AN ABSTRACT OF THE THESIS OF

Michael A. Jennings for the Master of Science Degree in Physical Science presented on May 2, 1991.

Title: Nitrate Study of Lyon County, Kansas Private Wells, 1990 - 1991.

Abstract Approved: David Schroeder

Committee Members: Dr. David Schroeder, Chairperson

Dr. James Aber

Prof. Paul Johnston

An investigation into the water quality of private wells from Lyon County, Kansas concentrating on nitrates was conducted from July, 1990 through April, 1991. Eleven wells, located throughout Lyon County, were analyzed monthly for nitrate concentrations studying the seasonal and local variations of each well. This is a continued study started by Paul Thompson from June, 1988 through February, 1989.

Excessive fertilization of crops with nitrogen-based compounds is largely responsible for the high amounts of nitrates found in ground water. Nitrogen-fixing legumes, plant residues, and animal feces and urine remains are sources of high organic nitrogen compounds. Nitrogen compounds are converted to ammonia, in the soil, which can be oxidized to nitrate through a process known as nitrification. At high concentrations, nitrates can be very harmful to adults and even fatal to infants.

Local bedrock and soil geology have an influence on the flow of ground water, which varies throughout Lyon County and the different well sites. Nearby agricultural crops and livestock are major sources for nitrates found in ground water. Monthly samples were analyzed for nitrates by HPLC and UV Molecular Absorption techniques. Resulting nitrate concentrations were recorded and compared for local and seasonal fluctuations between the differ-

ent well sites. Comparison with previous studies show similar values for nitrate samples from corresponding site locations and overall seasonal trends.

The highest overall nitrate concentrations were observed in September of 1990, which coincides with the fertilization of winter wheat crops in the early fall. An increase in concentrations during the late fall months corresponded to a decrease in nitrogen fixation, from legume plants, due to dropping temperatures.

NITRATE STUDY OF LYON COUNTY, KANSAS PRIVATE WELLS, 1990-1991

A Thesis

Presented to

the Physical Science Division

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

By

Michael A. Jennings

May, 10 1991

James J Ake

Approved for the major Department

James E Wolfe

Approved for the Graduate Council

ACKNOWLEDGEMENTS

I extend appreciation and gratitude to the following persons and organizations:

My wife Kathy, daughters Ashley and Cassandra, and the rest of my relatives: for their patience and support during my studies, even though they didn't know what exactly it was I was doing.

Anne Scheve, Emporia Health Department: For her willingness to take time out of her busy schedule to help and guide me on this project.

Dr. James Aber, head of Emporia State University Earth Science Department: For encouraging me to continue my education and for his many hours of instruction and guidance during my graduate studies.

Committee members; Dr. David Schroeder, Dr. James Aber and Prof. Paul Johnston: For their advice and assistance with the technical aspects of preparing a thesis report, and for their willingness to drop what they were doing to answer any questions.

TABLE OF CONTENTS

TABLES

Table Page

FIGURES

Figure Page

CHAPTER 1: INTRODUCTION

Purpose and scope:

Shallow aquifers in east-central Kansas supply water for public and private drinking water, irrigation for crops, livestock, and some industrial uses. Private wells in Lyon County are mainly used to supply private drinking water, irrigation and livestock. The water quality of private wells is not as well documented as for public wells, which have strict regulations and are closely monitored.

A common water quality problem in east-central Kansas is the high amount of nitrate found in ground water. High nitrate concentrations in water can be detrimental to both humans and animals. The harmful effects of nitrates and the increasing amounts found in ground water have given rise to much concern, forcing investigation of the sources of the problem.

This report presents the results of an investigation of 11 private wells located in Lyon County, Kansas from July 1990 to April 1991. The purpose of the investigation was to monitor the nitrate concentrations of the 11 wells monthly, then describe the changes and present possible sources for seasonal and regional variations.

Previous studies:

This report is a continuing investigation started by Paul H. Thompson from June 1988 to February 1989. The results he published in May, 1990 as "Nitrate Analysis of Private Wells in Lyon County, Kansas" will be considered in this report.

C. C. Delwiche (1970) "The Nitrogen Cycle" described nitrogen sources, chemical and biological reactions, and the pathways between the atmosphere, soil, and water. Howard O'Connor (1953) surveyed rock formations of Lyon County mapping surface outcrops and underlying stratigraphic columns. He also published the

"Ground water resources of Lyon County" (1953), in which he discussed the movement of water below the surface, water quality of Lyon County, and mapped the different ground water regions and depth to water table.

Dwight F. Metzler (1958) investigated the sources and seasonal variations of nitrates in private and public water supply wells, particularly with respect to the occurrence of infant cyanosis.

Nitrogen Transformations in the Soil:

Nitrogen; a colorless, odorless, tasteless gas, makes up 78% of dry air. Some of the most important microorganism mediated chemical reactions in aquatic and soil environments are those involving nitrogen compounds. Each of these important chemical processes is summarized below:

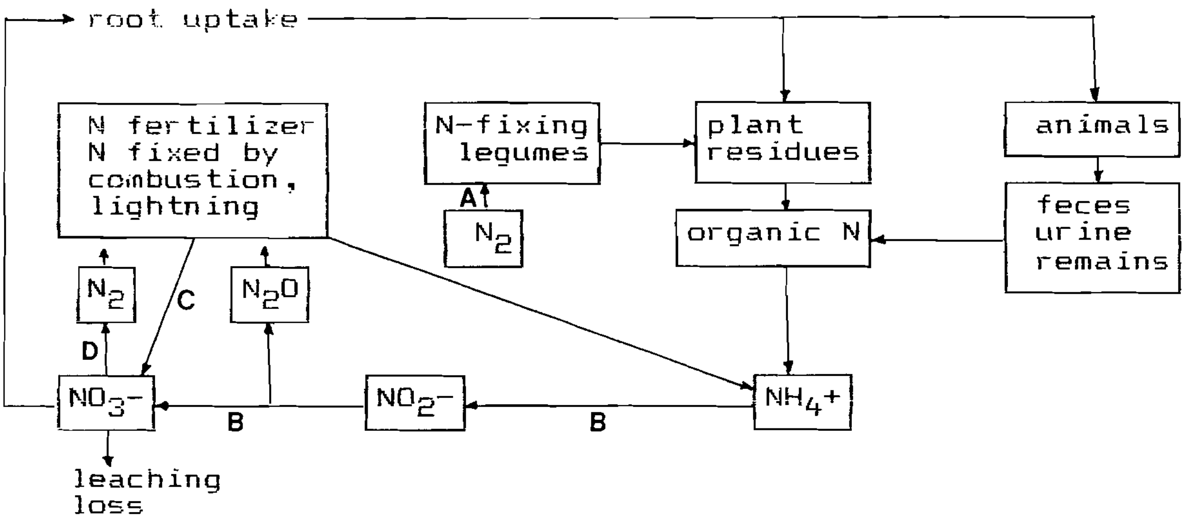


Figure 1. Nitrogen Transformations in the Soil
(Modified from Manahan 1979, Fig. 10.4)

A. NITROGEN FIXATION: Blue green algae, N-fixing legumes.
(N_2 ---> Organic nitrogen)

B. NITRIFICATION: Chemoautotrophic bacteria.
($NH_4^+ + 2O_2$ ---> $NO_3^- + H_2O + 2H^+$)

C. COMBUSTION & LIGHTNING: automobile exhaust & lightning.
($N_2 + O_2$ ---> $2NO$ ---> NO_2^- ---> NO_3^-)

D. DENITRIFICATION: Decomposers (anaerobic) when no O2 present.
($2NO_3^-$ ---> N_2)

Agriculture is the major source of nitrates found in ground water. Feces and urine-remain seepage from feedlots and holding tanks for hog manure, plus decomposing plants and nitrogen-fixing legume plants are responsible for the large amounts of organic nitrogen released into the soil. Fertilizers, which are high in nitrogen compounds, as well as industrial-fixation have become major sources for nitrogen seeping into surface and ground waters over the last century. Atmospheric fixation and fixed juvenile nitrogen, from volcanic activity, are minor sources of nitrogen compared to biological sources and human agricultural practices (Delwiche 1970).

Before nitrogen can be fixed it must be activated (Delwiche 1970), which means split into two separate atoms of nitrogen, which then "fix" with three hydrogen atoms to form two molecules of ammonia (NH_3). A few chemoautrophic microorganisms represented by the genus *Nitrosamas*, employ nitrification of the ammonium ion as their sole source of energy (Delwiche 1970). In the presence of oxygen, ammonia is converted to nitrite ion (NO_2-) plus water. Another specialized group of microorganisms, represented by *Nitrobacter*, are able to further oxidize nitrite ions to nitrate ions (NO_3-) (Delwiche 1970), For the Earth as a whole, however, the greatest natural source of fixed nitrogen is from legumes: alfalfa, peas, and beans (Delwiche 1970).

Combustion from automobile exhaust and lightning are other processes which can oxidize nitrogen gas (N_2) directly, forming nitrite and nitrate ions. Once nitrate is introduced into the soil, it can move freely because of the negative ionic charge. If nitrates become concentrated in the soil they may eventually become concentrated in ground water.

Nitrates and nitrites are taken out of the soil and ground water by denitrification and root uptake by plants. Numerous kinds of denitrifying bacteria live in the soil (for example *Pseudomonas Denitrificans*) that, if obliged to exist in the absence of oxygen, are able to reduce nitrate and nitrite ions for the oxidation of organic compounds (Delwiche 1970). Nitrates not denitrified may either be absorbed by plant roots or lost to ground water by leaching.

Whereas late-19th-century scientists were concerned that denitrifying bacteria were exhausting the nitrogen in the soil, we must be concerned today that denitrification may not be keeping pace with nitrogen fixation, considering the large amounts of fixed nitrogen that are being introduced into the biosphere by industrial fixation and the cultivation of legumes (Delwiche 1970). The amount of nitrogen fixed industrially has been increasing steadily at an alarming rate. If we add to this extra nitrogen the amount fixed by the cultivation of legumes, it already exceeds (by perhaps 10%) the amount of nitrogen fixed in nature (Delwiche 1970).

Nitrate effects:

Agriculture, as previously stated, is the major source of nitrates in ground water. Food stuffs, however, supply the majority of ingested nitrates in most consumers. 95 mg is the average daily intake for human consumption. Vegetables and cured meats are the major sources for nitrogen compounds ingested. In cured meats, such as bacon, nitrate compounds are used as curing agents and nitrite compounds are used as preservatives. Because nitrate and nitrite compounds are known to be harmful to infants, they are no longer used as preservatives in baby food.

In humans it is the reduction of nitrate to nitrite which causes harmful effects. Nitrite is formed from the reducing action of bacteria, such as *E. coli*, in the digestive tract. In adults, nitrates are absorbed high in the digestive tract before reduction can take place. In infants, however, stomach pH is less acidic allowing *E. coli* bacteria to colonize higher up in the tract reducing nitrates to nitrites before they can be absorbed. Nitrite is toxic because it can combine with hemoglobin forming a complex called "methemoglobin" which deprives the tissues of oxygen. Severe cases of methemoglobinemia, better known as "blue baby," can cause mental retardation of the infant and even death. Twenty cases of blue baby reported in Kansas, between 1940 and 1953, were associated with water supplies containing 30 to 180 mg/l nitrate reported as N (O'Connor 1953).

Another problem with the reduction of nitrates at stomach pH is that (NO_2-) converts to (H_2NO_2+) which is capable of nitrosating secondary amines which may be carcinogenic. A concentration of 90 ppm of nitrate in drinking water has been found, by the Kansas State Board of Agriculture, as being dangerous to infants, and some authorities recommend that no more than 45 ppm be used for formula preparation. (O'Connor 1953). High nitrate levels are not as harmful to older children and adults. The primary drinking standard for nitrate, reported as nitrogen (N), is 10 mg/l (Viets *et al.* 1971).

CHAPTER 2: AREA GEOLOGY AND GEOGRAPHY

The eleven wells studied are located in different areas of Lyon County. The locations range from the northwest and northeast quarters to the southeast quarter with the majority of the wells located in central Lyon County near Emporia (Fig 2). The local nature of soil exposed at the surface (Fig. 3 and Table 1) is a reflection of the underlying bedrock. The locations of the eleven wells result in different soil and bedrock conditions for each well due to varying local geologic settings. The difference in soil and bedrock conditions have a direct influence on the physical properties of the aquifer and resulting ground water.

The topography of most of Lyon County, Kansas is represented by the Osage Cuestas region, except for western and northern portions of the county which are part of the Flint Hills Uplands. The Osage Cuestas were formed from alternating limestone and shales of the Upper Pennsylvanian and Lower Permian. Successively younger beds overlap one another to the west, like tilted steps of a giant staircase. More resistant outcrops of limestone form the tops of steps, and weatherable shale acts as the risers (Buchanan 1985). All beds slope toward the west-northwest with the dipping strata forming a series of parallel ridges having gently sloping west and steeply sloping east faces.

The Flint Hills were formed by erosion of gently westward-dipping strata in much the same fashion as the Osage Cuestas, but the Permian-aged limestones of the Flint Hills contain bands of chert, or flint, which is more resistant to weathering than limestone lacking chert. The area of the Flint Hills is higher than the areas to the west and east because the cherty-gravel forms a protective cover from erosion.

Quaternary age river deposits are found through a large section of central-Lyon County which corresponds to the Cotton-

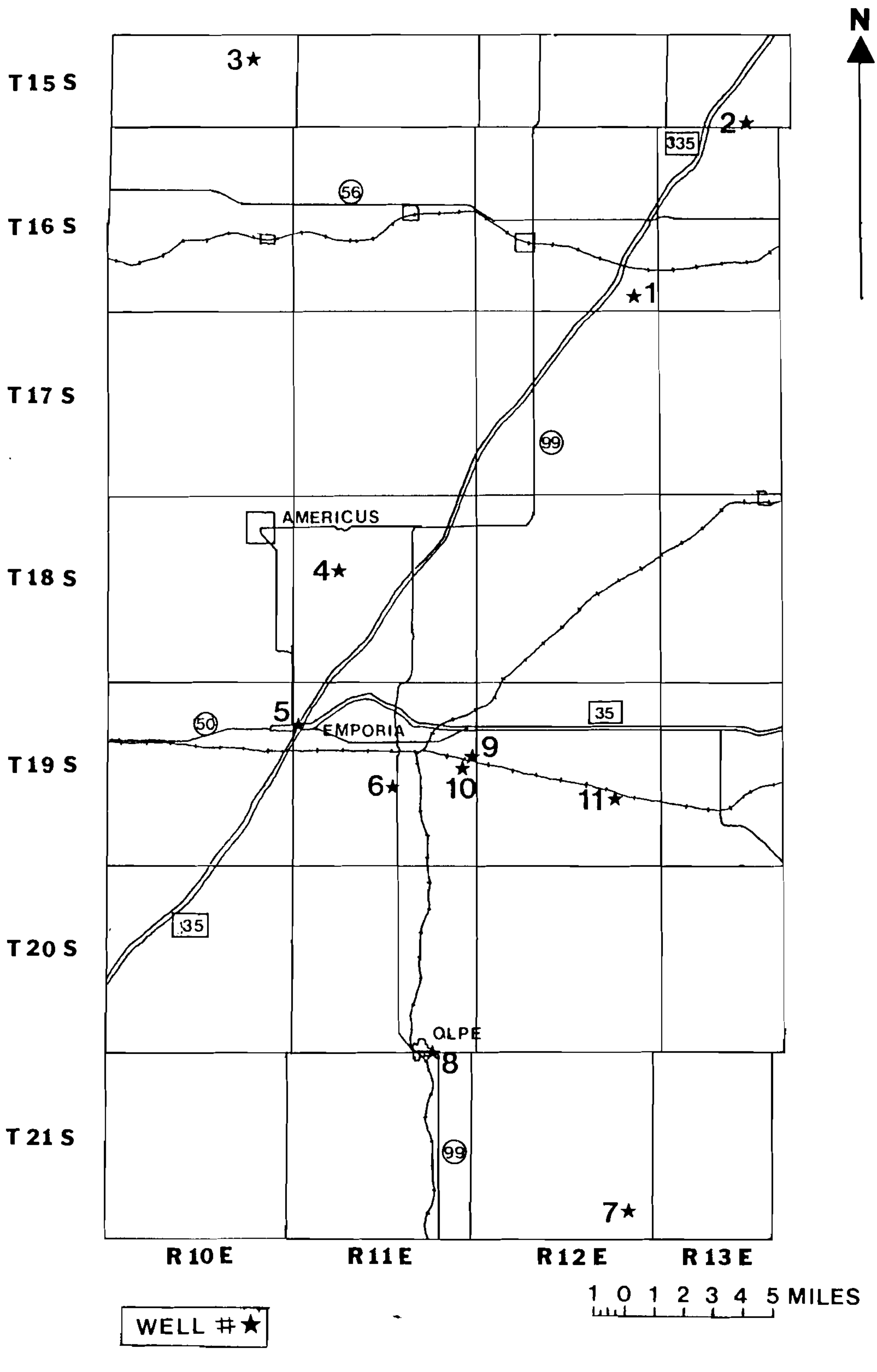


Figure 2. Well Locations in Lyon County, Kansas
(base map from Neill 1981)

