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Hydrogeology and Subsurface Nitrate in the Upper Big Blue Natural Resources District, Central Nebraska, July 1995 through September 1997

By I.M. Verstraeten, V.L. McGuire, *and* K.L. Heckman

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Upper Big Blue Natural Resources District

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
acre	4,047	square meter
pound (lb)	0.4536	kilogram
acre-foot (acre-ft)	1.233	cubic meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.0929	meter squared per day
inch per year (in/yr)	25.4	millimeter per year
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon per day (gal/d)	3.785	liters per day
gallon per minute (gal/min)	3.785	liter per minute

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.

Hydrogeology and Subsurface Nitrate in the Upper Big Blue Natural Resources District, Central Nebraska, July 1995 Through September 1997

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ABSTRACT

Following the designation of the Upper Big Blue Natural Resources District as a Special Protection Area by the Nebraska Department of Environmental Quality in 1993, the Upper Big Blue Natural Resources District requested that the U.S. Geological Survey, in cooperation with the Natural Resources District, develop a monitoring approach to identify the spatial and temporal variability of nitrate concentrations in ground water and assess the presence of nitrate concentrations in the unsaturated zone. A ground-water-quality monitoring network of 197 existing domestic and registered wells was proposed, along with 8 nested wells (18 wells) and associated unsaturated-zone subsites. Most of the wells are completed in the shallow (104), deep (86), and combined (3) parts of the High Plains aquifer, with 123 wells screened in the unconfined parts and 70 wells screened in the confined part. One well is completed in the Greenhorn Formation, and three wells are completed in the Dakota aquifer.

The ground water in the Upper Big Blue Natural Resources District had a median nitrate concentration of 4.6 mg/L (milligrams per liter). Water samples from the shallow and deep parts of the High Plains aquifer had median nitrate concentrations of 6.3 and 3.4 mg/L, respectively. Water from the Dakota aquifer had a median nitrate concentration of 0.11 mg/L. Forty-one of the 197 samples (21 percent) exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level for drinking water of 10 mg/L for nitrate as nitrogen. Among the 12 management zones established by the Upper Big Blue Natural Resources District to manage water quantity and quality, the median nitrate concentrations varied from 0.97 mg/L in zone 12 to 10 mg/L in zone 5. The latter median concentration exceeded the Phase II trigger of 9 mg/L established by the Upper Big Blue Natural Resources District in their Special Protection Area Action Plan.

Nitrate concentrations and field measurements of water samples collected from the nested wells generally agree with the results from the proposed ground-water-quality monitoring network of domestic and registered wells. Nitrate concentrations in water samples from the well nests generally did not appear to vary with time during the 19 months of data collection. Major-ion data indicate that water in the High Plains aquifer generally is a calcium-bicarbonate type and shows little spatial variation. The tritium data indicate that water from the shallow part of the High Plains aquifer likely was recharged during the last 10 to 20 years, while water from the deep, confined part of the High Plains aquifer likely was recharged more than 50 years ago. The tritium data indicate that, where confined conditions exist in the deep part of the High Plains aquifer and have not been modified through penetration of wells, the water could remain unaffected by nitrate contamination.

Nitrate concentrations of 245 unsaturated-zone sediment samples analyzed varied from less than 0.05 to 69 milligrams per kilogram with a median of 3.7 milligrams per kilogram. Nitrate concentrations in the unsaturated-zone sediment samples varied among sample subsites, and were not related to the depth at which the samples were collected. At site DH4, nitrate concentrations in

unsaturated-zone sediment samples collected below nonirrigated cropland were larger than nitrate concentrations from samples collected below irrigated or pasture land. Nitrate concentrations below pasture land generally were smaller than nitrate concentrations below cropland.

INTRODUCTION

The Nebraska Department of Environmental Quality (NDEQ) conducted a water-quality study in the Upper Big Blue Natural Resources District (UBBNRD) (fig. 1) in central Nebraska from 1989 through 1991 to determine if the ground water was sufficiently contaminated to require Special Protection Area designation (Gottula, 1990; Gottula and Link, 1992). Results from a water-quality monitoring program of the UBBNRD conducted prior to the NDEQ study indicated that nitrate concentrations in the principal aquifers were increasing (R.D. DeBuhr, UBBNRD, written commun., 1997). In addition, the City of Seward, whose municipal water supply contains large nitrate concentrations, requested further investigation. On September 23, 1993, the NDEQ declared the UBBNRD a Special Protection Area. Twelve management zones, and action levels at the Phase II trigger of 9 mg/L (milligrams per liter) and Phase III trigger of 12 mg/L, were established in the UBBNRD's Special Protection Area Action Plan, potentially imposing increased monitoring or best management practices (BMPs) in the affected management zones (Upper Big Blue Natural Resources District, 1994).

Following the designation of the Special Protection Area, the UBBNRD formed a citizens advisory committee and requested that the U.S. Geological Survey (USGS) develop a monitoring approach that with time: (1) would identify the spatial and temporal variability of nitrate concentrations in ground water with emphasis on the shallow part of the High Plains aquifer (the major source of water underlying the UBBNRD); and (2) would quantify nitrate concentrations in the unsaturated zone to aid in developing and assessing long-term BMPs. The UBBNRD received a Clean Water Act 319 grant (RFP No. SWSRF94-1) for the UBBNRD's Special Protection Area Groundwater Quality Program used in part to finance the installation of nested wells discussed herein.

Previous studies have determined that the general water quality of the High Plains aquifer in the study area is a calcium-bicarbonate type (Johnson and Keech, 1959; Keech and Dreeszen, 1959; Keech, 1962 and 1978; Gottula, 1990; Gottula and Link, 1992). A regional study of nitrates by Kolpin and others (1994) demonstrated that large nitrate concentrations were detected in the near-surface unconsolidated aquifer in the study area. The UBBNRD, through the ground-water-quality program started in the 1980s, identified an increase in nitrate concentrations from the early to late 1980s (Gottula and Link, 1992). Deep core samples were collected by the UBBNRD in 1990 and analyzed for nitrogen species (Gottula and Link, 1992). Results showed potential movement of nitrogen below the root zone and generally larger nitrogen levels under cropland than under pasture land.

The USGS, in cooperation with the UBBNRD, (1) conducted a hydrogeologic study, (2) evaluated the UBBNRD's existing ground-water-quality monitoring network, and (3) developed a saturated- and unsaturated-zone monitoring approach in the entire UBBNRD from 1995 through 1997 based on land use, physiography, soil, geology, and hydrology. The objectives of the study were to: (1) describe the hydrogeology of the study area (the UBBNRD); (2) develop a monitoring approach to evaluate the spatial and temporal variations in subsurface nitrate concentrations, including unsaturated zone and principal aquifers; and (3) perform an initial assessment of nitrate and major-ion concentrations in ground water and nitrate in the unsaturated zone in the study area. The intent of this study was to aid the UBBNRD with the development of data collection efforts for determining long-term effectiveness of current and future management practices that may be beneficial in the reduction of nitrate in the ground water of the study area. Results of this study also may be useful in addressing these issues in other areas with similar hydrogeologic settings.

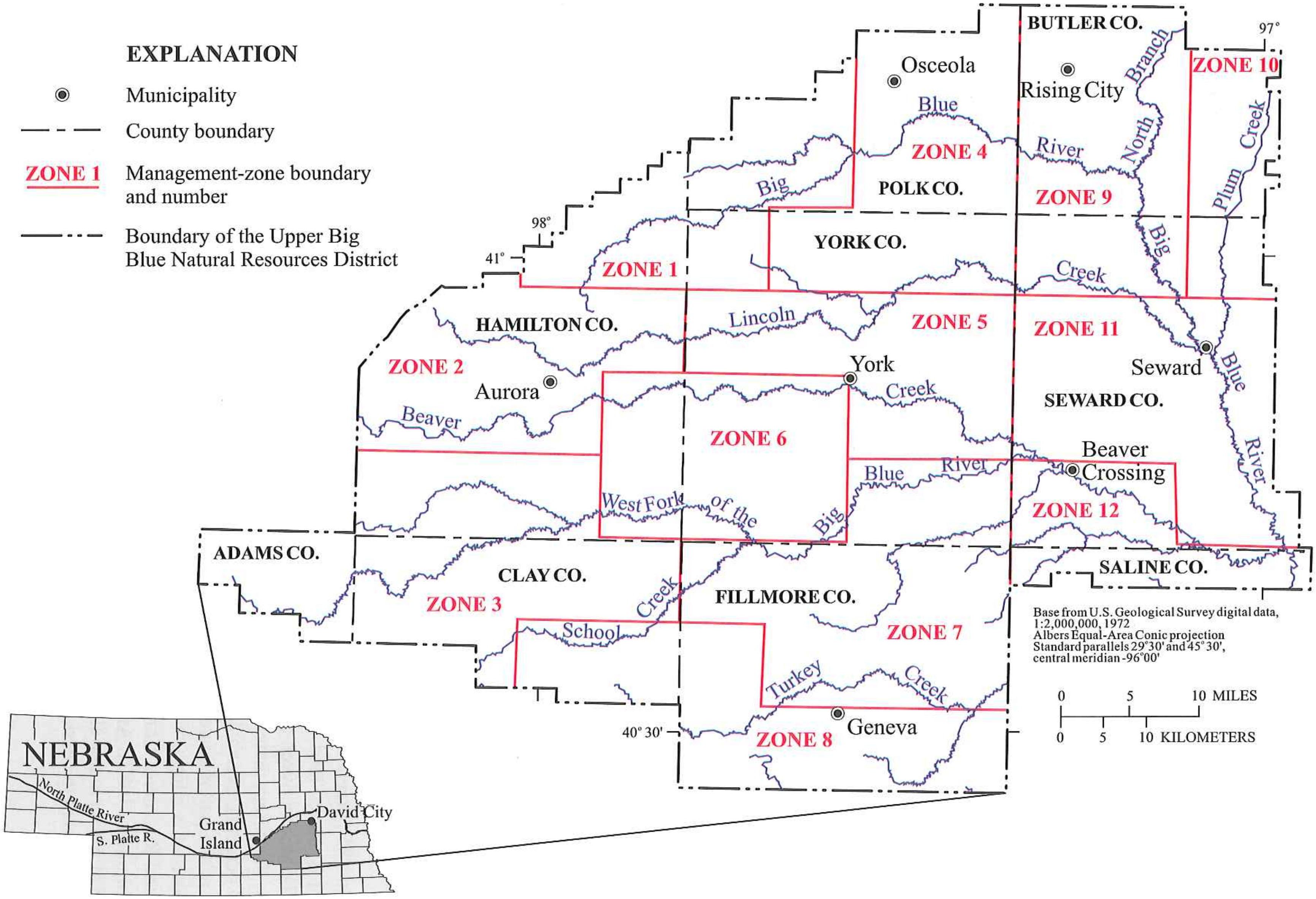

Figure 1. Location of the Upper Big Blue Natural Resources District, central Nebraska.

Purpose and Scope

This report presents the results of the study. The monitoring approach used about 200 domestic and registered irrigation, municipal, and industrial wells, along with 18 nested wells at 8 nested well sites, and associated unsaturated-zone subsites, established for this study. Spatial and temporal trends in nitrate concentrations in ground water and the unsaturated zone are described. Spatial trends of major-ion concentrations, and results of analyses of tritium concentrations used for estimating the relative age of water, also are described. Hydrogeologic data used in this study were collected from July 1995 through September 1997.

Description of Study Area

The study area comprises about 2,860 mi^2. According to the 1990 census, the population in the study area was 55,264, of which 66 percent was urban. The study area mainly lies in the upper reaches of the Big Blue River Basin in central Nebraska (fig. 1) and consists mostly of a gently rolling loess (wind-deposited silt) upland of low relief dissected by small meandering streams occupying wide shallow valleys (Johnson and Keech, 1959). The primary streams in the study area are the Big Blue River and its tributaries, Turkey Creek, School Creek, West Fork of the Big Blue River, Beaver Creek, Lincoln Creek, North Branch of the Big Blue River, and Plum Creek. Generally, these streams flow to the east southeast (fig. 1). Small shallow marshes mainly are in Clay County.

About 85 percent of the land is upland, 10 percent is terrace land, and 3 percent is foot slopes—the area between upland and bottomland. Generally, the parent material of the soil is loess (about 90 percent), especially on the upland. Only 1 percent of the parent material is glacial till and about 1 percent is alluvium (unpublished data from U.S. Natural Resources Conservation Service, written commun., 1983). Areas with soils having glacial till as parent material mainly are in Butler and Seward Counties in the eastern part of the study area (fig. 1).

In part, the susceptibility of the land to movement of contaminants through the unsaturated zone is reflected by the drainage class of the soil, which in turn is affected by the parent material of the soil. Approximately 88 percent of the land has soils that are well drained and 10 percent of the land has soils that are poorly drained (unpublished data from U.S. Natural Resources Conservation Service, written commun., 1983). As a result, ground water in the area generally may be susceptible to nonpoint-source contamination. The poorly-drained soils generally are on the upland and have B horizons— a layer within the soil generally consisting of illuvial colloids located below the A horizon which itself tends to be darkened by an accumulation of organic matter. In the marshy areas and in areas with glacial till as parent material, the soils tend to be poorly drained. Only about 1 percent of the land is excessively drained. These areas generally are on the bottomlands (terraces and floodplains) near the streams.

The climate is typical of a mid-latitude, continental setting with pronounced seasonal ranges in temperature. The mean annual precipitation in the area ranges from about 25 in. in the western part of the study area to 27 in. in the eastern part. Most precipitation is received during thunderstorms in the spring and summer.

The study area is one of the more intensively cultivated and irrigated areas in Nebraska. About 54 percent of all the land in the study area is irrigated cropland (table 1). About 33 percent of the land is dry cropland and about 9 percent of the land is dry pasture and range land. Other land uses such as urban areas, forest land and surface water make up less than 4 percent of the land mass. These statistics are based on land use in the part of each county in the study area (unpublished data from U.S. Natural Resources Conservation Service, written commun., 1983).

Acknowledgments

The authors thank the well owners in the study area for granting permission to sample their wells and for their assistance in the field. The authors thank Vince Dreeszen (formerly with the Conservation and Survey Division of Nebraska) for his comments and input on a portion of the description of the hydrogeology of the study area.

Table 1. Summary of land use by county, Upper Big Blue Natural Resources District, central Nebraska, 1983-84

[all units are in square miles; unpublished data from U.S. Natural Resources Conservation Service, written commun., 1983]

	Land-use class						
County	Irrigated cropland	Dry crop-land	Irrigated pasture land	Dry pasture and range land	Forest land	Surface water	Other
Adams	43	21	0.1	3.8	0.0	0.3	3.2
Butler	81	150	.2	23	.0	.3	5.9
Clay	141	73	.2	23	1.4	.3	5.2
Fillmore	213	159	.3	44	.6	.9	15
Hamilton	355	83	.4	39	.8	.7	21
Polk	139	89	.0	17	.0	.5	11
Saline	31	23	.0	7.2	.0	.1	2.4
Seward	157	245	.0	41	6.9	.2	9.7
York	387	107	.0	57	.0	.8	24
Total	1,547	950	1.2	255	9.7	4.1	97.4

HYDROGEOLOGY

The description of the hydrogeology of the study area is based on hydrologic and geologic information contained in published and unpublished reports by the Conservation and Survey Division (CSD), Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln and by the USGS. A township-range-section system (fig. 2) was used in the report to identify well and site locations. A summary of the geologic units that comprise the unconsolidated and bedrock deposits beneath the study area and corresponding hydrogeologic units and water-bearing properties (table 2) was made. Test holes (fig. 3, table 3) provided data used in construction of generalized geologic sections (fig. 4). Previous studies were used in summarizing the hydrogeology of the study area including: Ellis (1986); Emery (1966); Ginsberg (1983); Johnson and Keech (1959); Keech (1962 and 1978); Keech and Dreeszen, (1959, 1968a, and 1968b); Keech, and others (1967); Pettijohn and Chen (1983a); Gottula (1990); and Gottula and Link (1992).

Water-Bearing Hydrogeologic Units

Unconsolidated Deposits

The High Plains aquifer is the principal source of water in the study area. This aquifer consists of alluvial clay, silt, sand, and gravel and in some areas glacial till of Quaternary age and alluvial clayey and sandy silt of Tertiary age (table 2). For purposes of this report the High Plains aquifer has been subdivided into a shallow part (mainly consisting of sediments of Illinoian age) and a deep part (mainly consisting of sediments of pre-Illinoian age at times separated by glacial till). The hydrogeologic conditions of aquifer parts are designated as unconfined (UF) and confined (CF).

The hydrologic conditions of the High Plains aquifer vary from unconfined, perched to confined conditions. The base of the High Plains aquifer is the bottom of the lowermost sand and gravel units, generally corresponding with the top of the bedrock, including the Ogallala Formation. The thickness of the High Plains aquifer (fig. 5) is in part controlled by the relief of the bedrock surface. Generally, the

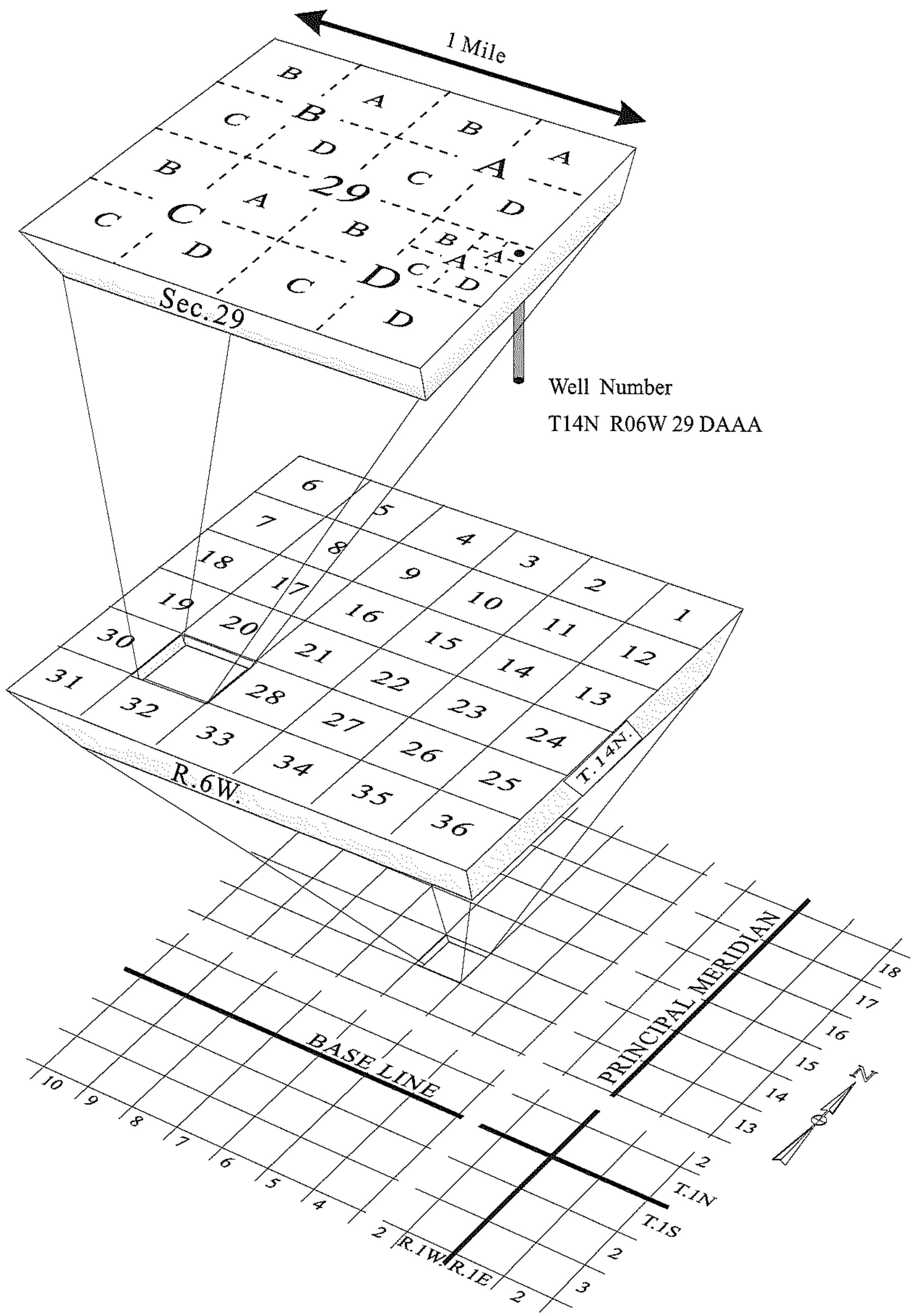

Figure 2. Township-range-section numbering system.

Table 2. Generalized summary of the geologic units of Cretaceous age or younger and their water-bearing properties, Upper Big Blue Natural Resources District, central Nebraska

[--, water-bearing units absent]

System	Series	Geologic unit	Approximate thickness (feet)	Description	Water-bearing hydrogeologic unit	Water-bearing properties
Quaternary	Holocene (Recent)	Undifferentiated soil, surficial alluvium, and loess deposits	0-17	Widespread soil; alluvial deposits of clay, silt, sand, and gravel; isolated wind-deposited silt and clay.	--	Not a known source of water supply because deposits generally are unsaturated; significant as a permeable conduit for ground-water recharge.
	Pleistocene	Undifferentiated unconsolidated deposits	0-460	Wind-deposited silt and clay; terrace deposits of sand and gravel; paleosols; unsorted and unstratified glacial till; alluvial sand, silt, and gravel of Illinoian, and pre-Illinoian age; silt with a basal gravel locally. Underlies most of the study area.	High Plains aquifer and undifferentiated glacial till aquifer	Sand and gravel can yield abundant water to wells if water is present; these deposits are the principal source of ground water in the study area and comprise a major part of the High Plains aquifer; water-bearing units are unconfined, perched, semiconfined, or confined in the study area. Sand lenses in glacial till, not hydraulically connected to the main aquifer, can yield small amounts of water to wells in the eastern part of the study area near Seward.
Tertiary	Pliocene	Undifferentiated unconsolidated silt	0-130	Silt that mainly blankets bedrock.	--	Not a known source of water supply; generally too fine textured to yield water to wells.
	Miocene	Ogallala Formation	0-130	Alluvial sandy and clayey brownish gray and gray silt; partially calcareous and mostly unconsolidated; locally contains lenses of sand and basal gravel; underlies a small area in the western part of the study area.	High Plains aquifer	Generally a minor source of water supply in the study area; may yield sufficient amounts of water to domestic wells; constitutes a small part of the High Plains aquifer in the study area.
Cretaceous	Upper Cretaceous	Niobrara Formation	0-260	Yellow and gray marine chalky shale and chalk; underlying most of the study area.	Niobrara water-bearing units	Generally not a known source of water supply; can yield water to wells where fractured in Fillmore County.
		Carlile Shale	0-230	Gray marine shale; calcareous and fossiliferous in the lower part; underlying most of the study area.	--	Not a known source of water supply.
		Greenhorn Limestone	0-50	Gray fossiliferous limestone interbedded with calcareous shale; underlying most of the study area.	--	Not a known source of water supply.
		Graneros Shale	0-85	Gray shale, calcareous in part; contains some sand and sandy shale; carbonaceous materials present in basal part; underlying most of the study area.	--	Not a known source of water supply.
	Lower Cretaceous	Dakota Group	240-680	Interbedded clay, silty and sandy shale, and sandstone; underlies the entire study area.	Dakota aquifer	Contains moderately to highly mineralized water; sandstone layers comprise the Dakota aquifer and yield water to wells; deep wells in the eastern part of the study area obtain water from this aquifer.

