

# Hydrogeology and Water Quality of Five Principal Aquifers in the Lower Platte South Natural Resources District, Eastern Nebraska, 1994

*By A.D. Druliner and J.P. Mason*

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## Conversion Factors and Vertical Datum

Multiply	By	To obtain
inch	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.004047	square kilometer
square foot (ft <sup>2</sup> )	929.0	square centimeter
square foot (ft <sup>2</sup> )	0.09290	square meter
square mile (mi <sup>2</sup> )	2.590	square kilometer
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
acre-foot (acre-ft)	1,233	cubic meter
picocurie per liter (pCi/L)	0.037	becquerel per liter

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:  

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:  

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) / 1.8$$

**Sea level:** In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

**Altitude,** as used in this report, refers to distance above or below sea level.

**Specific conductance** is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

**Concentrations of chemical constituents** in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

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## ABSTRACT

The U.S. Geological Survey, in cooperation with the Lower Platte South Natural Resources District, conducted a hydrogeologic and water-quality reconnaissance study of the five principal aquifers in deposits of Quaternary age in the Natural Resources District. The purpose of the study was to delineate the approximate extent of the aquifers, to estimate volumes of drainable water in three aquifers, to provide information that could be useful in designing future ground-water-quality monitoring, and to determine baseline water-quality conditions in the aquifers, focusing on nitrate concentrations.

The approximate lateral boundaries of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers were defined as areas in which the thickness of continuous sand and gravel deposits was less than 40 feet. The three aquifers were determined to contain about 1,340,000; 1,540,000; and 172,000 acre-feet of drainable water, respectively, assuming a specific yield of 0.20.

During the summer of 1994, ground-water samples were collected from 46 wells in the five aquifers and analyzed for nitrate and screened for triazine herbicides. Additionally, water samples from 39 of these wells were analyzed for major ions, iron, and manganese, and 35 were analyzed for radon.

Water-quality analyses revealed that the water in the five aquifers had specific conduc-

tances that ranged from 399 to 2,040 microsiemens per centimeter and was a calcium-carbonate to calcium-magnesium-sodium carbonate type. The most mineralized water samples were from the Crete-Princeton-Adams aquifer, which contained a median concentration of dissolved solids of 520 milligrams per liter. Concentrations of nitrate in water samples from the aquifers ranged from less than 0.05 to 23 milligrams per liter as nitrogen, and only six water samples exceeded the Maximum Contaminant Level established by the U.S. Environmental Protection Agency of 10 milligrams per liter. The median concentration of radon for water samples from the five aquifers was 300 picocuries per liter, which is the proposed Maximum Contaminant Level. Water samples from the Crete-Princeton-Adams and Waverly aquifers had the largest concentrations of radon among the five aquifers. The Crete-Princeton-Adams aquifer had a median concentration of 440 picocuries per liter, and the Waverly aquifer had a median concentration of 390 picocuries per liter. Herbicides were detected in water from only six wells, which were in four of the five aquifers. Atrazine, metabolites of atrazine, metolachlor, and metribuzin were detected in concentrations generally less than 1.00 microgram per liter.

## INTRODUCTION

Residents of the Lower Platte South Natural Resources District (LPS NRD), located in eastern

Nebraska, derive much of their irrigation, industrial, and drinking-water supplies from five principal aquifers in deposits of Quaternary age. These five aquifers are the Dwight-Valparaiso, the Crete-Princeton-Adams, the Waverly, the Platte River, and the Missouri River aquifers (fig. 1). The quantity and quality of water in these aquifers are principal concerns of residents of the LPS NRD. Furthermore, the ground-water management plan of the LPS NRD (Glenn Johnson, LPS NRD, oral commun., 1994) requires that these aquifers be managed in a manner that will ensure an adequate supply of clean, usable water for generations to come. To accomplish this goal, it is important that the extent of each of these aquifers and the amount of drainable water in each aquifer—water that is available for use—be estimated.

In the recent past, water-quality information has been collected in the LPS NRD as part of studies by the National Uranium Resource Evaluation Program (1981), the University of Nebraska, the Nebraska Department of Health (NDOH), and the LPS NRD. These studies and data-collection efforts show elevated concentrations of nitrate as nitrogen and dissolved solids in the principal aquifers in the LPS NRD. To evaluate and manage these ground-water quality resources efficiently, a system of water-quality-sampling sites that are representative of each of the principal aquifers and a more accurate delineation of these aquifers would be useful.

To satisfy these data needs, the U.S. Geological Survey (USGS), in cooperation with the LPS NRD, conducted a hydrogeologic and water-quality reconnaissance study of the five principal aquifers in deposits of Quaternary age in the LPS NRD.

## Purpose and Scope

The objectives of the study were (1) to delineate the approximate extent of the principal aquifers and estimate the volumes of drainable ground water in the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers, (2) to provide information that could be useful in designing future ground-water-quality monitoring, and (3) to determine baseline water-quality conditions, with an emphasis on nitrate concentrations. The data may serve as a baseline for the determination of trends in water quality.

## Description of the Study Area

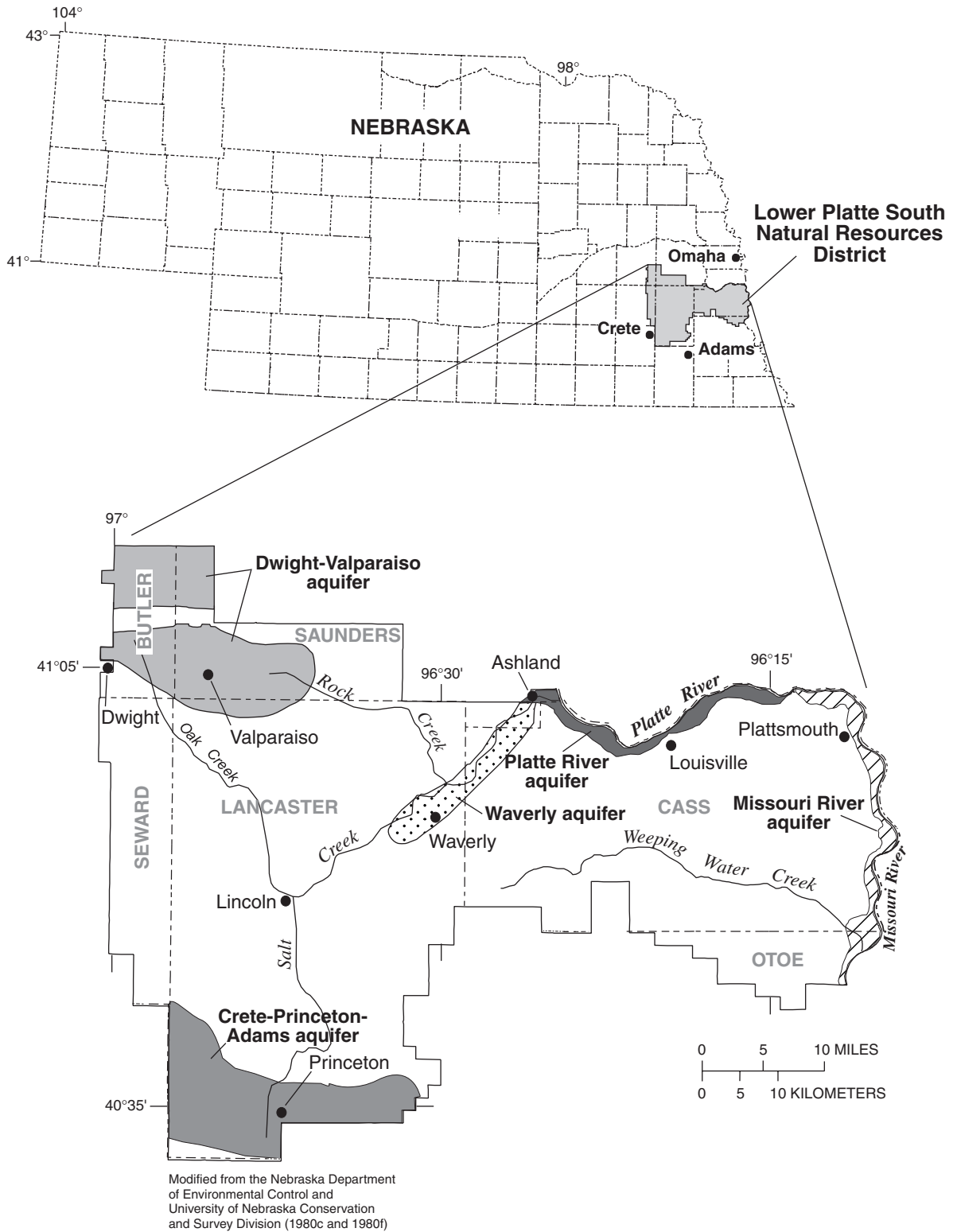
### Location and Surface Features

The LPS NRD occupies about 1,690 mi<sup>2</sup> (square miles) in the extreme eastern part of Nebraska and is bordered by the Platte River on the north and the Missouri River on the east (fig. 1). It includes most of Cass and Lancaster Counties and parts of Butler, Saunders, Seward, and Otoe Counties. The LPS NRD consists principally of two drainage basins. Salt Creek occupies the largest of the basins and drains parts of Saunders, Butler, and Seward Counties and nearly all of Lancaster County. Salt Creek flows into the Platte River in northwestern Cass County. Weeping Water Creek drains the southern two-thirds of Cass County and the northeastern corner of Otoe County, where it flows into the Missouri River.

Physiographically, the LPS NRD is located in the Dissected Till Plains Section of the Central Lowland Province (Fenneman, 1946). Topographically, the study area consists of gently rolling to steep upland areas that encircle the Salt Creek drainage area and divide the Weeping Water Creek drainage and the local Platte River drainage to the north. The upland areas are composed of glacial tills and loess-covered tills that tend to be deeply dissected by numerous small drainages. Terraces are limited mostly to the lower part of the Salt Creek drainage area near the communities of Lincoln and Waverly and to the Platte River. The terraces consist mostly of silt or loess deposits that overlie sand and gravel. Bottomlands extend along the principal streams in the study area.

### Hydrogeologic Setting

The units considered in this report include only bedrock formations that are directly overlain by unconsolidated deposits of Quaternary age (table 1) and the Quaternary-age deposits that overlie them (table 2). Most of the information presented in this section is from Condra and Reed (1959), Goodenkauf (1978), Holly (1980), Lawton and others (1984), and the Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division (1980a-f). Bedrock in the study area consists of rocks of Pennsylvanian, Permian, and Cretaceous age. The Permian and Pennsylvanian rocks underlie most of the LPS NRD and consist of shales interbedded with limestones and sandstones. Aquifers in



**Figure 1.** Location of five principal aquifers, Lower Platte South Natural Resources District.

**Table 1.** Characteristics of selected bedrock units, Lower Platte South Natural Resources District

[Modified from Tanner and Steele, 1991, and Condra and Reed, 1959]

System	Unit	Description	Maximum saturated thickness (feet)	Hydrogeologic characteristics
Cretaceous	Undifferentiated Carlile Shale, Greenhorn Limestone, and Graneros Shale	Shale, marl, and limestone. Shale is calcareous. Limestone is thin-bedded, argillaceous, and interbedded with marl and shale beds.	90	Forms a regional confining unit that, where present, separates the Dakota Sandstone from aquifers in surficial deposits. Occurs only in southeastern Butler County and has a relatively small areal extent (about 10 square miles).
	Dakota Sandstone	Predominantly massive to cross-bedded friable sandstone with interbedded red to light gray, argillaceous to slightly sandy shales. Sandstone may contain ironstone or spherulitic siderite concretions and chert pebbles. Sandstone and shales may be micaceous.	Less than 140	Generally an unconfined to semi-confined aquifer. Wells can yield 50 to 750 gallons per minute. Can be hydraulically connected to saturated sand and gravel in overlying unconsolidated deposits.
Permian and Pennsylvanian	Undifferentiated shale, limestone, and sandstone	Shales interbedded with limestone and sandstone. Shales may be laminated argillaceous, micaceous, arenaceous, calcareous, and fossiliferous and may contain fine gypsum. Limestones may be massive, geodal, fossiliferous, or contain chert. Sandstone is predominantly thin bedded and may contain coal.	Less than 1,000	Contains some minor unconfined to semiconfined aquifers. Wells can yield 20 to 50 gallons per minute in areas where secondary porosity has developed in fractured zones in the limestone sequences. Locally thick sandstone may increase yield. Can be hydraulically connected to saturated sand and gravel in overlying unconsolidated deposits. Where secondary porosity of limestone is not present, the unit is not used for water supply.

Permian and Pennsylvanian rocks underlying the LPS NRD generally are not considered to be major sources of water supply; however, they may yield small volumes of water locally in fracture zones and where sandstone is present.

The Dakota Sandstone of Cretaceous age unconformably overlies Permian and Pennsylvanian rocks in the western part of the LPS NRD. The Dakota Sandstone consists of fine- to medium-textured sandstone interbedded with shale and approaches 140 ft in thickness in some locations. The Dakota Sandstone is an unconfined to semiconfined aquifer and is frequently hydraulically connected to overlying sands and gravels of Quaternary age. The Dakota Sandstone is a significant source of water supply in the LPS NRD, especially where aquifers in deposits of Quaternary age are very thin or absent. Water from the Dakota Sandstone

frequently is of poorer quality than water from overlying aquifers.

A sequence of younger Cretaceous-age rocks—the Carlile Shale, Greenhorn Limestone, and Graneros Shale—overlies the Dakota Sandstone in the extreme northwestern corner of the LPS NRD. These deposits are not considered to be major sources of water supply and form a confining unit that hydraulically separates the underlying Dakota Sandstone from overlying Quaternary-age deposits.

A complex mixture of unconsolidated deposits of Quaternary age unconformably overlies bedrock of Cretaceous, Permian, or Pennsylvanian age in most locations in the LPS NRD. Pleistocene-age deposits of alluvial sands and gravels fill paleovalleys cut into the bedrock. Glacial till of Pleistocene age overlies much of the LPS NRD, and loess of Pleistocene age covers much of the glacial till. Alluvial sediments of Pleis-



**Table 2.** Characteristics of aquifers in unconsolidated deposits, Lower Platte South Natural Resources District

[Modified from Tanner and Steele, 1991]

System	Aquifer	Description	Maximum saturated thickness (feet)	Hydrogeologic characteristics
Quaternary	Platte River aquifer	Predominantly Holocene- and Pleistocene-age sand, gravel, and silt deposits located within the incised bedrock valley of the Platte River.	70	Unconfined alluvial aquifer with wells yielding 900 to 2,000 gallons per minute. Depth to water ranges from 5 to 10 feet.
	Missouri River aquifer	Predominantly Holocene- and Pleistocene-age sand, gravel, and silt deposits within the incised bedrock valley of the Missouri River.	80	Alluvial aquifer usually unconfined but locally may be semiconfined. Most wells yield 600 to 1,200 gallons per minute. Depth to water ranges from 5 to 15 feet.
	Paleovalley alluvial aquifers, including Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers	Predominantly Pleistocene-age silt, sand, gravel, and clay deposits within bedrock valleys. Commonly overlain by thick deposits of fine-textured material, mostly glacial till and some loess.	275	Major alluvial aquifers that are generally semiconfined to confined. Basic directional trend of paleovalleys is west to east. Depth to water ranges from less than 10 to 250 feet. Wells yield 400 to 1,200 gallons per minute.

tocene and Holocene age fill the Platte River and the Missouri River valleys.

Five aquifers provide much of the ground water used in the LPS NRD. The Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers, also called the paleovalley alluvial aquifers (table 2), are in paleovalleys incised into the top of the Dakota Sandstone or older bedrock in the western part of the LPS NRD. The paleovalley alluvial aquifers consist of silts, sands, gravels, and clays and are overlain by glacial till and loess deposits. Along the northeastern and eastern borders of the LPS NRD are the alluvial aquifers of the Platte and Missouri Rivers.

The Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers are identified by the names of the communities near them (fig. 1). The Dwight-Valparaiso aquifer is in the northwestern part of the LPS NRD, consists of about 97 mi<sup>2</sup>, and extends from west to east. The Crete-Princeton-Adams aquifer lies along the southwestern boundary of the LPS NRD, consists of about 115 mi<sup>2</sup>, and extends from west to east. The Waverly aquifer is in the central part of the LPS NRD, consists of about 25 mi<sup>2</sup>, and extends from southwest to northeast. These aquifers generally are

semiconfined to confined, are overlain by glacial till and some loess, and have varying thicknesses. Although total saturated thickness in the areas of the Dwight-Valparaiso and the Crete-Princeton-Adams aquifers can exceed 250 ft, the coarser textured alluvial materials [sand and(or) gravel], in which most water-supply wells are screened, tend to be in the lower parts of these paleovalleys and generally are less than 100 ft thick. These three aquifers are the major sources of ground-water supply in the area, and most of the LPS NRD's more than 500 registered irrigation wells are screened in them.

The Platte River and Missouri River aquifers are unconfined to semiconfined and consist of sand, gravel, and silt deposits that overlie bedrock. The thicknesses of these aquifers are about 70 and 80 ft, respectively, and change little along the river valleys. These aquifers are relatively narrow, and both contain some segments that are nearly isolated from the others on the LPS NRD side of the rivers. Some domestic and irrigation wells are in the Platte and Missouri River aquifers in the study area; for example, the cities of Lincoln and Omaha operate large municipal well fields in the Platte River aquifer near Ashland.

Most recharge in the study area results from infiltration of precipitation (Ellis and others, 1985). Some recharge to and discharge from the aquifers of interest likely occur as seepage from and to less permeable sediments or rocks adjacent to the aquifers. Recharge from streams also occurs in the Waverly, Platte River, and Missouri River aquifers during periods of high flow in Salt Creek, the Platte River, and the Missouri River, respectively. During periods of low flow in the Platte and Missouri Rivers, ground water is discharged from the alluvial aquifers into the rivers.

## Soils

Soil associations present in the LPS NRD have been mapped by the U.S. Department of Agriculture, Natural Resources Conservation Service, and University of Nebraska, Conservation and Survey Division (1990). The Sharpsburg-Pawnee-Steinauer Association covers most of the northwestern quarter of the LPS NRD. This association is characterized by very deep, nearly level to steep, moderately to excessively drained loamy and silty soils with clayey subsoils on the uplands. This association typically forms over glacial till and loess.