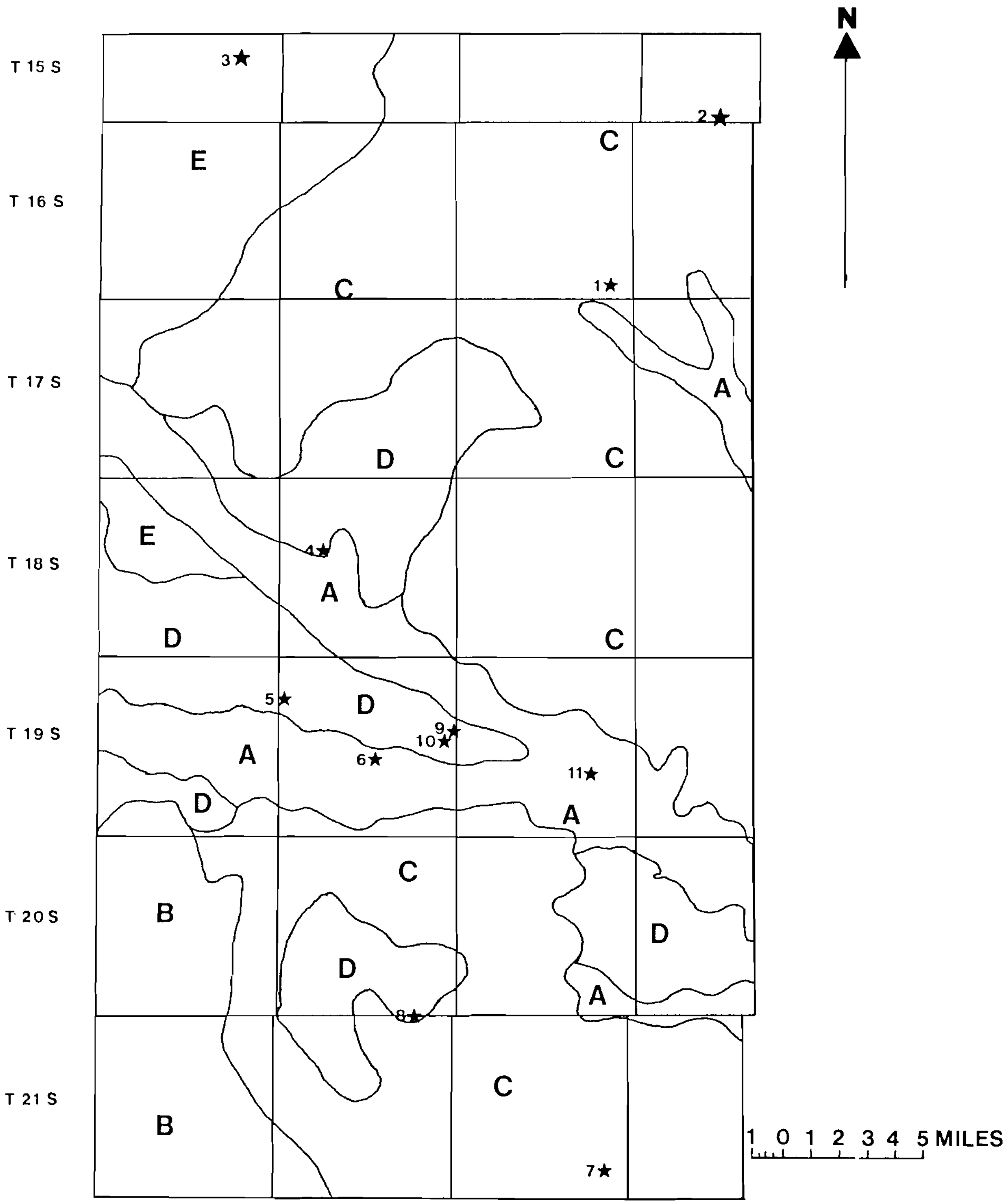


Figure 3. Soil Regions in Lyon County
See Table 1. for descriptions
(based on Neill 1981)

wood and Neosho River flood plains and some of their larger tributaries. These deposits correspond to region A (Fig. 3) and consist primarily of sand and gravel with a silty-clay subsoil.

Table 1. Soil Legend (See Fig. 3). Based on Neill (1981)

A. Chase-Osage Association: Deep, nearly level, moderately well drained soils that have a dominantly silty clay subsoil; on flood plains and low terraces

B. Clime-Sloan Association: Moderately deep and shallow, moderately sloping to moderately steep, moderately well drained and somewhat excessively drained soils that have a silty clay subsoil or lack of subsoil; on uplands

C. Kenoma-Martin-Elmont Association: Deep, gently and moderately sloping, moderately well drained and well drained soils that have a silty clay or silty clay loam subsoil; on uplands

D. Kenoma-Ladysmith Association: Deep, nearly level and gently sloping, moderately well drained soils that have a silty clay subsoil; on uplands

E. Tully-Florence Association: Deep, gently sloping and strongly sloping, well drained soils that have a dominantly silty clay or cherty clay subsoil; on uplands

---

General soil regions for Lyon County are shown in Fig. 3. Specific soil types and other geologic data: underlying rock outcrops, well locations with corresponding surface elevations, and well drilling information are described in Table 2. The positions of corresponding rock outcrops, listed in Table 2, are shown in the stratigraphic column for Lyon County, Kansas (Fig. 4).

Precipitation amounts of rainfall, reported in inches, from Lyon County, Kansas for the period of January 1990 through April 1991 are listed in Table 3. Precipitation amounts, recorded at four different locations, are averaged and compared to normal monthly precipitation levels (Aiken et al. 1990). Departure from

Table 2. Geologic Data for Wells in Lyon County (1990 - 1991

WELL	TWNSHP	RANGE	SECT.	QUAD.	SURF ELEV.
1	T16S	R12E	36	SW1/4	1145
2	T15S	R13E	33	SE1/4	1210
3	T15S	R10E	23	SE1/4	1445
4	T18S	R11E	17	SW1/4	1147
5	T19S	R11E	7	NW1/4	1144
6	T19S	R11E	22	NW1/4	1105
7	T21S	R12E	36	NW1/4	1185
8	T21S	R11E	2	NW1/4	1185
9	T19S	R11E	13	SE1/4	1107
10	T17S	R11E	13	SW1/4	1120
11	T19S	R12E	23	SW1/4	1079

WELL	ALL VALUES IN FT WELL DPTH.	WELL DIAM.	AVERAGE DEPTH TO WATER (FT)	WELL TYPE WELL AGE
1	24	5	18	DUG (1934)
2	56	5	40	DUG (1890)
3	24	3.5	12	DUG (1925)
4	36	ND	12	DUG ( )
5	30	ND	18	DUG ( )
6	24	ND	12	DUG (1930)
7	16	5	8	DUG (1915)
8	34	5	6	DUG (1908)
9	30	1.75	20	DUG (1938)
10	24	4	12	DUG ( )
11	28	4	VAR	DUG (19)

WELL	SOIL SYMB.	AGE & ROCK TYPE OF OUTCROP	
1	Ka	Penn.	Pierson Pt. Shale
2	Ec	Penn.	Pierson Pt. Shale & Quat. alluviu
3	Le	Perm.	Lower Chase Grp. LS & SH
4	Ka	Quat.	Emporia terrace deposits
5	Ka	Quat.	Emporia terrace deposits
6	Os	Quat.	alluvium
7	Ma	Penn.	White Cloud Shale
8	Ka	Quat.	Wiggwam terrace & alluvium deposi
9	Le	Quat.	Wiggwam terrace deposits
10	Le	Quat.	Wiggwam terrace deposits
11	Ra	Quat.	alluvium

SOIL SYMBOL LEGEND

Ka Kenoma silt loam (3-6% slopes)
Ec Elmont silty clay loam (3-7% slopes)
Le Ladysmith silty clay loam (0-2% slopes)
Os Osage silty clay
Ma Martin silty clay loam (1-4% slopes)
Ra Reading silt loam

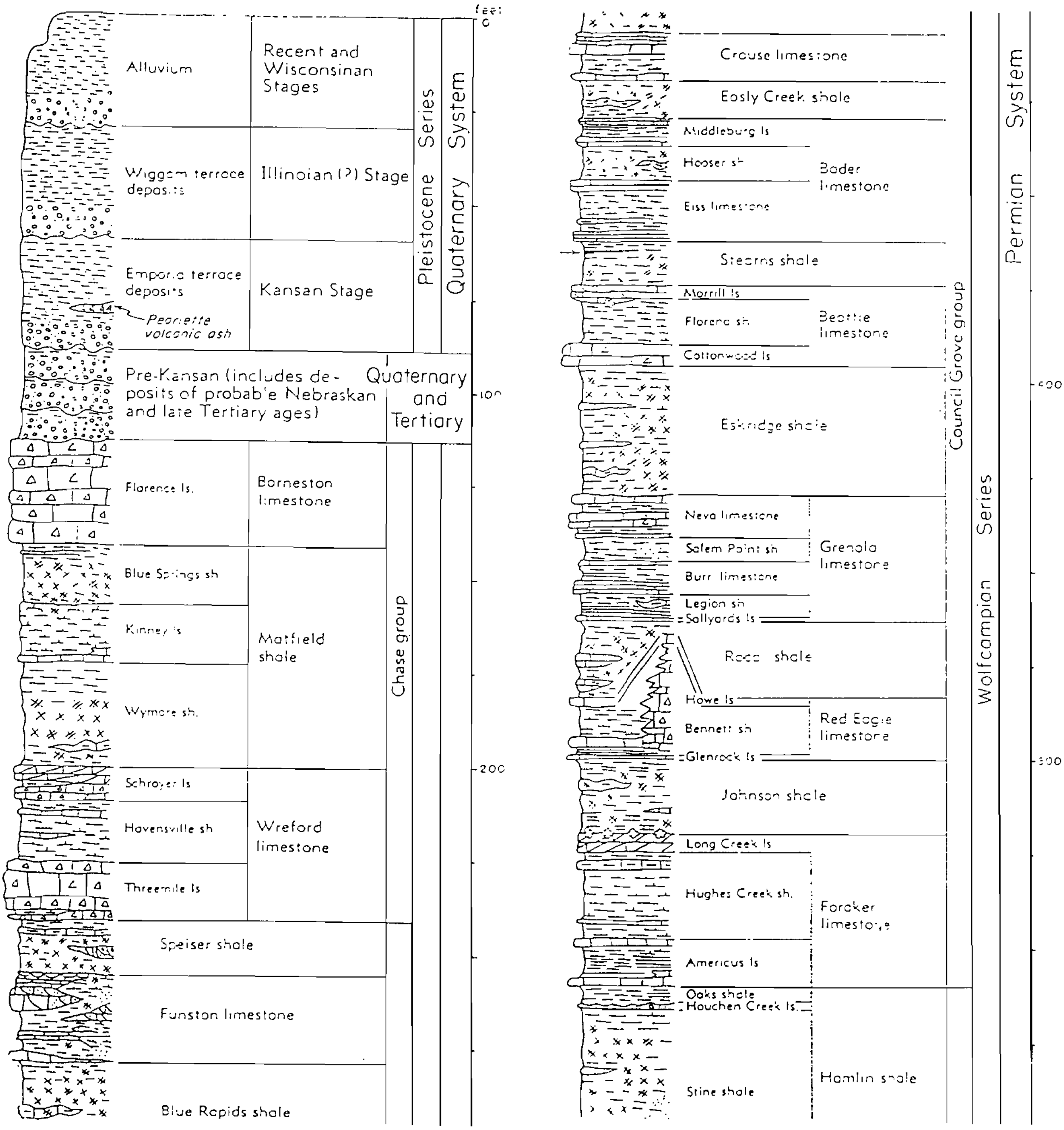


Figure 4. Lyon County Stratigraphy
(based on O'Connor 1953)

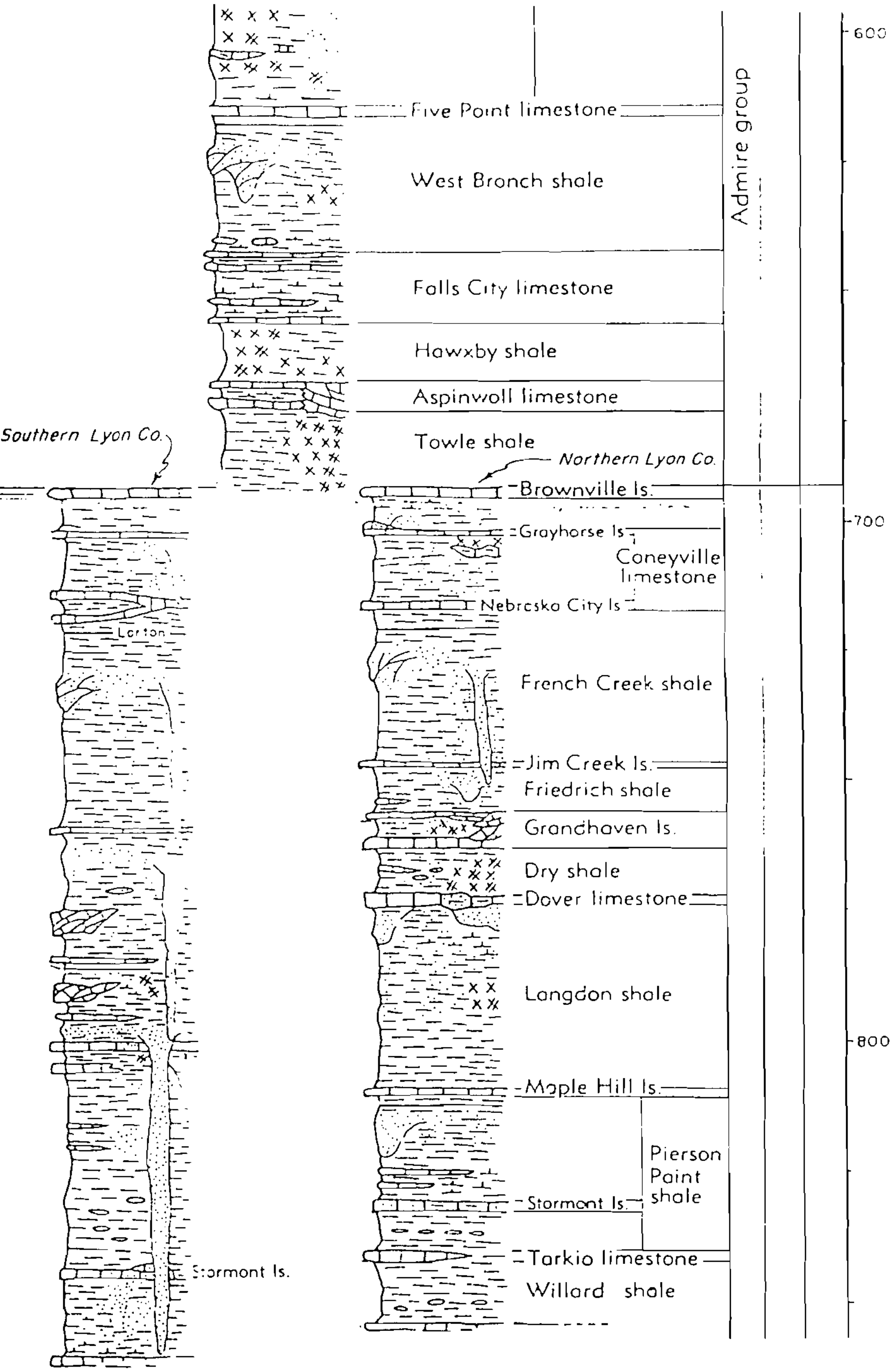
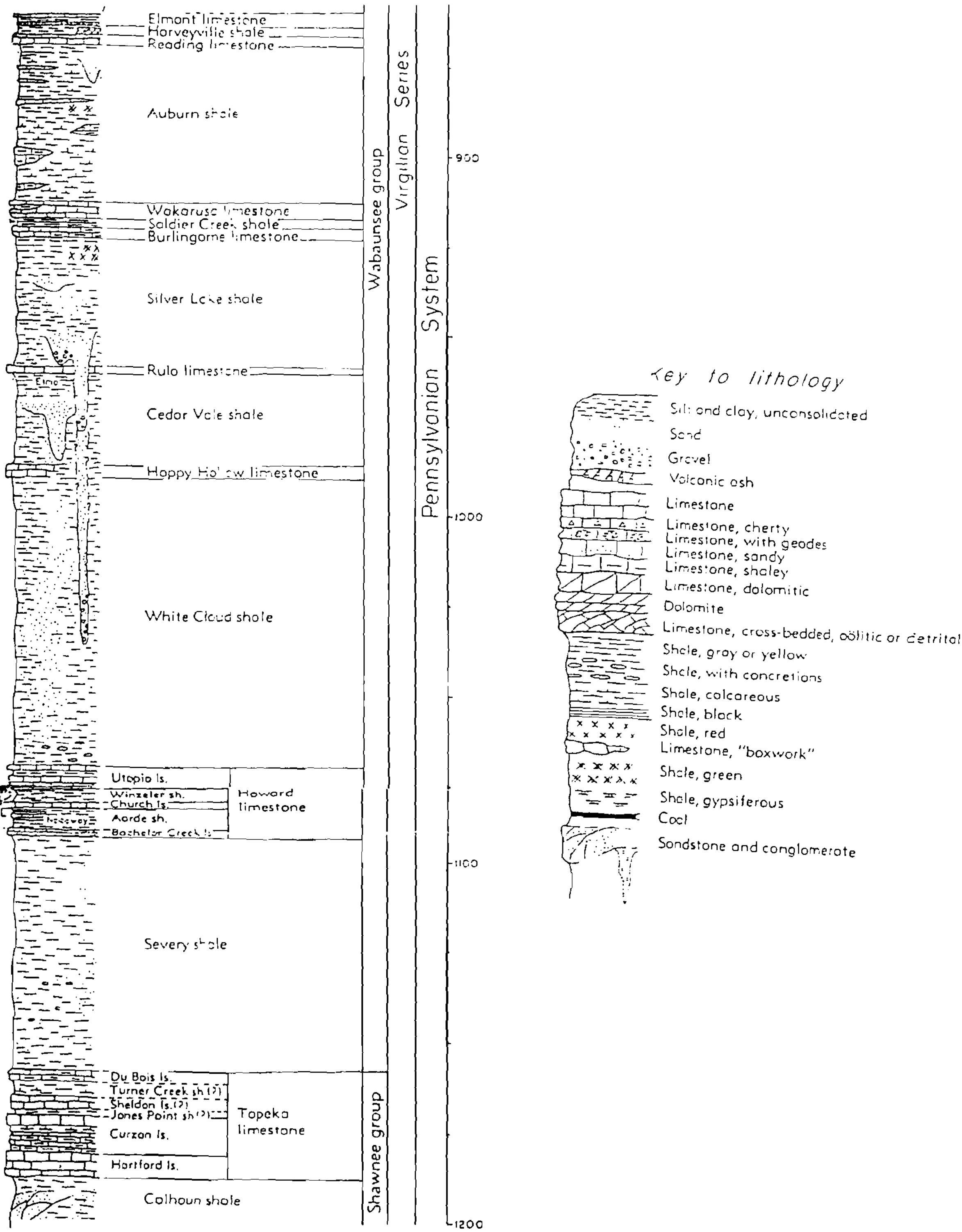


Figure 4. (continued)



igure 4. (continued)

Table 3. Rainfall Data for Lyon County, Kansas

Jan. 1990 - Apr. 21, 1991

ALL VALUES REPORTED IN INCHES

DATE	STAT. 1	STAT. 2	STAT. 3	STAT. 4	AVERAGE	DEPARTURE FROM NORMAL
JAN. 1990	1.71	2.20	1.84	0.40	1.54	0.9
FEB.1990	1.54	1.42	2.14	1.25	1.59	0.1
MAR. 1990	3.89	3.82	4.82	3.39	3.78	0.2
APR. 1990	1.88	1.15	2.03	2.15	1.30	-0.5
MAY 1990	9.48	6.50	7.91	6.62	7.63	5.3
JUNE 1990	4.44	12.19	8.91	4.14	7.42	3.4
JULY 1990	2.52	2.57	1.93	1.41	2.11	-1.2
AUG. 1990	4.12	2.97	5.55	3.88	4.13	1.1
SEPT. 1990	0.91	0.28	1.62	0.97	0.95	-2
OCT. 1990	1.11	0.48	1.09	1.75	1.11	-1
NOV. 1990	2.10	4.81	3.05	1.23	2.60	1.6
DEC. 1990	0.59	0.26	0.68	0.17	0.43	-0.3
JAN. 1991	0.68	0.18	1.04	0.57	0.62	0
FEB. 1990	0.02	1.09	0.00	0.00	0.28	-0.5
MAR. 1991	0.92	0.98	1.47	1.60	1.24	-0.5
APR. 1991	2.62	1.95	2.59	2.30	2.37	?