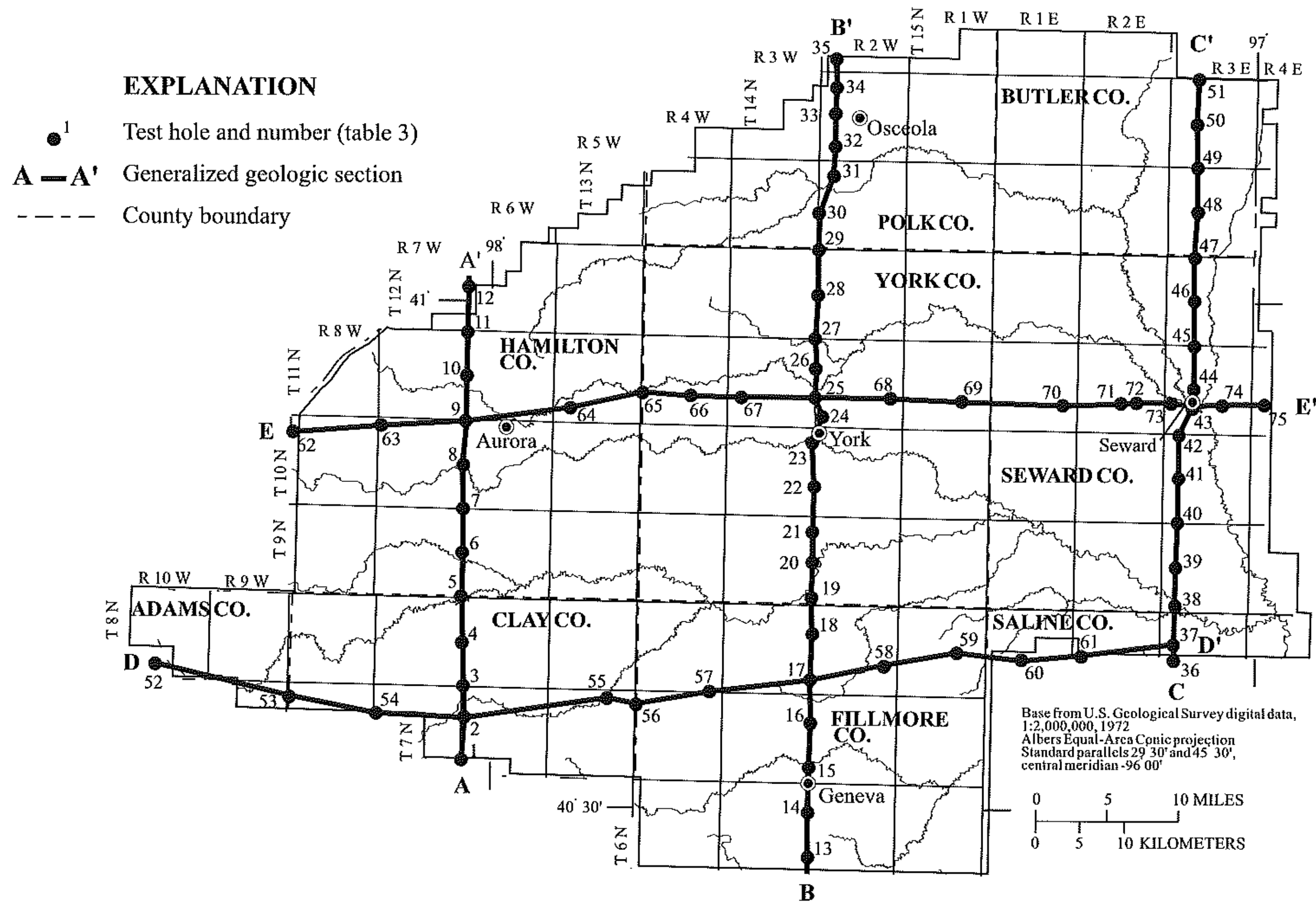

Figure 3. Locations of test holes and generalized geologic sections (figure 4).

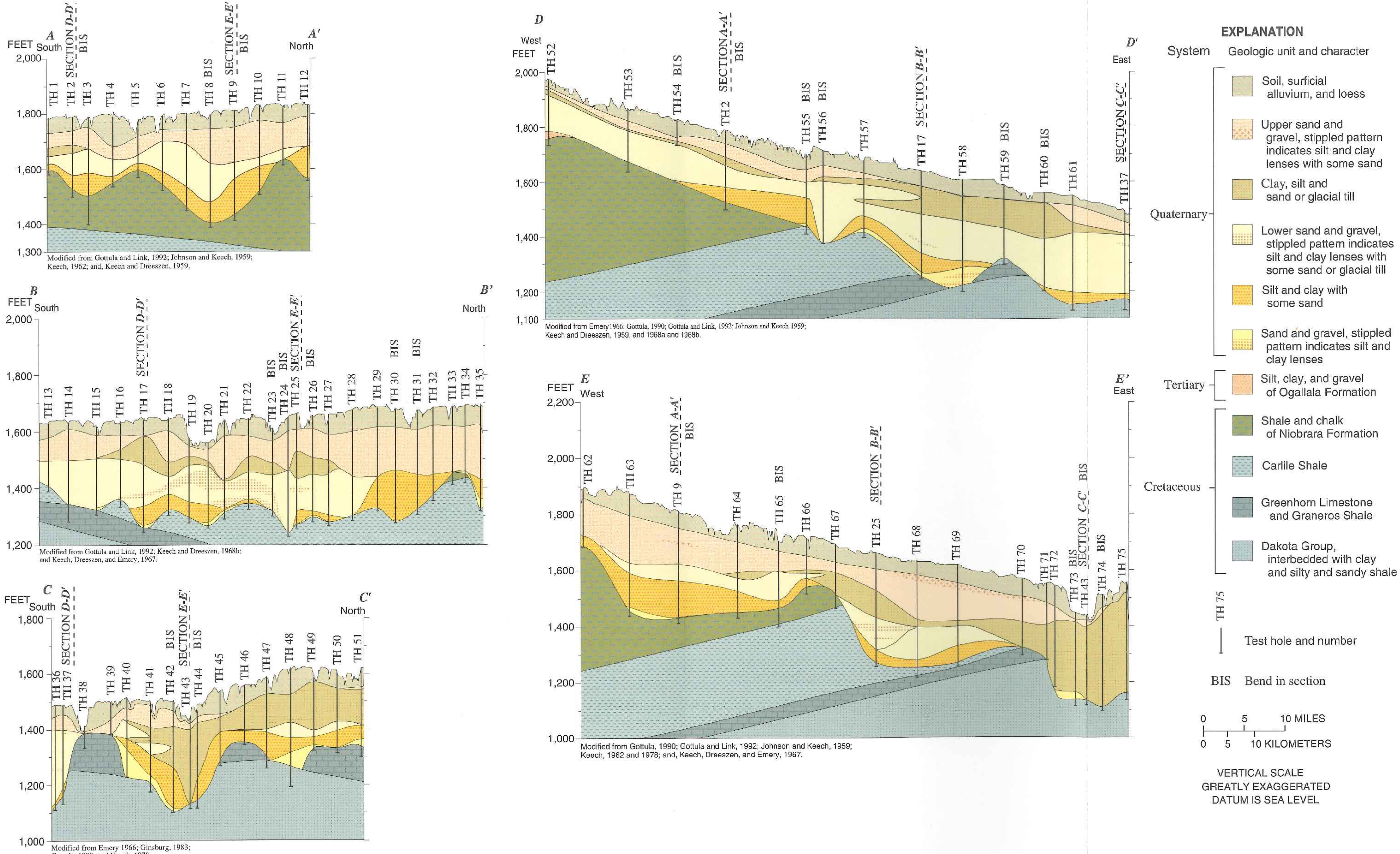

Figure 4. Generalized geologic sections *A-A'* through *E-E'* showing the principal geologic units transected by test holes, Upper Big Blue Natural Resources District, central Nebraska.

Table 3. Test-hole sites used in generalized geologic sections, Upper Big Blue Natural Resources District, central Nebraska

Test-hole site[1] (fig. 3)	Geologic section	Conservation and Survey Division test-hole identification number	Location (fig. 2)
1	A-A'	34-B-49	T07N R07W 25 DD
2	A-A' and D-D'	40-U-41	T07N R06W 18 BB
3	A-A'	35-B-49	T08N R07W 36 DD
4	A-A'	2-40	T08N R07W 24 AA
5	A-A'	36-B-49	T09N R07W 36 DD
6	A-A'	37-B-49	T09N R07W 13 DD
7	A-A'	38-B-49	T10N R07W 36 DD
8	A-A'	39-B-49	T10N R07W 24 AA
9	A-A' and E-E'	40-B-49	T10N R07W 01 AA
10	A-A'	41-B-49	T11N R07W 13 DD
11	A-A'	42-B-49	T11N R07W 01 AA
12	A-A'	43-B-49	T12N R07W 13 DD
13	B-B'	58-A-49	T06N R02W 31 BB
14	B-B'	59-A-49	T06N R03W 13 AA
15	B-B'	64-B-49	T07N R03W 25 DD
16	B-B'	63-B-49	T07N R02W 07 CC
17	B-B' and D-D'	39-U-41	T08N R03W 36 AA
18	B-B'	62-B-49	T08N R02W 07 CC
19	B-B'	61-B-49	T09N R02W 31 BC
20	B-B'	60-B-49	T09N R02W 19 BB
21	B-B'	59-B-49	T09N R03W 12 AA
22	B-B'	58-B-49	T10N R02W 19 CC
23	B-B'	57-B-49	T10N R03W 01 DD
24	B-B'	58-A-57	T11N R02W 31 BA
25	B-B' and E-E'	46-B-46	T11N R03W 24 DD
26	B-B'	56-B-49	T11N R03W 12 DD
27	B-B'	55-B-49	T12N R03W 36 DD
28	B-B'	54-B-49	T12N R02W 19 BB
29	B-B'	53-B-49	T13N R02W 31 CC
30	B-B'	52-B-49	T13N R03W 24 AD
31	B-B'	51-B-49	T13N R02W 06 DD
32	B-B'	17-B-45	T14N R02W 29 CC
33	B-B'	50-B-49	T14N R02W 18 DA
34	B-B'	18-B-45	T14N R02W 05 CC
35	B-B'	49-B-49	T15N R02W 31 AA
36	C-C'	45-A-59	T08N R03E 19 AD
37	C-C' & D-D'	36-U-41	T08N R03E 18 AA
38	C-C'	26-B-48	T09N R03E 31AA
39	C-C'	18-A-48	T09N R03E 18 AA
40	C-C'	17-A-48	T10N R03E 32 CC
41	C-C'	16-A-48	T10N R03E 17 CC
42	C-C'	15-A-48	T10N R03E 05 BB
43	C-C' & E-E'	14-A-48	T11N R03E 29 AA

Table 3. Test-hole sites used in generalized geologic sections, Upper Big Blue Natural Resources District, central Nebraska --Continued

Test-hole site[1] (fig. 3)	Geologic section	Conservation and Survey Division test-hole identification number	Location (fig. 2)
44	C-C'	23-B-48	T11N R03E 16 BB
45	C-C'	22-B-48	T11N R03E 04 BB
46	C-C'	21-B-48	T12N R03E 17 CC
47	C-C'	20-B-48	T12N R03E 05 BB
48	C-C'	19-B-48	T13N R03E 16 CC
49	C-C'	18-B-48	T14N R03E 32 DD
50	C-C'	17-B-48	T14N R03E 20 AA
51	C-C'	16-B-48	T15N R03E 32 DD
52	D-D'	13-B-46	T08N R10W 32 AA
53	D-D'	14-B-46	T07N R09W 12 AA
54	D-D'	3-40	T07N R07W 07 CC
55	D-D'	38-U-41	T07N R05W 03 DA
56	D-D'	4-A-59	T07N R05W 01 DD
57	D-D'	18-B-46	T08N R04W 36 CC
58	D-D'	30-B-45	T08N R02W 25 BB
59	D-D'	29-B-45	T08N R01W 22 AA
60	D-D'	37-U-41	T08N R01E 21 AD
61	D-D'	42-U-41	T08N R02E 19 AB
62	E-E'	112-B-47	T10N R09W 12 AA
63	E-E'	45-B-49	T10N R07W 06 BC
64	E-E'	47-B-49	T11N R05W 29 CC
65	E-E'	40-B-46	T11N R04W 19 CC
66	E-E'	48-B-49	T11N R04W 22 CD
67	E-E'	45-B-46	T11N R03W 30 AA
68	E-E'	47-B-46	T11N R02W 24 CC
69	E-E'	23-B-45	T11N R01W 27 AA
70	E-E'	6-B-44	T11N R01E 26 AA
71	E-E'	2-A-58	T11N R02E 21 DD
72	E-E'	2-B-44	T11N R02E 23 CC
73	E-E'	1-B-44	T11N R03E 19 CD
74	E-E'	13-A-48	T11N R03E 22 DD
75	E-E'	41-U-41	T11N R04E 19 DD

[1]Note: The Conservation and Survey Division of the University of Nebraska county test-hole log books references are: Adams County: Conservation and Survey Division, University of Nebraska, written commun., no date; Butler and Colfax County: Conservation and Survey Division, University of Nebraska, written commun., no date; Clay County: by Burchett and Smith, 1994; Fillmore County: by Conservation and Survey Division and U.S. Geological Survey, 1953; Hamilton County: by Keech, 1960; Polk County: by Burchett and Smith, 1996; Saline County: by Smith, Emery, and Souders, 1964; Seward County: by Burchett and Smith, 1993; and York County: by Smith, 1963.

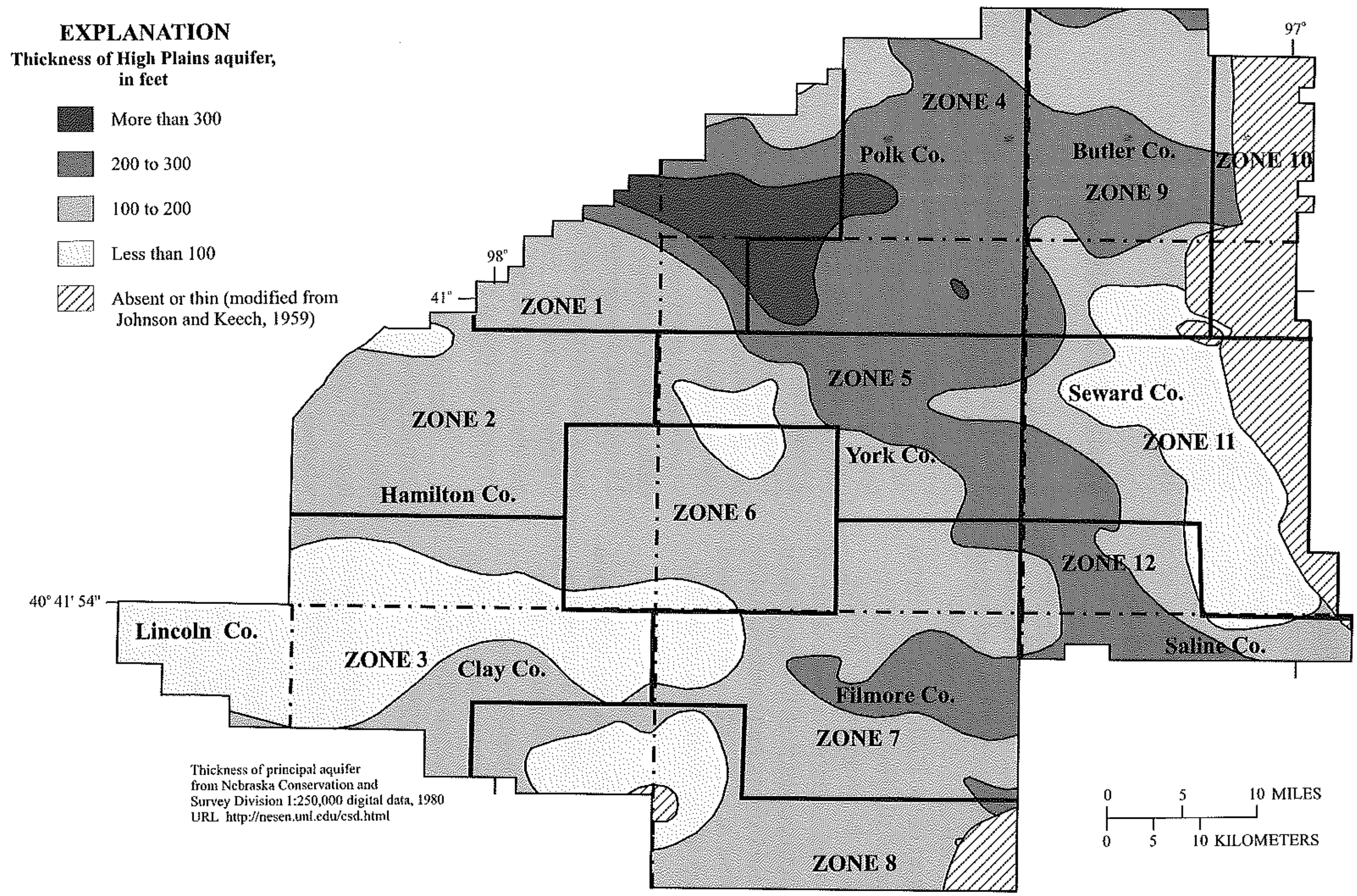

Figure 5. Thickness of High Plains aquifer and management zones, Upper Big Blue Natural Resources District, central Nebraska.

largest thickness (more than 200 ft) can be found in parts of Butler, Fillmore, Hamilton, Polk, Saline, Seward, and York Counties. These thick sequences mainly occur in major paleovalleys in the bedrock surface. The High Plains aquifer is less than 100 ft thick in parts of Adams, Clay, Fillmore, Hamilton, Saline, Seward, and York Counties. The High Plains aquifer is thin or absent in parts of Butler, Clay, Fillmore, and Seward Counties. Here the undifferentiated glacial till aquifer (table 2) is present and consists mainly of glacial till with small lenses of sand and gravel, which yield only small amounts of water.

The shallow and deep parts of the High Plains aquifer generally are unconfined in most of Hamilton County, and parts of York, northern Clay, and Adams Counties. In a part of Seward County, only the shallow unconfined part of the High Plains aquifer is present. The deep part of the High Plains aquifer generally is confined in the southern part of York County, most of Fillmore County, the central part of Clay County, the eastern part of Polk County, Butler County, eastern Seward County, and northern Saline County. Water may flow at land surface to a limited extent along the valley of the West Fork of the Big Blue River (fig. 1).

In some parts of the study area, the infiltration of water to the regional water table is retarded by extensive silt and clay lenses of low permeability, creating perched water-table conditions. For example, perched conditions occur near Rising City in Butler County and in northeastern Fillmore County (fig. 1) (Gottula and Link, 1992).

The sources of water to the High Plains aquifer in the study area include ground water by underflow from areas west of the study area, by deep percolation of water from precipitation and irrigation, and by surface-water recharge when the stream stage is higher than the water table where streams are in hydraulic connection with the ground water. Yields from wells screened in the High Plains aquifer locally can exceed 1,000 gal/min.

Bedrock

The Dakota aquifer is another source of water supply in the study area, although the mineralized character of the water limits its use as a source for potable water supply. The Dakota aquifer (table 2) is used for water supply only in the eastern part of the study area, where the aquifer is relatively shallow and the High Plains aquifer generally is thin or absent (fig. 5). Yields from wells screened in the Dakota aquifer vary from a few gallons to 400 gal/min. These variable yields result from the interbedded character of this hydrogeologic unit (Keech, 1978). The source of ground water is thought to be mainly by under flow.

Water-Table Altitude

The water-table altitude from the spring of 1996 (fig. 6) generally indicates west to east ground-water flow. Water-table contours are inferred in the extreme eastern part of the area, underlain by glacial till, because there are few wells available for water-level measurement. The configuration of the water table generally mirrors the topography. Because of artesian conditions in a part of the area near Beaver Crossing (fig. 1) and perched aquifer conditions locally throughout the study area, the contour lines in figure 6 may reflect these conditions rather than water-table conditions in some areas. The water-table gradient generally ranges from about 4 to 25 ft/mi and averages about 7 ft/mi. The depth to the water table varies from less than 1 ft in stream valleys to more than 200 ft along the divide between the Platte (north of the study area) and Big Blue Rivers near David City (fig. 1).

Throughout the year, the water-table configuration varies considerably depending upon rates of discharge and recharge at any given time. Rates of recharge depend upon climatic conditions, whereas rates of discharge depend upon climatic conditions and water use. Rates of recharge from precipitation are estimated to be 3 to 5 in/yr (Dugan and Zelt, in press). Since predevelopment (1950), the water level has risen 22.6 ft in a well in the central part of Polk County for unknown reasons. Since predevelopment (1950), the water level has declined 31 ft in a well in the northwestern part of Fillmore County and at least 5 ft in a large part of Hamilton, Clay, and Fillmore Counties, and in a small part of south-central York and west central Seward Counties (H.H. Chen, U.S. Geological Survey, written commun., 1998).