The Wymore-Pawnee-Burchard Association covers most of the southern part of the LPS NRD. This association is characterized by very deep, nearly level to moderately steep, moderately well-drained to well-drained, loamy and silty soils with clayey subsoils on the uplands. This association also forms over glacial till and loess.

The Sharpsburg Association covers much of the north-central part of the LPS NRD. This association is characterized by very deep, nearly level to strongly sloping, moderately well drained silty soils. This association forms on uplands covered with loess.

The Marshall-Ponca Association covers much of the northeastern part of the LPS NRD. This association is characterized by very deep, gently sloping to moderately steep, well-drained, silty soils. This association also is found on uplands covered with loess.

The Monona-Ida Association occurs directly adjacent to the flood plains of the Platte and Missouri Rivers. This association is characterized by deep to very deep, strongly sloping to very steep, well to excessively drained, silty soils. This association also is found on uplands covered with loess.

The Albaton-Haynie-Sarpy Association is found on the flood plain of the Platte and Missouri Rivers. This association is characterized by deep, nearly level, poorly to excessively drained, clayey, silty, and sandy soils.

The Kennebec-Nodaway-Zook Association is found on the flood plains of Salt and Oak Creeks. This association is characterized by deep, nearly level, moderately well to poorly drained, silty soils.

The Kipson-Sogn-Wymore Association is found on and adjacent to the Weeping Water Creek flood plain where bedrock occurs at or near the surface. This association is characterized by very shallow to very deep, nearly level to steep, moderately well to somewhat excessively drained, loamy and silty soils formed on bedrock or loess.

## Climate

The LPS NRD lies within the continental interior in the middle latitudes where the climate is characterized by hot summers, severe winters, and moderate amounts of precipitation. The following average climatological conditions are based on the 30-year averages between 1961 and 1990 and on 1994 averages for the Lincoln Municipal Airport, which is generally representative of the LPS NRD (National Oceanic and Atmospheric Administration, 1994a,b). The average annual temperature is about 50 degrees Fahrenheit (°F). The hottest month of the year is usually July with an average temperature of 73°F. The coldest month of the year is usually January with an average temperature of 21°F.

During 1994, the Lincoln Municipal Airport received about 23 inches of precipitation. About 77 percent, or 17 inches, of the precipitation that fell in 1994 occurred during the growing season (April through September).

## Land Use

The principal land use in the LPS NRD is agriculture. In 1992, approximately 79 percent of the land in Cass and Lancaster Counties was used for agriculture. Of the total cropland in Cass and Lancaster Counties in 1992, 30 percent was planted in soybeans, 25 percent was planted in sorghum, and 24 percent was planted in corn (Nebraska Department of Agriculture, 1994).

Figure 2A shows the number of registered irrigation wells for Cass and Lancaster Counties from 1968 through 1993. A sharp increase in the number of wells from the mid- to late-1970s was followed by a gradual increase over the following 15 years. Figure 2B shows annual nitrogen fertilizer sales in Cass and Lancaster Counties during the same period. Nitrogen use during this time varied greatly with no apparent trends. The increased nitrogen fertilizer sales during 1990–92 could be the result of a change in the reporting categories for nitrogen fertilizer used by the Nebraska Department of Agriculture.

## Previous Investigations

A series of maps was produced that show bedrock altitude and approximate thickness of aquifers in deposits of Quaternary age for the Fremont and Omaha quadrangles and for the Lincoln and Nebraska City quadrangles (Nebraska Department of Environmental Control and University of Nebraska, Conservation and Survey Division, 1980, a–f). The bedrock-altitude maps used contour intervals of 50 ft and the aquifer-thickness maps used contour intervals of 100 ft. Cretaceous- through Quaternary-age geology in parts of Lancaster County also was described (Goodenkauf, 1978; Holly, 1980).

The NDOH conducted comprehensive water-quality sampling in the LPS NRD during the late 1980s. Exner and Spalding (1990) compiled data on concentrations of nitrate in ground water from 1984 to 1988 and concentrations of pesticides in ground water prior to 1989 for the entire State using data from the LPS NRD, USGS, University of Nebraska Conservation and Survey Division, Lincoln-Lancaster County Health Department, and the Nebraska Department of Environmental Quality. Part of the data compiled for approximately 100 wells (mostly domestic) in the LPS NRD shows that water samples from about 35 percent of the wells contained nitrate concentrations equal to or larger than 7.5 mg/L as nitrogen.

Exner and Spalding (1990) also reported results of ground-water analyses for atrazine, alachlor, and propachlor in the LPS NRD. About 7 percent of the 70 wells (mostly domestic) in the LPS NRD from which water samples were collected and analyzed for pesticides contained atrazine at concentrations equal to or larger than 0.01 µg/L. No water samples collected from the 70 wells contained alachlor concentrations

that equaled or exceeded that study's analytical detection limit of 0.40 µg/L. One water sample from an irrigation well in the LPS NRD was analyzed for propachlor, which was not detected.

Lawton and others (1984) compiled available data on the water quality in parts of the Dakota Sandstone in eastern Nebraska. They found the water quality from 18 wells screened in the Dakota Sandstone in the Lincoln area to be highly variable. They reported most water samples in the Lincoln area from the Dakota Sandstone were primarily a calcium bicarbonate type and had dissolved-solids concentrations ranging from 248 to 1,360 mg/L. Sodium and chloride were the dominant major ions in 4 of the 18 water samples. These four samples had dissolved-solids concentrations ranging from 23,700 to 43,800 mg/L.

## Acknowledgments

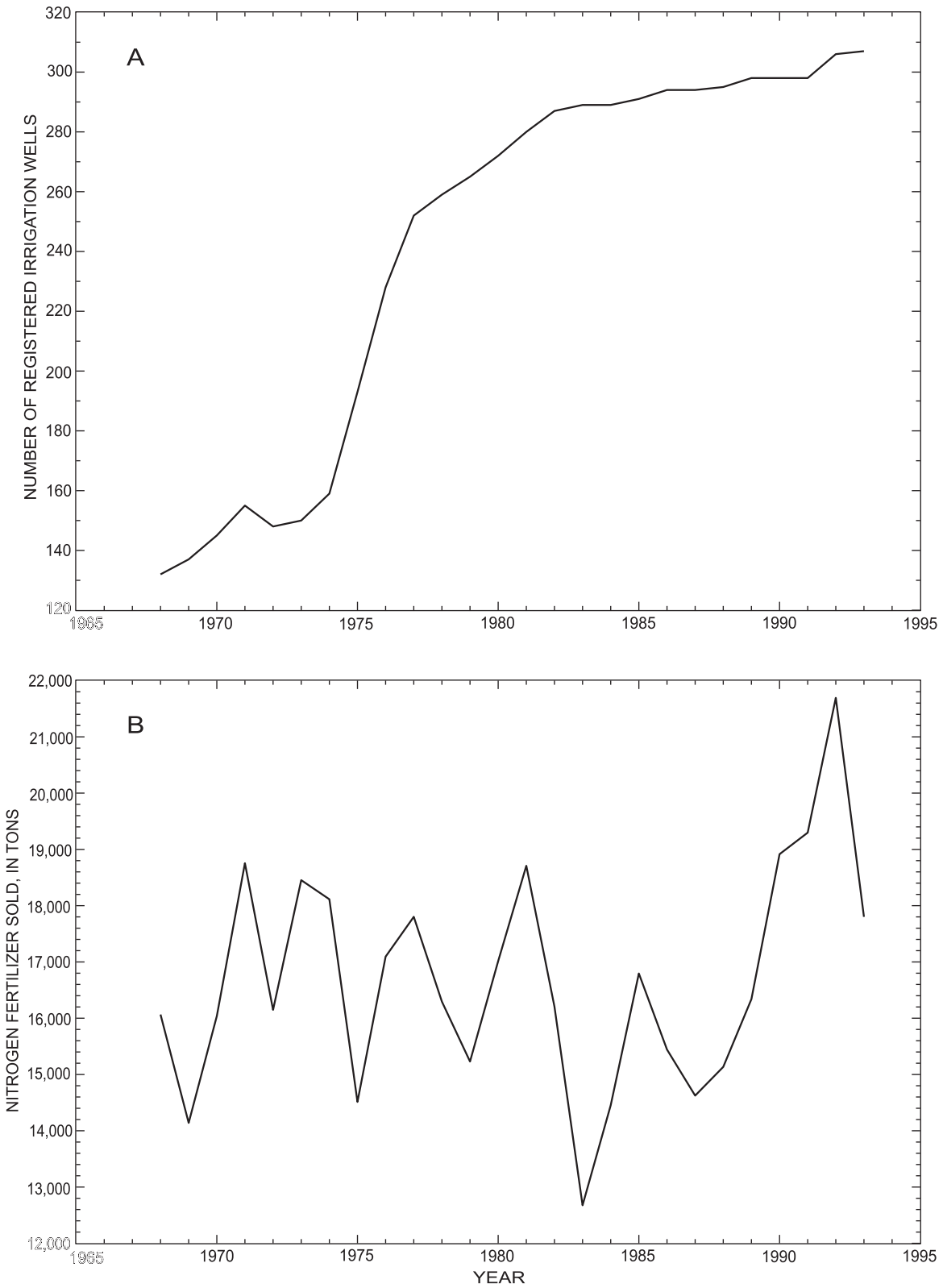
The authors thank the landowners who permitted the USGS to collect ground-water samples from their wells and who have provided the USGS with land- and chemical-use information. The authors thank Vince Dreeszen, former director of the University of Nebraska, Conservation and Survey Division, for sharing his interpretation of bedrock topography in the study area. The authors also thank Dan Schulz and Justin Krajewski of the LPS NRD for their work in securing permission to collect samples from private wells and collecting ground-water-level data in the study area.

## METHODS

The following sections describe the methods used in conducting this study. Included are the methods used to select wells, measure water levels, delineate aquifer extent, collect and analyze ground-water samples, and provide quality assurance for those samples.

### Aquifer Delineation and Drainable-Volume Estimation

Test-hole data, logs from registered wells, available bedrock maps (produced by the Nebraska Department of Environmental Control and the University of



**Figure 2.** Trends in (A) irrigation-well development and (B) nitrogen-fertilizer use in Cass and Lancaster Counties, 1968–93.

Nebraska, Conservation and Survey Division, 1980a and d; University of Nebraska, Conservation and Survey Division, 1986), and available and measured water-level data were used to delineate the boundaries and estimate drainable volumes of water in the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers. Bedrock-surface altitudes were determined from test-hole data, logs from registered wells, and data from available bedrock maps. These altitudes were contoured manually and used to produce geographic information system (GIS) coverages representing the base of the aquifers. The base-of-aquifer coverages were compared to and, in places, modified to agree with interpretations produced by the University of Nebraska, Conservation and Survey Division (Vince Dreeszen, written commun., 1996).

Water-level measurements were made by USGS personnel using a 200-ft steel tape with 0.01-ft increments in 37 wells in the western two-thirds of the LPS NRD during October 1994 to supplement semiannual measurements made by personnel of the LPS NRD. Because of the wet summer and limited ground-water withdrawals for irrigation that ended in mid-August 1994, it was assumed that ground-water-level measurements made in October (about 2 months after the end of the irrigation season) were representative of an unstressed system. The 37 wells were nonrandomly selected from available registered irrigation wells to provide an areal distribution of water-level data for the area that includes three paleovalley alluvial aquifers. Land-surface altitudes for all water-level-altitude data points were determined to the nearest 5 ft using USGS 7.5-minute topographic maps. Coordinates for well locations were identified using a global positioning system (GPS) with a horizontal accuracy of 100–200 ft.

As previously described, the Quaternary-age unconsolidated deposits in the study area contain ground water under a mixture of unconfined, semi-confined, and confined conditions. This complex hydrogeology limits the capability to describe water-level and saturated-thickness patterns in individual aquifers by using available data. Therefore, for purposes of this report, it was assumed that some hydraulic interconnection exists throughout the unconsolidated deposits and that the combined water-level data represent an approximation of the regional water-level surface (top of the saturated part of the deposits). It is likewise assumed that altitudes of perennial streams obtained from topographic maps are valid

indicators of the general water table. Streams in the study area appear to be gaining throughout most of their reaches (Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division, 1980c and 1980f; Goodenkauf, 1978; Holly, 1980), which indicates hydraulic connection with the unconsolidated deposits. A map of the water table was modified from the same sources using the ground-water-level altitudes and the topographic-map-derived perennial stream altitudes. That surface then was converted to a GIS coverage.

A map of total saturated thickness of the unconsolidated deposits was modified from Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division (1980b and 1980e) for the western two-thirds of the LPS NRD, which included the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers. The map was developed by first overlaying the water-table and base-of-aquifer coverages and subtracting the corresponding altitudes. The resultant distribution of saturated thickness then was compared to the original (source) maps and modified appropriately. The total saturated thickness in the study area includes fine-textured deposits such as glacial till and loess that have very low permeabilities and that yield little water. The total saturated thickness map was combined with test-hole and well-log data describing sediment texture to determine the approximate lateral extents of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers. Because of the complexity of the deposits, lateral limits of the aquifers were designated where the aquifer thickness diminished to less than 40 ft of coarse-textured [sand and(or) gravel], saturated sediment. The volume of drainable water in each of the three aquifers was estimated by contouring the thickness of saturated sand and gravel deposits in each of the aquifers and multiplying the volume of those saturated deposits by an estimated storage coefficient.

## **Ground-Water-Quality Sample Collection and Analysis**

### **Well Selection**

Sixty-one wells were selected for water-quality sample collection from the more than 500 registered irrigation, municipal, and industrial wells in the LPS NRD by using a modified stratified-random selection

method. A preliminary estimate of the general boundaries of the five aquifers was made, and wells within these boundaries that were screened in deposits of Quaternary age were selected randomly. A distance-weighting factor was used to ensure a minimum distance of 1.5 mi between selected wells. In the Platte and Missouri River aquifers, where relatively few registered wells were present, all registered wells that met the spacing requirements were selected for water-sample collection. Nonregistered domestic wells of known depths also were selected randomly for sample collection. Fifteen wells were identified for sample collection in each of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers, and eight wells were identified in both the Platte and Missouri River aquifers. Because of the relatively cool temperatures and the nearly 16 inches of rain that fell during the summer of 1994, many irrigation wells in the study area were operated infrequently or not at all. Therefore, water-quality samples were collected from only 46 of the 61 selected wells.

After water-quality samples were collected at the 46 wells, more detailed delineation of the approximate extent of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers revealed that five of the sampled wells (DV-101, CPA-75B, CPA-83, W-66, and W-689) were just beyond the extents of the coarse-textured sediments of the three aquifers. Nonetheless, water samples from those five wells were considered to be representative of general water-quality conditions in the aquifers and were used in characterizing the water quality of the aquifers for this report.

### Site Identification

Three different methods of site identification were used to identify wells in this report (fig. 3). The first method, USGS site identification, is a 15-character number derived from the international system of latitude and longitude. This number contains no blanks or alphabetic characters and generally is used as an internal control number. Although the site identification number is initially derived from the site location, the number is an IDENTIFIER and not a LOCATOR. The site identification number is a pure number and has no locational significance (Mathey, 1990, p. 2-10).

The second method, legal location, was assigned on the basis of land subdivisions in the U.S. Bureau of

Land Management's survey of Nebraska. The numeral preceding N (north) indicates the township, the numeral preceding E (east) indicates the range, and the numeral preceding the terminal letters indicates the section in which the well is located (fig. 3). The terminal letters, designated A, B, C, and D, denote the quarter section, the quarter-quarter section, the quarter-quarter-quarter section, and the quarter-quarter-quarter-quarter section. The designation is given in a counter-clockwise fashion beginning with "A" in the northeast corner of each subdivision. If two or more wells exist in the same subdivision, they are distinguished by adding a sequential number to the well number. Sequential numbers are assigned by the order in which the wells are inventoried. For example, a well with a legal location of T13N R5E 15BBAB1 should be in Township 13 North, Range 5 East, in Section 15, in quarter section B, quarter-quarter section B, quarter-quarter-quarter section A, quarter-quarter-quarter-quarter section B, well 1 (fig. 3).

The third method, local identification (ID) number, is based on the aquifer in which the well is completed. In the field identifications for all sampled wells, the first one to three letters denote the principal aquifer in which they are screened—DV for Dwight-Valparaiso aquifer, CPA for Crete-Princeton-Adams aquifer, W for Waverly aquifer, PR for Platte River aquifer, and M for Missouri River aquifer.

