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Effects of Water-well Construction on Temporal Variability of Ground-water Quality in Lincolnville, Marion County, Kansas

by

Pamela K. Chaffee

Kansas Geological Survey
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047-3726

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by

Pamela K. Chaffee
B.S., Wichita State University, 1979

Submitted to the Department of Civil Engineering and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Science.

Ernest C. Pogge
Professor in Charge

Howard G. O'Connor

Donald O. Whittemore

Carl E. Burkhead
Committee Members

John T. Easley
For the Department

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Date Thesis Accepted

EFFECTS OF WATER-WELL CONSTRUCTION ON TEMPORAL VARIABILITY OF GROUND-WATER QUALITY IN LINCOLNVILLE, MARION COUNTY, KANSAS

Pamela K. Chaffee
M.S. in Water Resources Science

ABSTRACT

Seasonal and short-term variations were observed in ground-water quality from domestic water wells tapping a confined aquifer in the rural town of Lincolnville, Kansas. The seasonal trend consisted of declining or stable constituent concentrations from late summer through late winter. In early spring through early summer concentrations increased, coincident with increasing precipitation. Short-term water-quality fluctuations were most often observed during this latter period.

The frequency and amplitude of the variations were dependent upon the quantity and quality of soil water and the shallow ground water in an intermittent underlying aquifer, the Herington Limestone Member, and the construction of the wells. Wells that allowed hydraulic interconnection between the shallow zones and the confined Winfield aquifer showed the greatest concentrations of chloride, nitrate, total organic carbon, and/or fecal Streptococcus bacteria. In addition, greater values of specific conductance and more dissolved gases, sediment, and sometimes discolored water were observed after periods of extended precipitation generally in the period from late winter to early summer.

Wells studied were constructed both prior to and since 1974 when regulations governing minimum well-construction standards were established in Kansas. Hydraulic interconnection occurred in pre-1974 wells that lacked any surface casing or enough to extend through the entire thickness of the Herington or were completed in leaky well pits. It also occurred in post-1974 wells in which the grouted interval did not extend through the Herington.

Wells constructed to prevent hydraulic interconnection between water in the soil or Herington and the Winfield aquifer produced ground water of generally good quality with concentrations of dissolved inorganic constituents that did not fluctuate significantly throughout the year. However, wells that were located downgradient of other wells with a hydraulic interconnection produced ground water exhibiting short-term variations in quality on a seasonal basis.

Wells located near nitrate contamination sources commonly yielded water in which nitrate concentrations fluctuated and often exceeded 45 mg/L as NO_3. Such sources included a bulk-nitrogen fertilizer storage and handling facility and application of nitrogen fertilizers to yard and garden areas.

Department of Civil Engineering
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Thesis Supervisor
Dr. Ernest C. Pogge
Professor

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CHAPTER 1

INTRODUCTION

Origin of Investigation

Seasonal trends have recently been observed in water levels and water quality for two domestic water wells in Marion County, Kansas (O'Connor et al., in preparation). Each well supposedly had been constructed to meet the State's minimum well-construction standards established in 1973. Hydrographs and sample analyses for one well (#31), located in a farm pasture, indicated relatively small water-level and water-quality fluctuations occurred during the period from December 1981 to July 1984 (Fig. 1). During the same interval hydrographs and water-quality data for the other well (#10), located six miles south in the small, rural town of Lincolnville, showed much greater fluctuations (Fig. 1). The largest fluctuations generally occurred during the period from late winter to early summer when the ground had thawed, precipitation was increasing, evapotranspiration losses were relatively low, and soil-moisture deficiencies had been satisfied.

Water levels rose an average of 3 ft in the farm well in comparison with an average of 7 ft in the town well during this period. During this interval chloride

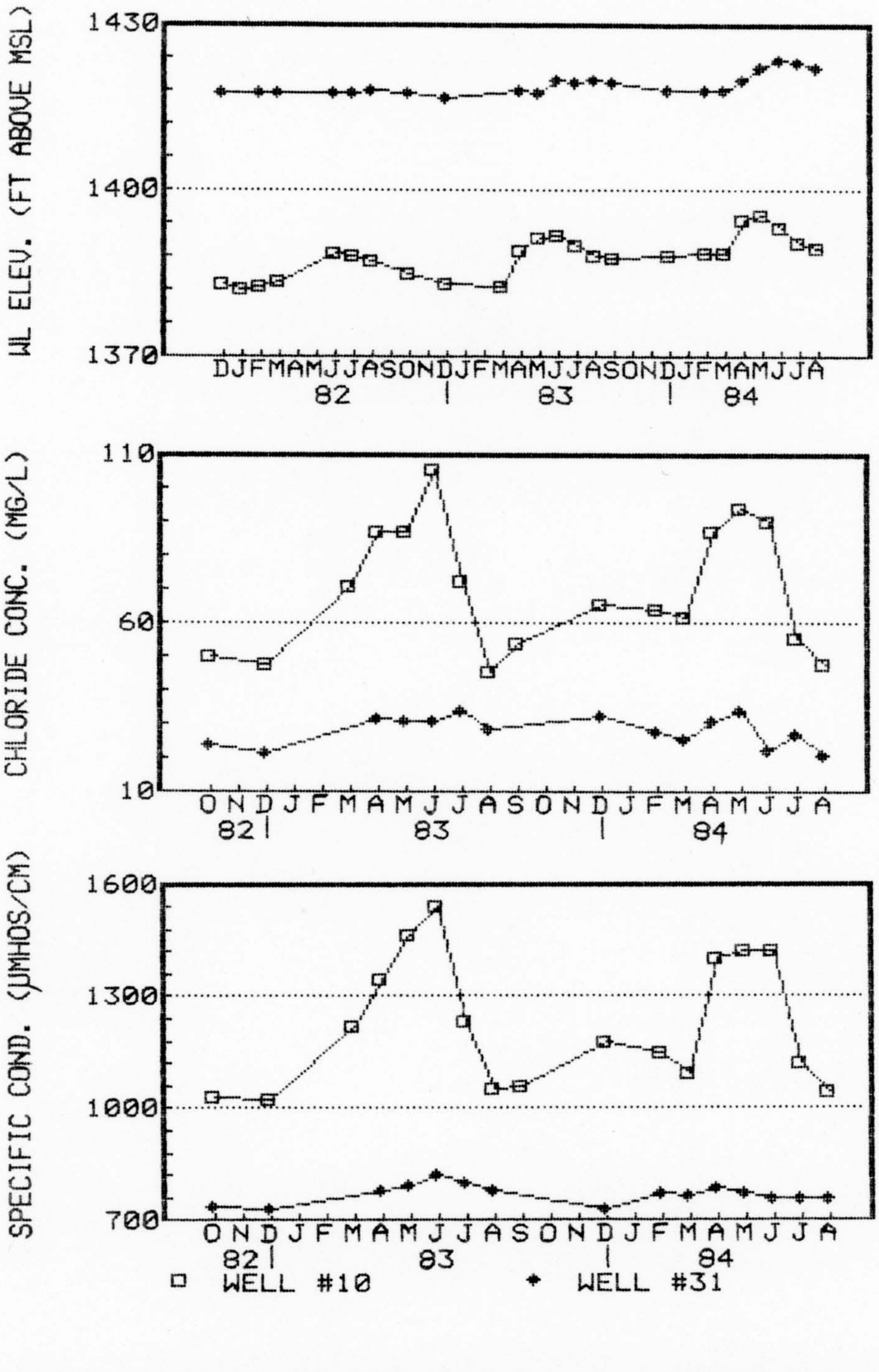


Figure 1. Water-level and water-quality hydrographs for monitoring wells #10 and #31 from previous county study (O'Connor _et_ _al_., in preparation).

concentrations increased an average of 6 and 34 milligrams per liter (mg/L) and specific conductance increased an average of 35 and 322 micromhos per centimeter (µmhos/cm) in the farm and town well, respectively.

Both wells produced ground-water from confined bedrock aquifers for domestic supplies. In addition, both wells had been constructed since 1974 when regulations governing the minimum well-construction standards were established in Kansas. Hydrographs for the farm well were typical of a confined aquifer system characterized by a nearly constant chemical quality. In contrast, the hydrographs for the town well resembled the rapid and sometimes dramatic changes typical of a shallow or surficial aquifer which is more susceptible to chemical changes brought about by natural events occurring at the land surface or from man-induced pollution (Pettyjohn, 1982).

Purpose and Scope

The purpose of the study was to determine the effect of domestic water-well construction on the temporal variability of ground-water quality observed in Lincolnville, Kansas. The methods of water-well construction and completion utilized in Lincolnville both before and since the establishment of minimum well-construction standards in Kansas were investigated.

Qualitative and quantitative aspects of the ground-water quality from water wells both in and outside of Lincolnville, and the public-health aspects of the water quality were also studied.

Location and Extent of Study Area

Water wells studied were located in and around the town of Lincolnville in the northeast part of Marion County, Kansas. The area of study includes approximately four square miles whereas Lincolnville itself only covers about two-tenths of a square mile.

Previous work

The previous Marion County study conducted by the Kansas Geological Survey (O'Connor and Chaffee, 1983, and O'Connor *et al*., in preparation), utilized a private domestic well (#10) in Lincolnville and a domestic farm well (#31) located six miles north as monitoring wells. Water levels were measured in these wells on approximately a monthly schedule for two and one-half years and water samples were collected for determination of chloride concentration and specific conductance during the latter two years. Figure 1 shows hydrographs of these data for wells #10 and #31. The wells, which supposedly had been constructed to meet minimum standards, produced adequate domestic ground-water supplies from confined bedrock aquifers in the Chase Group of Permian age. Some of the construction standards included the use of watertight and approved casing materials, a minimum of 10 ft of grout in the annular space, and disinfection upon completion.

The previous county study also included gaging and sampling of streamflow in Clear Creek just east of Lincolnville, and test-hole drilling and coring at a site just north of the town.

Method of Investigation

The study consisted of two phases. The first phase involved the collection and analysis of existing geologic, hydrologic, and water-quality data for the town of Lincolnville and surrounding area. An initial inventory and screening of twenty private water wells in the study area were made in late July and early August 1984. Monitoring well #10 from the previous county study was included and will be referred to hereinafter as well L10.

The second phase consisted of selecting eight representative wells for use as monthly monitoring wells for a one-year period beginning in September 1984 and ending in August 1985. Fourteen other wells were added after the study began and were monitored on a less regular basis.

The water samples were analyzed for chloride and nitrate concentrations and specific conductance using in-field testing equipment. Due to a delay in shipping of some of the equipment, in-field nitrate measurement began in November 1984. Monitoring of well #31, also from the previous study, for these three properties was continued. Figure 2 shows the locations of the wells used in the study and the frequency with which they were sampled. Twice during the one-year period water samples from the eight monitoring wells were collected and analyzed for total organic carbon (as volatile and nonvolatile organic carbon) (May and August 1985), fecal bacteria (December 1984 and May 1985), and standard inorganic chemistry (September 1984 and May 1985). One of the sample collections was made during the spring months when water levels, chloride concentrations, and specific conductance had been observed to be at their highest in the town monitoring well, and the other collection during the period when they had declined and become relatively stable, generally in the fall and winter months.

Once during the study, water samples were collected from the monitoring wells and analyzed for dissolved gases, including methane, oxygen, and carbon dioxide.

Water samples were collected from Clear Creek on an almost-monthly basis and analyzed for nitrate and chloride concentrations and specific conductance.

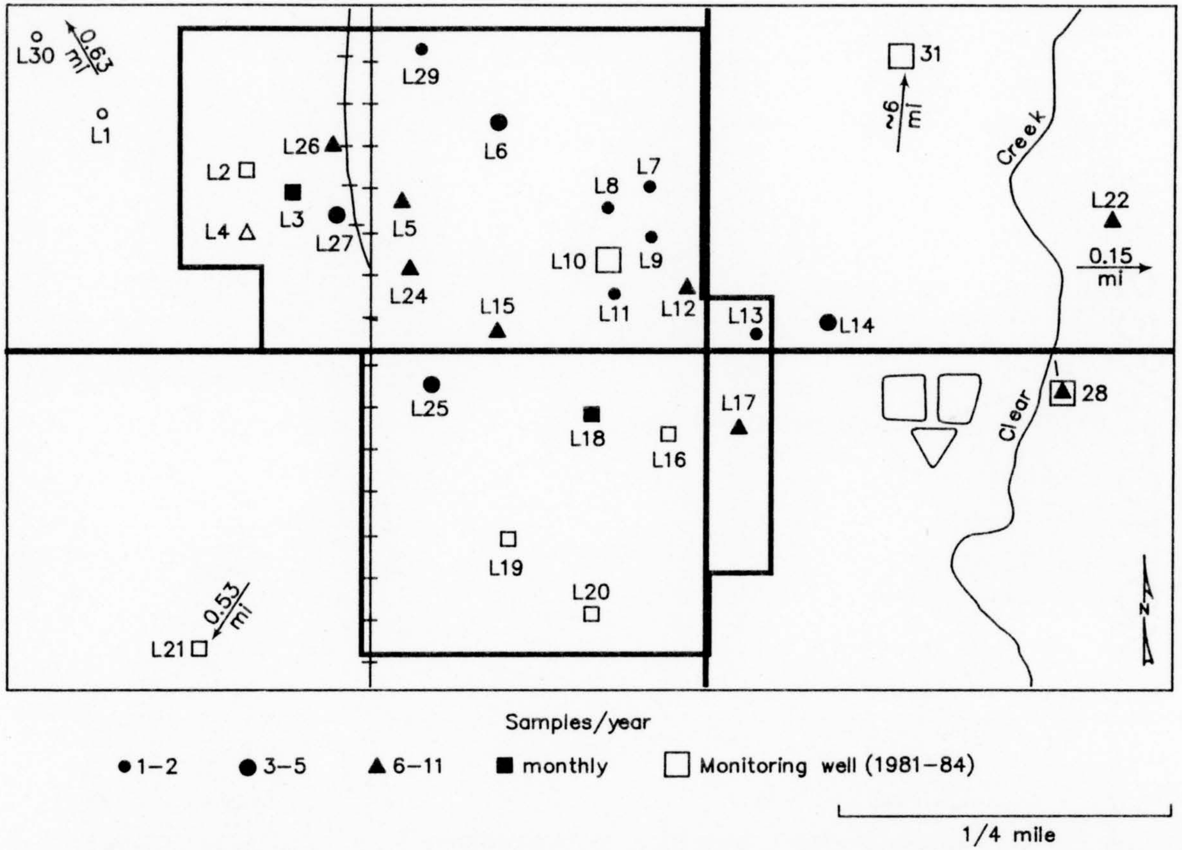


Figure 2. Map of Lincolnville showing the locations of the wells (by well number) used in the study and sampling frequency. The arrows show the direction and distance from the map edge to wells located outside the map figure. The true relationship of these well locations to the study area can be seen in Figure 4. Solid symbols represent wells of pre-standard construction and open symbols represent wells of post-standard construction. Frequency and location of sample collections from Clear Creek are also shown.

CHAPTER 2

DESCRIPTION OF STUDY AREA

Physiography, Geography, and Soils

Lincolnville is located in the northeastern portion of Marion County, which is situated along the west edge of the Flint Hills Upland Physiographic Region of east-central Kansas (Fig. 3). The town lies between two areas: one to the east that is characterized by a well-dissected topography with deeply-incised valleys, thin soils, and many limestone outcrops, and another to the west characterized by more rounded hills because of the greater thickness of shale exposed at the surface. The major drainage in the study area is southward along the axis of Clear Creek which practically borders the town on the east.

The predominant soil type in the study area consists of Irwin silty clay loam ranging in thickness from 4 feet, where it overlies thin unconsolidated deposits, to 1 foot where it is underlain by shale or limestone. This soil type has a slow to moderately slow percolation rate (0.06 to 0.6 inches/hour). It is commonly calcareous, has a high to moderate shrink-swell potential, and has a high risk for corrosion to uncoated steel and a low risk to

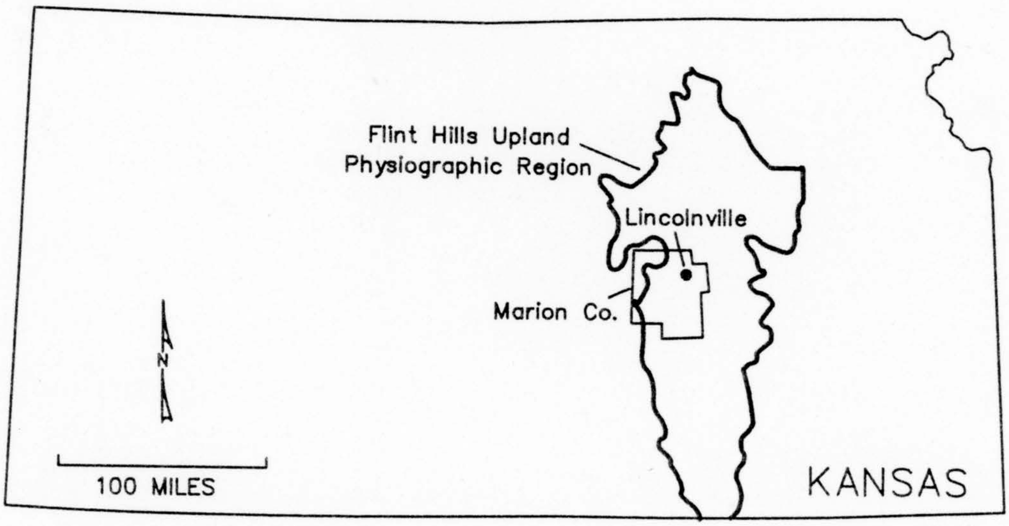


Figure 3. Map of Kansas showing the Flint Hills Upland Physiographic Region, Marion County, and the town of Lincolnville (adapted from Schoewe, 1949).

concrete (Soil Conservation Service, 1983).

Geology and Geohydrology

General

The generalized surface geology of Marion County has been previously described by Byrne et al. (1959). Figure 4, shows the surface geology of a portion of northeast Marion County, including the study area. A simplified stratigraphic column, represented in Figure 5, is useful in the following discussions on the geology and geohydrology of the study area.

Unconsolidated deposits of Quaternary and/or Tertiary age overlie older Permian bedrock in some of the study area (Byrne et al., 1959), but their thickness is generally less than 10 ft; therefore, they were not represented in Figure 4, except along Clear Creek where these deposits reach a thickness of 20 ft (State Highway Commission of Kansas, 1970). However, they are not an important source of ground water in the study area.

Rocks of the lower Sumner and upper Chase groups, Lower Permian Series, are exposed or very near the surface in the study area. In most of the study area, the Wellington Formation occurs as a thin weathered veneer over the Chase Group, becoming thicker to the north and

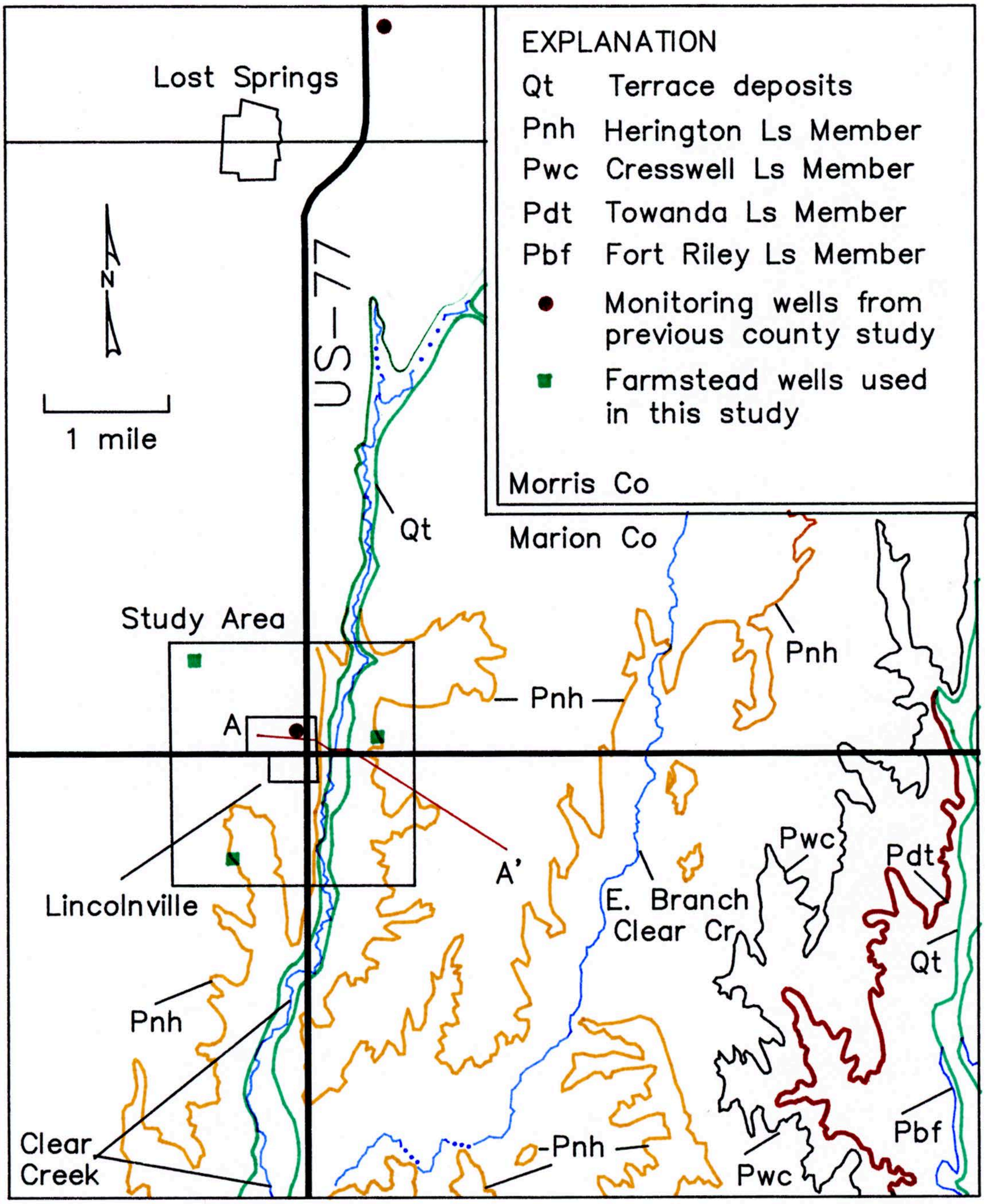
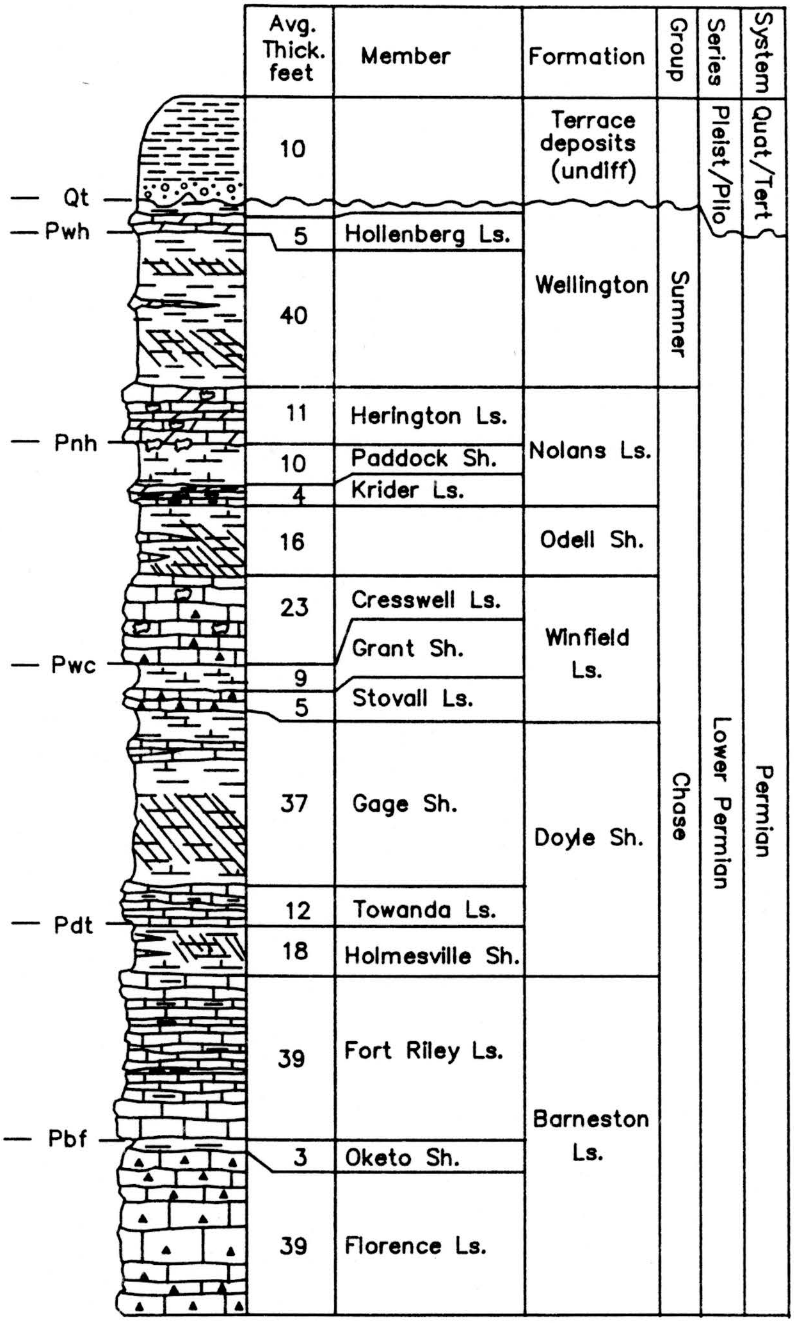


Figure 4. Mapped Geologic Bases Northeast Marion County,Ks. (after Meyers,1984)



Avg. Thick. feet	Member	Formation	Group	Series	System
10		Terrace deposits (undiff)		Pleist/Plio	Quat/Tert
5	Hollenberg Ls.	Wellington	Sumner	Lower Permian	Permian
40					
11	Herington Ls.	Nolans Ls.	Chase		
10	Paddock Sh.				
4	Krider Ls.				
16		Odell Sh.			
23	Cresswell Ls.	Winfield Ls.			
9	Grant Sh.				
5	Stovall Ls.				
37	Gage Sh.	Doyle Sh.			
12	Towanda Ls.				
18	Holmesville Sh.				
39	Fort Riley Ls.	Barneston Ls.			
3	Oketo Sh.				
39	Florence Ls.				

Figure 5. Stratigraphic column of rocks in northeastern Marion County, Kansas (adapted from Moore _et al_., 1951, Byrne _et al_., 1959, and Mudge _et al_., 1958).

west of Lincolnville. The four uppermost formations of the Chase Group are of hydrogeologic importance to the study.

To illustrate the generalized hydrogeologic setting near Lincolnville, a geologic cross-section was constructed (Fig. 6). Its location in the study area is shown as line A-A' in Figure 4. The cross-section is based on a lithologic log submitted by a water-well contractor and a cross-section from a foundation report for the bridge over Clear Creek just east of town (State Highway Commission of Kansas, 1970). In addition, two gamma-ray logs were used in the construction of the cross-section. The gamma-ray and lithologic logs in Lincolnville are provided in Appendix I.

Although several lithologic logs from water-well records (WWC-5 Forms) exist for water wells in the study area, especially in Lincolnville, their inconsistent quality makes interpretation and correlation of the geologic units difficult. The WWC-5 Form or Water Well Record is a standard form which all licensed water-well contractors are required to complete for each water well drilled in Kansas. Regulations concerning the records are administered by the Kansas Department of Health and Environment and the original or first copy of the Water Well Record is maintained in a public file by the Kansas Geological Survey. Records of wells used in the study

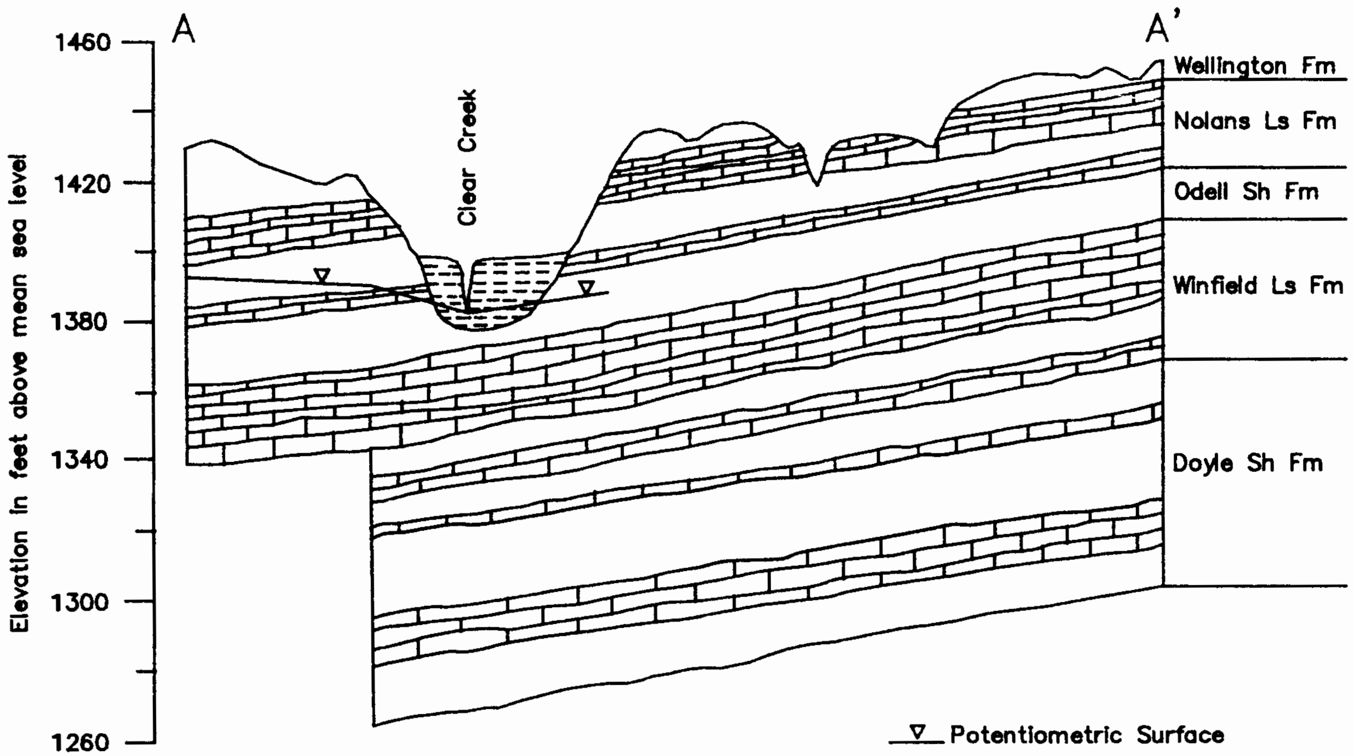


Figure 6. Geologic cross-section A-A' showing potentiometric surface of the Winfield aquifer.

area are included in Appendix II.

Inconsistencies in lithologic logs for different wells result mainly from a lack of the basic knowledge of geology and geologic nomenclature on the part of several of the local water-well contractors. As a result, greater subsurface geologic detail at Lincolnville could not be shown. Although formation and member boundaries on the geologic cross-section were inferred in places, the four sources of geologic information used represent the best quality available.

The cross-section shows a regional westward dip averaging 15 ft/mi for the geologic units in and east of the study area. The upper formations of the Chase Group, the Nolans and Winfield limestones, contain limestone members that act as aquifers in the study area and are recharged by precipitation where they occur at the surface or at shallow depths. In Lincolnville, the Herington Limestone Member of the Nolans Limestone occurs at a relatively shallow depth as indicated in several water-well records for wells in the town (Appendix II). Therefore, the Herington is easily recharged in Lincolnville and to the east and south of town where it is exposed at the surface (Fig. 4). The Winfield Limestone is recharged east of the study area. The intervening shale unit, the Odell, averages 16 ft in thickness and acts as a confining bed or aquitard.

Nolans Limestone

The Nolans Limestone, comprising two limestone members and a shale member, is reported to reach a thickness of 30 ft in Marion County (Byrne et al., 1959). However, its high topographic position has facilitated weathering and erosion leaving it less than this thickness locally. The uppermost limestone member, the Herington, is thick-bedded, dolomitic and medium-hard near the top; while in the lower part it is thin-bedded and soft. It is characterized by siliceous and calcareous geodes and concretions, and califlower-like masses of chert and quartz. The thickness of the Herington is reported to range from 7 ft (Mudge et al., 1958) to 18 ft (Byrne et al., 1959). Upon weathering the Herington increases in porosity and permeability due to solution development along joints, fractures, and calcareous geodes. Evidence of this can be seen at outcrops and in core samples taken from a test hole drilled by the Kansas Geological Survey less than one mile north of Lincolnville. (Appendix I contains the test hole log and includes descriptions of core obtained).

Beneath the Herington is the Paddock Shale Member which is blocky, clayey, and somewhat calcareous in its middle part. Its thickness may average 10 to 15 ft.

The lowermost limestone member of the Nolans is the

Krider. It consists of one or more beds of soft, dolomitic and argillaceous limestone and averages 4 ft in thickness.

Because of the lithology of the lower Nolans and the nature of the drill cuttings, water-well contractors will commonly refer to a major portion of the lower Nolans as 'clay' or 'shale,' thus making it difficult to differentiate the Paddock and Krider members from the Odell Shale based on the drillers' log from the water-well records.

Although water-well contractors do not report the Nolans as yielding ground water to wells in Lincolnville, some ground water has been reported near the base of the Herington (State Highway Commission of Kansas, 1970) and Krider limestone members of the Nolans (Stout and Brison, 1980). In addition, it has been reported that hand-dug wells supplied ground water from the Nolans early in the town's history during the 1800's. Therefore, it is known that the Nolans is capable of yielding some ground water in Lincolnville, at least during certain times of the year.

Odell Shale

The Odell Shale is mainly silty, varicolored shale, and in its middle part is calcareous. Gray-green and maroon zones are abundant in its upper part and tan-gray and gray zones are typical of the lower part. Its average thickness is about 16 ft in the study area.

Winfield Limestone

The Winfield Limestone, separated from the Nolans Limestone by the Odell Shale, consists of a thick upper limestone member, the Cresswell, and a thin lower limestone member, the Stovall. The limestone members are separated by the Grant Shale Member which is about 8 ft thick.

The Cresswell Limestone Member, averaging 23 ft in thickness, is generally a massive limestone that is locally thin-bedded, clayey, and soft in the upper one-third and thick-bedded and harder with thin shale partings in the lower two-thirds. It commonly bears calcareous and siliceous geodes and concretions.

The Stovall Limestone Member of the Winfield ranges from 2 ft to 7 ft in the study area and is a hard, dense limestone commonly bearing chert nodules.

