 0.63.

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Table 6. Mean nitrate-N concentration by precipitation region, mg/l.  
(underlined values are statistically equivalent)

<u>PR1</u>	<u>PR5</u>	<u>PR2</u>	<u>PR4</u>	<u>PR3</u>
5.46	5.48	6.31	9.54	14.41

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Confidence level is 0.75.

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at least 75 percent confident for the precipitation regions that the differences are real. There is evidence that farmstead wells in the northeast, north central and south central regions have a higher probability of nitrate contamination than elsewhere in the state.

Selenium: Selenium contamination did not vary significantly in the water regions. Significant differences were found for geographical and precipitation regions. Tables 7 and 8 show these differences for precipitation regions and geographical regions. By using the same significance level that was used for the nitrate models, one may be at least 63 percent confident for the geographical regions and 75 percent confident for the precipitation regions that the differences are real.

Farmstead wells in the southwest and north central regions appeared to contain more selenium than those in the rest of the state. Areas with average annual rainfall greater than 30 inches have less contamination with selenium.

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Table 7. Mean selenium concentration by geographical region, mg/l.  
(underlined values are statistically equivalent)

<u>GR2</u>	<u>GR1</u>	<u>GR4</u>	<u>GR5</u>	<u>GR3</u>	<u>GR6</u>
.0014	.0020	.0021	.0034	.0103	.0141

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Confidence level is 0.63.

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Table 8. Mean selenium concentration by precipitation region, mg/ℓ.  
(underlined values are statistically equivalent)

<u>PR5</u>	<u>PR4</u>	<u>PR3</u>	<u>PR1</u>	<u>PR2</u>
.0006	.0017	.0032	.0088	.0150

Confidence level is 0.75.

Tests for Correlation:

Nitrate: Correlations were tested between nitrate and chlorides, nitrate and pesticides/VOCs, nitrate and distance to possible sources of organic contamination [A feedlot, septic tank, etc where biological organic material may be located and from which nitrate is a potential product of the breakdown of these materials.] (PSOC), nitrate and the level (Relative elevation at ground level of a possible source of contamination compared to the ground at the well, 1 = lower, 3 = same, 5 = higher.) of PSOC, nitrate and ammonia, and nitrate and chlorides (omitting geographical Region 3). Region 3 was eliminated from the last analysis because of the high natural chlorides concentrations in the groundwater in that region. The results of these correlations are shown in Table 9.

Table 9. Results of correlation analysis.

<u>VARIABLE</u>	<u>VARIABLE</u>	<u>CORRELATION COEFFICIENT</u>
Nitrate	Chlorides	0.088
Nitrate	Chlorides*	0.157
Nitrate	Pesticides**	0.102
Nitrate	PSOC	-0.120
Nitrate	Level***	0.062
Nitrate	Ammonia	-0.106
Selenium	Soil texture	-0.026

- \* Geographical Region 3 omitted.
- \*\* Includes VOCs
- \*\*\* Relative elevation to well of PSOC

Very weak correlations between nitrate and chlorides or PSOC may indicate that high nitrate levels have very little linear relationship with possible human or animal waste contamination. Location of feedlots, septic tank characteristics and drainage characteristics by themselves may not be strong predictors of possible nitrate contamination. The weak correlation between nitrate and pesticides/VOC indicate that high nitrate levels appear to have little linear relationship with these

conditions on farms. A correlation analysis between only wells with nitrate greater than MCL and those wells with pesticide/VOC might work, but the number of such samples from this survey was too small. The weak linear relationship between nitrate concentrations and pesticide/VOC concentrations indicates that high nitrate may not be an appropriate indicator for possible pesticide/VOC contamination. The fact that these data were collected as part of a random sample which was not planned for testing hypotheses must be kept in mind when judging the power of the statistical correlations in this study.

Selenium: A correlation coefficient was computed between selenium and soil texture. Table 9 depicts the result. This indicates that there is almost no linear relationship between these two variables.

#### Multiple Regression:

Nitrate: To insure that every possible predictor variable was considered, the "all models" approach to regression analysis was used. The assumption was made that a new well should have only low concentrations of nitrate. Thus, only no-intercept models were examined. Several models were significant at the  $\alpha = 0.01$  significance level. The best model included the age of the well (AGE in years), land use around the well (USE from 1 to 30) and the distance from the well to any possible source of organic contamination (PSOC from 1 to 1000 feet) with the latter two being described in Table A2, Appendix A. This model can be depicted as

$$\text{NITRATE-N} = 19.2 + 0.0941(\text{AGE}) - 0.509(\text{USE}) - 0.0108(\text{PSOC}), \text{ mg}/\ell.$$

From this model an estimate of the nitrate-N concentration would be 3.9 mg/ $\ell$  for a well that is 30 years old, land use around the well is primarily pasture (a value of 25), and where the well is 500 feet from a septic tank or feedlot. This model was selected in preference to its competitors based on its having one of the higher coefficients of determination ( $r^2=0.18$ ), low mean square error and intuitive appeal. Predictions using a regression model should not be made outside the range of the data points used in its development. The range for this equation is concentrations of nitrate-N from 0 to 91 mg/ $\ell$ .

Selenium: The average rainfall for each precipitation region was used as an independent variable to develop a prediction model. A simple regression model was run and inches of precipitation (IP) was a significant variable at the 0.003 significance level. This model can be depicted as

$$\text{SELENIUM} = 0.0204 - 0.000569(\text{IP}), \text{ mg}/\ell.$$

From this model an estimate of the selenium concentration would be 0.010 mg/ $\ell$  for a well in an area where the annual precipitation was 18 inches. This model's coefficient of correlation is ( $r^2=0.09$ ). Other than using the precipitation model as a predictor, geographical regions 3 and 6 could be used as another way to identify wells that may exceed MCL for selenium. Knowledge of the extent of seleniferous soils and rock formations is probably a better predictor but it could not be tested with the data available.