### Water-Quality Sample Collection

To ensure that water samples are representative of the aquifers, a minimum of three casing volumes of water were removed from wells prior to sample collection for water-quality analysis. Water samples generally were collected from irrigation and municipal wells after the pumps had been running for several hours to several days. The cool and wet conditions that prevailed during the summer of 1994 made it necessary to collect water samples from some irrigation wells that had not been pumped for many weeks. These wells were pumped for a minimum of 30 minutes prior to sample collection, which removed 10 or more casing volumes of water from most wells. Prior to sample collection, a flow-through chamber was used in conjunction with the appropriate field instruments to monitor pH, specific conductance, temperature, and dissolved oxygen in discharge water from the wells. Water samples were collected after the required volumes of water were discharged from the

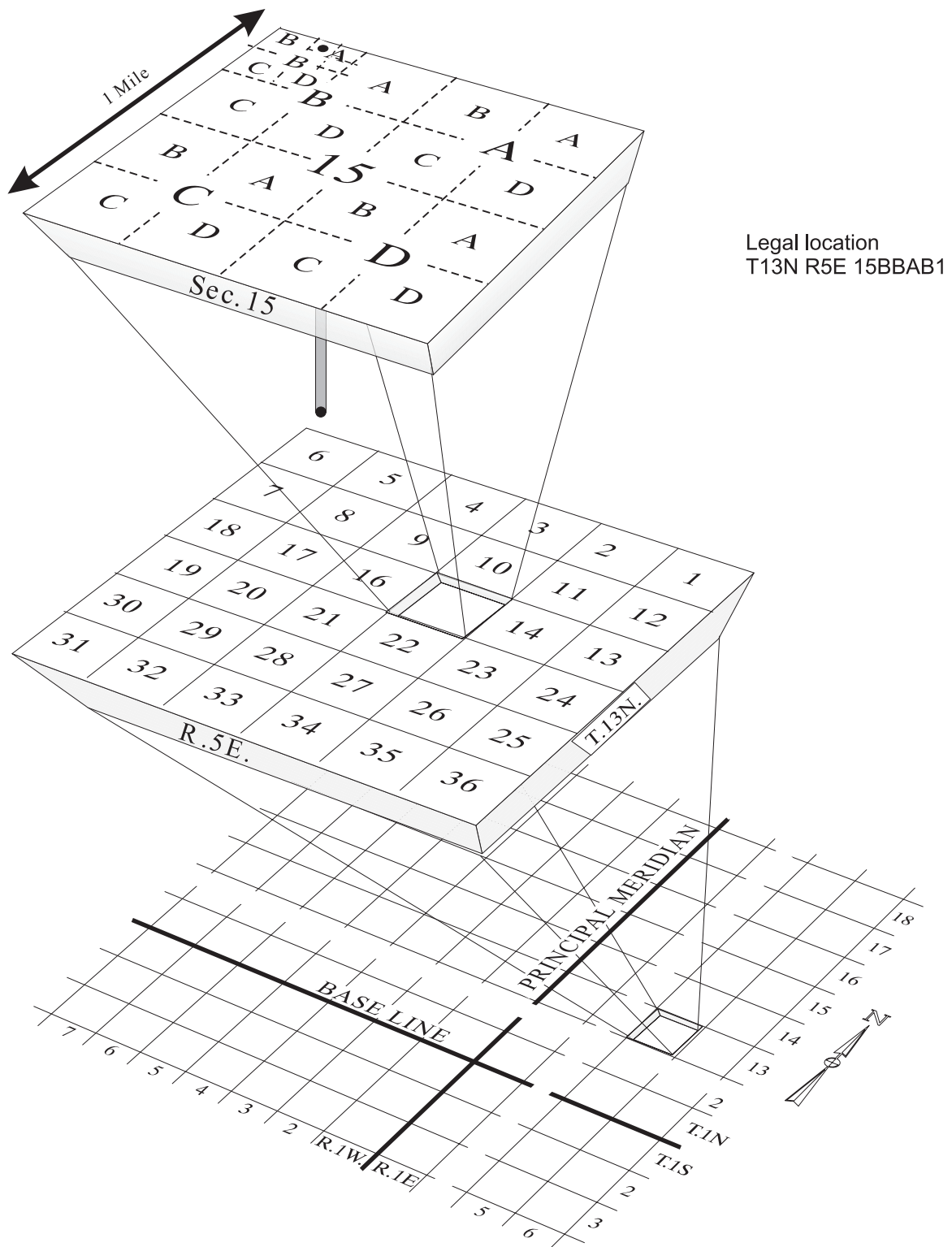


Figure 3. Well-numbering system.

wells and after the field measurements, made during 3-minute increments, had stabilized (no more than a 5-percent change from the previous measurements).

Water samples from all wells were analyzed for nitrite and nitrate as nitrogen, hereinafter to be referred to collectively as nitrate. Also, water samples from all sampled wells were screened for the presence of triazine herbicides using an enzyme-linked immunosorbent assay procedure (ELISA) (Pomes and others, 1991), which nonselectively detects triazines and their metabolites, deethylatrazine and deisopropylatrazine. The water samples that tested positive for triazine herbicides were sent to the USGS National Water-Quality Laboratory (NWQL) in Arvada, Colorado, for further analysis. About 10 water samples from each of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers and all of the water samples from the Platte and Missouri River aquifers also were analyzed for major ions, iron, manganese, and radon.

Unfiltered water samples were collected directly from the well. Filtered samples were collected in a 6-L (liter) polypropylene churn splitter and pumped through the appropriate-sized filter using a peristaltic pump with Tygon tubing. The churn splitter was washed with Alconox in the laboratory and rinsed with distilled deionized water prior to use in the field. After the first use in the field, the churn splitter was rinsed 10 times with discharge water from the well from which the next water samples were to be collected. Water samples collected for nitrate analysis were filtered through a 0.45- $\mu\text{m}$  (micrometer) membrane filter, preserved with 0.5 mL (milliliter) mercuric chloride and hydrochloric acid, and immediately chilled to about 4°C (degrees Celsius). Water samples collected for metal analysis were filtered through 0.45- $\mu\text{m}$ -membrane filters and adjusted to a pH of 2 or less with 1 mL nitric acid. Water samples collected for anion analysis were filtered through a 0.45- $\mu\text{m}$ -membrane filter and stored at ambient temperature without preservation. Water samples collected for pesticide analysis were filtered through a 0.7- $\mu\text{m}$  glass filter into a 1-L baked glass bottle with a polytetrafluoroethylene-lined cap and immediately chilled to about 4°C.

### Laboratory Analyses

The analyses for concentrations of all inorganic species were performed at the NWQL using methods described by Fishman and Friedman (1989). Metals were analyzed using atomic absorption and emission

spectrometric methods. Inductively coupled plasma methods were used to analyze silica and chloride; a turbidimetric method was used for sulfate and an ion-selective electrode method was used for fluoride. Nitrate was analyzed by cadmium reduction. Water samples were analyzed for radon using a liquid scintillation method.

When the triazine-screening test indicated total triazine concentrations of 0.1  $\mu\text{g/L}$  or more, a 1-L water sample was forwarded to the NWQL for gas chromatograph (GC)/mass spectrometry (MS) analysis. The method involves the solid-phase extraction of water sample, elution with hexane-isopropanol, and analysis by capillary-column GC/MS with selected-ion monitoring (Sandstrom and others, 1991).

### Statistical Analyses

Summary statistics were used to compare distributions of water-quality data among aquifers. Spearman's rho statistic (Spearman, 1904; Conover, 1971), a nonparametric correlation technique, was used to identify relations between selected water-quality constituents within and between aquifers. Because of the small sample sizes (10 or less) used to produce some of the Spearman's rho statistics, only Spearman's rho statistics that have a 95-percent or larger confidence level, as described by Yevjevich (1972), are included in this report.

### Quality Assurance and Quality Control

A variety of quality-assurance and quality-control techniques are part of every analysis performed at the NWQL. The following is a brief overview of some of the techniques used by the NWQL to ensure reliable, precise, and accurate analytical data (Jones, 1987). Bottles used for sample collection, the chemicals used for sample preservation, and the field filters are subject to quality control by the NWQL. The NWQL adheres to standard analytical methodologies and maintains strict protocols in handling both samples and analytical results. The NWQL maintains a series of checks and balances on analytical production such as the systematic inclusion of laboratory blanks and standards of known concentrations with each batch of field samples that are analyzed.

The water-quality assurance program of the NWQL includes a laboratory blind-sample program in



which blind quality-assurance samples are intermixed with field samples on a daily basis to verify the precision and accuracy of inorganic analyses. Additionally, the NWQL participates in USGS and U.S. Environmental Protection Agency interlaboratory evaluation programs in which laboratories throughout the Nation receive and analyze blind samples. Another quality-assurance check for major ions is the anion-cation balance. Because water is essentially neutrally charged, the sum of the positive charges should equal the sum of the negative charges for any water sample. If the ionic charges do not balance within a 5-percent difference, the NWQL reanalyzes the major anions and cations.

The quality of field measurements for water-quality parameters was ensured through the calibration of field meters with standard reference materials at each site prior to the collection of water-quality samples. In addition, field quality-assurance samples were submitted for most analyses. About 5 percent of all samples submitted to the NWQL for analysis were replicate samples for one or more sites. The analysis of these samples provided an external check on the precision of the laboratory analyses. Repetitive sampling of the same sites over several weeks also makes it possible to compare new analyses with earlier ones as a means of identifying nonrepresentative samples.

## HYDROGEOLOGY

This section describes the general hydrogeology of the western part of the LPS NRD and provides a more detailed description of the hydrogeology of the five principal aquifers—the Dwight-Valparaiso, Crete-Princeton-Adams, Waverly, Platte River, and Missouri River aquifers.

### General Description of the Western Part of Lower Platte South Natural Resources District

This section describes maps of the water table, bedrock geology and altitude of bedrock surface, and total saturated thickness of unconsolidated deposits of Quaternary age in the western part of the LPS NRD.

### Water Table

Water-level data from 37 wells measured in October 1994 (table 3), water-level data gathered by LPS NRD personnel in the fall of 1994 from 31 wells, and altitudes of perennial streams were used to modify maps (Goodenkauf, 1978; Holly, 1980; Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division, 1980c and 1980f) showing the altitude of the water table in the western part of the LPS NRD (fig. 4). The altitudes of the water table generally mirror the topography, with higher altitudes bordering the western, southern, and eastern edges of the western part of the LPS NRD (Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division, 1980c and f).

### Base of Aquifers

Bedrock units comprise the base of the principal aquifers in the study area. Bedrock units in the western part of the LPS NRD are the Dakota Sandstone and shale, limestone, and sandstone of Permian and Pennsylvanian age (fig. 5). The bedrock of Permian and Pennsylvanian age directly underlies Quaternary deposits in southeastern Lancaster County and western Cass County where the Dakota Sandstone is absent. The Carlile Shale, Greenhorn Limestone, and Graneros Shale are present in the southeastern part of Butler County where they overlie the Dakota Sandstone. The Graneros Shale is not officially recognized in Nebraska by the USGS, but it is recognized by the University of Nebraska–Lincoln.

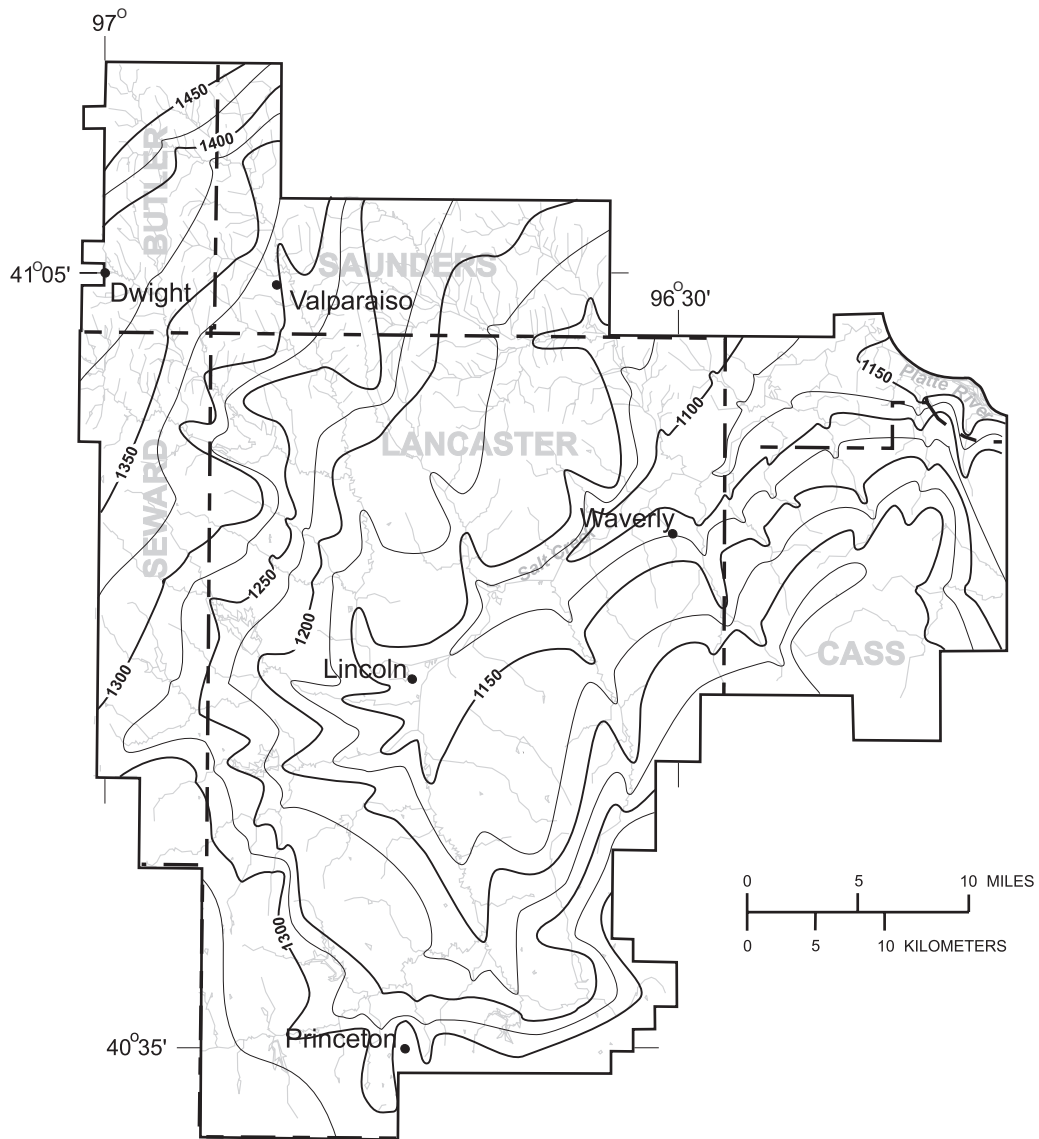
The bedrock surface in the study area is irregular and contains some incised valleys. Some valleys cut through the Dakota Sandstone and expose underlying Permian and Pennsylvanian rocks. The bedrock surface generally slopes from the west to the east. The highest bedrock altitude is about 1,350 ft above sea level and is along the western edge of the study area in Butler and Seward Counties. The lowest bedrock altitude is below 1,000 ft and is in northwestern Cass County and southern Lancaster County.

A broad depression in the bedrock surface is in central Lancaster County, with a narrow paleochannel extending through northeastern Lancaster County and northwestern Cass County. This channel is incised into limestone and shale of Permian and Pennsylvanian age and contains the Waverly aquifer (fig. 1).

**Table 3.** Water-level data for wells completed in the western part of the Lower Platte South Natural Resources District, fall 1994

[ID, identification; altitudes are relative to sea level]

Site ID number	Legal location	Date measured	Depth to water below land surface (feet)	Altitude of water table (feet)
<b>Dwight-Valparaiso aquifer</b>				
410234 096492301	12N 5E 2ACBB	10-26-94	9.25	1,266
410102 096543101	12N 5E 18BB	10-26-94	8.33	1,314
410611 096510201	13N 5E 15BBBB	10-26-94	14.4	1,314
410535 096425301	13N 6E 14CCBA	10-19-94	15.3	1,240
410509 096453601	13N 6E 20ABDD	10-19-94	107	1,238
410522 096423801	13N 6E 23BABB	10-19-94	10.9	1,224
410428 096442301	13N 6E 28AABB	10-19-94	36.8	1,243
410800 096524201	14N 5E 32DCCD	10-26-94	26.0	1,364
410345 096502301	13N 5E 27DCBD	10-26-94	18.1	1,277
411050 096504501	14N 5E 15C	10-26-94	156	1,374
410545 096373201	13N 7E 16DBAA	10-31-94	50.7	1,179
410646 097001501	13N 4E 8BCCC	10-31-94	247	1,403
410043 096480801	12N 5E 13ACAC	10-26-94	7.67	1,232
405510 096481301	11N 5E 13DACB	10-31-94	42.6	1,204
<b>Crete-Princeton-Adams aquifer</b>				
403557 096455701	7N 6E 5DACC	10-21-94	25.0	1,275
403505 096423401	7N 6E 11DACC	10-20-94	83.3	1,307
403425 096425101	7N 6E 14DBBB	10-20-94	130	1,300
403228 096444701	7N 6E 28DDBB	10-20-94	172	1,300
403347 096320301	7N 8E 21BCAA	10-20-94	54.3	1,256
403556 096441801	7N 6E 3CDBB	10-21-94	84.5	1,303
403503 096515501	7N 5E 9DCBB	10-21-94	24.9	1,315
403929 096581001	8N 4E 15CBCD	10-24-94	25.3	1,342
404019 096485101	8N 5E 12CACC	10-24-94	133	1,217
404614 096594801	9N 4E 8BAAA	10-24-94	191	1,281
404422 096434701	9N 6E 22ABBC	10-24-94	8.86	1,169
404234 096371301	9N 7E 34BACB	11-01-94	237	1,173
403905 096433101	8N 6E 22AADB	11-01-94	20.2	1,242
<b>Waverly aquifer</b>				
410002 096232401	12N 9E 22AABA	10-19-94	18.7	1,082
405755 096274901	12N 9E 31CBBB	10-19-94	13.3	1,083
405324 096341001	11N 7E 25DDBA	10-12-94	11.2	1,120
405636 096291501	11N 8E 11ABAA	10-12-94	14.4	1,086
405632 096302501	11N 8E 10ABAD	10-12-94	23.2	1,089
405544 096292501	11N 8E 11DCCD	10-12-94	12.7	1,103
405842 096260901	12N 9E 29BDDD	10-19-94	8.84	1,079
405404 096283501	11N 8E 24CDCA	10-19-94	11.5	1,128
410114 096331701	12N 8E 8CBDA	10-31-94	5.89	1,124
405228 096331801	11N 8E 32C	10-12-94	41.0	1,158

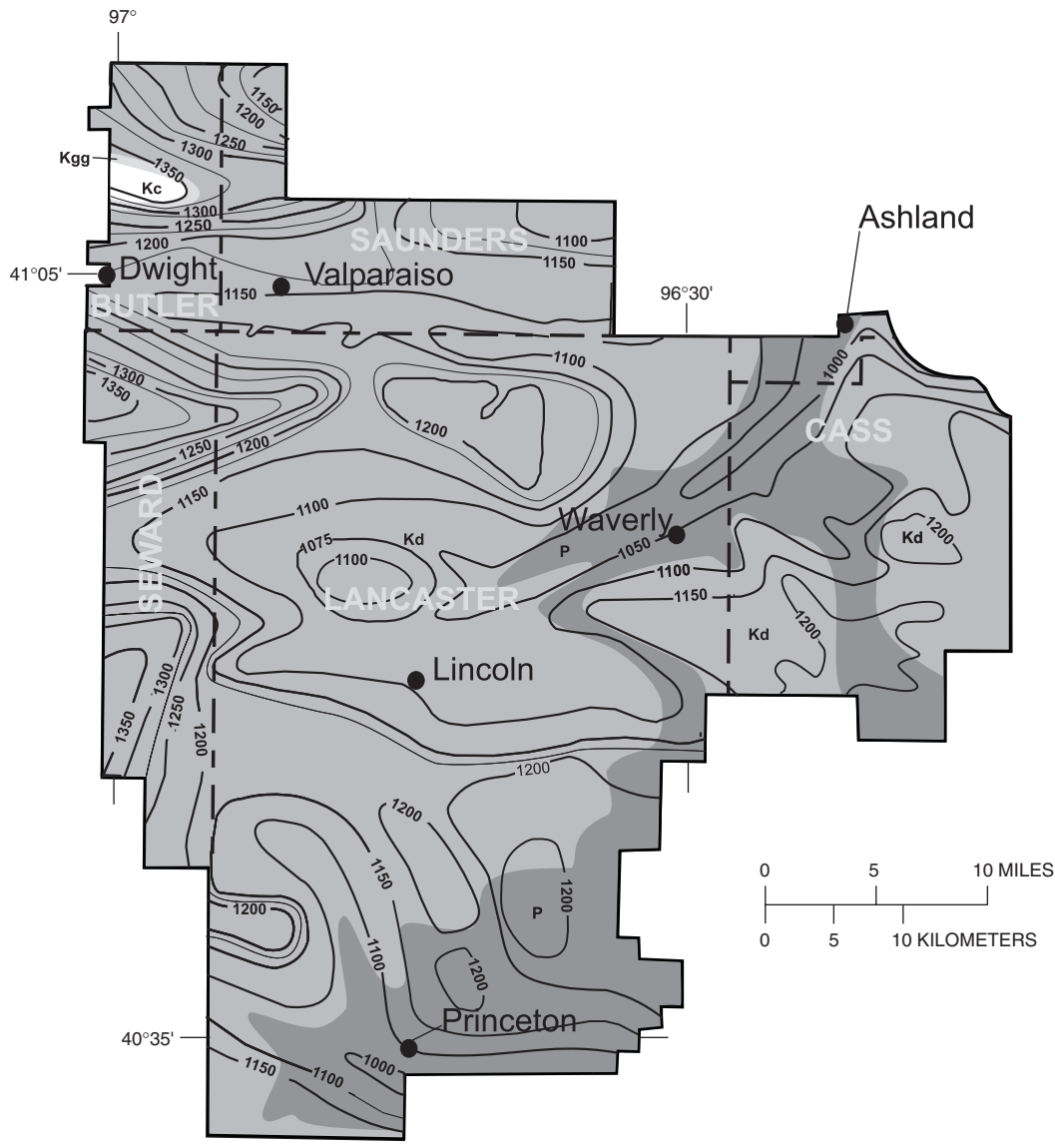


Modified from Goodenkauf (1978), Holly (1980), and Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division (1980c and 1980f)

#### EXPLANATION

— 1300 — WATER-TABLE CONTOUR  
 Contour interval 25 feet.  
 Datum is sea level

**Figure 4.** Configuration of the water table in the western part of the Lower Platte South Natural Resources District, fall 1994.