As with the Nolans Limestone, water-well contractors will refer to the softer zones of the Cresswell as clay or shale. Very commonly they will log sand and/or gravel while drilling through the Winfield. The 'sand' notation represents the calcite and quartz grains that result from drilling through the calcareous and siliceous geodes while the 'gravel' may represent the siliceous concretions and chert nodules that are commonly found in the Cresswell and Stovall members.

Water wells in the study area obtain all or part of their ground-water supplies from the Winfield Limestone. Water-well records indicate that these wells yield as much as 50 gallons per minute (gpm) from one or two zones in the Winfield. The upper zone is associated with the Cresswell Limestone Member and the lower zone is associated with the Stovall Limestone Member and/or a thin limestone in the upper part of the Gage Shale Member of the underlying Doyle Shale.

Doyle Shale

The Doyle Shale is composed of two shale members separated by a limestone member, the Towanda. The lowermost shale member, the Holmesville, and the Towanda are known to supply some ground water to wells just east of the study area and in Chase County, whereas the uppermost shale, the Gage, does not (Moore _et_ _al_., 1951). The Gage is primarily calcareous shale with one to four feet of platy limestone in the upper part and varicolored shale in the lower and middle parts. The average thickness of the Gage is 33 ft.

The Towanda Limestone Member consists of many thin beds of hard, gray to tan-brown limestone. It averages 12 ft in thickness and can yield 15 gpm of ground water to wells just east of the study area.

Hydrology

The regional flow of ground water in the Winfield aquifer, which supplies the town of Lincolnville, is to the west following the dip of the Winfield Formation. Locally, ground-water discharge from the Winfield is to Clear Creek and pumping wells in the study area.

As part of the previous county study, streamflow in Clear Creek was measured during base-flow conditions in the fall of 1983. The results showed that Clear Creek was a gaining stream along the reach in the study area obtaining its base flow from effluent seepage from the Winfield and Nolans limestones in and upstream of the study area.

The potentiometric surface of the Winfield aquifer in the study area is shown on the geologic cross-section (Fig. 6), and is based on water-level measurements made in the fall of 1985. The slope of the potentiometric surface towards Clear Creek confirms that the Winfield discharges to the stream.

A potentiometric surface map of the region around the study area (Fig. 7), shows the effluent condition of Clear

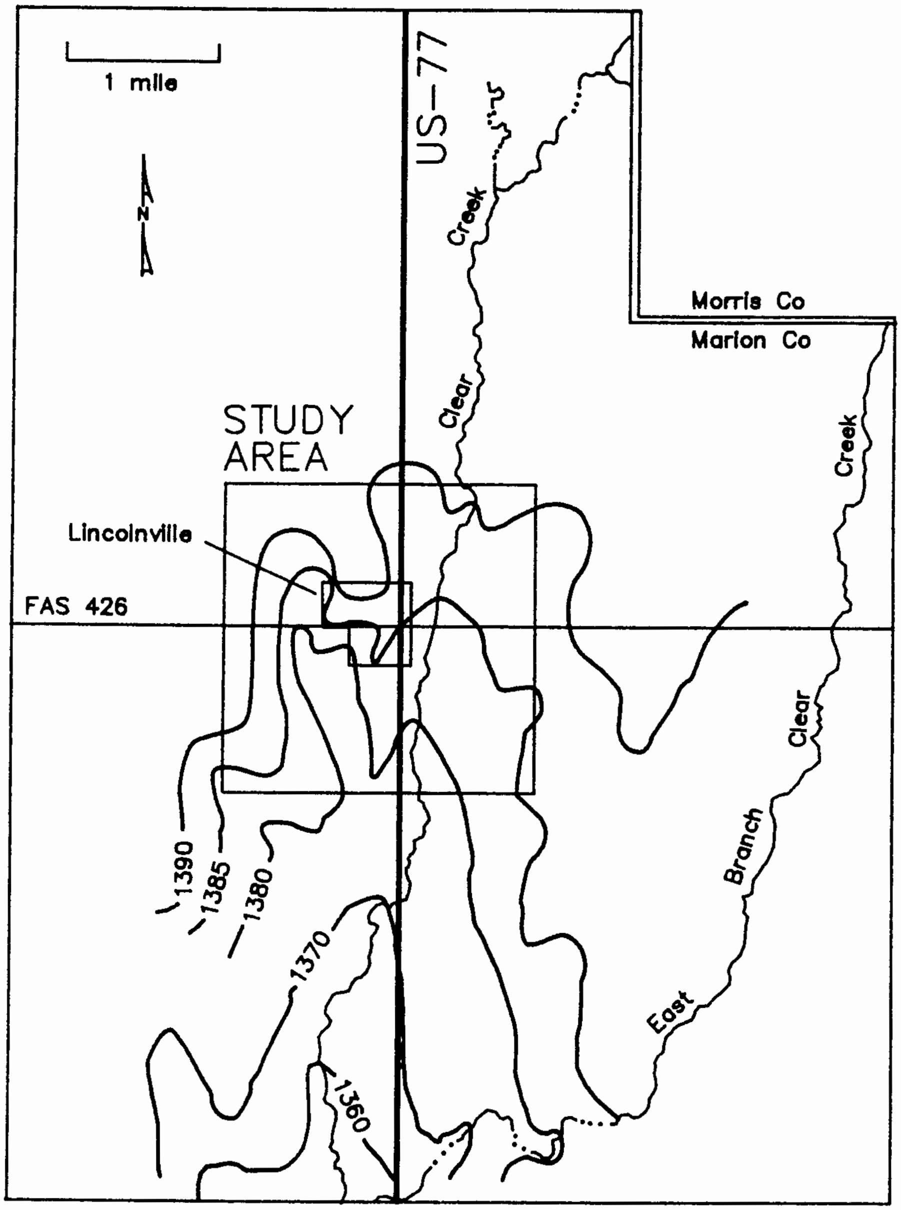


Figure 7. Potentiometric surface map of wells completed in the Winfield Limestone in and around the study area.

Creek in the study area. The direction of ground-water flow in the study area is towards Clear Creek and a small tributary drainage that is just southwest of town.

In addition, artesian flow from the Cresswell Limestone Member was reported during the drilling of pile footings for the bridge over Clear Creek just east of Lincolnville.

Climate

The climate of the study area is characterized by wide variations in temperature and precipitation. The winters are usually short and fairly cold and the summers are relatively long and hot.

The normal annual precipitation, based on a 30-yr period of record (1955 to 1985), is 34.4 inches at Herington, Kansas, 12 mi north of Lincolnville (National Weather Service, NOAA, 1985).

The U.S. Weather Service has maintained a precipitation gage at Lincolnville since 1966. The mean annual precipitation in town for 1980-1984 is 35.2 inches. The monthly precipitation at Lincolnville for the period of January 1981 through August 1985 is shown in Figure 8.

The greatest amount of precipitation generally falls during the growing season, April through September. The normal monthly precipitation values (at Herington), for

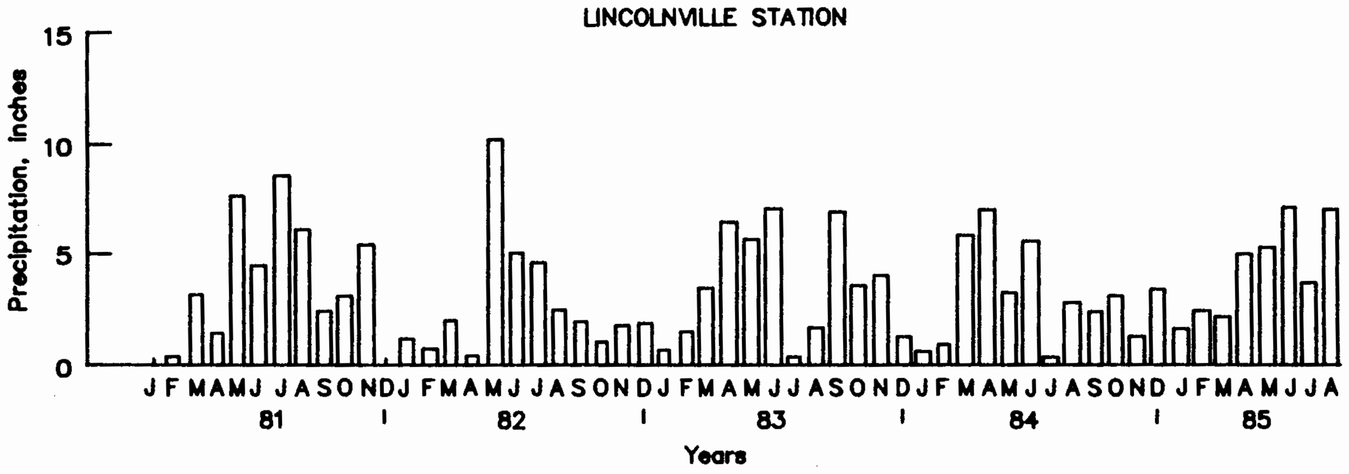


Figure 8. Precipitation at Lincolnville, Kansas.

the months of March through September are listed below:

	Normal Monthly Precipitation (inches)
March	2.27
April	3.04
May	4.47
June	5.83
July	3.73
August	3.00
September	4.16

The mean annual runoff for the study area is between 3.7 and 3.9 inches (Kansas Water Resources Board, 1960).

Cultural Features

The town of Lincolnville is a small rural community with a population of about 235. Figure 9 shows Lincolnville with its approximately 100 homes, 16 businesses, and two churches. Each building or house utilizes a private well for water supply. Three waste stablization lagoons are located just to the east of town and the public sewer system has been in operation since 1960. The town is served by U.S. Highway 56/77, Federal-Aid Secondary Highway 426, and the Chicago, Rock Island & Pacific Railroad. Three rural farm wells located outside Lincolnville were included in the study for all or part of the 13-month study period.

Potential point sources of ground-water contamination recognized in Lincolnville are shown in Figure 10. These

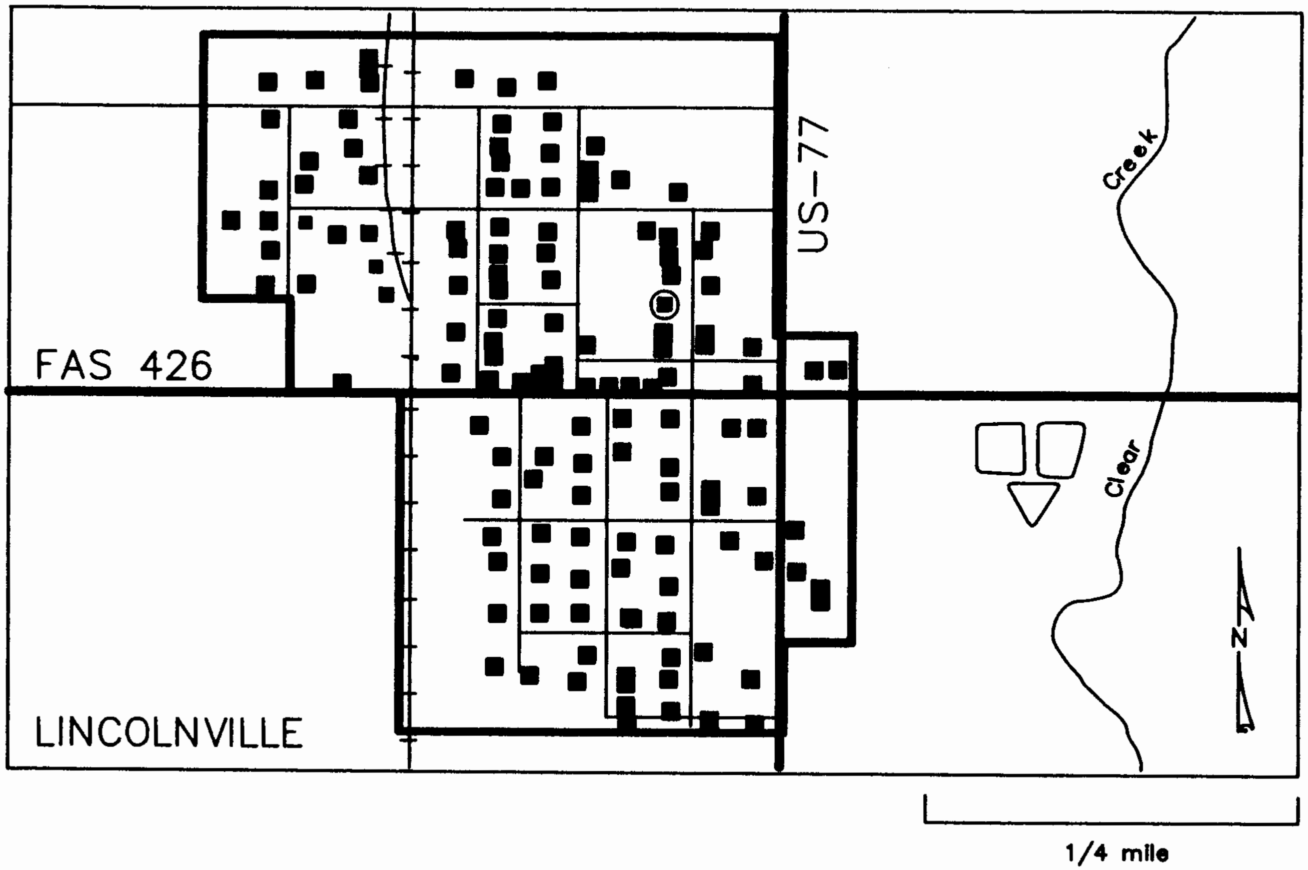


Figure 9. Map of Lincolnville, Kansas showing cultural features (modified from U.S. Geological Survey, 1971).

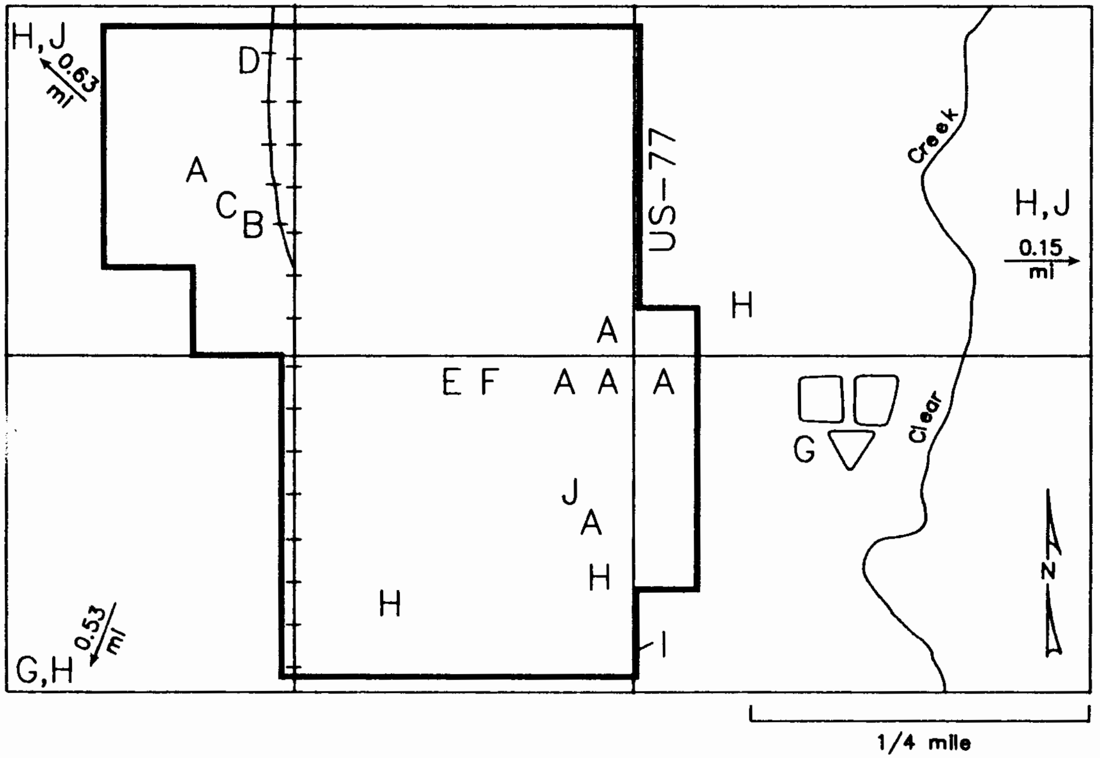


Figure 10. Location of potential point sources of contamination recognized in the study area which include (A) bulk petroleum-product storage and retail service stations, (B) bulk-fertilizer handling and storage, (C) bulk-farm-chemical storage and tank-mixing, (D) grain elevator, (E) garage-machine shop, (F) car wash, (G) waste stablization lagoons, (H) livestock pens, (I) highway where deicing salts are applied, and (J) septic tanks and lateral fields. The arrows show the direction and distance from the map edge to potential point sources of contamination in the vicinity of wells studied on farms located outside the map figure.

potential contamination sources involve, for the most part, the small businesses of Lincolnville. They include service stations and bulk petroleum-product storage, where some former spillage and leakage has been reported; a bulk-fertilizer handling and storage facility, where significant spillage along the railroad tracks and around the buildings occurs annually during loading and unloading; and a nearby farm-chemical (herbicides and pesticides) tank-mix area, where spillage also occurs. In addition, a well used for filling the tank where the farm chemicals are mixed was not equiped with a check-valve to prevent back syphoning of the chemicals into the well.

Other potential point sources include a grain elevator, where grain fumigates such as carbon tetrachloride have probably been used; a garage-machine shop, where greases and solvents are used; a car wash, where dirt, manure, highway deicing salts, greases, and other petroleum products are washed from automobiles and farm machinery; waste stablization lagoons, where the town's sewage effluent is discharged (also a small lagoon is used for domestic wastes at one of the farmsteads used in the study); livestock pens located at each of the farm sites and also a few located on the outer edges of town; and the highway that has deicing salts applied to it in winter.

Potential point sources of contamination in

Lincolnville which are not shown in Figure 10 include sewer lines, abandoned dug or drilled wells, trash-burning sites, fertilizers and pesticides applied to lawn and garden areas and pesticides to house foundations, and former privies, septic tanks, and lateral drain fields. However, one former septic tank in Lincolnville that was included in Figure 10, was reported to be 12 ft by 22 ft in size and was used by an old, large school building that was cleared from the site in the 1970's.

CHAPTER 3

RELEVANCE, METHODOLOGY, AND RELATED RESEARCH

Background

Because of the established relationship of water-well construction and siting to ground-water contamination, attempts were made to develop uniform well-construction standards nation-wide as early as 1948 (Hudson, 1948). These were not successful until 1965 when the Water Well Construction and Pump Installation Act was passed (Humes, 1966). This model law provided a framework under which states could develop regulations to assure safe and adequate supplies of potable water.

At the time, however, Kansas did not take advantage of the model law, but instead issued the "Manual of Recommended Practice for Locating, Constructing, and Equipping Water Wells for Rural Homes," (Shull and Jackson, 1965), through its then State Department of Health. It was not until after the passage of the Federal Clean Water Act in 1972 that Kansas passed the Groundwater Exploration and Protection Act that established minimum water-well construction standards and provided for the licensing of water-well contractors and the submission of hydrogeologic data to the State (Kansas Statutes, 1973).

Since 1974 a yearly average of 4,000 water wells have been constructed or reconstructed and reported in Kansas to at least meet the minimum standards. Approximately 1,100 of these wells were for domestic use in 1985 (Plummer, 1986). Some of these minimum construction standards (Kansas Administrative Regulations, 1974) include use of approved casing and grouting materials, grouting the top 10 ft of the annular space of the well between the casing and the borehole (which is required to be a minimum of three inches larger in diameter than the casing in order to effectively place the grout material), and proper siting distance from potential pollution sources. These regulations greatly improved standards of construction for water wells in Kansas.

Hydrographs from the two domestic water wells used as monitoring wells in the previous Marion County study (O'Connor et al., in preparation) showed that despite each supposedly being constructed to meet minimum well-construction standards and each tapping a confined carbonate aquifer, the water quality and water levels in well L10, located in Lincolnville, fluctuated significantly and relatively rapidly compared to well #31 (Fig. 1), located on a farm six miles north.

According to information submitted by the contractor on the water-well record (Appendix II), the town well (L10), had been drilled to a depth of 115 ft and was grouted in the annular space from 2.5 ft to 17 ft, which is 4.5 ft more than the required minimum of 10 ft (see Figure 11). It should be noted that although the contractor only reported a 6 inch borehole on the WWC-5 Form (which would allow only a one inch annular space the total length of the well), it is believed that the contractor did drill a larger diameter borehole, probably 10 inch, in the upper 10 to 15 feet of well L10, but merely failed to report it on the WWC-5 Form. This is concluded after studying the other forms for domestic water wells constructed in the study area by the same water-well contractor during the same time period, on which he consistently reported a larger diameter borehole in the upper 10 or 15 ft. Therefore, the minimum requirement of a 3-inch annular space in the grouted interval from 2.5 ft to 10 or 15 ft probably was met.

The 12 ft of limestone from 9 to 21 ft in the driller's log is most likely the Herington Limestone Member of the Nolans Limestone. The 'clay' and 'shale' intervals from 21 to 52 ft probably represent at least the remainder of the Nolans Limestone and possibly some of the Odell Formation, of which the red shale interval from 52 to 67 ft is definitely a part. The 5 ft of light brown 'shale' from 67 to 72 ft could be either a part of the lower Odell Shale or the upper Cresswell Limestone Member of the Winfield Limestone. It is not possible to assign

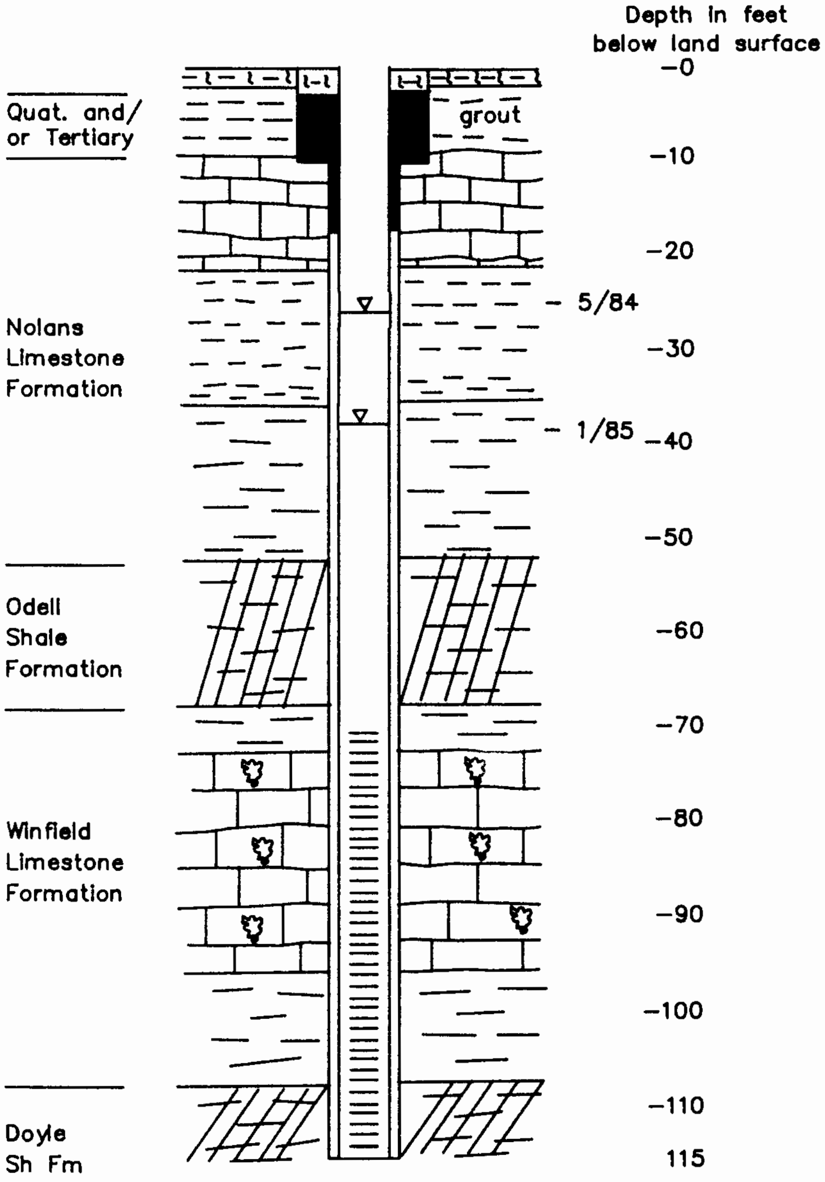


Figure 11. Representation of construction details of well L10 (drilled January 12, 1979).

exact boundaries between members and formations based on the generalized nature of the lithologic log provided by the contractor. However, it is important to point out that possibly as much as 51 ft of 'clay' and 'shale' separate known water-bearing limestone beds in the Nolans and the Winfield formations, thus acting as a confining bed or aquitard above Lincolnville's water supply, the Winfield aquifer.

Because of the extent of solution-cavity formation or solution permeability observed at outcrops and during drilling and coring of the Herington Limestone Member (Appendix I), its close proximity to the ground surface, and reports of ground-water seepage near its base, it is believed that the Herington is capable of yielding significant quantities of ground water during the period from late winter through early summer when snow is melting, frost has left the ground, precipitation is increasing, and evapotranspiration is still relatively low.

The Herington probably becomes an unconfined aquifer in parts of the study area during this period. The water table that forms would possess a higher hydraulic head than that of the Winfield aquifer. In well L10 (Fig. 11), the hydraulic head of the Herington Limestone would have been between 9 and 21 ft. The static water level in well L10 fluctuated between 24 and 38 ft below ground surface during the previous county study (O'Connor _et_ _al_., in preparation). This difference in hydraulic head and the fact that the annular space in well L10 was not grouted below 17 ft, therefore not completely sealing out the entire thickness of the Herington Limestone, would result in the downward movement of ground water in the annular space from the Herington to the Winfield Limestone aquifer. This phenomenon, termed hydraulic interconnection (O'Connor, 1982), would explain the seasonal trend observed in the hydrographs for this well where recharge appeared as rapid and significant water-level and water-quality fluctuations, causing the confined Winfield aquifer to resemble a shallow, unconfined aquifer highly susceptible to recharge and potential pollution.

Relevance

Because of the seasonal potential for pollution inferred from the hydrographs for a well in a town that obtains its water supply solely from private, domestic water wells, it was desirable that the magnitude and extent of the water-quality variability and possibly contamination be determined in Lincolnville.

In addition, the extensive use of domestic water wells in the study area made it necessary to evaluate water-well construction methods utilized both before and after standards were established to determine the effect of the minimum construction standards on ground-water quality.

While a great number of case histories and studies have shown that certain factors of water-well construction and completion can result in contamination of domestic ground-water supplies, these factors are usually typical of older water wells constructed before the establishment of any well construction standards. However, little research has been dedicated to the evaluation of the effectiveness of the minimum standards to provide domestic ground-water supplies that are safe for drinking, especially in Kansas.

The hydrogeologic setting in the study area, consisting of consolidated bedrock strata and a confined aquifer system, is typical of the eastern one-third of the State. Thus, results of this research are applicable to an extensive number of wells and beneficial to a large number of people including water-well users and contractors, regulatory agencies, and public-health officials.

Although the main objective of the study was concerned with the construction details of domestic water wells and their resulting effect on ground-water quality, an important indirect concern was the public-health aspects of the ground-water quality. Therefore, nitrate and fecal bacteria concentrations, for which primary drinking water standards exist, were monitored in the study. Determination of these concentrations is standard in Kansas in the evaluation of potable water. Total organic carbon (TOC), measured as volatile and nonvolatile organic carbon (VOC and NVOC) concentrations, were also measured in ground-water samples from the water wells. Since VOC's are human-made chemicals and do not occur naturally (with the exception of the gas methane), their presence would be an indication of anthropogenic contamination. Although NVOC's can have either a human-made or natural source, their presence was not expected in a confined carbonate aquifer unless water from the ground surface or the unsaturated soil zone carrying them was able to enter the confined aquifer. Monitoring for chloride concentration and specific conductance was continued because secondary or recommended drinking water standards, exist for chloride and total-dissolved-solids (TDS) contents. The TDS of a water can be estimated by multiplying the specific conductance by a constant applicable for the area.

Methodology

In order to fulfill the objectives of the study, an investigation of water wells was initiated in and around

Lincolnville, Kansas. Ground-water quality was monitored both in wells constructed prior to the establishment of minimum construction standards (pre-1974) and those constructed since 1974 and supposedly meeting minimum standards.

Water levels were measured in some wells, if convenient, on a monthly basis and in others on a less regular basis. Water-level measurements were made prior to pumpage of the well and collection of the ground-water sample so as to obtain a water level as near static conditions as possible. However, since prior pumpage of these wells could not be controlled completely during the study, some of the measurements represented recovering water levels.

A time-series sampling program was used to try and reproduce the seasonal trend observed in the Lincolnville monitoring well from the previous county study (O'Connor _et_ _al_., in preparation), and to monitor water-quality constituents related to public health and potential pollution sources.

At least 118 water wells are believed to exist in the study area. Undoubtedly more exist but were not reported or readily identifiable and are most likely old abandoned wells which may or may not be properly plugged.

Twenty wells were inventoried during the latter part of July and early part of August 1984. All but one were in Lincolnville. The inventory involved obtaining information about the well from the owner or user and included materials used in and details of the well construction, total depth and date drilled, water-well contractor, servicing or maintenance, type of pump used, lithology and aquifer material (if known), and past or present activities in the vicinity that had or could have resulted in contamination of the well. In addition, any historical data available for the well were obtained such as previous measurements of static water level, well yield, and water-quality constituents. Finally, verbal descriptions of the quality and quantity of water produced by the well were obtained from the well owner or user. Sketches of each well inventoried and its surroundings were made and in many cases print and slide photographs were taken.

Data from these wells were reviewed in order to select the monitoring wells from which to collect a suite of ground-water samples twice during the one-year study. Because of a limited project budget only eight wells were used as the primary monitoring wells. The samples collected from these wells were analyzed for fecal coliform and fecal Streptococcus bacteria, total organic carbon (TOC) as volatile and nonvolatile organic carbon (VOC and NVOC), the dissolved gases methane, oxygen, and carbon dioxide, and standard inorganic chemistry.

One of the sample collections from the monitoring wells was made in May of 1985 (TOC and standard inorganic chemistry on May 8th; and bacteria and samples for analysis of chloride, nitrate, and specific conductance on May 20th and 23rd) during a period when chloride concentrations and specific conductance as well as water levels had been quite high in well L10 from the previous county study (Fig. 1). The second sample collection was made during the period from mid-summer to late winter which was represented in well L10 hydrographs by lower and relatively stable constituent concentrations and water levels (TOC - August 1985, standard inorganic chemistry - September 1984, and fecal bacteria -December 1984).

The monitoring wells were, however, monitored monthly for chloride and nitrate concentrations and specific conductance using in-field testing equipment which was convenient and inexpensive. Nitrate analysis did not begin until November 1984 due to a delay in shipping of the equipment.

Because of the convenience of the in-field testing equipment, some additional wells were monitored for chloride and nitrate concentration and specific conductance. In addition, the interest and cooperation expressed by many of the townspeople made it possible to include wells that allowed better areal coverage and the opportunity to monitor sites of known or suspected ground-water pollution in the study area.

In all, 14 additional wells were sampled at least twice during the one-year program. Figure 2 shows the locations of the wells used in the study and the frequency with which they were sampled. Three wells in the study area which had been inventoried in the previous county study were included in this project.

Although pumping rate, scheduling, and sampling procedure have been shown in the literature to be important in a water-quality investigation involving water or monitoring wells, several additional factors had to be considered in the design of this study. First, the wells used in the project were existing domestic water wells that were in current use.

The average daily domestic use per person of ground water has been estimated to be 50 to 75 gallons per day (gpd) (U.S. Environmental Protection Agency, 1982). For most of the wells in the study area this average volume equals or nearly equals one well-bore volume, traditionally the minimum amount of water pumped out of monitoring wells before ground-water samples are collected for chemical analysis. In wells where the borehole diameter was known to be larger than the casing diameter and no grout had been placed in the annular space opposite the static or pumped water levels, an amount of ground water equal to the larger borehole volume should be expelled before a sample is collected. The borehole volume for the wells in the study area was generally a little more than one to as much as four times more than the average daily use per person. However, since the average number of persons per household studied in Lincolnville was 2.4 for domestic wells used year-round, then at least one well-bore and in most cases one borehole volume of ground water was pumped from each well on a daily basis.

In most cases, wells were pumped until the ground-water temperatures stabilized near the typical range for ground water in Marion County, 54 to 59 degrees Fahrenheit (12.2 to 15.0 degrees Celsius), before samples were collected (usually after at least 5 minutes of pumping). Temperatures above or below this range usually indicated water which had been stored somewhere in the piping system and been affected by air or shallow ground temperatures. Specific details as to method of sample collection and storage, and analytical methods and results are presented in Appendicies V and VI.

Several duplicate samples were collected and analyzed for nitrate concentration in order to estimate the analytical error of the in-field testing equipment. The duplicates were analyzed by the Analytical Services Section of the Kansas Geological Survey. The estimated accuracy of the method utilized by them was 4 percent or less. The difference in nitrate concentrations determined by the two methods ranged from 4 to 27 percent with the average difference being 16 percent. The greater percent differences were associated with longer holding times of some samples before nitrate analysis could be performed using the in-field testing equipment. Because samples analyzed using the in-field testing equipment were not preserved at time of collection, nitrate values reported were consistently lower than those obtained by the Analytical Services Section.

The estimated analytical error of the chloride concentrations determined by the in-field testing equipment was 4 percent and was based on repeated determinations of standards during each set of samples. That for specific conductance was approximately 2 percent.

RELATED RESEARCH

Proper well construction for sanitary well-water supplies has been advocated by many in the water well industry literature over the years (Bennison, 1947; DeFrain, 1949; Fawcett, 1949; McEllhiney, 1955; Guardino, 1964; Campbell and Lehr, 1973; U.S. EPA, 1975; American Water Works Association, 1985; and Driscoll, 1986).

In 1983, Chaffee and O'Connor advocated the use of additional grouting material in the annular space of gravel-packed water wells, a popular method of well construction in Kansas, beyond the State's minimum requirement of 10 ft near the ground surface. The recommendation was made to further assure protection of the aquifer both during the use of the well and after its abandonment and plugging.

Considerable reference in the literature has been made to ground-water contamination as it relates to improper or inadequate construction or abandonment and nonplugging of water wells (Williams, 1948; Vogt, 1961; Deutsch, 1965; Jorgensen, 1968; Anonymous, 1970; Ham, 1971; McDermott, 1971; and Jones, 1971).