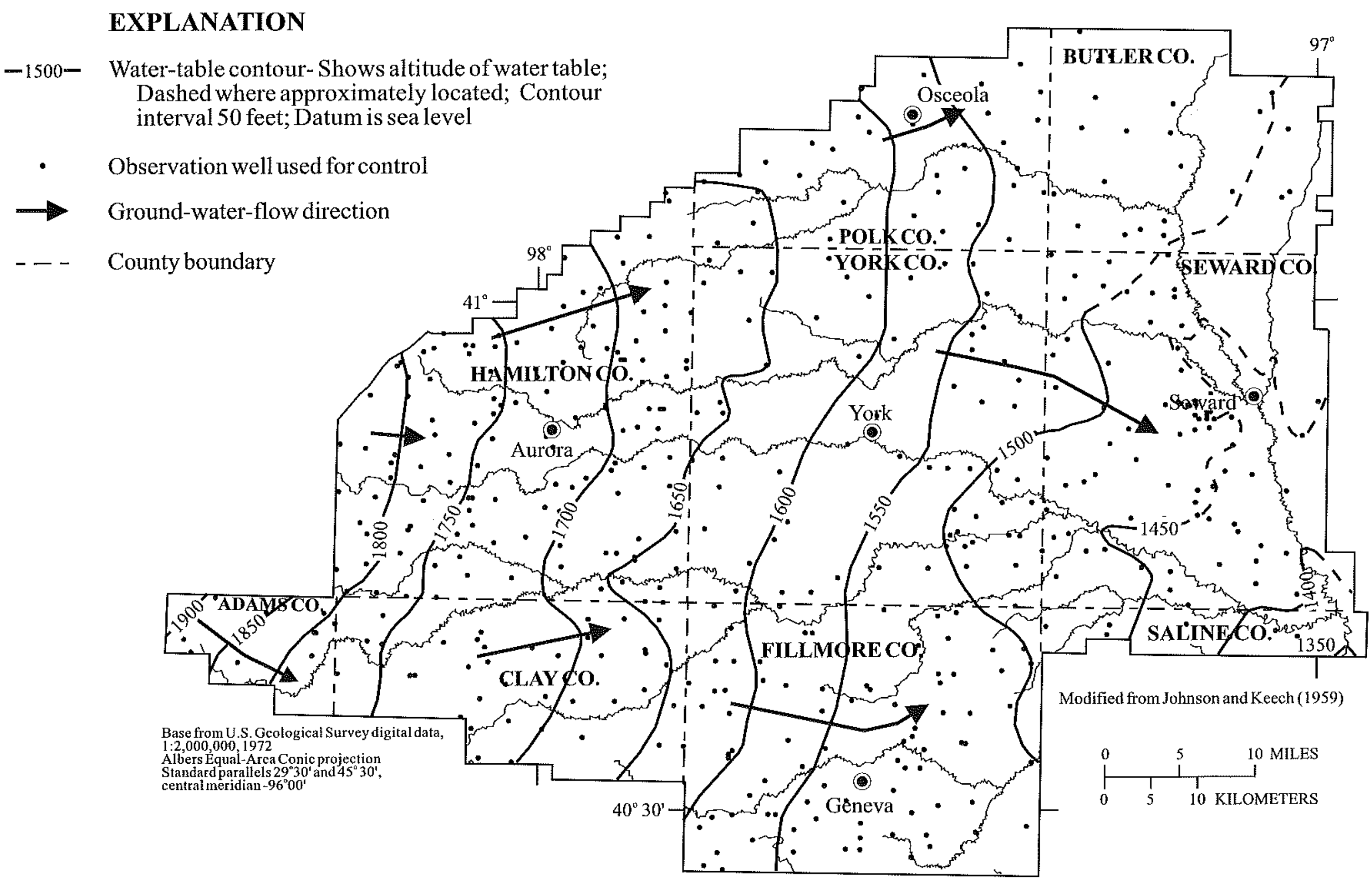

Figure 6. Configuration of water-table altitude, Upper Big Blue Natural Resources District, central Nebraska, spring 1996.

Hydraulic Properties

Hydraulic conductivity is a measure of the ability of an aquifer to transmit water and largely is dependent on the nature of the pore space and, thus, the particle-size distribution of the deposits that constitute the aquifer. In most of the study area, the hydraulic conductivity varies from less than 25 to 100 ft/d (Pettijohn and Chen, 1983b). Estimates of transmissivity are obtained by multiplying the thickness of the aquifer by hydraulic conductivity. The transmissivity of the High Plains aquifer in the study area is estimated to range from about 0 to about 45,000 ft^2/d (Pettijohn and Chen, 1983a, 1983b). Areas with transmissivities less than 7,000 ft^2/d usually cannot provide large well yields (more than 750 gal/min), and areas with transmissivities larger than 14,000 ft^2/d can sustain large well yields (Keech, 1978).

Specific yield is a measure of the ability of the aquifer to yield water by gravity. The specific yield varies from approximately 5 percent in an area near Seward and south of David City to 25 percent in several small areas scattered across the study area (Pettijohn and Chen, 1983b). The specific yield multiplied by the saturated thickness of the aquifer provides an estimate of the volume of water that the aquifer would yield in an area if the aquifer would be drained by gravity. The volume recoverable from a square mile of aquifer in the study area is estimated to vary from 3,200 acre-ft near Seward to 48,000 acre-ft near Rising City.

The water probably moves at widely differing rates among the shallow and deep parts of the High Plains aquifer and within parts of the High Plains aquifer. The hydraulic conductivity of the shallow part of the High Plains aquifer in the Platte River Valley near Grand Island was determined to be about 134 ft/d and, assuming porosity is 28 percent and the gradient was 7 ft/mi, the average ground-water velocity was estimated to be about 0.63 ft/d (Lugn and Wenzel, 1938).

The High Plains aquifer and parts of the Big Blue River and its tributaries (fig. 1) are hydraulically connected (Keech, 1978). The High Plains aquifer and Plum Creek do not appear to be hydraulically connected (fig. 1) in Butler County (Ginsberg, 1983). Also, there is likely little hydraulic interaction between streams and ground water in Seward County, especially between the High Plains aquifer and the Big Blue River.

MONITORING APPROACH

During the first year of the study (1995), a thorough evaluation of soils, land use, geology, and hydrology in the study area was conducted in part through analysis of spatial data layers with a geographic information system. Based on this evaluation, a ground-water monitoring network of about 200 wells was proposed. The network included (1) domestic and registered irrigation, municipal, and industrial wells; and (2) eight newly constructed nested-well sites, each consisting of two or three nested wells, screened at various depths assumed to represent the hydrogeologic conditions in the study area (two nested-well sites with three separate monitoring wells and six nested-well sites with two separate nested wells for a total of 18 wells). Samples collected from the unsaturated zone near the eight nested-well sites completed the monitoring approach.

Ground Water

Domestic and Registered Wells

The domestic and registered wells included in the proposed ground-water-quality monitoring network were selected using a modified, random-spatial approach, from 96 domestic wells and about 11,000 registered wells in the UBBNRD. A list of domestic wells was derived from a survey of rural residents who submit water samples annually to the UBBNRD for water-quality analysis; domestic wells were included in the selection process if the well-construction was known (58 domestic wells). The registered wells included all irrigation, municipal, and industrial wells on file with the Nebraska Department of Water Resources (unpublished data from Nebraska Department of Water Resources, written commun., 1991). The modified random-spatial approach was applied to two groups of wells: (1) domestic and nearby registered wells (within 750 feet), and (2) registered wells that are not near domestic wells (within 750 feet).

The modified, random-spatial approach for selecting domestic and nearby registered wells consisted of assigning a random number (1) to each township and range in which the domestic wells were located, and then (2) to each of the 58 included domestic wells. The townships and ranges with the 58 smallest random numbers were the selected areas for sampling. Within each of the selected townships and ranges, the domestic well with the smallest random number was chosen for sampling. Nearby registered wells of approximately the same depth also were selected for sampling. If, during the first year of sampling, the nitrate concentration in water from the domestic well would be larger than the concentration in the nearby irrigation well, then the domestic well would be dropped from the network because of possible point-source contamination. The registered well would be retained in the network. If the nitrate concentrations in the domestic and nearby registered well were similar, the domestic well would be retained in the network, and an additional registered well screened in the same geologic unit, but not located near the domestic well, was randomly selected for sampling. Using this methodology, 116 domestic and registered wells were selected to be included in the monitoring network.

The modified random-spatial approach also was used to select an additional 96 registered wells that were not near the domestic wells. This approach consisted of (1) arranging the registered wells into eight groups based on well depth, (2) determining a target number of townships and ranges needed to represent adequately the hydrogeologic unit the wells are completed in based on the number of wells in each group; (3) identifying the townships and ranges where the registered wells were located for each of the eight groups; (4) assigning a number randomly to each identified township and range; and (5) assigning a number randomly to each well. The previously determined target number of townships and ranges needed were selected for each group (ranging from 5 to 20). Within each of the selected townships and ranges, the registered well with the smallest random number was selected.

The resulting set of registered wells were screened in the office and in the field to determine their suitability for sampling. The selection criteria included an acceptable drillers' log; complete well-construction information; a continuous well screen that is in only one hydrogeologic unit; an accessible tap that is near the wellhead; and permission from the well owner to sample. If a well did not meet the selection criteria, an alternate registered well in that township and range with a similar depth (within plus or minus 50 ft) was selected and screened. If a well selected as part of the monitoring program has to be replaced in the future because of well abandonment or other issues, a new well fitting the selection criteria mentioned previously should be selected, of similar depth and nearest the well originally selected.

Following these selection procedures, 206 wells were sampled in 1995. These 206 wells were reviewed in early 1996 for inclusion in the proposed ground-water monitoring network, based on their location, local geology, well completion, and proximity of potential point sources of contamination. Wells were omitted if (1) wells completed at similar depth (within about 20 ft) were located within 6 mi of each other; (2) wells were screened in both unconfined and confined parts of the High Plains aquifer; (3) the well construction appeared unsuitable; or (4) the nitrate concentration could be affected by a potential point source nearby. Spatial gaps in data were addressed by selecting additional monitoring sites within these areas.

Based on this review, 163 of the 206 wells sampled in 1995, and 48 new wells, were sampled in 1996. Ten of these wells were resampled in 1997 for quality assurance (QA) and quality control (QC) purposes. A review of all the data was done in 1997. After re-analysis of data for all the wells sampled since 1995, 197 domestic and registered wells were proposed for the ground-water monitoring network in the study area (fig. 7 and table 4). The wells comprising the proposed ground-water monitoring network reflect the ranges of depths of registered wells and are considered representative of the existing well distribution, hydrogeologic conditions, and water-quality conditions in the study area.

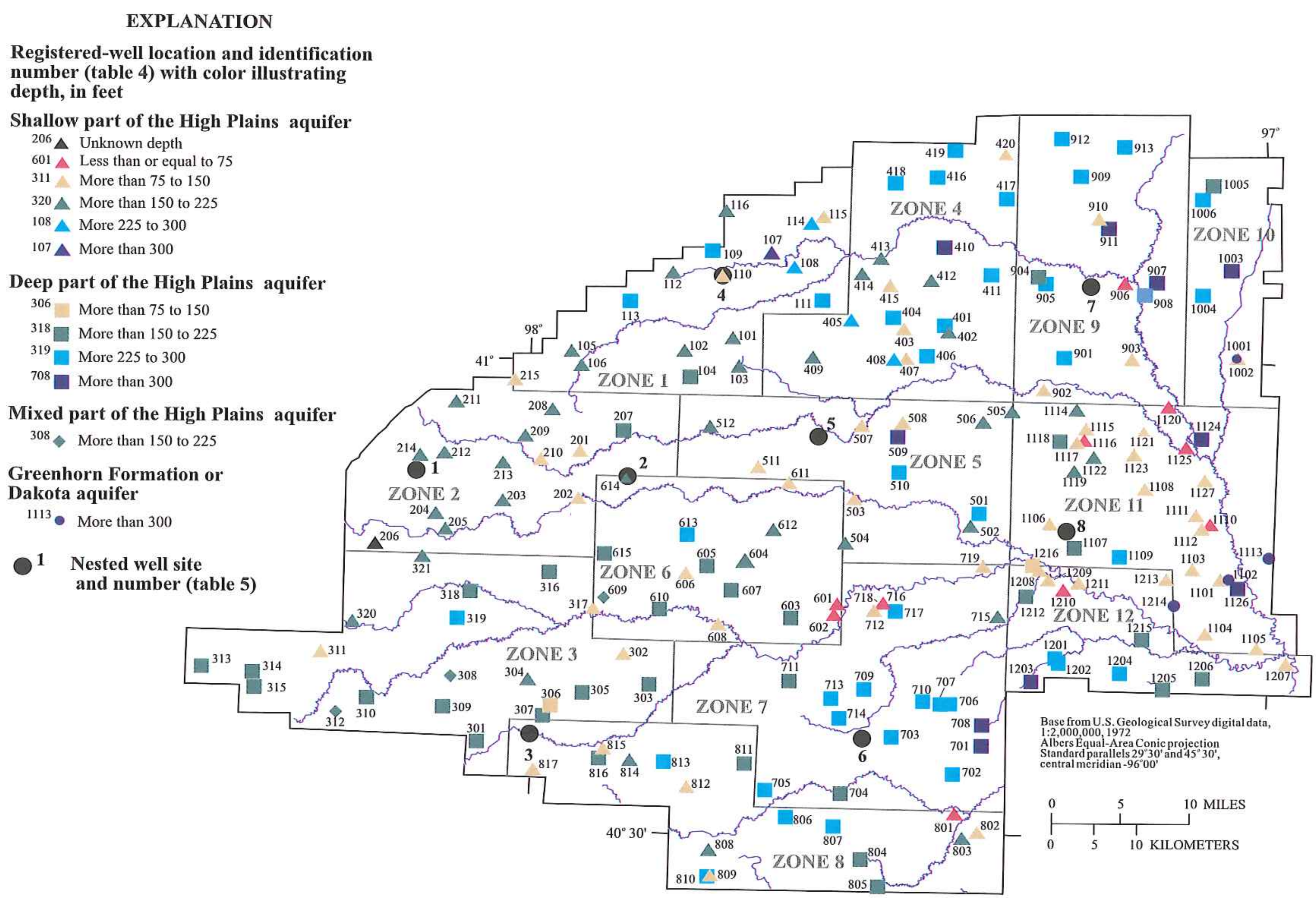

Figure 7. Ground-water-quality monitoring network indicating well depth, aquifer in which wells are completed, and locations of nested wells, Upper Big Blue River Natural Resources District, central Nebraska.

Table 4. Well information for ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska

[ft, feet; bls, below land surface; A, shallow part of High Plains aquifer; B, deep part of High Plains aquifer; M, undifferentiated part of High Plains aquifer; DA, Dakota aquifer or Greenhorn Formation (well 1001); UF, unconfined part of High Plains aquifer; CF, confined part of High Plains aquifer; NA, not applicable; I, registered irrigation well; D. domestic well; C, registered industrial well; P, registered public-water-supply well; --, data not available]

Well identification number (fig. 7)	Water-bearing zone	Hydrogeologic condition	Well type	U.S. Geological Survey station identification number	Well registration number	Latitude and longitude	Location (fig. 2)	Land surface altitude (ft above sea level)	Well depth (bls)	Depth of screen (ft bls)	Bottom of screen (ft bls)
0101	A	UF	I	410117097451901	G-00765	4101170974519	T12NR04W10DDBB	1,732	196	100	196
0102	A	UF	I	410024097491801	G-66189	4100240974918	T12NR04W18CACC	1,748	209	105	209
0103	A	UF	I	405930097444401	G-17488	4059300974444	T12NRW23CCAA	1,730	181	129	181
0104	B	UF	I	405843097484601	G-03497	4058430974846	T12NR04W30DBDD	1,770	221	157	221
0105	A	UF	I	410013097584301	G-71723	4100130975843	T12NR06W14CCCC	1,818	200	120	200
0106	A	UF	D	405915097573401	--	4059150975734	T12NR06W25BBBC	1,790	155	--	--
0107	A	UF	I	410644097421801	G-61947	4106440974218	T13NR03W 7BBDD	1,716	364	107	363
0108	A	UF	I	410551097402301	G-02852	4105510974023	T13NR03W16CBAB	1,700	262	202	262
0109	B	UF	I	410657097471301	G-57880	4106570974713	T13NR04W 9BBDD	1,760	277	205	276
0110	A	UF	D	410513097461801	--	4105130974618	T13NR04W21AADD	1,730	125	--	--
0111	B	UF	I	410346097444001	G-23684	4103400974440	T13NR04W26CDBC	1,720	260	170	258
0112	A	UF	D	410521097502601	--	4105210975026	T13NR05W24BABB	1,756	160	--	--
0113	B	UF	I	410327097535801	G-10894	4103270975358	T13NR05W33BCAA	1,773	230	169	229
0114	A	UF	I	410840097390401	G-19788	4108400973904	T14NR03W25BCAA	1,665	240	176	240
0115	A	UF	I	410906097380401	G-22451	4109060973804	T14NR03W26CCBB	1,745	129	100	124
0116	A	UF	D	410922097460701	--	4109220974607	T14NR04W27BCCD	1,748	175	--	--
0201	A	UF	I	405351097575001	G-17816	4053510975750	T09NR06W23DACC	1,750	134	74	134
0202	A	UF	I	405050097575301	G-04736	4050500975753	T10NR06W11DCAA	1,745	142	74	142
0203	A	UF	D	405034098040901	--	4050340980404	T10NR07W13BBAA	1,821	200	--	--
0204	A	UF	I	404939098093401	G-03230	4049390980934	T10NR07W19ABBA	1,850	174	91	171
0205	A	CF	I	404840098084301	G-24000	4048400980843	T10NR07W29BCAA	1,830	218	140	216
0206	A	UF	I	405036098143201	A-05410	4050360981432	T10NR08W16BA	1,920	--	--	--
0207	B	UF	D	405513097541201	--	4055130975412	T11NR05W17DADD	1,751	190	--	--
0208	A	UF	I	405628098001101	G-59098	4056280980011	T11NR06W 9AACC	1,808	221	130	221
0209	A	UF	I	405445098022201	G-38179	4054450980222	T11NR06W19ADBA	1,822	203	150	203
0210	A	UF	D	405315098010401	--	4053150980104	T11NR06W29DD	1,801	140	--	--
0211	A	UF	I	405648098080701	G-73272	4056480980807	T11NR07W 5DO	1,849	200	125	200
0212	A	UF	I	405332098085901	G-09984	4053320980859	T11NR07W30DA	1,855	183	123	183
0213	A	UF	I	405259098040801	G-26384	4052590980408	T11NR07W36BBDD	1,820	202	138	202
0214	A	UF	I	405320098105801	G-07374	4053200981058	T11NR08W25CO	1,856	195	150	195
0215	A	UF	D	405818098032201	--	4058180980322	T12NR07W36AADD	1,832	145	--	--
0301	B	CF	I	403511098054001	G-56699	4035110980540	T07NR07W10DBDD	1,791	201	136	201
0302	A	UF	I	404059097534801	G-40014	4040590975348	T08NR05W 9BBAA	1,741	136	91	136
0303	B	UF	I	403904097513401	G-02881	4039040975134	T08NR05W23BO	1,720	171	108	171
0304	A	UF	D	403913098013601	--	4039130980136	T08NR06W20BA	1,781	160	--	--
0305	B	UF	I	403827097570501	G-31384	4038270975705	T08NR06W24CD	1,760	215	157	215
0306	B	CF	D	403734097594401	--	4037340975944	T08NR06W28DD	1,771	140	100	140
0307	B	UF	I	403656098001801	G-62766	4036560980018	T08NR06W33CDAA	1,770	201	136	201
0308	M	UF	I	403917098075801	G-14577	4039170980758	T08NR07W20ABAA	1,823	190	130	190
0309	B	CF	I	403721098083101	G-14392	4037210980831	T08NR07W32BD	1,824	184	108	184
0310	B	CF	I	403747098144601	G-25125	4037470981446	T08NR08W29DD	1,872	200	152	200

Table 4. Well information for ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska--Continued

Well identification number (fig. 7)	Water-bearing zone	Hydrogeologic condition	Well type	U.S. Geological Survey station identification number	Well registration number	Latitude and longitude	Location (fig. 2)	Land surface altitude (ft above sea level)	Well depth (bls)	Depth of screen (ft bls)	Bottom of screen (ft bls)
0311	A	UF	I	404038098184301	G-20502	4040380981843	T08NR09W11CAAA	1,894	135	119	135
0312	M	UF	I	403649098171601	G-39604	4036490981716	T08NR09W36CDAA	1,900	201	136	201
0313	B	CF	D	403928098282801	--	4039280982828	T08NR10W17CDBB	1,996	170	--	--
0314	B	CF	I	403912098241501	G-24755	4039120982415	T08NR10W23AACD	1,954	166	102	166
0315	B	CF	D	403814098240401	--	4038140982404	T08NR10W26ADAA	1,940	180	--	--
0316	B	CF	I	404603098000501	G-15814	4046030980005	T09NR06W 9AB	1,785	184	124	184
0317	A	UF	I	404351097562401	G-25075	4043510975624	T09NR06W24DADD	1,721	122	48	122
0318	B	UF	I	404444098073401	G-42583	4044440980734	T09NR07W16CBDD	1,790	215	130	215
0319	B	CF	I	404259098073401	G-24168	4042590980734	T09NR07W28CCAB	1,830	228	152	228
0320	A	UF	I	404535098161401	G-05278	4045350981614	T09NR08W 7DCAA	1,900	167	107	167
0321	A	UF	I	404653098103301	G-22284	4046530981033	T10NR08W 1ABAA	1,877	201	108	201
0401	B	CF	I	410220097275001	G-22979	4102200972750	T12NR01W 5CBBB	1,639	290	209	290
0402	A	UF	D	410156097273001	--	4101560972730	T12NR01W 5CDCC	1,625	172	--	--
0403	A	UF	D	410204097311501	--	4102040973115	T12NR02W 2CCBC	1,646	150	--	--
0404	B	UF	I	410246097320801	G-18610	4102460973208	T12NR02W 3BABB	1,660	251	179	251
0405	A	UF	I	410234097353501	G-04413	4102340973535	T12NR02W 6BDDD	1,688	247	130	247
0406	B	CF	I	410024097291601	G-54205	4100220972916	T12NR02W13DBDD	1,620	245	153	245
0407	A	UF	D	410011097305901	--	4100110973059	T12NR02W14CDCC	1,639	150	--	--
0408	A	UF	I	410008097515801	G-71772	4100080973158	T12NR02W22BABA	1,645	230	120	230
0409	A	UF	I	410010097384101	G-13558	4100100973841	T12NR03W22ABBB	1,695	152	116	152
0410	B	CF	I	410718097280101	G-70844	4107180972801	T13NR01W 6DDBB	1,649	351	208	351
0411	B	CF	I	410536097240601	G-33414	4105360972406	T13NR01W14CACC	1,621	274	195	273
0412	A	UF	I	410512097290101	G-18090	4105120972901	T13NR01W19BBCC	1,655	180	108	180
0413	A	UF	I	410632097331301	G-26855	4106320973313	T13NR02W 9CDBD	1,621	182	120	181
0414	A	UF	I	410532097344501	G-06455	4105320973445	T13NR02W17CCCB	1,667	169	109	169
0415	A	UF	D	410449097322701	--	4104490973227	T13NR02W21DAD	1,662	130	--	--
0416	B	UF	I	411145097284301	G-21311	4111450972843	T14NR01W 7CCAA	1,688	242	194	242
0417	B	CF	I	411027097225801	G-09174	4110270972258	T14NR01W24BBDC	1,620	233	188	233
0418	B	CF	I	411119097321101	G-11375	4111190973211	T14NR02W15BCBA	1,668	246	192	246
0419	B	CF	I	411329097271701	G-33346	4113290972717	T15NR01W32CADD	1,650	250	184	249
0420	A	UF	D	411319097230801	--	4113190972308	T15NR01W36CCDD	1,638	140	--	--
0501	B	CF	I	405023097244201	G-74345	4050230972442	T10NR01W15AACC	1,599	300	200	300
0502	A	UF	I	404936097252101	G-21442	4049360972521	T10NR01W22BB	1,585	165	85	165
0503	A	UF	I	405110097345901	G-40889	4051100973459	T10NR02W 7ADCC	1,589	100	35	100
0504	A	UF	I	404819097354301	G-05619	4048220973538	T10NR02W30CB	1,645	156	110	156
0505	A	UF	I	405409097282401	G-62918	4056580972208	T11NR01W 1DACD	1,604	154	101	153
0506	A	UF	I	405615097242901	G-63219	4056150972429	T11NR01W10DABA	1,620	155	95	155
0507	A	UF	D	405552097343101	--	4055520973431	T11NR02W 8CDCC	1,610	80	--	--
0508	A	UF	D	405606097311001	--	4056060973110	T11NR02W11CBCC	1,641	130	--	--
0509	B	CF	I	405511097313201	G-40396	4055110973132	T11NR02W11CBCC	1,641	313	120	313
0510	B	CF	I	405255097312201	G-18998	4052550973122	T11NR02W35BBDD	1,622	136	76	136
0511	A	UF	I	405305097430001	G-06930	4053050974300	T11NR04W36ACAA	1,703	110	62	110
0512	A	UF	I	405537097470201	G-14953	4055370974702	T11NR04W16BDDD	1,714	181	105	181
0601	A	UF	I	404428097361401	G-16189	4044280973614	T9NR30W24 AABC	1,578	63	32	62
0602	A	UF	I	404347097362701	G-11012	4043470973627	T09NR03W24DDBC	1,573	67	27	67