STATION LOCATION & RECORDER

1 STATION EMPORIA WASTEWATER TREATMENT PLANT

2 STATION NEOSHO RAPIDS (WILLIAM F. PHILLIPS)

3 STATION READING 2N (WILLIAM F. COFFMAN)

4 STATION BUSHONG (WALTER V. THOMAS)

normal monthly precipitation is also listed as (+) for values above normal and (-) for values below normal. Local and seasonal fluctuations in nitrate concentrations due to changing precipitation amounts are discussed in chapter 5.

CHAPTER 3: METHODS OF INVESTIGATION AND PROCEDURE

Sampling methods:

Each of the eleven wells in this study was sampled once a month, except for March 1991, for the period of June 1990 through April 1991. The samples were collected during the first week of each month in this period. Samples from wells 1 and 8 were collected by lowering a bucket directly into the well. The samples from the remaining 9 wells were collected externally from pumps or faucets inside or outside the residents' houses. The water was allowed to run, up to 5 minutes for some, until fresh water from the well was collected in a plastic sample bottle.

After the samples were collected, they were taken back to the laboratory at Emporia State University and 0.5 ml of dilute HCL acid was added to each 400 ml sample. The samples were then placed in a refrigerator and tested the following day whenever possible.

Analytical techniques:

The samples, from the first three months, were tested using High Performance Liquid Chromatography (HPLC), and the remaining samples, taken from the following months, were analyzed by UV molecular absorption (UVMA). The initial testing, of nitrate levels, was accomplished using a Varian HPLC with a reverse phase column. A 0.3 M solution of dipotassium phosphate in dilute phosphoric acid was used for the mobile phase. A 1.0 mg/l standard was prepared and then 0.5 ml of standard was added to 2.0 ml of phosphate buffer. The samples were prepared the same way, and the wells with nitrate concentrations above 5.0 mg/l were diluted 20 times with distilled water.

Approximately 1 ml of standard or sample was injected into the HPLC column, and two or more trials were run for each standard and sample. The trials were analyzed for nitrate concentration using the procedure developed by Schroeder (1987, 1988). The method uses a spectrophotometer set at 210 nm. The following parameters were used for the procedure: flow rate of 1.0 ml/min., range of 0.16. The absorbance data were relayed to a mV recorder (10 mV full scale) that was set at 1.0 cm/min.

The nitrate absorbances were registered as peaks on the recorder and measured in cm, and then nitrate concentrations were calculated by: (peak ht. sample / peak ht. std.). The retention time of analyte in the column was 2.8 - 3.0 minutes.

The samples from the remaining months were analyzed by UV molecular absorbance, because the HPLC column began to leak which made the results unreliable. The samples were collected in the same manner previously stated; however, the preparation for analysis was as follows: A fresh 5.0 mg/l nitrate standard was prepared each month from a 1000 mg/l stock solution diluted with deionized water, a fresh blank (zero nitrate concentration) was prepared each month from deionized water, and fresh samples were collected from the wells each month (samples with nitrate concentrations above 5.0 mg/l were diluted with deionized water accordingly).

Nitrate absorbances were then analyzed by GCA McPherson UV molecular absorbance, with the following parameters: wavelength setting of 220 nm, slit width 0.50 nm, and a deuterium lamp used for the light source. Organic material absorbances were detected at a wavelength setting of 275 nm. Deionized water was placed in the reference cell and then the blank, standard, and sample absorbances were detected at both 220 and 275 nm settings.

Nitrate concentrations were calculated by:

$$\boxed{\frac{\text{sample absorbance } (220 - 275)}{\text{stand. absorbance } (220 - 275)} \times 5.0 \text{ mg/l } (\times \text{ dilution})}$$

Samples collected in January and February of 1991 were analyzed for chloride concentrations by potentiometric titration. 25.00 ml of 0.100N KCL solution + 75.00 ml of distilled H_2O pipetted into two 140 ml beakers were used as standards. One of the standards was placed on a magnetic stirring apparatus and a silver billet and calomel reference electrodes were inserted into the solution to measure E in (mV). 0.014M $Hg(NO_3)2$ was used as the titrant and the KCL solution was titrated to the endpoint which occurred about 140 mV higher than the starting E. Buret and mV readings were recorded every 20 mv until about 80 mV past the endpoint. The procedure was repeated for the other standard.

Two trials were conducted using 100 ml of each well sample, titrating with $Hg(NO_3)_2$, recording mV and buret readings. Chloride concentrations, reported in mg/l, were calculated by:

$$\boxed{Cx = 88.6\ Vx / Vs}$$

Vx = volume of titrant needed for sample

Vs = volume of titrant needed for standard

Iron concentrations were analyzed in January of 1991 but were not found to be significant except for well 6 which recorded a very high iron concentration.

CHAPTER 4: RESULTS

Nitrate concentrations:

The resulting nitrate concentrations, reported in mg/l, for the period of July 1990 through April 1991 are listed in Table 4. Average nitrate concentrations for each well and monthly nitrate averages from the 11 wells, are also calculated and reported. Graphs showing nitrate concentrations for each of the 11 wells have been constructed, using *Date of Sampling* as the X-axis and *Nitrate Level (mg/l)* as the Y-axis (Figs. 5 - 15).

Well 1 (Fig. 5) nitrate concentrations fluctuated greatly from month to month, with a large increase from August to September 1990 followed by a large decrease from September to August 1990. The well went dry in December 1990 so no samples were taken in January and February 1991, which is illustrated by the dotted line connecting December 1990 and April 1991.

Well 2 (Fig. 6) monthly nitrate concentrations varied only slightly, with the exception of the large increase in August 1990, which then gradually decreased into the winter months, rising slightly again in January 1991.

Well 3 (Fig. 7) monthly nitrate concentrations decreased slightly from July to August 1990 and then increased sharply in September followed by a drop, of roughly 30 mg/l, in October 1990. The nitrate concentrations, of the remaining months, rose slightly in November followed by a gradual decrease into February 1991.

Well 4 (Fig. 8) nitrate concentrations dropped sharply from July through September 1990 followed by a large increase in October. For the convenience of the well owner, no samples were collected after October 1990.

Well 5 (Fig. 9) nitrate concentrations dropped from July to August 1990 and then increased in September, followed by a large

Table 4. Nitrate Concentrations from Lyon County Wells

Concentrations reporteed in (mg/l)

DATE COLLECTED & SAMPLE #

WELL #	JULY 90 SAMPLE 1	AUG. 90 SAMPLE 2	SEPT. 90 SAMPLE 3	OCT.90 SAMPLE 4	NOV. 90 SAMPLE 5
1	5.00	6.10	20.00	0.49	8.20
2	0.60	13.79	1.60	0.47	0.05
3	17.10	15.17	72.00	43.90	49.60
4	8.30	6.86	5.00	6.02	
5	10.50	8.04	13.20	3.50	6.62
6	0.10	0.10	0.04	0.25	0.47
7	0.40	0.14	0.10	0.10	0.14
8	40.90		21.00		35.00
9	13.60	25.71	28.50	19.40	21.10
10	8.10	10.34	7.60	7.30	6.76
11	45.00	61.25	90.00	102.00	108.20
MONTHLY AVERAGE	17.42	13.41	20.55	16.68	21.47
DEPARTURE FROM AVG.	-0.53	-4.54	5.6	-1.27	3.52

DATE & SAMPLL #

WELL #	DEC. 90 SAMPLE 6	JAN. 90 SAMPLE 7	FEB.91 SAMPLE 8	APR.91 SAMPLE 9	AVG.
1	7.49			19.52	9.54
2	0.11	0.69	0.54		2.23
3	46.67	42.84	34.09		40.42
4					6.55
5	6.06	7.29	6.58	7.48	7.70
6	0.47	0.21	0.06	0.02	0.19
7	0.11	0.03	0.00	0.00	0.11
8	25.94	8.22	5.86	7.14	20.58
9	22.26	16.52	18.35	18.27	22.63
10	6.27	6.83	6.65	5.79	7.29
11	114.79	110.8	106.84	98.35	95.25
MONTHLY AVERAGE	20.92	17.58	16.27	14.23	17.95
DEPARTURE FROM AVG.	2.97	-0.37	-1.68	-3.72	0

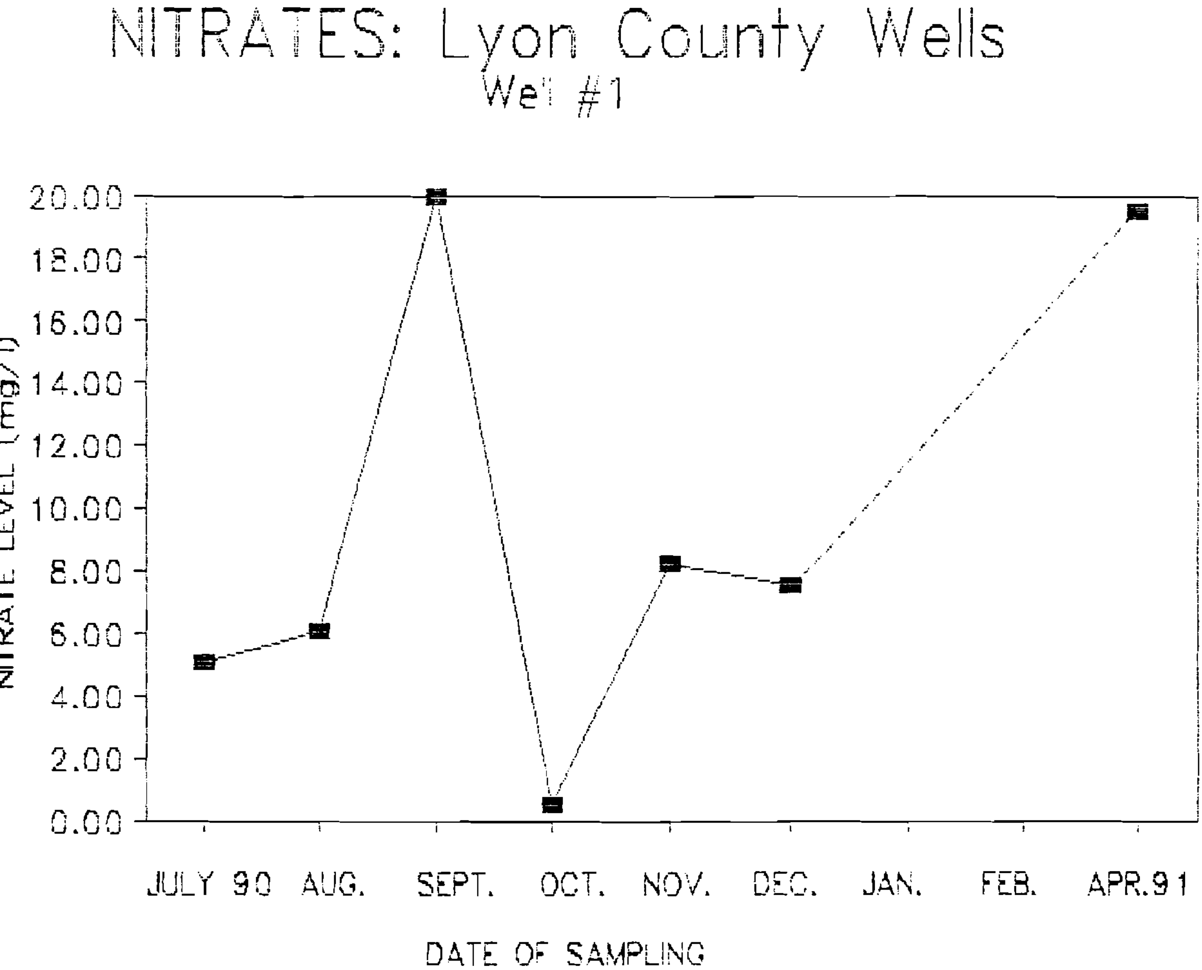

NITRATES: Lyon County Wells
Well #1
NITRATE LEVEL (mg/l)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 5.

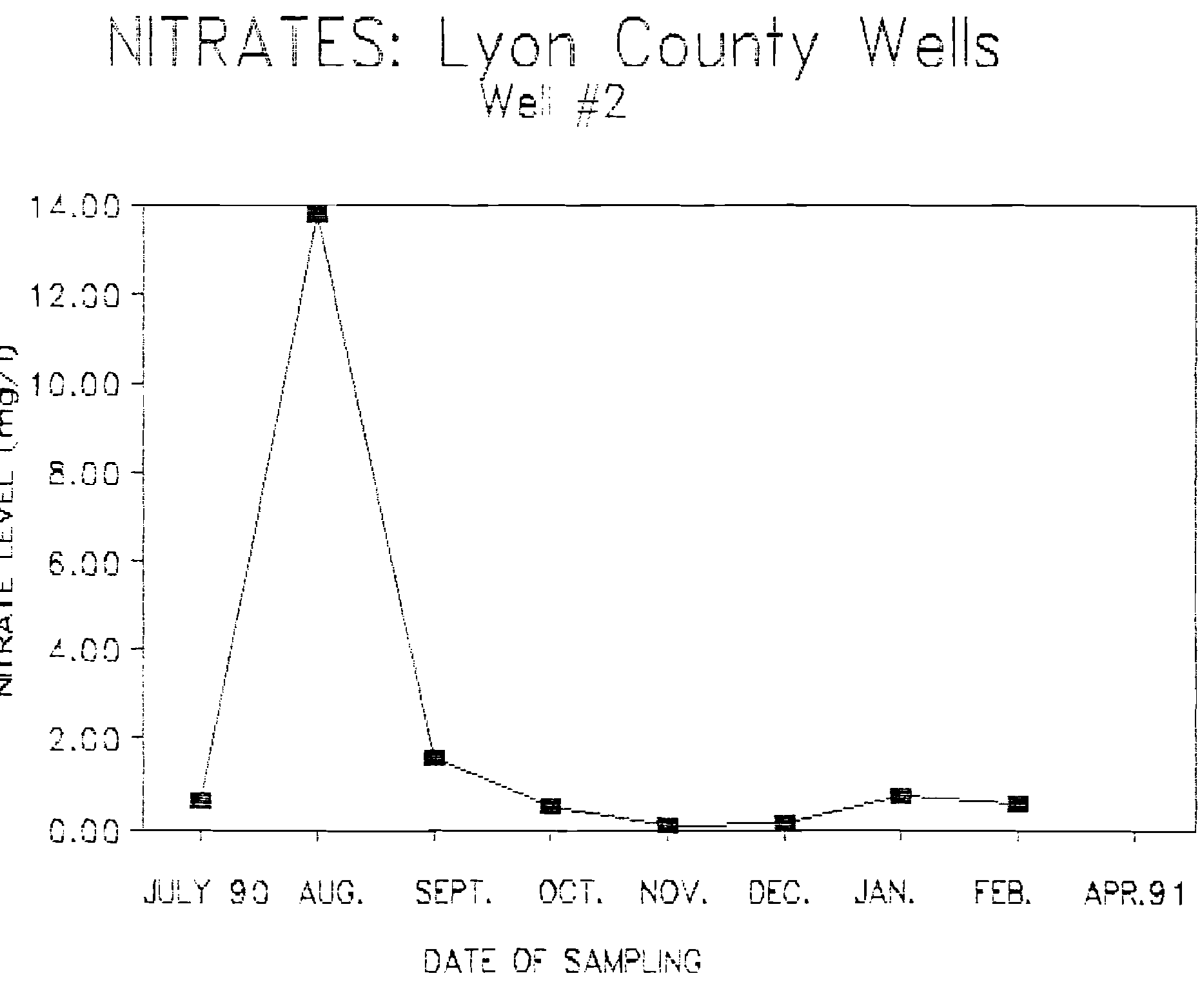

NITRATES: Lyon County Wells
Well #2
NITRATE LEVEL (mg/l)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 6.