More recently, Exner and Spalding (1985), studied water wells used for households and livestock-watering in southeast Nebraska. Of the total 268 wells studied, 71 percent exceeded 10 mg/L nitrate-nitrogen (NO_3-N) and total coliform (TC) bacteria density of 1 per 100 mL of sample. Only 10 percent of the total met Nebraska's criteria for private well construction, and of these, 4 percent had greater than 10 mg/L NO_3-N and 30 percent had a TC greater than or equal to 1 count/100 mL. The most common inadequacies of the wells not meeting the construction criteria were location too near a source of nitrate and location in a pump pit or depression where ponding of surface water occurred, and a lack of watertight casing, well cap, and/or grout seal in the annular space.

The water-quality study of Kansas farmstead wells conducted in 1985 and 1986 attempted to assess the quality of water produced by private farmstead wells (Heiman et al., 1987). Of 103 wells tested, eight and two had detectable amounts of pesticides and VOC, respectively, and 38 wells had concentrations of one or more inorganic constituents exceeding Maximum Contaminant Levels (MCL's) established by the U.S. EPA (1984). These wells included both those constructed before and since regulations governing the minimum well-construction standards had been established for private wells in Kansas in 1974.

Pettyjohn (1976, 1982), discussed the effects of recharge events in humid areas on seasonal changes in ground-water quality. During the spring recharge period large quantities of water soluble substances are leached from storage in the unsaturated zone to the water table causing significant changes in ground-water quality. Therefore, the major influx of contaminants to a shallow aquifer can occur on an annual basis. In the summer months, the potential for rapid, but localized changes in ground-water quality exists because large and abundant macropores and fractures can allow considerable ground-water recharge.

Keith et al. (1983), discussed not only the various sources of temporal-spatial variability in ground-water-quality data but also methods of controlling or accommodating the sources of variability. They grouped the sources into three general categories: 1) variability due to the impact of land use upon ground-water quality; 2) varibility due to the well-vadose zone-aquifer system - specifically well construction, pumping rates and schedules, geology, hydraulic conditions at the sample site, and physical-chemical processes in the well bore, vadose zone and aquifer; and 3) variability due to sampling and analysis.

In regional monitoring programs in which existing production wells were utilized, they considered the major well-construction parameters of concern to be the perforated interval and the annular seal. Of special interest were cases where the perforated interval (or gravel pack or open annulus hydraulically connected with perforations) intercepted more than one aquifer. In these cases, one could expect an exchange of water between various strata in perched, water-table, and confined aquifers while the well was not pumping due to vertical hydraulic gradients. The contribution of water from each stratum could vary with time when the well was pumped.

Keely (1982) has shown that the patterns of arrivals of contaminants as a function of pumpage, obtained from chemical time-series sampling of monitoring wells, can be used to interpret the locations of contaminant sources and plumes.

Wilson and Rouse (1983), caution that over-pumping of a monitoring well installed in a complex hydrologic regime can result in mixing of waters of different quality and, in the extreme case, contamination of noncontaminated aquifers by previously localized or stratified pollutants. In addition, too high a rate of pumpage or extended pumpage, resulting in a large cone of depression, can also result in mixing of aquifer waters or induce leakage.

Graphical techniques were used by Allen and Walker (1984), to identify monitoring parameters that exhibited temporal variation. They found that temporal variation of ground-water quality is apparent in monitoring wells sampled quarterly for as few as two years. Parameters that exhibited temporal variation included pH, conductivity, TOC, chloride, sodium, sulfate, iron, and calcium. The first four were closely correlated with seasonal changes. They also found that the amplitude and frequency of fluctuations in ground-water quality are lower in confined ground water aquifers and in relatively impervious strata such as clays and bedrock compared with sands and till. Futhermore, that the frequency of these fluctuations did not appear to correlate with seasonal changes.

Schmidt (1977) also used graphical techniques and water-quality data from large-capacity wells to define short-term, seasonal, and long-term trends in well-water quality (versus ground-water quality). He found that changes in water quality after a few minutes or hours of pumping are often related to pump operation. Large fluctuations over short time periods can occur when wells are constructed so as to draw water directly from the strata nearest the water table in developed areas and when wells are close to point or line sources of recharge or pollution, particularly in cases where large volumes of recharge or high pollutant loads are involved. Schmidt determined that seasonal changes in well-water quality were related primarily to (1) pumping patterns, (2) variations in the magnitude and quality of recharge from point or line sources, and (3) amount and quality of water reaching the water table from the vadose zone.

Contamination of ground water with nitrate is a concern because of the known connection between infant methemoglobinemia (also known as cyanosis or "blue baby syndrome") and high nitrate concentrations in drinking water. Nitrate is not the causative agent, but is converted by intestinal bacteria into nitrite which lessen the oxygen carrying capacity of the blood, sometimes to the point of death. Infants below three months of age and young animals are extremely susceptible to high levels of nitrate poisoning (Ronnebaum, 1987). In 1984 the U.S. EPA established an MCL of 10 mg/L for NO_3-N, or 45 mg/L as

NO_3.

Several studies have shown nitrate concentration in ground water to exhibit seasonal trends, generally increasing during periods of increasing precipitation, and also short-term variations in shallow wells. Some of these studies also established an inverse relationship between nitrate concentration and well depth and/or depth of well casing or casing perforations (Crabtree, 1972; Walker, 1973; Piskin, 1973; Tryon, 1976; Schmidt, 1977; Spruill, 1983).

CHAPTER 4

WATER-WELL CONSTRUCTION METHODS UTILIZED IN LINCOLNVILLE

General

It has been reported (A. Riffel, 1984, verbal comm.), that very early in Lincolnville's history shallow dug and later drilled wells obtained ground water from the Nolans Limestone. As the town grew and the number of wells increased, the Nolans became a less reliable source of water supply and subsequent wells were drilled to the Cresswell Limestone Member, the upper member of the Winfield Limestone. In the mid-1950's during a five-year drought, existing wells again were deepened or new ones drilled to greater depths. This time the wells tapped an aquifer in the lower part of the formation, the Stovall Limestone Member or the Gage Shale Member in the upper part of the Doyle Shale. It was reported that a few wells went even deeper to the "big water" which is believed to be the Towanda Limestone Member of the Doyle Formation.

The older drilled wells (pre-1974), represent construction and completion methods utilized in Lincolnville before minimum well-construction standards were established. Many of these methods were no longer allowed under the rules and regulations passed in 1974 which governed such items as materials used for casing, screening, and grouting, grouted interval in the annular space, watertight joints in the casing, distance from potential source of pollution or contamination, licensing of water-well contractors, and well abandonment and plugging; etc.

Water-well records (WWC-5 Forms) for post-1974 wells are presented in Appendix II. All available information concerning the construction details of the pre-1974 wells used in the study is presented in Appendix III.

Pre-1974 Water-Well Construction

Any of the large-diameter, shallow dug wells that were common early in Lincolnville's history have long since been filled-in and/or covered over and can no longer be identified. However, many of the older drilled wells still exist, several of which are still in use. The older drilled wells were usually constructed using a cable tool or percussion-type drill rig. They were cased with heavy wrought iron and/or light-weight galvanized steel. The latter type of casing was generally thin-walled (0.062 inch) and especially susceptible to corrosion. In addition, galvanized steel casing had screw-type joints at 4 or 5 ft intervals which leaked.

According to the late Arnold Riffel, a water-well contractor from Lincolnville, he or his father constructed or reconstructed many of the wells in and around the study area from the 1940's to the early 1970's. Reconstruction involved replacing the old casing and sometimes included deepening the well several feet to obtain a more adequate water supply.

Mr. Riffel commonly constructed or reconstructed his wells with both heavy iron and galvanized steel casing. He usually would use a 10 or 20 ft segment of the iron casing at the top of a well to protect the thinner (typically 1/16 or 0.062 inch), galvanized steel casing from the corrosive effects of shallow soil water in the weathered zone. The surface casing protected the well from the otherwise eventual entrance of shallow water potentially carrying bacteria and contaminants.

In a few cases where pollution from a gasoline spill had affected nearby water wells or where additional protection from surface contamination was desired, Riffel installed longer sections of the iron surface casing. For example, in his own well he installed 50 ft of surface casing and in well L22, located on a farm one-half mile east of town, he reportedly recased the well to 30 ft.

Another local water-well contractor was recalled to well L17 soon after he had constructed it in the early 1970's because the water produced by the well contained a petroleum fuel product from a former nearby fuel spill. The contractor reconstructed the well and grouted the annular space to a depth of 35 ft and the problem was corrected (P. Backhus, 1985, written comm.)(Fig. 12).

Mr. Riffel began grouting the annular space around surface casing in his water wells in the early 1950's. For grout he used either cement, drilling mud, or dirt and drill cuttings. If the surface casing was to be installed in shale, he merely 'drove' it into the borehole with his cable-tool rig.

Traditional slotted screen was not used in bedrock wells in this part of the State, Riffel claimed. Instead he and other drillers perforated the galvanized steel casing with holes adjacent to the water-bearing zone(s). In some cases where large intervals of limestone were encountered during drilling, some drillers would not install any casing. This method was referred to as 'open-hole' construction.

Records kept by Riffel on wells that he or his father constructed or reconstructed showed the well owner, date drilled, total depth, and footage of galvanized steel casing installed. Because he did not charge for the iron surface casing or its installation, very few records were kept for these wells as to the length of surface casing used or whether it was grouted or driven into place. Figure 13 is a hypothetical representation of well L5

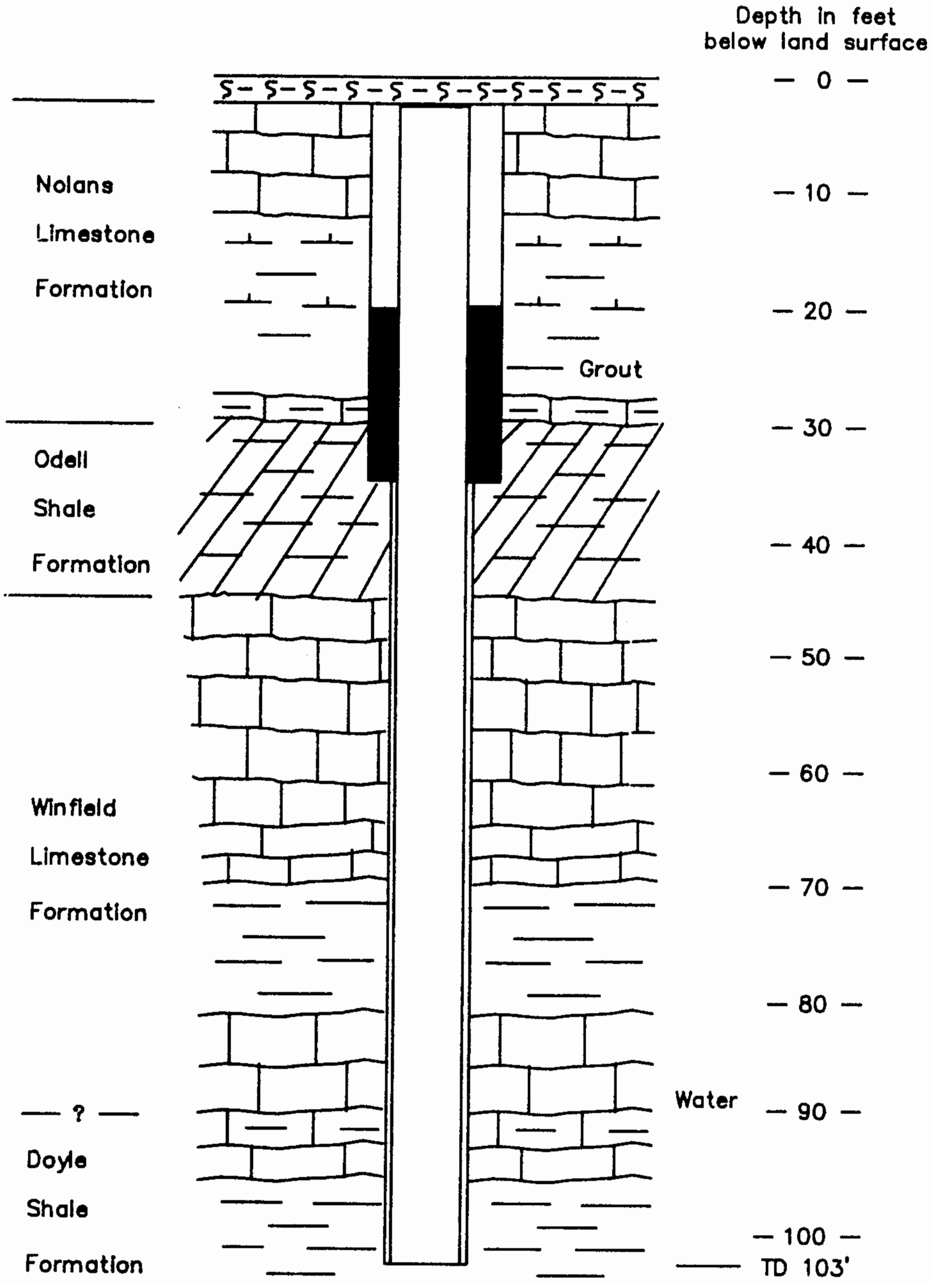


Figure 12. Representation of reconstruction details of well L17 (1973). Geology based on driller's logs of nearby wells.

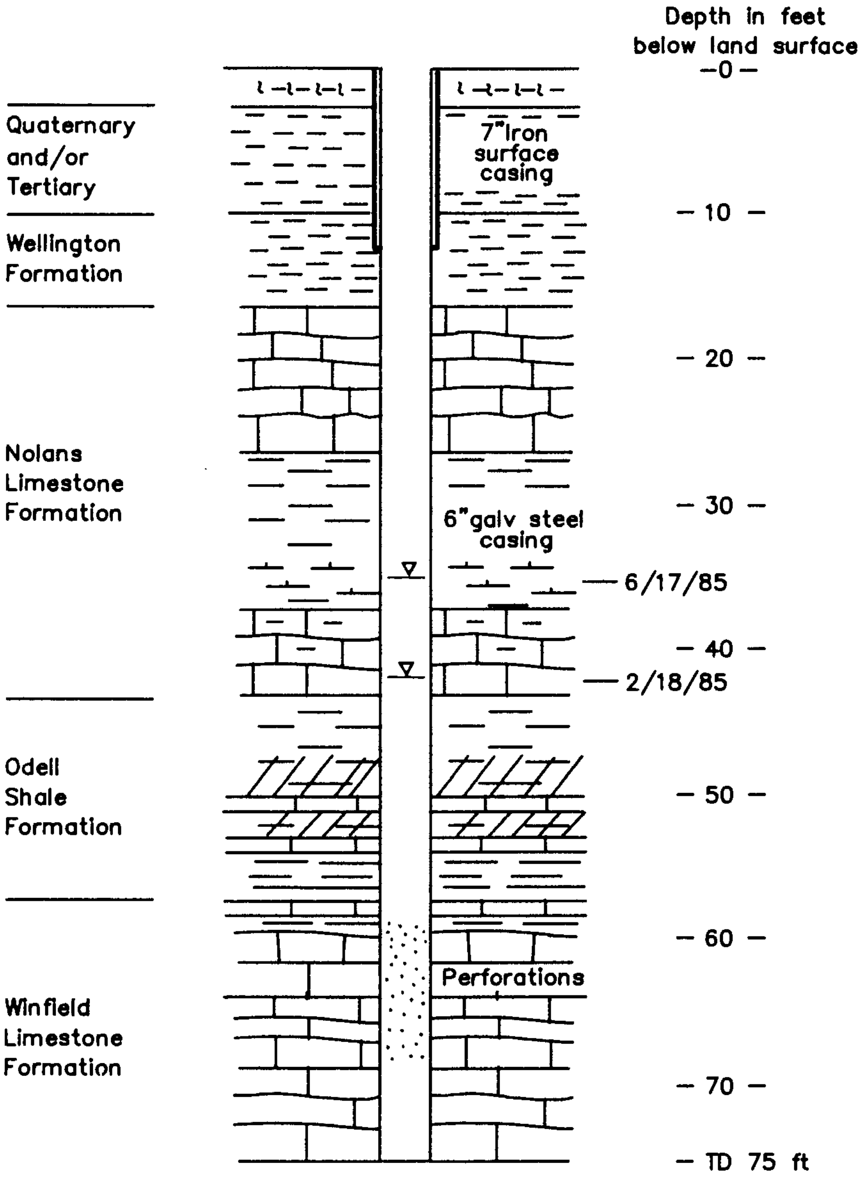


Figure 13. Representation of reconstruction details of well L5 (recased 1953). Geology based on driller's logs of nearby wells.

which was reconstructed by Riffel in 1953. His records showed that he recased the well with 12 ft of iron surface and 75 ft of galvanized steel casings. The geological information was extrapolated from driller's logs from water well records for two nearby wells.

In one case, well L3, the original homeowner needed a water well but because of financial difficulties requested that Riffel construct the well as inexpensively as possible. Therefore, Riffel drilled a well about 90 ft deep, installed 25 ft of iron surface casing, and left the rest of the hole open.

Several wells in Lincolnville were constructed by other local drillers mostly in the late 1960's and early 1970's at a time when drilling by Riffel slowed down considerably owing to health problems. It was during this period that plastic casing was becoming popular and fewer wells were completed using heavy-steel surface casing.

At the same time, some advances in equipment used in water-well completion were introduced into the area. The equipment included the pitless well adaptor and unit, and the sanitary well seal (Pritz, 1986, verbal comm.). Although these offered much needed sanitary protection to the water well, their use was strictly optional and did not gain great popularity until after the establishment of well-construction regulations in 1974.

Before the introduction of the pitless well adaptor and sanitary well seal, well-completion methods used in Lincolnville left a great deal to be desired. In most cases water wells were constructed by the drilling contractor and then completed by a pump installer or plumber. Some of the methods used to complete the installation of a water well included a well pit, underground completion, and above-ground completion in well houses. These three types of completion have been shown to allow the entrance of contaminants into the well under certain conditions. The well pit has been cited as the most notorious for allowing shallow surface water to enter a water well (DeFrain, 1949; Anonymous, 1970; Ham, 1971).

In fact, the older wells initially inventoried that were completed in well pits all had unsanitary conditions. In each instance the casing was cut off a short distance above the floor of the pit for the expressed purpose of allowing water that seeped into the pit to drain back into the well, preventing it from disrupting the motor and electrical circuits. In some cases a hole or notch had been placed in the side near the top of the casing to further insure that seepage water did not accumulate too deep in the well pit.

Evidence that shallow soil water had seeped into well pits or was capable of doing so included: turbid and discolored water standing in the bottom of the well pit just below the top of the casing (or hole in casing), soil and organic material such as plant fragments and insects lining the bottom of the well pit, cracks in the walls and along seams, and water stains along the cracks and as a line along the base of the pit walls.

Post-1974 Water-Well Construction

Compliance to and enforcement of each regulation established for the water-well industry in Kansas in 1974 had a slow beginning, as might be expected for any newly regulated industry. However, minimum standards were for the most part met by water wells constructed in Lincolnville after 1974.

Appendix IV is a listing of Article 30 from the Kansas Administrative Regulations (Chapter 28, 1974), which regulates the construction, reconstruction, treatment, and plugging of water wells and sets forth procedures for the licensing of water-well contractors as required by the Kansas Statutes Annotated (Chapter 82a, Article 12, 1973). The listing of Article 30 in the appendix is an amended version showing some current changes that became effective May 1, 1987, and have been incorporated into the previous version which was in effect at the time of this study.

The standards established regulations that govern the types of casing, screen, and grouting material that can be used in the construction of water wells. For example, limits established on the minimum thickness of galvanized steel casing that can be used (0.141 inch) eliminated the use of a thinner type of galvanized steel casing (0.062 inch) previously placed in wells throughout the study area before 1974. The most common type of casing used since the 1970's in the study area has been thermoplastic, in particular, polyvinyl chloride or PVC.

A requirement of the 1974 well construction regulations was that at least a 10 ft interval of annular space at or near the ground surface must be sealed with approved grout material. To facilitate grouting, the regulations further required that the borehole diameter be a minimum of three inches greater than the outside diameter of the well casing in the interval to be grouted.

In addition, confined aquifers must be separated from each other and from unconfined aquifers encountered in the same borehole with grout in areas designated by the Kansas Department of Health and Environment. The only areas that had been so designated were in western Kansas for wells penetrating both the Ogallala and the Dakota aquifers, and in southeastern Kansas for wells penetrating both the Mississippian and Ordovician aquifers (Chaffee and O'Connor, 1983).

More recently the wording of this regulation was changed (effective May 1, 1987) to require a minimum interval of 20 ft of grout in the annular space at the top of the well or a minimum of five feet into the first clay or shale layer, if present, whichever is greater, and separation of all aquifers ecountered in the same borehole with grout in the annular space (K.A.R. 28-30-6(b)(1) and (c)) [See Appendix IV]. Preliminary results of this study (O'Connor and Chaffee, 1985) were presented prior to the regulation change to the Kansas Department of Health and Environment and the House Energy and Natural Resources Committee of the Kansas Legislature who were instrumental in changing the regulation.

The minimum 10 feet of grout at the top of the well, while preventing the drainage of very shallow, easily contaminated soil and/or ground water down the annular space, still allowed for the potential of hydraulic interconnection between two or more aquifers in the annular space below the minimum 10 ft grouted interval. This construction was common not only in newer wells in the study area, but also in a large proportion of water wells constructed in Kansas. In many of these wells a continuous, highly permeable envelope of gravel, known as a gravel pack, was used in the annular space from the bottom of the well up to the base of the grouted interval, 10 feet or so below the ground surface (Chaffee and O'Connor, 1983).

Previously, the gravel pack had almost exclusively been used in wells tapping unconsolidated aquifers for reasons well-founded in industry literature (Bennison, 1947 and Driscoll, 1986). The gravel pack has experienced renewed popularity since the 1970's with some contractors in Kansas (including some in the study area), who construct wells in consolidated or bedrock aquifers. However, it has not been supported in the industry literature for use in consolidated aquifers.

In effect, wells constructed in the manner described above could hydraulically interconnect aquifers with the potential for downward or upward movement of ground water in the annular space depending on differences in the hydraulic heads of the aquifers encountered.

According to water-well records submitted by contractors for newer wells (post-1974) in the study area, many of the wells were constructed in this manner, although not all of the wells had a gravel pack. Well L20 is gravel-packed, for example, to the bottom of its 98 ft depth and is probably effectively grouted from 3 to 13 ft (meeting the 10 ft minimum requirement). However, the driller's log reported limestone from 5 to 17 (see WWC-5 Form in Appendix II), therefore the annular space is open at the basal 4 ft of the Herington Limestone Member potentially allowing intermittent unconfined flow to drain down the gravel pack to the Winfield aquifer.

The average reported depth to which grout had been placed in the annular space of these newer wells was 17 ft, this average includes information from WWC-5 Forms for wells not used in the study but located in the study area. The effectiveness of some of these reported grouted intervals is questionable because they extend below the reported depth to which a required 3-inch-minimum annular space was maintained in the well for grouting purposes.

For example, construction details provided for well L19 (Fig. 14) from the WWC-5 Form, indicate that the contractor drilled a 10-inch bore hole to 10 ft and then a 6-inch borehole to the total depth of the well (107 ft). The well was then cased with 5 inch PVC casing and had slotted PVC screen from 67 to 107 ft. The well was not gravel-packed and, as the contractor reported, was grouted with neat cement from 2.5 to 20 ft. Because the borehole diameter was only one inch greater than the casing diameter from 10 to 20 ft, it is questionable that this interval received an effective grout seal. Industry literature recommends that the annular space to be grouted should have a diameter that is 4 to 8 inches larger than the casing in order to obtain a uniform sheath of cement around the casing for the entire vertical distance to be grouted (Driscoll, 1986).

An additional problem for well L19 is the presence of the Herington Limestone Member at 15 to 24 ft as indicated in the driller's log. Even if the well was effectively

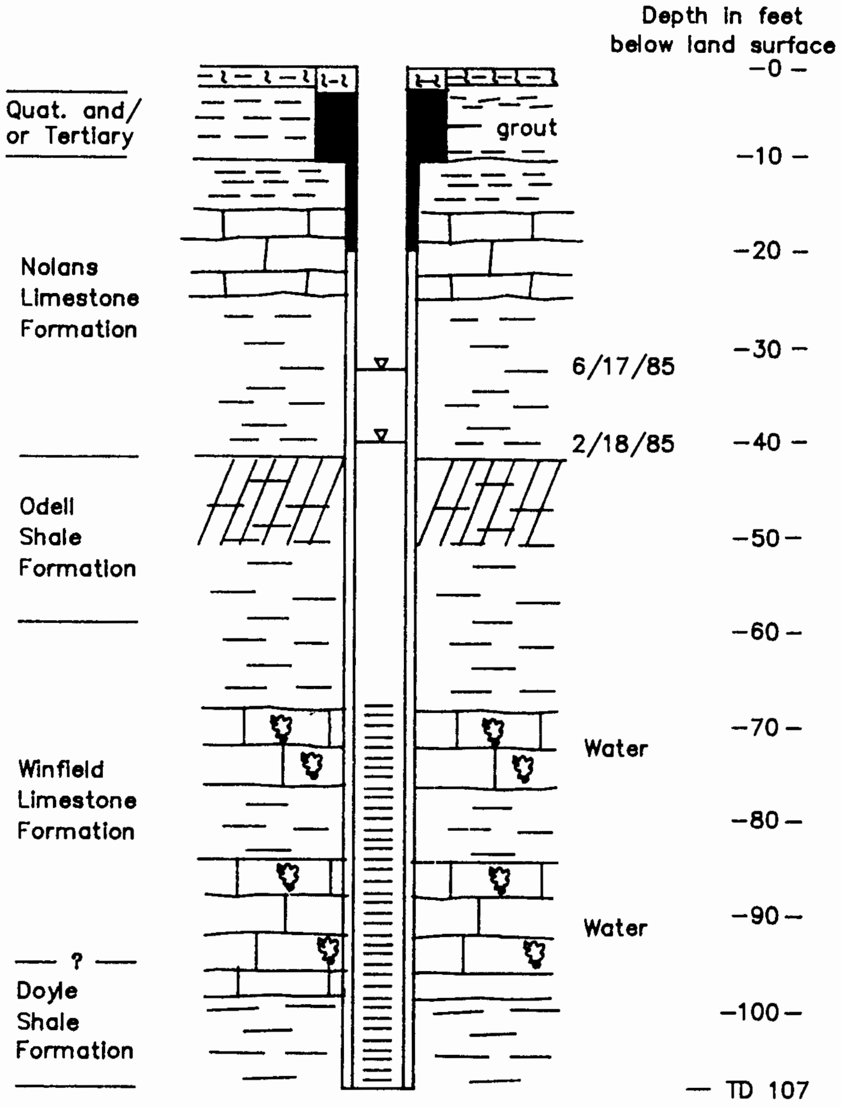


Figure 14. Representation of construction details of well L19 (drilled December 1978).

grouted to a depth of 20 ft, the basal four feet of the Herington is still exposed in the annular space of the well providing a potential hydraulic interconnection between the Herington and Winfield aquifers. Figure 14 illustrates the well construction details with respect to the geology at well L19.

In addition to the aforementioned regulations, wells had to be completed with at least one foot of casing above ground and topped with a sanitary well seal and a well vent. These restrictions essentially prohibited completing water wells in pits or underground and were dutifully adhered to by the water-well contractors to a point. Since most contractors did not install the pump or the connections from the well to the point of use, they did not always have control over the final phases of well completion.

Pump-installers, however, were involved with the final construction phases. Working with the well owner, they determined the type of pump used, where it was to be located (if not a submersible pump), whether or not a pitless adaptor or unit was used (also if installed correctly), and whether or not a sanitary well seal and well vent were installed properly. Most of the newer wells constructed and completed in the study area did not have an approved well vent installed. However, one of the functions of the well vent was remedied, in most cases, by the types of sanitary well seals utilized which allowed the well to 'breath' without allowing contaminant entry. A few cases of water-well contamination due to improper well venting are discussed in the literature (Joyce, 1982; van der Kamp and Owusu, 1984; Keech, 1984).

Abandoned Wells

Whether constructed and abandoned before or after the establishment of water-well regulations, abandoned wells that are not plugged or have not been properly plugged have the potential for affecting ground-water quality and quantity. In addition to water wells, other abandoned and unplugged or improperly plugged wells (oil and gas), test holes, and seismic-shot holes, etc., have the potenial for affecting ground-water quality.

Historically, the plugging of abandoned water wells has never been a high priority issue in Kansas owing to the fact that the responsibility rests on the land owner (K.A.R. 28-30-7) [see Appendix IV], who many times lacks an understanding of the nature of ground water and the effect that a hole in the ground, such as an abandoned well, can have on ground water.

There are abandoned and unplugged and some improperly plugged wells in the study area. Many have been identified, others reported, and undoubtedly others unknown by anyone to exist.

In a conversation with Mr. Riffel, he reported that he had been hired by the local plumber/pump installer to plug many old wells in Lincolnville. Since most of the wells to be plugged had galvanized steel casing, Riffel pulled the casing (where possible) and/or drilled down 10 to 15 ft, and then put a plug "on" the well. As Mr. Riffel put it, there were many old wells that were just "covered up."

Drive-Through Water Well Survey

A 'drive through' Lincolnville was conducted in an attempt to survey the number of wells and the types of completion used. The results are presented in Table 1, in addition to information obtained during the initial water-well inventory and by word-of-mouth. The number of wells constructed after 1974, most of which met minimum construction standards, was based on the number of WWC-5 forms on file at the Kansas Geological Survey. Three wells located outside of town but in the study area were included.

In summary, some of the methods of water-well construction and completion used in Lincolnville, Kansas, can result in potential hydraulic interconnetion between the Winfield aquifer and shallower, seasonally-water-bearing zones in the Herington Limestone and/or soil mantle.

Table 1. Well Completion Survey

	Number of wells	Percent of total
Post-1974 wells		
Ks. Dept. Health & Environ. Standards	20	17
Pre-1974 wells		
Above ground in well house	39	33
Below ground in well pit	22	19
Underground completion	3	2
Basement completion	4	3
Inside completion in garage	1	1
Abandoned, not plugged	16	14
Unknown completion	13	11
Total	118	100

CHAPTER 5

RESULTS

WATER LEVEL MEASUREMENTS

Water levels were measured in some of the wells during the study period. Some wells were measured on an almost-monthly basis while others not as regularly. In Lincolville the average water level fluctuation was about seven feet. The lowest levels were in the winter months (usually January or February) and the highest levels were in the spring/summer months (June). The water-level hydrographs for wells L2 and L16 shown in Figure 15 represent the trends seen in other wells measured in town. Measurements for February and August 1985 in well L16 represent recovering water levels and show the drawdown effect a pumping well can have in town. The hydrograph for well L22 shows the same trend as wells L2 and L16, but only five feet of fluctuation occurred from the lowest level in January to the highest level in June (Fig. 15).

SEASONAL VARIATIONS IN CHEMISTRY

Ground-water quality from wells of both pre- and post-standard construction exhibited seasonal variations

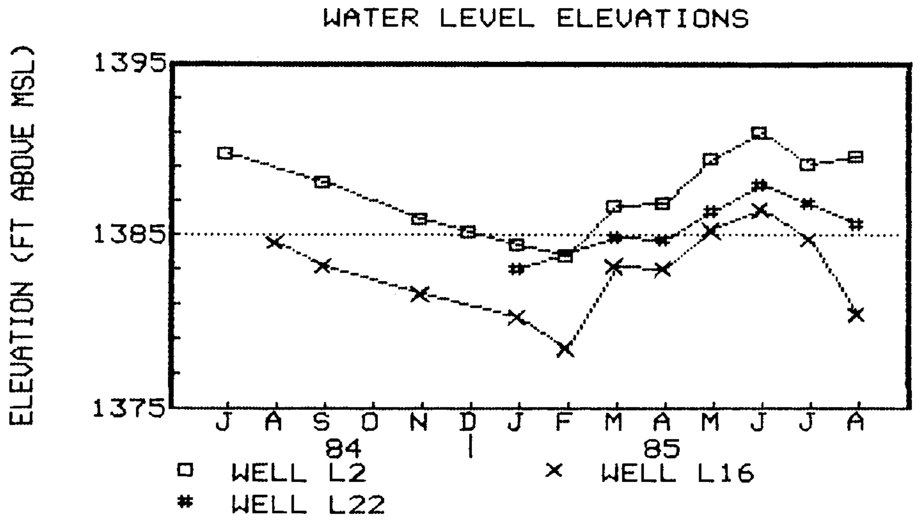


Figure 15. Water-level-elevation hydrographs for wells L2 and L16 (post-standard construction), and well L22 (pre-standard construction).

during the thirteen-month study period. These variations were generally represented by decreasing and/or stablized specific conductance and concentrations of chloride and nitrate starting in the summer and continuing through late winter. The conductance and constituent concentrations then increased through the spring and early summer, usually reaching a maximum in the May/June period coincident with increased precipitation.

The seasonal trend is exhibited by water-quality hydrographs for older (pre-1974) wells L5, L12, and L18 in Figures 16 and 17; and also by newer (post-1974) wells L2, L4, L10, and L19 in Figures 18 and 19. Newer wells L16, L20, and L21 showed only slight seasonal trends in water quality through the study period in Figure 19. Some of the small fluctuations exhibited by water quality in these latter three wells were less than the analytical error of the in-field testing equipment. Thus, the trends shown by the water-quality hydrographs for these wells may not represent true conditions.