Modified from Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division (1980a and 1980d)

### EXPLANATION

— 1150 — BEDROCK CONTOUR-- SHOWS ALTITUDE OF TOP OF BEDROCK  
 Contour interval is 25 feet.  
 Datum is sea level

<p><span style="border: 1px solid black; padding: 2px;">Kc</span> CARLILE SHALE <i>Shale</i></p>	<p><span style="border: 1px solid black; padding: 2px;">Kd</span> DAKOTA SANDSTONE, UNDIFFERENTIATED <i>Sandstone and shale</i></p>
<p><span style="border: 1px solid black; padding: 2px;">Kgg</span> GREENHORN LIMESTONE AND GRANEROS SHALE, UNDIFFERENTIATED <i>Limestone and shale</i></p>	<p><span style="border: 1px solid black; padding: 2px;">P</span> PERMIAN AND PENNSYLVANIAN, UNDIFFERENTIATED <i>Shale, limestone, and sandstone</i></p>

**Figure 5.** Bedrock geology and altitude of top of bedrock surface in the western part of the Lower Platte South Natural Resources District. (The Graneros Shale is not officially recognized in Nebraska but is recognized by the University of Nebraska-Lincoln.)

A second, deep channel in the bedrock surface lies along the southern end of Lancaster County and trends to the east-southeast. The base of this channel and the bedrock to the north and east of the channel are composed of shale, limestone, and sandstone of Permian and Pennsylvanian age. This channel contains the Crete-Princeton-Adams aquifer (fig. 1).

Two additional channels are cut into the bedrock surface through the southeastern corner of Butler County and through northern Lancaster and southern Saunders Counties. These channels trend to the east and are separated by a bedrock composed of Carlile Shale, Greenhorn Limestone, and Graneros Shale in Butler County. These channels contain the Dwight-Valparaiso aquifer (fig. 1).

### **Total Saturated Thickness**

The total saturated thickness of Quaternary-age deposits in the western part of the LPS NRD ranged from less than 50 to about 250 ft (fig. 6). The areas with the greatest total saturated thickness were in southeastern Butler and southwestern Saunders Counties and in southern Lancaster County. Total saturated thickness is largest in the channels in the bedrock surface that correspond with the Dwight-Valparaiso and Crete-Princeton-Adams aquifers. Conversely, areas with very limited total saturated thickness corresponded mostly with topographic highs in the underlying bedrock surface. Because much of the total saturated thickness of Quaternary-age deposits is composed of fine-textured materials, such as glacial till, that have low permeabilities, areas containing significant thicknesses (40 continuous feet or more) of more permeable sand and gravel deposits were delineated (fig. 6) and helped to identify practical boundaries of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers.

## **Description of Principal Aquifers**

### **Dwight-Valparaiso Aquifer**

The Dwight-Valparaiso aquifer within the LPS NRD is a semiconfined to confined aquifer overlying rocks of Cretaceous age and is separated by a bedrock into two parts. The southern part occupies about 97 mi<sup>2</sup>, and the northern part occupies about 42 mi<sup>2</sup> (figs. 1, 6, and 7). Total saturated thickness in this area ranges from about 50 to 275 ft, with the largest thick-

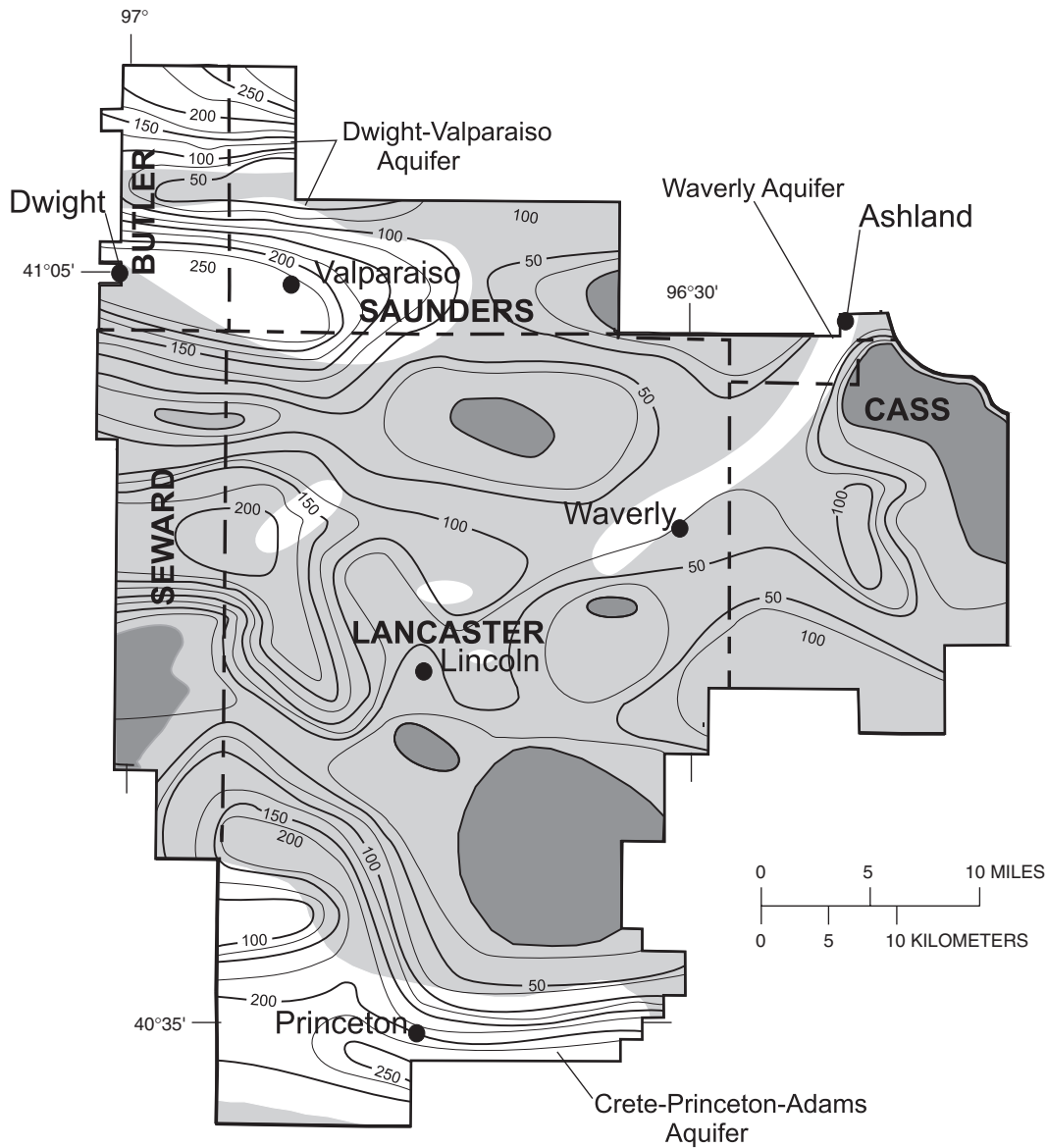
ness along the western and northern boundaries of the LPS NRD. Depth to water below land surface ranges from less than 10 ft along the southern edge of the aquifer to about 250 ft near the western edge of the aquifer. The sand and gravel deposits in the aquifer are about 40 to 100 ft thick and commonly are overlain by relatively thick glacial till and some loess deposits.

Sand and gravel deposits occupy about 6,700,000 acre-ft of the aquifer, as determined during this study, based on the thickness and extent of the sand and gravel deposits. About 20 percent of this volume is drainable water. The volume of water that is released from storage per unit surface-area of aquifer per unit decline in head is called the storage coefficient. Given a storage coefficient of 0.20, a typical value for an unconfined to semiconfined aquifer (Freeze and Cherry, 1979) and similar to the storage coefficient determined by Holly (1980) for the southern part of the aquifer, the estimated volume of drainable water in the sand and gravel deposits of the aquifer is about 1,340,000 acre-ft. Unconfined conditions were assumed because the water table would have to be lowered beneath the semiconfining and confining layers of the sand and gravel deposits for significant volumes of water to be released from storage. Such a decline in head would cause the aquifer to behave as an unconfined system. Some water also is stored in the finer textured deposits overlying the sand and gravel deposits, but little of that water would be released from storage as the head declines.

### **Crete-Princeton-Adams Aquifer**

The Crete-Princeton-Adams aquifer is along the southern border of Lancaster County and is semiconfined to confined. The aquifer occupies about 115 mi<sup>2</sup> beneath the southern part of the LPS NRD (fig. 1). The aquifer trends from west to east beneath parts of Lancaster and bordering counties (figs. 1 and 6). Total saturated thickness in this area ranges from about 50 to more than 250 ft and generally increases from west to east as the bedrock altitude decreases to the east (fig. 6). Depth to water ranges from about 9 to 237 ft and increases from north to south as land-surface altitude increases.

Because of the complex layering of glacial till, loess, sand, and gravel and the limited number of wells that penetrate the entire thickness of the aquifer, only an approximation of the volume of drainable ground



**EXPLANATION**

- 250 — LINE OF EQUAL SATURATED THICKNESS  
Contour interval 25 feet.  
Datum is sea level
- PRINCIPAL AQUIFER (THICKNESS GENERALLY INCLUDES AT LEAST 40 FEET OF SAND AND(OR) GRAVEL)
- QUATERNARY-AGE DEPOSITS COMPOSED PRIMARILY OF FINE-TEXTURED DEPOSITS, MOSTLY GLACIAL TILL, GENERALLY WITH LESS THAN 40 FEET OF SAND AND(OR) GRAVEL
- QUATERNARY-AGE DEPOSITS ABSENT OR VERY THIN

**Figure 6.** Total saturated thickness of Quaternary-age deposits and distribution of deposits composed of 40 or more feet of sand and gravel in the western part of the Lower Platte South Natural Resources District, fall 1994.

water in storage for the part of the aquifer that lies within the LPS NRD is possible. The volume of sand and gravel in the aquifer that lies in the study area is about 7,700,000 acre-ft. Assuming a storage coefficient of 0.20, the estimated volume of drainable ground water is about 1,540,000 acre-ft.

### **Waverly Aquifer**

The Waverly aquifer is semiconfined to confined and extends about 18 mi from northeast of Lincoln to the Platte River. It has a maximum width of about 2 mi and mostly overlies rocks of Permian and Pennsylvanian age. The aquifer occupies about 25 mi<sup>2</sup> in the LPS NRD (fig. 7). Average total saturated thickness in this area is about 75 ft. Depth to water ranges from about 6 to 41 ft (table 3). The sand and gravel deposits that compose most of the water-yielding potential of the Waverly aquifer are from about 40 to 65 ft thick and have an estimated volume of 860,000 acre-ft. Assuming a storage coefficient of 0.20 for unconfined aquifers, an estimated 172,000 acre-ft of water is drainable.

### **Platte River Aquifer**

The Platte River aquifer is an unconfined alluvial aquifer and extends about 30 mi east from the southeastern corner of Saunders County to the confluence of the Platte River with the Missouri River (fig. 1). The lateral boundaries of the Platte River aquifer are controlled by the edges of the flood plain (fig. 8). Most of the Platte River aquifer lies north of the Platte River, just outside of the LPS NRD northern boundary. The parts of the aquifer that lie in the LPS NRD are narrow (less than 0.25 to about 1 mi wide) and nodular in shape. The aquifer overlies rocks of Cretaceous and Permian and Pennsylvanian age and consists of fluvial sand, gravel, and silt deposits. The aquifer has a relatively uniform thickness of about 70 ft, and the depth to water ranges from about 5 to 10 ft.

### **Missouri River Aquifer**

The Missouri River aquifer is a largely unconfined aquifer that extends south about 32 mi from the Platte River confluence through the northeastern corner of Otoe County in the LPS NRD (fig. 1). The Missouri River aquifer in the LPS NRD is underlain by rocks of Permian and Pennsylvanian age, and its

lateral extent is controlled by the extent of the flood plain on the western bank of the Missouri River (also the eastern LPS NRD boundary). The Missouri River aquifer is nodular in shape and its width varies from less than 0.25 mi to about 3 mi. The aquifer consists of fluvial sand, gravel, and silt deposits with some clay lenses locally. The Missouri River aquifer thickness is about 80 ft, and the depth to water is about 5 to 10 ft.

## **GROUND-WATER QUALITY**

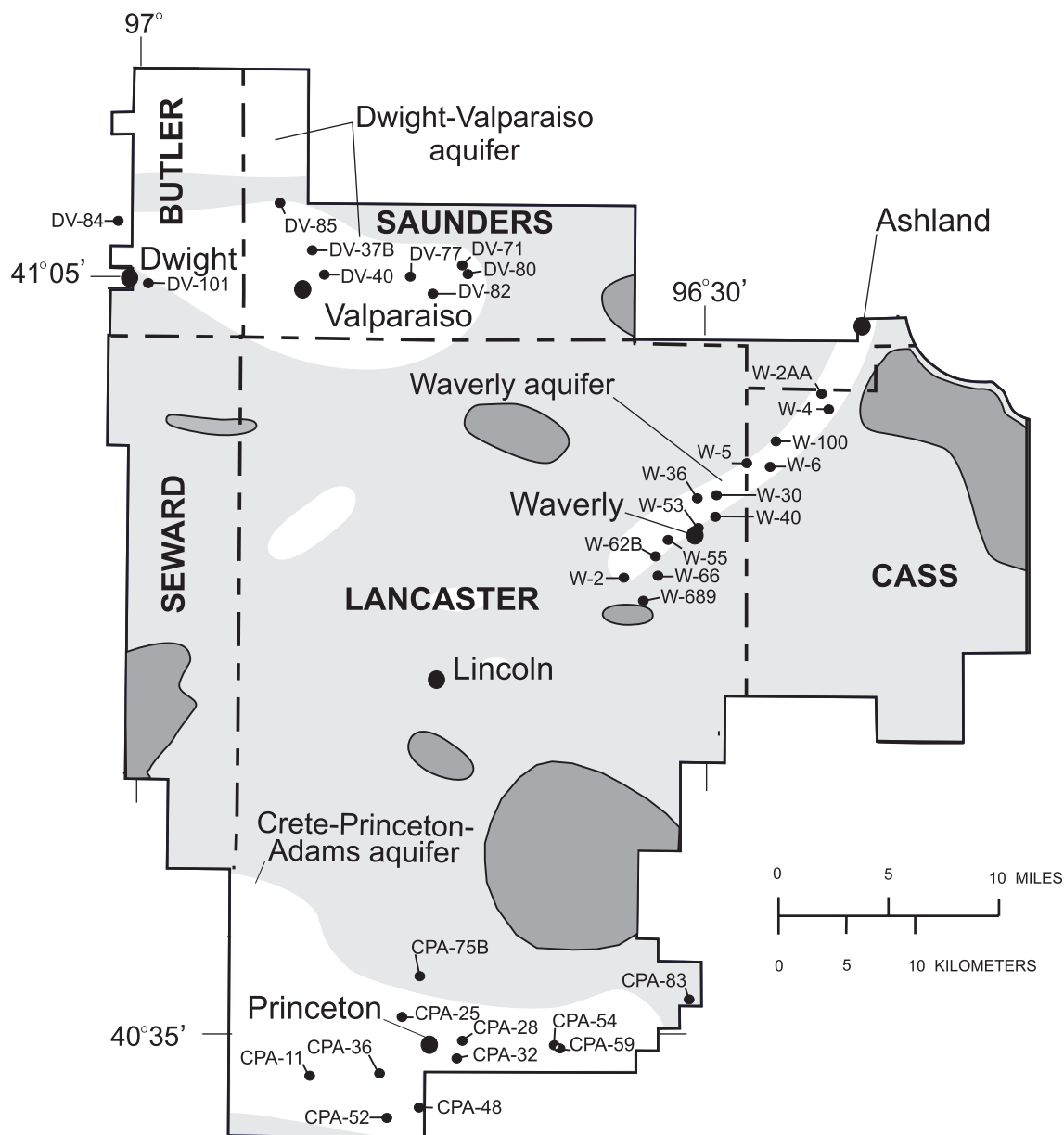
The following is a discussion of the results of field measurements and chemical analyses for water samples collected from wells in the five principal aquifers (figs. 7 and 8) during the summer of 1994.