Table 4. Well information for ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska--Continued

Well identification number (fig. 7)	Water-bearing zone	Hydrogeologic condition	Well type	U.S. Geological Survey station identification number	Well registration number	Latitude and longitude	Location (fig. 2)	Land surface altitude (ft above sea level)	Well depth (bls)	Depth of screen (ft bls)	Bottom of screen (ft bls)
0603	B	CF	I	404331097395901	G-09741	4043310973959	T09NR03W28BADD	1,662	171	107	171
0604	A	UF	I	404706097435101	G-20122	4047060974351	T09NR04W 1BBBB	1,684	180	112	180
0605	B	UF	I	404641097470001	G-69907	4046410974700	T09NR04W 4CABB	1,707	180	112	180
0606	A	UF	D	404613097484501	--	4046130974845	T09NR04W 7ABAA	1,716	140	--	--
0607	B	UF	I	404511097445601	G-09723	4045110974456	T09NR04W14BBCC	1,692	181	109	181
0608	A	UF	I	404301097460001	G-15976	4043010974600	T09NR04W27CCBB	1,615	87	27	87
0609	M	UF	I	404431097553101	G-05682	4044310975531	T09NR05W19AB	1,745	181	113	181
0610	B	UF	I	404353097505101	G-53571	4043530975051	T09NR05W23DDAA	1,695	208	130	208
0611	A	UF	I	405208097402601	G-06929	4052080974026	T10NR03W 5ADAA	1,663	106	56	100
0612	A	UF	I	404906097413501	G-69928	4049060974135	T10NR03W20CCBB	1,680	152	84	152
0613	B	UF	I	404839097484301	G-71128	4048390974843	T10NR04W30ACAA	1,725	230	100	220
0614	A	UF	I	405212097535201	G-04338	4052120975352	T10NR05W 3BA	1,762	153	105	209
0615	B	CF	I	404720097553301	G-35061	4047200975533	T10NR05W31DBDD	1,761	200	132	200
0701	B	CF	I	403536097240701	G-54536	4035360972407	T07NR01W11BBDD	1,582	351	247	351
0702	B	CF	I	403346097262401	G-09422	4033460972624	T07NR01W21BCAD	1,598	290	210	290
0703	B	CF	I	402959097345901	G-55332	4036030973130	T07NR02W3DACC	1,631	299	234	299
0704	B	CF	C	403224097353301	G-73010	4032240973533	T07NR02W30CCDD	1,632	200	180	200
0705	B	CF	I	403233097414301	G-65543	4032310974146	T07NR03W30DCAA	1,640	234	156	234
0706	B	CF	D	403814097264601	--	4038140972646	T08NR01W29AADC	1,608	240	--	--
0707	B	CF	I	403813097273201	G-50497	4038130972732	T08NR01W29B	1,610	299	234	299
0708	B	CF	I	403655097240701	G-47734	4036550972407	T08NR01W35CCAA	1,582	320	255	320
0709	B	CF	I	403904097335001	G-41000	4039040973350	T08NR02W20AACC	1,639	273	208	273
0710	B	CF	I	403822097285901	G-25631	4038220972859	T08NR02W25AAAA	1,615	290	206	290
0711	B	CF	I	403930097395901	G-47662	4039300973959	T08NR03W16DBDD	1,638	185	133	185
0712	B	CF	I	403904097385401	G-65213	4039040973854	T08NR03W22BACC	1,655	236	171	236
0713	B	CF	I	403826097363201	G-65519	4038260973632	T08NR03W25BABA	1,650	260	195	260
0714	B	CF	D	403711097355001	--	4037110973550	T08NR03W36ADAB	1,650	288	--	--
0715	A	UF	I	404352097225801	G-12193	4043520972258	T09NR01W24CACC	1,557	158	110	158
0716	A	UF	I	404438097323201	G-06590	4044350973228	T09NR02W16DD	1,558	50	30	50
0717	B	CF	I	404404097312401	G-33944	4044040973124	T09NR02W22DABA	1,611	300	208	300
0718	A	UF	I	404405097331001	G-64683	4044050973310	T09NR03W23DABA	1,605	136	84	136
0719	A	UF	I	404703097241601	G-24398	4047030972416	T09NR01W 2BB	1,510	94	40	94
0801	A	UF	I	403115097261201	G-04306	4031150972612	T06NR01W 4BABB	1,555	70	16	70
0802	A	UF	D	403005097241801	--	4030050972418	T06NR01W11CBAA	1,585	90	--	--
0803	A	UF	I	402943097253001	G-66403	4029430972530	T06NR01W15BBBB	1,580	162	97	162
0804	B	CF	I	402814097334701	G-27783	4028140973347	T06NR02W20DBDD	1,632	212	140	212
0805	B	CF	I	402616097321901	G-25262	4026160973219	T06NR02W34CCCC	1,610	210	134	210
0806	B	CF	I	403049097400101	G-47406	4030490974001	T06NR03W 4CA	1,648	257	166	257
0807	B	CF	I	403018097360501	G-74408	4030180973605	T06NR03W24CBDD	1,640	260	180	260
0808	A	UF	I	402839097461701	G-02922	4028390974617	T06NR04W21AACB	1,682	221	143	221
0809	A	UF	D	402701097460801	--	4027010974608	T06NR04W33AACA	1,680	145	--	--
0810	B	UF	I	402657097462201	G-50990	4026570974622	T06NR04W33AB	1,674	257	153	257
0811	B	CF	I	403411097433001	--	4034110974330	T07NR04W13CCAB	1,680	214	154	214
0812	A	UF	D	403237097481601	G-09893	4032370974816	T07NR04W30DADD	1,690	130	--	--

Table 4. Well information for ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska--Continued

Well identification number (fig. 7)	Water-bearing zone	Hydrogeologic condition	Well type	U.S. Geological Survey station identification number	Well registration number	Latitude and longitude	Location (fig. 2)	Land surface altitude (ft above sea level)	Well depth (bls)	Depth of screen (ft bls)	Bottom of screen (ft bls)
0813	B	CF	I	403413097501301	G-67711	4034100975013	T07NR05W13DCAA	1,740	260	182	260
0814	A	UF	D	403415097530101	--	4034150975301	T07NR05W16DC	1,755	205	192	205
0815	A	UF	D	403456097551601	G-07849	4034560975516	T07NR05W18AAA	1,745	90	75	90
0816	B	CF	I	403418097553501	G-16027	4034180975535	T07NR05W18DCAD	1,755	205	160	205
0817	A	UF	I	403330098010101	G-24009	4033300980101	T07NR06W20DAA	1,774	150	95	150
0901	B	CF	I	410026097175101	G-43139	4100260971751	T12NR01E15DCAA	1,586	292	193	292
0902	A	UF	I	405822097193201	G-07160	4058220971932	T12NR01E33BBAC	1,520	109	37	109
0903	A	UF	I	410025097121301	G-24711	4100250971213	T12NR02E16DCAC	1,550	127	87	126.5
0904	B	CF	I	410533097193701	G-16177	4105330972007	T13NR01E16CCAC	1,565	179	119	179
0905	B	CF	I	410507097193001	G-26880	4105070971930	T13NR01E21BO	1,604	264	188	264
0906	A	UF	D	410514097125601	--	4105140971256	T13NR02E20AADD	1,502	40	--	--
0907	B	CF	I	410518097101701	G-45443	4105180971017	T13NR02E23BBDA	1,585	304	199	304
0908	B	CF	I	410431097111501	G-72305	4104310971115	T13NR02E27BABA	1,519	244	143	244
0909	B	CF	I	411159097164501	G-27404	4111590971645	T14NR01E11ACCC	1,585	227	139	227
0910	A	UF	D	410918097151201	--	4109180971512	T14NR02E30CBBC	1,598	110	--	--
0911	B	CF	I	410842097142101	G-57715	4108420971421	T14NR02E31ADBB	1,595	303	225	303
0912	B	CF	I	411422097182501	G-04235	4114220971825	T15NR01E27CCBD	1,620	243	171	243
0913	B	CF	I	411355097131001	G-73824	4113550971310	T15NR02E32AACC	1,627	243	194	242
1001	DA	NRA	P	410034097033401	G-72288	4100340970334	T12NR03E14CBAC	1,562	368	328	368
1002	A	UF	P	410035097033001	G-28285	4100350970330	T12NR03E14CBAD	1,563	95	75	95
1003	B	CF	I	410608097040701	G-45124	4106080970407	13NR03E15ABCA	1,610	430	300	430
1004	B	CF	D	410433097062601	--	4104330970626	T13NR03E20DCCD	1,615	285	--	--
1005	B	CF	I	411131097054201	G-73044	4111310970542	T14NR03E 9CDCD	1,591	197	177	197
1006	B	CF	I	411038097063501	G-47019	4110380970635	T14NR03E20ABBB	1,563	240	186	226
1101	A	UF	I	404627097043601	G-33780	4046270970436	T09NR03E3CDBB	1,493	112	80	112
1102	DA	NRA	I	404628097035601	G-70815	4046280970356	T09NR03E 3DDDB	1,470	358	315	355
1103	A	UF	I	404704097065501	G-23634	4047040970655	T09NR03E 5BABA	1,530	140	100	140
1104	A	UF	I	404259097054801	G-29058	4042590970548	T09NR03E28CACC	1,473	98	66	98
1105	A	UF	I	404206097013101	G-51481	4042060970131	T09NR03E36DDAA	1,445	97	32	97
1106	A	UF	I	404949097184801	G-17148	4049490971848	T10NR01E16DDDB	1,565	136	88	136
1107	B	CF	I	404819097164001	G-40262	4048190971640	T10NR01E26DABC	1,552	215	150	215
1108	A	UF	I	405208097105701	G-62771	4052080971057	T10NR02E 3AO	1,525	121	77	121
1109	B	CF	I	404748097125701	G-44369	4047480971257	T10NR02E33BBCC	1,540	290	186	290
1110	A	UF	I	404957097053201	G-64121	4049570970532	T10NR03E16DCBB	1,440	50	30	50
1111	A	UF	I	405031097064101	G-33025	4050310970641	10NR03E17ABCC	1,490	100	44	100
1112	A	UF	D	404940097061201	--	4049400970612	10NR03E20AAAC	1,483	86	68	86
1113	DA	NA	I	404752097003901	G-64099	4047520970039	T10NR04E31AACB	1,471	420	366	420
1114	A	UF	I	405709097164201	G-52744	4057090971642	T11NR01E 2ACDD	1,580	168	104	168
1115	A	UF	D	405556097155601	--	4055560971556	T11NR01E12CDCC	1,573	90	--	--
1116	A	UF	I	405512097160501	G-07142	4055120971605	T11NR01E13CCAA	1,546	61	--	--
1117	A	UF	I	405502097163901	G-46950	4055020971639	T11NR01E14DDCB	1,593	130	70	130
1118	B	CF	I	405507097182301	G-57892	4055070971803	T11NR01E15CCAD	1,584	225	160	225
1119	A	UF	I	405313097164901	G-68540	4053130971649	T11NR01E35ABAB	1,561	166	101	166
1120	A	UF	I	405726097090801	G-26635	4057260970908	T11NR02E 1BACD	1,460	42	22	42
1121	A	UF	I	405551097110801	G-51687	4055510971108	T11NR02E10DCCC	1,500	95	51	95

Table 4. Well information for ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska--Continued

Well identification number (fig. 7)	Water-bearing zone	Hydrogeologic condition	Well type	U.S. Geological Survey station identification number	Well registration number	Latitude and longitude	Location (fig. 2)	Land surface altitude (ft above sea level)	Well depth (bls)	Depth of screen (ft bls)	Bottom of screen (ft bls)
1122	A	UF	I	405408097151301	G-35928	4054080971513	11NR02E19CCCC	1,565	165	105	165
1123	A	UF	I	405420097115401	G-17147	4054200971154	11NR02E21DDBA	1,545	128	92	128
1124	B	CF	I	405524097062101	G-70405	4055240970621	T11NR03E17DCDC	1,446	462	402	462
1125	A	UF	D	405457097075501	--	4054510970737	T11NR03E19BAAB	1,501	70	--	--
1126	B	CF	D	404554097031001	G-85864	4045540970310	T11NR03E23ABBB	1,522	378	368	378
1127	A	UF	D	405246097060101	--	4052460970601	T11NR03E33CBBB	1,481	120	--	--
1201	B	CF	I	404116097180801	G-65052	4041160971808	T08NR01E 3DBBB	1,550	266	201	266
1202	B	CF	I	404058097175001	G-52169	4040580971750	T08NR01E10AABC	1,551	247	182	247
1203	B	CF	I	403945097200701	G-66719	4039450972007	T08NR01E17AC	1,530	312	195	312
1204	B	CF	I	404023097124501	A-04499R	4040230971245	T08NR02E 9CC	1,532	292	227	292
1205	B	UF	I	404930097091401	G-07141	4039240970909	T08NR02E13CO	1503	220	140	220
1206	B	CF	I	404008097055501	G-58947	4040080970555	T08NR03E16BABB	1,478	195	130	195
1207	A	UF	I	404109096590601	G-23552	4041090965906	T08NR04E 4CC	1,383	100	40	100
1208	A	UF	I	404653097193501	G-48066	4046530971935	T09NR01E 4BCAD	1,474	90	24	89
1209	A	UF	D	404616097185001	--	4046160971850	T09NR01E 5DDDD	1,505	120	65	120
1210	A	UF	D	404538097173401	--	4045380971734	T09NR01E10DDDD	1,531	65	20	65
1211	A	UF	I	404606097161801	G-64347	4046060971618	T09NR01E12BCBA	1,450	130	104	130
1212	B	CF	I	404511097204001	G-53766	4045110972040	T09NR01E17BO	1,525	208	143	208
1213	A	UF	I	404630097090501	G-42251	4046300970905	T09NR02E 1CDBA	1,535	147	94	147
1214	DA	NA	I	404445097082401	G-38989	4044450970824	T09NR02E13DAAA	1,546	485	434	485
1215	B	CF	I	404234097105701	G-65685	4042340971057	T09NR02E34AO	1,500	154	128	154
1216	B	CF	I	404708097201101	G-73781	4047080972011	T10NR01E32DCDC	1,465	140	140	100

The number of wells in a management zone, delineated by the UBBNRD, are: 16 in zone 1, 15 in zone 2, 21 in zone 3, 20 in zone 4, 12 in zone 5, 15 in zone 6, 19 in zone 7, 17 in zone 8, 13 in zone 9, 6 in zone 10, 27 in zone 11, and 16 in zone 12 (fig. 7 and table 4). Of the 197 wells, 104 wells are completed in the shallow part (designated A in table 4) of the High Plains aquifer, 86 are completed in the deep part of the High Plains aquifer (B), 3 are completed in both parts of this aquifer (M), 1 is completed in the Greenhorn Formation (well 1001) (DA), and 3 are completed in the Dakota aquifer (DA) (fig. 7 and table 4). Of the 193 wells completed in the High Plains aquifer, 123 are screened in an unconfined part of the High Plains aquifer and 70 are screened in a confined part of the High Plains aquifer (table 4). The wells exceeding a depth of 300 ft generally are in the eastern part of the study area (fig. 1, fig. 7). Wells less than 150 ft deep commonly are in the central and eastern parts of the study area (fig. 1, fig. 7). Wells completed in the shallow part of the High Plains aquifer commonly are in Hamilton, Polk, Seward, and York Counties. Wells completed in the deep part of the High Plains aquifer generally are in Adams, Butler, Clay, Fillmore, Polk, York, and Saline Counties. This deep part of the High Plains aquifer generally is unconfined in parts of Clay, Polk, and York Counties. The wells completed in confined parts of the High Plains aquifer generally are in Butler, Fillmore, and Saline Counties (fig. 8 shown later in report).

Nested Wells

Eight nested-well sites representative of the hydrogeologic conditions in the study area were selected for the installation of 18 nested wells in 1995 (table 5) (fig. 7). Nested-well sites and completion depths were selected based on: the management zones established by the UBBNRD (eight sites for the 12 zones) (Upper Big Blue Natural Resources District, 1994); the presence of irrigated cropland at the site with known amounts of chemical fertilizer and pesticide use; the availability of detailed geologic descriptions of test holes preferrably within 1 mi of the selected sites; the suitability of the location for well construction; and the permission of the landowner(s). Well depths of the nested wells vary from 55 to 250 ft, screen lengths in each well vary from 5 to 10 ft, and screen slot sizes vary from 0.100 to 0.025 in. and are dependent upon the hydrogeologic conditions at the site.

Unsaturated Zone

Near each nested well, unsaturated-zone samples of unconsolidated sediments were collected from cores that varied in depth from 5 to 90 ft and were analyzed for nitrate (table 6). Near each nested-well site, one unsaturated-zone-core subsite was selected on irrigated cropland. In addition, samples were collected from duplicate cores at nested-well sites 2 and 3. Additional unsaturated-zone core subsites were selected, based on landscape position or land use, near nested-well sites 3, 4, 6, and 7, to evaluate whether nitrate concentrations in the unsaturated zone vary with landscape position (upland or bottomland) and land use (table 6). Samples varied in depth from 0.25 to 90 feet.

METHODS

This section presents an overview of the sample-collection procedures of ground-water and sediment samples, laboratory procedures, data-analysis procedures, and the quality-assurance and quality-control measures implemented during the study.

Sample-Collection Procedures

Ground-Water Samples

In 1995, water samples were collected from 206 domestic and registered irrigation, municipal, and industrial wells. In 1996, water samples were collected from 211 domestic and registered irrigation, municipal, and industrial wells. In 1997, 10 domestic and registered wells were resampled. Samples from 18 nested wells at 8 nested-well sites were collected monthly or bimonthly from November 1995 through May 1997.

Table 5. Locations and descriptions of nested wells, Upper Big Blue Natural Resources District, central Nebraska

[ft, foot; bls, below land surface; A, shallow part of the High Plains aquifer; B, deep part of the High Plains aquifer; UF, unconfined part of the High Plains aquifer; CF, confined part of the High Plains aquifer]

Well-nest site number (fig. 7)	Nested-well identification number	Unique well-identification number representing latitude, longitude, and two-digit sequence number	Well registration number	Location (fig. 2)	Estimated altitude (ft bls)	Well depth (ft)	Depth of screened interval (ft bls)	High Plains aquifer part	Hydrogeologic condition of water-bearing strata sampled
1	1A	405220098111201	G-086355	T10N R08W 01 BBBA	1,860	95	90-95	A	UF
1	1B	405220098111202	G-086356	T10N R08W 01 BBBA	1,860	205	200-205	B	CF
2	2A	405220097535201	G-086357	T10N R05W 04 BBAA	1,767	107	102-107	A	UF
2	2B	405220097535202	G-086358	T10N R05W 04B BAA	1,767	195	190-195	B	UF
3	3A	403549098012501	G-086359	T07N R06W 08 ABBB	1,750	100	95-100	A	UF
3	3B	403549098012502	G-086360	T07N R06W 08 ABBB	1,750	165	160-165	B	UF
4	4A	410515097461401	G-086361	T13N R04W 21 AADA	1,720	95	90-95	A	UF
4	4B	410515097461402	G-086362	T13N R04W 21 AADA	1,720	125	120-125	B	UF
5	5A	405509097380901	G-086363	T11N R03W 15 DDDA	1,650	92	82-92	A	UF
5	5B	405509097380903	G-086364	T11N R03W 15 DDDA	1,650	233	223-233	B	CF
6	6A	403603097340301	G-086365	T07N R02W 05 DBCD	1,669	150	140-150	B	CF
6	6B	403603097340302	G-086366	T07N R02W 05 DBCD	1,669	247	240-247	B	CF
7	7A	410459097155601	G-086367	T13N R01E 24 CAAB	1,547	55	45-55	A	UF
7	7B	410459097155602	G-086368	T13N R01E 24 CAAB	1,547	112	102-112	B	CF
7	7C	410459097155603	G-086369	T13N R01E 24 CAAB	1,547	250	243-250	B	CF
8	8A	404928097173201	G-086370	T10N R01E 22 ADAD	1,560	100	90-100	A	UF
8	8B	404928097173202	G-086371	T10N R01E 22 ADAD	1,560	130	120-130	A	UF
8	8C	404928097173203	G-086372	T10N R01E 22 ADAD	1,560	230	225-230	B	CF

Ground-water samples were collected from domestic, registered, and monitoring wells by USGS and UBBNRD personnel. On site, the well integrity was evaluated, and potential point sources of contamination, such as septic tanks, feedlots, municipal dumps, and industry near the sampled wells, and prevalent land use within a 1-mi radius of the well, were noted on the field sheet. The land-surface altitude was estimated from USGS 7.5-minute topographic maps (scale 1:24,000) with accuracy of about 5 ft. The location of each well was determined with a global positioning system. Generally, the well locations were determined with an accuracy of less than 25 ft to as much as 50 ft.

Water was collected from each well as close to the well head as possible. If a spigot was not present, spigots were installed when possible. Field measurements for specific conductance, pH, water temperature, and dissolved oxygen (when a sample was not collected from a gated pipe) were made at 5minute intervals with a flow-through chamber. Water samples were collected after the field measurements stabilized, typically after 15 to 25 minutes. The field measurements were considered stable on the basis of three tolerances: specific conductance remained within 5 percent; pH remained within 0.1 standard unit; and water temperature remained within 0.2 °C (degrees Celsius). These procedures were assumed to be sufficient for collecting water samples representative of water-bearing units surrounding the well screen.