At the same time, water quality data for older wells L3, L26, and L15, showed possible seasonal trends that were partially masked by short-term fluctuations (Figs. 16 and 20). This was also the case for Clear Creek (Fig. 20), where the sporadic fluctuations were in direct response to precipitation events. However, the trend exhibited by Clear Creek of higher constituent

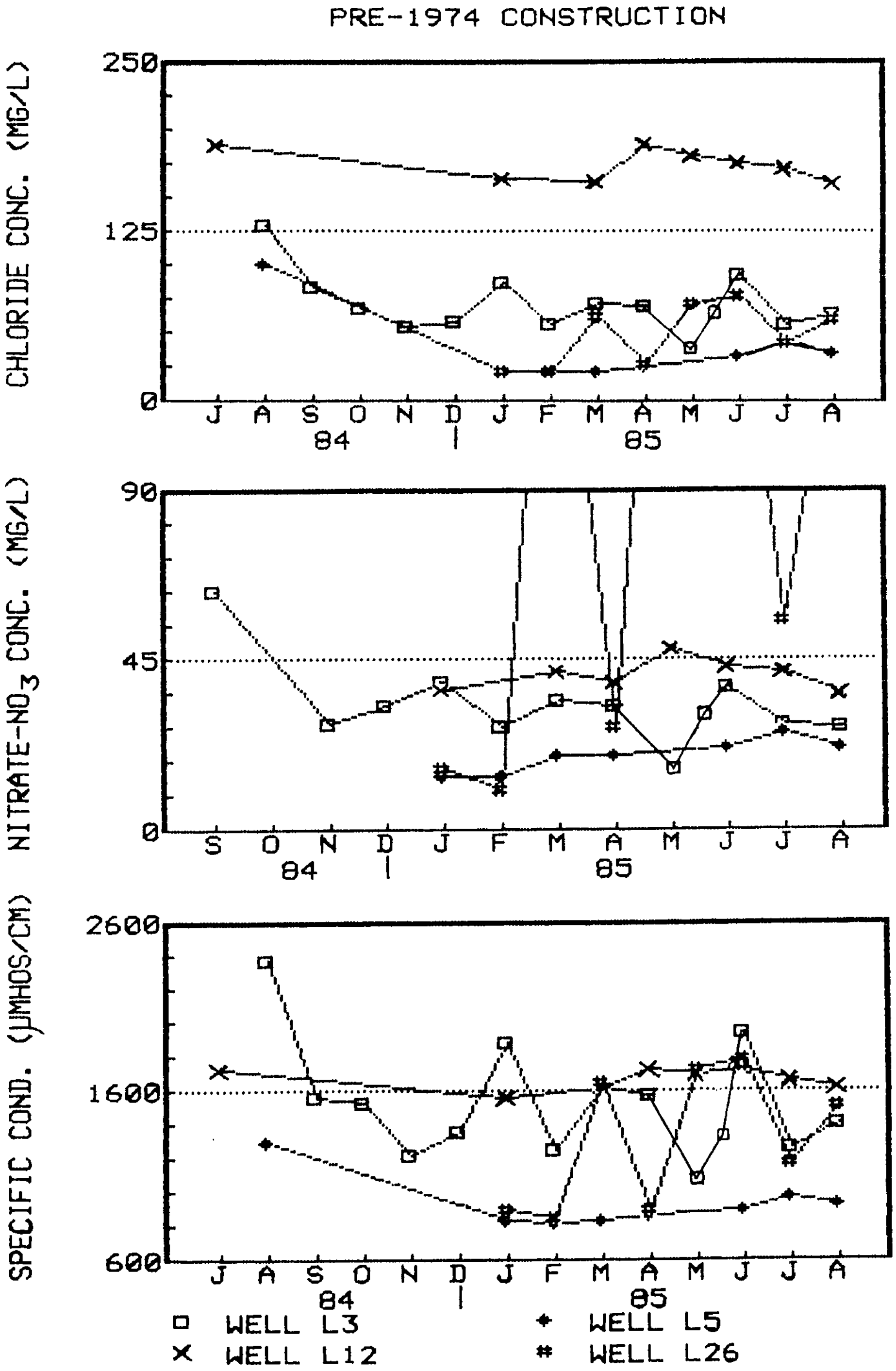


Figure 16. Water-quality hydrographs for wells L3, L5, L12, and L26 (pre-standard construction).

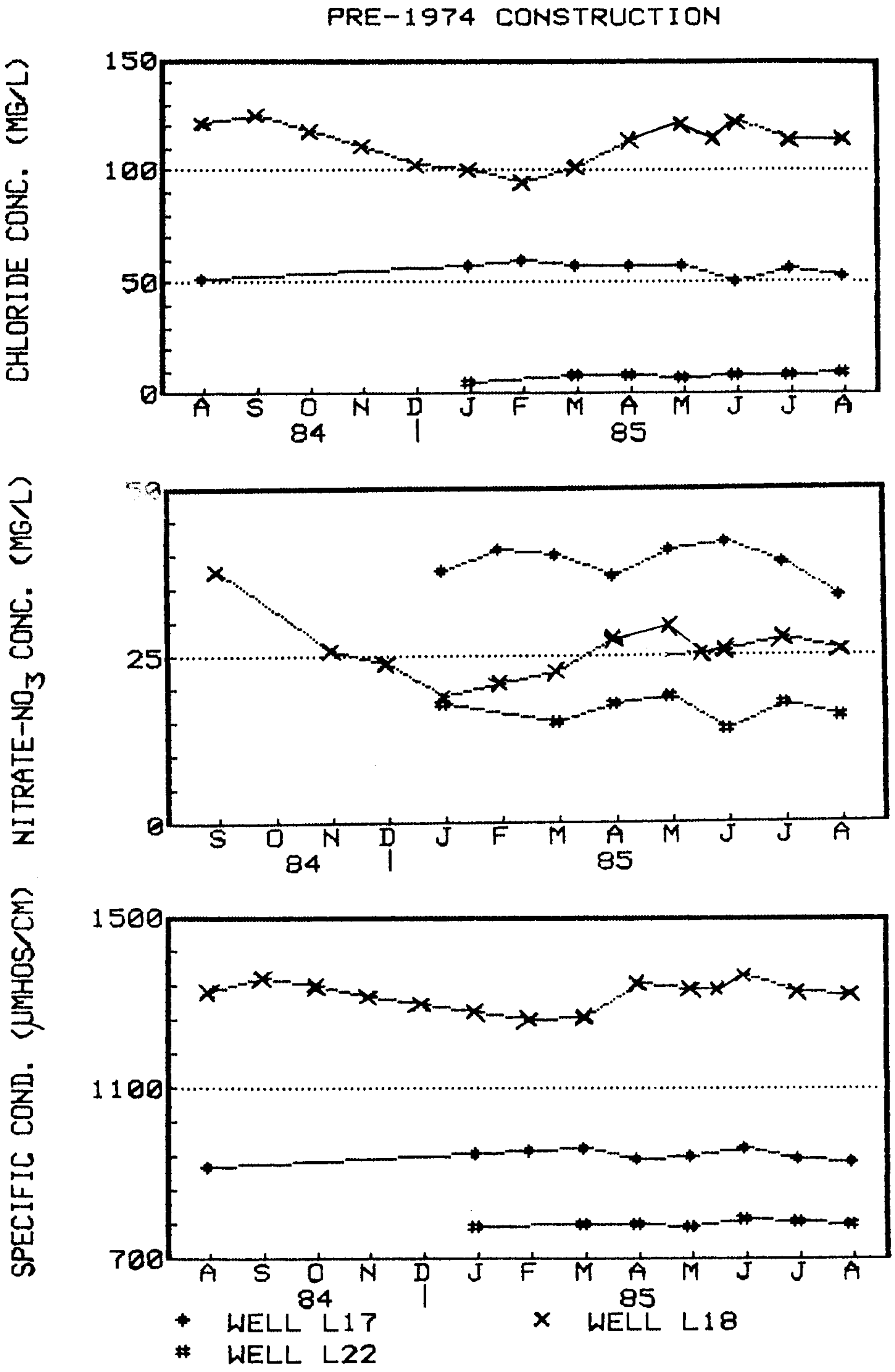


Figure 17. Water-quality hydrographs for wells L17, L18, and L22 (pre-standard construction).

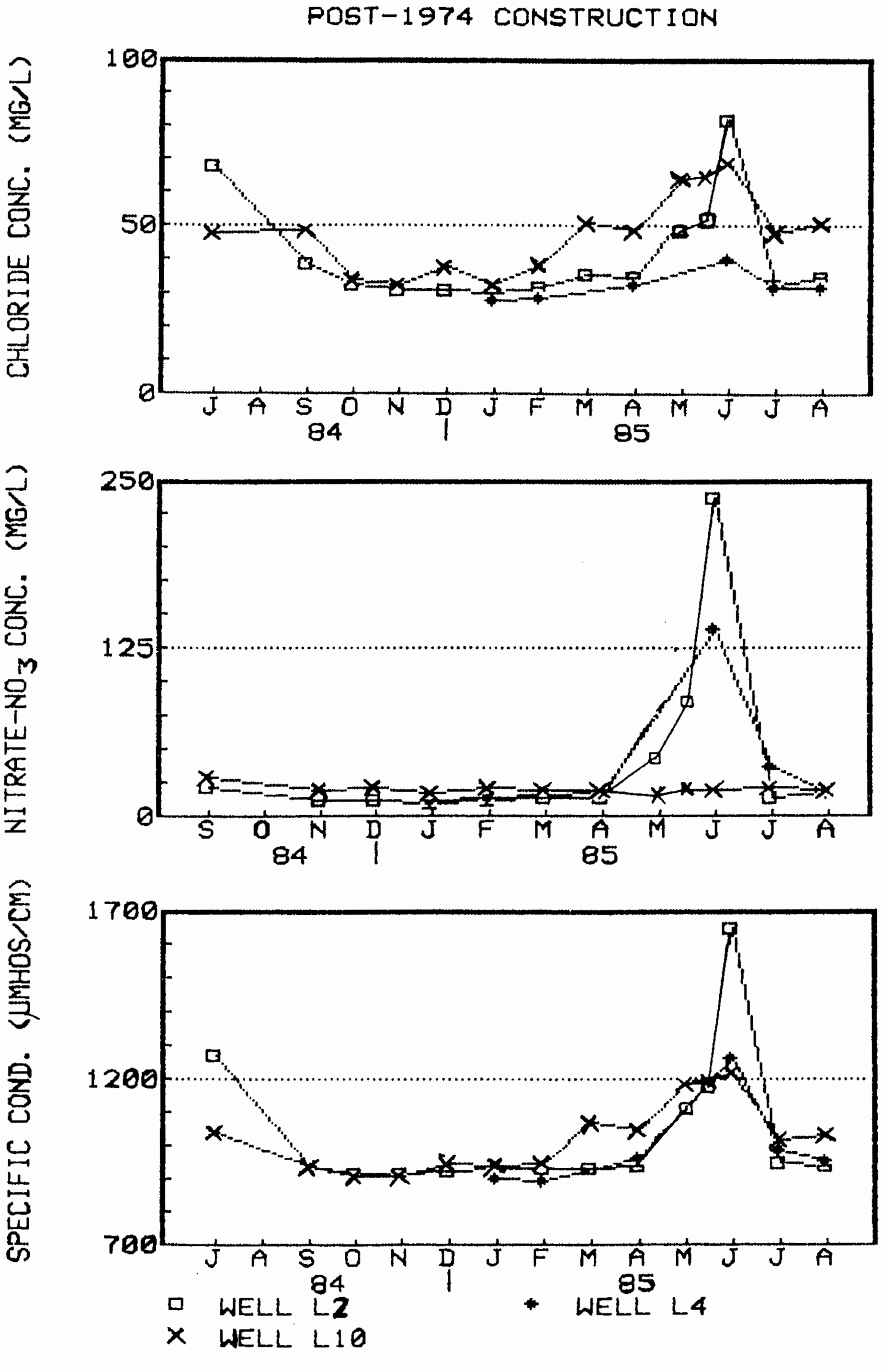


Figure 18. Water-quality hydrographs for wells L2, L4, and L10 (post-standard construction).

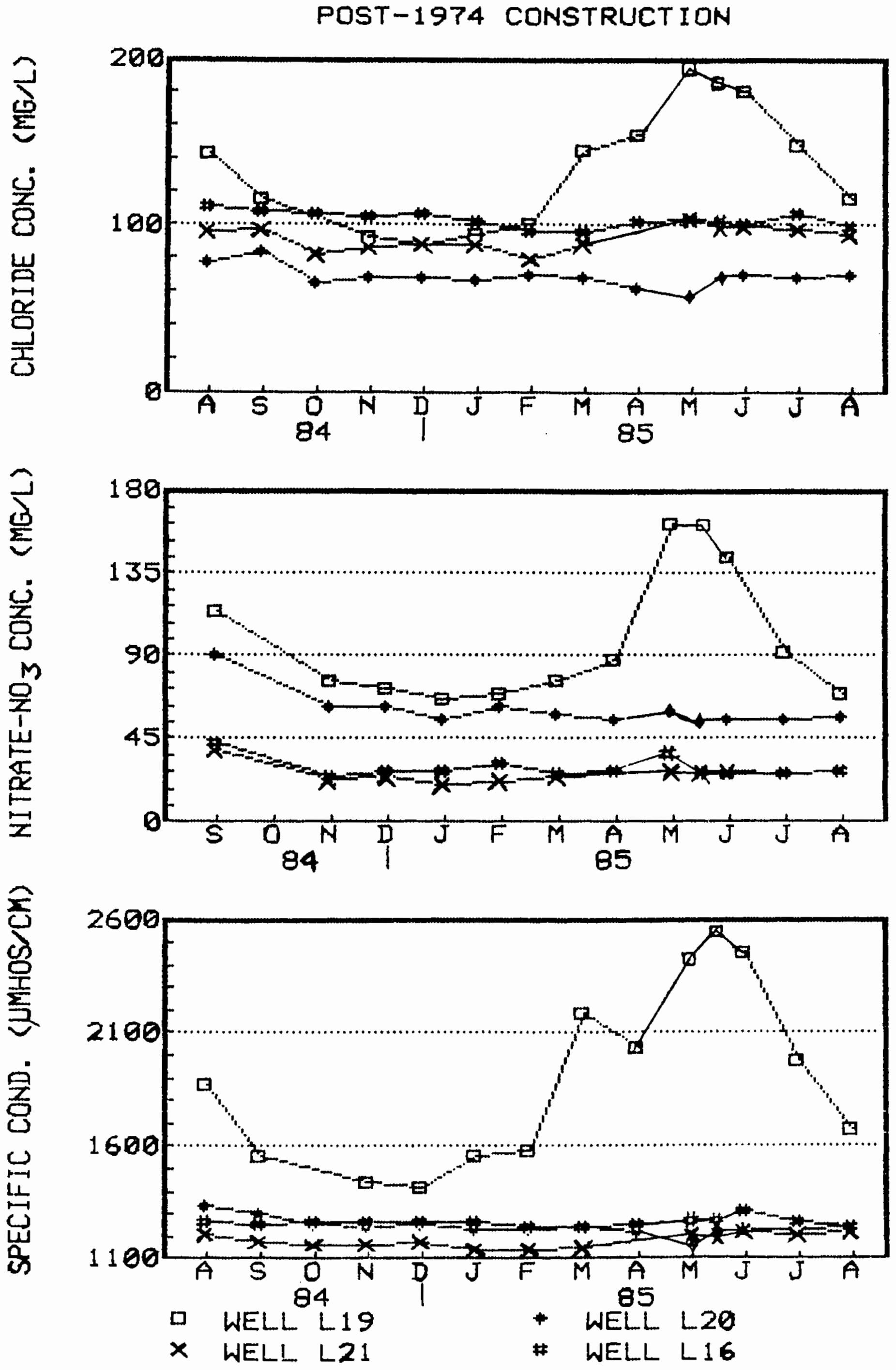


Figure 19. Water-quality hydrographs for wells L19, L20, L21, and L16 (post-standard construction).

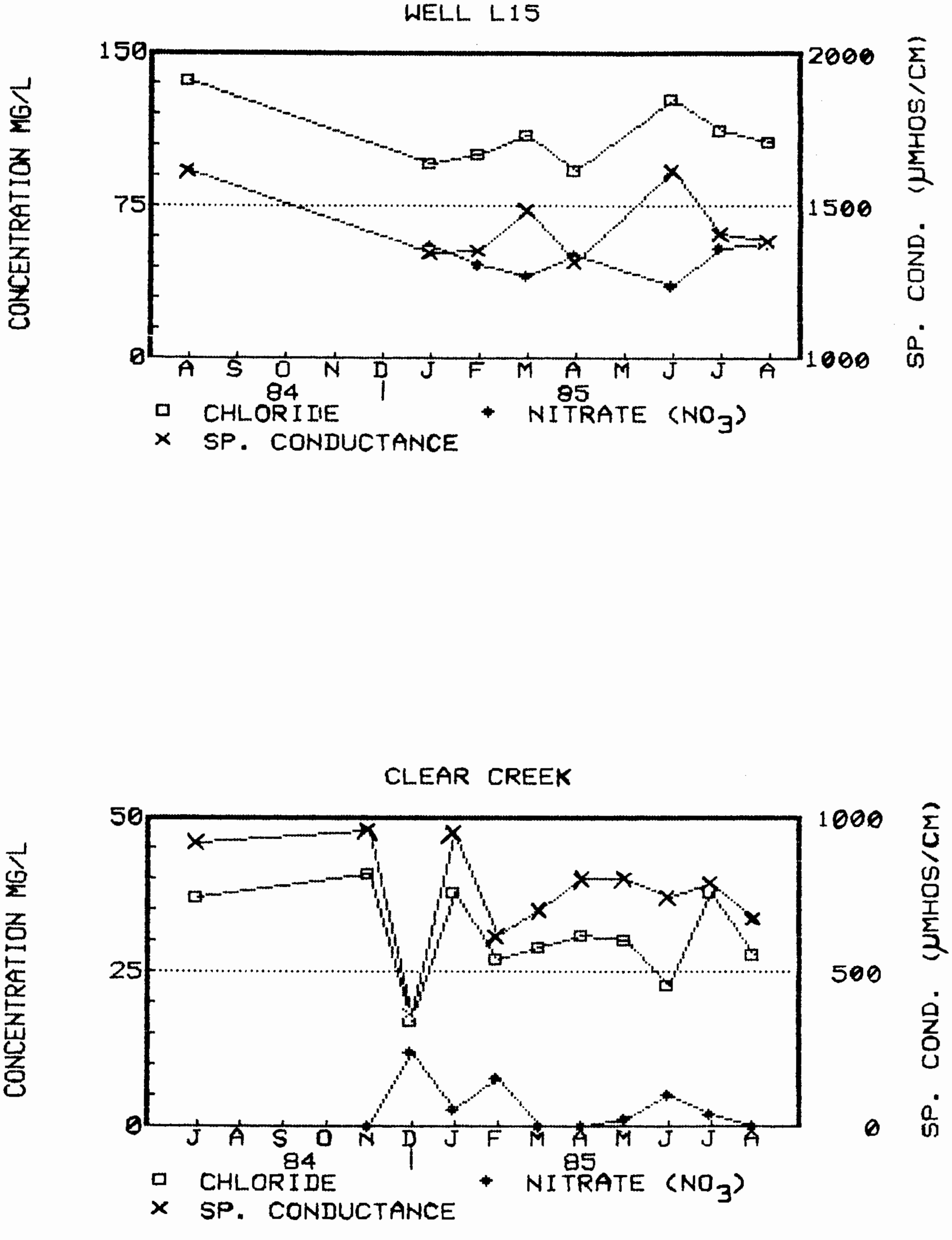


Figure 20. Water-quality hydrographs for well L15 (pre-standard construction) and Clear Creek.

concentrations in the winter and lower in the spring/ summer months was the inverse of that exhibited by the wells. Higher discharge during the spring could have diluted higher constituent concentrations present in baseflows.

Two older wells (L17 and L22) showed little or essentially no fluctuation in ground-water quality on a seasonal basis (Fig. 17). In addition, well L22 showed only slight variation during a short-term pump test (see discussion below). No short-term water quality data was obtained for well L17.

SHORT-TERM VARIATIONS IN CHEMISTRY

Monthly Sampling

Short-term variations exhibited by some wells involved significant increases and decreases between monthly samples and usually occurred within the period May-July. Examples include: wells L2, L3, L4, L10, L19,and L26. Some of these wells also exhibited short-term fluctuations during the winter or early spring in response to precipitation as did Clear Creek.

Bi-Weekly Sampling

Because of the importance of sampling and determination of the constituents involved in the study (TOC, standard inorganic chemistry, bacteria, dissolved gases, chloride and nitrate concentrations, and specific conductance) during a spring month when precipitation was greatest, May was chosen as the month for sample collection. In order to alleviate the logistical problems associated with these sample collections, they were divided between two different sampling dates. On May 8, the eight monitoring wells were sampled for TOC (well L5 was also included) and standard inorganic chemistry analyses. On May 20, samples were collected for examination of bacteria and for determination of chloride and nitrate concentrations and specific conductance using field-testing equipment. In order to monitor ground-water quality during the month of May from other wells besides the eight monthly monitoring wells, samples were collected from five additional wells and Clear Creek on May 22 and 23, and were also analyzed for chloride and nitrate concentrations and specific conductance.

On May 6 and 7, two days before samples were collected for the TOC and inorganic chemistry analyses, a total of 3.45 inches of precipitation fell in the study area. Between the May 8 and May 20-23 sample collections, only one-half inch of precipitation fell in Lincolnville.

Table 2 shows the percent change in the constituent concentrations of ground water from the wells monitored during these two 2-week periods. Constituent concentrations in three of the six newer wells monitored (L2, L10, and L19) increased significantly within the first two-week period. One of two older wells sampled (L3) showed substantial decreases because shallow soil-water, which had seeped into the pit that the well was completed in, was overtopping the casing and flowing into the well on the day the sample was collected.

Table 2. Percent change in constituent concentration during bi-weekly sampling schedule (April-May 1985).

	Chloride Concentration		Nitrate-NO_3 Concentration		Specific Conductance	
Well No.	% Change 4/24-5/8	% Change 5/8-5/20	% Change 4/24-5/8	% Change 5/8-5/20	% Change 4/24-5/8	% Change 5/8-5/20
L2	26	11	68^	45^	16	5
L3*	-46	42	-54	52	-52	43
L10	22	2	-19	23	11	1
L16	1	0	23	-26	2	0
L18*	7	-8	7	-17	-1	0
L19	21	-4	45^	0^	16	5
L20	-3	12	8^	-10^	-5	7
L21	--	-6	--	-4	--	0

(negative values indicate a decrease in concentration)

* well of pre-standard construction

^ this percentage change caused the nitrate concentration to exceed the U.S. EPA Interim Primary Drinking Water Standard of 45 mg/L as NO_3.

These results support the hypothesis that the Nolans Limestone in Lincolnville is rapidly recharged by precipitation leaching water-soluble constituents and contaminants from the vadoze zone and ground surface. Depending on the construction and completion of the local water wells and the direction of ground-water flow, the recharge water can enter the wells and/or the Winfield aquifer and rapidly and appreciably change the water quality.

This sampling schedule in May 1985, with respect to precipitation, also showed that some wells, namely L16, L18, and L20, are capable of very short-term water-quality fluctuations that may not have otherwise been evident on a monthly sampling schedule.

Time-Series Sampling During Short-Term Pump-Tests

Short-term water-quality fluctuations were observed in samples collected from a newer well (L19) during a 60-minute pump-test (Fig. 21). The water quality from this well had not yet stablized by the end of the test even though at least three well-bore volumes of water had been pumped. According to Keely (1982), the pattern exhibited by well L19, suggests not only the possibility that the well penetrated a contaminant plume and, at the same time, was experiencing a brief, localized recharge event, but also the possibility of intermittent loadings of contaminants, as might occur in karstic limestone aquifers.

Later that same day, however, when time-series sampling was conducted during a 90-minute pump-test on an older well (L22), variations in the ground-water quality

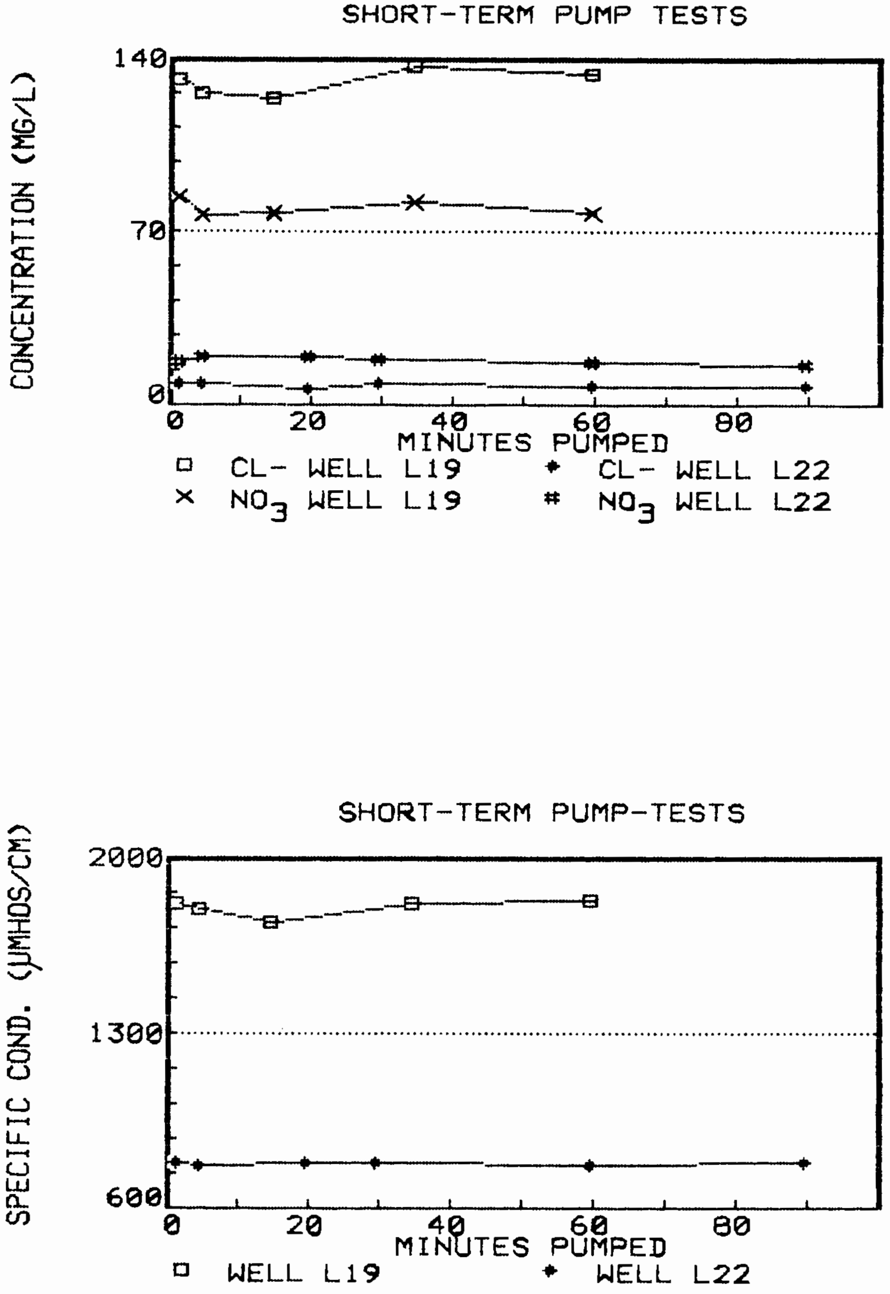


Figure 21. Water-quality hydrographs for wells L19 and L22 from time-series sampling during short-term pump-tests.

remained within the analytical error (Fig. 21). In fact, the range of constituent concentrations during the pump-test (7.5-9.5 mg/L chloride; 17-20 mg/L nitrate; and 783-784 µmhos/cm specific conductance) was slightly less than the total range exhibited through the eight-month period that the well was sampled during the project (5-10 mg/L chloride; 14-19 mg/L nitrate; and 778-796 µmhos/cm specific conductance).

TOTAL ORGANIC CARBON

Figure 22 shows the May and August 1985 concentrations of total organic carbon (TOC) in ground water from the monitoring wells and wells L5 and L22. Volatile organic carbon (VOC), and nonvolatile organic carbon (NVOC) concentrations from each well sampled are presented in Appendix VI. Because there were no detectable amounts of VOC in either sampling, the TOC concentrations shown in Figure 22 actually represent only NVOC concentrations. The fact that VOC concentrations were not detected in the May or August samplings may have been greatly affected by the sampling methods used (see Appendix V). The types of pumps used in the water wells were not conducive to sampling for volatiles and may have resulted in the loss of VOC, if present. In addition, VOC concentrations in the May samples may also have been

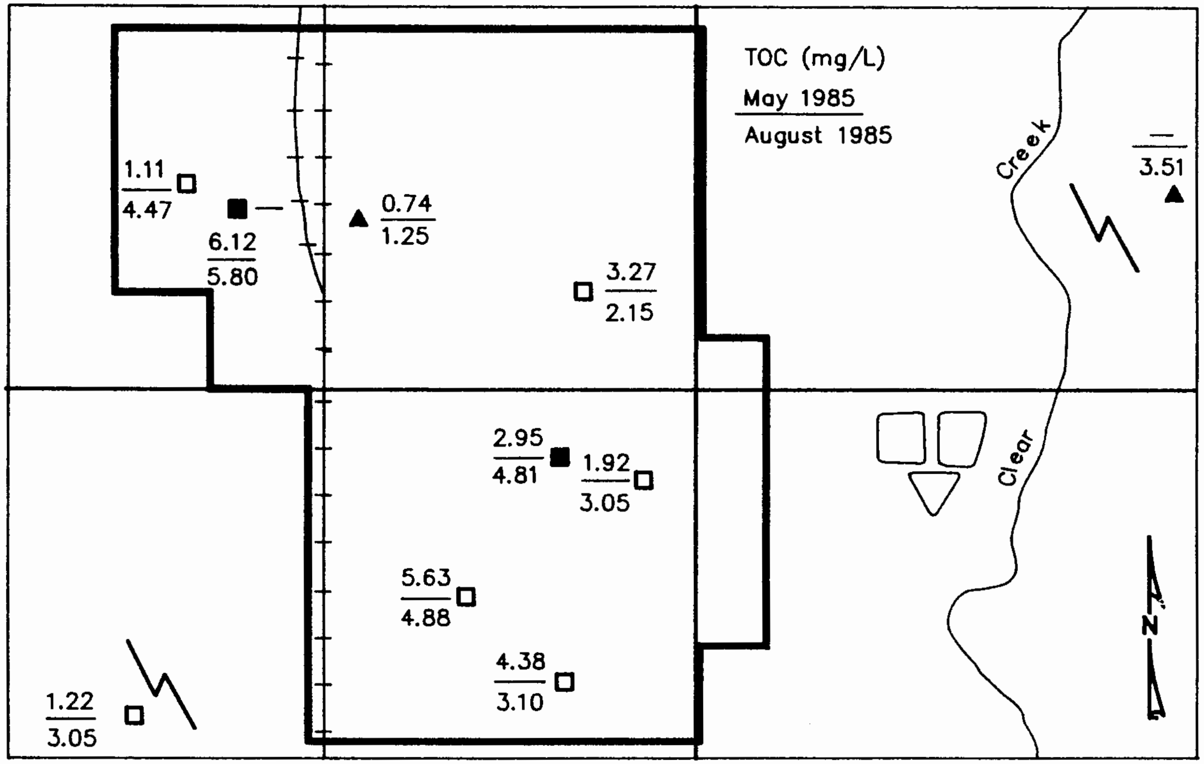


Figure 22. Map of Lincolnville showing total organic carbon (TOC) in ground water from monitoring wells and wells L5 and L22 (represented by solid triangles). Samples collected May 8 and August 15, 1985. Solid symbols represent wells of pre-standard construction and open symbols represent wells of post-standard construction.

affected by equipment malfunction in the laboratory (see Appendix VI).

Dissolved organic carbon (DOC) is defined as the concentration of organic matter in a water sample passed through a 0.45 micrometer membrane filter. Ground water samples collected for TOC analysis in this study were not filtered prior to analysis, therefore, potentially containing both dissolved (DOC) and particulate organic carbon (POC).

The mean concentration of TOC in the May 8th sampling was 3.04 mg/L and the median concentration was 2.95 mg/L. The range of TOC concentrations in May was 0.74 to 6.12 mg/L. The mean and median TOC concentrations in the August sampling was 3.61 and 3.10 mg/L, respectively, while the range of concentrations was 1.25 to 5.80 mg/L.

With the exception of well L5, an older well, all of the wells sampled May 8th produced ground water containing TOC concentrations greater than the range found by Miller (1987) in uncontaminated ground water from consolidated aquifers in Kansas which did not exceed 1 mg/L TOC. In her study the range of TOC concentrations for all samples of uncontaminated ground water from all aquifer types in Kansas was 0.21 to 3.31 mg/L with alluvial aquifers exhibiting the highest values.

The concentrations of DOC found in uncontaminated ground water from limestone aquifers by Leenheer _et al._

(1974), ranged from 0.2 to 5 mg/L with a median value of 0.5 mg/L. TOC concentrations in wells L3 (pre-1974) and L19 (post-1974) exceeded 5 mg/L in the May 8th sampling, and only well L3 exceeded that level in August. The August values for wells L19 and L18 were also close to the 5 mg/L level TOC.

A wider range of DOC in ground waters (1.5-7.3 mg/L) was found in well-water supplies of five small towns in Illinois (Robinson *et al*., 1967).

Many of the samples exhibited an inverse relationship between TOC and NO which agreed with observations made in other studies (Miller, 1987, and Junk *et al*., 1980).

According to Junk *et al*. (1980), the absence of a significant correlation between nitrate and NVOC concentrations in the same well implies major differences in leaching and vertical transport through the unsaturated layer. The primary components of DOC are fluvic acids, which are large polymeric molecules, thus different mobilities from nitrate are to be expected.

Because of the amount of precipitation that fell in the study area prior to the May 8th sampling, discolored soil water had seeped into the well pit of well L3 and was flowing over the top of the casing directly into the well, accounting for its higher TOC concentrations. This undoubtedly would have also occurred in wells L25 and L26 or any of the other wells in the study area completed in pits. However, the concentrations of TOC in many of the other wells probably would have been higher had the samples been collected during the May 20 sampling due to potentially slower travel times for organic molecules (Junk _et al_., 1980).

DISSOLVED GASES

Concurrent with TOC analysis (as VOC and NVOC), determinations of dissolved methane (CH_4), oxygen (O_2), and carbon dioxide (CO_2) were made on duplicate samples collected May 8, 1985. Sampling procedures, analytical methods and results are given in Appendices V and VI. A sample collected at well L21 was accidentally broken in the laboratory and therefore no measurements of these gases are available. If VOC concentrations in any of the ground water samples had been in the detectable range (> 0.02 mg/L), it would have been necessary to determine what fraction was naturally occurring methane. The remaining fraction, therefore, would have indicated anthropogenic contamination.