### **Field Measurements**

Specific conductance is a measure of the electrical conductivity of water and is directly proportional to the concentration of dissolved material in the water. The specific conductance of water samples collected from the 46 wells ranged from 399 to 2,040  $\mu\text{S}/\text{cm}$  (tables 4 and 5 in the Appendix). The smallest median values for specific conductance were from the Platte River (629  $\mu\text{S}/\text{cm}$ ) and the Waverly (635  $\mu\text{S}/\text{cm}$ ) aquifers. The largest specific conductance measurements were from water samples from the Crete-Princeton-Adams (2,040  $\mu\text{S}/\text{cm}$ ) and the Missouri River (1,140  $\mu\text{S}/\text{cm}$ ) aquifers. Large specific conductance values in the Crete-Princeton-Adams aquifer were associated with large concentrations of sodium and chloride. Water samples from the Missouri River aquifer with large values for specific conductance also had large concentrations of calcium and magnesium and high alkalinity.

The pH ranged from 6.8 to 7.8, and water temperature at the time of collection varied from 12.0 to 17.0° C. Neither measurement showed apparent patterns among the aquifers or associations with other water-quality parameters measured or analyzed during this study.

Concentrations of dissolved oxygen in water samples ranged from 0.1 to 13.5 mg/L. The smallest median dissolved oxygen concentrations, 0.8 and 1.3 mg/L, were from the Platte River and Missouri River aquifers, respectively (table 4). These values correspond to large concentrations of iron and



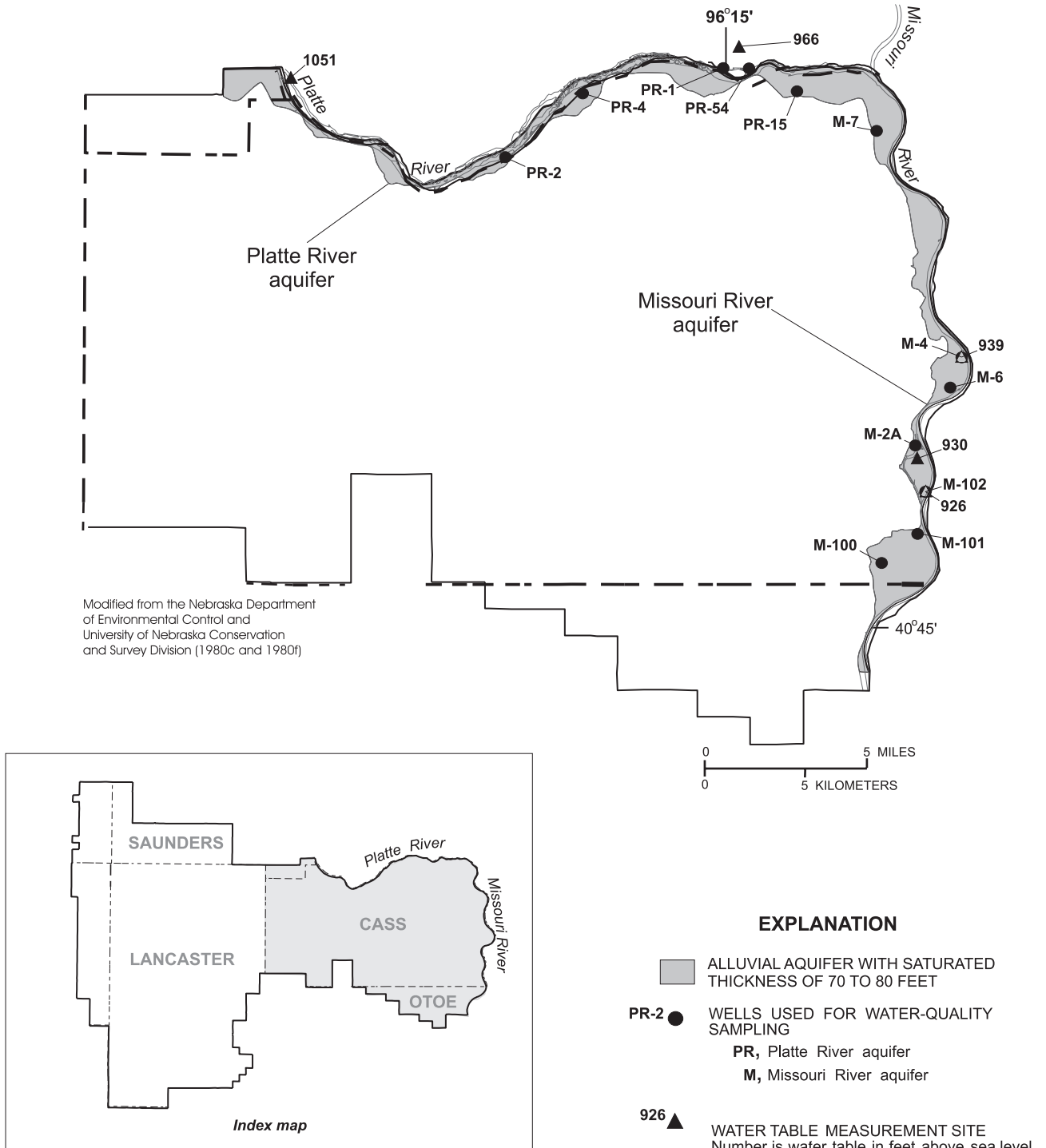
Modified from Nebraska Department of Environmental Control and University of Nebraska Conservation and Survey Division (1980b and 1980e)

### EXPLANATION

- PRINCIPAL AQUIFER (THICKNESS GENERALLY INCLUDES AT LEAST 40 CONTINUOUS FEET OF SAND AND (OR) GRAVEL)
- QUATERNARY-AGE DEPOSITS COMPOSED PRIMARILY OF FINE-TEXTURED MATERIAL, GENERALLY WITH LESS THAN 40 CONTINUOUS FEET OF SAND AND (OR) GRAVEL
- QUATERNARY-AGE DEPOSITS ABSENT OR VERY THIN
- WELLS USED FOR WATER-QUALITY SAMPLING

**Figure 7.** Approximate extent of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers, and the locations of wells used for water-quality sampling in the Lower Platte South Natural Resources District, 1994.





**Figure 8.** Approximate extent and saturated thickness of the Platte and Missouri River aquifers and the locations of wells used for water-quality sampling in the eastern part of the Lower Platte South Natural Resources District, 1994.

manganese measured in water samples from these aquifers. Such conditions generally indicate a reducing chemical environment.

Alkalinity is a measure of the capacity of water to neutralize acid and is reported as milligrams per liter of calcium carbonate. The alkalinity of ground water in Nebraska is related to the presence of calcium carbonate minerals in the aquifers (Engberg, 1984). The largest alkalinity values were measured in water samples collected from the Missouri River aquifer (528 mg/L) (table 4).

## Major Ions and Dissolved Solids

Most of the water samples from the study area were a calcium carbonate to a calcium-magnesium-sodium carbonate water type (fig. 9). The water types for the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers plotted in the same general locations on the trilinear diagrams, with the exception of several water samples from the Crete-Princeton-Adams aquifer that plotted as calcium-carbonate to sodium-chloride water types. Water-quality data from the Platte River aquifer plotted in a similar location on the trilinear diagram as surface-water-quality data from the Platte River at Louisville (Boohar and others, 1995). Water-quality data from the Missouri River aquifer tended to have small percentages of sodium and chloride and did not plot in the same location on trilinear diagrams as data from the Missouri River near Omaha (Melcher and others, 1987), which was collected in 1986. Water-quality data from the Platte River aquifer tended to indicate larger percentages of sodium and chloride than data from the Missouri River aquifer and the paleovalley aquifers.

Calcium was the dominant cation in all water samples with concentrations ranging from 45 to 140 mg/L and had a median concentration of 90 mg/L (table 4). The largest median concentration of calcium was detected in water samples from the Missouri River aquifer (120 mg/L). The smallest median concentration was detected in water samples from the Platte River aquifer (64 mg/L).

Concentrations of magnesium were similar in most water samples; the median concentration was 21 mg/L. Water samples from the Missouri River aquifer had the largest median concentration (32 mg/L) and water samples from the Platte River

aquifer had the smallest median concentration (16 mg/L).

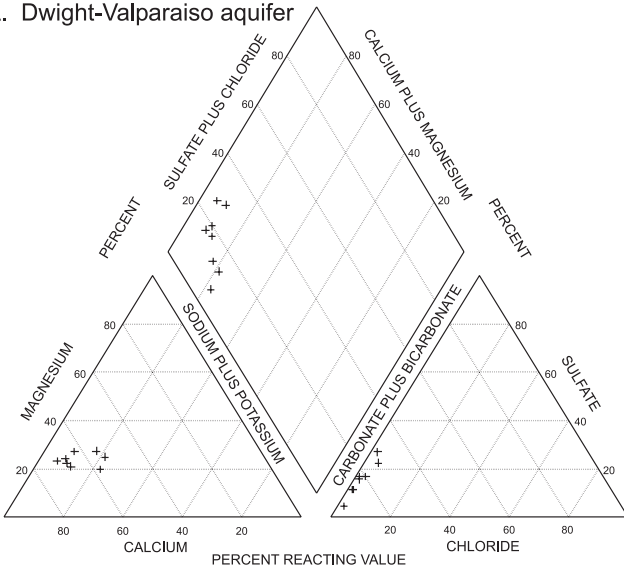
Concentrations of sodium in water samples ranged from 8.8 to 240 mg/L and had a median concentration of 32 mg/L. Although concentrations of sodium were small in most water samples, two samples from relatively deep wells in the Crete-Princeton-Adams aquifer had sodium concentrations that exceeded 100 mg/L. In general, however, concentrations of sodium were not associated with well depth in any of the five aquifers.

Concentrations of potassium were small (less than 15 mg/L) in most water samples and also showed no relation to well depth. Water samples with concentrations of potassium larger than 10 mg/L were generally from wells near the edges of the Dwight-Valparaiso and Crete-Princeton-Adams aquifers and may be influenced by minerals in rocks adjacent to the aquifers.

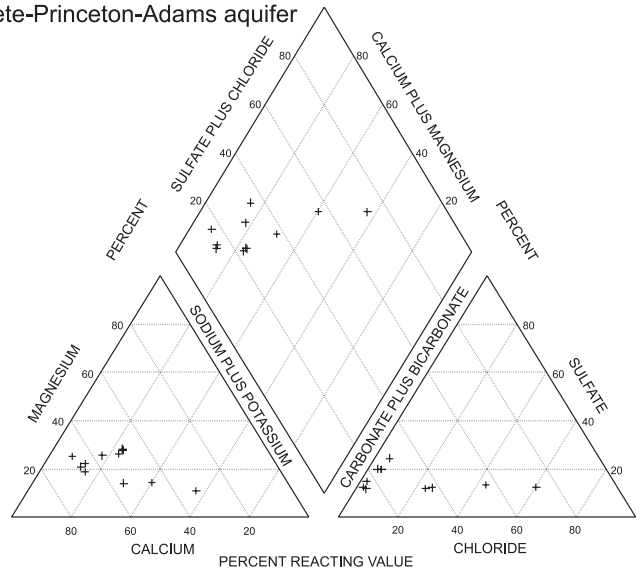
Concentrations of sulfate in water samples from the five aquifers ranged from 5.9 to 160 mg/L and had a median concentration of 51 mg/L. Sulfate concentrations in water samples did not exceed the U.S. Environmental Protection Agency's (1994) Secondary Maximum Contaminant Level (SMCL) of 250 mg/L from any of the aquifers. Concentrations of sulfate increased proportionally with increased well depth in the Crete-Princeton-Adams aquifer (Spearman's rho 0.86) and decreased with increasing well depth in the Missouri River aquifer (Spearman's rho -0.81). Sulfate did not show any associations at the 95-percent confidence level with well depth or location in the remaining three aquifers.

Concentrations of chloride ranged from 1.4 to 390 mg/L and had a median concentration of 9.2 mg/L. The largest concentrations of chloride, 170 and 390 mg/L, were from water samples collected from the Crete-Princeton-Adams aquifer (fig. 10). The larger of these two concentrations exceeded the U.S. Environmental Protection Agency's (1994) SMCL of 250 mg/L. Generally the largest concentrations of chloride were in mineralized water with the largest concentrations of dissolved solids. Concentrations of chloride were directly associated with concentrations of sodium in the Crete-Princeton-Adams aquifer and Platte River aquifer (Spearman's rho 0.80 and 1.00, respectively). In all but the Waverly aquifer, larger concentrations of chloride were common in water with small concentrations of dissolved oxygen and nitrate.

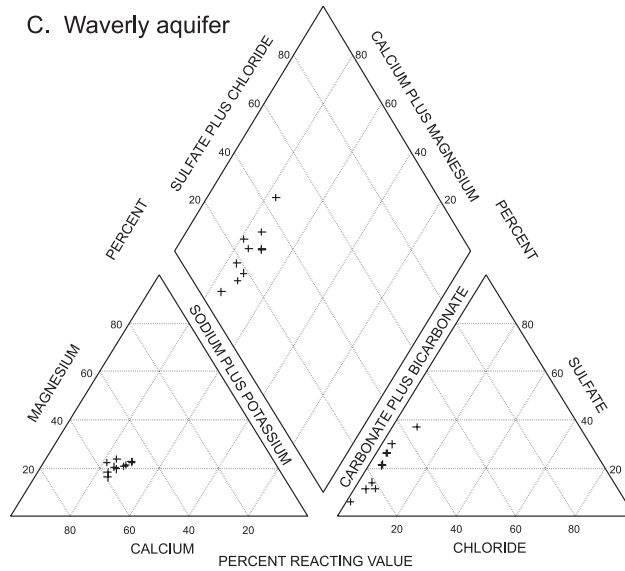
A. Dwight-Valparaiso aquifer



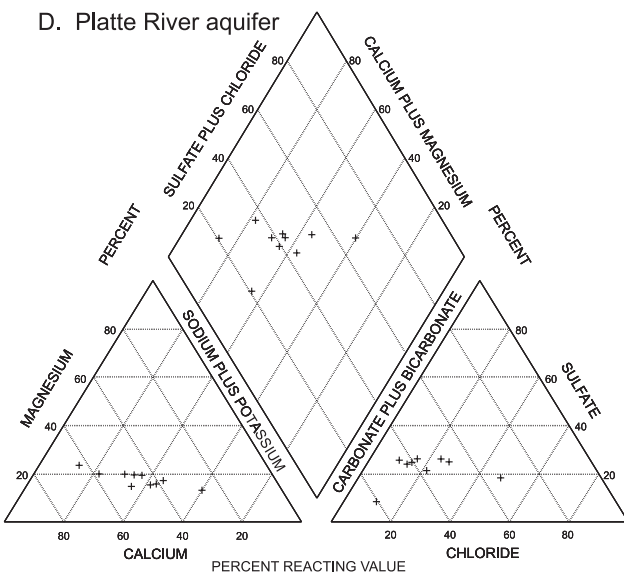
B. Crete-Princeton-Adams aquifer



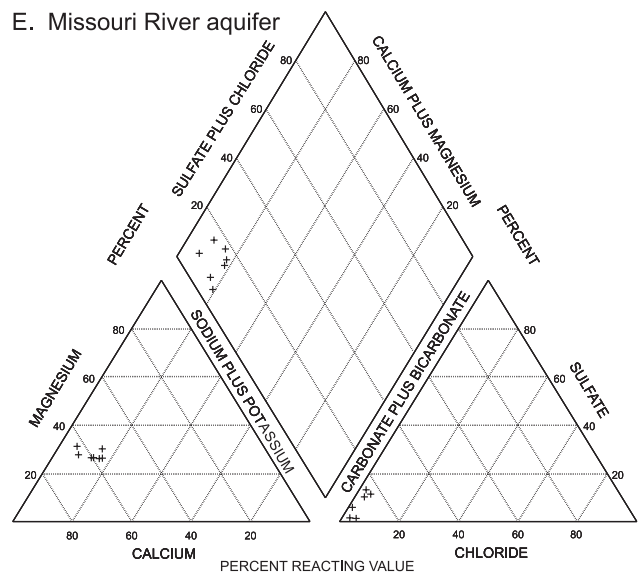
C. Waverly aquifer



D. Platte River aquifer



E. Missouri River aquifer



**Figure 9.** Ionic composition of ground water by aquifer, in percentage reacting value: A. Dwight-Valparaiso aquifer; B. Crete-Princeton-Adams aquifer; C. Waverly aquifer; D. Platte River aquifer; and E. Missouri River aquifer, 1994.