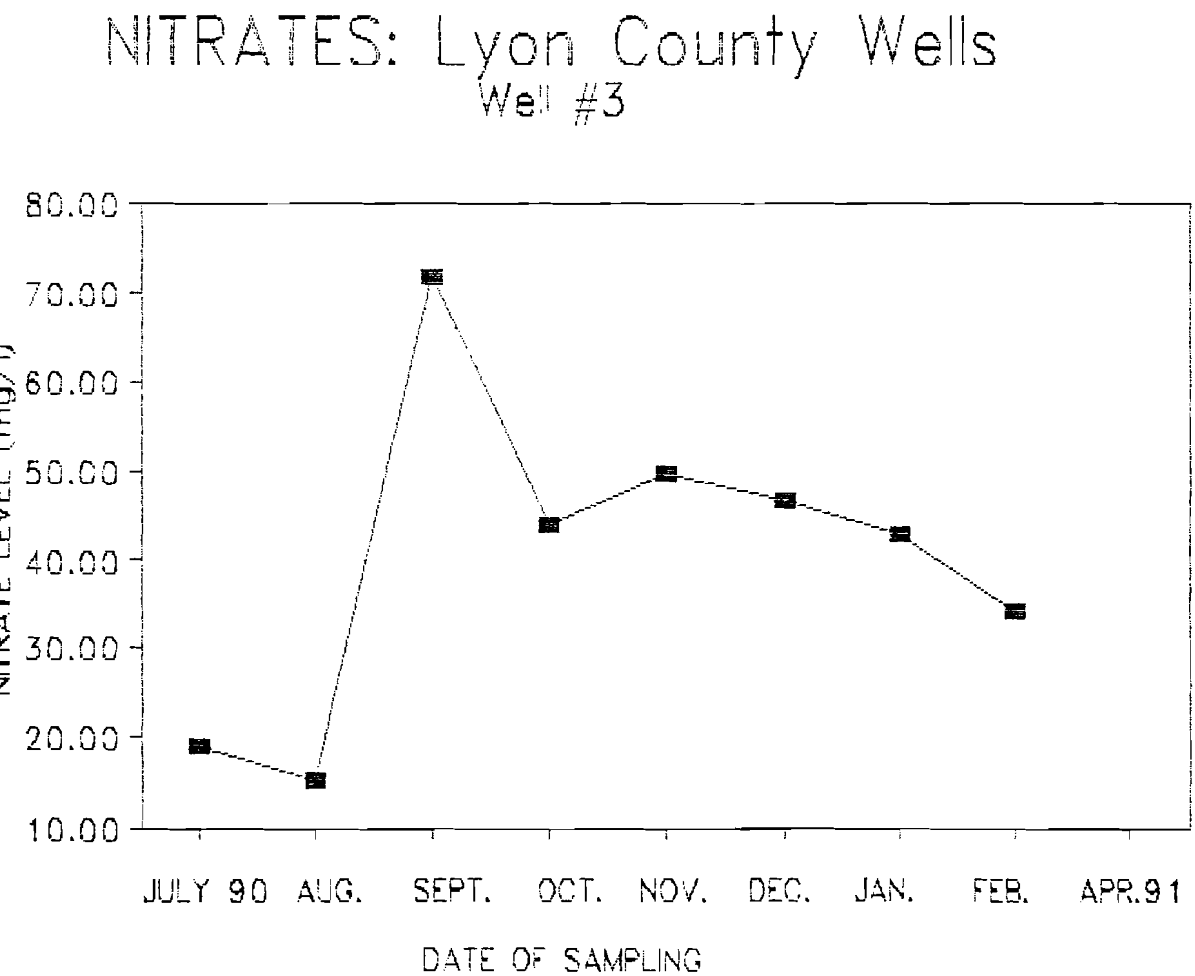

NITRATES: Lyon County Wells
Well #3
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 7.

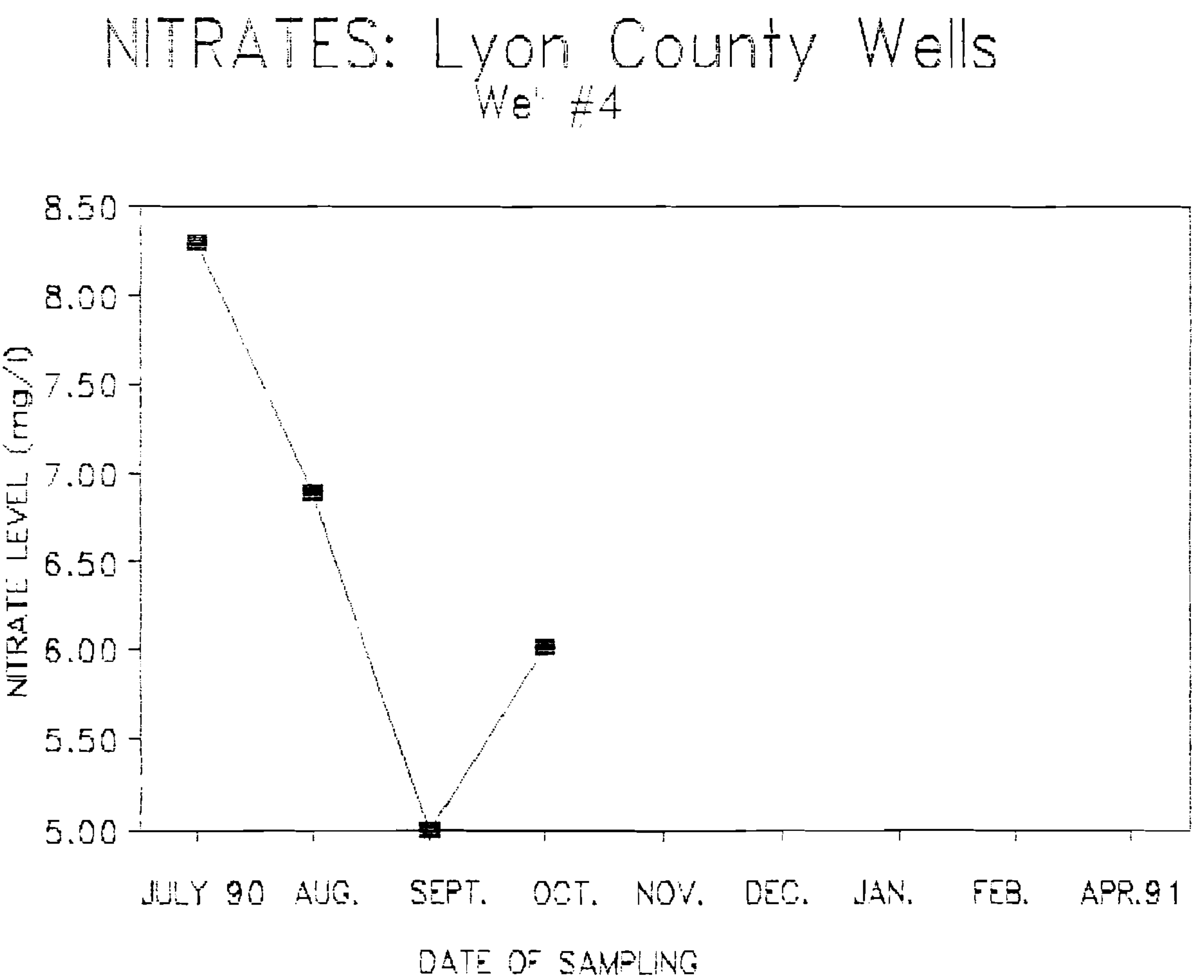

NITRATES: Lyon County Wells
We #4
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
NITRATE LEVEL (mg/l)
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 8.

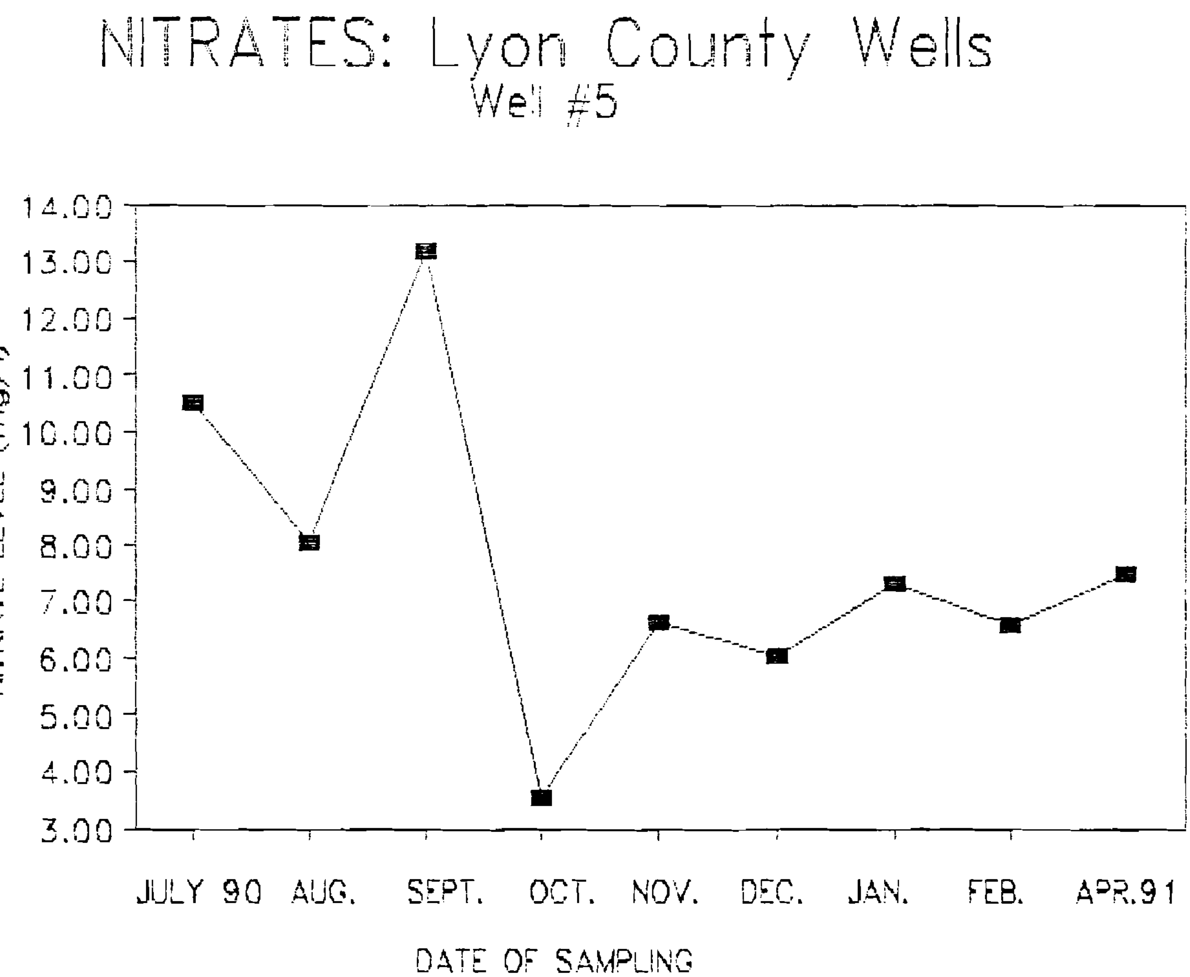

NITRATES: Lyon County Wells
Well #5
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 9.

decrease in October. The nitrate concentrations, of the remaining months, rose and fell repeatedly from October 1990 through April 1991.

Well 6 (Fig. 10) nitrate concentrations dropped slightly from August to September 1990 followed by sharp increase into November, which then stabilized through December and then decreased sharply through April 1991.

Well 7 (Fig. 11) nitrate concentrations dropped from July to September 1990 and then rose in November, followed by an overall decrease from December 1990 through April 1991.

Well 8 (Fig. 12) nitrate concentrations for August and October 1990 are not known because samples were not collected for these months. Dotted lines show a decrease in nitrate level for September followed by an increase in November 1990. After November, nitrate concentrations dropped steadily through February 1991 and then rise slightly in April.

Well 9 (Fig. 13) nitrate concentrations fell and rose repeatedly between July 1990 and April 1991, with an overall decrease during this time period.

Well 10 (Fig. 14) nitrate concentrations rose sharply in August and then fell sharply in September 1990 followed by a gradual decrease through December. Nitrate concentrations increased slightly in January and then decreased through April 1991.

Well 11 (Fig. 15) nitrate concentrations fell slightly from July to August 1990, then rose sharply in September and continued to rise until December 1990, which was followed by a gradual decrease through April 1991.

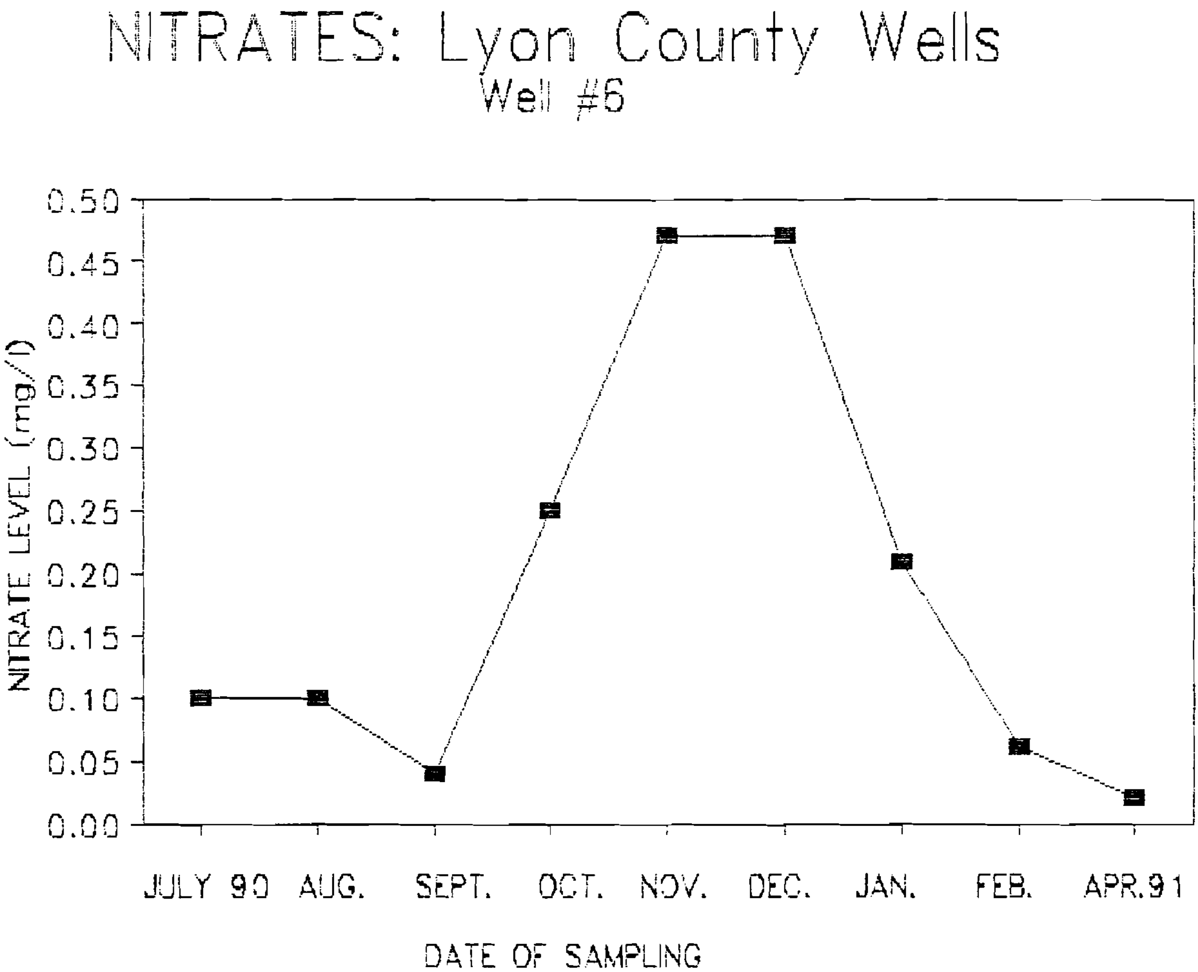

NITRATES: Lyon County Wells
Well #6
NITRATE LEVEL (mg/l)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 10.

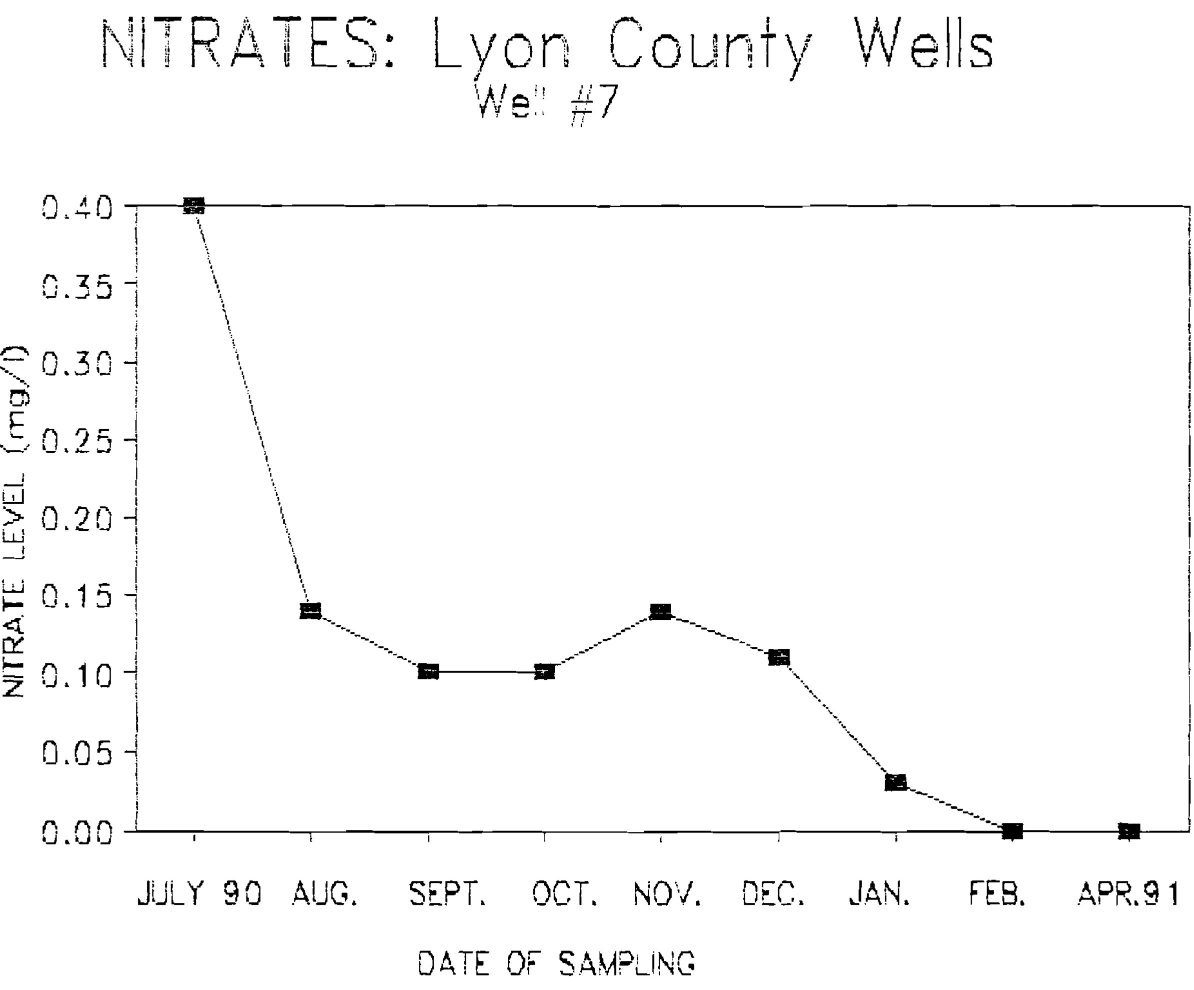

NITRATES: Lyon County Wells
Well #7
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
NITRATE LEVEL (mg/l)
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 11.