Methane concentrations in the ground water samples ranged from 0.1 micrograms per liter (μg/L) in wells L5 and L18 (both older wells) to 2.7 μg/L in well L20 (a newer well), and averaged 1.1 μg/L. Figure 23 shows methane concentrations in ground water from the monitoring

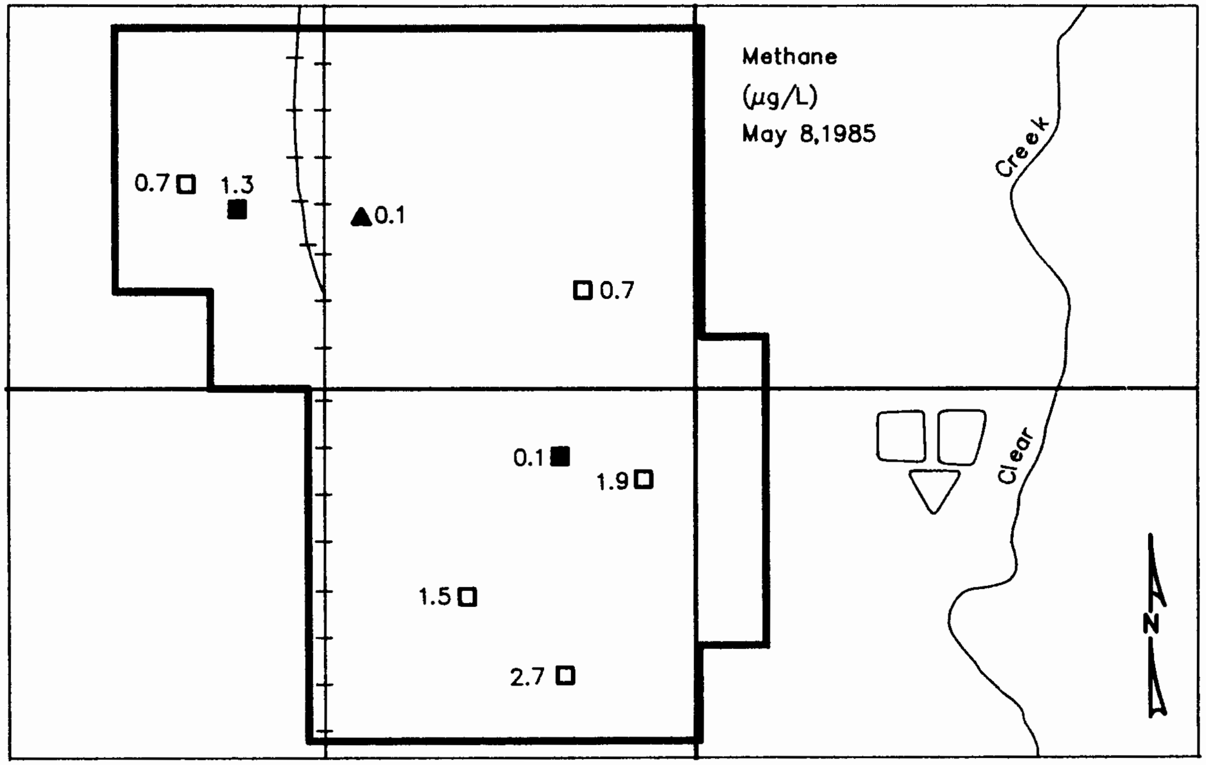


Figure 23. Map of Lincolnville showing concentrations of dissolved methane (CH_4) in ground water from monitoring wells and well L5 (represented by the solid triangle). Solid symbols represent wells of pre-standard construction and open symbols represent wells of post-standard construction.

wells and well L5.

Figure 24 shows concentrations of dissolved oxygen and carbon dioxide in the ground-water samples. Dissolved oxygen concentrations ranged from 0.5 mg/L in well L16 to 6.5 mg/L in well L19, both newer wells, with a mean dissolved oxygen concentration of 2.3 mg/L. Dissolved carbon dioxide ranged from 3.0 mg/L in well L5 (pre-1974) to 40 mg/L in well L19 (post-1974), with a mean concentration of 11.5 mg/L.

STANDARD INORGANIC CHEMISTRY

Most of the wells sampled produced $CaHCO_3$ with a few producing $CaSO_4$ type ground waters. Results of the two standard inorganic-chemistry determinations (September 1984 and May 1985) are listed in Appendix VI. Along with the concentrations for each constituent is a calculated percentage change which, according to Summers (1972), is necessary in evaluating differences in the source of the sample when only two complete chemical analyses are available. Summers proposes that the following criteria apply in this case: If on a 1:1 comparison most concentrations have changed by at least 10 percent, significant differences have occurred in the source. If the concentration of only one constituent has changed by more than 10 percent, analysis of that constituent is

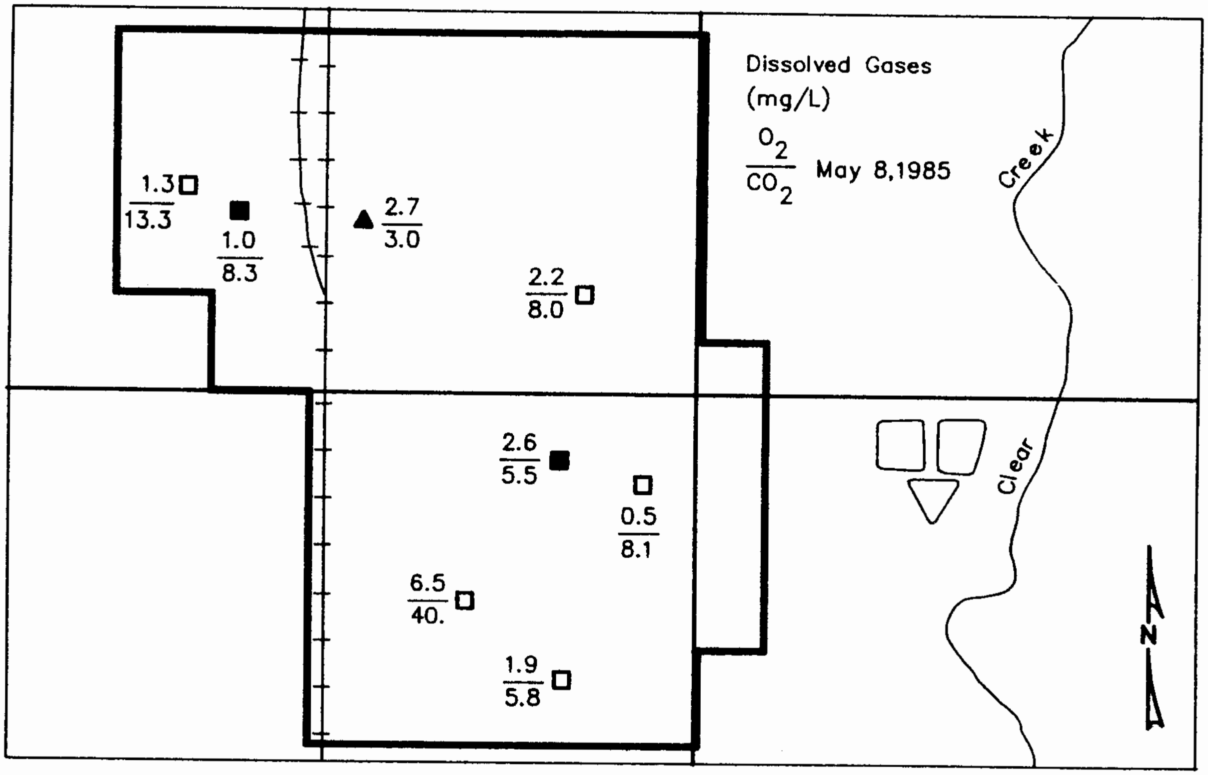


Figure 24. Map of Lincolnville showing concentrations of dissolved oxygen (O_2) and carbon dioxide (CO_2) in ground water from monitoring wells and well L5 (represented by the solid triangle). Samples collected May 8, 1985. Solid symbols represent wells of pre-standard construction and open symbols represent wells of post-standard construction.

suspect. If the differences are less than 10 percent, differences may exist in the source, but two analyses are not sufficient to identify them.

Wells that showed more than a 10 percent increase in most constituent concentrations from the September 1984 samping to the May 1985 sampling were wells L2, L10, and L19 (all newer wells). Hydrographs for these wells (Figs. 18 and 19) showed the substantial increases that occur in chloride and nitrate concentrations and specific conductance during the spring. In addition, historical data from a standard inorganic analysis of a water sample collected from well L10 (June 1983), in the previous Marion County study (O'Connor _et_ _al_., in preparation) is presented in Appendix VI. Figure 1 shows water quality hydrographs for well L10 during the previous county study. There was also a greater than 10 percent increase in most constituent concentrations from the September 1984 sampling to the June 1983 sampling.

Well L3 (an older well) and L20 (a newer well) showed more than a 10 percent decrease in most constituent concentrations from the September 1984 to the May 1985 standard inorganic analyses. Well L3 also showed greater than a 10 percent decrease in constituent concentrations on a short-term basis (see Figure 16 and Table 2).

Ground water from the remaining three wells (L16, L18, and L21), showed less than a 10 percent change in constituent concentrations between the September and May samplings. However, wells L16 and L18 showed a greater than 10 percent change in nitrate concentration on a short-term basis (see Figures 19 and 17, and Table 2).

PUBLIC HEALTH ASPECTS

Nitrate

Nitrate values for the 13-month study period are listed in Appendix VI. Nitrate concentrations (reported as NO_3) in ground-water samples from 23 of the water wells in the study area ranged from 11 to 237 mg/L. Nitrate contents of ground-water samples from the well used at the warehouse facilities, where bulk-nitrogen fertilizer and agri-chemicals were stored and handled, often exceeded 400 mg/L, with one sample (water standing in the casing) exceeding 600 mg/L. Surface water samples from Clear Creek contained from <1 to 12 mg/L nitrate.

Of the 24 wells that were sampled and tested for nitrate at least once during the study period, 12 wells (50 percent) exceeded the MCL of 45 mg/L (or 10 mg/L as N), established by the U.S. EPA (Fig. 25). Four wells (16.5 percent) had been constructed since minimum well construction standards had been established in Kansas in 1974, and eight wells (33.5 percent) had been constructed

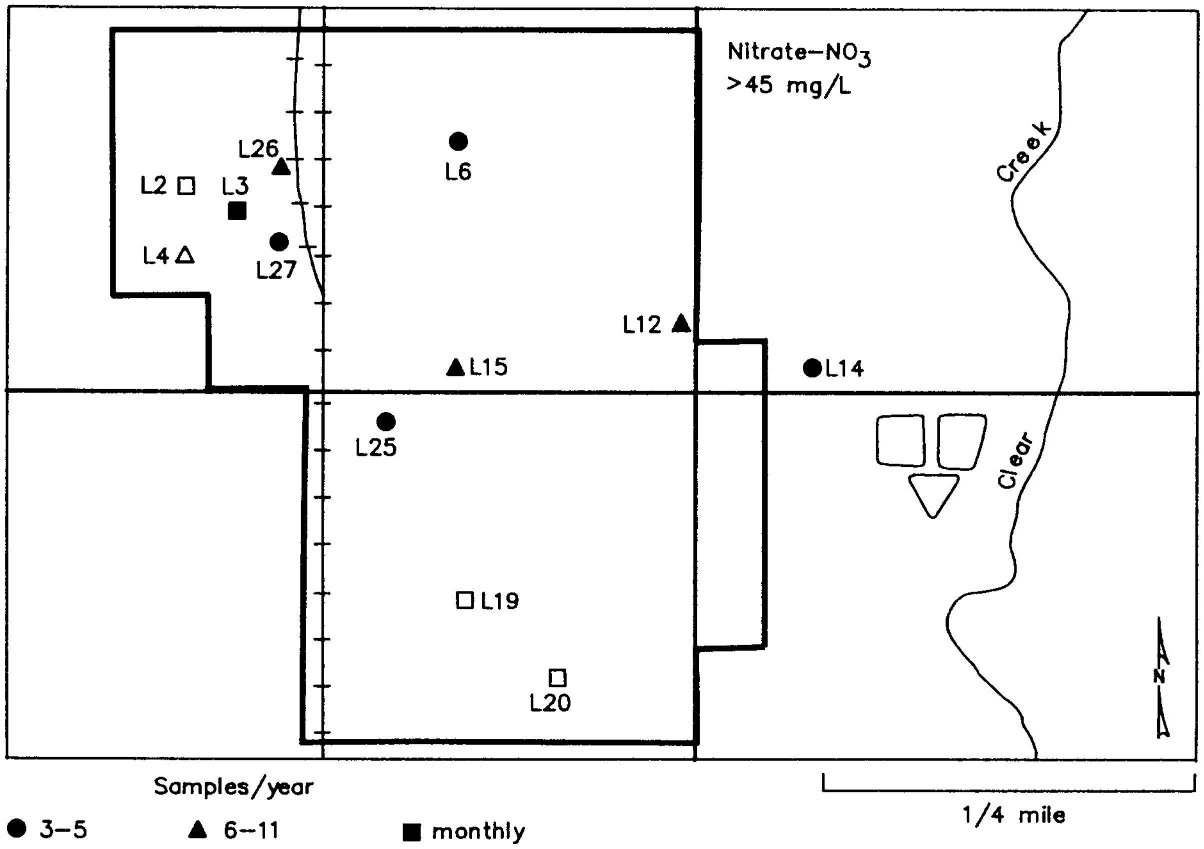


Figure 25. Map of Lincolnville showing water wells (by well number) used in the study that exceeded 45 mg/L NO_3 at least once and sampling frequency. Solid symbols represent wells of pre-standard construction and open symbols represent wells of post-standard construction.

or reconstructed prior to 1974.

Miller (1987) sampled 50 wells across Kansas that were either public water supply or private domestic wells for which well construction information was available. She attempted to select wells supplying uncontaminated ground water. Three of the wells (6 percent) produced ground water containing more than 45 mg/L nitrate.

In the Kansas Farmstead Well Water Quality Study Heiman et al. (1987) sampled 104 farmstead wells in a random, but even distribution, across Kansas between December 1985 and February 1986. Twenty-nine percent of the wells exceeded 45 mg/L nitrate. The wells included both those constructed prior to and since the 1974 minimum well-construction standards.

Wells in this study were similar in construction to many of the farmstead wells studied by Heiman et al. (1987). Based on the seasonal and short-term variations exhibited by many of the wells in this study, it is believed that the percentage of wells in the farmstead well study producing nitrate concentrations in excess of the MCL would have been much greater if the wells had been sampled during the spring months.

Bacteria

Six of the newer wells (post-1974) and two older wells (pre-1974) were sampled in December 1984 for bacteriological examination. Fecal coliform (FC) or fecal Streptococcus (FS) bacteria were below detection limits for nearly all of the wells (Fig. 26). One exception was a sample of water siphoned back from a livestock tank into well L21 through a garden hose connected to a frost-proof hydrant lacking a back-flow preventer, thus producing a large count of fecal Streptococcus bacteria.

Samples collected from these wells on May 20, 1985 still showed fecal coliform bacteria below detection limits (Fig. 26). However, both of the older wells and two of the newer wells showed quantities of fecal Streptococcus greater than the one colony per 100 mL allowed by the U.S. EPA National Primary Drinking Water Standards for public water supplies (U.S. EPA, 1984). The number of bacteria colonies counted might have been much higher had the samples been collected during the May 8 sampling that followed two days in which a considerable amount of precipitation fell in the study area. Research by Bitton _et al_. (1983) has shown that the decay rate for fecal Streptococcus bacteria is lower than for fecal or total coliform bacteria in ground water. Thus accounting for the relatively small quantities of fecal Streptococcus bacteria still present in the May 20 samples.

Because the ratios of FC/FS were less than 0.7 for ground-water samples examined in this study, the source of bacterial pollution is from animal wastes (Pipes, 1982).

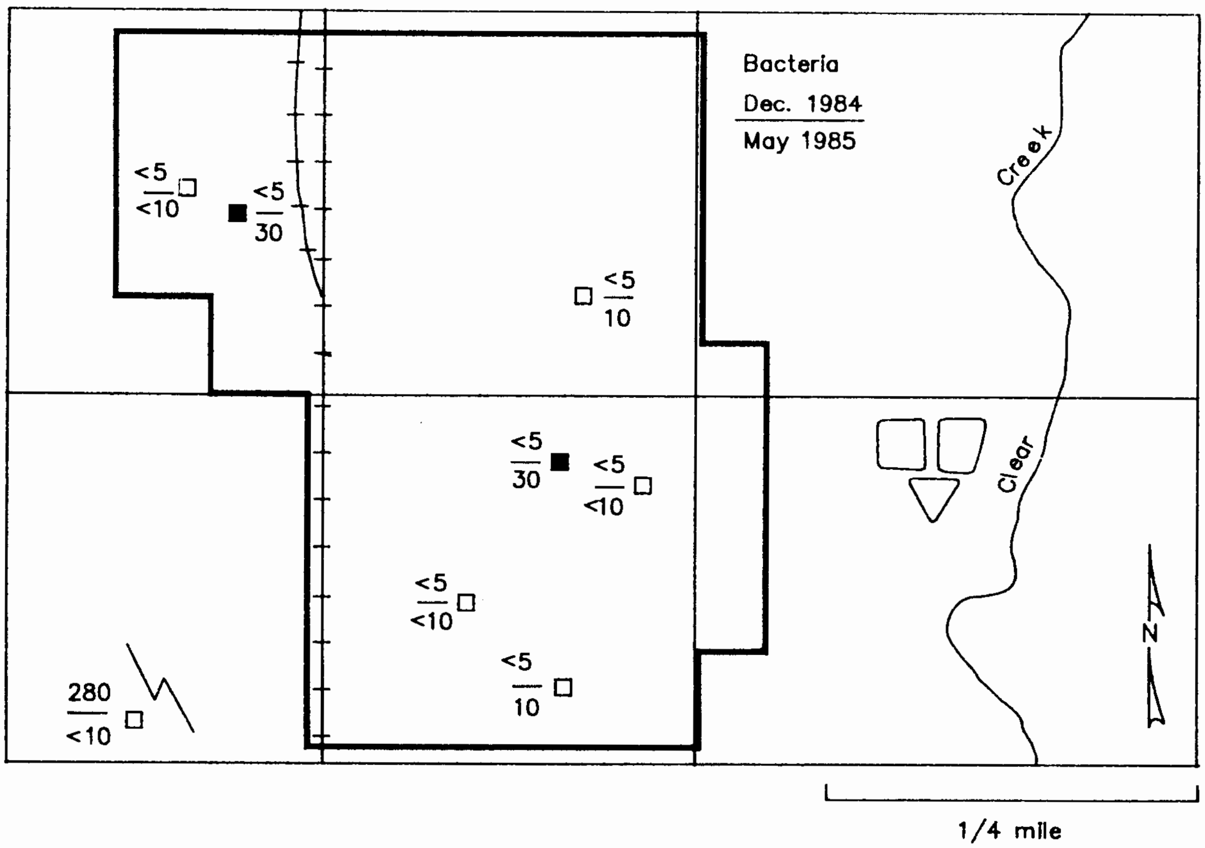


Figure 26. Map of Lincolnville showing fecal Streptococcus bacteria in ground water from monitoring wells sampled December 1984 and May 20, 1985. Results reported as counts per 100 mL sample. Fecal coliform bacteria were not detected. Solid symbols represent wells of pre-standard construction and open symbols represent post-standard construction.

CHAPTER 6

DISCUSSION

The Winfield Limestone, the regional confined aquifer, outcrops east of the study area and is recharged by precipitation. Ground water in the Winfield then moves downgradient to the west-northwest supplying numerous domestic water wells in Lincolnville.

Clear Creek, just east of town, is an effluent stream obtaining its base flow from the Winfield and Nolans aquifers. Water-quality hydrographs for Clear Creek (Fig. 20), provide an indication of the water quality of the Winfield and that of runoff. The large fluctuations observed in December, February, and June represent runoff from recent precipitation events which cause the chloride concentrations and specific conductance to decrease. Simultaneously, the nitrate concentrations increase due to the greater leachability of nitrate during the dormant stage (December and February samples) of vegetation and soil-organisms which tend to tie-up nitrate, and to runoff of agriculturally applied nitrogen fertilizer (June sample) (Bormann, et al., 1968). In addition, baseflow in Clear Creek during the winter months would contain a somewhat greater concentration of nitrate because of the dormancy of vegetation and organisms that otherwise thrive in the stream during the summer months and utilize nitrate, thereby resulting in lower concentrations (H. O'Connor, 1987, verbal comm.).

Chemical variations representative of the Winfield aquifer are shown by the hydrographs of well L22 (Fig. 17). The well is located upgradient from most sources of contamination found in Lincolnville, although it is within 60 ft of both a cattle pen and a septic tank. The well was recased in 1953 by Mr. Riffel who installed and cemented-in 30 ft of iron surface casing (Mrs. Kaiser, written comm., 1986). As a result, water-quality constituents remain relatively constant on both a seasonal and short-term basis (Figs. 17 and 21), despite the fact that the Herington Limestone Member is at a very shallow depth in the vicinity of the well site.

Ground-water quality in well L17 also remained relatively constant on seasonal basis probably due to the long interval of grout from 20 to 35 ft in the annular space of the well (Fig. 12). The grout was apparently effective in preventing hydraulic interconnection between shallow ground water in the Herington and the Winfield.

The Herington Limestone Member of the Nolans Limestone, which is exposed along the upper banks of Clear Creek in the study area, is hydraulically separated from the Winfield aquifer by the lower members of the Nolans and the Odell Shale. The extensive solution permeability and relatively shallow depth throughout the study area easily allow recharge by precipitation. Thus, the Herington becomes an intermittently unconfined aquifer during extended wet periods, in particular during the spring months.

Seasonal recharge to the Herington results in the seasonal leaching of water-soluble substances from the ground surface and unsaturated zone to an intermittent water-table (Pettyjohn, 1982). Recharge to the Herington occurs, for the most part, as infiltration through soils rather than direct entry through fractures or conduits. Soil infiltration can deliver to ground water greater masses and higher concentrations of nitrate, and chloride and a greater mass of pesticides than direct recharge. Recharge occurring as direct entry, or run-in water, results in high concentrations of suspended sediment, pesticides, and bacteria (Hallberg et al., 1985).

The relatively rapid and significant water-quality fluctuations, or 'spikes' exhibited by some of the water wells in the study area represent recharge to the Heringtion being imposed on the Winfield aquifer either directly into the individual well or into an upgradient well or borehole. A spike represents a high-concentration slug of contaminant, which has undergone little mixing with native ground water, that is entering the well (Walker, 1973).

The seasonal spikes observed in water-quality hydrographs for wells L2 and L4 (Fig. 18), represent a slug of high nitrate concentration moving through the Winfield aquifer that originated from shallow seepage into well L27 which is located at the facilities where bulk-nitrogen fertilizer is stored, handled, and spilled. In addition, other types of agricultural fertilizers and chemicals are stored, handled, tank-mixed, and spilled at these facilities, possibly accounting for the high chloride concentration observed at the same time as the high nitrate concentration.

Well L27 is an old well for which very little information exists. At the surface, the well is not adequately covered and appears to have some galvanized steel casing which undoubtedly leaks and is nearly flush with ground level. Therefore, seepage into this well can certainly occur from the shallow subsurface and/or directly into the top of the well. On several occassions when two samples were collected (minutes apart) from well L27, the first sample contained considerably higher concentrations of nitrate, also indicating shallow seepage into the well. The lowest nitrate concentration measured in a sample from this well was 246 mg/L.

Well L26, the elevator office well, is located very near well L27 and the above-mentioned facilities. High nitrate concentration spikes are also observed in water-quality hydrographs for this well (Fig. 16). Because the well is completed in a pit and water had been observed standing in the bottom of the pit on several occasions, the spikes may be related to shallow soil water high in dissolved nitrate overtopping the casing and draining into the well.

Well L3, which is located between wells L26 and L27, and wells L2 and L4, did not exhibit the spikes of high nitrate concentration observed in water-quality hydrographs for these other wells. Conversely, it exhibited a spike of 'fresh' water during the May 8th sampling (Fig. 16) which resulted in a greater than 10 percent decrease in concentration of the standard inorganic constituents from the September 1984 analyses. This spike resulted from soil water that had seeped into the pit of well L3 and was flowing over the top of the casing directly into the well. Although this soil water was 'fresher' with respect to dissolved inorganic constituents, it contained sufficient amounts of organic material (probably humic material and fluvic acids), to cause discoloration and give the water a pH of 6.65 and a TOC concentration of 6.12 mg/L even after one well-bore volume (110 gallons) had been discharged from the well.

Because well L3 is completed in a pit and there is another well (abandoned and unplugged) in a pit about 170 ft north, it is believed that the potential volume of 'fresh' water that entered the Winfield aquifer from these two wells, after any of the precipitation events that occurred during the spring months, was sufficient to cause the slug of high nitrate concentration that was also in the Winfield aquifer to be 'deflected' around or considerably diluted by the bulb of 'fresh' water that was formed.

However, following the decreases in well L3 were substantial increases in constituent concentrations which seemed to be maintained throughout the year except for the occassional sporadic short-term variations. Because neither this trend of ground-water quality nor the constituent concentrations were exhibited by wells L2 and L4, it is believed that ground water in the Herington containing considerably more leached constituents was entering the well bore of well L3. In this case, the 25 feet of iron surface casing in this well was not adequate, either in length or installation, to prevent hydraulic interconnection between the Herington and the Winfield.

Well L5, located just east of the aforementioned facilities, did not exhibit spikes of high nitrate concentration in its water-quality hydrographs similar to those observed in wells L2, L4, and L26, further confirming the direction of ground-water flow in the Winfield to be to the west-northwest. However, well L5 did show a similar pattern of elevated chloride concentration early in the study as exhibited by well L3

(Fig. 16). In addition, a small peak in nitrate concentration occurred in July 1985, one month after the peak concentrations were observed in wells L2 and L4. Even though nitrate concentration data for ground water from Well L5 was not available before January 1985, it is believed that possibly movement toward and seepage into the well had been induced by pumpage of wells east of the railroad for irrigating corn grown in the east right-of-way of the railroad (Albert Riffel, verbal comm., 1985).

Construction details for well L5 suggest that this occurrence is possible, because the well was recased in 1953 using only 12 feet of iron surface casing and 75 feet of galvanized steel casing. Therefore, the Herington Limestone could be exposed to leaky and possibly corroded galvanized steel casing (Fig. 13).

The short-term 'spikes' of appreciably high or low constituent concentrations exhibited by several wells in the study area occurred on a seasonal basis during periods of increasing rainfall, and in some cases in direct response to a precipitation event. They are probably the result of contaminated or 'fresh' water slugs that have entered the Winfield aquifer from the Herington or the soil zone by way of boreholes, whether a new or old domestic or an old abandoned and unplugged well, and have moved downgradient into a well being sampled.

However, water-quality hydrographs for other wells exhibited a different seasonal trend in which constituent concentrations began increasing as early as February and March when warmer temperatures caused frozen conditions in the soil to thaw and allowed infiltration of soil-moisture. In general, these increases were initially gradual but became greater with increased precipitation and usually reached a maximum in June. (This is the same trend exhibited by the water level fluctuations in the study area shown in Figure 15).

An example of such a seasonal trend in chloride and specific conductance was exhibited by well L10 (Fig. 18). The increases were also evident in hydrographs from the previous county study (O'Connor _et_ _al_., in preparation) (Fig. 1) and probably represent recharge to the Herington that resulted from precipitation leaching highway deicing salts applied to Highway 56/77. An insufficient grout interval (Fig. 11) and the proximity of the well to the highway could allow recharge water to enter the Herington, and then reach the annular space of the well and drain downward to the Winfield aquifer. This pathway was supported by a substantial increase in chloride concentration exhibited on a short-term basis (Table 2) subsequent to a major rainfall event in early May 1985.

The large water quality variations, both seasonal and short-term exhibited by well L19 (Figs. 19 and 21, and Table 2) confirm the suspected inadequacy of the grout seal in the annular space of the well (Fig. 14). In this well, the Herington Limestone Member is hydraulically connected to the Winfield aquifer. The well appeared at the surface and from data in the Water Well Record to meet minimum standards. However, the activities of the well owners at the ground surface in the vicinity of the well were reflected in the quality of the well water. The owners applied the following chemicals once a year to their property: Chlordane around the outside of the house, nitrogen and phosphorus fertilizers on the yard and garden in the fall, and 2-4-D to the yard to kill dandelions and other broad leaf weeds. Leaching and transport through the soil into the Herington of some of the soluble chemicals and other soil constituents in the vicinity of the well probably occurs. Once in the Herington the water moves to and drains down the well bore to the Winfield aquifer because of the inadequate grout seal (Fig. 14), and causes appreciable increases in constituent concentrations in ground water from well L19 in the spring and early summer period and high TOC concentrations.

The setting of Well L20 is almost identical to that of Well L19 except that there are two old abandoned wells at the site. One of the wells was reported to be plugged and covered. The other well (L23) was used in the study to measure water levels and was inadequately covered. The owners of the site reported applying fertilizer to their yard in the spring of 1984 and that they only do so every two or three years. The nitrate-concentration hydrograph for well L20 has both similarities to and differences from that of well L19 (Fig. 18). First, both begin at an excessive nitrate concentration (>45 mg/L), then show a similar decline and stablization in concentration in the fall through late winter period. Then, as the concentration increases towards another peak in May 1985 for well L19, that of well L20 decreases slightly, followed by a small increase by May 8th, then remains relatively constant through the rest of the study period.

The trends exhibited by these hydrographs may be related to the applications of nitrogen fertilizer as reported by the well owners. Fall applications could have been observed in the spring/summer at well L19, while a single application in the spring of 1984 probablly caused the peak prior to the start of the study at well L20, then by late fall evidence of the application had disappeared.

The average rate of nitrogen fertilizer application to turf lawn has been estimated to range from 1.46 to 3 lbs N/1000 sq ft (Porter, 1980). Approximately 60 percent of the nitrogen from this source can eventually reach ground-water bodies (Katz et al., 1980). One study showed that inorganic nitrogen fertilizer applied in early October had virtually disappeared from the soil profile (top 20 inches) by mid-March (Porter, 1980).

Shallow intermittent ground water in the Herington could contain less total-dissolved inorganic constituents due to short residence time, but also could contain organic material and other contaminants. A greater than 10 percent decrease in the inorganic constituent concentrations between the September 1984 and the May 1985 samplings, a decrease in chloride concentration and specific conductance on a short-term basis, and the owners' reports of 'dirty' and 'lake-odor' water produced by well L20 during wet periods fit this interpretation. This could also partially explain the TOC concentration of 4.38 mg/L in well L20 on May 8th and a fecal Streptococcus bacteria count of 10 per 100 mL of sample on May 20th.

The most numerous recorded occurrences of dissolved gases, sediment, discoloration, and/or odor in ground water from the sampled wells were in the spring and early summer months. However, these observations were influenced by several factors: if the sample was collected from an inside-the-house tap these occurrences would not have been as apparent; if water was allowed to discharge into a container, a better visual examination was possible; less attention to such occurrences was taken during sample collection early in the study; and problems in the pump or piping system of a well might have introduced air into the water sample.

The methane concentrations, ranging from 0.1 to 2.7

micrograms per liter (µg/L), found in the samples collected May 8th were considered to be low (Judson, verbal comm., 1985). Concentrations of VOC's and the dissolved gases methane, oxygen, and carbon dioxide, were undoubtedly affected by the method of sampling, especially where variable displacement pumps were used, such as the submersible and jet pumps in all of the wells in the study area. Barcelona et al., (1984), investigated positive displacement types of ground water sampling equipment in a laboratory setting under ideal conditions. Even though positive displacement pumps, as opposed to variable displacement types, are extensively used in ground water monitoring wells, their research showed that several types of the sampling mechanisms caused varying amounts of degassing and loss of volatiles.

The dissolved oxygen concentrations in the samples ranged from 0.5 to 6.5 mg/L (Fig. 23). The concentrations may be typical of ground water from depths comparable to those of the water wells used in the study area (75 to 115 ft in depth). The solubility of oxygen in water at 5^{o}C and atmospheric pressure is 12.8 mg/L and it decreases with higher temperature to 7.5 mg/L at 30^{o}C. The oxygen content of ground water at depths greater than 100 to 150 feet is often low, because it is consumed by the oxidation of organic matter as the water flows through both the vadose and saturated zones (Driscoll, 1986). The highest dissolved oxygen concentration observed, 6.5 mg/L, in the sample from well L19 probably represents the rapid flushing of very shallow water into the 107 ft-deep well.

The highest concentration of dissolved carbon dioxide was also found in the sample from well L19 (40 mg/L), further indicating a shallow source where considerable biochemical and hydrochemical activities occur (Freeze and Cherry, 1979). Oxidation of the higher concentration of TOC in ground water from this well could supply some of the dissolved carbon dioxide.

Kerfoot _et al_., (1988), showed a general correlation between ground-water inorganic carbon and organic carbon concentrations. Their findings are in agreement with several observations by others of increased ground-water inorganic carbon concentrations due to subsurface oxidation of organic material.

The concentration of bicarbonate in the May 8th sample from well L19 was comparatively higher than for all other ground-water samples (Appendix VI), indicating greater dissolution of calcium carbonate. Although the higher ionic strength of the water could account for some of the greater calcite solubility, the high concentration of carbon dioxide suggests that higher carbonic acid concentrations were more important in increasing carbonate dissolution.

CHAPTER 7

CONCLUSIONS

The domestic water needs of Linconville are supplied by private water wells tapping the Winfield Limestone aquifer. Water-well construction methods used in the area prior to 1974, when regulations governing well construction standards were established, were different from those utilized since 1974. The methods of water-well construction were found to appreciably affect the temporal variability of the ground-water quality in Lincolnville.

Water wells constructed before 1974 with a sufficient length of heavy iron surface casing extending from above ground surface down through the entire thickness of the Herington Limestone Member, produced ground water of generally good quality. Concentrations of dissolved inorganic constituents were typically low and did not fluctuate significantly throughout the year.

Older wells (pre-1974) constructed without the length of iron surface casing or completed in leaky well pits allowed shallow ground water from the Herington or soil water to enter the well bore or casing, thereby hydraulically connecting these shallow zones with the Winfield aquifer. This caused water-quality variations on a seasonal and often times short-term basis.

Although the minimum standards improved water wells constructed since 1974, many of the newer wells in the study area exhibited seasonal and short-term water quality fluctuations similar to those observed in the older wells. These fluctuations were also the result of hydraulic interconnection between the Herington and the Winfield due to an inadequate grout seal in the annular space of the well. Two common problems that were indentified as causing an inadequate grout seal were an insufficient annular space for effective grout placement and an insufficient length of grouted interval to seal out the entire thickness of the Herington Limestone Member. Newer wells that were constructed with an adequate grout seal, such that hydraulic interconnection between the Winfield aquifer and water in the soil or Herington was prevented, produced ground water that showed very little temporal variation in quality. However, such wells that were located downgradient of other wells with a hydraulic interconnection, produced ground water exhibiting short-term variations in quality on a seasonal basis.

The seasonal trend most commonly observed in the ground water from wells monitored monthly consisted of declining or stablized constituent concentrations from late summer through late winter. In early spring through early summer concentrations increased, coincident with increasing precipitation. Short-term water-quality fluctuations were most often observed during this latter period.

The frequency and amplitude of the water quality variations were dependent upon the quantity and quality of soil water and the shallow ground water in the Herington Limestone Member and the construction details of the wells. Wells that allowed hydraulic interconnection between the shallow zones and the Winfield aquifer could be expected to show the greatest concentrations of nitrate, chloride, and fecal Streptococcus bacteria. In addition, greater values of specific conductance and more dissolved gases, sediment, and sometimes discolored water were observed after periods of extended precipitation generally in the period from late winter to early summer.