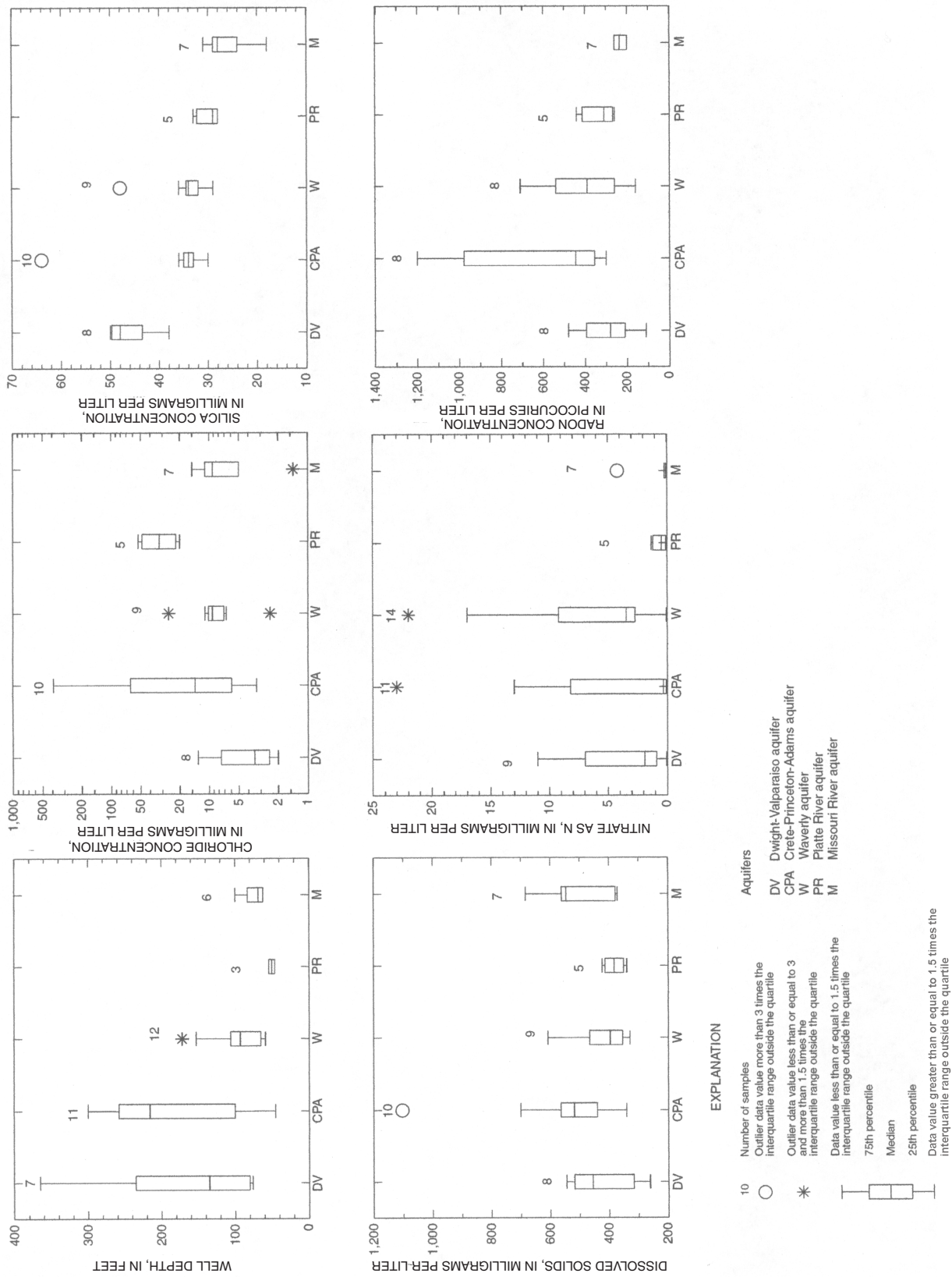


Figure 10. Distribution of well depth and selected chemical constituents by aquifer in the Lower Platte South Natural Resources District, 1994.

Concentrations of fluoride varied little in water samples from the five aquifers. The median concentration of fluoride was 0.3 mg/L. The largest concentrations of fluoride (0.6 to 0.8 mg/L) were measured in water samples from scattered locations in the Crete-Princeton-Adams aquifer. Concentrations of fluoride did not appear to be associated with well depth or location in the Crete-Princeton-Adams aquifer, nor was fluoride closely correlated with other water-quality measurements or constituents in the five aquifers.

Concentrations of silica ranged from 18 to 64 mg/L in the five aquifers and had a median concentration of 34 mg/L (table 4 and fig. 10). Water samples from the Dwight-Valparaiso aquifer had the largest median concentration of silica (48 mg/L). Concentrations of silica in samples showed no significant correlation with well depth in samples collected from the five aquifers.

Median concentrations of iron and manganese for individual aquifers ranged from less than 3 to 13,000 µg/L and from less than 1 to 3,600 µg/L, respectively (table 4). The largest median concentrations and the largest maximum concentrations of iron and manganese were from the Missouri River and Platte River aquifers where local redox conditions may promote large dissolved concentrations of iron and manganese while limiting concentrations of dissolved oxygen and nitrate. In the Missouri River aquifer, concentrations of iron generally decreased with increases in well depth (Spearman's rho -0.80) and with increases in concentrations of dissolved oxygen (Spearman's rho -0.80). Concentrations of iron increased with increases in concentrations of alkalinity, silica, and radon (Spearman's rho 0.80, 1.00, and 0.79, respectively).

Concentrations of dissolved solids in water samples, the sum of all dissolved major ions, ranged from 262 to 1,100 mg/L with a median of 430 mg/L for the five aquifers (table 4 and fig. 10). This range of concentrations was similar to those reported by Lawton and others (1984) in water samples from the Dakota Sandstone in the Lincoln area.

Concentrations of dissolved solids in the Dwight-Valparaiso aquifer ranged from 262 to 545 mg/L and showed no correlation with well depth. Although the distribution of sampling sites in the Dwight-Valparaiso aquifer is not uniform, it appears that concentrations of dissolved solids in ground-water samples generally increase from the eastern to the western part of the aquifer.

The Crete-Princeton-Adams aquifer contained the most mineralized water samples with a median dissolved-solids concentration of 520 mg/L and a maximum concentration of 1,100 mg/L. Median concentrations of dissolved solids for the Crete-Princeton-Adams aquifer (520 mg/L) and the Missouri River aquifer (540 mg/L) exceeded the SMCL for public water supplies of 500 mg/L (U.S. Environmental Protection Agency, 1994). The Crete-Princeton-Adams aquifer had the two largest concentrations of dissolved solids, 701 and 1,100 mg/L. The large concentrations of dissolved solids in these samples were the result of correspondingly large concentrations of sodium, sulfate, and chloride.

The ground water generally becomes more mineralized with depth in the Crete-Princeton-Adams aquifer as indicated by the positive correlation of dissolved solids with depth (Spearman's rho 0.75). The residence time of ground water is much longer at greater depths, and the extended exposure of the water to minerals in the aquifer presumably may increase the concentrations of dissolved solids in the water.

Concentrations of dissolved solids in water samples from the Waverly aquifer ranged from 346 to 608 mg/L and did not appear to be strongly associated with well depth. Concentrations of dissolved solids and corresponding values of specific conductance appear to be larger in the southwestern part of the aquifer than in the northeastern part.

Concentrations of dissolved solids in the Missouri River aquifer, which ranged from 371 to 684 mg/L, appear to decrease with depth. This inverse relation between dissolved solids and well depth could be caused by evaporation of irrigation water or flood water on the land surface, which would concentrate dissolved minerals in the water that recharges the upper part of the aquifer.

## Nitrate

Concentrations of nitrate in ground-water samples from the five aquifers ranged from less than 0.05 to 23 mg/L and had a median value of 1.2 mg/L (table 4 and fig. 10). Only 6 of 46 water samples (13 percent of the samples collected) contained concentrations of nitrate that exceeded the Maximum Contaminant Level (MCL) of 10 mg/L for public drinking water (U.S. Environmental Protection Agency, 1994).

Concentrations of nitrate in ground water from the five aquifers did not show a strong correlation with any of the field measurements or inorganic constituents. Concentrations of nitrate from the five aquifers did, however, show a negative correlation with concentrations of iron and manganese (Spearman's rho  $-0.71$  and  $-0.71$ , respectively).

Concentrations of nitrate in the Dwight-Valparaiso aquifer ranged from less than  $0.05$  to  $11$  mg/L and had a median concentration of  $1.9$  mg/L (table 4). The only water sample to exceed the MCL of  $10$  mg/L was from a domestic well with a depth of  $76$  ft, the shallowest of the sampled wells in the aquifer. Water samples from two additional wells contained concentrations of nitrate larger than  $5$  mg/L. Concentrations of nitrate were not correlated significantly with other water-quality constituents.

The median concentration of nitrate in the Crete-Princeton-Adams aquifer was  $0.31$  mg/L, and only two water samples collected from wells in this aquifer had nitrate concentrations that exceeded the MCL. The largest concentration of nitrate,  $23$  mg/L, was in a domestic well  $45$  ft deep, the shallowest of the sampled wells in the aquifer. Most, but not all, of the nitrate concentrations larger than  $5$  mg/L were in water samples collected from wells that were less than  $200$  ft deep.

Concentrations of nitrate from the Crete-Princeton-Adams aquifer were positively correlated with dissolved oxygen (Spearman's rho  $0.83$ ), which was generally larger in samples from shallower wells. Concentrations of nitrate were correlated negatively with dissolved-solids concentrations (Spearman's rho  $-0.78$ ). The small concentrations of nitrate in this aquifer are probably a function of the greater well depths (median well depth was  $216$  ft) compared to the other aquifers and the presence of locally confining layers of sediment in the aquifer.

Three of the six water samples that contained concentrations of nitrate larger than  $10$  mg/L were collected from the Waverly aquifer. The median concentration of nitrate in ground water in the Waverly aquifer was  $3.3$  mg/L. Although not very large, this concentration was  $3$  to  $10$  times larger than the median concentrations of nitrate in water samples from the other aquifers. The Waverly aquifer has the shallowest depth to water of the paleovalley aquifers, which may explain the large concentrations of nitrate. Most of the ground-water samples with the largest nitrate concen-

trations were from wells in the southwestern part of the Waverly aquifer.

Most concentrations of nitrate in the Platte River aquifer were quite small, ranging from less than  $0.05$  to  $6.5$  mg/L with a median concentration of  $0.78$  mg/L. Wells in the Platte River aquifer are generally less than  $60$  ft deep (fig. 10) and are close enough to the river for the chemistry of the water samples to be influenced by recharge water from the river. The median concentration of nitrate in the Platte River near Louisville (fig. 1) from  $1992$  to  $1995$  was  $1.20$  mg/L (Frenzel and others,  $1998$ ), which generally agrees with concentrations from the Platte River aquifer.

Concentrations of nitrate in the Missouri River aquifer were the smallest of the five aquifers. Concentrations of nitrate ranged from less than  $0.05$  to  $4.2$  mg/L and had a median concentration of  $0.06$  mg/L (table 5 and fig. 10). The largest concentration of nitrate was detected in a water sample collected from a domestic well with a depth of about  $30$  ft. Concentrations of nitrate in these ground-water samples showed no correlations with concentrations of other constituents. The general absence of significant concentrations of nitrate in the Missouri River aquifer may be the result of local clay deposits near the top of the alluvial aquifer that inhibit leaching of nitrogen from agricultural sources into the ground water or may reflect local chemical reducing conditions in the aquifer. Also, the aquifer may be affected by water from the Missouri River, which contains very small concentrations of nitrate (Melcher and others,  $1987$ ).

## Radon

Radon- $222$  is a radioactive gas produced from the decay of radium- $226$ , which in turn is produced by the decay of naturally occurring uranium- $238$ . Radon- $222$  has a half-life of  $3.8$  days, the longest of the radon isotopes, and therefore is the only radon isotope of environmental importance (Hem,  $1985$ ). The source of dissolved radon- $222$  (hereinafter referred to as radon) in ground water is frequently the decay product of minerals containing radium- $226$  in the aquifer. Because radon is a gas, it is very soluble in water and is transported easily to the water from the sediment in which it was formed.

Concentrations of radon in the five aquifers ranged from  $110$  to  $1,200$  pCi/L (picocuries per liter) (table 5 and fig. 10). The median concentration of

radon was 300 pCi/L. The concentration of 300 pCi/L also is the proposed MCL for radon in drinking water (U.S. Environmental Protection Agency, 1994). Water samples from the Crete-Princeton-Adams aquifer had the largest concentration of radon among the five aquifers—a median concentration of radon of 440 pCi/L. All water samples collected from the Crete-Princeton-Adams aquifer that were analyzed for radon had concentrations that exceeded the proposed MCL. The median concentration for the Waverly aquifer was 390 pCi/L. The Missouri River aquifer was the only aquifer of the five that contained no water samples with radon concentrations above the proposed MCL (table 4). Concentrations of radon did not show any correlation with well depth, field measurements, or other chemical constituents, using Spearman's rho.

## Herbicides

Using ELISA, all water samples were screened for the presence of triazine herbicides. Thirty-three of the 46 ground-water samples were submitted for GC/MS analysis, and six of those samples contained detectable concentrations of triazine herbicides or related compounds (tables 4 and 5). The compounds detected were atrazine, a preplant and pre-emergence herbicide used to control grasses and broadleaf weeds in corn; deethylatrazine and deisopropylatrazine, metabolites of atrazine; metolachlor, a preplant and pre-emergence herbicide for control of grasses and broadleaf weeds in corn and soybeans; and metribuzin, a pre-emergence herbicide used to control grasses and broadleaf weeds in soybeans (table 4). With the exception of one metolachlor concentration of 3.00 µg/L, all of the measured herbicide concentrations were less than 1.00 µg/L.

None of the six water samples contained concentrations of herbicides that exceeded the MCLs for drinking water. These water samples were collected from irrigation (3), domestic (1), industrial (1), and municipal (1) wells in four of the five aquifers. The irrigation and domestic wells were in areas where irrigated corn and soybean fields were the dominant land use. The municipal and industrial wells that contained detectable concentrations of atrazine and its metabolites were in the Platte River aquifer near the river. The herbicides present in these water samples could be from recharge to the aquifer from the Platte River during spring and early summer runoff

events when herbicide concentrations in the river can exceed 30 µg/L (Stamer and Huntzinger, 1994). Four of the six wells in which herbicides were detected were less than 100 ft deep.

## Quality-Assurance Results

Replicate analyses were performed for 12 constituents in water samples that were collected at one to three of the 46 sample-collection sites during July and August of 1994 (table 6). The average percent difference between the initial and replicate samples ranged from 0 to 50 percent, and the mean percent difference was 12.8. With the exception of concentrations of iron, all constituents with average percent differences larger than 15 percent had maximum variation in concentrations of less than two units (mg/L or µg/L). Thus, the precision for all of the analyses except iron is considered acceptable.

Examination of the data indicates that one of the pairs of regular and replicate iron analyses is suspect (less than 3 and 130 µg/L). Concentrations of the remaining pair of regular and replicate iron samples were identical (780 µg/L). This apparent inconsistency

**Table 6.** Results of replicate ground-water-quality analyses for major ions, selected metals, and nitrate in the Lower Platte South Natural Resources District, summer 1994

[All concentrations are in milligrams per liter except iron and manganese; µg/L, micrograms per liter]

Constituent	Number of paired samples	Average percent difference in concentrations of paired samples	Maximum variation in concentrations of paired samples
Alkalinity, as CaCO <sub>3</sub>	2	6	32
Calcium	2	4	4
Magnesium	2	12	4
Sodium	2	8	8
Potassium	2	17	1.7
Sulfate	1	0	0
Chloride	2	1	.2
Fluoride	2	22	.2
Silica	2	8	5
Iron, in µg/L	2	50	127
Manganese, in µg/L	2	25	.5
Nitrate	3	1	.1

in analyses of iron increases the uncertainty of concentrations for individual water samples; however, statistical summaries of concentrations of iron for individual aquifers are considered valid.

## CONSIDERATIONS FOR FUTURE GROUND-WATER-QUALITY MONITORING

The results of this study could be useful in designing future ground-water quality monitoring in the LPS NRD. A network of available wells used for sample collection during this study, in addition to a pattern of spatially distributed wells screened in the Dakota Sandstone, could be used to provide long-term water-quality data in the LPS NRD. Additional wells either could be identified or drilled to provide increased information from the western and northern parts of the Dwight-Valparaiso aquifer and in the northern and western parts of the Crete-Princeton-Adams aquifer. Because of little use of the Missouri River aquifer for drinking-water supply in the study area, the installation of additional water-quality monitoring wells may not be as warranted in that area.

Water samples could be collected from this network of wells periodically (for example, about every 3 years) to determine temporal variations in fields measurements and in concentrations of nitrate and radon. It also may be useful to install three nested monitoring wells (screened at different depths) in the Waverly aquifer to allow determination of vertical and seasonal variations in concentrations of nitrate. Water samples could be collected from the nested wells either monthly or bimonthly, for example. Periodically (for example, every 3 years), water samples could be collected and analyzed for triazine and other commonly used herbicides.

Follow-up water-quality collection and analyses for radon could be performed in areas that had elevated radon concentrations in the initial water-quality samples, especially from wells used for public water supply. The areal extent of locations with elevated concentrations of radon (larger than 300 pCi/L) in the five aquifers also could be determined through the collection and analysis of additional water samples.

## SUMMARY

The U.S. Geological Survey, in cooperation with the LPS NRD, conducted a hydrogeologic and water-quality reconnaissance study of the five principal aquifers in deposits of Quaternary age in the LPS NRD. The purpose of the study was to delineate the approximate extent of the aquifers, estimate volumes of drainable water in three aquifers, provide information that could be useful in designing future ground-water-quality monitoring, and determine baseline water-quality conditions in the aquifers with an emphasis on nitrate concentrations.

The approximate lateral boundaries of the Dwight-Valparaiso, Crete-Princeton-Adams, and Waverly aquifers were defined as areas in which the thicknesses of continuous sand and gravel deposits were less than 40 ft. The three aquifers were determined to occupy about 97, 115, and 25 mi<sup>2</sup>, respectively. Using a storage coefficient of 0.20, estimates of drainable water in the sand and gravel strata of the three aquifers were 1,340,000; 1,540,000; and 172,000 acre-ft, respectively.

Water samples were collected from 46 wells in the five principal aquifers during the summer of 1994. These samples were analyzed for nitrate and screened for triazine herbicides. Additionally, water samples from 39 of these wells were analyzed for major ions, iron, and manganese, and 35 were analyzed for radon.

Water samples had specific conductances of 399 to 2,040  $\mu\text{S}/\text{cm}$  and were a calcium carbonate to a calcium-magnesium-sodium carbonate type. The Crete-Princeton-Adams aquifer contained the most mineralized water samples with a median dissolved-solids concentration of 520 mg/L and a maximum concentration of 1,100 mg/L. Relatively large concentrations of sodium and chloride were measured in water samples from some of the deeper wells in the Crete-Princeton-Adams aquifer. One water sample from the Crete-Princeton-Adams aquifer had chloride concentrations in excess of the SMCL established by the U.S. Environmental Protection Agency. Median concentrations of iron and manganese for individual aquifers ranged from less than 3 to 13,000 and from less than 1 to 3,600  $\mu\text{g}/\text{L}$ , respectively.

Concentrations of nitrate in water samples ranged from less than 0.05 to 23 mg/L. The largest median concentration of nitrate, 3.3 mg/L, was from the Waverly aquifer, which contained three of the six



water samples that exceeded the primary MCL for drinking water.