### DISCUSSION

Only nine wells were found to have detectable levels of pesticides and only two had detectable amounts of VOCs. The herbicide atrazine was the only pesticide detected more than once in the survey; it was found

in four wells. The fact that concentrations detected were low was somewhat reassuring that most farmstead wells are not grossly contaminated with these materials. It does, however, point out that contamination is already occurring and that the number of wells contaminated may increase in the future as greater amounts of materials are used and there is enough time for these materials to move into groundwater and into wells. Concern for the future must not be dismissed.

Nitrate is a naturally-occurring contaminant in groundwater in some areas. Also, there are many sources of nitrate both natural and man-made. Contamination by septic tanks has been indicated by accompanying high chloride levels (Driscoll, 1986). In the sample 25 percent of high nitrate wells were high in chloride. Statistical analysis yielded a very low correlation coefficient of 0.102 and an insignificant F value at the 90 percent confidence level. Nitrogen fertilizer is another major source of nitrate. We could not get an estimate of the effect, if any, of fertilizers on groundwater quality.

The high number of wells with nitrate levels exceeding the MCL of 10 mg/l is worrisome. Of particular concern is that over half of the exceedances were more than twice the MCL. Infants and fetuses are affected by high nitrate levels. Because so many wells are likely contaminated with excess nitrate, every farmstead where infants, pregnant women, or small animals might drink the water should be tested for nitrate. Harmful effects on adults of drinking water with high concentrations of nitrate have not been documented.

High selenium and fluoride concentrations in some samples were very likely because of naturally-occurring soils and rock formations. Selenium levels are generally higher in exposed Cretaceous shales. If these shales are buried, this may lead to the elevated selenium levels in groundwater. There have been no reports of human health problems related to selenium in the U.S. (Oldfield, 1986).

The pesticides and VOCs found in farmstead wells were certainly introduced by human activity. At the present time the actual sources of all these contaminants have not been determined. In the case of VOCs, the two occurrences were attributed to fuel spills near the well. For pesticides it is not known whether spills or normal agricultural application practices were responsible. Resampling of wells with pesticides or VOCs during May and June, 1986 usually revealed concentrations greater than in the original samples taken during the winter months. Higher pesticide and nitrate levels have been reported by researchers in the spring of the year (Jones and Schwab, 1986). This spring increase is thought to result from higher moisture levels in soils and the start of the application season.

Several characteristics of the aquifer and well construction are important. Major factors examined in detail were soil type, depth to water table, depth to well screen, depth to well bottom, horizontal distance to contaminant sources, well history, and method of well construction. Factors found to correlate with nitrate contamination were age of the well, land use around the well, and distance to a PSOC. Older wells are more likely to be contaminated than new ones. The age of the well is likely indicative of the age of the farmstead and length of time that potentially polluting activities have been located near the well. For land use around a well, pasture is less likely to be a cause of contamination than feedlots or cropland. Distance to a PSOC is also related to land use around the well. In other words all of these factors are interrelated and not truly separate factors.

Statistical analyses were performed on as many aspects of the well construction and location for which data were considered adequate. Only enough information was available for nitrate to allow testing. Even with nitrate tests we were unable to determine strong relationships between nitrate levels and various characteristics of the wells. A strong argument may be made for depth to water table as a predictor variable, but several outliers had the effect of causing rejection of this hypothesis. Again, the set of data collected for this project was chosen to obtain a representative sample of farmstead wells from Kansas to obtain a best estimate of the percentage of wells contaminated with pesticides, VOCs, and inorganic chemicals. From this data set we did not expect to get strong relationships with predictor variables. We did, however, feel obligated to make such statistical tests to prove the lack of relationships. The high costs for the sampling and analyses justified statistically analyzing the data to get as much value as possible from it.

#### SUGGESTIONS FOR FURTHER RESEARCH

The goal of KDHE is to protect the public health of all Kansans. This project was started because of KDHE personnel's concerns about finding a few farm wells that were contaminated with VOCs. KDHE needed data from farm wells to determine the extent of the problem and to find a way to help people on farmsteads assure that their drinking water is safe. When this project was conceived two separate objectives were considered. The first was to obtain a best estimate of the level of and the extent of the contamination problem. The second objective was to identify factors which put wells at risk of being or becoming contaminated. Limited funds for the study could not give the complete answer to both objectives. We chose to get the best estimate first because so little was known about the extent of contamination.

The results from our random sample of 103 wells in Kansas provide a statistical estimate that water from about 1,200 to 6,000 of the 40,000 farmstead wells in Kansas have detectable amounts of pesticides in them. From none to 2,000 probably yield water with detectable amounts of VOCs and from 14,000 to 28,000 wells provide water with nitrate concentrations above the MCL. Many of these wells should be tested to determine if concentrations of these materials are above safe levels. Thus, the second objective that should be studied is to determine ways to identify the wells that should be tested. This information would aid KDHE in using its limited funds and laboratory capabilities to best advantage and to provide a basis for a public education program for farmstead and rural residents.

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APPENDIX A.

Table A1. Farmstead activities survey questions and descriptive statistics.

This table contains questions on the survey questionnaire and summary statistics of the answers to those questions. Questions were grouped into sections by type. A Page/Column offset is used throughout the appendices to identify the corresponding columns in the appendices.

The units for each question are described with the question. Answers to Yes/No questions were coded as 1 = "Yes" and 0 = "No". For Yes/No questions, the statistics given were number responding to the question (N) and percent responding yes. The minimum, maximum, mean and median were given for quantitative questions. Other questions are in logical fashion, if feasible.