Wells located near point or line sources of nitrate contamination commonly exhibited fluctuations in water quality in which nitrate concentrations often exceeded the MCL of 45 mg/L as NO_3 established for public drinking water supplies. In some cases nitrate concentrations exceeded the MCL by several times. A major source of nitrate contamination was a bulk-nitrogen fertilizer storage and handling facility in the northwest part of Lincolnville. Another source of nitrate contamination believed to be responsible for elevated concentrations in some of the wells was application of nitrogen fertilizers to yard and garden areas.

The study indicates that if minimum construction standards do not preclude the possibility of hydraulic interconnection of the Winfield aquifer and water in the soil or Herington Limestone Member in domestic water wells constructed during the period from 1974 to May 1987, the quality of ground water produced could pose a threat to public health. The current regulations on minimum well-construction standards, as of May 1987, provide a greater degree of protection than the past regulations that were in effect during the period of this study, because they require a minimum of 20 ft of grout in the annular space or to a minimum of five feet into the first clay or shale layer, if present, whichever is greater. It is further required that waters from two or more separate aquifers shall be separated from each other in the borehole by sealing the borehole between the aquifers with grout.

APPENDIX I

Lithologic and Gamma Ray Logs

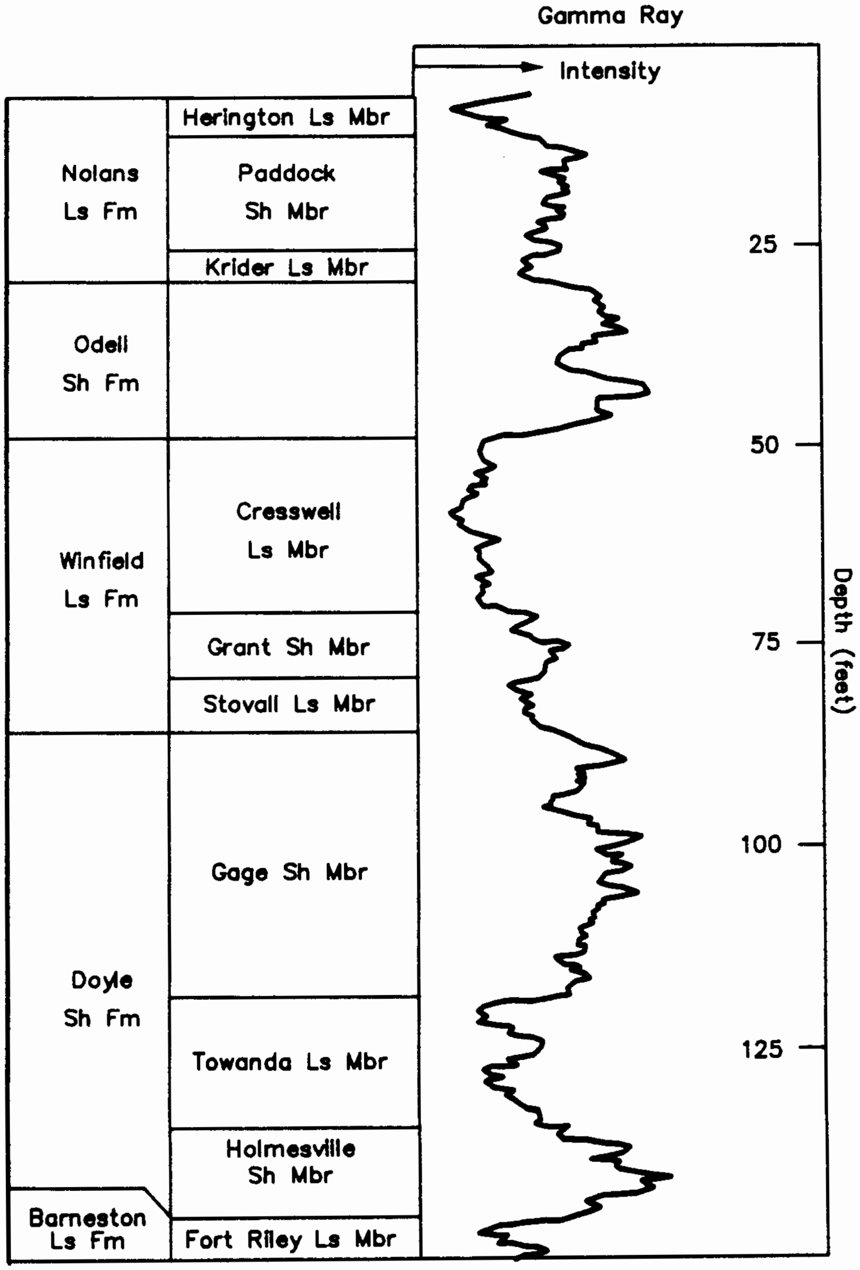
Driller's log of a partially rotary drilled and partially cored test hole bored by the Kansas Geological Survey on July 29, 1982, at the Kansas Department of Transportation materials/mixing strip located on the west side of Highway 56/77 less than one mile north of Lincolnville, Kansas, in NE 1/4, SE 1/4, NE 1/4, NW 1/4, sec. 11, T. 18 S., R. 4 E. Surface altitude, 1,422 feet.

	Thickness, feet	Depth, feet
Soil, sandy, dark brown	2	2
Quaternary and/or Tertiary (undif.)		
Clay, sandy, dark grey-brown	2.5	4.5
Clay, sandy, dark red-brown and grey-brown	1.5	6
Permian - Leonardian		
Wellington Formation		
Shale, red-brown	2	8
Shale, grey-green	2	10.2
Limestone, dolomitic, tan	0.8	11
Limestone, dolomitic, light green-grey, with calcite concretions	1.5	12.5
Shale, green	2	14.5
Shale, calcareous, tan; contains thin limestones streaks	2	16.5
Nolans Limestone Formation		
Limestone, tan	1.9	18.4
Void; circulation lost	0.5	18.9
Limestone, dolomitic, very hard, tan to light brown; contains solution vugs (0.5 mm to 5 cm) lined with calcite crystals	0.8	19.7
Mudstone, dolomitic, hard, very light tan	3.3	23.0
Blind drilling, no samples; drilling was hard and 'crunchy' sounding	5	28
Shale, blue-grey; material on drill bit when stopped drilling at 28 ft depth		

Driller's log of a water well drilled with a cable tool rig in Lincolniville, Kansas, by Joe Zinn for Ben Schnieder on October 28-30, 1985, in SW 1/4, NE 1/4, SW 1/4, SW 1/4, sec. 11, T. 18 S., R. 4 E. Surface altitude, 1,430 feet; depth to water, reported 36 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Fill material		
Clay, light grey	5.5	7.5
Sand	4.5	12
Permian - Leonardian		
Wellington Formation		
Shale, green	8	20
Shale, cavey, yellow	3	23
Nolans Limestone Formation		
Limestone, hard, yellow	4	27
Limestone, soft, fractured	5	32
Limestone, hard, yellow	1	33
Shale, hard, grey	10	43
Limestone, hard, light brown, harder at 45 feet	8	51
Odell Shale Formation		
Shale, light blue-green	5	56
Shale, red	2	58
Limestone	1	59
Shale, red	2	61
Limestone	1	62
Shale, blue-grey	3	65
Winfield Limestone Formation		
Limestone, light tan	1	66
Shale, grey	1	67
Limestone, light tan	5	72
Break; water	1	73
Limestone, dolomitic	2	75
Shale	1	76
Limestone, light grey, hard at 80 ft; very few cuttings - very fine grained from 83.5 to 90 feet	14	90

Gamma ray log run on a test hole for Ted Haefner in Lincolnville, Kansas, in the SW 1/4, SW 1/4, SE 1/4, sec. 11, T. 18 S., R. 4 E. Surface altitude approximately 1,415 feet. Date of the log and the company that ran it are not known.



APPENDIX II

WWC-5 Forms for Post-1974 Water Wells Used in Study

USE TYPEWRITER OR BALL POINT PEN-PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

JUL 24

3 80 16800

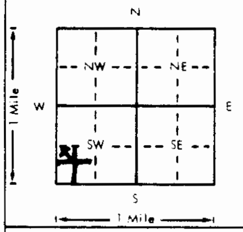
Kansas ~~Department of~~ Health and
~~Environment-Division~~ of Environment
(Water well Contractors)
Topeka, Kansas 66620

1. Location of well:	County	Fraction	Section number	Township number	Range number
	Marion	NW 1/4 SW 1/4 SW 1/4	11	T 18 S	R 4 E/W

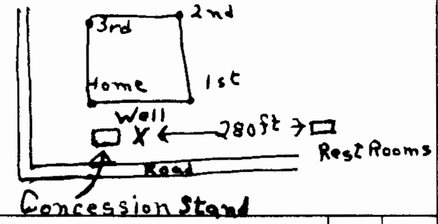
2. Distance and direction from nearest town or city: 1/4 W. 1/4 N.
Street address of well location if in city: from Lincolnville, Kans.

3. Owner of well: Lincolnville Athletic Assoc.
R.R. or street: Robert Kleinschmidt - Pres.
City, state, zip code: Lincolnville Kans. 66858

4. Locate with "X" in section below:



Sketch map:



6. Bore hole dia. 6 in. Completion date 7-1-80
Well depth 85 ft.

7. X Cable tool __ Rotary __ Driven __ Dug __ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: __ Domestic __ Public supply __ Industry __ Irrigation __ Air conditioning __ Stock __ Lawn __ Oil field water X Other

9. Casing: Material Plastic Height: Above ~~or below~~
Threaded ____ Welded X Surface 14 in.
RMP ____ PVC X Weight 2.5 lbs./ft.
Dia. 5 in. to 55 ft. depth Wall Thickness: inches or
Dia. ____ in. to ____ ft. depth gage No SDR 21

5. Type and color of material	From	To
Clay - Brown	0	6
Clay - Light yellow	6	18
Limestone Rock - Light yellow	18	24
Lime - Light Grey	24	32
Blue Shale - Dark	32	48
Shale - Light Gray	48	52
Clay - Red	52	60
Shale - Gray	60	65
Shale - Layers with Water Sand - Med.	65	78
Blue Shale - Light	78	85
(Use a second sheet if needed)		

10. Screen: Manufacturer's name Certain Teed
Type Plastic Dia. 5 in
Slot/~~gauze~~ 3/32 x 4 Length ____
Set between 55 ft. and 85 ft.
____ ft. and ____ ft.
Gravel pack? NO Size range of material ____

11. Static water level: mo./day/yr.
45 ft. below land surface Date 7-1-80

12. Pumping level below land surfaces:
66 ft. after 1/2 hrs. pumping 24 g.p.m.
____ ft. after ____ hrs. pumping ____ g.p.m.
Estimated maximum yield 30 - 40 g.p.m.

13. Water sample submitted: mo./day/yr.
__ Yes X No Date ____

14. Well head completion:
X Pitless adapter 14 Inches above grade

15. Well grouted? yes
With: X Neat cement ____ Bentonite ____ Concrete
Depth: From 2.5 ft. to 15 ft.

16. Nearest source of possible contamination:
ft. 280 Direction S. Type Rest Rooms
Well disinfected upon completion? X Yes ____ No

17. Pump: ____ Not installed
Manufacturer's name Dempster
Model number B30 8YR HP 1/2 Volts 220
Length of drop pipe 82 ft. capacity 13.5 g.p.m.
Type:
X Submersible ____ Turbine
____ Jet ____ Reciprocating
____ Centrifugal ____ Other

18. Elevation:

Topography:
____ Hill
____ Slope
X Upland
____ Valley

19. Remarks: No. 8 Other - Watering of Ball Diamond field.
Sign has been Posted - Not for Drinking Purposes.

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Benda Drilling 161
Business name License No.
Address Lincolnville, Ks. 66858
Signed Paul W. Benda Date 7-22-80
Authorized representative

T 18 — R 4 W — Sec 11 — 1/4 1/4 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL L2

USE TYPEWRITER OR BALL POINT PEN–PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

Kansas Department of Health and
Environment–Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

1. Location of well: County: Marion | Fraction: Sw 1/4 Sw 1/4 Se 1/4 | Section number: 11 | Township number: T 19 S | Range number: R 4 [✓ E] W

2. Distance and direction from nearest town or city: In Lincolnville

Street address of well location if in city: North of main St.

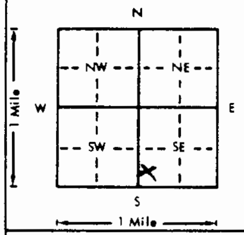
3. Owner of well: David Schneider

R.R. or street: City

City, state, zip code: Lincolnville Ks 66858

4. Locate with "X" in section below:

Sketch map:



5. Type and color of material

	From	To
Top Soil	0	2
yellow Clay	2	12
Lime Stone	12	34
Yellow Shale	34	70
Lime Stone	70	85
water	85	
Lime Stone	85	91

(Use a second sheet if needed)

6. Bore hole dia. 10 in. Completion date 6-11-76

Well depth 90 ft.

7. ☒ Cable tool ☐ Rotary ☐ Driven ☐ Dug ☐ Hollow rod ☐ Jetted ☐ Bored ☐ Reverse rotary

8. Use: ☒ Domestic ☐ Public supply ☐ Industry ☐ Irrigation ☐ Air conditioning ☐ Stock ☐ Lawn ☐ Oil field water ☐ Other

9. Casing: Material PVC Height: Above or below

Threaded ____ Welded ____ Surface 15 in.

RMP ____ PVC X Weight Sch 40 lbs./ft.

Dia. 5 in. to 90 ft. depth Wall Thickness: inches or

Dia. ____ in. to ____ ft. depth gage No. .258

10. Screen: Manufacturer's name M.P.I.

Type PVC Dia. 5"

Slot/gauze 40 Length 20

Set between 70 ft. and 90 ft.

____ ft. and ____ ft.

Gravel pack? X Size range of material 30

11. Static water level: mo./day/yr.

____ ft. below land surface Date ____

12. Pumping level below land surfaces:

____ ft. after ____ hrs. pumping ____ g.p.m.

____ ft. after ____ hrs. pumping ____ g.p.m.

Estimated maximum yield ____ g.p.m.

13. Water sample submitted: mo./day/yr.

____ Yes ____ No Date ____

14. Well head completion:

X Pitless adapter ____ Inches above grade

15. Well grouted? X

With: X Neat cement ____ Bentonite X Concrete

Depth: From 20 ft. to 30 ft.

16. Nearest source of possible contamination: City Sewer

ft. 60 Direction E Type Line

Well disinfected upon completion? X Yes ____ No

17. Pump: X Not installed

Manufacturer's name ____

Model number ____ HP ____ Volts ____

Length of drop pipe ____ ft. capacity ____ g.p.m.

Type:

☐ Submersible ☐ Turbine
☐ Jet ☐ Reciprocating
☐ Centrifugal ☐ Other

18. Elevation:

Topography:
☒ Hill
☐ Slope
☐ Upland
☐ Valley

19. Remarks: Owner to run concrete slab around well 4' x 4' x 4'

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Backhus Drg 180
Business name License No.

Address Tampa Ks

Signed Paul Backhus Date 6-16-76
Authorized representative

T 19 R 4 W (E) Sec 11 SwSwSE 1/4 1/4 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL L4

USE TYPEWRITER OR BALL POINT PEN–PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

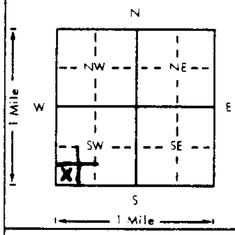
Kansas Department of Health and Environment–Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

	County	Fraction	Section number	Township number	Range number
1. Location of well:	Marion	SW 1/4 SW 1/4 SW 1/4	11	T 18 S	R 4 E/W

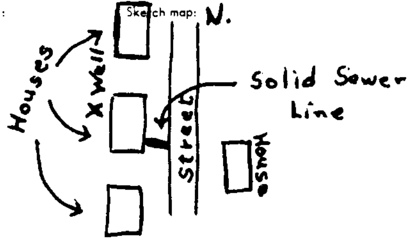
2. Distance and direction from nearest town or city: In Lincolnville Kans.
Street address of well location if in city: Marion Ave.

3. Owner of well: Rudy Leeker
R.R. or street: Marion Ave.
City, state, zip code: Lincolnville, Kans. 66858

4. Locate with "X" in section below:



Sketch map:



X 6. Bore hole dia. 6 in. Completion date 12-22-78
Well depth 100 ft.

7. X Cable tool __ Rotary __ Driven __ Dug
__ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: X Domestic __ Public supply __ Industry
__ Irrigation __ Air conditioning __ Stock
__ Lawn __ Oil field water __ Other

X 9. Casing: Material Plastic Height: Above or below
Threaded ____ Welded X Surface 16 in.
RMP ____ PVC X Weight 2½ lbs./ft.
[✓ Dia.] 5 in. to 65 ft. depth Wall Thickness inches or
Dia. ____ in. to ____ ft. depth gage No 1/30

5. Type and color of material	From	To
Good Black Soil	0	4
Brown Clay	4	8
Limestone	8	20
Med. yellow Clay	20	27
Dark Blue Shale	27	44
Red Clay	44	60
Light Gray Shale	60	71
Med size Light Gray Sand-Water Bearing	71	95
Blue Shale	95	100
10" — 10'		
(Use a second sheet if needed)		

10. Screen: Manufacturer's name Certain Teed
Type Plastic Dia. 5 in
Slot/~~gauze~~ 3/32 x 4 in Length 35 ft.
Set between 65 ft. and 100 ft.
____ ft. and ____ ft.
Gravel pack? NO Size range of material ____

11. Static water level: mo./day/yr.
49 ft. below land surface Date 12-22-78

12. Pumping level below land surfaces:
64 ft. after ¼ hrs. pumping 18 g.p.m.
____ ft. after ____ hrs. pumping ____ g.p.m.
Estimated maximum yield 50 g.p.m.

13. Water sample submitted: mo. day/yr.
__ Yes X No Date ____

14. Well head completion: Well Cap
X Pitless adapter 16 Inches above grade

15. Well grouted? yes
With: X Neat cement ____ Bentonite ____ Concrete
Depth: From 2½ ft. to 14 ft.

16. Nearest source of possible contamination: Solid
ft. 20 Direction S.E. Type Sewer
Well disinfected upon completion? X Yes ____ No

17. Pump: __ Not installed
Manufacturer's name F and W
Model number 021901 HP ¾ Volts 220
Length of drop pipe 94 ft. capacity 18 g.p.m.
Type:
X Submersible __ Turbine
__ Jet __ Reciprocating
__ Centrifugal __ Other

18. Elevation:
Topography:
____ Hill
____ Slope
X Upland
____ Valley

19. Remarks:
Well is completed.

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Benda Drilling 161
Business name License No.
Address Lincolnville Kans
Signed Paul W. Benda Date 12-27 1978
Authorized representative

T 18 R 4 W [✓ E] Sec 11 SW 1/4 SW 1/4 SW 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL L10

USE TYPEWRITER OR BALL POINT PEN–PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

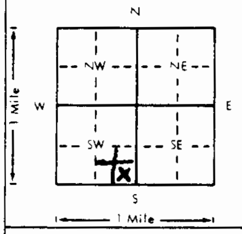
Kansas Department of Health and Environment–Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

1. Location of well:	County Marion	Fraction SE 1/4 SE 1/4 SW 1/4	Section number 11	Township number T 18 S	Range number R 4 E/W

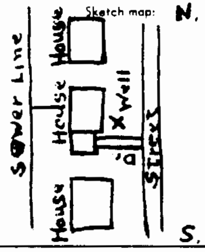
2. Distance and direction from nearest town or city: In Lincolnville Kans.
Street address of well location if in city: Lombard Ave.

3. Owner of well: Edgar Tiemier
R.R. or street: Lombard Ave.
City, state, zip code: Lincolnville, Kans. 66858

4. Locate with "X" in section below:



Sketch map:



6. Bore hole dia. 6 in. Completion date 1-12-79
Well depth 115 ft.

7. X Cable tool __ Rotary __ Driven __ Dug
__ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: X Domestic __ Public supply __ Industry
__ Irrigation __ Air conditioning __ Stock
__ Lawn __ Oil field water __ Other

9. Casing: Material Plastic
Threaded ____ Welded X
RMP ____ PVC X
Dia. 5 in. to 70 ft. depth
Dia. ___ in. to ___ ft. depth
Height: Above or ~~below~~
Surface 14 in.
Weight 2½ lbs./ft.
Wall Thickness inches or gage No. 7/32

10. Screen: Manufacturer's name Certain Teed
Type Plastic Dia. 5 in
Slot/~~gauze~~ 3/32 x 4 in Length 45 ft.
Set between 70 ft. and 115 ft.
____ ft. and ____ ft.
Gravel pack? NO Size range of material ____

11. Static water level:
49 ft. below land surface Date 1·12·79 mo./day/yr.

12. Pumping level below land surfaces:
64 ft. after ½ hrs. pumping 11 g.p.m.
____ ft. after ____ hrs. pumping ____ g.p.m.
Estimated maximum yield 50 g.p.m.

13. Water sample submitted:
__ Yes X No Date ____ mo. day/yr.

14. Well head completion: Well Cap
X Pitless adapter 14 inches above grade

15. Well grouted? Yes
With: X Neat cement ____ Bentonite ____ Concrete
Depth: From 2½ ft. to 17 ft.

16. Nearest source of possible contamination: Solid
Ft. 20 Direction W Type ~~Sewer~~
Well disinfected upon completion? X Yes ____ No

17. Pump: ____ Not installed
Manufacturer's name Red Jacket
Model number 50W19BCZ HP ½ Volts 220
Length of drop pipe 102 ft. capacity 11 g.p.m.
Type:
X Submersible ____ Turbine
__ Jet ____ Reciprocating
__ Centrifugal ____ Other

5. Type and color of material	From	To
Good Top Soil Black	0	2
Clay Brown	2	9
Limestone Med. Hard Dark yellow	9	21
Clay Med yellow	21	35
Shale Med Blue	35	52
Shale Red	52	67
Shale Light Brown	67	72
Sand + Shale Light Gray – Water	72	95
Shale Med Blue	95	107
Shale Red	107	115

(Use a second sheet if needed)

18. Elevation:
Topography:
____ Hill
____ Slope
X Upland
____ Valley

19. Remarks:
Well is completed

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Business name Benda Drilling License No. 161
Address Lincolnville, Ks.
Signed Paul W. Benda Date 2-9-79
Authorized representative

T 18 - R 4 - Sec 11 - 1/4 1/4 1/4 SESESW

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL L16

WATER WELL RECORD Form WWC-5 KSA 82a-1212

1 LOCATION OF WATER WELL
County Marion
Fraction Ne ¼ Ne ¼ Nw ¼
Section Number 14
Township Number T 18 S
Range Number R 4 EW
Distance and direction from nearest town or city? in City Lincolnville
Street address of well if located within city?

2 WATER WELL OWNER Mrs Erwin Lewerens
RR#, St. Address, Box #
City, State, ZIP Code Lincolnville Ks. 66858
Board of Agriculture, Division of Water Resources Application Number

3 DEPTH OF COMPLETED WELL 96 ft. Bore Hole Diameter 9 in. to 15 ft., and 7 in. to 96 ft.

Well Water to be used as [✓ 1 Domestic] 2 Irrigation 3 Feedlot 4 Industrial 5 Public water supply 6 Oil field water supply 7 Lawn and garden only 8 Air conditioning 9 Dewatering 10 Observation well 11 Injection well 12 Other (Specify below)

Well's static water level 50 ft. below land surface measured on 10 month 12 day 79 year
Pump Test Data Well water was ft. after hours pumping gpm
Est. Yield 25 gpm. Well water was ft. after hours pumping gpm

4 TYPE OF BLANK CASING USED: 1 Steel [✓ 2 PVC] 3 RMP (SR) 4 ABS 5 Wrought iron 6 Asbestos-Cement 7 Fiberglass 8 Concrete tile 9 Other (specify below)
Casing Joints: Glued ☒ Clamped Welded Threaded
Blank casing dia 5 in. to 76 ft., Dia in. to ft., Dia in. to ft.
Casing height above land surface 12 in., weight Sch 40 lbs ft. Wall thickness or gauge No 258 +

TYPE OF SCREEN OR PERFORATION MATERIAL: 1 Steel 2 Brass 3 Stainless steel 4 Galvanized steel 5 Fiberglass 6 Concrete tile [✓ 7 PVC] 8 RMP (SR) 9 ABS 10 Asbestos-cement 11 Other (specify) 12 None used (open hole)

Screen or Perforation Openings Are: 1 Continuous slot 2 Louvered shutter 3 Mill slot 4 Key punched 5 Gauzed wrapped 6 Wire wrapped 7 Torch cut [✓ 8 Saw cut] 9 Drilled holes 10 Other (specify) 11 None (open hole)

Screen-Perforation Dia 5 in. to 96 ft. Dia in. to ft. Dia in. to ft.
Screen-Perforated Intervals: From 76 ft. to 96 ft., From ft. to ft.
From ft. to ft., From ft. to ft.
Gravel Pack Intervals: From 15 ft. to 96 ft., From ft. to ft.
From ft. to ft., From ft. to ft.

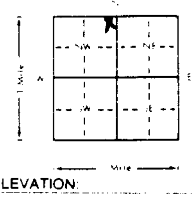
5 GROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout 3 Bentonite 4 Other
Grouted Intervals: From 3 ft. to 13 ft. From ft. to ft. From ft. to ft.

What is the nearest source of possible contamination: 1 Septic tank 2 Sewer lines 3 Lateral lines 4 Cess pool 5 Seepage pit 6 Pit privy 7 Sewage lagoon 8 Feed yard 9 Livestock pens 10 Fuel storage 11 Fertilizer storage 12 Insecticide storage [✓ 13 Watertight sewer lines] 14 Abandoned water well 15 Oil well/Gas well 16 Other (specify below)

Direction from well N How many feet 40
Water Well Disinfected? Yes ☒ No
Was a chemical/bacteriological sample submitted to Department? Yes No ☒ If yes, date sample was submitted month day year
Pump Installed? Yes No ☒
If Yes: Pump Manufacturer's name Model No. HP Volts
Depth of Pump Intake ft. Pumps Capacity rated at gal/min
Type of pump: 1 Submersible 2 Turbine 3 Jet 4 Centrifugal 5 Reciprocating 6 Other

6 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction and was completed on 10 month 12 day 78 year and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. 188
This Water Well Record was completed on 10 month 12 day 79 year under the business name of Backhus Drilling by (signature) Paul Backhus

7 LOCATE WELL'S LOCATION WITH AN "X" IN SECTION BOX.



ELEVATION:

FROM	TO	LITHOLOGIC LOG	FROM	TO	LITHOLOGIC LOG
0	2	Top Soil			
2	12	Lime Stone			
12	30	Gray Clay			
30	45	Red Rock			
45	70	Lime Stone			
70	82	Blue Clay			
82	88	Lime Stone			
88	90	Water			
90	96	Lime Stine			

Depth(s) Groundwater Encountered 1. ft. 2. ft. 3. ft. 4. ft. (Use a second sheet if needed)

INSTRUCTIONS: Use typewriter or ball point pen, *please press firmly* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Division of Environment, Water Well Contractors, Topeka, KS 66620. Send one to WATER WELL OWNER and retain one for your records.

OFFICE USE ONLY
T 18
R 4 EW
SEC 14
NE¼ NE¼ NW¼

WELL L19

USE TYPEWRITER OR BALL POINT PEN-PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

Kansas Department of Health and Environment-Division of Environment
(Water well Contractors)
Topeka, Kansos 66620

1. Location of well: County Marion; Fraction SW 1/4 NE 1/4 NW 1/4; Section number 14; Township number T 18 S; Range number R 4 (E)W

2. Distance and direction from nearest town or city: In Lincolnville Kans.

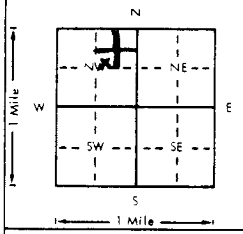
Street address of well location if in city: 3rd. + Adams

3. Owner of well: Merle Albrecht

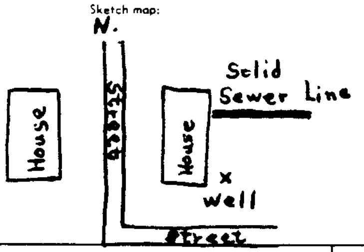
R.R. or street: 3rd. + Adams.

City, state, zip code: Lincolnville, Kans. 66858

4. Locate with "X" in section below:



Sketch map:



X. Bore hole dia. 6 in. Completion date 12-11-78

Well depth 107 ft.

7. X Cable tool __ Rotary __ Driven __ Dug __ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: X Domestic __ Public supply __ Industry __ Irrigation __ Air conditioning __ Stock __ Lawn __ Oil field water __ Other

X. Casing: Material Plastic Height: Above or below Surface 16 in.

Threaded ___ Welded X

RMP ___ PVC X

Weight 2½ lbs./ft.

(Dia.) 5 in. to 67 ft. depth

Dia. ___ in. to ___ ft. depth

Wall Thickness inches or gage No. 1/32

5. Type and color of material	From	To
Black Top Soil	0	2
Brown Clay	2	10
Light yellow Clay	10	15
Limestone Rock	15	24
Dark yellow Clay	24	41
Med. Red Clay	41	52
Dark Blue Shale	52	68
Light Gray Sand - Fine - Water	68	75
Dark Blue Shale	75	82
Light Gray Sand - Med. - Water	82	96
Dark Blue Shale	96	107
10" — 10'		
(Use a second sheet if needed)		

10. Screen: Manufacturer's name Certain Teed

Type Plastic Dia. 5 in.

Slot/gauze 3/32 x 4 in. Length 40 ft.

Set between 67 ft. and 107 ft.

___ ft. and ___ ft.

Gravel pack? NO Size range of material ___

11. Static water level: 44 ft. below land surface Date 12-11-78 mo. day/yr.

12. Pumping level below land surfaces:

65 ft. after ½ hrs. pumping 12 g.p.m.

___ ft. after ___ hrs. pumping ___ g.p.m.

Estimated maximum yield 50 g.p.m.

13. Water sample submitted: ___ Yes X No Date ___ mo./day/yr.

14. Well head completion: Well Cap

X Pitless adapter 14 Inches above grade

15. Well grouted? yes

With: X Neat cement ___ Bentonite ___ Concrete

Depth: From 2½ ft. to 20 ft.

16. Nearest source of possible contamination: Solid Sewer

ft. 18 Direction N. Type Solid Sewer

Well disinfected upon completion? X Yes ___ No

17. Pump: ___ Not installed

Manufacturer's name Red Jacket

Model number 50V1982 HP ½ Volts 220

Length of drop pipe 94 ft. capacity 12 g.p.m.

Type:

X Submersible ___ Turbine

___ Jet ___ Reciprocating

___ Centrifugal ___ Other

18. Elevation:

Topography:

___ Hill

___ Slope

X Upland

___ Valley

19. Remarks:

Well is Complete

20. Water well contractor's certification:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Benda Drilling 161

Business name License No.

Address Lincolnville, Kans.

Signed Paul W. Benda Date 12-27 1978

Authorized representative

T 18 R 4 (W) Sec 14 SW 1/4 NE 1/4 NW 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL L20

USE TYPEWRITER OR BALL
POINT PEN–PRESS FIRMLY,
PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

Kansas Department of Health and
Environment–Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

X Location of well:	County Marion	Fraction NE 1/4 NE 1/4 NW 1/4	Section number 14	Township number T 19 S	Range number R 4 [✓ E] W

X Distance and direction from nearest town or city: in Lincolnville

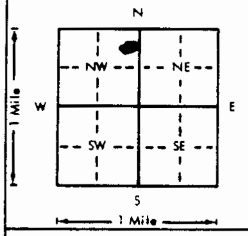
Street address of well location if in city: 58 Main St

3. Owner of well: Duane Kahns

R.R. or street: Lincolnville KS

City, state, zip code: 66858

4. Locate with "X" in section below:



Sketch map:

6. Bore hole dia 12-7 in. Completion date 8-22-76
Well depth 98 ft.

7. X Cable tool ___ Rotary ___ Driven ___ Dug
___ Hollow rod ___ Jetted ___ Bored ___ Reverse rotary

8. Use: X Domestic ___ Public supply ___ Industry
___ Irrigation ___ Air conditioning ___ Stock
___ Lawn ___ Oil field water ___ Other

9. Casing: Material PVC
Threaded ____ Welded ____
RMP ____ PVC X
Dia. 5 in. to 98 ft. depth
Dia. ___ in. to ___ ft. depth
Height: [✓ Above] or below
Surface 12 in.
Weight Sch 40 lbs./ft.
Wall Thickness: inches or gage No. .258

5. Type and color of material	From	To
yellow Clay	0	5
Lime Stone	5	17
Blue Shale	17	34
yellow Shale	34	47
Red Rock	47	65
Lime Stone	65	70
Some water	70	
Lime Stone	70	88
water	88	
Blue Shale	88	98
(Use a second sheet if needed)		

X 10. Screen: Manufacturer's name ~~D~~ A S C m
Type PVC Dia. ~~2~~ 5"
Slot/gauze 8 Length 20'
Set between ____ ft. and ____ ft.
____ ft. and ____ ft.
Gravel pack? X Size range of material 38

11. Static water level: mo./day/yr.
____ ft. below land surface Date ____

12. Pumping level below land surfaces:
____ ft. after ____ hrs. pumping ____ g.p.m.
____ ft. after ____ hrs. pumping ____ g.p.m.
Estimated maximum yield ____ g.p.m.

13. Water sample submitted: mo./day/yr.
____ Yes ____ No Date ____

14. Well head completion:
X Pitless adapter ____ Inches above grade

15. Well grouted? X
With: ____ Neat cement ____ Bentonite X Concrete
Depth: From 3 ft. to 13 ft.

16. Nearest source of possible contamination: City
ft. 80 Direction E Type Sewer Line

Well disinfected upon completion? X Yes ____ No

17. Pump: X Not installed
Manufacturer's name ____
Model number ____ HP ____ Volts ____
Length of drop pipe ____ ft. capacity ____ g.p.m.
Type:
___ Submersible ___ Turbine
___ Jet ___ Reciprocating
___ Centrifugal ___ Other

18. Elevation:

Topography:
___ Hill
___ Slope
X Upland
___ Valley

19. Remarks:

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Backhus Drg. Inc
Business name License No.
Address Tampa Ks. 67483
Signed Paul Backhus Date 8-22-76
Authorized representative

T 19 – R 4 (E) W – Sec 14 – NE 1/4 NE 1/4 NW 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

USE TYPEWRITER OR BALL POINT PEN-PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

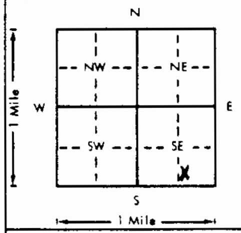
Kansas Department of Health and
Environment-Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

1. Location of well: County: Marion — Fraction: SW 1/4 SE 1/4 SE 1/4 — Section number: 15 — Township number: T 18 S — Range number: R 4E E/W

2. Distance and direction from nearest town or city: 1 mile South ½ mile west of [illegible] Lincolnville Ks
Street address of well location if in city:

3. Owner of well: Mrs Martin B. Hein
R.R. or street: 933 S. Wichita
City, state, zip code: Wichita, Kansas 67213

4. Locate with "X" in section below:



Sketch map:

6. Bore hole dia. 9 in. Completion date May 22 1979
Well depth 86 ft.

7. X Cable tool __ Rotary __ Driven __ Dug
__ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: X Domestic __ Public supply __ Industry
__ Irrigation __ Air conditioning __ Stock
__ Lawn __ Oil field water __ Other

9. Casing: Material Plstic Threaded ____ Welded ____ RMP ____ PVC X
Dia. 6 in. to 87 ft. depth
Dia. ___ in. to ___ ft. depth
Height: Above or below Surface 12 in.
Weight ____ lbs./ft.
Wall Thickness: inches or gage No. Sch 40

10. Screen: Manufacturer's name home made
Type Plas Dia. 6 in
Slot/gauze 1/2 Length 20 ft
Set between 67 ft. and 87 ft.
____ ft. and ____ ft.
Gravel pack? X Size range of material 1/4

11. Static water level: 50 ft. below land surface Date May 22 1979 mo./day/yr.

12. Pumping level below land surfaces:
____ ft. after ____ hrs. pumping ____ g.p.m.
____ ft. after ____ hrs. pumping ____ g.p.m.
Estimated maximum yield 20 g.p.m.