Concentrations of radon ranged from 110 to 1,200 pCi/L in ground-water samples from the five principal aquifers. The median concentration of radon was 300 pCi/L, which is the proposed MCL for drinking water. Water samples from the Crete-Princeton-Adams and Waverly aquifers had the largest concentrations of radon among the five aquifers and had median concentrations of 440 and 390 pCi/L, respectively.

Triazine and related herbicides were detected in six water samples from four of the five aquifers. None of the herbicide concentrations exceeded the MCL for drinking water. Atrazine, metabolites of atrazine, metolachlor, and metribuzin were detected in concentrations generally less than 1.00 µg/L.

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# APPENDIX

**Table 4.** Statistical summary of ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994

[A, all aquifers; DV, Dwight-Valparaiso aquifer; CPA, Crete-Princeton-Adams aquifer; W, Waverly aquifer; PR, Platte River aquifer; M, Missouri River aquifer; NA, not applicable;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter;  $\text{mg}/\text{L}$ , milligrams per liter; <, less than;  $\text{pCi}/\text{L}$ , picocuries per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Measurement or constituent	Aquifer	Number of samples	Minimum	25th Percentile	Median	75th Percentile	Maximum	Public drinking-water regulation or criterion
Well depth below land surface, in feet	A	41	45	65	96	166	365	NA
	DV	7	76	80	135	235	365	
	CPA	11	45	100	216	258	300	
	W	13	59	65	93	106	172	
	PR	3	46	46	54	84	84	
	M	6	62	62	69	87	100	
Specific conductance, in $\mu\text{S}/\text{cm}$ at 25 degrees Celsius	A	46	399	588	696	838	2,040	NA
	DV	9	399	449	683	784	830	
	CPA	11	540	720	833	971	2,040	
	W	14	477	544	635	772	1,010	
	PR	5	586	587	629	678	717	
	M	7	664	704	941	988	1,140	
pH, in standard units	A	46	6.8	7.0	7.1	7.3	7.8	NA
	DV	9	6.9	7.0	7.3	7.4	7.6	
	P	11	7.0	7.1	7.2	7.3	7.4	
	W	14	6.8	6.9	7.0	7.1	7.5	
	PR	5	7.1	7.1	7.3	7.6	7.8	
	M	7	7.0	7.2	7.2	7.4	7.4	
Water temperature, in degrees Celsius	A	46	12.0	12.5	13.0	14.0	17.0	NA
	DV	9	12.0	12.2	12.5	13.6	15.5	
	CPA	11	13.0	13.0	14.0	14.0	15.5	
	W	14	12.0	12.4	12.5	13.5	15.0	
	PR	5	12.0	12.2	12.5	15.2	17.0	
	M	7	12.5	12.5	13.0	13.0	14.0	
Dissolved oxygen, in $\text{mg}/\text{L}$	A	39	.1	1.0	2.4	6.7	13.5	NA
	DV	8	.2	1.6	5.6	8.0	8.8	
	CPA	7	.4	.6	2.5	5.5	10.5	
	W	14	.5	2.1	4.7	7.7	8.8	
	PR	5	.7	.7	.8	.9	13.5	
	M	5	.1	.2	1.3	1.4	1.4	

**Table 4.** Statistical summary of ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[A, all aquifers; DV, Dwight-Valparaiso aquifer; CPA, Crete-Princeton-Adams aquifer; W, Waverly aquifer; PR, Platte River aquifer; M, Missouri River aquifer; NA, not applicable;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter;  $\text{mg}/\text{L}$ , milligrams per liter; <, less than;  $\text{pCi}/\text{L}$ , picocuries per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Measurement or constituent	Aquifer	Number of samples	Minimum	25th Percentile	Median	75th Percentile	Maximum	Public drinking-water regulation or criterion
Alkalinity, in $\text{mg}/\text{L}$ as $\text{CaCO}_3$	A	39	174	248	297	347	528	NA
	DV	8	174	205	308	346	375	
	CPA	10	247	252	300	366	390	
	W	9	223	251	276	300	338	
	PR	5	199	200	207	241	248	
	M	7	330	330	409	426	528	
Calcium, dissolved, in $\text{mg}/\text{L}$	A	39	45	75	90	110	140	NA
	DV	8	45	57	91	110	130	
	CPA	10	76	87	100	110	120	
	W	9	58	66	75	97	120	
	PR	5	58	58	64	78	80	
	M	7	77	77	120	130	140	
Magnesium, dissolved, in $\text{mg}/\text{L}$	A	39	9.4	16	21	28	40	NA
	DV	8	9.4	14	21	27	29	
	CPA	10	14	16	22	30	32	
	W	9	12	16	19	22	24	
	PR	5	11	12	16	17	18	
	M	7	22	25	32	35	40	
Sodium, dissolved, in $\text{mg}/\text{L}$	A	39	8.8	18	32	47	240	NA
	DV	8	13	14	19	21	32	
	CPA	10	13	18	44	70	240	
	W	9	30	33	43	54	59	
	PR	5	16	22	38	52	63	
	M	7	8.8	17	26	42	46	
Potassium, dissolved, in $\text{mg}/\text{L}$	A	39	2.6	4.3	5.2	6.9	15	
	DV	8	3.7	4.6	5.6	7.8	13	
	CPA	10	2.6	3.4	4.3	5.0	15	
	W	9	3.4	4.3	4.5	5.4	7.1	
	PR	5	3.8	4.5	6.8	9.2	9.4	
	M	7	3.6	4.3	5.4	7.1	8.1	

**Table 4.** Statistical summary of ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[A, all aquifers; DV, Dwight-Valparaiso aquifer; CPA, Crete-Princeton-Adams aquifer; W, Waverly aquifer; PR, Platte River aquifer; M, Missouri River aquifer; NA, not applicable;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter;  $\text{mg}/\text{L}$ , milligrams per liter;  $<$ , less than;  $\text{pCi}/\text{L}$ , picocuries per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Measurement or constituent	Aquifer	Number of samples	Minimum	25th Percentile	Median	75th Percentile	Maximum	Public drinking-water regulation or criterion
Sulfate, dissolved, in $\text{mg}/\text{L}$	A	39	5.9	27	51	77	160	<sup>1</sup> 250
	DV	8	7.2	23	44	77	100	
	CPA	10	27	35	58	85	110	
	W	9	14	27	59	96	160	
	PR	5	5.9	16	72	77	80	
	M	7	7.0	7.2	51	67	85	
Chloride, dissolved, in $\text{mg}/\text{L}$	A	39	1.4	5.0	9.2	15	390	<sup>1</sup> 250
	DV	8	2.0	2.4	3.5	7.6	13	
	CPA	10	3.3	5.4	14	90	390	
	W	9	2.4	7.0	9.3	10	26	
	PR	5	5.4	13	28	45	53	
	M	7	1.4	5.0	9.2	11	15	
Fluoride, dissolved, in $\text{mg}/\text{L}$	A	39	.2	.3	.3	.4	.8	<sup>2</sup> 4.0
	DV	8	.3	.3	.3	.4	.4	
	CPA	10	.3	.3	.4	.8	.8	
	W	9	.2	.3	.3	.3	.4	
	PR	5	.3	.4	.4	.4	.5	
	M	7	.3	.3	.3	.4	.4	
Silica, dissolved, in $\text{mg}/\text{L}$	A	39	18	29	34	38	64	NA
	DV	8	38	44	48	50	50	
	CPA	10	30	33	34	35	64	
	W	9	29	31	34	35	48	
	PR	5	28	28	30	32	33	
	M	7	18	24	28	29	31	
Iron, dissolved, in $\mu\text{g}/\text{L}$	A	39	<3	4	20	780	13,000	<sup>1</sup> 300
	DV	8	<3	<3	7	120	160	
	CPA	10	3	6	26	620	1,000	
	W	9	<3	<3	4	66	2,300	
	PR	5	<3	3	50	1,780	3,300	
	M	7	4	4,500	8,200	11,000	13,000	

**Table 4.** Statistical summary of ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[A, all aquifers; DV, Dwight-Valparaiso aquifer; CPA, Crete-Princeton-Adams aquifer; W, Waverly aquifer; PR, Platte River aquifer; M, Missouri River aquifer; NA, not applicable;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter;  $\text{mg}/\text{L}$ , milligrams per liter; <, less than;  $\text{pCi}/\text{L}$ , picocuries per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Measurement or constituent	Aquifer	Number of samples	Minimum	25th Percentile	Median	75th Percentile	Maximum	Public drinking-water regulation or criterion
Manganese, dissolved, in $\mu\text{g}/\text{L}$	A	39	<1	5	89	680	3,600	<sup>1</sup> 500
	DV	8	<1	1	14	58	450	
	CPA	10	6	15	220	480	710	
	W	9	<1	<1	2	53	1,100	
	PR	5	62	160	770	2,900	3,600	
	M	7	370	600	850	1,900	2,500	
Dissolved solids, in $\text{mg}/\text{L}$	A	39	262	370	430	540	1,100	<sup>1</sup> 500
	DV	8	262	320	460	520	545	
	CPA	10	340	420	520	600	1,100	
	W	9	346	353	400	500	608	
	PR	5	340	350	380	400	420	
	M	7	371	380	540	560	684	
Nitrogen $\text{NO}_2 + \text{NO}_3$ , dissolved, as N, in $\text{mg}/\text{L}$	A	46	<.05	.09	1.2	6.5	23	<sup>2</sup> 10
	DV	9	<.05	.84	1.9	7.1	11	
	CPA	11	<.05	.08	.31	8.2	23	
	W	14	<.05	.61	3.3	10.9	22	
	PR	5	<.05	<.05	.78	3.9	6.5	
	M	7	<.05	<.05	.06	2.0	4.2	
Radon, in $\text{pCi}/\text{L}$	A	35	110	260	300	440	1,200	<sup>2</sup> 300
	DV	8	110	210	280	390	480	
	CPA	8	300	360	440	980	1,200	
	W	8	160	260	390	540	710	
	PR	5	260	260	290	380	440	
	M	6	200	200	240	260	260	
Atrazine, dissolved, in $\mu\text{g}/\text{L}$	A	33	<.05	<.05	<.05	<.05	.45	<sup>2</sup> 3.0
	DV	7	<.05	<.05	<.05	<.05	<.05	
	CPA	6	<.05	<.05	<.05	<.05	<.05	
	W	10	<.05	<.05	<.05	<.05	<.05	
	PR	4	<.05	<.05	.18	.44	.45	
	M	6	<.05	<.05	<.05	<.05	<.05	

**Table 4.** Statistical summary of ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[A, all aquifers; DV, Dwight-Valparaiso aquifer; CPA, Crete-Princeton-Adams aquifer; W, Waverly aquifer; PR, Platte River aquifer; M, Missouri River aquifer; NA, not applicable;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter;  $\text{mg}/\text{L}$ , milligrams per liter; <, less than;  $\text{pCi}/\text{L}$ , picocuries per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Measurement or constituent	Aquifer	Number of samples	Minimum	25th Percentile	Median	75th Percentile	Maximum	Public drinking-water regulation or criterion
Deethyl-atrazine, dissolved, in $\mu\text{g}/\text{L}$	A	33	<0.05	<0.05	<0.05	<0.05	0.08	NA
	DV	7	<.05	<.05	<.05	<.05	<.05	
	CPA	6	<.05	<.05	<.05	<.05	<.05	
	W	10	<.05	<.05	<.05	<.05	<.05	
	PR	4	<.05	<.05	.02	.08	.08	
	M	6	<.05	<.05	<.05	<.05	<.05	
Deisopropyl-atrazine, dissolved, in $\mu\text{g}/\text{L}$	A	33	<.05	<.05	<.05	<.05	.05	NA
	DV	7	<.05	<.05	<.05	<.05	<.05	
	CPA	6	<.05	<.05	<.05	<.05	<.05	
	W	10	<.05	<.05	<.05	<.05	<.05	
	PR	4	<.05	<.05	<.05	.02	.05	
	M	6	<.05	<.05	<.05	<.05	<.05	
Metolachlor, dissolved, in $\mu\text{g}/\text{L}$	A	33	<.05	<.05	<.05	<.05	3.00	<sup>3</sup> 70
	DV	7	<.05	<.05	<.05	<.05	<.05	
	CPA	6	<.05	<.05	<.05	<.05	<.05	
	W	10	<.05	<.05	<.05	<.05	3.00	
	PR	4	<.05	<.05	<.05	<.05	<.05	
	M	6	<.05	<.05	<.05	<.05	<.05	
Metribuzin, dissolved, in $\mu\text{g}/\text{L}$	A	33	<.05	<.05	<.05	<.05	.11	<sup>4</sup> 200
	DV	7	<.05	<.05	<.05	.09	.11	
	CPA	16	<.05	<.05	<.05	<.05	<.05	
	W	10	<.05	<.05	<.05	<.05	<.05	
	PR	4	<.05	<.05	<.05	<.05	<.05	
	M	6	<.05	<.05	<.05	<.05	<.05	

<sup>1</sup>Secondary Maximum Contaminant Level (U.S. Environmental Protection Agency, 1994).

<sup>2</sup>Maximum Contaminant Level (U.S. Environmental Protection Agency, 1994).

<sup>3</sup>Maximum Contaminant Level Goal (U.S. Environmental Protection Agency, 1994).

<sup>4</sup>Life-time health advisory for 70-kilogram adult (U.S. Environmental Protection Agency, 1994).



**Table 5. Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994**

[ $\mu\text{S/cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $^{\circ}\text{C}$ , degrees Celsius;  $<$ , less than; --, no data;  $\text{mg/L}$ , milligrams per liter;  $\mu\text{g/L}$ , micrograms per liter;  $\text{pCi/L}$ , picocuries per liter]

Site ID number	Legal location	Local ID number	Date	Time	Sample type	Depth of well below land surface (feet)	Specific conductance ( $\mu\text{S/cm}$ )	pH (standard units)	Temperature, water ( $^{\circ}\text{C}$ )
410613096504901	13N 5E 15BBAB1	DV-37B	08-26-94	1226	Regular	76	683	7.0	15.5
410516096500201	13N 5E 22AACAA1	DV-40	08-16-94	1154	Regular	160	790	7.2	12.5
410534096425301	13N 6E 14CCBA1	DV-71	08-18-94	1330	Regular	--	626	7.6	13.0
410509096453401	13N 6E 20ABDD1	DV-77	08-29-94	1800	Regular	235	399	7.0	12.5
			08-29-94	1806	Replicate	235	--	--	--
410521096423801	13N 6E 23BABB1	DV-80	08-12-94	1357	Regular	115	457	7.4	12.5
410427096442401	13N 6E 28AABB1	DV-82	08-26-94	1011	Regular	135	441	6.9	12.0
410715097010501	13N 4E 6CDBCB1	DV-84	08-23-94	1632	Regular	365	830	7.3	14.0
410801096523701	14N 5E 32DCCD1	DV-85	08-29-94	1647	Regular	80	778	7.3	12.0
410448096592701	13N 4E 20DBDA1	<sup>1</sup> DV-101	09-06-94	1207	Regular	--	776	7.3	13.0
403340096503301	7N 5E 22ACDA1	CPA-11	08-18-94	1255	Regular	192	720	7.2	13.0
403600096454401	7N 6E 5DACC1	CPA-25	08-17-94	1650	Regular	91	800	7.4	14.0
403505096423301	7N 6E 11DDO1	CPA-28	08-17-94	1250	Regular	216	815	7.4	13.0
403425096425001	7N 6E 14DBBB1	CPA-32	08-22-94	1411	Regular	258	2,040	7.1	13.5
403347096465501	7N 6E 19AAC	CPA-36	08-02-94	1442	Regular	257	1,200	7.3	14.0
403228096444901	7N 6E 28DO1	CPA-48	08-02-94	1624	Regular	300	855	7.1	14.5
403203096463001	7N 6E 32B1	CPA-52	08-18-94	1526	Regular	282	890	7.2	14.0
403456096373901	7N 7E 10CCCD1	CPA-54	08-19-94	1215	Regular	104	585	--	13.0
403452096372801	7N 7E 15BABBB1	CPA-59	08-02-94	1124	Regular	100	--	7.1	15.5
403740096444701	8N 6E 28DDDBA1	<sup>1</sup> CPA-75B	08-02-94	1015	Regular	45	971	7.1	14.0
403645096303901	8N 8E 34DCBC1	<sup>1</sup> CPA-83	08-17-94	1031	Regular	228	833	7.0	14.0
			08-17-94	1036	Replicate	228	--	--	--
410042096231301	12N 9E 15CADA1	W-2AA	07-28-94	1147	Regular	--	503	7.0	13.5
			08-15-94	1750	Regular	--	498	6.8	14.0
410002096232501	12N 9E 22AABA1	W-4	08-15-94	1017	Regular	93	--	7.4	13.0
405754096274701	12N 9E 31CBBB1	W-5	08-18-94	1100	Regular	93	764	7.0	12.5
405748096262901	12N 9E 32CBAD1	W-6	07-28-94	1007	Regular	105	630	7.0	14.5
			08-15-94	1440	Regular	105	626	7.1	15.0

**Table 5.** Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[ $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $^{\circ}\text{C}$ , degrees Celsius;  $<$ , less than; --, no data;  $\text{mg}/\text{L}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter;  $\text{pCi}/\text{L}$ , picocuries per liter]