These questionnaires were filled out by a wide variety of participants. Many questions were left unfilled and these have a "." (missing data) in Table A3. Multiple choice questions often had half or more responses marked. Given the above facts, it is not surprising some statistics make less than complete logical sense (esp. Pesticide/Herbicide Data).

**FARMSTEAD CHARACTERISTICS:**

<u>Page/ Column</u>	<u>Question</u>	<u>Answers and/or Values</u>
1 1	Geological Water Region.	Range = 1-14.
1 2	Number living on farmstead?	Number = 102, Minimum = 1, Maximum = 9 and Mean = 3.9.
1 3	Do you drink from the well?	1 = Yes (96%,N=102), 0 = No.
1 4	Is the water treated before use?	1 = Yes (25%,N=102), 0 = No.
1 5	Number that regularly drink water from the well.	Number = 103, Minimum = 0, Maximum = 13 and Mean = 3.6.
1 6	Number of households connected to the well.	Number = 103, Minimum = 0, Maximum = 3 and Mean = 1.1.

If you raise livestock, indicate the approximate number of each.

	Number	Min.	Max.	Mean	Median	
1 7	Number of cattle.	81	10	1000	173	100
1 8	Number of hogs.	23	4	10000	1118	200
1 9	Number of dairy cattle.	5	70	325	157	70
1 10	Number of poultry.	15	7	40000	3361	24
1 11	Number of sheep.	8	6	1000	233	90

If you raise grain or forage, indicate approximate number of each.

	Number	Min.	Max.	Mean	Median	
1 12	Acres of wheat.	95	30	1800	385	290
2 1	Acres of soybeans.	44	10	600	129	80
2 2	Acres of corn.	26	5	700	181	100
2 3	Acres of hay.	75	5	500	84	50
2 4	Acres of sorghum.	81	10	1400	274	200
2 5	Acres of other crops.	21	25	225	76	50
2 6	Acres of range/pasture.	89	0	4750	661	330

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

TOPOGRAPHY, SOIL CHARACTERISTICS, AND LAND USE AROUND THE WELL:

Page/ Column	Question	Answers and/or Values
2 7	Does water ever stand or pool around the well?	1 = Yes (11%,N=102). 0 = No.
2 8	What is the lie of the land near the well?	5 = higher than farmstead area. 3 = about the same level and 1 = lower than farmstead area.
2 9	Term that best describes the soil type near well.	1 = sandy, 2 = silty, 3 = gravelly, 4 = clayey, 5 = loamy and 6 = other. <u>Note:</u> These are actual survey questionnaire values. Values in the questionnaire table are revised to Table A2 specifications.
2 10	Term that best describes the land use around well.	1 = cropland, 2 pasture or grass, 3 = dry lot, paved lot with surface of: 4 = concrete, 5 = gravel, 6 = asphalt, 7 = farm yard, 8 = feed lot, and 9 = other <u>Note:</u> These are actual survey questionnaire values. Values in the questionnaire table are revised to Table A2 specifications.

HOUSEHOLD WASTEWATER DISPOSAL METHODS:

For 2/11 to 3/5:

- 1 = septic tank to open ground, 2 = septic tank with laterals,
- 3 = septic tank to seepage pit, 4 = open ground,
- 5 = cesspool 6 = lagoon and "." = no answer.

Values in Answer are numbers of "Yes" answers.

Page/ Column	Question	Answer						
		1	2	3	4	5	6	."
2 11	Sink water.	27	37	1	18	7	7	4
2 12	Dishwater.	21	25	3	14	7	6	27
3 1	Garbage disposal.	7	13	1	3	2	2	75
3 2	Clothes washing machine.	23	26	6	33	5	7	3
3 3	Bath/shower(s).	24	43	6	15	6	7	2
3 4	Toilet(s).	26	47	7	6	19	7	1
3 5	Water softener backwash.	13	12	4	9	2	4	59
3 6	Number of years the disposal method has been in service.	Highest response given for any one of the above disposal methods (6 blanks). Number = 99, Minimum = 3, Maximum = 75 and Mean = 27.						
3 7	Have you had difficulty with your waste disposal system?	1 = Yes (24%,N=100). 0 = No.						
3 8	Use of septic cleaning aids or chemicals.	1 = Yes (17%,N=98). 0 = No.						

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

PROXIMITY TO OTHER FARM USAGE AREAS:

Question: Give the distance as well as you can to the following structures and activities at your farmstead if they are within about a quarter of a mile of your well. Check whether activity is on higher ground, lower ground or the same level as the well. Write NA in distance column for any which are not applicable.

Ratings: Area = Structure or activity:

Answer in table = distance in feet.

Level:

1 = lower, 3 = same and 5 = higher.

NA = "."

Legend:

Page/ Column	Area	Number	Min.	Max.	Mean	Median
3 9	Farm house.	97	5	4000	218.5	80
3 10	Level.	99	1	5	3.3	
3 11	Garden.	81	0	4000	259.6	110
3 12	Level.	83	1	5	2.7	
4 1	Farm shop.	89	10	4000	309.5	150
4 2	Level.	90	1	7	3.0	
4 3	Cattle feed lot.	71	10	4000	337.4	200
4 4	Level.	73	1	5	2.2	
4 5	Swine building.	24	30	1000	314.6	200
4 6	Level.	23	1	5	2.5	
4 7	Swine pen.	20	50	1000	305.0	190
4 8	Level.	20	1	5	1.8	
4 9	Poultry building.	20	30	1000	194.3	150
4 10	Level.	22	1	5	2.5	
4 11	Insecticide storage.	45	3	2700	366.3	200
4 12	Level.	43	1	5	2.7	
5 1	Poultry pens.	8	60	500	156.0	110
5 2	Level.	9	1	5	2.8	
5 3	Herbicide storage.	41	10	1500	286.5	200
5 4	Level.	41	1	5	2.8	
5 5	Soil trt. chemicals.	22	50	1500	409.3	275
5 6	Level.	23	1	5	2.6	
5 7	Fuel, above ground	86	30	4000	347.0	200
5 8	Level.	89	1	5	2.6	
5 9	Fuel, below ground	19	50	500	215.8	175
5 10	Level.	17	1	5	2.4	
5 11	Dairy.	5	10	1000	432.0	200
5 12	Level.	6	1	3	1.7	
6 1	Railroad right of	18	300	5280	1013.0	2250
6 2	Level.	15	1	5	1.8	
6 3	Fertilizer storage	17	75	40000	2617.1	200
6 4	Level.	17	1	5	2.6	
6 5	Machinery wash area.	57	6	1500	297.6	250
6 6	Level.	55	1	5	2.4	
6 7	Livestock insct. dip.	9	3	400	175.9	140
6 8	Level.	8	1	5	2.0	
6 9	Grain storage.	77	10	2000	20.8	250
6 10	Level.	77	1	5	2.4	
6 11	Drainage ditch.	51	10	1000	232.5	180
6 12	Level.	47	1	5	1.5	
7 1	Private waste dump	17	100	3000	982.4	1000
7 2	Level.	16	1	5	2.3	
7 3	Septic tank to ope.	34	45	1200	309.0	200

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

PROXIMITY TO OTHER FARM USAGE AREAS (Continued):

Legend:

Page/ Column	Area	Number	Min.	Max.	Mean	Median
7 4	Level.	34	1	5	1.7	
7 5	Septic tank/lateral	51	30	1800	277.3	175
7 6	Level. field.	50	1	5	2.1	
7 7	Septic tank/seepage	11	50	1200	453.2	250
7 8	Level. pit.	11	1	5	2.1	
7 9	Public landfill.	7	3000	90000	35182.9	36000
7 10	Level.	5	1	5	2.2	
7 11	Waste lagoon.	12	50	500	256.3	250
7 12	Level.	12	1	5	1.5	
8 1	Cesspool.	16	40	1200	229.7	105
8 2	Level.	14	1	5	1.4	
8 3	Privy.	10	50	1200	237.0	105
8 4	Level.	9	1	3	1.7	
8 5	Cistern.	9	10	1200	257.8	100
8 6	Level.	8	1	5	2.8	
8 7	Abandoned well.	34	10	2500	291.4	100
8 8	Level.	31	1	5	2.7	
8 9	Crude oil tanks.	7	450	5280	1904.3	1200
8 10	Level.	5	1	5	3.0	
8 11	Oil well.	12	300	5280	1767.5	1200
8 12	Level.	9	1	5	3.2	
9 1	Oil pipeline.	12	45	5280	1634.6	1100
9 2	Level.	9	1	5	3.0	
9 3	Gas well.	4	750	2500	1612.5	1600
9 4	Level.	4	1	5	3.5	
9 5	Gas pipeline.	17	0	3200	610.9	150
9 6	Level.	16	1	5	2.4	
9 7	Upright silo.	24	70	1000	388.8	330
9 8	Level.	25	1	5	2.2	
9 9	Trench silo.	29	50	1500	631.9	500
9 10	Level.	28	1	5	2.0	
9 11	Manure pile.	22	90	1200	372.0	250
9 12	Level.	22	1	5	1.9	
10 1	Public road.	85	20	1600	406.7	250
10 2	Level.	83	1	5	2.9	
10 3	Industrial activity.	4	50	90000	23372.5	1720
10 4	Level.	4	3	5	3.5	
10 5	Electric transformer.	93	10	1600	219.6	125
10 6	Level.	88	1	5	2.8	
10 7	Dairy wash disposal.	6	100	1200	483.3	200
10 8	Level.	6	1	3	1.7	
10 9	Cattle pens (coral).	71	5	1600	285.5	250
10 10	Level.	69	1	5	2.2	
10 11	Other _____.	5	36	400	203.2	50
10 12	Level.	5	1	5	2.2	

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

PAST PRACTICES AND EVENTS:

Past disposal methods for the following:

For 11/1 to 11/11:

- 1 = Had it hauled off the farm.
- 2 = spread on ground or road.
- 3 = poured into a pit,
- 4 = farm trash dump.
- 5 = burned and
- 6 = other (specify).
- "." = No answer given.

Values below Answer are number of "Yes" answers for following questions.

Page/ Column	Question	Answer					
		1	2	3	4	5	6 "."
11 1	Motor Oil.	7	67	0	2	10	11 6
11 2	Paint.	18	11	2	20	7	3 41
11 3	Paint thinners.	10	21	2	17	7	5 41
11 4	Degreasers.	9	31	0	12	10	2 41
11 5	Bad fuel.	8	18	0	8	22	2 45
11 6	Insecticides.	28	7	1	18	5	6 32
11 7	Empty insecticide containers.	40	1	1	26	12	4 19
11 8	Herbicides.	30	6	0	20	5	5 37
11 9	Empty herbicide containers.	41	1	1	27	12	2 19
11 10	Household trash.	22	1	0	26	38	0 16
11 11	Other wastes.	5	0	0	3	2	0 93

Distance of disposal area from well in feet (if less than 1/4 mile):

Page/ Column	Question	Answers and/or Values			
		Number	Min.	Max.	Mean
11 12	Had it hauled off the farm.	9	6	2500	790
12 1	Spread on ground or road.	20	50	1300	336
12 2	Poured into a pit.	1	600	600	600
12 3	Farm trash dump.	16	150	5280	1174
12 4	Burned.	22	20	2500	573
12 5	Other (specify).	2	600	2500	1550

HERBICIDES AND PESTICIDES:

Question: If you have used herbicides or pesticides, please check appropriate box. Please indicate by checking the appropriate box whether the material by yourself or by a commercial service, contractor or outsider.