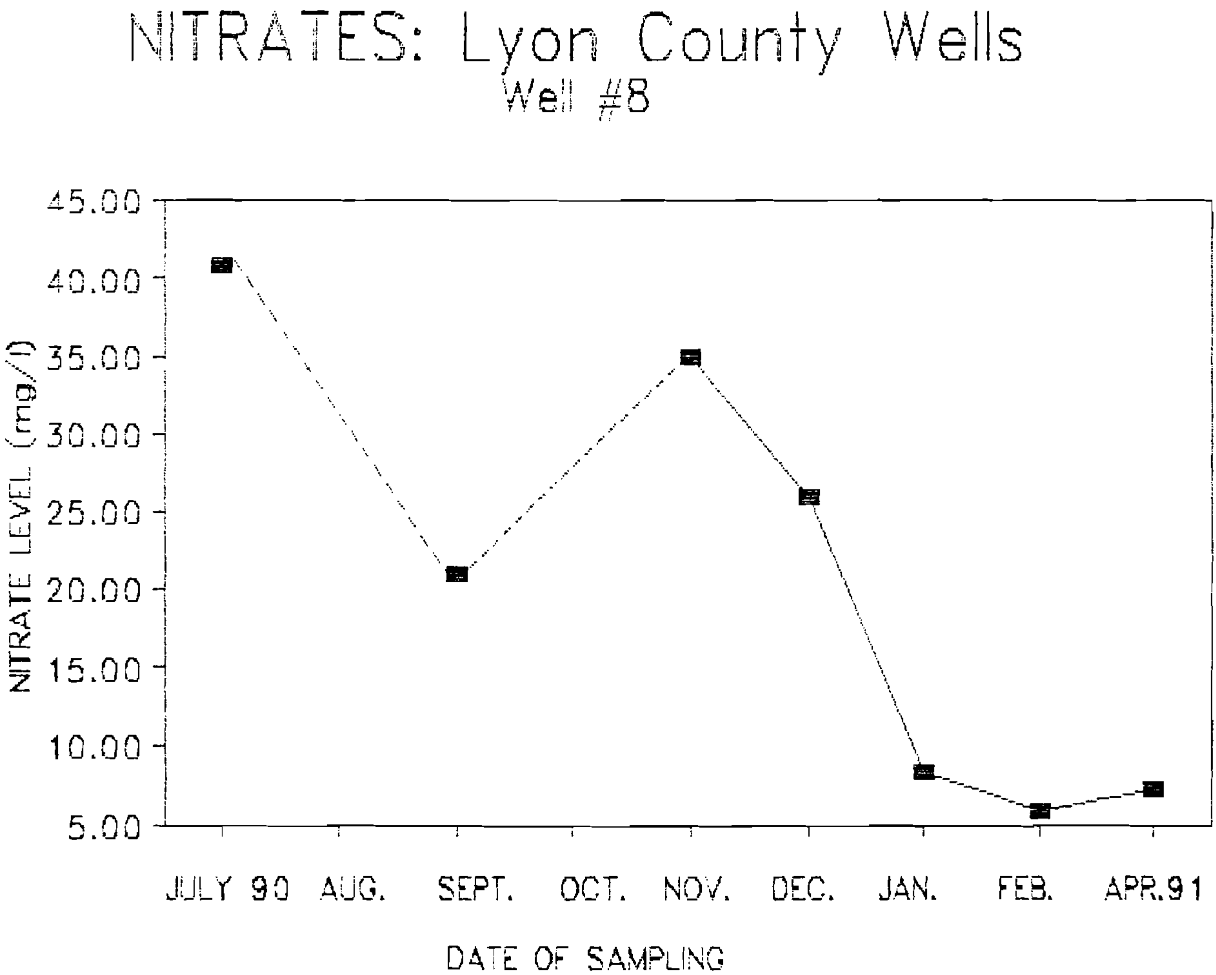

NITRATES: Lyon County Wells
Well #8
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
NITRATE LEVEL (mg/l)
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 12.

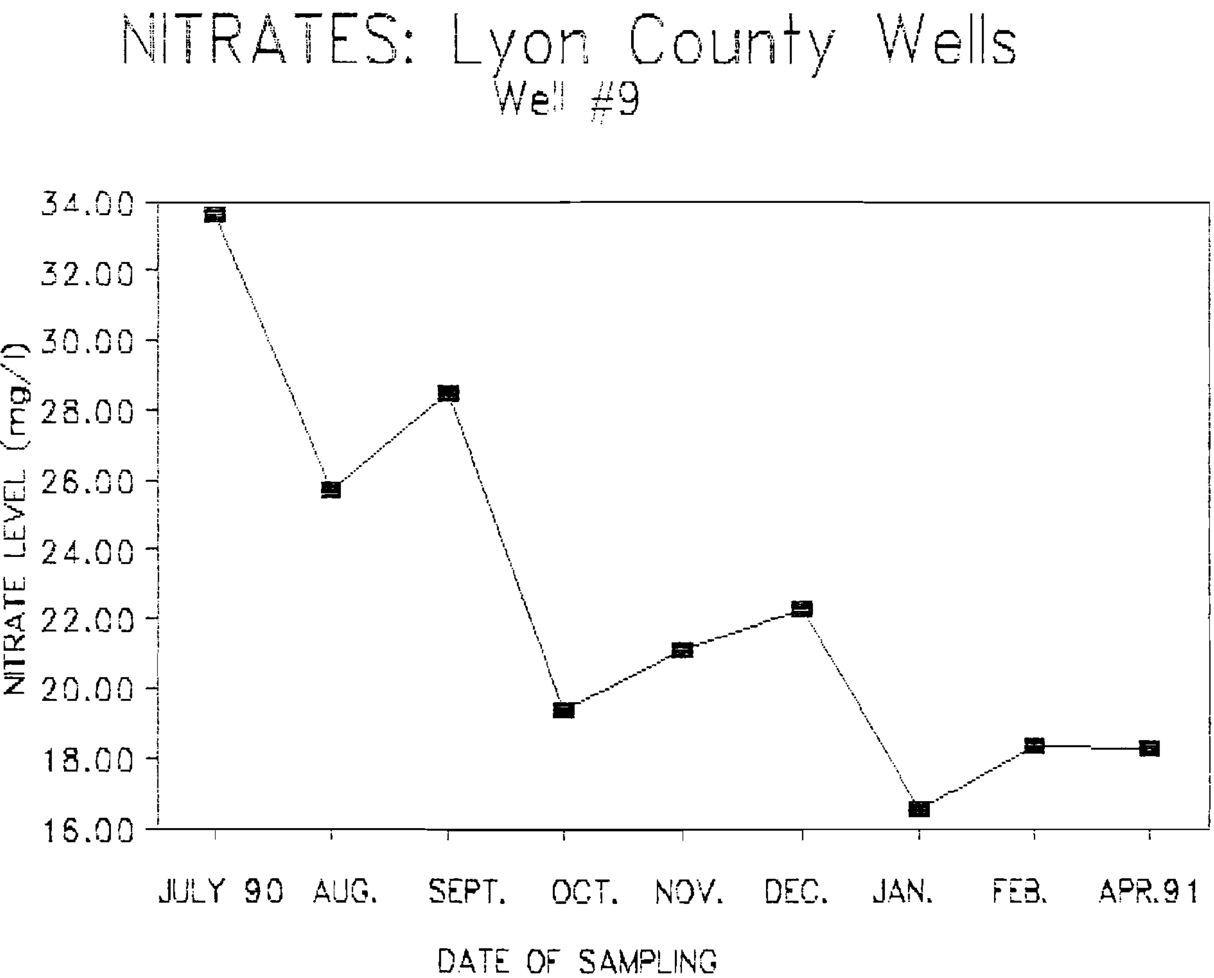

NITRATES: Lyon County Wells
Well #9
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
16.00
NITRATE LEVEL (mg/l)
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 13.

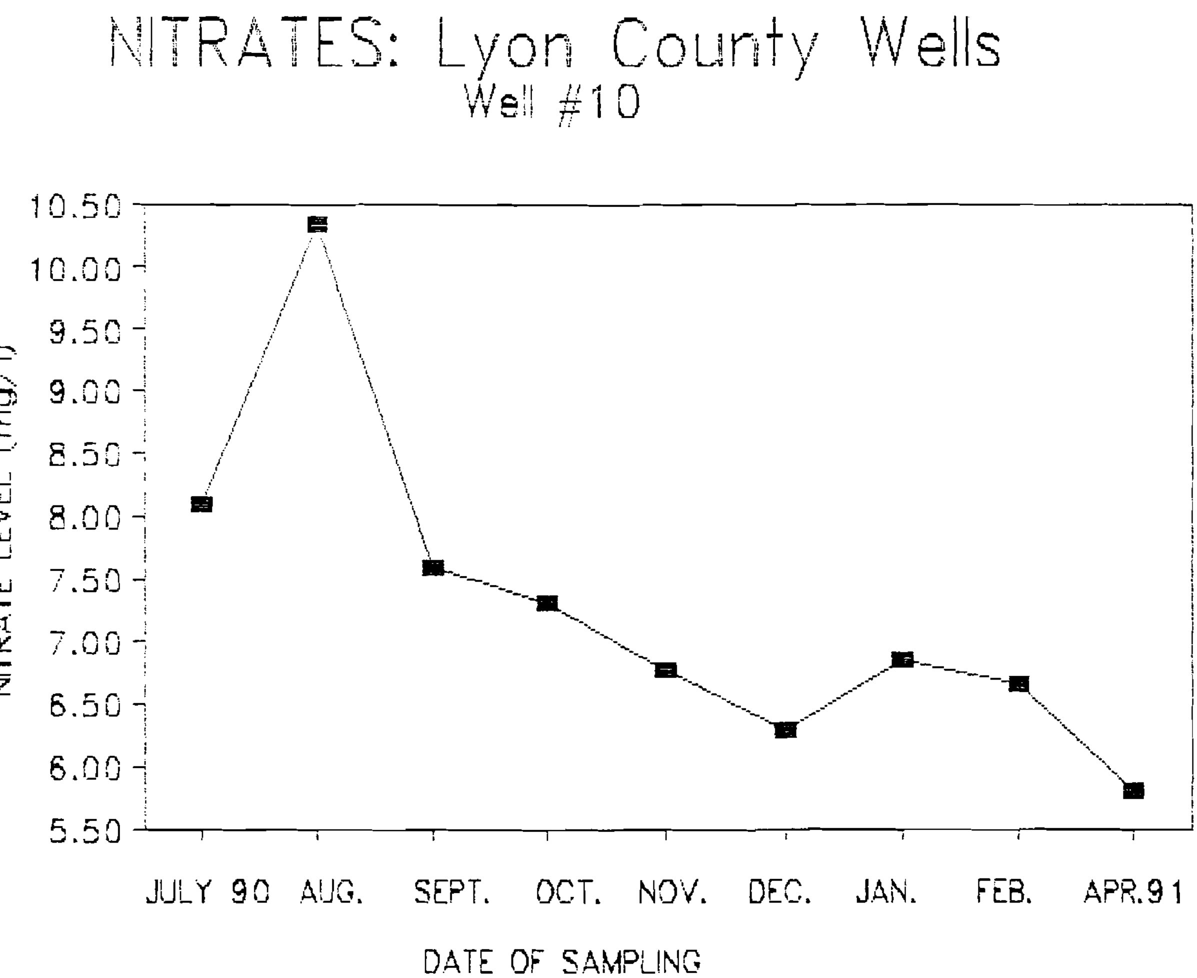
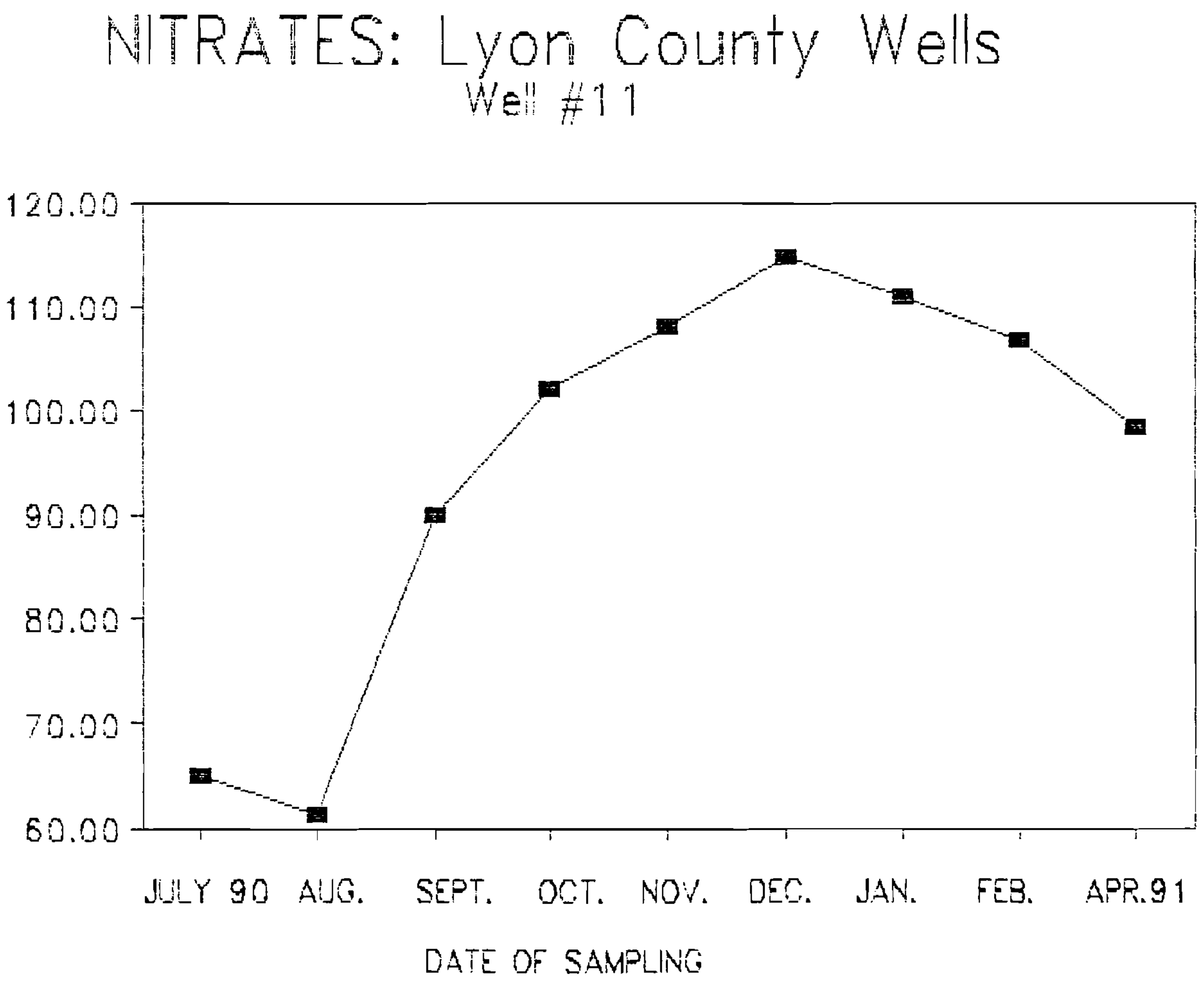

NITRATES: Lyon County Wells
Well #10
10.50
10.00
9.50
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

Figure 14.



NITRATES: Lyon County Wells
Well #11
120.00
110.00
100.00
90.00
80.00
70.00
60.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
DATE OF SAMPLING

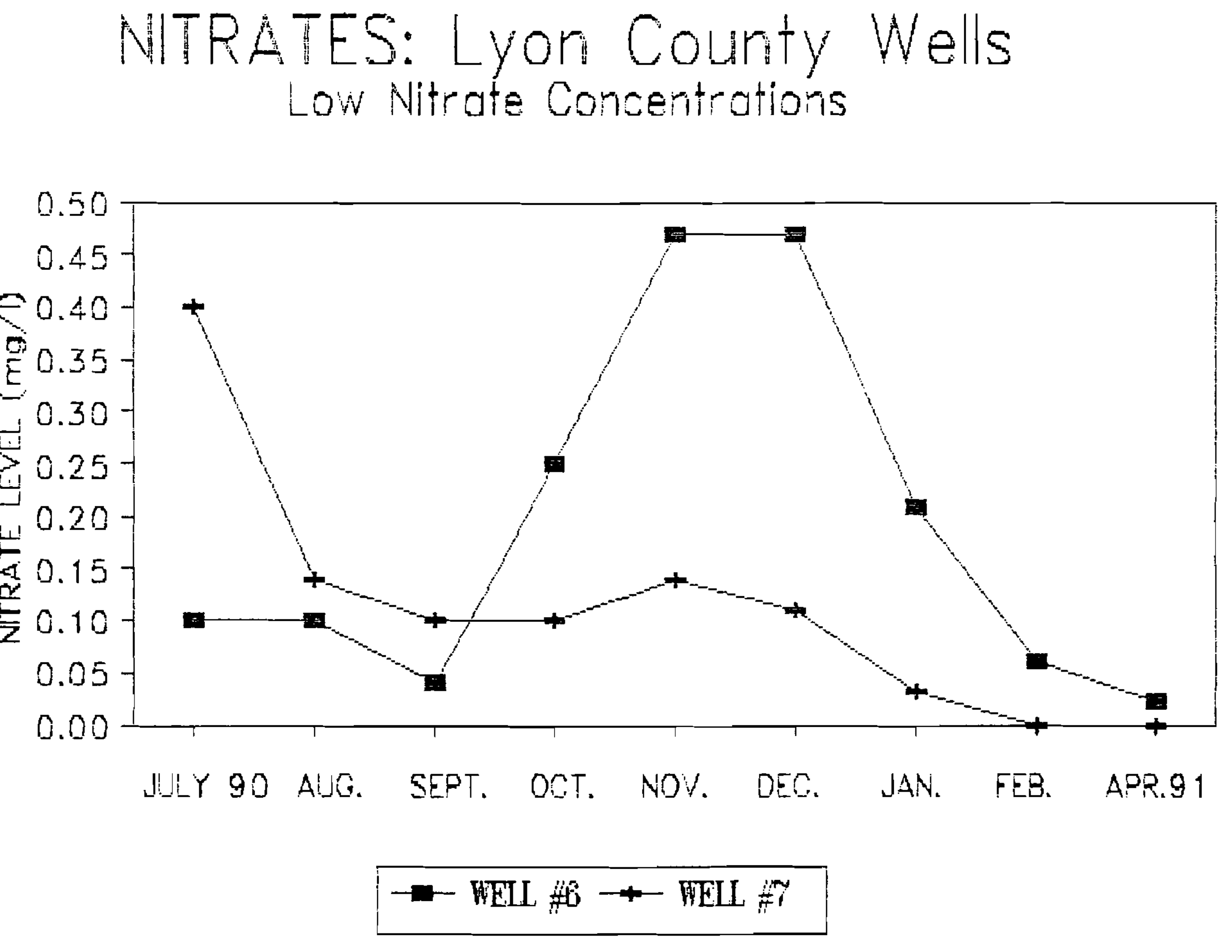
Figure 15.