13. Water sample submitted: __ Yes X No Date ____ mo./day/yr.

14. Well head completion: X Pitless adapter ____ inches above grade

15. Well grouted? X
With: X Neat cement ____ Bentonite ____ Concrete
Depth: From 3 ft. to 25 ft.

16. Nearest source of possible contamination: ____ ft. Direction 1 mi Type Lincolnville Ks
Well disinfected upon completion? X Yes ____ No

17. Pump: X Not installed
Manufacturer's name ____
Model number ____ HP ____ Volts ____
Length of drop pipe ____ ft. capacity ____ g.p.m.
Type:
__ Submersible __ Turbine
__ Jet __ Reciprocating
__ Centrifugal __ Other

5. Type and color of material

5. Type and color of material	From	To
Gumbo	0	4
Lime	4	20
Soap stone	20	30
Red Rock	30	45
Blue Shale	45	55
S Lime	55	75
Blue Shale	75	86

(Use a second sheet if needed)

18. Elevation:
Topography:
____ Hill
____ Slope
____ Upland
____ Valley

19. Remarks:

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Schmidt Water Well — License No. 228
Business name
Address Marion Ks
Signed William [illegible] — Authorized representative — Date ____

18 T — 4 R W (E) — 15 Sec — SW 1/4 SE 1/4 SE 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL L30

USE TYPEWRITER OR BALL POINT PEN-PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

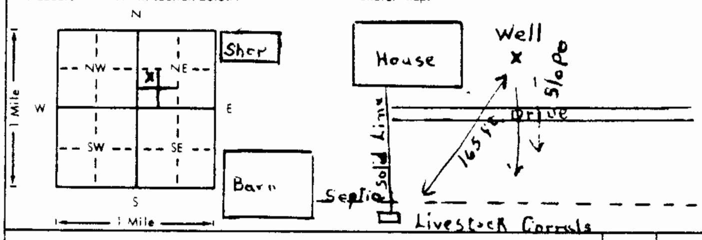
Kansas Department of Health and Environment-Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

1. Location of well: County: Marion — Fraction: NW 1/4 SW 1/4 NE 1/4 — Section number: 10 — Township number: T 18 S — Range number: R 4 E/~~W~~

2. Distance and direction from nearest town or city: ½ mi W. ½ mi N. from Lincolnville, Kans.
Street address of well location if in city:

3. Owner of well: Gary Diepenbrock
R.R. or street: # 1,
City, state, zip code: Lincolnville, Kans. 66858

4. Locate with "X" in section below: Sketch map:



5. Type and color of material

Type and color of material	From	To
Top Soil Black	0	1
Clay Brown	1	4
Limestone	4	10
Clay Med. Yellow	10	31
Clay Red	31	34
Lime Hard Gray White	34	64
Sand Fine Med. Gray	64	67
Shale Light Blue	67	92
Clay Red	92	98
Lime and Sand Med. Light Gray	98	114
Hard Flint Rock Gray White	114	118
Sand Corse Gray White	118	125
Shale Med Blue	125	135

(Use a second sheet if needed)

6. Bore hole dia. 10 in. Completion date 1-21-80
Well depth 135 ft.

7. X Cable tool __ Rotary __ Driven __ Dug
__ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: X Domestic __ Public supply __ Industry
__ Irrigation __ Air conditioning X Stock
__ Lawn __ Oil field water __ Other

9. Casing: Material Plastic
Threaded __ Welded X
RMP __ PVC X
Dia. 8 in. to 85 ft. depth
Dia. __ in. to __ ft. depth
Height: Above or ~~below~~
Surface 16 in.
Weight 5 lbs./ft.
Wall Thickness inches or gage No. .332

10. Screen: Manufacturer's name Certain Teed
Type Plastic Dia. 8 in
Slot/~~gauze~~ 3/32 x 4 in Length 50 ft.
Set between 85 ft. and 135 ft.
__ ft. and __ ft.
Gravel pack? NO Size range of material __

11. Static water level: 55 ft. below land surface Date 1-21-80 mo./day/yr.

12. Pumping level below land surfaces:
56 ft. after 2 hrs. pumping 60 g.p.m.
__ ft. after __ hrs. pumping __ g.p.m.
Estimated maximum yield 100 + g.p.m.

13. Water sample submitted: __ Yes X No Date __ mo./day/yr.

14. Well head completion: 1 Pipe Well Seal
__ Pitless adapter 16 Inches above grade

15. Well grouted? yes
With: X Neat cement __ Bentonite __ Concrete
Depth: From 0 ft. to 15 ft.

16. Nearest source of possible contamination: Septic
ft. 165 Direction SW Type __
Well disinfected upon completion? X Yes __ No

17. Pump: ~~Dempster~~ __ Not installed
Manufacturer's name Dempster
Model Number VBC 330052 HP 3 Volts 230
Length of drop pipe 125 ft. capacity 65 g.p.m.
Type:
X Submersible __ Turbine
__ Jet __ Reciprocating
__ Centrifugal __ Other

18. Elevation:
Topography:
__ Hill
__ Slope
X Upland
__ Valley

19. Remarks:
Bore Size 0 to 15 ft - 12 in
A concrete block Pump house, with concrete floor, houses the Pumping equipment.

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Benda Drilling — Business name — License No. 161
Address Lincolnville, Kans 66858
Signed — Authorized representative — Date 2-6-80

T 18 — R 4 — W — Sec 10 — NW SW NE 1/4 1/4 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

WELL #31

USE TYPEWRITER OR BALL POINT PEN–PRESS FIRMLY, PRINT CLEARLY.

WATER WELL RECORD
KSA 82a-1201-1215

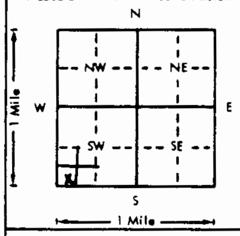
Kansas Department of Health and Environment–Division of Environment
(Water well Contractors)
Topeka, Kansas 66620

1. Location of well: County Marion; Fraction SW 1/4 SW 1/4 SW 1/4; Section number 12; Township number T 17 S; Range number R 4 [✓ E] W

2. Distance and direction from nearest town or city: 1 mile East and 1 Mile North of Lost Springs
Street address of well location if in city:

3. Owner of well: Warren Goentzel
R.R. or street: RR Lyle Hanschu
City, state, zip code: Hillsboro, Kan

4. Locate with "X" in section below: Sketch map:



6. Bore hole dia. 10 in. Completion date 7-5-76
Well depth 93 ft.

7. X Cable tool __ Rotary __ Driven __ Dug __ Hollow rod __ Jetted __ Bored __ Reverse rotary

8. Use: __ Domestic __ Public supply __ Industry X Irrigation __ Air conditioning __ Stock __ Lawn __ Oil field water __ Other

9. Casing: Material Plts
Threaded ____ Welded Glu
RMP ____ PVC X
Dia. 8 in. to 65 ft. depth
Dia. ___ in. to ___ ft. depth
Height: [✓ Above] or below Surface 18 in.
Weight ____ lbs./ft.
Wall Thickness: inches or gage No. .488

10. Screen: Manufacturer's name Certain teed
Type PVC Dia. 8"
[✓ Slot] gauze YB Length 28'
Set between 65 ft. and 93 ft.
____ ft. and ____ ft.
Gravel pack? NO Size range of material ____

11. Static water level: 65 ft. below land surface Date 7-5-76 mo./day/yr.

12. Pumping level below land surfaces:
65 ft. after 2 hrs. pumping 55 g.p.m.
80 ft. after 1 hrs. pumping 80 g.p.m.
Bottom of Pump
Estimated maximum yield 55 g.p.m.

13. Water sample submitted: __ Yes X No Date ____ mo./day/yr.

14. Well head completion: __ Pitless adapter 18 Inches above grade

15. Well grouted? Yes
With: __ Neat cement __ Bentonite X Concrete
Depth: From 0 ft. to 10 ft.

16. Nearest source of possible contamination: 150 ft. Direction South Type Road Ditch
Well disinfected upon completion? X Yes __ No

17. Pump: X Not installed
Manufacturer's name ____
Model number ____ HP ____ Volts ____
Length of drop pipe ____ ft. capacity ____ g.p.m.
Type: __ Submersible __ Turbine __ Jet __ Reciprocating __ Centrifugal __ Other

5. Type and color of material	From	To
Topsoil	0	4
Shale & Broken Lime - Yel	4	10
Shale - Yel	10	25
Lime - Yel	25	32
Shale - Gray	32	47
Lime - Wht	47	50
Red Rock - Red	50	56
Lime - Wht	56	58
Shale - Lite Gray water	58	62
Crevice with Broken Lime Drilling Lost water Hit Water	62	72
Shale Lite Gray	72	74
Lime - Gray	74	77
Shale - lite Blu	77	86
Lime - Gray	86	93
(Use a second sheet if needed)		

18. Elevation:
Topography: __ Hill __ Slope X Upland __ Valley

19. Remarks:

20. Water well contractor's certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Zinn Water Well Drilling 218
Business name License No.
Address Lost Springs, Kan
Signed Joseph A. Zinn Date 7-5-76
Authorized representative

12 T 17 R 4 (E) W Sec 12 SW 1/4 SW 1/4 SW 1/4

Forward the white, blue and pink copies to the Department of Health and Environment

Form WWC-5

MI-1023

APPENDIX III

Construction Details for Pre-1974 Water Wells Used in Study

Well No.	Well Owner	Water Well Contractor	Date Constructed or Reconstructed	Use of Well	Well depth (feet)	Casing		Casing height above lsd (feet)	Installed pumping capacity (gallons per minute)	Pump type	Method of Completion
						Material	Diameter (inches) to Depth (feet)				
L3	Edwin Suffield	A. Riffel	9/6/56	D	90	WI	7-25	-2.3	6	S	pit
L5	Herman Buethe	A. Riffel	1953	D	75	WI GS	7-12 6-75	0.1	8	S	well house
L6	Henry LeMoine	A. Riffel's father	?	D	90	GS	6-90	-7	6	S	basement
L7	L. Meirowsky	A. Riffel	1950's	D	90	WI PVC	7-20 5-90	?	30	C	well house
L8	L. Poppe	A. Riffel	1969	D	88	GS	6-88	?	?	J	underground
L9	R. Klein	A. Riffel	6/60	D	80	WI GS	7-? 6-80	0.4	+4	J	well house
L11	Wm. Beneke	?	1924	D	80?	GS	6-80	?	+4	J	basement
L12	Robt. Cook	?	1921	D	80	GS	6-80	?	5	J	well house
L13	Ted Haefner	A. Riffel	?	D	70	GS	6-70	-2.5	+4	S	pit
L14	A. Abbott	J. Richmond	?	D,S	90?	GS PVC	6-45 5-90	0.6	+4	S	well house
L15	Tiemeier's Store	?	1940's	C	?	WI	10-?	?	+4	S	inside bldg.
L17	Robt. Gillett	P. Backhus	1973	D	103	PVC	5-103	?	+4	S	underground
L18	M. Klein	?/owner	1981	D	95	GS PVC	6-10 5-95	0.1	4	S	well house
L22	L. Kaiser	A. Riffel	1953	D,S	81	WI	5-30	0.2	6	J	well house
L23	D. Kahns	?	?	N	66	WI	4-?	0.1	-	N	abandoned above gr.
L24	W. Olson	?	?	D	68	?	?	?	6	S	well house
L25	Karen Suffield	P. Backhus	1971	C	80	PVC	5-80	-3.5	+4	S	pit
L26	Elevator Office	A. Riffel	10/56	C	100	WI GS	7-? 6-100	-4	6	S	pit
L27	Ag-Chem Warehouse	?	?	C	?	GS	6-?	0.1	20	S	above ground
L29	Albert Riffel	?	1910	D	80	GS	6-80	0.6	6	S	well house

Use of Well: D - domestic, S - stock, N - none

Casing Material: WI - wrought iron, GS - galvanized steel,
PVC - Polyvinyl Chloride

Pump Type: S - submersible, C - centrifugal, J - jet, N - none

APPENDIX IV

Listing of Article 30 (Chapter 28) of the Kansas Administrative Regulations

ARTICLE 30--WATER WELL CONTRACTOR'S LICENSE; WATER WELL CONSTRUCTION AND ABANDONMENT

This article regulates the construction, reconstruction, treatment and plugging of water wells and sets forth procedures for the licensing of water well contractors as required by K.S.A. 82a-1201 to 82a-1215 and amendments thereto.

28-30-1. (Authorized by K.S.A. 1979 Supp. 82a-1202, 82a-1205; effective, E-74-34, July 2, 1974; modified, L. 1975 ch. 481, May 1, 1975; revoked May 1, 1980.)

28-30-2. Definitions. (a) "License" means a document issued by the Kansas state department of health and environment to qualified persons making application ~~therefor,~~ therefore, authorizing such persons to engage in the business of water well contracting.

(b) "Department" means the Kansas department of health and environment.

(c) "Abandoned water well" means a water well determined by the department to be a well; ~~that has been permanently taken out of use, or is in such a state of disrepair that using it for the purpose of obtaining groundwater is impracticable or threatens to contaminate or pollute groundwater aquifers'~~

(1) in which the use has been permanently discontinued;

(2) in which pumping equipment has been permanently removed;

(3) which is in such a state of disrepair that it cannot be used to supply water, or it has the potential for transmitting surface contaminants into the aquifer or both;

(4) which poses potential health and safety hazards; or

(5) which is in such a condition it cannot be placed in active or inactive status.

(d) "Water well contractor" or "contractor" means any individual, firm, partnership, association, or corporation who shall construct, reconstruct, or treat a water well. The term shall not include:

(1) An individual constructing, ~~or~~ reconstructing or treating a water well located on land ~~which is~~ owned by the individual, ~~and~~ when the well is used by the individual for farming, ranching, or agricultural purposes or for domestic purposes at the individual's place of abode.

(2) An individual who performs labor or services for a licensed water well contractor at the contractor's direction and under the contractor's supervision.

(e) "Aquifer" means an underground formation that contains and is capable of transmitting groundwater.

(f) "Confined aquifer" is an aquifer overlain and underlain by impermeable layers. Groundwater in a confined aquifer is under pressure greater than atmospheric pressure and will rise in a well above the point at which it is first encountered.

(g) "Unconfined aquifer" is an aquifer containing groundwater at atmospheric pressure. The upper surface of the groundwater in an unconfined aquifer is the water table.

(h) "Domestic uses" means the use of water by any person or ~~by~~ a family unit or household for household purposes, or for the watering of livestock, poultry, farm and domestic animals used in operating a farm, ~~and~~ or for the irrigation of lands not exceeding a total of two ~~(2)~~ acres in area for the growing of gardens, orchards and lawns.

(i) "Public water-supply well" means a well that provides groundwater to the public for human consumption, if such system has at least ~~ten (10)~~ 10 service connections or ~~regularly~~ serves an average of at least ~~twenty-five (25)~~ 25 individuals daily at least ~~sixty (60)~~ 60 days out of the year.

(j) "Groundwater" means ~~that~~ the part of the subsurface water which is in the zone of saturation.

(k) "Grout" means cement grout, neat cement grout, bentonite clay grout or other material approved by the department used to create a permanent impervious watertight bond between the casing and the undisturbed formation surrounding the casing or between two ~~(2)~~ or more strings of casing.

(1) "Neat cement grout" means a mixture consisting of one ~~(1) ninety-four (94)~~ 94 pound bag of portland cement to five ~~(5)~~ to six ~~(6)~~ gallons of clean water.

(2) "Cement grout" means a mixture consisting of one ~~(1) ninety-four (94)~~ 94 pound bag of portland cement to an equal volume of sand having a diameter no larger than 0.080 inches (2 millimeters) to five ~~(5)~~ to six ~~(6)~~ gallons of clean water.

(3) "Bentonite clay grout" means a mixture consisting of ~~not less than one-half (0.5) pound of commercial sodium bentonite clay (API specification: API 13A, 6th Edition, January 1974) to one (1) gallon of clean water.~~ water and commercial grouting or plugging sodium bentonite clay containing high solids such as that manufactured under the trade name of "volclay grout", or an equivalent as approved by the department.

(A) The mixture shall be as per the manufacturer's recommendations to achieve a weight of not less than 9.4 pounds per gallon of mix. Weighting agents may be added as per the manufacturer's recommendations.

(B) Sodium bentonite pellets, tablets or granular sodium bentonite may also be used provided they meet the specifications listed in K.A.R. 28-30-2(k), (3), above.

(C) Sodium bentonite products that contain low solids, are designed for drilling purposes or that contain organic polymers shall not be used.

(l) "Pitless well adapter or unit" means an assembly of parts installed below frost line which will permit pumped groundwater to pass through the wall of the casing or extension thereof and prevent entrance of contaminants.

(m) "Test hole" or "hole" means any excavation ~~that~~ ~~is~~ constructed for the purpose of determining the geologic, ~~and~~ hydrologic and water quality characteristics of underground formations.

(n) "Static water level" means the highest point below or above ground level which the groundwater in the well reaches naturally.

(o) "Annular space" means the space between the well casing and the well bore or the space between two ~~(2)~~ or more strings of well casing.

(p) "Sanitary well seal" is a manufactured seal installed at the top of the well casing which, when installed, creates an air- and watertight seal to prevent contaminated or polluted water from gaining access to the groundwater supply.

(q) "Treatment" means the stimulation of production of groundwater from a water well, through the use of hydrochloric acid, muriatic acid, sulfamic acid, calcium or sodium hypochlorite, polyphosphates or other chemicals and mechanical means, for the purpose of reducing or removing iron and manganese hydroxide and oxide deposits, calcium and magnesium carbonate deposits and slime deposits associated with iron or manganese bacterial growths which inhibit the movement of groundwater into the well.

(r) "Reconstructed water well" means an existing well that has been deepened or ~~the~~ ~~well's~~ has had the casing ~~has~~ ~~been~~ replaced, repaired, added to or modified in any way for the purpose of obtaining groundwater.

(s) "Pump pit" means a watertight structure constructed at least two ~~(2)~~ feet away from the water well and below ground level to prevent freezing of pumped groundwater and which houses the pump or pressure tank, distribution lines, electrical controls, or other appurtenances.

(t) "Grout tremie pipe" or "grout pipe" means a steel or galvanized steel pipe or similar pipe having equivalent structural soundness that is used to conduct pumped grout to a point of selected emplacement during the grouting of a well casing or plugging of an abandoned well or test hole.

(u) "Uncased test hole" means any test hole in which casing has been removed or in which casing has not been installed.

(v) "Drilling rig registration license number" means a number assigned by the department which is affixed to each drilling rig operated by or for a licensed water well contractor.

(w) "Active well" means a water well which is an operating well used to withdraw water, monitor or observe groundwater conditions.

(x) "Inactive status" means a water well which is not presently operating but is maintained in such a way it can be put back in operation with a minimum of effort.

(y) "Heat pump hole" means a hole drilled to install piping for an earth coupled water source heat pump system, also known as a vertical closed loop system. (Authorized by K.S.A. 82a-~~1203~~ 1205 and implementing K.S.A. ~~1979 Supp.~~ 82a-1202, 82a-1205, 82a-1213; effective, E-74-34, July 2, 1974; modified, L. 1975, Ch. 481, May 1, 1975; amended May 1, 1980; amended May 1, 1987.)

28-30-3. Licensing. (a) Eligibility. To be eligible for a water well contractor's license an applicant shall:

(1) Have passed an examination conducted by the department; or

(2) meet the conditions contained in subsection (c).

(b) Application and fees.

(1) Each application shall be accompanied by an application fee of $10.00.

(2) Before issuance of a water well contractor's license, each contractor shall pay a license fee of $100.00 plus $25.00 for each drill rig operated by or for the contractor. These fees shall accompany the application and shall be by bank draft, check or money order payable to the Kansas department of health and environment - water well licensure.

(c) Reciprocity.

(1) Upon receipt of an application and payment of the required fees from a nonresident, the secretary may issue a license, providing the nonresident holds a valid license from another state and meets the minimum requirements for licensing as prescribed in K.S.A. ~~1979 Supp.~~ 82a-1207, and any amendments thereto.

(2) If the nonresident applicant is incorporated, evidence shall be submitted to the department of health and environment showing that the applicant meets the registration requirements of the Kansas secretary of state.

(3) Nonresident fees for a license shall be equal to the fee charged a Kansas contractor by the applicant's state of residence but shall not be less than $100.00 The application fee and drill rig license fee shall be the same as the Kansas resident fees.

(d) Water well construction fee. A fee of $5.00 shall be paid to the Kansas department of health and environment, either by bank draft, check or money order, for each water well constructed by a licensed water well contractor. The construction fee shall be paid when the contractor requests the water well ~~records~~ record ~~(~~form WWC-5~~)~~ from the department or shall accompany the water well records submitted on ~~(~~form WWC-5~~)~~ as required under K.A.R. 28-30-4. No fee shall be required for reconstructed or plugged water wells.

(e) License number. Each drill rig operated by or for a licensed water well contractor shall have prominently displayed thereon the drill rig license number, as assigned by the department, in letters at least two inches in height. Decals, paint, or other permanent marking materials shall be used. (Authorized by K.S.A. ~~1981 Supp.~~ 82a-1205; implementing K.S.A. ~~1981 Supp.~~ 82a-1202, 82a-1205, 82a-1206, 82a-1207, 82a-1209; effective, E-74-34, July 2, 1974; effective, May 1, 1975; amended May 1, 1980; amended May 1, 1983; amended May 1, 1987.)

28-30-4. General operating requirements. (a) Water well record. Within ~~thirty (30)~~ 30 days after construction or reconstruction of a water well, the water well contractor shall submit a report of such work, to the Kansas department of health and environment and to the landowner, on the water well record form, ~~(~~form WWC-5~~)~~, provided by the department. The contractor shall report to the department and to the landowner on the water well record or attachments made thereto any polluted or other noncompliant conditions which the contractor was able to correct and ~~the~~ any conditions which the contractor was unable to correct. The contractor shall report to the department and the landowner the plugging of any abandoned water well. ~~giving~~ The report shall include the location, ~~landowner~~ landowner's name, method, ~~amount,~~ type of plug material, ~~and~~ its placement and amount used to plug the abandoned water well.

A landowner who constructs, reconstructs, or plugs a water well, which will be or was, used by the landowner for farming, ranching or agricultural purposes or is located at the landowner's place of abode, shall submit a water well record, on ~~(~~form WWC-5~~)~~, of such work to the department within ~~thirty (30)~~ 30 days after the construction, reconstruction or plugging of the water well. No fee shall be required from the landowner for the record.

(b) Artificial recharge and return. The construction of artificial recharge wells and freshwater return wells ~~must~~ shall comply with all applicable rules and regulations of the department.

(c) Well tests. When a pumping test is run on a well, results of the test shall be reported on the water well record, ~~(~~form WWC-5~~)~~, or a copy of the contractor's record of the pumping test shall be attached to the water well record.

(d) Water samples. Within ~~thirty (30)~~ 30 days after receipt of the water well record, ~~(~~form WWC-5~~)~~, ~~on a well;~~ the department may request the contractor, or landowner who constructs or reconstructs his or her own water well, to submit a sample of water from the well for chemical analysis. Insofar as is possible, the department will define in advance areas from which well water samples are required. (Authorized by K.S.A. 82a-~~1203~~ 1205, and implementing K.S.A. ~~1979 Supp.~~ 82a-1202, 82a-1205, 82a-1212, 82a-1213; effective, E-74-34, July 2, 1974; modified, L. 1975, ch. 481, May 1, 1975; amended May 1, 1980; amended May 1, 1987.)

28-30-5. Construction regulations for public water supply and reservoir sanitation zone wells. All activities involving public water supply wells and wells located in reservoir sanitation zones shall conform to existing statutes, and rules and regulations, of the Kansas department of health and environment, including K.A.R. 28-10-100, 28-10-101, and 28-15-16. (Authorized by K.S.A. ~~1981 Supp.~~ 82a-1205; implementing K.S.A. ~~1981 Supp.~~ 82a-1202, 82a-1205; effective, E-74-34, July 2, 1974; effective May 1, 1975; amended May 1, 1980; amended May 1, 1983; amended May 1, 1987.)

28-30-6. Construction regulations for all wells not included under section 28-30-5. (a) A water well shall be so located as to minimize the potential for contamination of the delivered or obtained groundwater and to protect groundwater aquifers from pollution and contamination.

(b) Grouting:

(1) ~~The top 10 feet of a constructed or reconstructed well shall be sealed by grouting the annular space between the casing and the well bore. If a pitless well adapter or unit is being installed, the grouting shall start below the junction of the pitless well adapter or unit where it attaches to the well casing and shall continue to at least 10 feet below this junction.~~ Constructed or reconstructed wells shall be sealed by grouting the annular space between the casing and the well bore from ground level to a minimum of 20 feet or to a minimum of five feet into the first clay or shale layer, if present, whichever is greater. If a pitless well adapter or unit is being installed, the grouting shall start below the junction of the pitless well adapter or unit where it attaches to the well casing and shall continue a minimum of 20 feet below this junction or to a minimum of five feet into the first clay or shale layer whichever is greater.

(2) To facilitate grouting, the ~~upper 10 feet of the~~ grouted interval of the well bore shall be drilled to a minimum diameter at least three inches greater than the maximum outside diameter of the well casing. If a pitless well adapter or unit is being installed on the well's casing, the well bore shall be a minimum diameter of at least three inches greater than the outside maximum diameter of the well casing ~~to a distance of at least 10 feet~~ through the grouted interval below the junction of the pitless well adapter or unit where it attaches to the well casing.

(c) If groundwater is encountered at a depth less than the minimum grouting requirement, the grouting requirement may be modified to meet local conditions if approved by the department.

(d) ~~Confined waters shall be separated from each other and from unconfined waters encountered in the same bore hole with grout or other approved materials in areas designated by the department.~~ Waters from two or more separate aquifers shall be separated from each other in the bore hole by sealing the bore hole between the aquifers with grout.

(e) The well casing shall terminate not less than one foot above the finished ground surface. No casing shall be cut off below the ground surface except to install a pitless well adapter unit which shall extend at least 12 inches above the ground surface. No opening shall be made through the well casing except for installation of a pitless well adapter so designed and fabricated to prevent soil, subsurface and surface water from entering the well.

(f) Well vents shall be used and shall terminate not less than one foot above ground surface and shall be screened with not less than 16-mesh, brass, bronze, copper screen or other screen materials approved by the department and turned down in a full 180 degree return bend so as to prevent the entrance of contaminating materials.

(g) Prior to completion of a constructed or reconstructed well, the well shall be cleaned of mud, drill cuttings and other foreign matter so as to make it suitable for pump installations.

(h) Casing. All wells shall have durable watertight casing from at least one foot above finished ground surface to the top of the producing zone of the aquifer. In no event shall the watertight casing extend less than ~~10~~ 20 feet below the ground level. Exceptions to either of the above may be granted by the department if warranted by local conditions. The casing shall be clean and serviceable and of a type to guarantee reasonable life so as to insure adequate protection to the aquifer or aquifers supplying the groundwaters. Used, reclaimed, rejected, or contaminated pipe shall not be used for casing any well. All water well casing shall be approved by the department.

(i) All wells, when unattended during construction, reconstruction, treatment or repair, or during use as cased test holes, observation or monitoring wells, shall have the top of the well casing securely capped in a watertight manner to prevent contaminating or polluting materials from gaining access to the groundwater aquifer.

(j) During construction, reconstruction, treatment or repair and prior to initiation of use, all wells producing water for human consumption or food processing, shall be disinfected according to K.A.R. 28-30-10.

(k) The top of the well casing shall be sealed by installing a sanitary well seal.

(l) All groundwater producing zones that are known or suspected to contain natural or man-made pollutants shall be adequately cased and grouted off during ~~completion~~ construction of the well to prevent the movement of the polluted groundwater to either overlying or underlying fresh groundwater zones.

(m) Toxic materials shall not be used in the construction, reconstruction, treatment or plugging of a water well unless those materials are thoroughly flushed from the well prior to use.

(n) Any pump pit shall be constructed at least two feet away from the water well. The pipe from the pump or pressure tank in the pump pit to the water well shall be sealed in a watertight manner where it passes through the wall of the pump pit.

(o) ~~Water wells constructed, reconstructed, or abandoned and plugged in a basement shall conform to these rules and regulations except that the finished grade of the basement floor shall be considered ground level. Grouting of the well casing shall extend a minimum of 10 feet below the basement floor.~~ Water wells shall not be constructed in pits, basements, garages or crawl spaces. Existing water wells which are reconstructed, abandoned and plugged in basements shall conform to these rules and regulations except that the finished grade of the basement floor shall be considered ground level.

(p) All drilling waters used during the construction or reconstruction of any water well shall be initially disinfected by mixing with the water enough sodium ~~or calcium~~ hypochlorite to produce at least 100 milligrams per liter, ~~(mg/l)~~, of available chlorine.

(q) Natural organic or nutrient producing material shall not be used during the construction, reconstruction or treatment of a well unless it is thoroughly flushed from the well and the groundwater aquifer or aquifers before the well is completed. Natural organic or nutrient producing material shall not be added to a grout mix used to grout the well's annular space.

(r) Pump mounting.

(1) All pumps installed directly over the well casing shall be so installed that an airtight and watertight seal is made between the top of the well casing and the gear or pump head, pump foundation or pump stand.

(2) When the pump is not mounted directly over the well casing and the pump column pipe or pump suction pipe emerges from the top of the well casing, a sanitary well seal shall be installed between the pump column pipe or pump suction pipe and the well casing. An airtight and watertight seal shall be provided for the cable conduit when submersible pumps are used. (Authorized by K.S.A. ~~1981 Supp.~~ 82a-1205; implementing K.S.A. ~~1981 Supp.~~ 82a-1202, 82a-1205; effective, E-74-34, July 2, 1974; modified, L. 1975, ch. 481, May 1, 1975; amended May 1, 1980; amended May 1, 1983; amended May 1, 1987.)

28-30-7. Plugging of abandoned wells, cased and uncased test holes. (a) All water wells abandoned by the landowner on or after July 1, 1979, and all water wells that were abandoned prior to July 1, 1979 which pose a threat to groundwater supplies, shall be plugged or caused to be plugged by the landowner. In all cases, the landowner shall perform the following as minimum requirements for plugging abandoned wells.

(1) The casing shall be cut off three feet below ground surface and removed.

(2) All wells shall be plugged from bottom to top using volumes of material equaling at least the inside volume of the well.

(3) Plugging top of well:

(A) For cased wells a grout plug shall be placed from six to three feet below ground surface.

(B) For ~~all~~ dug wells, ~~their~~ the lining material ~~(rock, brick, boards, mortar or other type of lining material)~~ shall be removed to at least five feet below ground surface, and then sealed at five feet with ~~at least~~ a minimum of six inches of concrete or other materials approved by the department. Compacted surface silts and clays shall be placed over the concrete seal to ground surface.

(4) Any groundwater displaced upward inside the well casing during the plugging operation shall be removed before additional plugging materials are added.

(5) From three feet below ground level to ground level, the plugged well shall be covered over with compacted surface silts or clays.

(6) Compacted clays or grout shall be used to plug all wells from the static water level to six feet below surface.

(7) All sand and gravel used in plugging ~~an~~ abandoned domestic or public water supply ~~well~~ wells shall be chlorinated prior to ~~introduction of the sand and gravel into~~ placement into a well.

(b) Abandoned wells formerly producing groundwater from an unconfined aquifer shall be plugged in accordance with the foregoing and in addition shall have washed sand, and gravel or other material approved by the department placed from the bottom of the well to the static water level.

(c) Abandoned wells, formerly producing groundwater from confined and unconfined aquifers or in confined aquifers only, shall be plugged according to K.A.R. 28-30-7 (a) and by using one of the following additional procedures:

(1) The entire well column shall be filled with grout, or other material approved by the department, by use of a grout tremie pipe.

(2) A 10 foot grout plug shall be placed opposite the impervious formation or ~~(~~confining layer~~)~~ above each confined aquifer or aquifers by use of a grout tremie pipe; and

(A) The space between plugs shall be filled with clays, silts, sand and gravel or grout and shall be placed inside the well so as to prevent bridging.

(B) A grout plug at least 20 feet in length shall be placed with a grout pipe so at least 10 feet of the plug extends below the base of the well casing and at least 10 feet of the plug extends upward inside the bottom of the well casing.

(C) A grout plug at least 10 feet in length shall be placed from at least 13 feet below ground level to the top of the cut off casing.

(3) Wells that have an open bore hole below the well casing, and where the casing was not grouted into the well bore when the well was constructed, shall be plugged by (1) or (2) above except that the top ~~10~~ 20 feet of well casing shall be removed or perforated with a casing ripper or similar device prior to plugging. If the well is plugged according to part

(2) of this subsection, the screened or perforated intervals below the well casing shall be grouted the entire length by use of a grout tremie pipe.

(d) ~~Uncased test holes shall be plugged by the contractor before the job is terminated by using applicable methods described in K.A.R. 28-30-7 (b) and (c).~~ Plugging of abandoned holes. If the hole penetrates an aquifer containing water with more than 1,000 milligrams per liter, mg/l, total dissolved solids or is in an area determined by the department to be contaminated, the entire hole shall be plugged with an approved grouting material from the bottom of the hole, up to within three feet of the ground surface using a grout tremie pipe or similar method. From three feet below ground surface to ground surface the plugged hole shall be covered over with compacted surface silts or clays; otherwise, the hole shall be plugged in accordance with the following paragraphs.