Ratings: 1 = Yes, 0 = No.

Page/ Column	Question	Statistics
12 6	Lasso (alachlor)	( 34%, N=103)
12 7	Application by self?	( 25%, N=103)
12 8	Application by other?	( 14%, N=103)
12 9	Atrazine (aatrex)	( 70%, N=103)
12 10	Application by self?	( 50%, N=102)
12 11	Application by other?	( 30%, N=102)
12 12	Dual (metachlor)	( 30%, N=102)
13 1	Application by self?	( 22%, N=102)
13 2	Application by other?	( 16%, N=103)

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

HERBICIDES AND PESTICIDES (continued):

Page/ Column	Question	Statistics
13 3	Miloguard (propazine)	30%, N=103
13 4	Application by self?	16%, N=103
13 5	Application by other?	18%, N=103
13 6	Ramrod (propachlor)	24%, N=103
13 7	Application by self?	16%, N=103
13 8	Application by other?	12%, N=103
13 9	Sencor, Lexone (metribuzin)	24%, N=103
13 10	Application by self?	20%, N=102
13 11	Application by other?	7%, N=102
13 12	Silvex (2,4,5-TP)	6%, N=103
13 13	Application by self?	5%, N=103
14 1	Application by other?	0%, N=103
14 2	2,4-D	79%, N=103
14 3	Application by self?	71%, N=103
14 4	Application by other?	26%, N=103
14 5	Treflan (trifluralin)	34%, N=102
14 6	Application by self?	27%, N=102
14 7	Application by other?	12%, N=103
14 8	Princep (simazine)	7%, N=103
14 9	Application by self?	5%, N=103
14 10	Application by other?	2%, N=103
14 11	Bladex (cyanazine)	11%, N=103
14 12	Application by self?	5%, N=103
15 1	Application by other?	4%, N=103
15 2	Roundup (glyphosate)	57%, N=103
15 3	Application by self?	48%, N=102
15 4	Application by other?	12%, N=102
15 5	Paraquat	7%, N=103
15 6	Application by self?	2%, N=103
15 7	Application by other?	6%, N=103
15 8	Eradicane (EPTC)	15%, N=103
15 9	Application by self?	12%, N=103
15 10	Application by other?	4%, N=103
15 11	Banvel (dicamba)	35%, N=103
15 12	Application by self?	31%, N=103
16 1	Application by other?	5%, N=103
16 2	Sutan + (butylate)	9%, N=103
16 3	Application by self?	10%, N=103
16 4	Application by other?	2%, N=103
16 5	Tordon	26%, N=103
16 6	Application by self?	20%, N=103
16 7	Application by other?	5%, N=103
16 8	Lorox (linuron)	0%, N=103
16 9	Application by self?	0%, N=103
16 10	Application by other?	0%, N=103
16 11	Prowl (pendimethalin)	3%, N=103
16 12	Application by self?	3%, N=103
17 1	Application by other?	1%, N=103
17 2	Dacthal	7%, N=103
17 3	Application by self?	7%, N=103
17 4	Application by other?	0%, N=103
17 5	Others	4%, N=103
17 6	Application by self?	2%, N=103
17 7	Application by other?	2%, N=103
17 8	2,4,5-T	32%, N=103
17 9	Application by self?	28%, N=103

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

HERBICIDES AND PESTICIDES (continued):

Page/ Column	Question	Statistics
17 10	Application by other?	5%, N=103
17 11	Theodan (endosulfan)	0%, N=103
17 12	Application by self?	0%, N=103
18 1	Application by other?	0%, N=103
18 2	Lintex (lindane)	7%, N=103
18 3	Application by self?	7%, N=103
18 4	Application by other?	1%, N=103
18 5	Marlate (methoxychlor)	4%, N=103
18 6	Application by self?	4%, N=103
18 7	Application by other?	1%, N=103
18 8	Parathion	27%, N=103
18 9	Application by self?	3%, N=103
18 10	Application by other?	24%, N=103
18 11	Strobane T (toxaphene)	5%, N=103
18 12	Application by self?	5%, N=103
19 1	Application by other?	0%, N=103
19 2	Cythion (malathion)	15%, N=103
19 3	Application by self?	15%, N=103
19 4	Application by other?	2%, N=103
19 5	Temick (aldicarb)	1%, N=103
19 6	Application by self?	0%, N=103
19 7	Application by other?	0%, N=103
19 8	Sevin (carbaryl)	43%, N=103
19 9	Application by self?	41%, N=102
19 10	Application by other?	6%, N=102
19 11	Furadan (carbofuran)	44%, N=103
19 12	Application by self?	33%, N=102
20 1	Application by other?	12%, N=101
20 2	Lead arsenate	3%, N=103
20 3	Application by self?	2%, N=103
20 4	Application by other?	1%, N=103
20 5	Pounce (permethrin)	1%, N=103
20 6	Application by self?	0%, N=103
20 7	Application by other?	1%, N=103
20 8	Thimet (phorate)	9%, N=103
20 9	Application by self?	11%, N=103
20 10	Application by other?	3%, N=103
20 11	Agrotox (thrchloronate)	1%, N=103
20 12	Application by self?	1%, N=103
21 1	Application by other?	0%, N=103
21 2	Kepon (chlordecone)	0%, N=103
21 3	Application by self?	0%, N=103
21 4	Application by other?	0%, N=103
21 5	Rotenone	4%, N=103
21 6	Application by self?	4%, N=103
21 7	Application by other?	0%, N=103
21 8	Lorsban	11%, N=103
21 9	Application by self?	10%, N=103
21 10	Application by other?	2%, N=103
21 11	Counter	8%, N=103
21 12	Application by self?	8%, N=103
22 1	Application by other?	0%, N=103
22 2	Spectracide (diazinon)	8%, N=103
22 3	Application by self?	8%, N=103
22 4	Application by other?	1%, N=103
22 5	Miticide (methidation)	5%, N=103