At each sample site, water samples collected to be analyzed for dissolved nitrate and nitrite as nitrogen—referred to as such in the tables, but referred to as dissolved nitrate in the remainder of the text and figures— and major ions were filtered immediately through a 0.45-micrometer membrane

Table 6. Locations and descriptions of unsaturated-zone sampling subsites, Upper Big Blue Natural Resources District, central Nebraska

[DH denotes unsaturated-zone location, the subsite number is the nested-well site number near which the site is located, and X, Y, or Z differentiates between subsites]

Local subsite identification number	Unique sample location number representing latitude and longitude	Location (fig. 2)	Nested-well site number (fig. 7)	Physiographic and land-use characteristics	Nitrogen applied (pounds per acre)	
					1995	1996
DH1	4052180981108	T10N R08W 01	1	Sprinkler-irrigated cropland, bottomland, minimum tillage, continuous corn	165	165
DH2X	4052200975353	T10N R05W 04	2	Gravity-irrigated cropland, upland, ridge till, corn (2 years) and bean (1 year) rotation	160	160
DH2Y	4052190975353	T10N R05W 04	2	Gravity-irrigated cropland, upland, ridge till, corn (2 years) and bean (1 year) rotation	160	160
DH3X	4035510980135	T7N R06W 08	3	Sprinkler irrigated cropland, bottomland, continuous corn	180	180
DH3Y	4035560980135	T7N R06W 08	3	Sprinkler-irrigated cropland, upland, continuous corn	180	180
DH4X	4105100974616	T13N R04W 21	4	Nonirrigated cropland, upland, conventional tillage, continuous corn	120	120
DH4Y	4105140974624	T13N R04W 21	4	Nonirrigated pasture land, bottomland, horse track	0	0
DH4Z	4105280974625	T13N R04W 21	4	Gravity-irrigated cropland, bottomland, conventional tillage, corn (2 years) and bean (1 year) rotation	190	190
DH5	4055010973818	T11N R03W 15	5	Gravity-irrigated cropland, upland, ridge till, continuous corn,	190	190
DH6X	4036030973402	T07N R02W 5	6	Pasture land, upland	0	0
DH6Y	4035490973433	T07N R02W 5	6	Gravity irrigated cropland, upland, conventional tillage, continuous corn	180	180
DH7X	4105000971555	T10N R03E 24	7	Gravity-irrigated cropland, bottomland, minimum tillage, corn (2 years) and bean (1 year) rotation	160	0
DH7Y	4104580971602	T10N R03E 24	7	Nonirrigated cropland, bottomland, minimum tillage, sorghum	120	120
DH8	4049330971729	T10N R01E 22	8	Sprinkler irrigated cropland, upland, ridge till, corn and soybean rotation	0	180

filter. Samples collected for analysis of dissolved nitrate were chilled to 4 °C immediately after sample collection, and this temperature was maintained during transport to the laboratory. The samples collected for analysis of major ions were preserved in accordance with methods described by Pritt and Jones (1989). Water samples for tritium analysis were collected in a 1-L (liter) plastic bottle, and were not filtered, chilled, or preserved.

Unsaturated-Zone Samples

Two-hundred and fifty sediment samples were collected from 1995 through 1997 and analyzed for nitrate content. In November and December 1995, cores were collected to a depth equal to the water table (or perched water table at site 3), of which the total depth varied from 15 to 90 ft. The cores were collected with a split-spoon sampler by a contractor with oversight from USGS and UBBNRD personnel. From December 1996 through January 1997 and in March 1997, samples were collected with a probe by UBBNRD personnel with oversight by USGS personnel. In general, samples were collected every 5 ft or at each lithologic change to a depth of 20 ft. At greater depths up to 31 ft, samples were collected about every 10 ft, or when a lithologic change warranted another sample. Sediment samples were kept below 4 °C to limit microbial degradation and chemical reactions.

Laboratory Procedures

Standard analytical procedures were used for laboratory analyses. Water samples to be analyzed for dissolved nitrate and alkalinity, residue on evaporation at 180 °C, and major ions were sent to the USGS National Water-Quality Laboratory (NWQL) in Arvada, Colorado, and analyzed in accordance with standard procedures described by Fishman and Friedman (1989). The analyses for tritium were done using an electrolytic enrichment gas-counting method at the University of Miami in Florida.

Unsaturated-zone sediment samples were analyzed for total nitrate by the Soil Testing Laboratory of the University of Nebraska-Lincoln (Page and others, 1982, p. 679-682). Other nitrogen species were not analyzed because it was assumed that concentrations of other nitrogen species would be negligible.

Data-Analysis Procedures

Statistical analyses were performed on the data to determine the distributions of variables, to identify relations between variables, and to test the significance of these relations. Analyses of data from the monitoring network and nested wells included the use of general statistical analyses, boxplots, the Spearman rank correlation coefficient, the Shapiro-Wilk test, the Kruskal-Wallis or Wilcoxon rank-sum test, and, when more than two groupings existed, Tukey's multiple comparison test (Helsel and Hirsch, 1992; Verstraeten and Ellis, 1995). A confidence level of 95 percent generally was used for interpretation. This means that the interpretation can be wrong in 5 of 100 cases.

The Shapiro-Wilk test was used to check for normality of the data sets and showed that field measurements and nitrate concentrations of water samples from the monitoring network are not normally distributed. Therefore, nonparametric statistical analyses that are not sensitive to outlying values were used for statistical interpretation. Either the Kruskal-Wallis (multiple groups) or Wilcoxon rank-sum (two groups) test was used to determine whether the median value of a constituent was statistically different among or between groups. Tukey's test was used to perform multiple comparisons to find which groups had statistically differing medians. The data were grouped to test for differences among and within groups according to: (1) aquifer; (2) hydrogeologic condition; and (3) management zone.

Quality Control and Quality Assurance

The chance of unrecognized contamination of the water-quality samples, including from bottles and preservatives, was reduced by quality control (QC) measures both in the field and in the laboratory. During sampling of the monitoring network, 29 duplicate water samples and 31 equipment blanks were collected. One duplicate and one equipment-blank sample were collected from well 8A (at nested-well site 8) 10 of the 13 times the nested wells were sampled. At one unsaturated-zone sample collection subsite, duplicate samples were collected from a nearby site (less than 50 ft) with the same land and chemical use and on the same landscape position.

At the NWQL, the QA program includes participation in the USGS and U.S. Environmental Protection Agency (USEPA) interlaboratory evaluations and submission of blind standard reference water samples to the USGS laboratory sample stream (Fishman and Friedman, 1989; Jones, 1987). In addition, cation-anion balances were calculated for each major-ion analysis. The cation-anion balances were within 10 percent for all samples analyzed for this study.

Nitrate concentrations in equipment blanks from the monitoring network varied from less than the method reporting level of 0.05 to 0.16 mg/L (milligrams per liter) with concentrations of 17 of the 29 equipment blanks below the method reporting level. Dissolved nitrate concentrations in equipment blanks from well 8A (well-numbering system is discussed under the Monitoring Approach Section) varied from less than the method reporting level of 0.05 to 0.07 mg/L. Seven of the 15 equipment blanks from well 8A had nitrate concentrations less than the method reporting level. The median nitrate concentration in all of the equipment blanks was 0.05 mg/L, with 75 percent of the samples having concentrations less than 0.07 mg/L. Concentrations of nitrate in duplicate samples collected from the monitoring network and well nests generally were within 10 percent of the nitrate concentrations in the environmental sample. The maximum difference in environmental and duplicate sample nitrate concentrations in the monitoring network was 0.6 mg/L. The Wilcoxon rank-sum test showed no significant differences in nitrate concentrations between the environmental and duplicate samples from the monitoring network (the two-sided p-value is 0.88) and those from the well nests (the two-sided p-value is 0.37). A p-value is the probability of obtaining a test statistic equal to or more extreme than the value computed from the same data when the medians of the two populations being tested are the same. Using a 95-percent confidence interval, p-values of 0.05 or smaller indicate that the medians of the populations being considered are significantly different. The smaller the p-value, the greater is the confidence in that difference.

In addition, split samples from the seven water samples collected in 1997 were sent to the NWQL and the Grand Island/Hall County Department of Health Laboratory in Grand Island, Nebraska, the laboratory which normally analyzes water samples for nitrates for the UBBNRD (table 7). The Wilcoxon rank-sum test shows that the concentrations of nitrate did not vary significantly between split samples (the two-sided p-value is 0.96).

Table 7. Results of split-sample analysis by the USGS National Water Quality Laboratory (sample 1) and the Grand Island Hall County Department of Health Laboratory (sample 2)

[Data provided by R.D. DeBuhr, Upper Big Blue Natural Resources District, written commun., 1998]

Well identification number (fig. 7)	Nitrate concentration (milligrams per liter)	
	Sample 1	Sample 2
0321	6.2	5.7
0706	.16	.30
0717	6.8	6.7
0809	10	9.7
0902	.31	.70
1205	15	16
1212	.75	1.2

Nitrate concentrations varied widely from 1995 to 1996 in water samples from some wells of the proposed ground-water-quality monitoring network. Water samples from 13 of the 417 wells that were sampled in both 1995 and 1996 had large variations in nitrate concentrations (data are flagged in the list of results in table 8). These wells were scheduled for resampling in 1997. Water samples from only nine of these wells could be collected because of weather and other logistical reasons. An additional well containing water with unexplainable large nitrate concentrations in 1996 was resampled in 1997. The Wilcoxon rank-sum test performed on the samples collected in 1995, 1996, and 1997 shows no difference in median nitrate concentrations among the samples collected in 1995 and 1997 (the two-sided p-value is 0.59). Significant differences existed between the samples collected in 1995 and those collected in 1996 (the two-sided P-value is 0.03).

The reason for the wide variability in results is unknown. Field contamination was omitted as a potential source of variability, because the variability of nitrate concentrations exceeded the highest detection of nitrate contained in the blank samples. Laboratory recording error was explored and samples were re-analyzed when possible. No analytical errors of more than 1 mg/L were identified. Therefore, the wells showing large variability in nitrate concentrations were not omitted from the sampling program because of the large variability alone. The Wilcoxon rank-sum test on the duplicate samples collected from the unsaturated zone of two nearby subsites with similar land and chemical use showed that there was no significant difference in the total nitrate concentrations between environmental and duplicate samples (the two-sided p-value is 0.93).

TRENDS IN NITRATE CONCENTRATIONS, FIELD MEASUREMENTS, AND MAJOR-ION AND TRITIUM CONCENTRATIONS IN GROUND WATER

This section addresses the ground-water quality in the UBBNRD with the focus on spatial and temporal distribution of nitrate concentrations in ground water. The water-quality data collected for this study are included in table 8 at the back of this report and are stored in the USGS's National Water Information System (NWIS) database.

Spatial Trends in Nitrate Concentrations and Field Measurements in Ground Water

Ground-Water Monitoring Network

Water samples were collected from 206 wells in 1995, 211 wells in 1996, and 10 wells in 1997. Only wells retained in the ground-water-quality monitoring network are shown on figure 8, 9, 10, and 11. A statistical summary of the 1995 (selected data) and 1996 analytical data collected from wells retained as part of the ground-water monitoring network by (1) aquifer, (2) hydrogeologic condition, and (3) management zone is listed in table 9 (at back of report) and boxplots are illustrated in figures 9 through 11. If no water samples were collected from a well of the ground-water-quality monitoring network in 1996, the data collected in 1995 were used in the statistical analyses. Well 1001, completed in the Greenhorn Formation, was considered to be completed in the Dakota aquifer for statistical purposes and interpretation.

Nitrate concentrations in water samples collected from the ground-water-quality monitoring network varied from 0.06 to 27 mg/L, with a median concentration of 4.6 mg/L (table 9). In the shallow part of the High Plains aquifer, the concentrations varied from 0.09 to 27 mg/L, with a median concentration of 6.3 mg/L (fig. 9 and table 9). In the deep part of the High Plains aquifer, the concentrations were generally less than in the shallow part. Nitrate concentrations varied from 0.06 to 21 mg/L with a median concentration of 3.4 mg/L. In the Dakota aquifer, the concentrations varied between 0.08 and 0.76 mg/L, with a median concentration of 0.11 mg/L.

Of the 197 water samples collected in 1995 and 1996, 41 water samples (21 percent), exceeded the USEPA Maximum Contaminant Level (MCL) for drinking water of 10 mg/L for nitrate as nitrogen (U.S. Environmental Protection Agency, 1996). Thirty-one of these water samples were obtained from wells completed in the unconfined part of the High Plains aquifer.

Nitrate concentrations of water samples collected from unconfined (median was 6.2 mg/L) and confined conditions (median was 2.9 mg/L) (fig. 10 and table 9) were similar to those classified as water samples collected from shallow and deep parts of the High Plains aquifer, respectively. These results suggest that, assuming that the water samples collected from the ground-water-quality monitoring network are representative of the conditions in the High Plains aquifer in the study area: (1) more than 50 percent of the shallow or unconfined part of the High Plains aquifer in the study area may contain ground water with nitrate concentrations that exceed 6 mg/L; and, (2) more than 25 percent of the shallow part of the High Plains aquifer in the study area may contain ground water with nitrate concentrations that exceed the action level (Phase II trigger) of 9 mg/L established by the UBBNRD's Special Protection Area action plan (Upper Big Blue Natural Resources District, 1994). In contrast, nitrate concentrations in more than 75 percent of the deep or confined part of the High Plains aquifer appear to be less than 6 mg/L; nitrate concentrations in more than 50 percent of these parts of the High Plains aquifer appear to be less than 3.5 mg/L.

EXPLANATION

Registered well location and identification number (table 4) with color illustrating nitrate concentration, as nitrogen, in milligrams per liter

Unconfined part of the High Plains aquifer

- ▲ Less than 0.05 to 4.0
- ▲ More than 4.0 to 9.0
- ▲ More than 9.0 to 12
- ▲ More than 12

Confined part of the High Plains aquifer, Greenhorn Formation or Dakota aquifer

- ■ Less than 0.05 to 4.0
- ■ More than 4.0 to 9.0
- ■ More than 9.0 to 12
- ■ More than 12

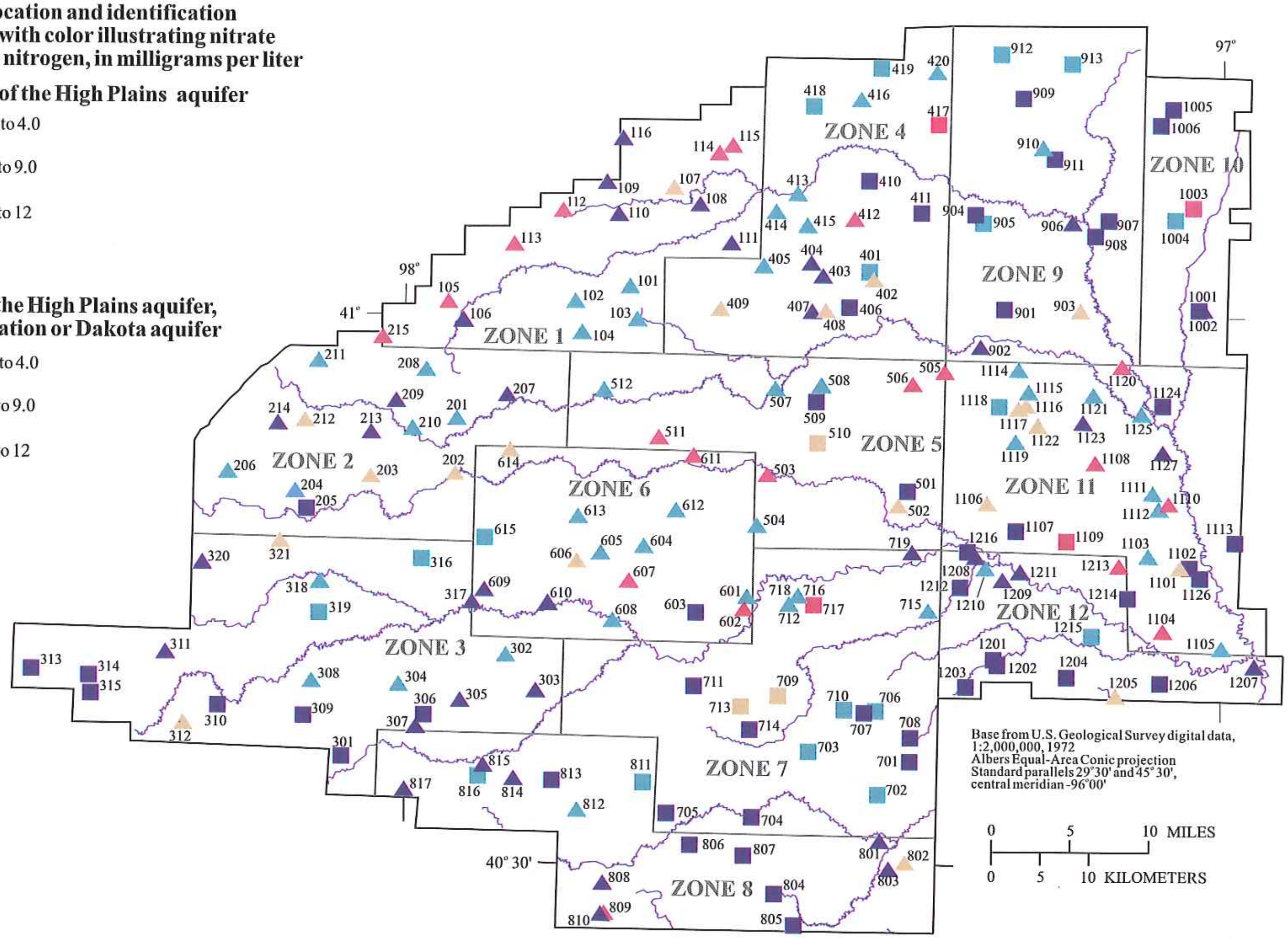

Figure 8. Nitrate concentrations and hydrogeologic conditions of the ground-water-quality monitoring network, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996.

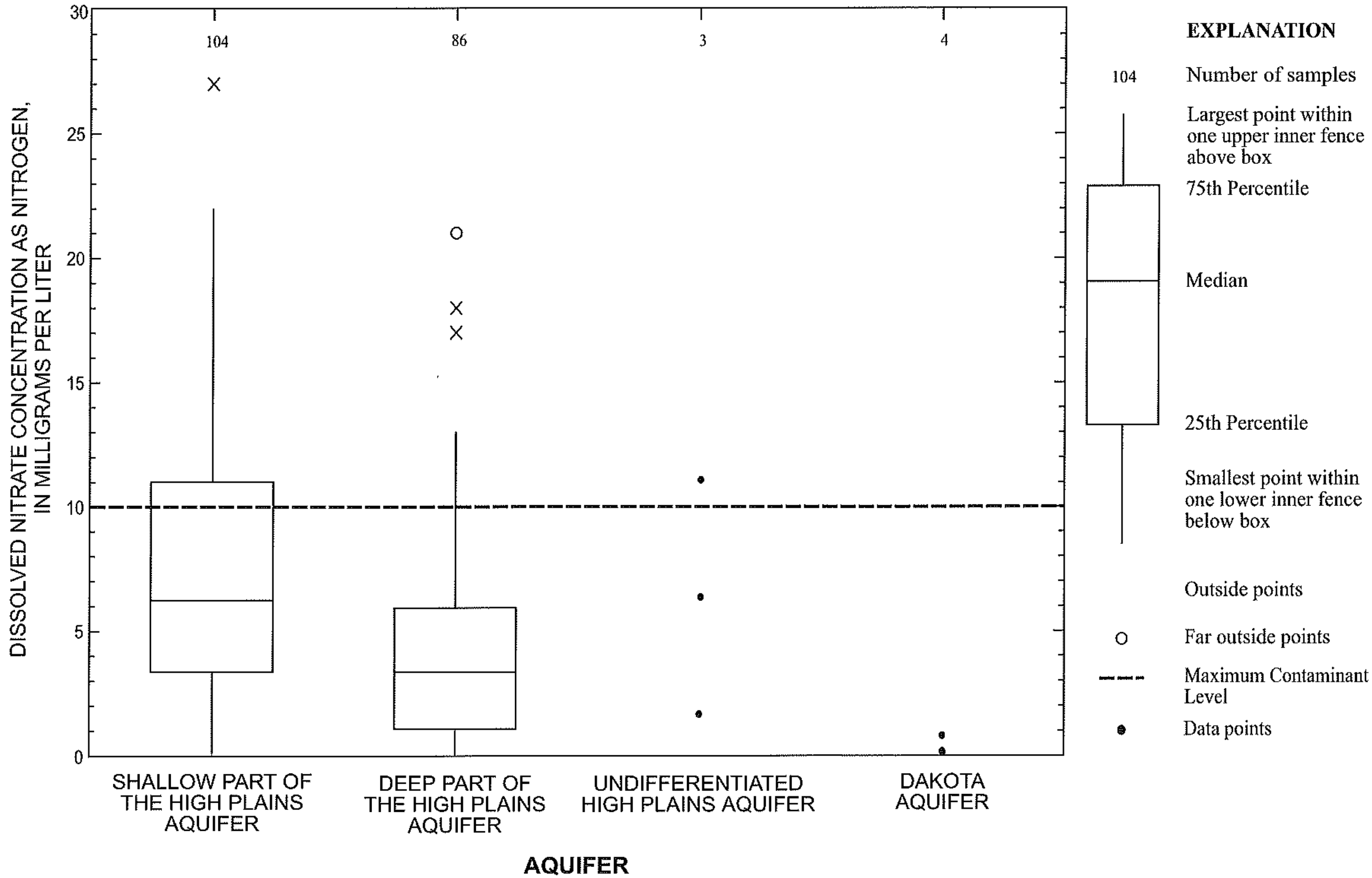

Figure 9. Distribution of nitrate concentrations by aquifer in the ground-water-quality monitoring network, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996.

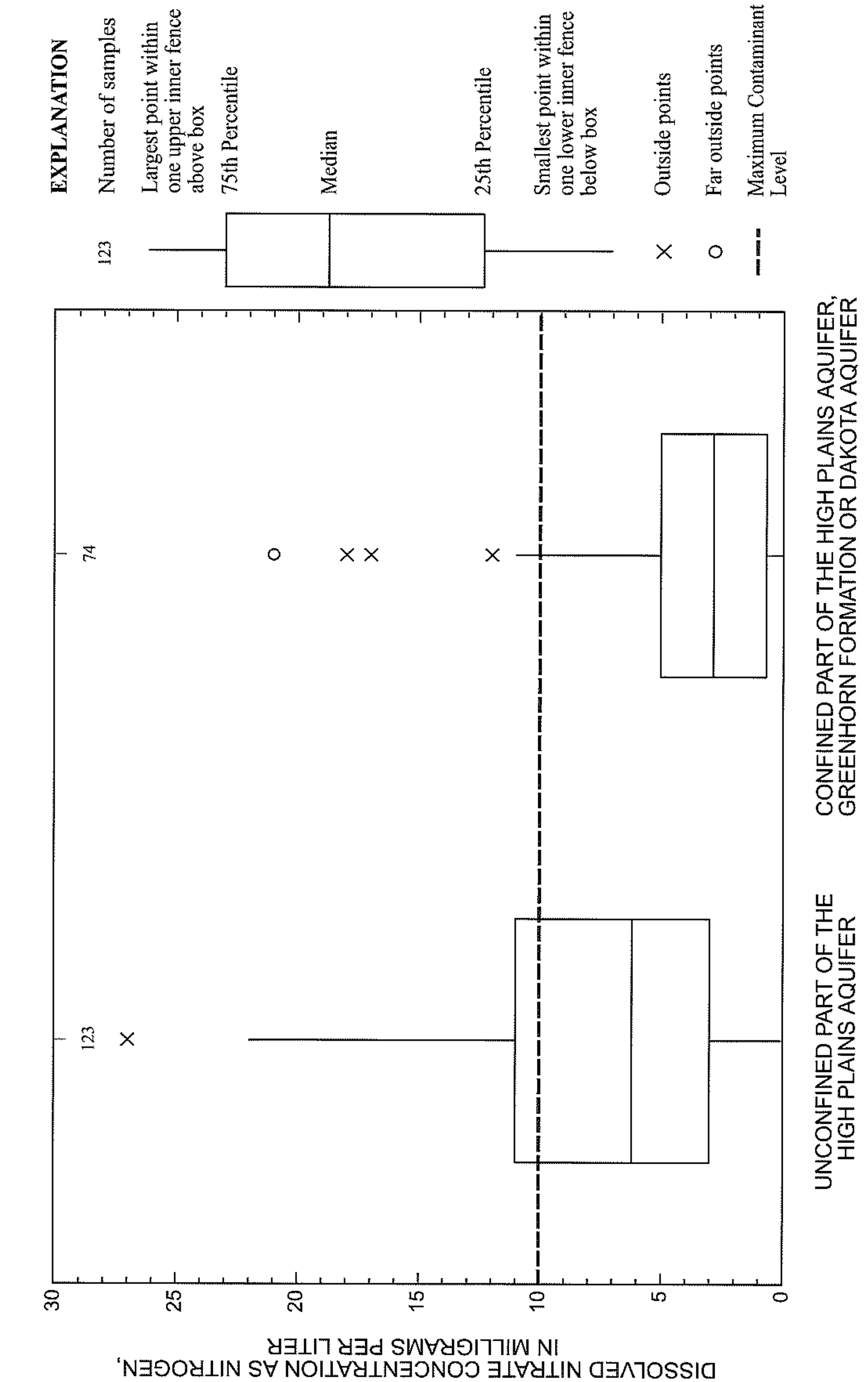

Figure 10. Distribution of nitrate concentrations by hydrogeologic condition in the ground-water-quality monitoring network, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996.