Wells that have similar nitrate concentrations are classified into 4 categories: low-nitrate concentrations, medium-low nitrate concentrations, medium-nitrate concentrations, and high-nitrate concentrations. Graphs displaying each category have been constructed (Figs. 16 - 20) and wells with corresponding nitrate concentrations are plotted together.

Wells 6 and 7 are classified as low-nitrate concentration wells (Fig. 16). Wells 1, 2, 4, 5, and 10 are classified as medium-low nitrate concentration wells. Wells 1 and 5 are plotted together (Fig. 17) and wells 2, 4, and 10 are combined (Fig. 18) due to similar fluctuation trends, displayed in the graphs. Wells 8 and 9 are classified as medium-nitrate concentrations wells (Fig. 19). Wells 3 and 11 are classified as high-nitrate concentration wells (Fig. 20).

Chloride concentrations:

Chloride concentrations, for January and February 1991, were used to construct a graph of chloride vs nitrate concentrations (Fig. 21). Chloride concentrations, reported in mg/l, are plotted on the X-axis and nitrate concentrations on the Y-axis. Leakage from septic tanks was suspected as the cause of some of the high nitrate concentrations. Wells that are contaminated with septic waste can have concentrations high in chloride. Wells that are contaminated from fertilizers would be high in nitrates but low in chloride. Well 11 has the highest nitrate concentration as well as the highest chloride concentration, therefore contamination from a leaking septic tank could be suspected. Well 3 has a high nitrate concentration but a low chloride concentration. However, an overall trend between higher nitrate concentrations and corresponding high chloride concentrations is observed.



NITRATES: Lyon County Wells
Low Nitrate Concentrations
NITRATE LEVEL (mg/l)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
WELL #6
WELL #7

Figure 16.

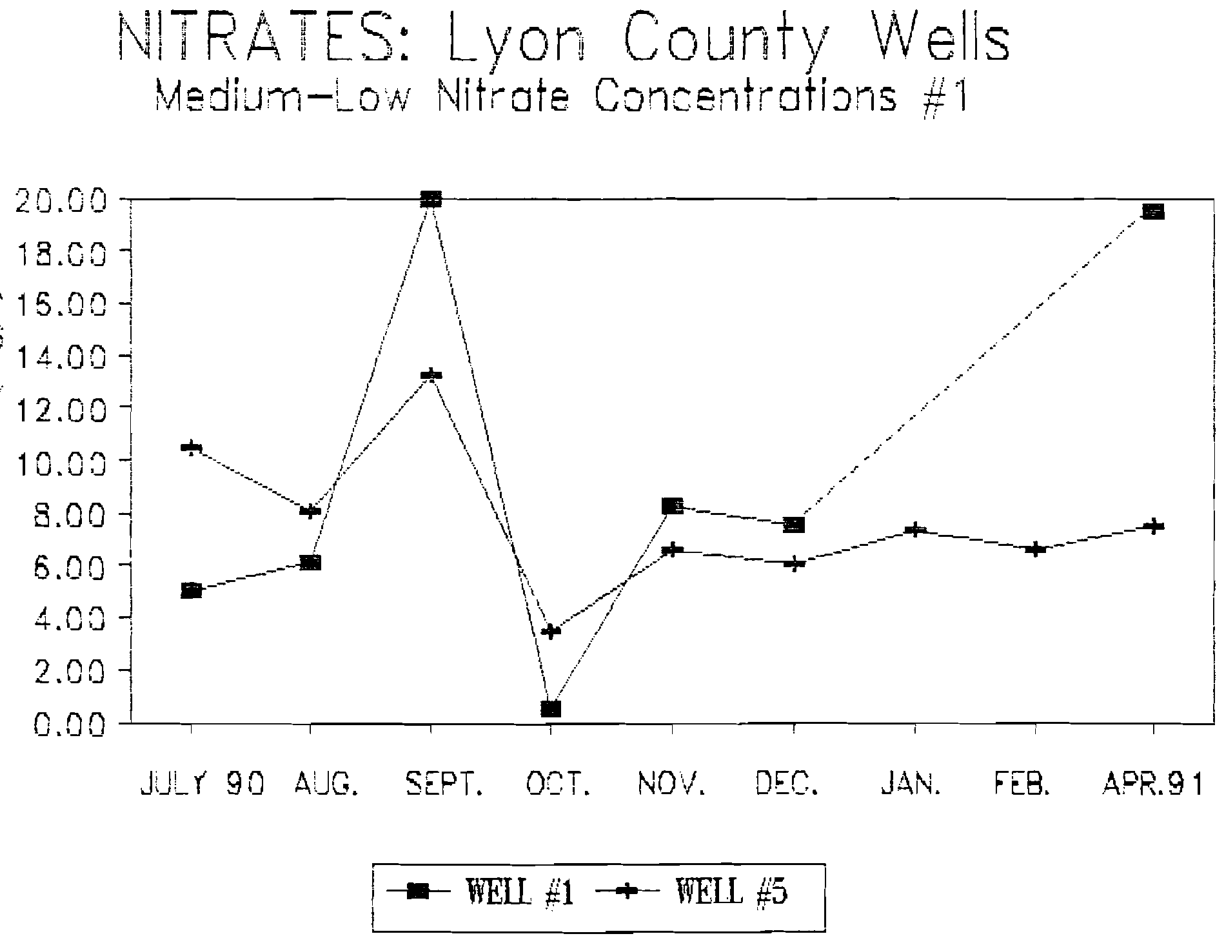

NITRATES: Lyon County Wells
Medium-Low Nitrate Concentrations #1
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
WELL #1
WELL #5

Figure 17.

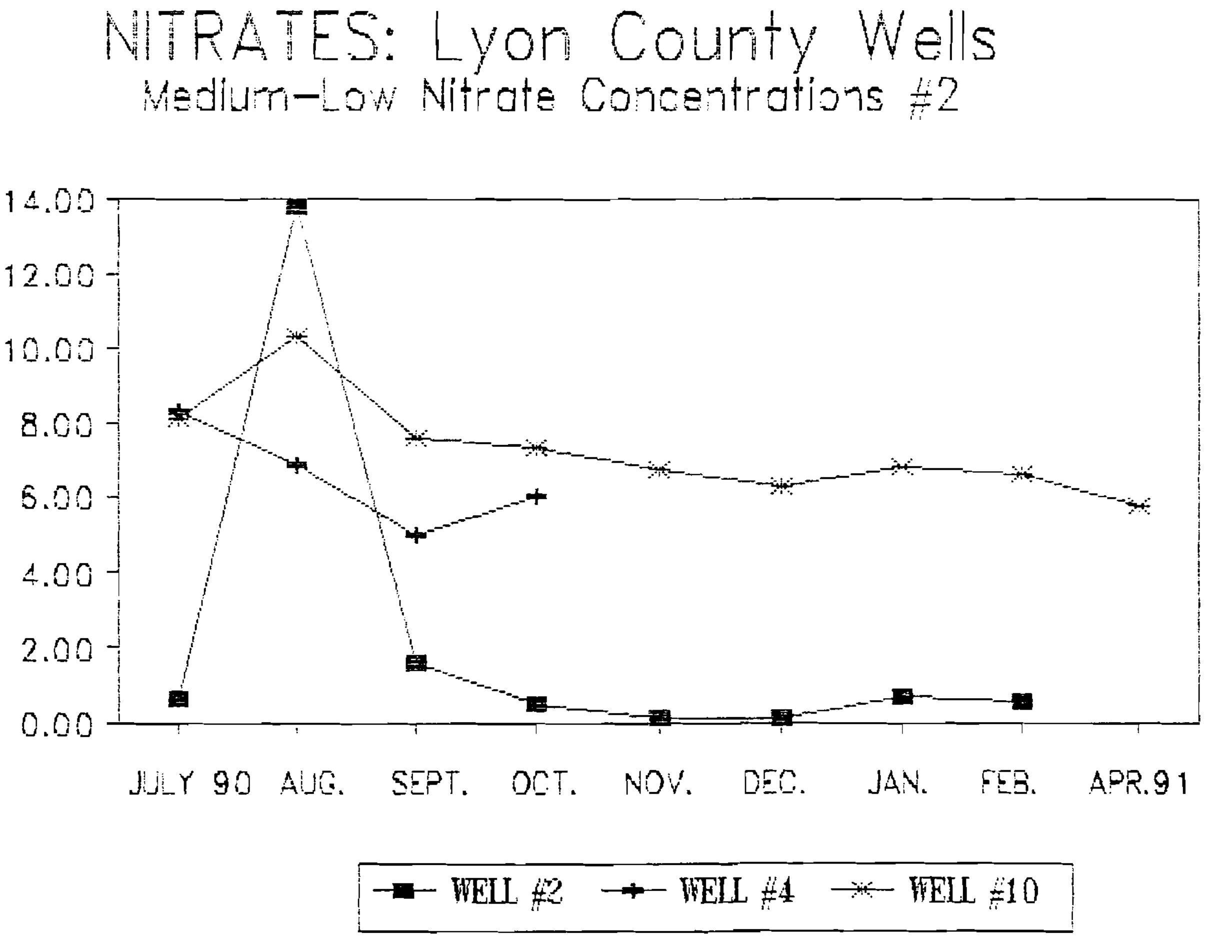

NITRATES: Lyon County Wells
Medium-Low Nitrate Concentrations #2
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
WELL #2
WELL #4
WELL #10

Figure 18.

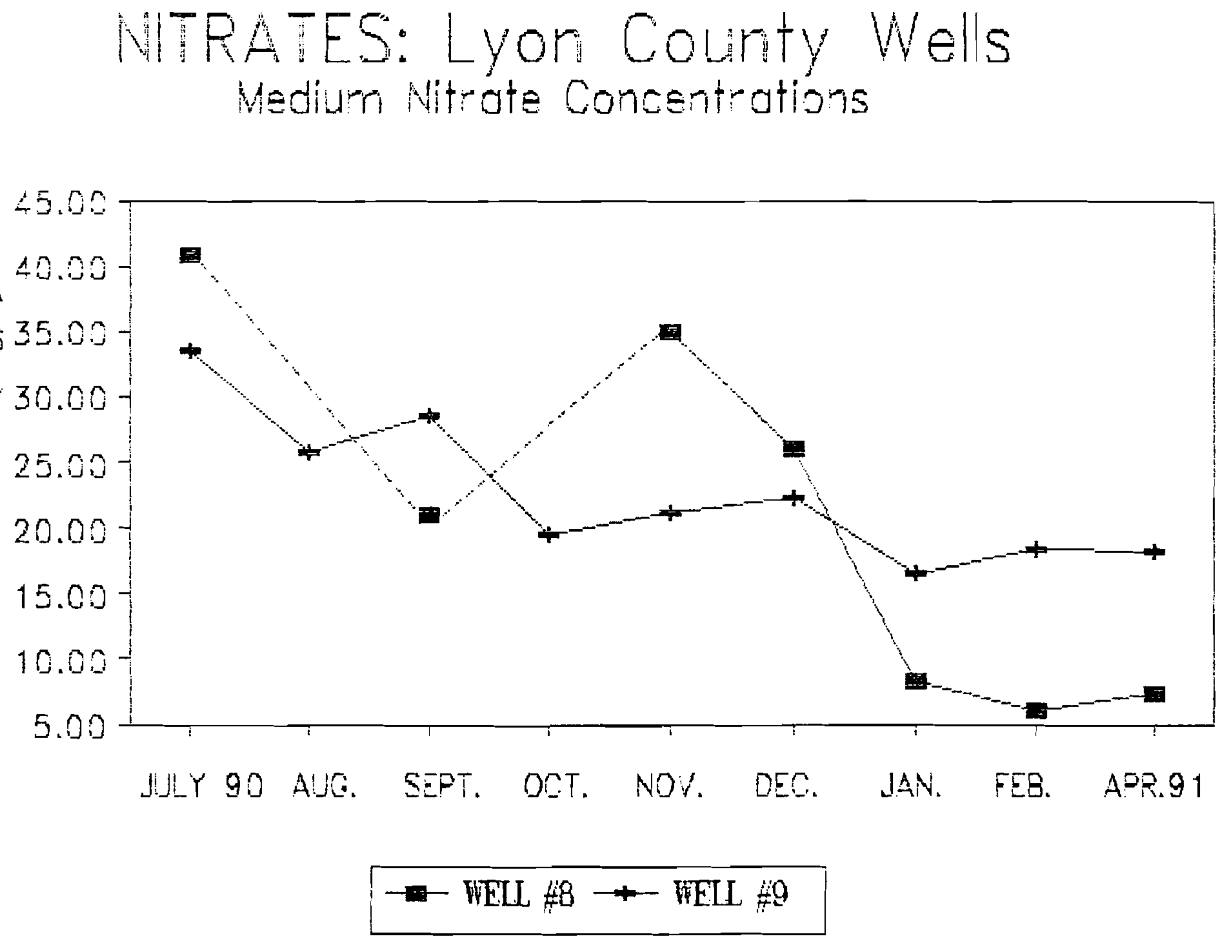

NITRATES: Lyon County Wells
Medium Nitrate Concentrations
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
WELL #8
WELL #9

Figure 19.

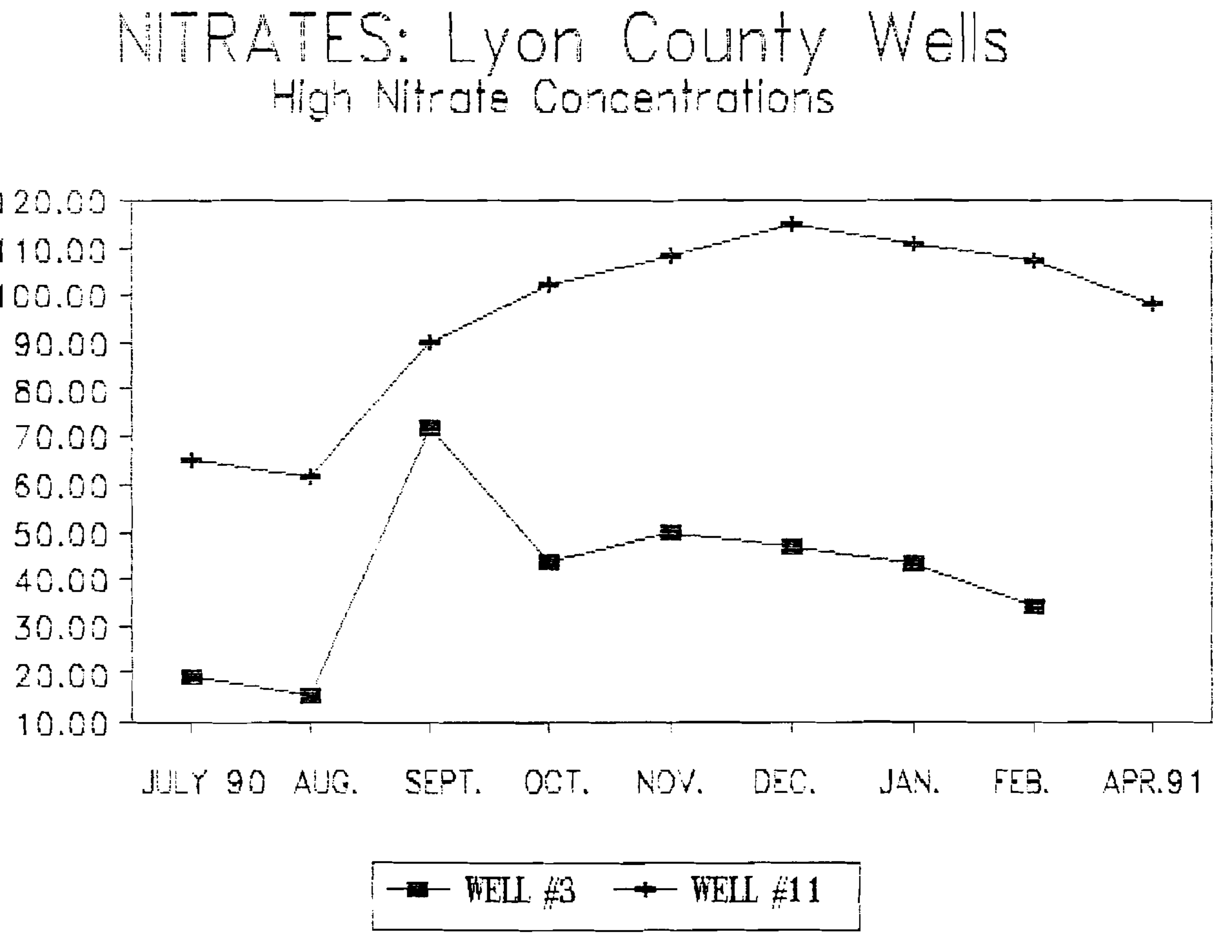

NITRATES: Lyon County Wells
High Nitrate Concentrations
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
JULY 90
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
APR.91
WELL #3
WELL #11

Figure 20.