Site ID number	Legal location	Local ID number	Date	Time	Sample type	Depth of well below land surface (feet)	Specific conductance ( $\mu\text{S}/\text{cm}$ )	pH (standard units)	Temperature, water ( $^{\circ}\text{C}$ )
405320096341001	11N 7E 25DDBA1	W-21	07-26-94	1015	Regular	60	508	7.1	12.0
			08-16-94	1510	Regular	60	490	6.8	12.5
405640096292301	11N 8E 2DCCA1	W-30	07-25-94	1545	Regular	88	--	7.0	12.5
			08-16-94	1420	Regular	88	650	7.2	12.5
405631096302301	11N 8E 10ABAD1	W-36	07-26-94	1220	Regular	65	1,010	7.5	12.0
405546096292501	11N 8E 11DCCD1	W-40	07-25-94	1730	Regular	96	--	6.9	12.5
			08-16-94	1350	Regular	96	640	7.3	12.0
405522096302001	11N 8E 15ADCC1	W-53	08-16-94	1720	Regular	--	920	--	12.0
405454096322501	11N 8E 16CDCD1	W-55	07-27-94	1435	Regular	59	--	7.1	13.5
			08-15-94	1545	Regular	59	687	6.8	13.5
405413096323401	11N 8E 20DDAA1	W-62B	08-15-94	1130	Regular	65	477	7.0	13.5
405326096322501	11N 8E 29DABB1	1W-66	07-27-94	1540	Regular	172	449	7.0	13.0
			07-27-94	1535	Replicate	172	--	7.0	13.0
			08-15-94	1630	Regular	172	579	6.8	13.0
405846096261001	12N 9E 29BDDD1	W-100	07-26-94	1530	Regular	80	645	7.0	12.0
			08-18-94	1000	Regular	80	620	6.8	12.5
405228096331301	11N 8E 32C1	1W-689	07-27-94	1115	Regular	153	650	7.0	12.5
			08-19-94	2000	Regular	153	794	7.1	12.5
410337095594001	13NE 13E 30DCCC1	PR-1	08-19-94	1523	Regular	46	639	7.4	12.0
410039096092401	12N 11E 14BCBD1	PR-2	08-22-94	1409	Regular	--	717	7.8	12.5
410247096055901	13N 12E 31DDDD1	PR-4	08-23-94	1114	Regular	--	588	7.3	17.0
410252095562201	13N 13E 34CDAC1	PR-15	08-22-94	1617	Regular	81	586	7.1	13.5
410337095583001	13N 13E 32ABBB1	PR-54	08-19-94	1344	Regular	54	629	7.1	12.5
425100095510401	10N 14E 16BBBA1	M-2A	08-19-94	1530	Regular	100	664	7.2	14.0
405353095491301	11N 14E 27ABDB1	M-4	09-07-94	1413	Regular	62	1,140	7.4	13.0
405256095493001	11N 14E 34ACAB1	M-6	09-07-94	1458	Regular	83	988	7.2	12.5
410131095524701	12N 14E 7ACDA1	M-7	08-23-94	1347	Regular	72	966	7.4	13.0
404704095523501	10N 14E 31DDDC1	M-100	08-19-94	1702	Regular	--	744	7.2	12.5
404802095505801	10N 14E 28CCAD1	M-101	08-24-94	1250	Regular	62	941	--	12.5
404925095504501	10N 14E 21BDAB1	M-102	08-25-94	1130	Regular	65	704	7.4	13.0

**Table 5. Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued**

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than; --, no data; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Local ID number	Date	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as CaCO <sub>3</sub> )	Alkalinity, lab (mg/L as CaCO <sub>3</sub> )	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO <sub>4</sub> )	Chloride, dissolved (mg/L as Cl)
DV-37B	08-26-94	4.6	310	272	91	20	13	0.3	5.3	41	2.9
DV-40	08-16-94	1.6	430	341	130	26	13	.3	7.0	83	13
DV-71	08-18-94	8.8	290	284	89	17	18	.5	5.3	46	2.6
DV-77	08-29-94	8.1	150	183	45	9.4	20	.7	4.4	7.2	2.4
	08-29-94	--	--	--	--	--	--	--	--	--	--
DV-80	08-12-94	6.7	--	--	--	--	--	--	--	--	--
DV-82	08-26-94	7.5	170	174	46	13	21	.7	3.7	18	2.0
DV-84	08-23-94	.2	390	332	110	29	20	.4	8.1	100	5.9
DV-85	08-29-94	--	370	347	110	22	18	.4	5.9	58	8.2
DV-101	09-06-94	1.6	340	375	90	27	32	.8	13	39	4.1
CPA-11	08-18-94	10.5	340	302	100	23	13	.3	4.2	43	4.0
CPA-25	08-17-94	--	280	270	90	14	57	1	4.4	42	64
CPA-28	08-17-94	--	350	252	110	19	29	.7	3.6	37	53
CPA-32	08-22-94	1.3	400	302	120	25	240	5	5.4	110	390
CPA-36	08-02-94	.4	360	297	110	21	110	3	4.6	73	17
CPA-48	08-02-94	.6	400	365	110	30	39	.9	4.2	100	15
CPA-52	08-18-94	2.5	370	390	99	31	51	1	4.8	80	8.9
CPA-54	08-19-94	5.5	260	247	78	15	17	.5	3.0	27	5.9
CPA-59	08-02-94	--	260	250	76	16	18	.5	2.6	29	3.3
CPA-75B	08-02-94	5.5	--	--	--	--	--	--	--	--	--
CPA-83	08-17-94	--	360	370	90	32	49	1	15	77	13
	08-17-94	--	350	370	89	31	49	1	15	77	13
W-2AA	07-28-94	4.5	210	223	58	16	30	.9	7.1	25	11
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-4	08-15-94	--	230	274	72	12	34	1	4.3	14	2.4
W-5	08-18-94	.5	--	--	--	--	--	--	--	--	--
W-6	07-28-94	2.0	260	258	75	18	32	.9	5.5	59	8.8

**Table 5.** Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than; --, no data; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Local ID number	Date	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as CaCO <sub>3</sub> )	Alkalinity, lab (mg/L as CaCO <sub>3</sub> )	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO <sub>4</sub> )	Chloride, dissolved (mg/L as Cl)
W-21	08-15-94	--	--	--	--	--	--	--	--	--	--
	07-26-94	2.4	--	--	--	--	--	--	--	--	--
	08-16-94	--	--	--	--	--	--	--	--	--	--
W-30	07-25-94	8.0	390	300	120	23	55	1	4.4	160	26
	08-16-94	--	--	--	--	--	--	--	--	--	--
W-36	07-26-94	8.5	--	--	--	--	--	--	--	--	--
W-40	07-25-94	4.9	370	338	110	24	59	1	4.5	120	9.3
	08-16-94	--	--	--	--	--	--	--	--	--	--
W-53	08-16-94	4.2	--	--	--	--	--	--	--	--	--
W-55	07-27-94	1.0	290	291	84	19	43	1	5.3	65	9.9
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-62B	08-15-94	5.5	--	--	--	--	--	--	--	--	--
W-66	07-27-94	6.6	250	244	69	20	48	1	5.1	--	7.0
	07-27-94	6.6	230	276	65	16	40	1	3.4	29	7.2
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-100	07-26-94	2.1	250	244	67	19	47	1	5.2	72	6.7
	08-18-94	--	--	--	--	--	--	--	--	--	--
W-689	07-27-94	8.8	290	300	82	21	52	1	4.3	41	9.8
	08-19-94	7.6	--	--	--	--	--	--	--	--	--
PR-1	08-19-94	.7	230	199	64	16	38	1	9.4	72	28
PR-2	08-22-94	2.2	210	201	59	14	63	2	8.9	74	53
PR-4	08-23-94	.7	190	234	58	11	42	1	5.2	5.9	37
PR-15	08-22-94	1.7	270	248	80	18	16	.4	3.8	27	5.4
PR-54	08-19-94	.8	250	207	75	16	27	.7	6.8	80	20
M-2A	08-19-94	1.4	280	330	77	22	26	.7	3.6	7.0	5.0
M-4	09-07-94	--	510	528	140	40	46	.9	7.1	85	9.2
M-6	09-07-94	1.3	440	409	120	35	42	.9	5.4	51	10
M-7	08-23-94	.2	430	413	120	32	29	.6	8.1	63	15
M-100	08-19-94	1.3	370	360	100	30	8.8	.2	4.8	26	1.4
M-101	08-24-94	.1	460	426	130	34	17	.3	6.4	67	5.7
M-102	08-25-94	--	300	330	77	25	22	.6	4.3	7.2	11

**Table 5.** Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued[ $\mu$ S/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than; --, no data; mg/L, milligrams per liter;  $\mu$ g/L, micrograms per liter; pCi/L, picocuries per liter]

Local ID number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Iron, dissolved ( $\mu$ g/L as Fe)	Manganese, dissolved (mg/L as Mn)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO <sub>2</sub> + NO <sub>3</sub> , dissolved (mg/L as N)	Radon-222, total (pCi/L)	Radon-222 sigma, water, whole, total (pCi/L)	Alachlor, water, dissolved ( $\mu$ g/L)	Ametryn, water, dissolved ( $\mu$ g/L)
DV-37B	08-26-94	0.4	47	<3	1	432	11	480	24	<0.05	<0.05
DV-40	08-16-94	.4	38	<3	26	545	6.80	260	22	<.05	<.05
DV-71	08-18-94	.3	45	6	<1	397	.73	110	17	<.05	<.05
DV-77	08-29-94	.3	50	20	1	262	3.1	240	19	--	--
	08-29-94	--	--	--	--	--	3.2	--	--	--	--
DV-80	08-12-94	--	--	--	--	--	.95	--	--	--	--
DV-82	08-26-94	.3	49	8	2	290	7.4	410	23	<.05	<.05
DV-84	08-23-94	.4	49	6	67	530	1.9	200	19	<.05	<.05
DV-85	08-29-94	.3	43	160	33	479	1.2	300	20	<.05	<.05
DV-101	09-06-94	.3	50	150	450	481	<.05	350	22	<.05	<.05
CPA-11	08-18-94	.6	35	29	8	440	8.2	300	21	<.05	<.05
CPA-25	08-17-94	.3	32	3	6	467	.31	--	--	<.05	<.05
CPA-28	08-17-94	.4	33	10	76	494	13	--	--	--	--
CPA-32	08-22-94	.3	30	1,000	620	1,100	.07	370	21	<.05	<.05
CPA-36	08-02-94	.3	33	570	430	701	<.05	400	21	--	--
CPA-48	08-02-94	.4	34	24	420	553	.23	910	29	--	--
CPA-52	08-18-94	.4	34	5	300	544	.19	1,000	31	--	--
CPA-54	08-19-94	.4	36	6	17	359	6.5	1,200	32	--	--
CPA-59	08-02-94	.3	34	60	130	341	2.6	490	23	<.05	<.05
CPA-75B	08-02-94	--	--	--	--	--	23	--	--	<.05	<.05
CPA-83	08-17-94	0.8	64	780	710	564	<0.05	350	23	<0.05	<0.05
	08-17-94	.9	64	780	700	562	<.05	--	--	--	--
W-2AA	07-28-94	.3	48	8	5	346	3.8	260	20	<.05	<.05
	08-15-94	--	--	--	--	--	4.9	--	--	--	--
W-4	08-15-94	.3	34	4	17	350	2.8	160	19	<.05	<.05
W-5	08-18-94	--	--	--	--	--	.61	--	--	--	--
W-6	07-28-94	.3	34	12	2	401	3.2	550	25	<.05	<.05
	08-15-94	--	--	--	--	--	3.1	--	--	--	--
W-21	07-26-94	--	--	--	--	--	--	--	--	--	--
	08-16-94	--	--	--	--	--	9.2	--	--	--	--

**Table 5.** Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than; --, no data; mg/L, milligrams per liter; μg/L, micrograms per liter; pCi/L, picocuries per liter

Local ID number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Iron, dissolved (μg/L as Fe)	Manganese, dissolved (mg/L as Mn)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO <sub>2</sub> + NO <sub>3</sub> , dissolved (mg/L as N)	Radon-222, total (pCi/L)	Radon-222 sigma, water, whole, total (pCi/L)	Alachlor, water, dissolved (μg/L)	Ametryn, water, dissolved (μg/L)
W-30	07-25-94	.2	36	2,300	1,000	608	.05	710	27	--	--
	08-16-94	--	--	--	--	--	<.05	--	--	--	--
W-36	07-26-94	--	--	--	--	--	--	--	--	<.05	<.05
W-40	07-25-94	.3	29	<3	<1	559	--	380	22	<.05	<.05
	08-16-94	--	--	--	--	--	16	--	--	--	--
W-53	08-16-94	--	--	--	--	--	22	--	--	<.05	<.05
W-55	07-27-94	.4	34	<3	2	452	3.8	260	22	<.05	<.05
	08-15-94	--	--	--	--	--	3.8	--	--	--	--
W-62B	08-15-94	--	--	--	--	--	2.7	--	--	<.05	<.05
W-66	07-27-94	.2	34	130	95	--	--	410	25	--	--
	07-27-94	.3	29	<3	<1	355	--	--	--	--	--
	08-15-94	--	--	--	--	--	2.8	--	--	--	--
W-100	07-26-94	.3	33	120	89	397	--	400	24	<.05	<.05
	08-18-94	--	--	--	--	--	4.8	--	--	--	--
W-689	07-27-94	.3	34	<3	<1	495	16	510	27	<.05	<.05
	08-19-94	--	--	--	--	--	17	--	--	--	--
PR-1	08-19-94	.4	28	<3	62	381	1.30	440	23	<.05	<.05
PR-2	08-22-94	.5	28	150	2,300	423	<.05	290	21	<.05	<.05
PR-4	08-23-94	.3	33	3,300	3,600	340	.11	330	21	--	--
PR-15	08-22-94	.4	31	4	250	361	6.80	270	19	<.05	<.05
PR-54	08-19-94	.4	30	260	770	384	.78	260	21	<.05	<.05
M-2A	08-19-94	.4	26	4,500	680	371	.20	200	17	<.05	<.05
M-4	09-07-94	.3	28	8,800	2,500	684	.06	250	20	<.05	<.05
M-6	09-07-94	.3	28	7,600	850	545	<.05	200	20	<.05	<.05
M-7	08-23-94	.3	31	13,000	1,900	561	<.05	260	19	<.05	<.05
M-100	08-19-94	.4	18	4	370	424	4.20	220	18	<.05	<.05
M-101	08-24-94	.4	29	11,000	600	557	.09	260	20	--	--
M-102	08-25-94	.3	24	8,200	910	378	<.05	--	--	<.05	<.05

**Table 5.** Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued[ $\mu$ S/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than; --, no data; mg/L, milligrams per liter;  $\mu$ g/L, micrograms per liter; pCi/L, picocuries per liter]

Local ID number	Date	Atrazine, water, dissolved ( $\mu$ g/L)	Cyanazine, water, dissolved ( $\mu$ g/L)	Atrazine, water, dissolved ( $\mu$ g/L)	Propylatrazine, water, dissolved ( $\mu$ g/L)	Metolachlor, water, dissolved ( $\mu$ g/L)	Metribuzin, sencor, water, dissolved ( $\mu$ g/L)	Prometon, water, dissolved ( $\mu$ g/L)	Prometryn, water, dissolved ( $\mu$ g/L)	Deethylpro-pazine, water, dissolved ( $\mu$ g/L)	Deisozimazine, water, dissolved ( $\mu$ g/L)
DV-37B	08-26-94	<0.05	<0.20	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
DV-40	08-16-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
DV-71	08-18-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
DV-77	08-29-94	--	--	--	--	--	--	--	--	--	--
	08-29-94	--	--	--	--	--	--	--	--	--	--
DV-80	08-12-94	--	--	--	--	--	--	--	--	--	--
DV-82	08-26-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
DV-84	08-23-94	<.05	<.20	<.05	<.05	<.05	.09	<.05	<.05	<.05	<.05
DV-85	08-29-94	<.05	<.20	<.05	<.05	<.05	.11	<.05	<.05	<.05	<.05
DV-101	09-06-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
CPA-11	08-18-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
CPA-25	08-17-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
CPA-28	08-17-94	--	--	--	--	--	--	--	--	--	--
CPA-32	08-22-94	<.05	<.20	<.05	<.05	<.05	.05	<.05	<.05	<.05	<.05
CPA-36	08-02-94	--	--	--	--	--	--	--	--	--	--
CPA-48	08-02-94	--	--	--	--	--	--	--	--	--	--
CPA-52	08-18-94	--	--	--	--	--	--	--	--	--	--
CPA-54	08-19-94	--	--	--	--	--	--	--	--	--	--
CPA-59	08-02-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
CPA-75B	08-02-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
CPA-83	08-17-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
	08-17-94	--	--	--	--	--	--	--	--	--	--
W-2AA	07-28-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-4	08-15-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
W-5	08-18-94	--	--	--	--	--	--	--	--	--	--
W-6	07-28-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-21	07-26-94	--	--	--	--	--	--	--	--	--	--
	08-16-94	--	--	--	--	--	--	--	--	--	--

**Table 5.** Ground-water-quality data from five aquifers in the Lower Platte South Natural Resources District, summer 1994—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than; --, no data; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter

Local ID number	Date	Atrazine, water, dissolved (µg/L)	Cyanazine, water, dissolved (µg/L)	Atrazine, water, dissolved (µg/L)	Propyl-atrazine, water, dissolved (µg/L)	Metolachlor, water, dissolved (µg/L)	Metribuzin, sencor, water, dissolved (µg/L)	Prometon, water, dissolved (µg/L)	Prometryn, water, dissolved (µg/L)	Deethyl-pro-pazine, water, dissolved (µg/L)	Deiso-simazine, water, dissolved (µg/L)
W-30	07-25-94	--	--	--	--	--	--	--	--	--	--
	08-16-94	--	--	--	--	--	--	--	--	--	--
W-36	07-26-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
W-40	07-25-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
	08-16-94	--	--	--	--	--	--	--	--	--	--
W-53	08-16-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
W-55	07-27-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-62B	08-15-94	<.05	<.20	<.05	<.05	3.00	<.05	<.05	<.05	<.05	--
W-66	07-27-94	--	--	--	--	--	--	--	--	--	--
	07-27-94	--	--	--	--	--	--	--	--	--	--
	08-15-94	--	--	--	--	--	--	--	--	--	--
W-100	07-26-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
	08-18-94	--	--	--	--	--	--	--	--	--	--
W-689	07-27-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--
	08-19-94	--	--	--	--	--	--	--	--	--	--
PR-1	08-19-94	.40	<.20	.08	.05	<.05	<.05	<.05	<.05	<.05	<.05
PR-2	08-22-94	.45	<.20	.08	<.05	<.05	<.05	<.05	<.05	<.05	--
PR-4	08-23-94	--	--	--	--	--	--	--	--	--	--
PR-15	08-22-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
PR-54	08-19-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
M-2A	08-19-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
M-4	09-07-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
M-6	09-07-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
M-7	08-23-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
M-100	08-19-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
M-101	08-24-94	--	--	--	--	--	--	--	--	--	--
M-102	08-25-94	<.05	<.20	<.05	<.05	<.05	<.05	<.05	<.05	<.05	--

<sup>1</sup> Well was completed beyond the extent of the most permeable sand and gravel deposits of the aquifer.