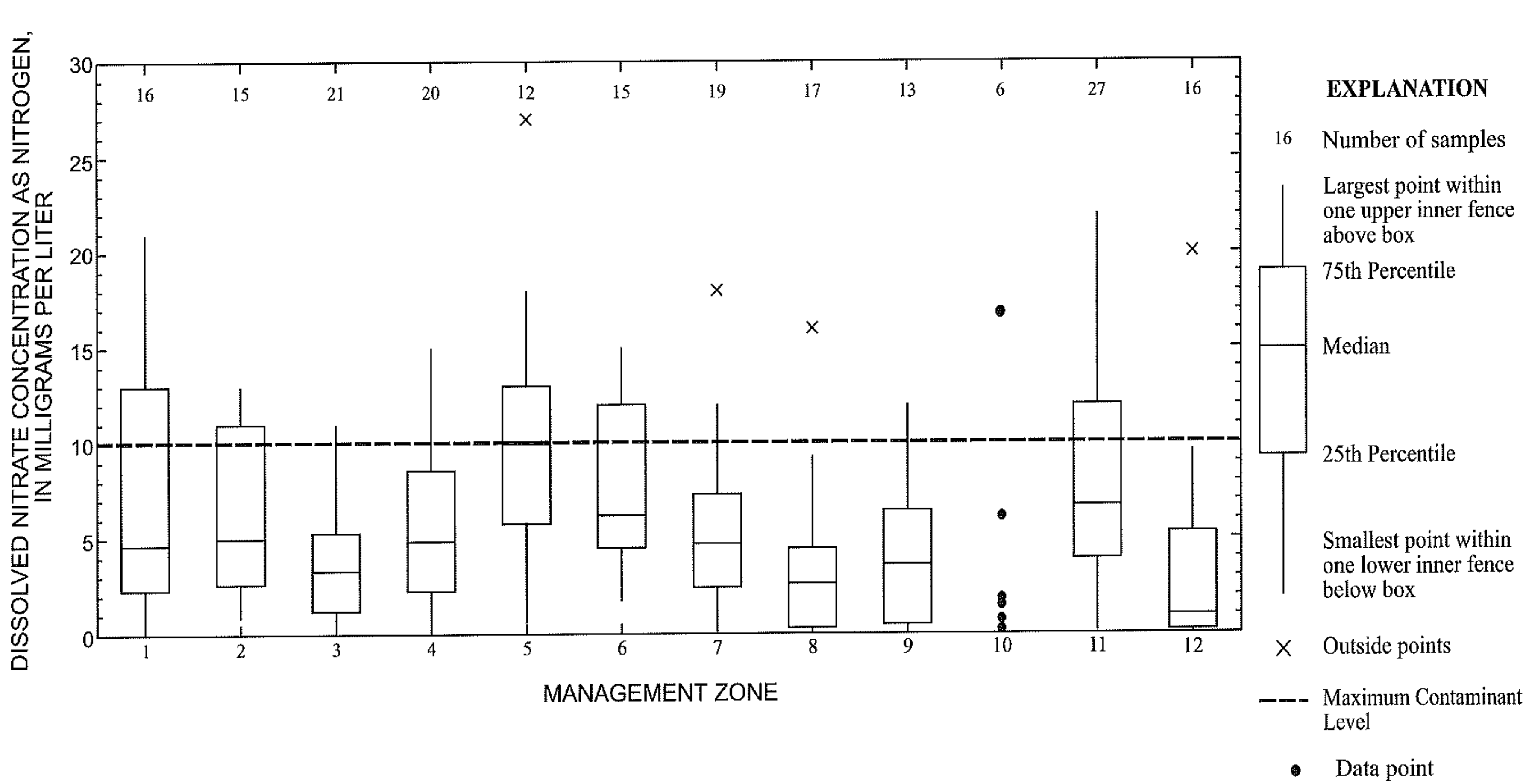

Figure 11. Distribution of nitrate concentrations by management zone in the ground-water-quality monitoring network, Upper Big Blue Natural Resources District central Nebraska, July 1995 through September 1996.

Water samples from 10 of 74 wells screened in the confined part of the High Plains aquifer had concentrations exceeding the USEPA MCL for drinking water of 10 mg/L (U.S. Environmental Protection Agency, 1996). In numerous cases, the annulus between the casing and the borehole wall are filled with gravel only and an intervening screen between the aquifer and land surface was not installed or has deteriorated, allowing entry of surface contaminants into the ground water. In other cases, the retarding clay layer may be discontinuous nearby, or nearby wells may be screened in both shallow and deep parts of the High Plains aquifer, leading to cross-contamination.

Because there often is no way to distinguish definitively between nonpoint and point sources of ground-water contamination with nitrate, it is difficult to exclude all wells affected by point sources of contamination or by cross-contamination of unconfined and confined aquifers in a network of monitoring wells. To reduce the influence of water samples affected by point sources, the median, and the 25th and 75th percentiles can be used to reflect the majority of the samples, and to aid management decisions. However, large nitrate concentrations caused by nonpoint-source contamination have been observed in other parts of Nebraska, such as in northern Holt County (Marty Link, Department of Environmental Quality, written commun., 1998).

Among the 12 management zones, the median nitrate concentrations varied from 0.97 to 10 mg/L (fig. 11 and table 9). The median nitrate concentrations (in mg/L) by zone ranked from smallest to largest were as follows: 0.97 in zone 12, 1.6 in zone 10, 2.6 in zone 8, 3.3 in zone 3, 3.6 in zone 9, 4.7 in zones 1 and 7, 4.9 in zone 4, 5.0 in zone 2, 6.2 in zone 6, 6.7 in zone 11, and 10 in zone 5. Median nitrate concentrations in water samples collected from wells located in zone 5 exceeded the action level of 9 mg/L established in the UBBNRD's Special Protection Area Action Plan (Upper Big Blue Natural Resources District, 1994).

Nonparametric statistical analyses using the Kruskal-Wallis test (Helsel and Hirsch, 1992) on the water-quality data leads to numerous conclusions. Nitrate concentration (two-sided p-value = 0.00, 197 samples), dissolved oxygen (two-sided p-value = 0.00, 172 samples), and pH (two-sided p-value = 0.00, 195 samples) differed significantly depending upon the sources of water being compared. The nitrate concentrations in water from the Dakota aquifer and water from the deep part of the High Plains aquifer are significantly smaller than in water from the shallow part of the High Plains aquifer (table 10).

Median nitrate concentrations (two-sided p-value = 0.00, 197 samples), dissolved oxygen (two-sided p-value = 0.00, 172 samples), and pH (two-sided p-value = 0.00, 195 samples) differed significantly among the aquifer groups depending upon the hydrogeologic condition of the aquifer from which the water was derived. The nitrate and dissolved oxygen concentrations tended to be largest in the unconfined part of the High Plains aquifer, generally suggesting the possible absence of denitrifying conditions.

Median values for well depth (two-sided p-value = 0.00, 196 samples), nitrate concentration (two-sided p-value = 0.00, 197 samples), dissolved oxygen (two-sided p-value = 0.00, 172 samples), and pH (two-sided p-value = 0.00, 195 samples) in the ground water varied among management zones. The Tukey's test (Helsel and Hirsch, 1992) indicates generally smaller nitrate concentrations in ground water in zones 12 and 8 and larger nitrate concentrations in zone 11, 6, and, especially 5 (table 9 and table 11).

Nitrate concentrations (two-sided p-value = 0.00, 197 samples), pH (two-sided p-value = 0.00, 194 samples), and dissolved oxygen concentrations (two-sided p-value = 0.00, 171 samples) in the ground water varied by depth (fig. 12 and table 12). Nonparametric statistical analyses established no relation between nitrate concentration and landscape position, depth to water (R.D. DeBuhr, Upper Big Blue Natural Resources District, written commun., 1998), or soil drainage class.

Spearman rank correlation coefficients (P) (Helsel and Hirsch, 1992) (99-percent confidence level, 159 samples) suggest the following relations:

a. Concentrations of nitrate in the ground water are larger in the shallow aquifers than in the deep aquifers (P = -0.33);

Table 10. Results of Tukey's test (95-percent confidence level) for differences in nitrate concentrations among aquifers, Upper Big Blue Natural Resources District, central Nebraska

[mg/L, milligrams per liter]

Aquifer (Median nitrate concentration in mg/L)	Dakota aquifer (0.11)	Deep part of the High Plains aquifer (3.4)	Undifferentiated High Plains aquifer (6.4)	Shallow part of the High Plains aquifer (6.3)
Significantly different groups of data[1]			■	■
	■	■	■	

[1]Groups shaded along the same row are not significantly different.

Table 11. Results of Tukey's test (95-percent confidence level) for differences in nitrate concentrations among management zones, Upper Big Blue Natural Resources District, central Nebraska

[mg/L, milligrams per liter]

Management zone (Median nitrate concentration in mg/L)	12 (0.97)	8 (2.6)	10 (1.6)	9 (3.6)	3 (3.3)	7 (4.7)	4 (4.9)	2 (5.0)	1 (4.7)	11 (6.7)	6 (6.2)	5 (10)
Significantly different groups of data[1]			■	■	■	■	■	■	■	■	■	■
		■	■	■	■	■	■	■	■	■	■	
		■	■	■	■	■	■	■	■	■		
	■	■	■	■	■	■	■	■	■			

[1]Groups shaded along the same row are not significantly different.

Table 12. Results of Tukey's test (95-percent confidence level) for differences in nitrate concentrations among well depths, Upper Big Blue Natural Resources District, central Nebraska

[mg/L, milligrams per liter]

Well depth (Median nitrate concentration in mg/L)	More than 300 feet (1.1)	From 226 to 300 feet (3.9)	From 151 to 225 feet (4.6)	From 0 to 75 feet (4.6)	From 76 to 150 feet (6.8)
Significantly different groups of data[1]		■	■	■	■
	■	■	■	■	

[1]Groups shaded along the same row are not significantly different.

b. Concentrations of nitrate are larger in ground water under unconfined conditions ($P = -0.37$);

c. Concentrations of nitrate increase as the well depth decreases ($P = -0.27$);

d. Concentrations of nitrate in ground water increase as the amount of oxygen in ground water increases ($P = 0.61$);

e. Concentrations of nitrate increase as the specific conductance of the water increases ($P = 0.40$);

f. Amount of dissolved oxygen in the ground water is larger in the shallow or unconfined part of the High Plains aquifer than in the deep or confined part of the High Plains aquifer ($P = -0.28$ or -0.38);

g. Amount of dissolved oxygen decreases with depth of well ($P = -0.38$);

h. The temperature increases with depth of well ($P = 0.26$); and,

i. pH tends to increase with the depth of the well ($P = 0.29$).

The strongest correlation indicated by the Spearman rank correlation coefficients was between nitrate concentration and the amount of dissolved oxygen. The specific conductance of ground water in the UBBNRD apparently does not vary significantly by aquifer, hydrogeologic condition, or management zone.

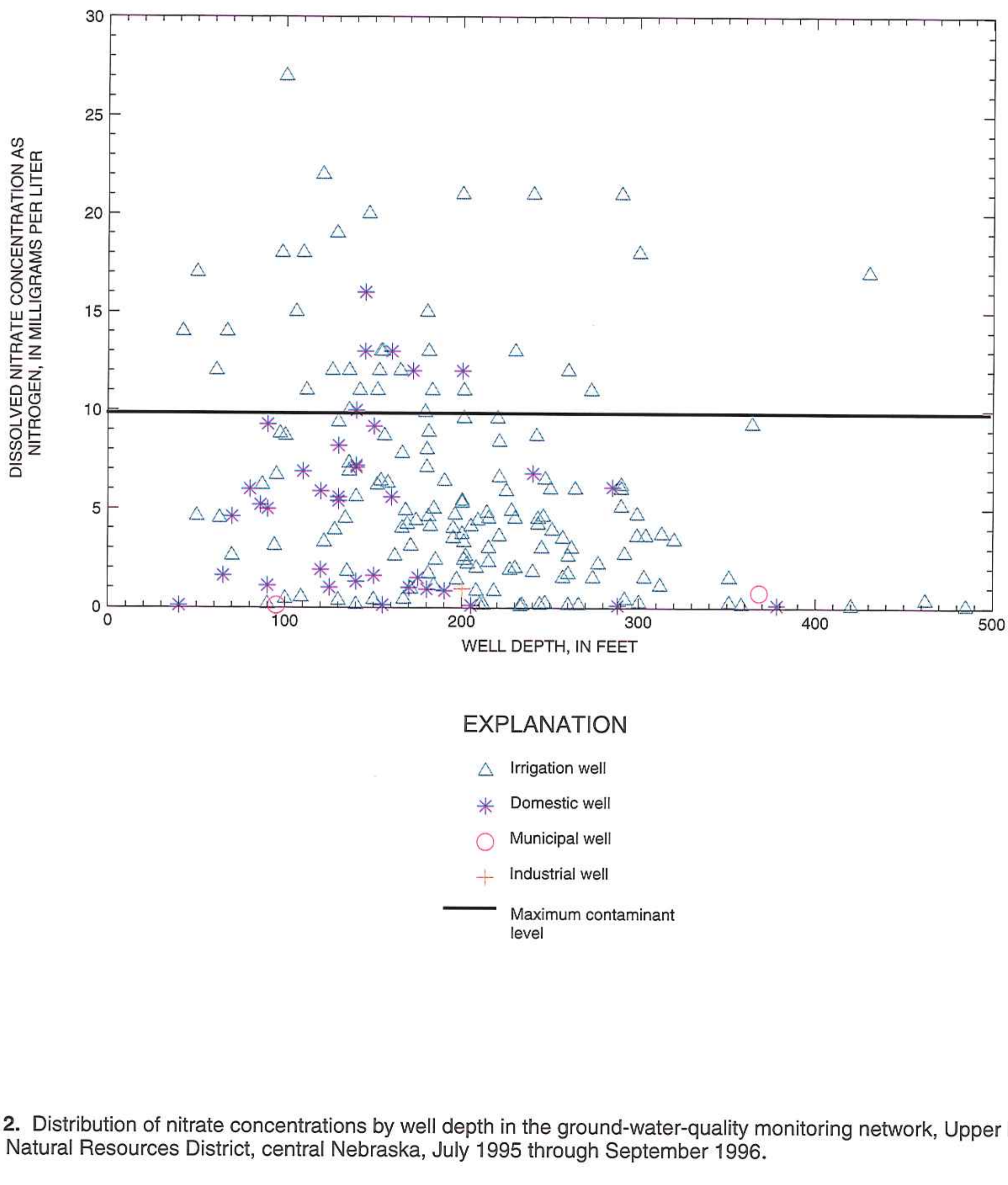

Figure 12. Distribution of nitrate concentrations by well depth in the ground-water-quality monitoring network, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996.

Nested Wells

Two hundred thirty-two water samples were collected from the nested wells by UBBNRD personnel (fig. 13; table 13 at back of report). Water samples were collected monthly from November 1995 to July 1996 and bimonthly from September 1996 to May 1997. Water levels generally were measured before sample collection. A statistical summary of the nitrate concentrations is listed in table 14 (at back of report).

The data collected from the nested wells (tables 13 and 14) generally support findings discussed for the data collected from the ground-water-quality monitoring network of domestic and registered wells. Water collected from the shallow part of the High Plains aquifer had a median nitrate concentration of 9.2 mg/L (table 14). Water collected from the deep part of the High Plains aquifer had a median nitrate concentration of 0.42 mg/L. Water collected from the unconfined and confined parts of the High Plains aquifer had median concentrations of 7.1 and 0.10 mg/L, respectively (table 14).

Water collected from well 7A generally had smaller nitrate concentrations than water collected from other nested wells completed in the unconfined shallow part of the High Plains aquifer (fig. 13). Additional data are needed to better understand the reason for the small nitrate concentrations in water obtained from this well. Dissolved-oxygen concentrations from 1.0 to 8.0 mg/L were present in the water collected at this site (table 13).

Nitrate concentrations in water samples from well 8B, screened from a depth of 120 to 130 ft, were larger than concentrations in water samples from well 8A, screened from a depth of 90 to 100 ft (fig. 13 and table 5). The dissolved-oxygen concentrations of water samples collected from wells 8A and 8B were similar, varying from 5.4 to 10.2 mg/L (table 13), and are too large to support denitrifying conditions. Potential explanations would be that, at shallow depths, (1) a dilution effect is occurring or (2) differing ground-water flow paths and time of travel exist.

Water samples with nitrate concentrations that exceeded the USEPA MCL of 10 mg/L for drinking water (U.S. Environmental Protection Agency, 1996) were collected from wells 1A, 4A, 8A, and 8B screened in the shallow part of the High Plains aquifer. The Upper Big Blue Special Protection Area Action Plan Phase III trigger of 12 mg/L of nitrate was exceeded in wells 1A, 4A, 8A, and 8B. The largest nitrate concentrations generally were detected in water samples from the unconfined part of the High Plains aquifer. Intermediate nitrate concentrations generally were detected in water samples from the unconfined deep part of the High Plains aquifer. The smallest nitrate concentrations generally were detected in water samples from the confined part of the High Plains aquifer.

Statistical analyses (Kruskal-Wallis test) suggest significant differences in nitrate concentrations by site, by aquifer, and by hydrogeologic condition (two-sided p-value = 0.00; 229 samples). In addition, Spearman rank correlation coefficients (99-percent confidence level; 205 samples) support the relation of the nitrate concentrations and field measurements established with the data from the ground-water-quality monitoring network. For example, water under unconfined conditions has larger nitrate concentrations and dissolved oxygen than water under confined conditions.

The shallow part of the High Plains aquifer appears to be susceptible to contamination with large nitrate concentrations. The potential for large nitrate concentrations in the High Plains aquifer is of most concern where (1) the shallow part of the High Plains aquifer is thin and in areas where confining conditions are absent, such as in parts of Seward and York Counties, or (2) where cross-contamination of unconfined and confined parts of the High Plains aquifer occurs, such as in York County.

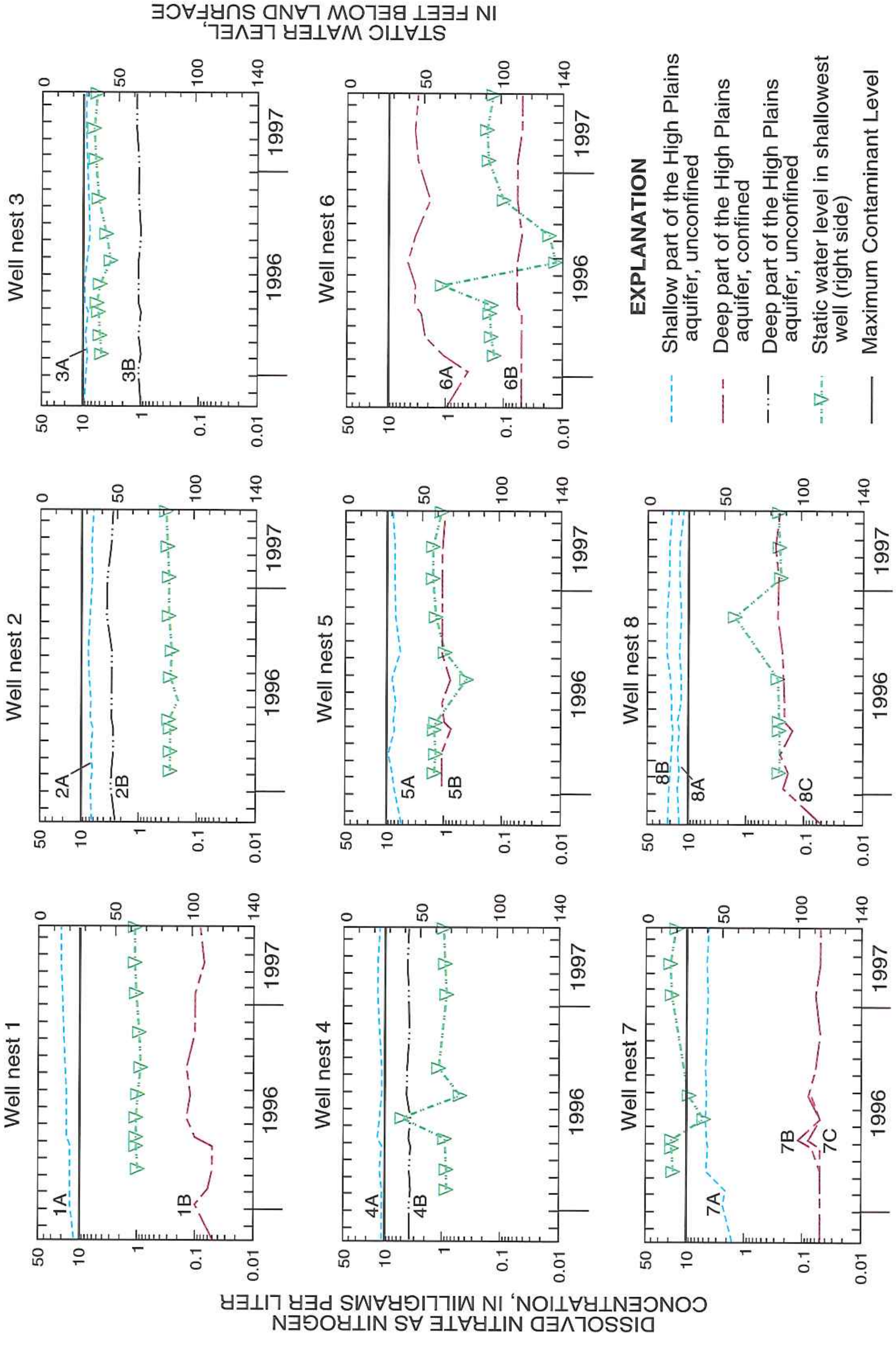

Figure 13. Trends in nitrate concentrations in water samples from nested wells, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through May 1997.