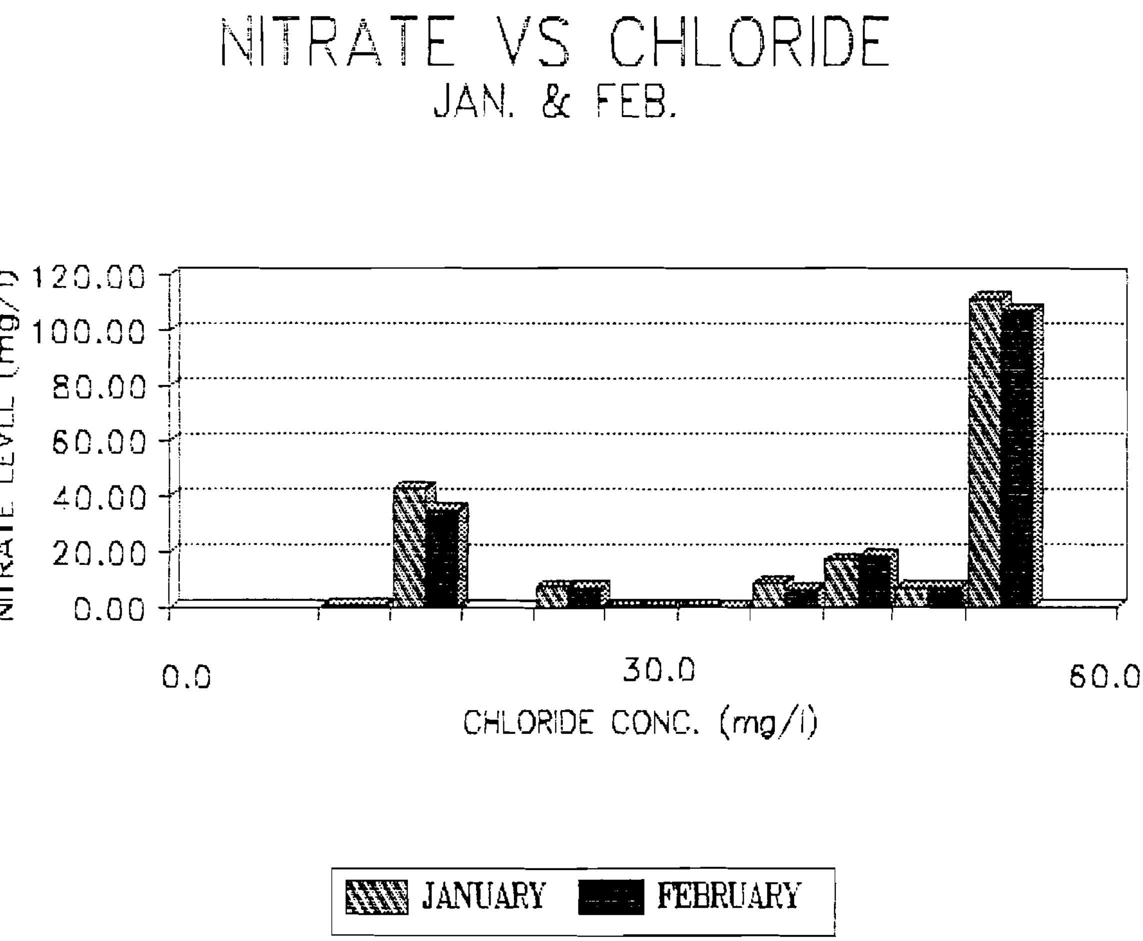
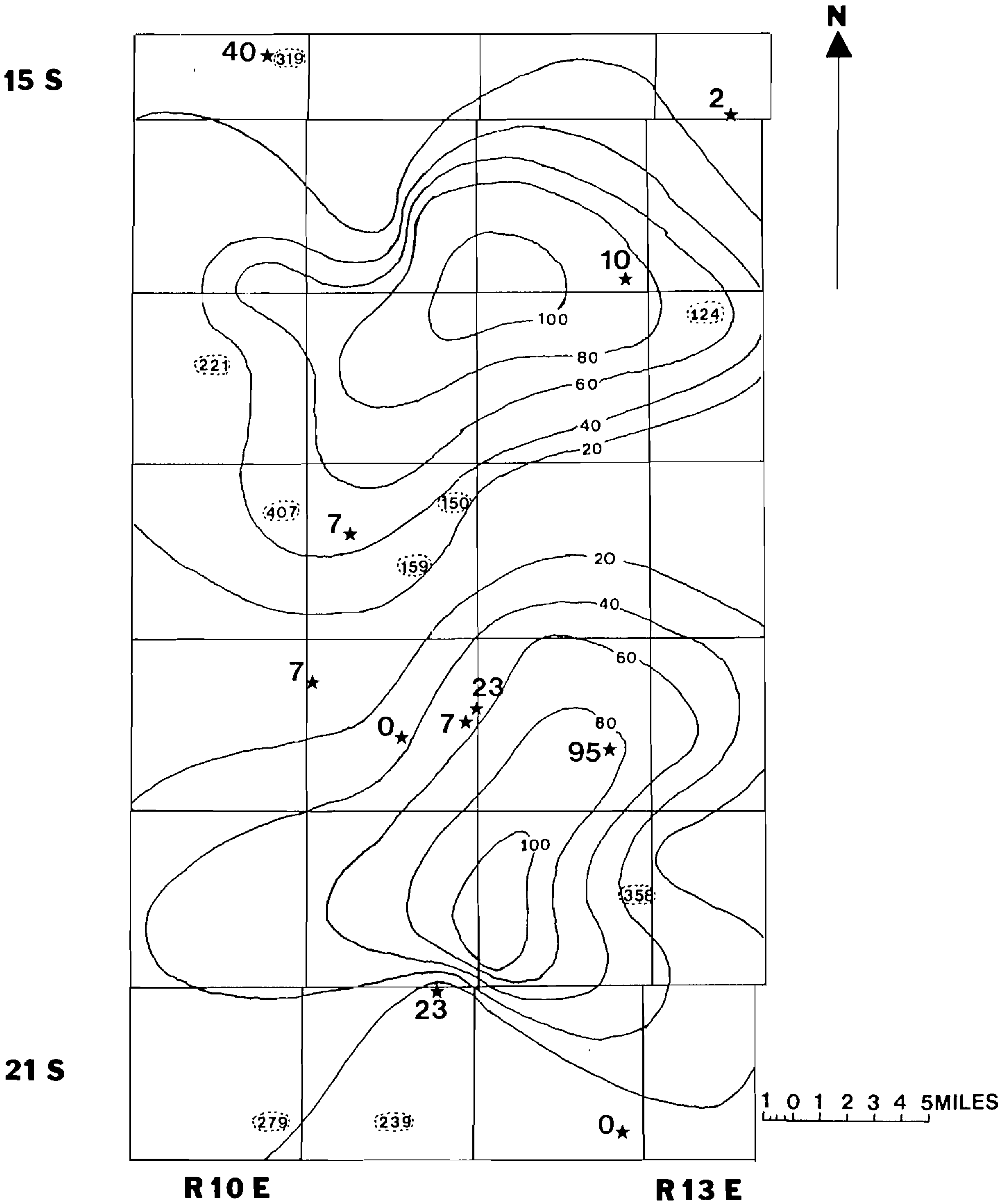

NITRATE VS CHLORIDE
JAN. & FEB.
NITRATE LEVEL (mg/l)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
30.0
60.0
CHLORIDE CONC. (mg/l)
JANUARY
FEBRUARY

Figure 21.

Previous nitrate studies:

Nitrate concentrations of 33 different wells (O'Connor 1953) were used to construct a contour map showing areas of high and low nitrate levels in Lyon County, Kansas (Fig. 22). The wells were plotted by location and corresponding levels of nitrate concentrations were joined together by contour lines, ranging from 0.0 to 100, with intervals of 20 mg/l. Wells with concentrations above 120 mg/l were treated as isolated cases of high nitrate levels and were not used to construct contour lines, but instead were plotted by location and circled with dotted lines. Average nitrate values from each of the 11 wells, of this study, were plotted by location and displayed next to the corresponding star. Some of the 11 well averages plotted, fall within or near the corresponding areas of concentration contours, however, others do not correspond.

Nitrate concentrations from these same 11 wells analyzed from June 1988 through February 1989 are listed in Table 5 (modified from Thompson 1990). Individual well averages and monthly nitrate averages were calculated for this data set. Thompson's nitrate concentration values for August, October, and December, 1988 plus February, 1989, were compared to the corresponding months of this 1990 - 1991 study (Table 6). Individual well averages from Thompson and this study are plotted in Fig. 23. Thompson's values were higher than the values of this study, with the exception of wells 3, 8, and 10. Monthly nitrate averages from both studies are plotted and compared in Fig. 24. Although Thompsons' values were consistently higher, comparable trends of rising nitrate concentrations from August to December, followed by parallel falling levels in February were observed.



★ Well Average Nitrate Concentration (July 1990 - April 1991)

Local High Nitrate Well (from O'Connor 1953)

Figure 22. Areas of Nitrate Concentration in Lyon County (based on O'Connor 1953)

Table 5. Well Collection Data for Lyon County: Thompson

WELL #	JUNE 88 SAMPLE 1	AUG. 88 SAMPLE 2	OCT. 88 SAMPLE 3	DEC. 88 SAMPLE 4	FEB.89 SAMPLE5	AVG.
1	17.80	12.40	15.80	15.00	14.20	15.04
2	13.30	3.60	0.30	0.20	0.70	3.62
3	52.30	32.30	29.20	23.00	19.80	31.32
4	7.40		7.30	8.80	8.80	8.08
5	14.20	9.90	0.90	10.00	7.60	8.52
6	0.60	0.80	0.10	0.50	0.10	0.42
7	0.10	0.10	0.20	0.10	0.10	0.12
8	44.70	4.70	3.20	3.50	2.40	11.70
9	34.80	30.00	7.30	25.90	24.40	24.48
10	10.70	6.60	4.80	6.20	5.00	6.66
11	141.70	63.20	137.50	150.00	114.30	121.34
MONTHLY AVERAGE	30.69	15.54	18.78	22.11	17.95	21.03
DEPARTURE FROM AVG.	9.66	-5.49	-2.25	1.08	-3.08	0

-

Table 6. Thompson VS Jennings Data

PAUL THOMPSON DATA

WELL #	AUG. 88 SAMPLE 2	OCT. 88 SAMPLE 3	DEC. 88 SAMPLE 4	FEB.89 SAMPLES	AVG.
1	12.40	15.80	15.00	14.20	11.68
2	3.60	0.30	0.20	0.70	1.36
3	32.30	29.20	23.00	19.80	21.46
4		7.30	8.80	8.80	8.08
5	9.90	0.90	10.00	7.60	6.68
6	0.80	0.10	0.50	0.10	1.50
7	0.10	0.20	0.10	0.10	1.50
8	4.70	3.20	3.50	2.40	4.36
9	30.00	7.30	25.90	24.40	19.32
10	6.60	4.80	6.20	5.00	6.52
11	63.20	137.50	150.00	114.30	95.20
MONTHLY AVERAGE	15.54	18.76	22.11	17.95	21.03
DEPARTURE FROM AVG.	-5.49	-2.25	1.08	-3.08	0

MICHAEL JENNINGS DATA

WELL #	AUG. 90 SAMPLE 2	OCT.90 SAMPLE 4	DEC. 90 SAMPLE 6	FEB.91 SAMPLE 8	AVG.
1	6.10	0.49	7.49		9.54
2	13.79	0.47	0.11	0.54	2.23
3	15.17	43.90	46.67	34.09	40.42
4	6.88	6.02			6.55
5	8.04	3.50	6.06	6.58	7.70
6	0.10	0.25	0.47	0.06	0.19
7	0.14	0.10	0.11	0.00	0.11
8			25.94	5.86	20.58
9	25.71	19.40	22.26	18.35	22.63
10	10.34	7.30	6.27	6.65	7.29
11	61.25	102.00	114.79	106.84	95.25
MONTHLY AVERAGE	13.41	16.68	20.92	16.27	17.95
DEPARTURE FROM AVG.	-4.54	-1.27	2.97	-1.68	0

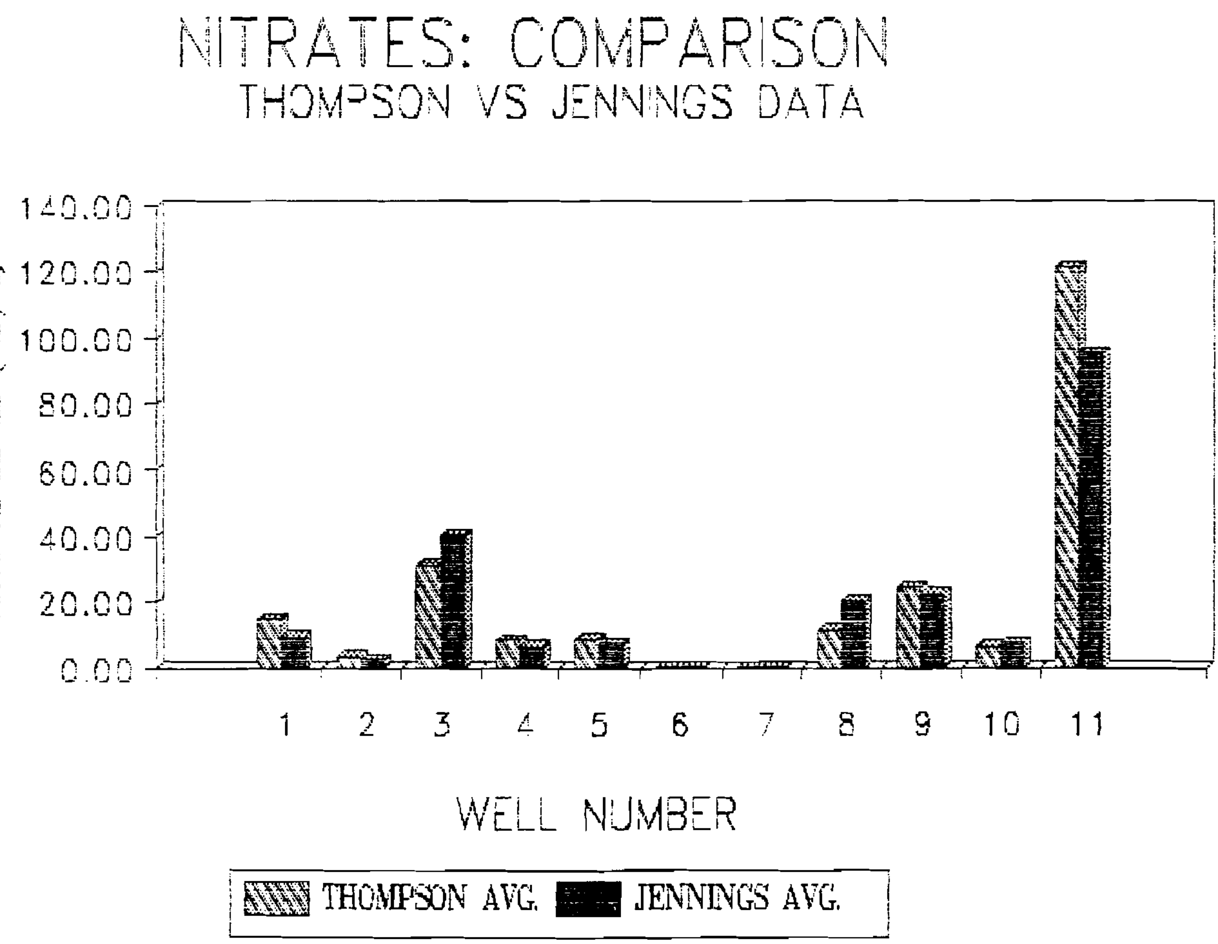

NITRATES: COMPARISON
THOMPSON VS JENNINGS DATA
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1
2
3
4
5
6
7
8
9
10
11
WELL NUMBER
THOMPSON AVG.
JENNINGS AVG.

Figure 23.

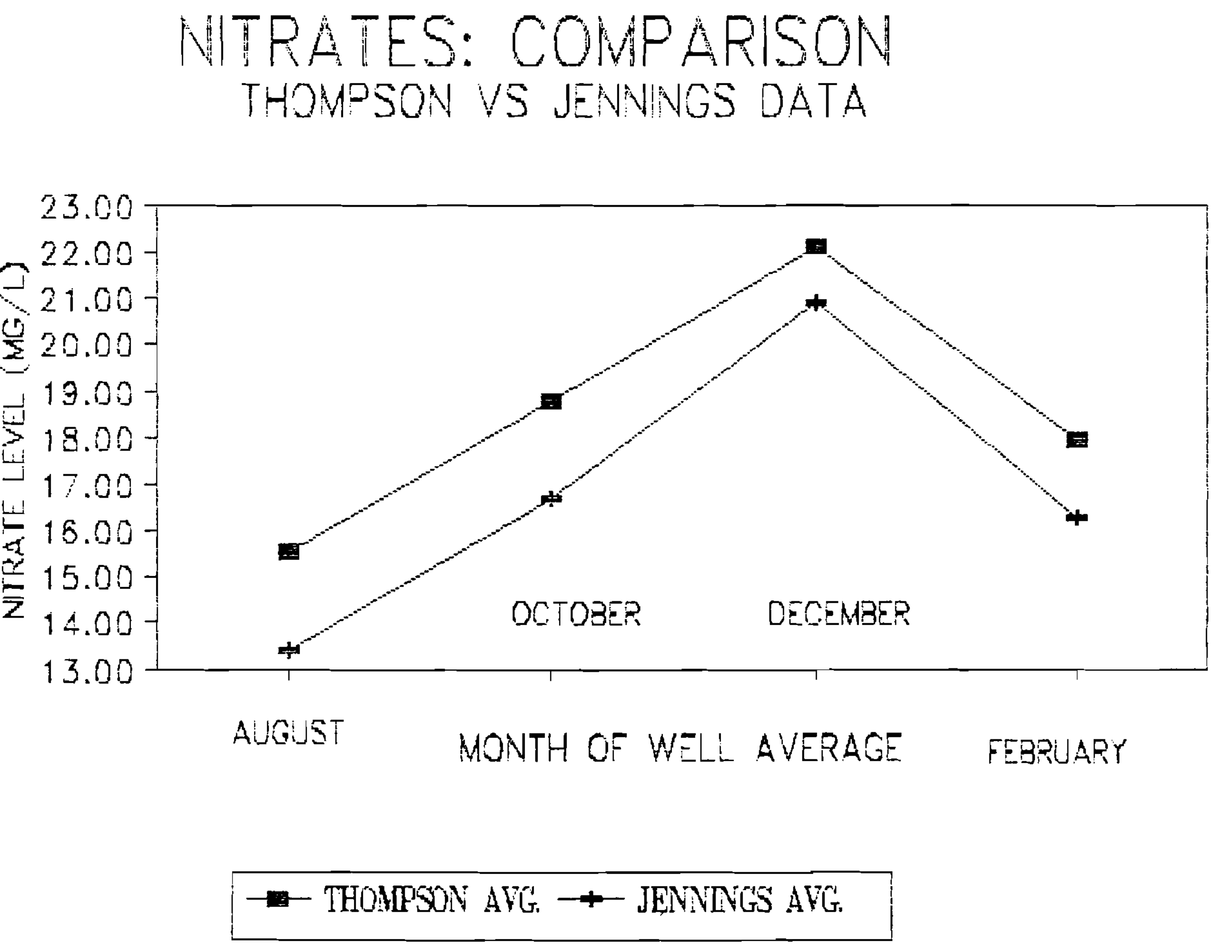

NITRATES: COMPARISON
THOMPSON VS JENNINGS DATA
NITRATE LEVEL (MG/L)
23.00
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
AUGUST
OCTOBER
DECEMBER
FEBRUARY
MONTH OF WELL AVERAGE
THOMPSON AVG.
JENNINGS AVG.