(1) Plugging of abandoned cased test holes. The casing shall be removed if possible and the abandoned test hole shall be plugged with an approved grouting material from the bottom of the hole, up to within three feet of the ground surface, using a grout tremie pipe or similar method. From three feet below ground surface to ground surface the plugged hole shall be covered over with compacted surface silts or clays. If the casing cannot be removed, in addition to plugging the hole with an approved grouting material the annular space shall also be grouted as described in K.A.R. 28-30-6 or as approved by the department.

(2) Abandoned uncased test holes, exploratory holes or any bore holes except seismic or oil field related exploratory and service holes regulated by the Kansas corporation commission under K.A.R. 82-3-115 through 82-3-117. A test hole or bore hole drilled, bored, cored or augered shall be considered an abandoned hole immediately after the completion of all testing, sampling or other operations for which the hole was originally intended. The agency or contractor in charge of the exploratory or other operations for which the hole was originally intended is responsible for plugging the abandoned hole using the following applicable method, within three calendar days after the termination of testing or other operations.

(A) The entire hole shall be plugged with an approved grouting material from bottom of the hole, up to within three feet of the ground surface, using a grout tremie pipe or similar method.

(B) From three feet below ground surface to ground surface the plugged hole shall be covered over with compacted surface silts or clays.

(C) For bore holes of 25 feet or less, drill cuttings from the original hole may be used to plug the hole in lieu of grouting material, provided that an aquifer is not penetrated or the bore hole is not drilled in an area determined by the department to be a contaminated area.

(3) Plugging of heat pump holes drilled for closed loop heat pump systems. The entire hole shall be plugged with an approved grouting material from bottom of the hole, to the bottom of the horizontal trench, using a grout tremie pipe or similar method approved by the department.

(e) ~~Cased test holes shall be plugged by the contractor within three days after completion of testing by using methods described in K.A.R. 28-30-7 (a) and (b), or (a) and (c), whichever applies.~~ Abandoned oil field water supply wells. A water well drilled at an oil or gas drilling site to supply water for drilling activities shall be considered an abandoned well immediately after the termination of the oil or gas drilling operations. The company in charge of the drilling of the oil or gas well shall be responsible for plugging the abandoned water well, in accordance with K.A.R. 28-30-7(a), (b), and (c), within 30 calendar days after the termination of oil or gas drilling operations.

Responsibility for the water well may be conveyed back to the landowner in lieu of abandoning and plugging the well but the well must conform to the requirements for active or inactive status. The transfer must be made through a legal document, approved by the department, advising the landowner of the landowner's responsibilties and obligations to properly maintain the well, including the proper plugging of the well when it is abandoned and no longer needed for water production activities. If a transfer is to be made, the oil or gas drilling company shall provide the department with a copy of the transfer document within 30 calendar days after the termination of oil or gas drilling operations. Within 30 calendar days of the effective date of the transfer of the well the landowner shall notify the department of the intended use and whether the well is in active status or inactive status in accordance with K.A.R. 28-30-7(f).

(f) Inactive status. Landowners may obtain the department's written approval to maintain wells in an inactive status rather than being plugged if the landowner can present evidence to the department as to the condition of the well and as to the landowner's intentions to use the well in the future. As evidence of intentions, the owner shall be responsible for properly maintaining the well in such a way that:

(1) The well and the annular space between the hole and the casing shall have no defects that will permit the entrance of surface water or vertical movement of subsurface water into the well;

(2) the well is clearly marked and is not a safety hazard;

(3) the top of the well is securely capped in a watertight manner and is adequately maintained in such a manner as to prevent easy entry by other than the landowner;

(4) the area surrounding the well shall be protected from any potential sources of contamination within a 50 foot radius;

(5) if the pump, motor or both, have been removed for repair, replacement, etc., the well shall be maintained to prevent injury to people and to prevent the entrance of any contaminant or other foreign material;

(6) the well shall not be used for disposal or injection of trash, garbage, sewage, wastewater or storm runoff; and

(7) the well shall be easily accessible to routine maintenance and periodic inspection.

The landowner shall notify the department of any change in the status of the well. All inactive wells found not to be in accordance with the criteria listed in lines one through seven above shall be considered to be abandoned and shall be plugged by the landowner in accordance with K.A.R 28-30-7(a) through (c). (Authorized by K.S.A. ~~1981 Supp.~~ 82a-1205; implementing K.S.A. ~~1981 Supp.~~ 82a-1202, 82a-1205, 82a-1212, 82a-1213; effective, E-74-34, July 2, 1974; modified, L. 1975, Ch. 481, May 1, 1975; amended May 1, 1980; amended May 1, 1983; amended May 1, 1987.)

28-30-8. Pollution sources. Well locations shall be approved by municipal and county governments with respect to distances from pollution sources and compliance with local regulations. The following minimum standard shall be observed.

(a) The horizontal distances between the well and the potential source of pollution or contamination such as sewer lines, pressure sewer lines, septic tanks, lateral fields, pit privy, seepage pits, fuel or fertilizer storage, pesticide storage, feed lots or barn yards shall be ~~fifty (50)~~ 50 feet or more as determined by the department.

(b) Proper drainage in the vicinity of the well shall be provided so as to prevent the accumulation and ponding of surface water within 50 feet of the well. The well shall not be located in a ravine or any other drainage area where surface water may flow into the well.

~~(b)~~ (c) When sewer lines are constructed of cast iron, plastic or other equally tight materials, the separation distance shall be ~~ten (10)~~ 10 feet or more as determined by the department.

~~(c)~~ (d) All wells shall be ~~twenty-five (25)~~ 25 feet or more from the nearest property line, allowing public right-of-ways to be counted; however, a well used only for irrigation or cooling purposes may be located closer than ~~twenty-five (25)~~ 25 feet to an adjoining property where:

(1) such adjoining property is served by a sanitary sewer and does not contain a septic tank system, disposal well or other source of contamination or pollution; and ~~where~~

(2) the property to be provided with the proposed well is served by both a sanitary sewer and a public water supply. (Authorized by and implementing K.S.A. ~~1979 Supp.~~ 82a-1202, 82a-1205; effective, E-74-34, July 2, 1974; modified, L. 1975, Ch. 481, May 1, 1975; amended May 1, 1980; amended May 1, 1987.)

28-30-9. Appeals. (a) Requests for exception to any of the foregoing rules and regulations shall be submitted to the ~~bureau of oil field and environmental geology of the~~ department in writing and shall contain all information relevant to the request.

(1) Those requests shall specifically set forth why such exception should be considered.

(2) The ~~bureau of oil field and environmental geology~~ department may grant exceptions when geologic or hydrologic conditions warrant an exception and when such an exception is in keeping with the purposes of the Kansas groundwater exploration and protection act.

(b) Appeals from the decision of the ~~bureau of oil field and environmental geology~~ department shall be made to the secretary, who after due consideration may affirm, reverse or modify the decision of the ~~bureau~~ department. (Authorized by K.S.A. ~~1981 Supp.~~ 82a-1205; implementing K.S.A. ~~1981 Supp.~~ 82a-1202, 82a-1205; effective, E-74-34, July 2, 1974; effective May 1, 1975; amended May 1, 1980; amended May 1, 1983; amended May 1, 1987.)

28-30-10. Water well disinfection for wells constructed or reconstructed for human consumption or food processing. (a) Gravel for gravel-packed wells shall be disinfected by immersing the gravel in a chlorine solution containing not less than ~~two hundred (200)~~ 200~~,~~ ~~(milligrams mg/l~~, ~~per liter)~~ milligrams per liter, mg/l, of available chlorine before it is placed in the wells annular space.

(b) Constructed or reconstructed wells shall be disinfected by adding sufficient hypochlorite solution to them to produce a concentration of not less than ~~one hundred (100)~~ 100 ~~(~~mg/l~~)~~ of available chlorine when mixed with the water in the well.

(c) The pump, casing, screen and pump column shall be washed down with a ~~two hundred (200)~~ 200 mg/l available chlorine solution.

(d) All persons constructing, reconstructing, or treating, a water well and removing the pump or pump column, replacing a pump, or otherwise performing an activity which has potential for contaminating or polluting the groundwater supply shall be responsible for adequate disinfection of the well, well system and appurtenances thereto. (Authorized by and implementing K.S.A. ~~1979 Supp.~~ 82a-1202, 82a-1205; effective, E-74-34, July 2, 1974; modified, L. 1975, ch. 481, May 1, 1975; amended May 1, 1980; amended May 1, 1987.)

Effective Date May 1, 1980

Kansas Department of Health and Environment
Approved Water Well Casing
(Authorization K.A.R. 28-30-6(h))

Water Well Casing for Water Wells Other Than Public
Water Supply and Reservoir Sanitation Zone Water Wells.

STEEL AND WROUGHT IRON

Depth of Casing in Feet	Nominal Diameter, (in inches)									
	4	6	8	10	12	14	16	18	24	30
	Minimum Wall Thickness *									
0-100	10	10	10	10	10	10	10	10	7	.219
100-200	10	10	10	10	10	7	7	7	.219	.219
200-400	10	10	10	10	7	7	7	.219	.250	.250
400-600	7	7	7	7	7	7	.219	.250	.312	.312
600 +	7	.219	.219	.219	.219	.219	.250	.375	.375	.375

*Decimal numbers indicate thickness in inches. Whole numbers indicate the United States standard gauge (10 gauge=0.141 inches and 7 gauge=0.179 inches).

Effective Date May 1, 1980

Kansas Department of Health and Environment
Approved Water Well Casing
(Authorization K.A.R. 28-30-6(h))

Water Well Casing for Water Wells Other Than Public
Water Supply and Reservoir Sanitation Zone Water Wells.

THERMALPLASTIC WATER WELL CASING

For Polyvinyl Chloride (PVC), Styrene Rubber (SR)
which is the same as Rubber Modified Polystyrene (RMP)
and Acrylonitrile - Butadiene - Styrene (ABS)

Minimum Wall Thickness (inches) and Tolerances (inches) made in
Standard Dimension Ratios (SDR).

Nominal	SDR 26		SDR 21		SDR 17		SDR 13.5	
Pipe Size	Minimum	Tolerance	Minimum	Tolerance	Minimun	Tolerance	Minimum	Tolerance
2	--	--	0.113	0.020	0.140	0.020	0.176	0.021
2.5	--	--	0.137	0.020	0.169	0.020	0.213	0.026
3	--	--	0.167	0.020	0.206	0.025	0.259	0.031
3.5	--	--	0.190	0.023	0.235	0.028	0.296	0.036
4	0.173	0.021	0.214	0.026	0.265	0.032	0.333	0.040
5	0.214	0.027	0.265	0.032	0.327	0.039	0.412	0.049
6	0.255	0.031	0.316	0.038	0.390	0.047	0.491	0.058
8	0.332	0.040	0.410	0.049	0.508	0.061	--	--
10	0.413	0.050	0.511	0.061	0.632	0.076	--	--
12	0.490	0.059	0.606	0.073	0.750	0.090	--	--
14	0.539	0.065						
16	0.616	0.074						

The minimum is the lowest wall thickness of the well casing pipe at any cross section. All tolerances are on the plus side of the minimum requirement.

APPENDIX V

Sampling and Storage Procedures

APPENDIX V

SAMPLING AND STORAGE PROCEDURES

Samples were usually collected from a faucet closest to the well. In many cases this involved an outside faucet either at the well house, the house, or from a frost-proof hydrant in the yard. Some samples were collected from faucets inside the house, where necessary, and when sampling for examination of bacteria. In cases where a softener was being used, a tap before the softener was used. Generally such a tap was located at the kitchen sink to provide drinking water.

The well was pumped for a period considered sufficient to obtain representative formation water. The water temperature was measured until it stabilized, serving as an indication of the representativeness of the water. Generally the domestic wells were used on a daily basis, therefore a long pumping period was not required.

When outside faucets were used, water was usually allowed to run into a plastic five-gallon bucket in order to calculate approximate discharge rate and to observe the water for sediment, odor, discoloration, and dissolved gases.

For monthly sampling and analysis of chloride and nitrate concentrations and specific conductance, 500-mL polyethelene bottles were filled, numbered, stored on ice and transported either to a nearby motel room or to laboratory facilities at the Analytical Services Section of the Kansas Geological Survey (KGS), housed in Moore Hall at the University of Kansas, in Lawrence, Kansas. There, measurement of nitrate concentration was usually conducted within 24 hours using a portable colorimeter (Hach Co., Model DR/1A, Ames, IA.). However, on a few occasions some samples were held longer, as much as 55 hours before analysis. Several acidified duplicate samples were collected for nitrate determination by the KGS Analytical Services Section. Results showed relatively good agreement in concentration values with the Hach method, especially for samples analyzed within 24 hours.

In most cases samples collected did not require filtration, with the exception of several samples from Clear Creek and well L26. Samples from these sources were filtered prior to analysis using filtration equipment at the KGS Analytical Services laboratory.

After the nitrate determinations were complete, the samples were stored at room temperature for several days to two weeks until the chloride analysis and measurement of specific conductance could be performed.

Samples collected for analysis of total organic carbon (TOC) (as volatile, VOC, and nonvolatile organic carbon NVOC), and the dissolved gases methane, oxygen, and carbon dioxide (May 8 and August 15, 1985), were collected from the same taps as were used for the monthly samplings, after temperatures of the discharging ground water had stablized. The discharge rate from the faucet was substantially reduced prior to sample collection in order to obtain an undisturbed sample to reduce the potential loss of VOC's, if present. However, because all of the wells used in the study area were equiped with variable displacement pumps, degassing probably affected the concentrations of VOC's and dissolved gases that were obtained (Barcelona, et al., 1984). Two 100-mL glass serum bottles were filled slowly until overflowing. A Teflon-lined septum was then inserted in an aluminum seal and carefully placed over each bottle and crimped into place. If at this point any air bubbles were present in a serum bottle, the seal was removed, the sample recollected, and the sealing process repeated until a sample was obtained that contained no air bubbles. The two samples (per well) were marked, stored on ice and transported to the University of Kansas in Lawrence within 24 to 48 hours. One of the samples was delivered to the C.L. Burt Laboratory housed at Learned Hall for analysis of TOC (as VOC and NVOC) by Dr. Stephen J. Randtke. The second sample (May sampling only) was deliverd to the Mass Spectrometry Laboratory housed in Malott Hall for determination of dissolved methane, oxygen, and carbon dioxide by Dr. Charles Judson. Because there were no detectable amounts (> 0.02 mg/L) of VOC in the August 1985 samples, analyses for the dissolved gases were not conducted.

Sampling for the standard inorganic chemistry analyses (September 24, 1984 and May 8, 1985), involved pumping the well until one well-bore volume of water had been discharged. Then field measurements of temperature, pH (portable meter - Model 607, Fisher Scientific Co., St. Louis, Mo.), and specific conductance (portable meter - Lectro-MHO Meter Model MC-1, Mark 4, Lab-Line Instr. Co., Melrose Park, IL.) were made on several grab samples until these parameters had stablized. One 500-mL polyethelene bottle was then filled for determination of pH, specific conductance, and major anions and cations. Also, a 250-mL polyethelene bottle containing 2 mL of redistilled 6N hydrochloric acid was filled to 200 mL for measurement of trace metals, nitrate, and ammonium. These bottles were marked, stored on ice, and transported to the Analytical Services Section laboratory of the KGS where the analyses were performed by the Section staff under the supervision of Dr. Lawrence Hathaway.

Sampling for the examination of fecal coliform and fecal Streptococcus bacteria (December 17, 1984 and May 20, 1985), was as per instructions from the Kansas

Department of Health and Environment (KDHE). The procedure involved running water for at least five minutes through a nonaerated faucet, preferably inside the house or building. Samples were collected in specially marked plastic bottles provided by the KDHE. The samples were stored on ice and tranported to the Environmental Laboratory, located in Forbes Building 740 in Topeka, Kansas within 24 hours to be examined for the presence of fecal coliform and fecal Streptococcus bacteria. The results were then interpreted and reported by the KDHE.

APPENDIX VI

Analytical Methods and Results

APPENDIX VI

ANALYTICAL METHODS AND RESULTS

Nitrate

Nitrate was determined using a portable colorimeter (Hach Co., Model DR/1A, Ames, IA.) according to a cadmium reduction method modified to use gentisic acid in place of 1-naphthylamine. All necessary reagents were combined into a single stable powder pillow called NitraVer 5 Nitrate Reagent. The test registered both nitrate and nitrite (as N) present in a 25 mL water sample. In most cases, dilutions were not needed because the operating range 0-30 mg/L as N was used.

The samples were brought to room temperature (20° to 24°C as recommended) before analysis. Only a few samples collected from Clear Creek and well L26 required filtering prior to analysis. One reagent blank (using distilled water) and three nitrate-N standards (10, 20, and 30 mg/L as N) were tested prior to and following each group of samples or when the chemical reagent of one lot number was exhausted and that of another was started. The three standards were freshly prepared each month just before analysis from a stock 100 mg/L nitrate-N standard which was prepared every two to three months.

After each group of samples was analyzed, an averaged blank value was subtracted from each of the sample concentrations and the resulting concentrations were corrected using calibration curves of the nitrate standards. Corrected values that were less than 1 mg/L or zero were reported as <1 mg/L.

The results were converted by multiplying by 4.43 and expressed as mg/L nitrate-NO_3 for this study. The results of the nitrate determinations are presented in Table A1.

Several duplicate samples were collected and analyzed for nitrate concentration in order to estimate the analytical error of the in-field testing equipment. The duplicates were analyzed by the Analytical Services Section of the Kansas Geological Survey. The reported accuracy of the automated cadmium reduction method utilized by the Section was 4 percent or less (Standard Methods, 1980). The difference in nitrate concentrations determined by the two methods ranged from 4 to 27 percent with the average difference being 16 percent. The greater percent differences were associated with longer holding times of some samples before nitrate analysis could be performed using the in-field testing equipment. Because samples analyzed using the Hach method were not preserved at the time of collection, the nitrate values reported were consistently lower than the nitrate values obtained using Standard Methods.

Table A1. Results of the nitrate, chloride, and specific conductance determinations.

Well No.		1984						1985								
		July 31	August 1-2	Sept. 24(a)	Oct. 24	Nov. 27	Dec. 17	Jan. 22-23	Feb. 18	March 18	April 24	May 8(a)	May 20-23	June 17	July 24	Aug. 15
L1	Cl		240													
	NO3		--													
	SpCond		2,900													
L2	Cl	68		39	33	31	31	30	32	36	35	47	53	82	33	35
	NO3	---		22	- - -	13	13	11	12	14	15	47	85	237	15	19
	SpCond	1,270		945	920	920	928	935	934	935	941	1,122	1,183	1,649	947	940
L3	Cl		130	84	69	55	59	88	57	72	71	38	65	94	56	65
	NO3		---	63	---	28	33	39	27	34	33	15	31	38	28	27
	SpCond		2,380	1,560	1,530	1,227	1,363	1,885	1,252	1,617	1,575	757	1,333	1,950	1,263	1,400
L4	Cl							28	29		33			40	32	32
	NO3							13	15		18			139	38	19
	SpCond							902	895		969			1,263	988	960
L5	Cl		100					23	23	23	26			33	43	36
	NO3		---					14	14	20	20			22	26	22
	SpCond		1,298					837	830	837	865			900	980	934
L6	Cl		64					23						145		31
	NO3		---					19						92		22
	SpCond		1,120					885						1,775		901
L7	Cl	48														
	NO3	---														
	SpCond	1,030														
L8	Cl	243														
	NO3	---														
	SpCond	2,195														
L9	Cl	63												60		
	NO3	---												7		
	SpCond	1,067												1,060		
L10	Cl	48		49	34	33	38	33	39	51	49	63	64	69	48	51
	NO3	---		30	---	20	22	19	22	21	21	17	22	21	22	20
	SpCond	1,046		940	909	915	974	942	949	1,072	1,052	1,181	1,192	1,219	1,017	1,031
L11	Cl	74														
	NO3	---														
	SpCond	1,361														
L12	Cl	190						164		162	189		182	175	173	161
	NO3	---						37		42	39		48	43	42	36
	SpCond	1,735						1,565		1,617	1,725		1,700	1,737	1,665	1,625

Table A1. (continued).

		1984						1985								
Well No.		July 31	August 1-2	Sept. 24(a)	Oct. 24	Nov. 27	Dec. 17	Jan. 22-23	Feb. 18	March 18	April 24	May 8(a)	May 20-23	June 17	July 24	Aug. 15
L13	Cl	32														
	NO3	---														
	SpCond	934														
L14	Cl	72						43						81		76
	NO3	---						13						62		34
	SpCond	1,128						960						1,227		1,135
L15	Cl		137					96	101	110	93			127	112	107
	NO3		---					56	47	41	51			36	55	57
	SpCond		1,620					1,353	1,360	1,488	1,316			1,620	1,410	1,390
L16	Cl		112	108	107	105	107	103	96	96	103	104	104	100	107	99
	NO3		---	43	---	25	28	27	31	26	27	35	26	26	26	27
	SpCond		1,272	1,260	1,270	1,270	1,270	1,271	1,246	1,245	1,262	1,286	1,288	1,316	1,271	1,245
L17	Cl		52					57	60	58	57		57	50	56	53
	NO3		- - -					38	41	40	37		41	42	39	34
	SpCond		921					949	955	960	935		941	959	935	933
L18	Cl		121	125	118	111	103	100	95	102	115	124	114	123	115	114
	NO3		---	38	---	26	24	19	21	23	28	30	25	26	28	26
	SpCond		1,328	1,360	1,345	1,316	1,297	1,280	1,261	1,270	1,352	1,337	1,335	1,370	1,333	1,326
L19	Cl		144	116		93	89	95	100	145	155	196	187	180	149	*116
	NO3		---	115		77	72	67	69	76	88	162	162	144	92	70
	SpCond		1,875	1,558		1,445	1,422	1,560	1,585	2,190	2,040	2,430	2,550	2,460	1,980	1,674
L20	Cl		77	84	66	69	68	67	70	69	63	61	69	70	68	70
	NO3		---	90	---	62	63	55	63	58	55	60	54	55	55	57
	SpCond		1,335	1,302	1,253	1,245	1,253	1,236	1,237	1,245	1,220	1,159	1,245	1,235	1,235	1,245
L21	Cl		96	97	83	87	89	88	79	88		104	98	99	98	95
	NO3		---	39	---	23	24	20	22	24		28	27	27	26	28
	SpCond		1,210	1,181	1,168	1,160	1,175	1,145	1,145	1,152		1,220	1,220	1,227	1,210	1,219
L22	Cl							5		9	9		8	8.5	9	10
	NO3							18		15	18		19	14	18	16
	SpCond							778		784	783		778	796	790	784
L24	Cl							* 26	28	25				* 33	35	38
	NO3							21	20	19				26	25	23
	SpCond							877	865	864				955	961	947
L25	Cl							30		71	45				42	38
	NO3							27		78	48				35	33
	SpCond							947		1,298	1,047				1,030	1,010

Table A1. (continued).

		1984						1985								
Well No.		July 31	August 1-2	Sept. 24(a)	Oct. 24	Nov. 27	Dec. 17	Jan. 22-23	Feb. 18	March 18	April 24	May 8(a)	May 20-23	June 17	July 24	Aug. 15
L26	Cl							23	23	63	27		73	78	44	61
	NO3							16	11	187	27		190	195	56	139
	SpCond							902	848	1,660	907		1,725	1,790	1,177	1,517
L27	Cl							58	56	63	55					
	NO3							464	473	629	434					
	SpCond							1,885	1,875	2,265	1,810					
L27	Cl								(b) 52	(b) 52	(b) 42			(c) 122		
	NO3								383	454	269			246		
	SpCond								1,675	1,875	1,466			1,445		
L28	Cl	37				41	17	38	27	29	31		30	23	38	28
	NO3	- - -				<1	12	3	8	<1	<1		1	5	2	<1
	SpCond	920				961	365	947	621	704	800		807	740	790	674
L29	Cl														114	107
	NO3														36	34
	SpCond														1,699	1,699
L30	Cl															173
	NO3															11
	SpCond															1,950
#31	Cl	27	21	26	20	21		19	20	31	21		34	37	22	
	NO3	- - -	- - -	- - -	- - -	33		29	34	28	31		29	28	26	
	SpCond	757	756	750	757	704		783	740	837	761		783	796	790	

(a) Chloride and nitrate concentrations represent results from standard inorganic chemistry analyses. Specific conductance values represent measurements made in field.

- Well L19: this sample was collected August 19, 1985
- Well L24: these samples were collected January 25 and June 20, 1985, respectively

(b) For well L27: These samples were collected minute(s) after first samples

(c) For well L27: This sample was collected after 2 minutes of pumping. It was reported that approximately 1,600 gallons had been pumped from this well prior to collection of this sample.

Cl = Chloride (mg/L)
NO3 = Nitrate (mg/L as NO3)
SpCond = Specific Conductance (umhos/cm)

Chloride

Chloride concentrations were determined by using a hand-held digital titrator, a 2.256N Mercuric Nitrate Titration Cartridge, and Diphenylcarbazon Reagent Powder Pillows (Hach Co., Ames, IA.). The analysis was performed on a 100 mL sample of water.

The samples were already at room temperature prior to analysis and several had been filtered prior to the nitrate determinations. One blank (distilled water) and four standards (50, 100, 250, and 500 mg/L Cl) were titrated before and after each group of samples, or when the chemical reagents of one lot number were exhausted and those of another were started. These titrated values were used to construct a calibration curve which was then used to correct the titrated sample concentrations. The estimated analytical error for the chloride determinations was 4 percent. The results are shown in Table A1.

Specific Conductance

Measurements of specific conductance were made at the same time as the chloride analyses. A portable meter (Lectro-MHO, Model MC-1, Mark 4, Lab-Line Instrument Co., Melrose Park, IL.) was used to determine specific conductance and the results are expressed in micromhos per centimeter at 25^{0}C (Table A1). The estimated accuracy of the conductivity meter was 2 percent.

Total Organic Carbon

Volatile (VOC) and nonvolatile organic carbon (NVOC) fractions of total organic carbon (TOC) were determined using a Dohrman/Envirotech DC-80 TOC Analyzer according to methods described by Barcelona (1984). Analyses were performed in the C.L. Burt Laboratory, Learned Hall, at the University of Kansas by Dr. Stephen J. Randtke. Analytical precision was ± 2% and the detection limit was approximately 0.02 mg/L of carbon. Results of the VOC and NVOC determinations are presented in Table A2.

Table A2

	May 8, 1985		August 15, 1985	
Well #	VOC (mg/L)	NVOC (mg/L)	VOC (mg/L)	NVOC (mg/L)
L2	Nil^	1.11	Nil	4.47
L3*	Nil	6.12	Nil	5.80
L5*	Nil	0.74	Nil	1.25
L10	Nil	3.27	Nil	2.15
L16	Nil	1.92	Nil	3.05
L18*	Nil	2.95	Nil	4.81
L19	Nil	5.63	Nil	4.88
L20	Nil	4.38	Nil	3.10
L21	Nil	1.22	Nil	3.05
L22*	--	--	Nil	3.51

^Nil = less than 0.020 mg-C/L.

* well of pre-standard construction

Analysis of the May 8th samples was performed with samples having 1-2 mL of headspace for 24 hours because equipment malfunction had caused the original analyses to be invalid (Randtke, 1985). This could have affected the detection of VOC in these samples. However, the method of sample collection for TOC probably had a greater effect on the detection of VOC.

The May 8th sample from well L3 had a trace of sediment, but the sediment was not disturbed and the sample was not filtered prior to analysis (Randtke, 1985).

Dissolved Gases

Samples collected May 8, 1985, were analyzed for dissolved methane, oxygen, and carbon dioxide using a gas chromatograph/mass spectrometer. The analyses were performed by Dr. Charles Judson of the Mass Spectrometry Laboratory at the University of Kansas. Methane was determined according to methods described by McAuliffe (1971). The results of the determinations are presented in Table A3.

A sample collected at Well L21 was accidentally broken in the laboratory, therefore, results are not available.

Table A3

Well #	Methane (CH_4) (μg/L)	Oxygen (O_2) (mg/L)	Carbon Dioxide (CO_2) (mg/L)
L2	0.7	1.3	13.3
L3*	1.3	1.0	8.3
L5*	0.1	2.7	3.0
L10	0.7	2.2	8.0
L16	1.9	0.5	8.1
L18*	0.1	2.6	5.5
L19	1.5	6.5	40.
L20	2.7	1.9	5.8
L21	--	--	--

* well of pre-standard construction

Standard Inorganic Chemistry

The standard inorganic chemistry analyses were performed by the Analytical Services Section of the Kansas Geological Survey housed at Moore Hall on the West Campus of the University of Kansas in Lawrence, KS.

Analytical results for the September 24, 1984 and May 8, 1985 samplings are presented in Table A4. The ionic balances computed for these results indicate that the analyses are very good with the greatest deviation from electroneutrality (the difference between the sums of milliequivalents/L of anions and cations divided by total milliequivalents/L) equal to 2.87 percent for the September 1984 analyses and 2.37 percent for the May 1985 analyses (Hathaway, 1984 and 1985).

Table A4. Results of the standard inorganic chemistry analyses showing percent differences between the September 1984 and May 1985 samplings.

Well No.	Sample date	Temp °C, field	Specific conductance, µmhos/cm	pH, field	pH, lab	Total dissolved solids, (calc) mg/L	SiO_2 mg/L	Ca mg/L
L2	09-24-84	15.5	955	7.2	7.7	598	23	117
	05-08-85	14.4	1122	7.15	7.35	699	18	132
	% change	-7	15	-1	-4	14	-22	11
L3	09-24-84	15	1430	7.15	7.6	1156	30	241
	05-08-85		757	6.65	6.8	464	17	90
	% change		-47	-7	-10	-60	-43	-63
L10	09-24-84	14.8	960	7.15	7.58	591	20	99
	05-08-85	14.7	1181	7.1	7.2	690	16	104
	% change	-1	19	-1	-5	14	-20	5
	06-21-83	15	1540	6.95		898	20	126
	% change	1	38	-3		34	0	21
L16	09-24-84	15	1270	7.1	7.5	759	26	134
	05-08-85	14.7	1286	7.05	7.15	744	21	132
	% change	-2	1	-1	-5	-2	-19	-1
L18	09-24-84	15	1380	6.95	7.45	825	28	143
	05-08-85	15	1337	7.05	7.15	767	21	130
	% change	0	-3	1	-4	-7	-25	-9
L19	09-24-84	14.6	1600	7.1	7.55	1032	24	137
	05-08-85	13.6	2430	7.05	7.2	1575	19	161
	% change	-7	34	-1	-5	34	-21	15
L20	09-24-84	15	1318	7.05	7.6	842	25	134
	05-08-85	14.4	1159	7.15	7.3	714	20	117
	% change	-4	-12	1	-4	-15	-20	-13
L21	09-24-84	14	1219	7.15	7.6	744	23	129
	05-08-85	14.2	1220	7.15	7.2	713	18	125
	% change	1	0	0	-5	-4	-22	-3

Table A4. (continued)

Well No.	Mg mg/L	Na mg/L	K mg/L	Sr mg/L	NH_4 mg/L	HCO_3 mg/L	SO_4 mg/L	Cl mg/L
L2	45	27	2.1	1.8	< 0.1	374	137	39
	49	42	1.8	1.9	< 0.1	400	163	47
	8	36	-14	5		6	16	17
L3	56	59	8.1	4.2	< 0.1	375	426	84
	16	52	1.4	1.2	< 0.1	267	102	38
	-71	-12	-83	-71		-29	-76	-55
L10	45	52	3.1	.6	< 0.1	428	81	49
	47	89	2.5	.6	0.1	523	93	63
	4	42	-19	0		18	13	22
	61	126	3.1	.6		553	148	106
	26	59	0	0		23	45	54
L16	58	57	3.8	.8	< 0.1	447	108	108
	57	56	3.9	.8	< 0.1	441	117	104
	-2	-2	2	0		-1	8	-4
L18	56	78	3	.7	< 0.1	473	120	125
	51	78	3.5	.6	< 0.1	483	91	124
	-9	0	14	-14		2	-24	-1
L19	68	126	3	1.9	< 0.1	459	215	116
	84	267	2.7	1	< 0.1	642	366	196
	19	53	-10	-47		28	41	41
L20	58	72	4.5	1.2	< 0.1	400	176	84
	49	59	6.3	1	< 0.1	388	150	61
	-16	-18	28	-17		-3	-15	-27
L21	55	57	5.4	.9	< 0.1	398	141	97
	50	60	2.5	1	< 0.1	410	123	104
	-9	5	-54	10		3	-13	7

Table A4. (continued)

Well No.	F mg/L	NO_3 mg/L	PO_4 mg/L	B µg/L	Total Hardness ($CaCO_3$) mg/L	Non-Carbonate Hardness ($CaCO_3$) mg/L
L2	.3	22	.09	123	479	173
	.3	47		80	533	205
	0	53		-35	10	15
L3	.3	63	.12	422	836	529
	.2	15		90	292	73
	-33	-76		-79	-65	-86
L10	.2	30	.25	54	433	82
	.3	17		89	453	25
	33	-43		39	4	-70
	.2	35			566	113
	0	14			23	27
L16	.2	43	.27	183	574	207
	.2	35		105	565	203
	0	-19		-43	-2	-2
L18	.2	38	.58	203	588	200
	.3	30		95	535	139
	33	-21		-53	-9	-30
L19	.4	115	.19	144	624	248
	.4	162		163	748	222
	0	29		12	16	-10
L20	.2	90	.22	135	574	246
	.2	60		92	495	177
	0	-33		-32	-14	-28
L21	.3	39	.37	114	549	223
	.3	28		63	519	183
	0	-28		-45	-5	-18

Bacteriological Examination

Examination for fecal coliform and fecal Streptococcus bacteria was conducted by The Environmental Laboratory and interpreted and reported by the Kansas Department of Health and Environment, both located at Forbes Building 740 in Topeka, KS.

The examination consisted of a search for the presence of coliform bacteria in the water samples collected December 17, 1984 and May 20 and 21, 1985. The method used was the membrane filter count according to <u>Standard Methods for the Examination of Water and Wastewater</u> (1980). The results are presented in Table A5.

The examination consisted of either a 10 mL or 20 mL portion of a 100 mL sample. The number of bacterial counts (colonies) was reported per 100 mL. Therefore, if no bacteria were found, results were reported as less than 10 counts per 100 mL for a 10 mL aliquot, and less than 5 counts per 100 mL for a 20 mL aliquot.

Table A5

	December 17, 1984		May 20-21, 1985	
Well #	fecal coliform	fecal Streptococcus	fecal coliform	fecal Streptococcus
L2	<5	<5	<10	<10
L3*	<5	<5	<10	30
L5*	--	--	<10	<10
L10	<5	<5	<10	10
L16	<5	<5	<10	<10
L18*	<5	<5	<10	30
L19	<5	<5	<10	<10
L20	<5	<5	<10	10
L21	<5	280	<10	<10

* well of pre-standard construction

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