Spatial Trends in Major-Ion and Tritium Concentrations in Ground Water

In September 1996, ground-water samples were collected from all the nested wells and were analyzed for alkalinity, residue on evaporation at 180 °C, and major ions (table 15, at back of report) to provide background information on general water chemistry. Tritium analyses were performed on water samples collected from wells 1A, 1B, 6A, 6B, 8A, 8B, and 8C to estimate the age of ground water, and on a precipitation sample collected at well site 8 on June 22, 1997. The precipitation sample had a tritium concentration of 45 pCi/L (picocuries per liter) tritium.

The results from this study indicate that water in the High Plains aquifer generally is a calcium-bicarbonate type, confirming the findings of Johnson and Keech (1959), Keech and Dreeszen (1968a), Ginsberg (1983), Gottula (1990), and Gottula and Link (1992). The relative major-ion composition of the water did not vary much spatially. Generally, the water was hard and locally contained large concentrations of iron (as much as 140 µg/L) and manganese (as much as 850 µg/L). Water from well 6A contained large concentrations of manga-nese (670 µg/L) and sulfate (190 µg/L), and water from well 6B contained large concentrations of iron (140 µg/L) and manganese (850 µg/L) (table 15). Locally, water from the High Plains aquifer may exceed the Secondary Maximum Contaminant Levels for drinking water of 50 µg/L for manganese (U.S. Environmental Protection Agency, 1996).

Previous work suggests that water from the deep part of the High Plains aquifer tends to be a sodium-carbonate type (Keech, 1978). Water from the Dakota aquifer generally is a sodium-bicarbonate type and has lower amounts of alkalinity in Butler County (Ginsberg, 1983), but is a calcium-sodium-bicarbonate type in Seward County (Keech, 1978).

Tritium is a radioactive isotope of hydrogen with a half-life of 12.43 years. In 1952, above-ground testing of thermonuclear devices resulted in the release of large amounts of tritium to the atmosphere. Tritium concentrations in water samples from the nested wells varied considerably depending upon the part of the High Plains aquifer in which the wells are completed. Water samples from the shallow part of the High Plains aquifer had the largest tritium concentrations varying from 26 pCi/L in well 1A screened from 90 to 95 ft to 39 pCi/L in well 8A screened from 90 to 100 ft (table 15). Tritium concentrations in water samples from the deep, confined part of the High Plains aquifer varied from less than 0.3 pCi/L in well 1B screened from 200 to 205, and well 8C screened from 225 to 300 ft, to 2.5 pCi/L in well 6B screened from 240 to 247 ft.

Tritium concentration is related to the age of the water collected. Larger tritium concentrations (about 40-45 pCi/L) would occur in water recharged from about 1953 through the 1970s, whereas smaller concentrations indicate water older than 1953 (Druliner, 1997). The tritium data indicate that water from the shallow part of the High Plains aquifer, likely recharged during the last 10 to 20 years, is younger, while water from the deep part of the High Plains aquifer, likely recharged more than 50 years ago, is older. The tritium data indicate that, where confined conditions exist in the deep part of the High Plains aquifer and where confining conditions have not been modified through pene-tration of wells, the water could remain unaffected by nitrate contamination, if water from the shallow part of the High Plains aquifer that is contaminated with nitrate is not reaching the area along longer flow paths from laterally distant areas.

Locally, denitrification also can play a role in reducing the nitrate concentrations. In areas where the lower part of the High Plains aquifer is unconfined, such as at wells 2B, 3B, and 4B, the deep part of the High Plains aquifer might be affected by nitrate contamination (fig. 13; table 13). In areas where the aquifer appears confined, some leakage may occur into the deep, confined part of the High Plains aquifer, as suggested by the detectable amounts of tritium in samples collected from wells 6A (1.6 pCi/L) and 6B (2.5 pCi/L) (table 15) or they could be baseline values not necessarily indicating leakage.

Temporal Trends in Nitrate Concentrations and Field Measurements in Ground Water

Samples were collected from the nested wells monthly from November 1995 through July 1996, which was modified to bimonthly sample collection from July 1996 through May 1997. The results of this sampling effort show that the nitrate concentrations in water from the nested wells generally did not vary much over this 19-month period of data collection (fig. 13; table 13). However, there appears to be a small gradual increase in nitrate concentrations in water samples collected from well 1A (fig. 13; table 13). Little seasonal variation in nitrate concentrations was observed. Because of the limited variation in nitrate concentrations and the short period of data collection, trend analyses were not performed.

Nitrate concentrations in water samples from well 1A increased from 12 mg/L on November 8, 1995, to 21 mg/L on May 19, 1997 (table 13). Nitrate concentrations in water samples from wells 6A and 7A also increased over time, with increases during the first 4 months of sample collection followed by apparent stabilization in nitrate concentrations (fig. 13). Overall, variable nitrate concentrations were noted in water from several wells (table 13).

The water temperature generally was higher during the summer in water samples from wells completed in the unconfined part of the High Plains aquifer than in water samples from wells completed in the confined part of the High Plains aquifer (table 13). Concentrations of dissolved oxygen and pH did not fluctuate with time. The data suggest that representative sampling of the nested wells generally may be performed during any time of the year and that biannual sampling in the spring and fall may be sufficient to establish trends in water quality.

SPATIAL TRENDS IN NITRATE CONCENTRATIONS IN SEDIMENT OF THE UNSATURATED ZONE

Two-hundred and fifty unsaturated-zone sediment samples were collected during three samplings: (1) near the eight nested-well sites (or 14 subsites) (table 6) in November and December 1995; (2) near the same eight nested-well sites (or 14 subsites) in December 1996 and January 1997; and (3) near three nested-well sites (or seven subsites) in March 1997 (figs. 14 through 16, and table 16, at back of report). In November and December 1995, unsaturated-zone samples were collected from 0.25 ft to a depth of as much as 90 ft. In December 1996 and January 1997, and in March 1997, unsaturated-zone samples were collected to a depth of as much as 31 ft. The nitrate concentrations of the 245 unsaturated-zone samples analyzed varied from less than 0.05 to 69 mg/kg (milligrams per kilogram) and had a median concentration of 3.7 mg/kg. Fifty percent of the unsaturated-zone samples had nitrate concentrations between 2.15 and 5.6 mg/kg. Five additional samples were collected, but were lost during shipment or processing.

The depth from which the unsaturated-zone samples were collected varied from 0.25 to 90 ft with a median of 10 ft. Fifty percent of these samples were collected from a depth varying between 3 and 25 ft. Five to 13 samples were collected from each subsite (table 6) depending upon the hydrologic conditions at the site. Statistical analyses of the data indicate that: nitrate concentrations (two-sided p-value = 0.00, 245 samples) varied among sample subsites (Kruskal-Wallis test). The Spearman rank correlation coefficient indicates that the nitrate concentrations of the unsaturated-zone samples were not related to the depth at which the samples were collected.

Overall, the nitrate concentrations of the unsaturated-zone samples at each site remained similar from one sampling to the next. At site DH4, nitrate concentrations in unsaturated-zone samples for 1995, 1996, and 1997 below nonirrigated cropland were larger than those below irrigated cropland or pasture land (figs. 14-16). At site DH7, the differences in nitrate concentrations in unsaturated-zone samples between irrigated and nonirrigated crop land were not as pronounced as at site DH4. The differences at site DH4 in nitrate concentrations may be the result of dilution and rapid transport of nitrate through the unsaturated zone beneath irrigated land compared to the rate of transport beneath nonirrigated land. Other variables, such as the amount of nitrogen applied, soil type, organic matter content of the sediments, and the shrink-swell potential of the sediments, especially in the root zone, also could account for differences or nondifferences. For example, at site DH7 nondifferences in nitrate concentrations may be caused by an "overshadowing" of these other factors.

Nitrate concentrations in the unsaturated-zone samples below pasture land generally appear to be smaller than in unsaturated-zone samples below cropland, especially at site DH6, which is similar to the findings of Gottula and Link (1992). This is reasonable because nitrogen fertilizer was not applied to these areas, although excrement from horses is a potential source of nitrogen near subsite DH4B. At site DH3, the nitrate concentrations in unsaturated-zone samples below the upland (subsite DH3B) were smaller than on the bottomland (subsite DH3A) (figs. 14 and 15). This difference in nitrate concentration could result from transport of nitrogen in surface runoff from the upland to the bottomland. On the bottomland at site DH3A, a larger amount of nitrate will tend to accumulate than on sloping upland or foot slopes, probably resulting in more nitrate being available to leach into the unsaturated zone.

At subsite DH7A, an increase in nitrate concentrations with depth in the unsaturated zone was noted from 1995 to 1996 (figs. 14 and 15). This apparent increase in unsaturated-zone nitrate concentrations with depth could have resulted from differences in nitrogen application. Nitrogen fertilizer was applied in 1995, but was not applied to cropland in 1996 (table 6). At site DH8 no obvious differences in nitrate concentrations of unsaturated-zone samples were noted. The unsaturated-zone profile is intended to be monitored about every 3 years in the future for nitrate or nitrogen species concentrations by the UBBNRD as BMPs are implemented in the study area (R.D. DeBuhr, Upper Big Blue Natural Resources District, oral commun., 1998).

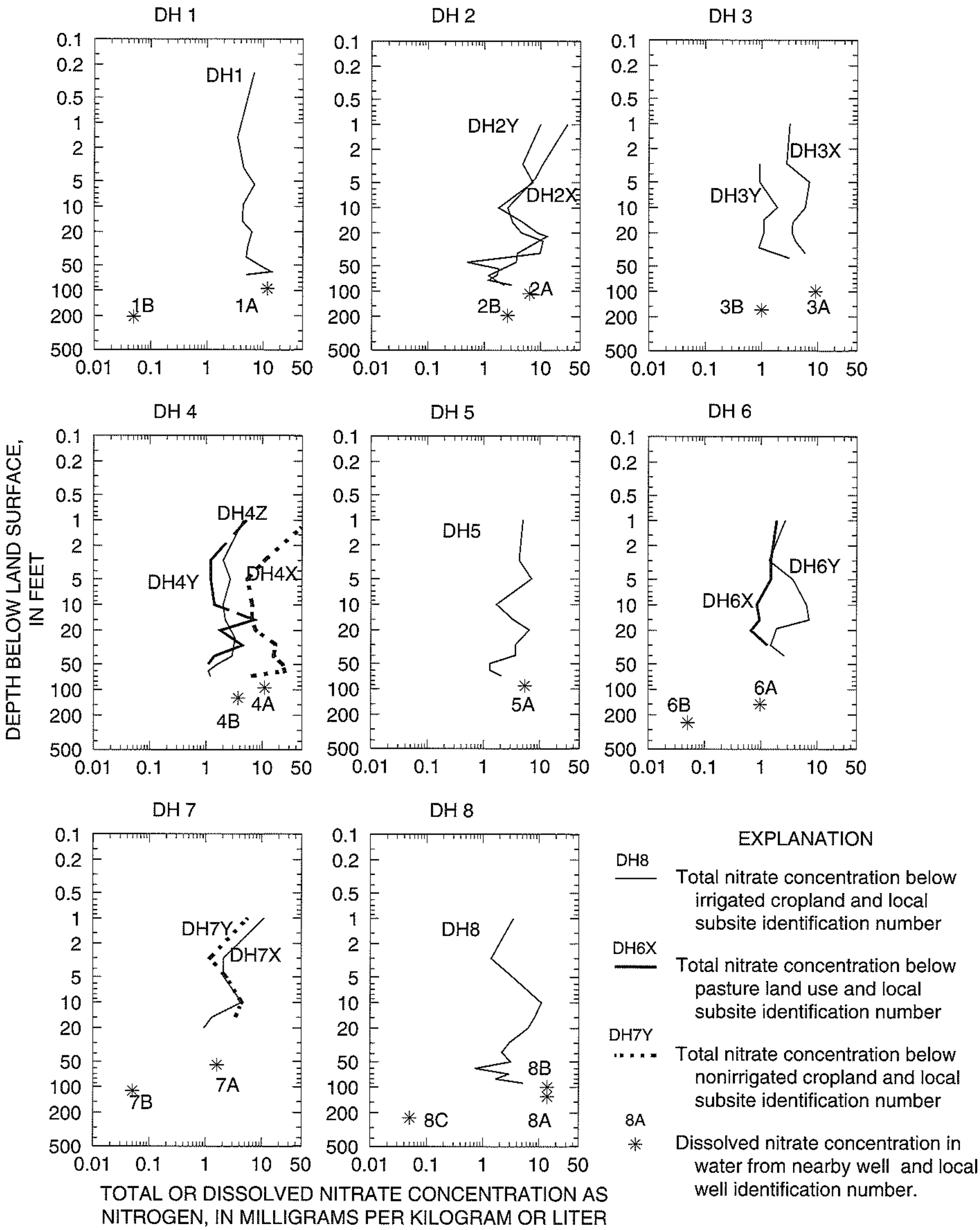

Figure 14. Nitrate concentrations in unsaturated-zone sediment samples from November and December 1995 and in water samples from nested wells from November 1995, by depth, Upper Big Blue Natural Resources District, central Nebraska.

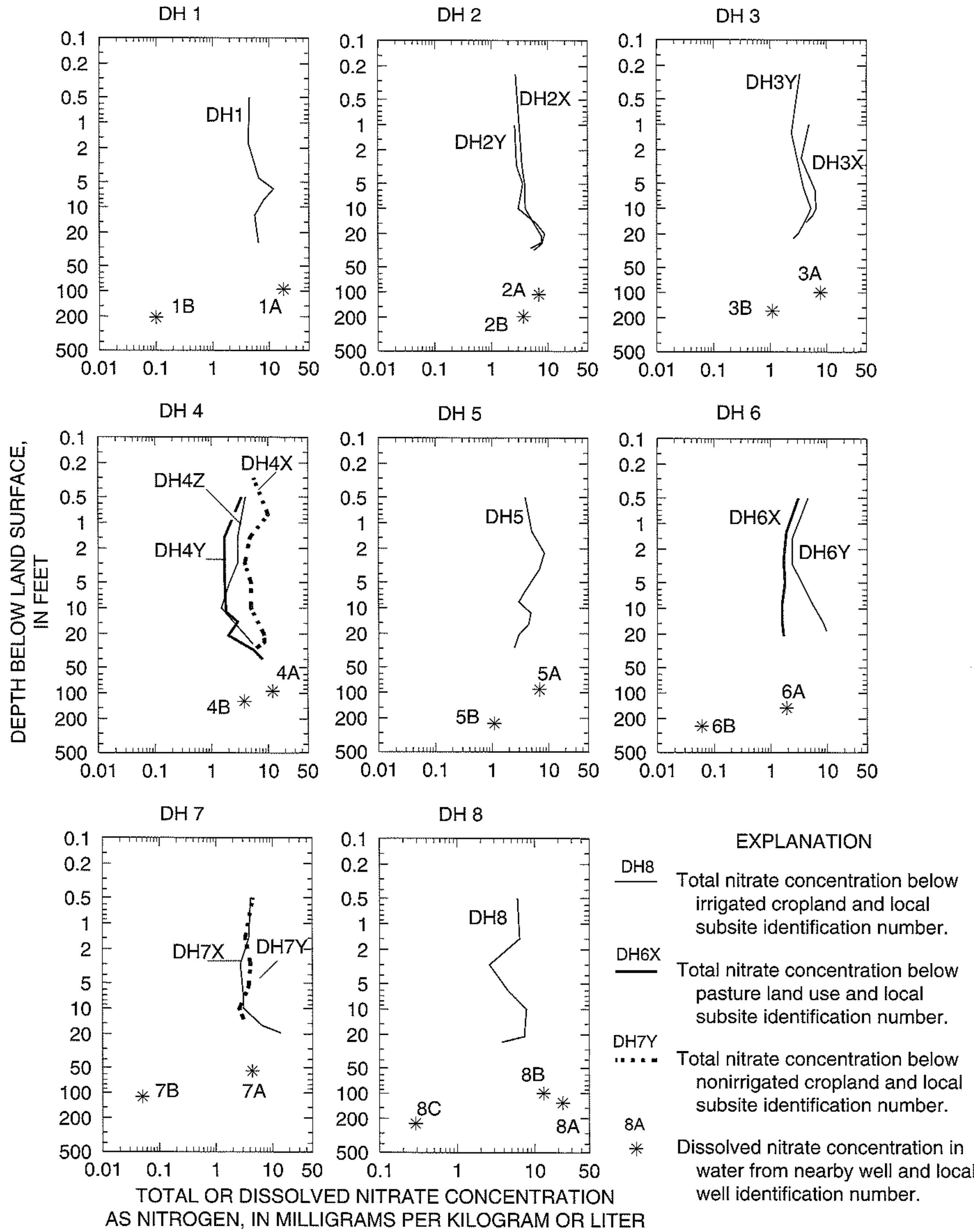

Figure 15. Nitrate concentrations in unsaturated-zone sediment samples from December 1996 and January 1997, and in water samples from nested wells from November 1996, by depth, Upper Big Blue Natural Resources District, central Nebraska.

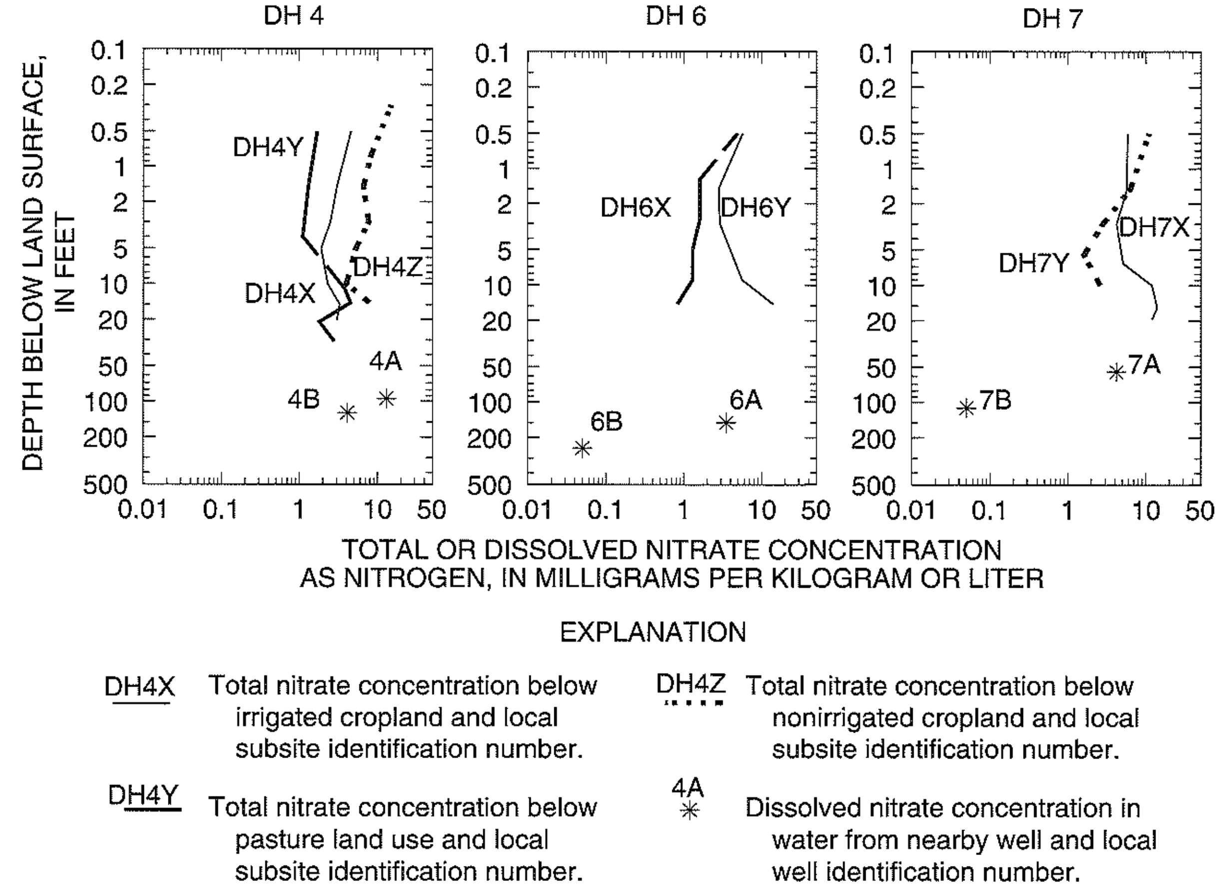

Figure 16. Nitrate concentrations in unsaturated-zone sediment samples from March 1997, and in water samples from nested wells from March 1997, by depth, Upper Big Blue Natural Resources District, central Nebraska.

SUMMARY AND CONCLUSIONS

Following the designation of the UBBNRD as a Special Protection Area by the Nebraska Department of Environmental Quality in 1993, the UBBNRD requested that the U.S. Geological Survey develop a monitoring approach to identify the spatial and temporal variability of nitrate concentrations in ground water and assess the presence of nitrate concentrations in the unsaturated zone. A ground-water-quality monitoring network of 197 domestic and registered wells, along with 8 nested-well sites (a total of 18 wells) and associated unsaturated-zone subsites was proposed during this study. Of the 197 wells in the monitoring-well network, 104 wells are completed in the shallow part of the High Plains aquifer, 86 are completed in the deep part of the High Plains aquifer, 3 are completed in both parts of this aquifer, 1 is completed in the Greenhorn Formation (well 1001), and 3 are completed in the Dakota aquifer. Of the 193 wells completed in the High Plains aquifer, 123 are screened in an unconfined part of the High Plains aquifer and 70 are screened in the confined part of the High Plains aquifer. Eight nested-well sites were selected for the installation of 18 nested wells, based on the hydrogeologic conditions, the management zones, the presence of irrigated cropland, and other selected reasons. Unsaturated-zone samples were collected near each nested-well site. Unsaturated-zone subsites were selected based on land use or landscape position.

Nitrate concentrations in the ground water in the UBBNRD ranged from 0.06 to 27 mg/L and had a median concentration of 4.6 mg/L. Of the 197 samples collected from the ground-water-quality monitoring network, 41 samples (21 percent) exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level for drinking water of

10 mg/L for nitrate as nitrogen. In the shallow part of the High Plains aquifer, nitrate concentrations ranged from 0.09 to 27 mg/L and had a median concentration of 6.3 mg/L. In the deep part of the High Plains aquifer, the nitrate concentrations ranged from 0.06 to 21 mg/L and had a median concentration 3.4 mg/L. In the Dakota aquifer, the median nitrate concentration was 0.11 mg/L. The median nitrate concentrations in the unconfined and the confined part of the High Plains aquifer were 6.2 and 2.9 mg/L, respectively.

Among the management zones, the median nitrate concentrations varied from 0.97 to 10 mg/L. The median nitrate concentrations (in mg/L) by zone ranked from small to large were: 0.97 in zone 12, 1.6 in zone 10, 2.6 in zone 8, 3.3 in zone 3, 3.6 in zone 9, 4.7 in zones 1 and 7, 4.9 in zone 4, 5.0 in zone 2, 6.2 in zone 6, 6.7 in zone 11, and 10 in zone 5. The median nitrate concentration (10 mg/L) of water samples from wells in zone 5 exceeded the Phase II trigger of 9 mg/L.