Figure 24.

CHAPTER 5: Interpretation

Weather conditions:

This study was conducted following periods of heavy precipitation in May and June, 1990, which were 5.3 and 3.4 inches above normal respectively. Precipitation amounts from June 1, 1990 to April 21, 1991 (Table 3) varied only slightly from the norm for individual months (Aiken et al.1990). July, September, October, and December of 1990, plus February and March of 1991 were below normal. June 1990 was 3.4 inches above normal, and August and November 1990 were only slightly above normal. However, precipitation totals for this period were very close to normal Kansas average precipitation amounts. Thompson sampled these same wells during a period of extended drought which could account for some variation in our reported nitrate levels. Temperature and snowfall were also close to normal Kansas weather conditions so this period can be considered to be typical for central Kansas.

Seasonal effects:

The nitrate concentrations from all the wells, except 1, 2 and 10, decreased from July to August of 1990. A period of heavy precipitation in May and June preceded this decline in nitrate levels. Nitrate pollution from surface run-off would tend to increase concentrations, however since nitrate levels dropped, dilution from excessive precipitation is likely to have occurred in most of the wells. Wells 1, 2 and 10 are surrounded by farmland, so surface run-off containing nitrogen is suspected to have increased nitrate levels. Possible dilution effects from rainfall also show up as a decline in nitrate concentrations from February to April of 1991, excluding wells 1, 5 and 8, which are surrounded by cropland which may have had surface run-off containing nitrogen from fertilizers.

Several of the wells show an increase in nitrate concentration followed by a decrease, during the late fall months, peaking in October or December, especially wells 3, 11 and 6, 7 (Fig. 16 and 20 respectively). The decreasing temperature may have slowed down nitrogen-fixing bacteria allowing damp soils to lose nitrogen, during the fall and winter months, because of leaching which could cause an increase in nitrates levels in the wells. The following decrease in nitrate concentration may correlate to a decline in leaching due to the small amount of rainfall from January to March of 1991. Other seasonal trends are not as obvious so any other fluctuations must be explained by either site differences or geologic settings.

Site differences:

Nitrate concentration fluctuations varied notably from site to site, and some wells also varied greatly from month to month. Wells 6 and 7 consistently recorded low nitrate concentrations, during this study, and display similar fluctuation curves for nitrate levels (Fig. 16). Although both wells display similar nitrate patterns, wells 6 and 7 have very different geologic and agricultural settings (Appendix 1). Well 6 is located in the middle of a fertilized field and high nitrate levels would be expected. The well samples were all very high in iron content, which may reduce nitrates to nitrogen gas resulting in very low nitrate concentrations. Well 6 is located in a topographic low, surrounded by steep slopes to the south and east, with a small creek, that is normally dry most of the year, running next to the well. The surrounding area is grassland with trees on the slopes with no farming in this drainage system. Lack of nitrogen introduced into this area, from fertilizers used for farming, makes this an ideal control well for low nitrate concentrations and explains the low nitrate levels.

Wells 1, 5 and 2, 4, 10 (Figs. 17 and 18 respectively) are classified as medium-low nitrate concentration wells. Nitrate concentrations range from 0.47 to 20.0 mg/l for these wells. Wells 1 and 5 display very similar fluctuation trends for changing nitrate concentrations and both are surrounded by nearby croplands, but have very different geologic settings. The peak in concentrations, for September samples, corresponds to the increased precipitation in August, which may have washed leached nitrogen into the local aquifers. Decreasing rainfall, in September, may then explain the drop from September to October but the following increase does not seem to follow this explanation as rainfall in October was low. Well 1 went dry in December so no samples were collected in January and February of 1991.

Wells 2 and 10 (Fig. 18) also display very similar fluctuation trends and both are surrounded by croplands, but have different geologic settings. Nitration Concentrations in both wells peaked in August followed by a gradual decline until a small increase occurred in January. The peak in August is suspected to be a lag time effect from leached nitrogen from spring fertilization of crops that slowly entered the water table. The following decline in nitrate concentrations could be from decreasing precipitation amounts during the winter months. No samples were taken from well 4 after October of 1990, for the convenience of the owner, so any trends are not available for analysis.

Wells 8 and 9 (Fig. 19) are classified as medium nitrate concentrations wells with 5 to 41 mg/l nitrogen reported as N. Both wells display fluctuation of nitrate concentrations, but rise and fall at different times. However, both display an overall decrease from July 1990 to April 1991. Both wells are located near active farmland, and also both are located on Quaternary age Wiggwam Terrace Deposits. Similar geologic and agricultural settings could explain comparable nitrate trends with site differences responsible for individual fluctuations. The higher nitrate concentrations, early in this study, must correlate to leached nitrogen from spring fertilization of crops followed by a dilution effect over time from continuing precipitation.

Wells 3 and 11 (Fig. 21) are classified as high nitrate concentration wells with 15 to 120 mg/l nitrogen reported as N. Both wells are surrounded by croplands but have different geologic settings. Fluctuation curves for both wells are very similar, excluding September concentration for well 3, which is suspected to have experimental error. Small amounts of rainfall in July could explain the drop in nitrate concentrations from July to August, and increasing rainfall in the autumn would then cause the gradual increase into the winter months. Another explanation could be the decreasing temperature, which slowed nitrogen-fixation by bacteria and allowed nitrogen to be leached into the ground from precipitation.

Chloride correlation:

Samples taken in January and February of 1991 were analyzed for chloride concentrations and plotted against nitrate levels (Fig. 21). Wells with very high nitrate concentrations, such as well 11, were suspected of contamination from leaking septic tanks. It was thought that wells contaminated from septic tank leakage would also be high in chloride. Wells that have been polluted from fertilizer contaminants are high in nitrates but low in chloride . Well 11 is very high in both nitrate and chloride concentrations, therefore septic tank contamination is suspected. A problem with chlorides is that some of the well owners dump chlorox bleach in their wells, on a regular basis, to kill any pathogens that may exist in the well water. Therefore, it is difficult to tell chloride that is purposely induced, from chloride that has entered the well from nearby septic tanks. Well 11 displays the highest concentrations for both nitrate and chloride, but the owner dumps chlorox into the well, at least once a month, which probably accounts for the high chloride concentration.

Previous study correlations:

Comparing resulting nitrate concentrations with the concentrations from O'Connor (1953) showed that several of the 11 wells studied fell within or near constructed areas of corresponding concentration (Fig. 22). However, wells 1, 3, 4 and 10 did not fall in or near suspected zones of concentration. Well 3 corresponds to a local high nitrate spot that has been treated as an isolated case. Since only 33 wells were available to construct this map, actual zones of concentration may have been quite different if more data were available. The accuracy of nitrate concentration values from O'Connor are suspected of experimental error, as several of the values are extremely high compared to more recent studies. However, the correlations between 1953 data and recent values are quite interesting. The isolated well values show that nitrate concentrations can vary greatly from different wells of close proximity, perhaps even sharing the same aquifer system.

Comparing the wells studied from the period of July, 1990 through April, 1991 with the results of Thompson's (1990) study from August, 1988 to February, 1989 reveals some interesting correlations (Table 6, Fig. 23). He sampled once every two months compared to once a month in this study, so only four months were available for correlation. The reported values for individual well averages were very similar, although his values were slightly higher overall than concentrations calculated in this study.

Plotted monthly averages for the total nitrate concentrations of all wells show parallel trends (Fig. 24). These trends seem compatible in graphical form but are incomplete. High nitrate averages for September and November 1990, which would change the shape of the graph considerably, cannot be compared to any existing data from 1988. Incompleteness of data for correlation limits comparison of nitrate fluctuations between the two studies and illustrates the need for more frequent sampling.

Nitrate levels were higher in Thompson's sampling than in this study, but similar trends are noticed. Sharp increases after August in nitrate concentrations, which peaked in the winter months for well 11, were possibly caused by the increased rainfall during this study, which diluted leached nitrogen in the ground water. Recent concentrations for well 3 were consistently higher, which may be due to increased rainfall allowing farm animal feces and urine remains, high in nitrogen, to penetrate the soil more readily. Well 8 nitrate concentrations were also consistently higher in this study, which also could be attributed to the increased rainfall causing run-off of nitrogen fertilizers to become concentrated in the water table.

CHAPTER 6: SUMMARY AND CONCLUSIONS

Nitrate analysis of water samples from the 11 private wells shows that nitrate pollution is a real problem in Lyon County, Kansas. Eight of the eleven wells analyzed recorded nitrate concentrations that were above the primary drinking water standard, at least once, during the period of July 1990 through April 1991. Three of these eight wells had concentrations that were consistently much higher than the primary drinking water standard of 10 mg/l.

Agricultural sources, such as; fertilization of crops, animal wastes high in organic nitrogen, nitrogen fixation from legumes, as well as leakage from nearby septic tanks, are responsible for the majority of high nitrate levels observed during this study of nitrates in Lyon County. The highest overall concentrations were observed in September of 1990 which coincides with the fertilization of winter wheat crops in the fall. Increased nitrate concentrations, during the winter months, correspond to a decrease in nitrogen-fixation from legume plants. Individual monthly fluctuations of nitrate concentrations were generated by changing amounts of local precipitation. Precipitation either diluted existing nitrates or increased ground water concentrations from leaching of nitrogen compounds in the soil.

Differing local topography, underlying rock outcrops and soil conditions are physical factors that control ground water flow characteristics. Aquifers in Lyon County are shallow features with low yield capacities, with the exception of certain individual river alluvium deposits. Once shallow aquifers become contaminated, it may take years for sufficient amounts of precipitation required to flush out the polluted aquifer. The large number of variables affecting nitrate concentrations create serious problems in isolating nitrogen sources.

Some surrounding agricultural fields are used to grow alternating crops from year to year, which may be fertilized at different times with varying amounts and types of fertilizers applied. Thompson's and this nitrate study represent a very limited illustration for Lyon County, Kansas. A long term study of Lyon County, Kansas wells would give much more insight into the local and seasonal changes of nitrate concentrations, under differing weather and agricultural conditions. Samples should be taken at least once a month for a more extended time period, and more wells per township and range analyzed to obtain a better picture of nitrates in ground water of Lyon County, Kansas.

REFERENCES CITED

Aiken, C., Burlew, T., Chillag, C., Edstrom, B., Emory, B., Morgan, J., Jan. 1990 - Oct. 1990. Climatalogical Data, Kansas. National Oceanic and Atmospheric Administration. National Climatic Data Center, Asheville, North Carolina. Volume 104, numbers 1 - 10, p 35.

Buchanan. R., 1985. Kansas Geology: An Introduction to Land scapes, Rocks, Minerals, and Fossils. University Press of Kansas, Lawrence, Kansas, p. 16 - 39.

Delwiche, C. C., 1970. The Nitrogen Cycle: Readings From Scientific American. W. H. Freeman and Company, San Francisco, California, p. 43 - 52.

Manahan, S. E., 1979. Chemistry in the Environment: Nitrogen Sinks and Pathways in the Soil, Willard Grant Press, Boston, Massachusetts, Fig. 10.4, p. 272.

Metzler, D. F., 1958. An Investigation of the Sources and Seasonal Variations of Nitrates in Private and Public Water Supply Wells, Particularly With Respect to the Occurrence of Infant Cyanosis. University of Kansas, Project Number RG 4775. 35 p.

Neill, J. T., 1981. Soil Survey of Lyon County, Kansas. United States Department of Agriculture Soil Conservation Service in cooperation with Kansas Agricultural Experiment Station, p 162.

O'Connor, H. G., 1953. Geology, Mineral Resources, and Ground-Water Resources of Lyon County, Kansas: State Geologic Survey of Kansas, University of Kansas Publication, Lawrence, Kansas, 59 p.

Schroeder, D. C., 1987. The Analysis of Nitrate in Environmental Samples by Reversed Phase HPLC: Journal of Chromatographic Science; Vol. 25, September 1987, pg. 405 - 408.

Schroeder, D. C., 1988. Modification in Nitrate Analysis by HPLC: Journal of Chromatographic Science; Vol. 25, June 1988.

Thompson, P. H., 1990. Nitrate Analysis of Private Wells in Lyon County, Kansas. Emporia State University, Emporia, Kansas, Masters thesis, 34 p.

Viets, F. G., Hageman, R. H., 1971. Factors Affecting the Accumulation of Nitrate in Soil and Plants: Agricultural Research Service, United States Department of Agriculture, Agriculture Handbook; No. 413, Washington, D. C., November 1971, 63 p.

APPENDIX

Description of Wells:

Well 1 is located in the SW 1/4 of section 36, range 12 E, township 16 S. The hand-dug well is located in the middle of a milo field 1/4 of a mile from the house. The well is 24 ft deep, 5 ft in diameter and the depth to water varies with precipitation amounts. Pennsylvanian age Pierson Point Shale outcrops are covered by soils consisting of Kenoma silt loams (3-6 % slopes). Samples were obtained by lowering a rope and bucket down into the well. The well went dry in December 1990, so no more samples were taken until April 1991.

Well 2 is located in the SE 1/4 of section 33, range 13 E, township 15 S. The bottleneck well is surrounded by a barnyard, pastures, and a small creek. The well is 56 ft deep, 5 ft in diameter and the depth to water is usually 40 ft. Pennsylvanian age Pierson Point Shale and Quaternary age alluvium outcrops are covered by soils consisting of Elmont silty clay loam (3-7 % slopes). Samples were obtained from a hydrant located just north of the house.

Well 3 is located in the SE 1/4 of section 23, range 10 E, township 15 S. The hand-dug well is located by two large barns and is flanked by several wheat fields. The well is 24 ft deep, 3.5 ft in diameter and the average depth to water is 12 ft. Permian age limestones and shales from Lower Chase Group are covered by soils consisting of Ladysmith silty clay loam (0-2 % slopes). Samples were collected from the kitchen faucet inside the house. Two ponds are located near the house, one to the east and the other to the west.

Well 4 is located in the SW 1/4 of section 17, range 11 E, township 18 S. The well is 36 ft deep and normally has a depth to water of 24 ft. A lagoon is located directly south of the well, which is surrounded by several wheat fields and a garden. Quaternary age Emporia terrace deposits are covered with soils consisting of Kenoma silt loam (3-6 % slopes). Samples were collected from a hose on the east side of the trailer. No samples were taken after November 1990, for the convenience of the owner.

Well 5 is located in the NW 1/4 of section 7, range 11 E, township 19 S. The well is 30 ft deep and has an average depth to water of 12 ft. The well is surrounded by outbuildings and a burned down barn. U.S. 50 highway runs directly south of the well but wheat fields surround the well from the other directions. Quaternary age Emporia terrace deposits are covered by soils consisting of Kenoma silt loam (3-6 % slopes). Samples were taken from the kitchen faucet located in the house.

Well 6 is located in the NW 1/4 of section 22, range 11 E, township 19 S. The well is 24 ft deep and has an average depth to water of 12 ft. The well is located in the middle of a wheat field a 1/4 of a mile from the Cottonwood river. Water is pumped, over 100 yards, through a pipe to the house. Quaternary age alluvial deposits are covered with soils consisting of Osage silty clay. Samples, that were very high in iron, were collected from a hydrant located south of the house.

Well 7 is located in the NW 1/4 of section 36, range 12 E, township 21 S. The well is 16 ft deep, 5 ft in diameter and has an average depth to water of 8 ft. The well is located next to a small creek, that is normally dry, some 75 yards east of the house. Pennsylvanian age White Cloud Shale outcrops are covered by soils consisting of Martin silty clay loam (1-4 % slopes). Samples were collected from a hydrant located northeast of the house.

Well 8 is located in the NW 1/4 of section 2, range 11 E, township 21 S. The well is located inside a barn that is used for a wood workshop. The well is 34 ft deep, 5 ft in diameter and usually has an average depth to water of 6 ft. The barn is surrounded by houses with an agricultural field to the south. Quaternary age Wiggwam terrace and alluvial deposits are covered by soils consisting of Kenoma silt loam (3-6 % slopes). Samples were collected by lowering a rope and bucket down into the well.

Well 9 is located in the SE 1/4 of section 13, range 11 E, township 19 S. The hand-dug bottleneck well is 30 ft deep, roughly 2 ft in diameter, and has an average depth to water of 20 ft. The well is located directly north of the house. Outbuildings and a barn, used for a horse, are located to the west of the house. Several different agricultural fields used for hay, wheat and beans surround the well. Quaternary age Wiggwam terrace deposits are covered by soils which consist of Ladysmith silty clay loams (0-2 % slopes). Samples were taken from a hydrant located between the house and the barn.

Well 10 is located in the SW 1/4 of section 13, range 11 E, township 19 S. The hand-dug well is 24 ft deep, 4 ft in diameter and has an average depth to water of 12 ft. The well is located just east of the house and the well cover is badly cracked. The well is surrounded by agricultural fields used for crops such as: soybeans, milo and wheat. Outcropping Quaternary age Wiggwam terrace deposits are covered with soils consisting of Ladysmith silty clay loams (0-2 % slopes). Samples were collected from a hose on the east side of the house.

Well 11 is located in the SW 1/4 of section 23, range 12 E, township 19 S. The well is located beneath the house and is 28 ft deep, 4 ft in diameter, and the depth to water varies according to water use and precipitation amounts. A garden is located to the east of the house and the surrounding area is used for agricultural fields to grow corn, oats, and soybeans. Quaternary age alluvium is covered by soils consisting of Reading silt loam.

Samples were taken from a hydrant located directly above the well.