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

HERBICIDES AND PESTICIDES (continued):

Page/ Column	Question	Statistics
22 6	Application by self?	( 4%, N=103)
22 7	Application by other?	( 1%, N=103)
22 8	Endrin	( 4%, N=103)
22 9	Application by self?	( 4%, N=103)
22 10	Application by other?	( 0%, N=103)
22 11	Aldrin	( 8%, N=103)
22 12	Application by self?	( 8%, N=103)
23 1	Application by other?	( 0%, N=103)
23 2	DDT	( 13%, N=103)
23 3	Application by self?	( 14%, N=103)
23 4	Application by other?	( 2%, N=103)
23 5	Chlordane	( 21%, N=103)
23 6	Application by self?	( 25%, N=103)
23 7	Application by other?	( 5%, N=103)
23 8	Dieldrin	( 7%, N=103)
23 9	Application by self?	( 7%, N=103)
23 10	Application by other?	( 0%, N=103)
23 11	Others	( 8%, N=103)
23 12	Application by self?	( 8%, N=103)
24 1	Application by other?	( 2%, N=103)

HERBICIDES AND PESTICIDES (other questions):

Page/ Column	Question	Answers and/or Values			
		Number	Min.	Max.	Mean Median
24 2	Distance from well to preparation area (feet)?	78	0	4000	475 200
24 3	Distance from well to container washing area (feet)?	64	0	5000	556 200
24 4	Distance from well to disposal area for excess and containers (feet)?	49	0	5280	2143 1325
24 5	Is grain stored on farm?	1 = Yes (76%,N=102), 0 = No			
24 6	Type of storage?	1 = steel bins with concrete floor (64%), 2 = wood bin with wood floor (8%), 3 = other (7%) and "." = missing data (21%).			
24 7	Capacity (in bushels)?	Number = 78, Minimum = 200, Maximum = 100000 and Mean = 14735.			
24 8	Is it a custom to treat stored grain with fumigants of insecticides?	1 = Yes (54%,N=81), 0 = No.			

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

CHARACTERISTICS OF THE HOUSEHOLD WELL:

Page/ Column	Question	Answers and/or Values
24 9	How was the well constructed?	1 = dug (15%), 2 = drilled (79%), 3 = driven (3%), 4 = other (0%), 5 = unknown (3%) and "." = (1%).
24 10	Age of well?	Number = 88, Minimum = 1, Maximum = 106 and Mean = 31.
24 11	Who constructed the well?	1 = licensed contractor (38%), 2 = contractor (23%), 3 = owner (16%), 4 = other (4%) and "." = (19%).
24 12	What casing material was used?	1 = plastic pipe: (type if known 5 = PVC, 6 = ABS and 7 = RMP), 2 = fiberglass, 8 = steel or iron, 4 = galvanized metal, 3 = concrete, 11 = asbestos-cement 9 = stone, 10 = brick 12 = none and 13 = other.
25 1	What grouting method was used?	1 = neat cement (4%), 2 = cement (28%), 3 = bentonite (17%), 4 = none (0%), 5 = other (15%) and "." = (37%).
25 2	To what depth does the grout extend (feet)?	Number = 32, Minimum = 0, Maximum = 145 and Mean = 25.5
25 3	How is the well protected at the surface?	1 = well house or shed, 2 = concrete pad, 3 = sanitary seal, 4 = covered pit, 5 = wooden cover and 6 = other.
		Number    Min.    Max.    Mean    Median
25 4	How deep is it to the water surface (feet)?	94        4        360      54      40
25 5	How deep is it to the top of the well screen (feet)?	66        5        360      73      46
25 6	How deep is it to the bottom of the well (feet)?	97        14       450      96      65
25 7	What type of pump is used in the well?	1 = submersible(68%), 2 = jet(22%), 3 = centrifugal (6%), 4 = hand (1%) and 5 = windmill (3%).

Table A1 (continued). Farmstead activities survey questions and descriptive statistics.

CHARACTERISTICS OF THE HOUSEHOLD WELL:

<u>Page/ Column</u>	<u>Question</u>	<u>Answers and/or Values</u>
25 8	Have you experienced any problem with your water?	1 = none, 2 = taste, 3 = odor, 4 = discoloration, 5 = cloudiness, 6 = ran dry and 7 = other.  <u>Note:</u> Combinations of the above answers were added together.
25 9	Have you had reason in the past to test your well? water?	1 = Yes (39%,N=98), 0 = No.
25 10	Maximum capacity of well (gallons/minute)?	Number = 62, Minimum = 3, Maximum = 100 and Mean = 19.
25 11	Have there been any known times when the well was contaminated directly by back-siphon, back pressure, etc.?	1 = Yes (4%,N=100), 0 = No.

APPENDIX A (continued).

Table A2. Actual values from questions and revised rating scales.<sup>a</sup>

<u>Variable:</u>	<u>Actual</u>	<u>Rating</u>	<u>Answer</u>	<u>Actual</u>	<u>Rating</u>
<u>Answer</u>	<u>Value</u>			<u>Value</u>	
<b>Casing material:</b>					
plastic pipe	1 & 5-7	30	fiberglass	2	28
steel or iron	8	22	galvanized metal	4	20
concrete	3	15	asbestos-cement	11	12
stone	9	6	brick	10	5
none	12	0	other	13	0
<b>Soil type surrounding the well:</b>					
clay	4	25	loamy	5	20
silt	2	5	sand	1	10
gravel	3	0	other	.	.
<b>Grouting method:</b>					
cement	1 & 3	20	bentonite	4	15
other	5	10	none	2	5
<b>Surface protection:</b>					
sanitary seal	4	25	well house	1	20
concrete pad	2	15	covered pit	8	10
wooden cover	16	5	other	32	5
<b>Water problems:</b>					
none	1	20	well ran dry	6	15
taste	2	10	odor	3	8
cloudiness	5	4	discoloration	4	4
other	7	4			
<b>Land use around well:</b>					
pasture or grass	4	30	farmyard	3	25
paved lot	2 & 7-9	20	cropland	1	15
drylot	6	10	feedlot	5	5
<b>Who constructed the well:</b>					
licensed			contractor	2	0
contractor	1	1	owner	3	0
other	4	0			
<b>Distance to possible organic contaminant source:<sup>b</sup> (mean=246, median=150)</b>					
septic tank to open field.			septic tank with laterals.		
septic tank with a seepage pit.			feedlot.		
waste lagoon.			cesspool.		
			privy.		
			manure pile.		
<b>Level with respect to well:</b>					
higher	5	1	same	3	3
lower	1	5			
<b>Water pooling around the well:</b>					
yes	1	0	no	0	1
<b>Well construction method:</b>					
dug	1	0	drilled	2	1
driven	3	1	other	4	1
unknown	5	.			

<sup>a</sup>The rating scales are designed to minimize negative regression effects in conjunction with well depths (greater depths are considered less likely to be contaminated), distances (further away is less likely to cause contamination), and judgment factors (greater values are considered less likely to cause contamination). All missing data are represented by an ".".

<sup>b</sup>The closest occurrence of any of these was chosen.



Table A3 (continued). Tabulated data from survey questionnaires.

QID #	1	2	3	4	5	6	7	8	9	10	11	12
1	100	100	100	100	100	100	100	100	100	100	100	100
2	100	100	100	100	100	100	100	100	100	100	100	100
3	100	100	100	100	100	100	100	100	100	100	100	100
4	100	100	100	100	100	100	100	100	100	100	100	100
5	100	100	100	100	100	100	100	100	100	100	100	100
6	100	100	100	100	100	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100	100	100	100	100	100
8	100	100	100	100	100	100	100	100	100	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	100	100
11	100	100	100	100	100	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100	100	100	100	100	100

















Table A3 (continued). Tabulated data from survey questionnaires.

Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	Q48	Q49	Q50	Q51	Q52	Q53	Q54	Q55	Q56	Q57	Q58	Q59	Q60	Q61	Q62	Q63	Q64	Q65	Q66	Q67	Q68	Q69	Q70	Q71	Q72	Q73	Q74	Q75	Q76	Q77	Q78	Q79	Q80	Q81	Q82	Q83	Q84	Q85	Q86	Q87	Q88	Q89	Q90	Q91	Q92	Q93	Q94	Q95	Q96	Q97	Q98	Q99	Q100																					
1200	1200	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780	790	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990	1000
100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	6300	6400	6500	6600	6700	6800	6900	7000	7100	7200	7300	7400	7500	7600	7700	7800	7900	8000	8100	8200	8300	8400	8500	8600	8700	8800	8900	9000	9100	9200	9300	9400	9500	9600	9700	9800	9900	10000			
100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	6300	6400	6500	6600	6700	6800	6900	7000	7100	7200	7300	7400	7500	7600	7700	7800	7900	8000	8100	8200	8300	8400	8500	8600	8700	8800	8900	9000	9100	9200	9300	9400	9500	9600	9700	9800	9900	10000			
100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	6300	6400	6500	6600	6700	6800	6900	7000	7100	7200	7300	7400	7500	7600	7700	7800	7900	8000	8100	8200	8300	8400	8500	8600	8700	8800	8900	9000	9100	9200	9300	9400	9500	9600	9700	9800	9900	10000			
100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	6300	6400	6500	6600	6700	6800	6900	7000	7100	7200	7300	7400	7500	7600	7700	7800	7900	8000	8100	8200	8300	8400	8500	8600	8700	8800	8900	9000	9100	9200	9300	9400	9500	9600	9700	9800	9900	10000			

APPENDIX B (continued)

Table B1. Statistical summary for chemical analyses.

Legend for Column Headings		STATISTICAL SUMMARY			
Page/Col	Description	Minimum	Maximum	Mean	Standard deviation
1- 0	Sample number				
1- 1	Hardness as CaCO <sub>3</sub> , mg/l	14.0	1841.000	371.9703	245.3605
1- 2	Calcium as CaCO <sub>3</sub> , mg/l	3.5	509.000	109.1584	70.6941
1- 3	Magnesium as CaCO <sub>3</sub> , mg/l	1.0	2804.000	59.4851	287.7148
1- 4	Sodium, mg/l	9.1	724.000	72.4911	116.9915
1- 5	Potassium, mg/l	0.2	21.600	3.8653	3.3187
1- 6	Alkalinity as CaCO <sub>3</sub> , mg/l	28.0	448.000	244.5346	79.7009
1- 7	Chloride, mg/l	1.6	795.000	74.8257	116.8928
1- 8	Sulfate, mg/l	12.0	1172.000	112.3663	178.5532
1- 9	Nitrate as N, mg/l	0.0	91.000	9.7400	13.9973
1-10	Fluoride, mg/l	0.1	3.500	0.5342	0.4975
1-11	pH	7.1	8.800	7.7485	0.2852
1-12	Turbidity, TU	0.0	65.000	1.5247	6.7802
2- 1	Specific cond., µmho/cm	0.0	3560.000	928.1089	571.3556
2- 2	T. dis. solids, mg/l	132.0	2706.000	606.9406	388.8082
2- 3	T. phosphate-P, mg/l	0.0	1.200	0.1962	0.2715
2- 4	Silica (SiO <sub>2</sub> ), mg/l	6.3	70.900	25.9683	15.0476
2- 5	Ammonia-N, mg/l	0.0	0.700	0.0420	0.1305
2- 6	CO <sub>3</sub> hardness as CaCO <sub>3</sub> , mg/l	0.0	448.000	227.7624	89.4474
2- 7	Non-CO <sub>3</sub> hard. as CaCO <sub>3</sub> , mg/l	0.0	1575.000	138.4065	223.2984
2- 8	NaHCO <sub>3</sub> alk. as CaCO <sub>3</sub> , mg/l	0.0	406.000	12.7930	59.6698
2- 9	Iron, mg/l	0.0	8.860	0.2556	0.9536
2-10	Manganese, mg/l	0.0	1.090	0.0539	0.1701
2-11	Arsenic, mg/l	0.0	0.015	0.0026	0.0029
2-12	Barium, mg/l	0.0	0.930	0.1792	0.1974
3- 1	Cadmium, mg/l	0.0	0.021	0.0008	0.0027
3- 2	Chromium, mg/l	0.0	0.010	0.0003	0.0017
3- 3	Copper, mg/l	0.0	0.700	0.0299	0.0764
3- 4	Lead, mg/l	0.0	0.064	0.0046	0.0121
3- 5	Mercury, mg/l	0.0	0.004	0.0000	0.0004
3- 6	Selenium, mg/l	0.0	0.090	0.0050	0.0116
3- 7	Silver, mg/l	0.0	0.060	0.0017	0.0063
3- 8	Zinc, mg/l	0.0	8.540	0.3088	1.0949
3- 9	Chloromethane, µg/l	0.0	0.000	0.0000	0.0000
3-10	Bromomethane, µg/l	0.0	0.000	0.0000	0.0000
3-11	Vinyl chloride, µg/l	0.0	0.000	0.0000	0.0000
3-12	Chloroethane, µg/l	0.0	0.000	0.0000	0.0000
4- 1	Dichloromethane, µg/l	0.0	5.800	0.1277	0.7571
4- 2	1,1-dichloroethylene, µg/l	0.0	0.000	0.0000	0.0000
4- 3	1,1-dichloroethane, µg/l	0.0	0.000	0.0000	0.0000
4- 4	Trans 1,2-dichloroethylene, µg/l	0.0	0.000	0.0000	0.0000
4- 5	Trichloromethane, µg/l	0.0	0.600	0.0059	0.0597
4- 6	1,2-dichloroethane, µg/l	0.0	0.900	0.0089	0.0895
4- 7	1,1,1-trichloroethane, µg/l	0.0	0.000	0.0000	0.0000
4- 8	Tetrachloromethane, µg/l	0.0	0.000	0.0000	0.0000
4- 9	Bromodichloromethane (THM), µg/l	0.0	0.000	0.0000	0.0000
4-10	1,2-dichloropropane, µg/l	0.0	0.000	0.0000	0.0000
4-11	Trans 1,3-dichloropropene, µg/l	0.0	0.000	0.0000	0.0000
4-12	Trichloroethylene, µg/l	0.0	0.000	0.0000	0.0000
5- 1	Benzene, µg/l	0.0	2.300	0.0228	0.2289
5- 2	Dibromochloromethane (THM), µg/l	0.0	0.000	0.0000	0.0000
5- 3	Cis 1,3-dichloropropene, µg/l	0.0	0.000	0.0000	0.0000
5- 4	1,1,2-trichloroethane	0.0	0.000	0.0000	0.0000
5- 5	Bromoform (THM), µg/l	0.0	0.000	0.0000	0.0000

Table B1 (continued). Statistical summary for chemical analyses.

Legend for Column Headings

## STATISTICAL SUMMARY

Page/Col	Description	Minimum	Maximum	Mean	Standard deviation
5- 6	1,1,2,2-tetrachloroethane, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
5- 7	Tetrachloroethylene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
5- 8	Toluene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
5- 9	Chlorobenzene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
5-10	Ethylbenzene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
5-11	Meta-xylene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
5-12	Ortho and/or para-xylene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6- 1	1,4-dichlorobenzene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6- 2	Alachlor, $\mu\text{g}/\ell$	0.0	0.880	0.0087	0.0876
6- 3	Aldrin, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6- 4	Atrazine, $\mu\text{g}/\ell$	0.0	1.500	0.0148	0.1493
6- 5	Chlordane, $\mu\text{g}/\ell$	0.0	3.400	0.0337	0.3383
6- 6	Dacthal, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6- 7	O.P' DDT, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6- 8	P.P' DDT, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6- 9	Dieldrin, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6-10	Dual, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6-11	PCB's, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
6-12	Ramrod, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 1	Sencor, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 2	Endrin, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 3	Lindane, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 4	Methoxychlor, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 5	Toxaphene, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 6	2,4-D as acid, $\mu\text{g}/\ell$	0.0	1.300	0.0129	0.1293
7- 7	Silvex as acid, $\mu\text{g}/\ell$	0.0	0.000	0.0000	0.0000
7- 8	2,4,5-T as acid, $\mu\text{g}/\ell$	0.0	1.100	0.0109	0.1094
7- 9	Tordon, $\mu\text{g}/\ell$	0.0	5.600	0.0554	0.5572
7-10	Heptachlor epoxide, $\mu\text{g}/\ell$	0.0	0.026	0.0003	0.0026