Nitrate concentrations in water from the Dakota aquifer and water from the deep part of the High Plains aquifer were significantly smaller than concentrations in water from the shallow part of the High Plains aquifer. Nitrate concentrations and dissolved oxygen differed significantly depending upon the hydrogeologic condition of the aquifer from which the water was derived. Nitrate concentrations and dissolved oxygen tended to be larger in the unconfined part of the High Plains aquifer, indicating no denitrifying conditions existed. Smaller concentrations of nitrate were detected in ground-water samples from wells in zones 8 and 12, than in water samples from the other zones. Larger nitrate concentrations were detected in water samples from wells in zones 11, 6, and 5, than in the remaining zones.

Two hundred thirty-two water samples were collected from the eight nested-well sites from November 1995 to May 1997. The nitrate concentrations and field measurements of water samples collected from the nested wells generally agreed with results from the proposed ground-water-quality monitoring network of domestic and registered wells. They show the largest nitrate concentrations in samples from the unconfined part of the High Plains aquifer, intermediate nitrate concentrations in samples from the unconfined, deep part of the High Plains aquifer, and the smallest nitrate concentrations in samples from the confined part of the High Plains aquifer. Water samples collected from the various parts of the High Plains aquifer had the following median concentrations: shallow, 9.2 mg/L; deep, 0.42 mg/L; unconfined, 7.1 mg/L; and confined, 0.10 mg/L.

Statistical analyses showed that nitrate concentrations varied significantly by site, aquifer, and hydrogeologic condition. In addition, statistical analyses of data collected from the nested wells supported the relations of the nitrate concentrations and field measurements determined with the data from the proposed ground-water-quality monitoring network. The data suggest that the shallow part of the High Plains aquifer appears to be very susceptible to contamination with nitrate. Nitrate contamination of the High Plains aquifer is of most concern where (1) the shallow part of the High Plains aquifer is thin and in areas where confining conditions are absent, or (2) where cross-contamination of unconfined and confined parts of the High Plains aquifer occurs. The data also suggest that representative sampling of the nested wells may be performed during any time of the year, and that biannual sampling in the spring and fall may be sufficient to establish trends in water quality based on the best management practices adopted by the UBBNRD.

In September 1996, water samples were collected from all the nested wells and analyzed for alkalinity, residue on evaporation at 180 °C, and major ion and tritium concentrations. The results suggest that water in the High Plains aquifer in the study area generally is a calcium-bicarbonate type and does not vary much spatially. Locally, the High Plains aquifer may exceed the USEPA Secondary Maximum Contaminant Standard of 50 µg/L for manganese.

Water samples from the shallow part of the High Plains aquifer had the largest tritium content, which varied from 26 pCi/L to 39 pCi/L. Tritium activity in the deep confined part of the High Plains aquifer varied from less than 0.3 pCi/L to 2.5 pCi/L. The tritium data, therefore, indicate that water samples from the shallow part of the High Plains aquifer, likely recharged during the last 10 to 20 years, is younger, while water samples from the deep part of the High Plains aquifer, likely recharged more than 50 years ago, is older. The tritium data also indicate that, where confined conditions exist in the deep part of High Plains aquifer and have not been modified through penetration of wells, the water could remain unaffected by nitrate contamination. However, generally, the water under confined conditions has measurable amounts of nitrate.

Unsaturated-zone sediment samples were collected three times at 14 subsites and were analyzed for nitrate. The nitrate concentrations detected in 245 of 250 samples collected varied from less than 0.05 to 69 mg/kg and had a median of 3.7 mg/kg. The depth from which these samples were collected varied from 0.25 to 90 ft with a median of 10 ft. Nitrate concentrations varied among sample subsites and were not related to the depth at which the samples were collected. At site DH4, nitrate concentrations in unsaturated-zone samples below nonirrigated cropland were larger than concentrations from samples below irrigated cropland and pasture land. Nitrate concentrations in unsaturated-zone sediment samples below pasture land generally were smaller than nitrate concentrations in samples from below cropland.

Thus, water from the High Plains aquifer, especially in the shallow unconfined part, is more affected by nonpoint-source nitrogen than the water present in the Dakota aquifer. However, the confined part of the High Plains aquifer also has been contaminated with nitrogen probably in part because of (1) some leakage through the confining layer, (2) long flow paths from unconfined to confined parts of the aquifer, or (3) cross-contamination caused by well construction and well completions. In summary, the potential for large nitrate concentrations in the High Plains aquifer is of most concern where (1) the shallow part of the High Plains aquifer is thin and in areas where confining conditions are absent, such as in parts of Seward and York Counties, or (2) where cross-contamination of unconfined and confined parts of the High Plains aquifer occurs, such as in York County.

For management purposes, the management areas of concern are management zones 5, 6, and 11. To identify trends in nitrate concentrations that may be associated with the implementation of best management practices in the study area, the UBBNRD could: (1) collect and analyze water samples from the proposed ground-water-monitoring network of domestic and registered irrigation wells every 1 to 3 years; (2) collect and analyze water samples from the nested wells in spring and fall; and (3) collect and analyze soil samples from the unsaturated-zone profile about every 3 years.

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Supplemental Data—Water-Quality Results (Tables 8, 9, 13, 14, 15, and 16)

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997

[*, flagged analytical results, because of large variability in nitrate concentrations from year to year; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; UF, unconfined part of the High Plains aquifer; CF, confined part of the High Plains aquifer; sample date, yyyymmdd; --, no data; <, less than]

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (µS/cm)	Water temperature (°C)
0101	UF	Environmental	19950829	1200	5.2	6.5	7.1	580	14.5
0101	UF	Environmental	19960716	1600	4.7	3.6	7.1	614	13.5
0101	UF	Blank	19960716	1605	.13	--	--	--	--
0101	UF	Duplicate	19960716	1610	4.6	3.6	7.1	614	13.5
0102	UF	Environmental	19960715	1400	4.4	6.1	7.3	634	13.5
0103	UF	Environmental	19960730	0830	4.6	7.9	7.0	620	12
0104	UF	Environmental	19950829	1030	5.5	6.7	7.1	660	14
0104	UF	Environmental	19960715	1553	6.6	7.1	7.2	701	15
0105	UF	Environmental	19950721	1010	*17	5.9	7.0	1,340	13.5
0105	UF	Environmental	19960829	1400	*21	9.6	6.8	1,200	12.5
0106	UF	Environmental	19950721	1050	.15	.5	7.5	574	13
0106	UF	Environmental	19960708	1405	.12	.1	7.1	568	13
0107	UF	Environmental	19950724	1150	*11	8.6	7.5	752	13.5
0107	UF	Environmental	19960710	1312	9.3	1.6	7.3	769	13
0108	UF	Environmental	19950726	1000	.14	4.0	6.5	604	13
0108	UF	Environmental	19960710	1234	3.0	3.9	7.1	622	12.5
0108	UF	Blank	19960710	1240	.06	--	--	--	--
0108	UF	Duplicate	19960710	1245	3.0	3.9	7.1	622	12.5
0109	UF	Environmental	19950727	1355	1.1	1.0	7.1	679	13
0109	UF	Environmental	19960710	1420	2.2	4.5	7.2	703	13
0110	UF	Environmental	19950801	1400	1.5	1.4	7.5	571	13
0110	UF	Duplicate	19950801	1405	1.3	1.4	7.5	571	13
0110	UF	Blank	19950801	1410	<.05	--	--	--	--
0110	UF	Environmental	19960719	0920	1.0	1.5	7.1	587	13.5
0111	UF	Environmental	19960719	0837	6.4	5.6	7.2	628	13.5
0112	UF	Environmental	19950721	1350	*12	8.0	7.1	860	14.5
0112	UF	Environmental	19960708	1240	*13	8.6	6.7	871	14.5
0113	UF	Blank	19950721	1305	<.05	--	--	--	--
0113	UF	Environmental	19950721	1306	*11	5.1	7.1	742	13
0113	UF	Environmental	19960708	1320	*13	6.5	6.9	773	13
0114	UF	Environmental	19960711	956	*21	8.3	6.9	1,680	12
0115	UF	Environmental	19960715	1245	*19	7.6	7.2	1,020	12
0116	UF	Environmental	19950721	1550	2.4	7.7	6.8	443	13.5
0116	UF	Environmental	19960710	1459	1.5	8.0	6.8	352	14
0201	UF	Environmental	19950721	0905	4.0	4.2	6.9	636	12.5
0201	UF	Environmental	19960717	1515	4.5	4.1	6.6	642	12.5
0202	UF	Environmental	19950728	1115	*11	7.7	7.5	714	13.5
0202	UF	Environmental	19960718	1040	*11	6.3	6.7	692	12.5
0202	UF	Duplicate	19960718	1045	*11	6.3	6.7	692	12.5
0202	UF	Blank	19960718	1050	.07	--	--	--	--
0203	UF	Environmental	19950719	1640	9.2	7.6	7.2	718	12.5
0203	UF	Duplicate	19950719	1645	9.3	7.6	7.2	718	12.5

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (µS/cm)	Water temperature (°C)
0203	UF	Blank	19950719	1650	<.05	--	--	--	--
0203	UF	Environmental	19960718	1440	*12	6.1	6.7	809	13
0204	UF	Environmental	19950731	1115	4.0	6.3	7.0	515	12.5
0204	UF	Environmental	19960716	1320	4.4	5.4	7.0	513	12.5
0205	CF	Environmental	19950727	1120	1.0	.5	7.4	554	14
0205	CF	Environmental	19960718	0815	.82	.1	6.9	553	13.5
0206	UF	Environmental	19960718	1140	5.0	6.4	6.8	642	13.5
0207	UF	Environmental	19950720	1410	.26	.5	7.1	497	13
0207	UF	Environmental	19960708	1700	.84	.1	6.9	497	13
0208	UF	Environmental	19950720	1050	6.9	5.7	7.1	605	13
0208	UF	Environmental	19960718	1320	8.4	5.9	6.7	630	13
0209	UF	Environmental	19950720	1200	2.1	5.7	7.3	433	13
0209	UF	Environmental	19960718	1350	2.2	8.5	7.4	357	15
0210	UF	Environmental	19950720	0955	7.1	7.6	7.0	600	12.5
0210	UF	Environmental	19960708	1610	7.2	7.5	6.8	627	13.5
0211	UF	Environmental	19950719	1330	4.2	3.7	7.3	920	13.5
0211	UF	Environmental	19960718	1245	5.3	3.6	6.8	920	13
0212	UF	Environmental	19960716	1455	*11	7.5	7.0	634	13
0213	UF	Environmental	19950719	1245	2.2	7.7	7.6	448	13.5
0213	UF	Environmental	19960716	1605	2.6	8.4	7.3	445	13
0214	UF	Environmental	19960716	1430	4.0	4.4	6.8	609	13
0215	UF	Environmental	19950719	1530	6.0	.8	7.4	714	13.5
0215	UF	Environmental	19960708	1435	*13	.9	6.9	820	14.5
0301	CF	Environmental	19950725	1245	3.2	4.4	7.2	677	13.5
0301	CF	Environmental	19960719	1430	3.3	6.3	6.8	533	14.5
0302	UF	Environmental	19950724	1725	5.9	7.5	7.4	468	13.5
0302	UF	Environmental	19960730	1405	6.9	7.4	7.2	1,010	13
0303	UF	Environmental	19960715	1215	.93	2.0	6.5	522	13
0304	UF	Environmental	19950718	1700	5.6	8.0	6.8	506	13.5
0305	UF	Environmental	19950718	1610	1.7	2.1	7.0	558	13
0305	UF	Environmental	19960715	1340	2.3	2.4	6.6	610	13.5
0306	UF	Environmental	19950718	1320	1.3	4.0	6.8	430	13.5
0306	UF	Environmental	19960709	1150	1.3	4.2	6.5	427	13.3
0306	UF	Duplicate	19960709	1155	1.2	4.2	6.5	427	13.5
0306	UF	Blank	19960709	1200	<.05	--	--	--	--
0307	UF	Environmental	19950725	0830	2.7	4.2	6.8	590	13.5
0307	UF	Duplicate	19950725	0835	2.7	4.2	6.8	590	13.5
0307	UF	Blank	19950725	0840	<.05	--	--	--	--
0307	UF	Environmental	19960719	1505	2.4	3.9	6.5	590	13.4
0308	UF	Environmental	19950724	1630	5.5	6.9	6.8	543	12.5
0308	UF	Environmental	19960717	1025	6.4	7.9	6.7	578	12.5

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (µS/cm)	Water temperature (°C)
0308	UF	Duplicate	19960717	1030	6.1	7.9	6.7	578	12.5
0308	UF	Blank	19960717	1035	.07	--	--	--	--
0309	CF	Environmental	19960717	1100	1.1	7.3	6.6	571	13
0310	CF	Environmental	19950718	1700	3.3	7.4	7.2	660	14
0310	CF	Environmental	19960715	1520	3.7	7.1	6.6	638	13.5
0311	UF	Environmental	19950717	1530	1.6	7.2	7.0	860	13
0311	UF	Environmental	19960716	1125	1.8	8.7	6.6	871	12.5
0312	UF	Environmental	19950717	1615	9.5	7.6	7.0	735	13.5
0312	UF	Environmental	19960716	1215	*11	7.1	6.8	734	13
0313	CF	Environmental	19950725	1010	1.0	2.6	7.4	436	13.5
0313	CF	Environmental	19960716	0950	1.0	2.5	6.9	441	13.5
0314	CF	Environmental	19950717	1430	4.0	6.7	7.2	766	13.5
0315	CF	Environmental	19950725	1120	1.5	.3	7.2	695	17
0315	CF	Environmental	19960716	0905	.92	.1	6.8	675	15.5
0316	CF	Environmental	19960718	1000	5.0	5.6	6.8	600	14
0317	UF	Environmental	19950721	830	2.2	3.8	7.0	627	13.5
0317	UF	Environmental	19960717	1425	3.3	4.5	6.7	642	13
0317	UF	Environmental	19960718	0855	4.5	3.0	6.6	651	13
0318	UF	Environmental	19950727	1045	4.3	3.3	6.9	652	13
0319	CF	Environmental	19950725	1555	4.9	7.2	7.2	592	13
0320	UF	Environmental	19950719	1000	.72	.6	7.0	831	12.5
0320	UF	Environmental	19960715	1625	.40	.1	6.7	851	12.5
0321	UF	Environmental	19950719	1055	*<.05	6.4	7.3	694	12.5
0321	UF	Environmental	19960716	1345	9.6	4.3	6.7	570	14
0321	UF	Environmental	19970729	1700	6.2	6.3	7.1	632	12.5
0401	CF	Environmental	19950720	0815	4.5	8.3	7.0	553	12
0401	CF	Environmental	19960709	1347	5.1	7.9	7.0	560	12
0402	UF	Environmental	19950720	1053	9.7	7.0	6.9	678	12.5
0402	UF	Environmental	19960709	1247	*12	8.2	6.9	717	13
0402	UF	Blank	19960709	1252	.06	--	--	--	--
0402	UF	Duplicate	19960709	1257	*11	6.9	6.9	717	13
0403	UF	Environmental	19950720	1125	1.6	4.8	6.8	543	13
0403	UF	Environmental	19960709	1429	1.6	4.7	7.0	538	13
0404	UF	Environmental	19950719	1506	6.5	5.9	6.9	590	13.5
0404	UF	Environmental	19950719	1733	3.7	7.2	7.4	511	12.5
0404	UF	Environmental	19960709	1512	3.9	6.1	7.1	572	13.5
0405	UF	Environmental	19950719	1509	6.5	5.9	6.9	590	13.5
0406	CF	Environmental	19950724	1800	3.4	3.7	6.8	561	12
0406	CF	Environmental	19950726	1500	3.4	3.9	7.0	554	12.5
0406	CF	Environmental	19960709	1655	3.0	3.4	6.9	554	12.5
0407	UF	Environmental	19950720	1220	8.3	7.3	6.8	613	13.5
0407	UF	Environmental	19960709	1157	9.2	7.8	7.0	628	13
0408	UF	Environmental	19950719	1655	1.9	2.0	7.0	528	13
0408	UF	Environmental	19960710	0832	2.0	2.2	7.2	587	12
0409	UF	Environmental	19960709	1004	*11	7.3	7.1	741	15

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (μS/cm)	Water temperature (°C)
0410	CF	Environmental	19950726	1345	<.05	6.3	7.5	502	14
0410	CF	Environmental	19960710	0958	.23	6.5	7.5	511	14
0411	CF	Environmental	19960719	1040	1.5	.9	7.1	674	14
0412	UF	Environmental	19960710	1047	*15	6.9	7.0	718	12.5
0413	UF	Environmental	19950724	1055	8.4	5.0	7.1	616	12
0413	UF	Environmental	19960715	1143	4.1	4.6	7.1	639	12.5
0414	UF	Environmental	19950728	1620	3.4	3.4	6.8	454	13.5
0414	UF	Environmental	19960715	1103	4.2	4.8	6.9	468	13
0415	UF	Environmental	19950724	0810	5.6	8.5	6.7	601	12.5
0415	UF	Environmental	19960710	1125	8.2	8.4	7.0	668	13
0416	UF	Environmental	19960711	1234	8.7	17	7.1	682	13
0417	CF	Blank	19960711	1414	.06	--	--	--	--
0417	CF	Duplicate	19960711	1415	*18	5.1	7.1	823	12
0417	CF	Environmental	19960711	1416	*18	5.0	7.1	823	12
0418	CF	Environmental	19960711	1107	4.6	5.8	7.1	736	13
0419	CF	Environmental	19960711	1319	6.0	9.3	7.0	473	12.5
0420	UF	Environmental	19950724	0950	5.5	9.5	7.3	527	13
0420	UF	Environmental	19960719	1139	7.1	8.8	6.8	576	14
0501	CF	Environmental	19950725	1721	.18	.3	7.3	550	13.5
0501	CF	Duplicate	19950725	1726	.17	.3	7.3	550	13.5
0501	CF	Blank	19950725	1731	<.05	--	--	--	--
0501	CF	Environmental	19960716	0833	.25	.8	7.4	560	14
0502	UF	Environmental	19960712	1445	*12	6.0	6.4	456	13
0503	UF	Environmental	19950726	1359	*27	5.3	6.2	616	14
0503	UF	Environmental	19960709	0911	*27	6.5	6.4	802	12
0504	UF	Environmental	19960712	0915	8.7	8.9	6.8	620	12.5
0504	UF	Duplicate	19960712	0920	9.3	8.9	6.8	620	12.5
0504	UF	Blank	19960712	0925	<.05	--	--	--	--
0505	UF	Environmental	19950717	1529	*12	7.8	6.7	646	13.5
0505	UF	Environmental	19960709	1042	*13	9.0	7.1	647	12
0506	UF	Environmental	19950830	1615	*13	8.4	7.2	560	13
0507	UF	Environmental	19950720	1305	6.2	8.7	6.9	611	12
0507	UF	Environmental	19960708	1600	6.0	7.4	7.1	603	13
0508	UF	Environmental	19950720	1345	4.2	5.0	7.0	571	13.5
0508	UF	Blank	19950720	1350	<0.05	--	--	--	--
0508	UF	Duplicate	19950720	1355	4.2	5.0	7.0	571	13.5
0508	UF	Environmental	19960708	1518	5.4	6.4	7.0	426	13.5
0509	CF	Environmental	19960708	1414	3.7	.8	7.4	482	15
0510	CF	Environmental	19950721	1420	*11	10	7.5	782	12.5
0510	CF	Environmental	19960709	0953	*12	9.6	7.1	772	12.5
0511	UF	Environmental	19950720	1425	*18	9.4	7.4	837	12.5
0511	UF	Environmental	19960715	1712	*18	7.8	7.2	865	13.5
0512	UF	Environmental	19950829	1430	4.8	5.0	7.1	550	14
0512	UF	Environmental	19960715	1628	8.9	6.7	7.1	646	13

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (μS/cm)	Water temperature (°C)
0512	UF	Blank	19960715	1633	.05	--	--	--	--
0512	UF	Duplicate	19960715	1638	8.7	6.7	7.1	646	13
0601	UF	Environmental	19950728	1590	4.5	6.9	7.0	534	12
0602	UF	Environmental	19950727	0938	7.1	9.1	7.2	785	14
0602	UF	Environmental	19960716	1100	*14	7.2	6.9	775	12.5
0603	CF	Environmental	19950829	1340	2.9	7.5	7.3	480	14.5
0603	CF	Environmental	19960814	1000	3.1	9.8	7.1	566	13
0604	UF	Environmental	19950724	1117	6.0	6.4	7.1	590	13
0604	UF	Environmental	19960716	1237	8.0	7.1	7.0	686	13.1
0605	UF	Environmental	19950724	1148	6.2	8.0	7.6	576	12.5
0605	UF	Environmental	19960712	1040	7.1	8.9	6.9	579	12.5
0606	UF	Environmental	19950724	1234	7.4	8.8	7.0	637	13
0606	UF	Environmental	19960716	1502	*10	7.4	7.0	644	13.7
0607	UF	Environmental	19960716	1207	*13	9.4	7.5	676	13
0608	UF	Environmental	19950724	1345	5.6	2.5	6.9	609	12.5
0608	UF	Environmental	19960712	1115	6.2	2.1	6.8	606	13
0609	UF	Environmental	19960717	1445	1.7	4.5	6.6	548	13
0610	UF	Environmental	19950719	1800	2.1	4.6	6.8	555	13.5
0610	UF	Environmental	19960719	1550	2.0	3.8	6.5	544	14
0610	UF	Duplicate	19960719	1555	1.8	3.8	6.5	544	14
0610	UF	Blank	19960719	1600	.12	--	--	--	--
0611	UF	Environmental	19950718	1755	*10	13	7.1	715	12.5
0611	UF	Environmental	19960715	1735	*15	11	7.3	752	13
0612	UF	Environmental	19960712	955	6.2	7.1	6.8	591	12
0613	UF	Environmental	19950724	1450	4.5	6.7	7.1	548	13.5
0613	UF	Environmental	19960716	1334	4.5	5.9	7.1	550	13
0614	UF	Environmental	19960716	1710	*12	7.3	6.7	694	12
0615	CF	Environmental	19950724	1419	6.8	6.9	7.1	587	13.5
0615	CF	Environmental	19950727	1220	4.6	5.9	6.8	503	13.5
0615	CF	Environmental	19960813	0930	5.4	7.8	6.7	551	13
0701	CF	Environmental	19950719	1032	.73	.1	7.3	414	13.5
0701	CF	Environmental	19960709	1630	1.5	0.2	7.0	479	13.5
0701	CF	Environmental	19960717	1431	1.1	.2	7.2	470	14.5
0702	CF	Environmental	19960717	1218	6.2	4.0	7.1	614	13.5
0703	CF	Environmental	19960730	1140	4.7	1.5	7.1	1,490	13
0704	CF	Environmental	19950721	0830	.12	.3	7.0	398	14
0704	CF	Environmental	19960710	1125	.96	.5	6.6	401	14
0705	CF	Environmental	19960718	1008	.12	.2	7.3	488	14
0706	CF	Environmental	19950725	1500	.12	--	7.2	690	13.5
0706	CF	Environmental	19960709	1550	*6.8	<.1	6.8	677	13
0706	CF	Environmental	19960718	1543	.37	.2	7.1	427	14
0706	CF	Environmental	19970729	1240	.16	.6	7.0	669	13
0707	CF	Environmental	19950719	1207	1.4	.2	7.1	646	14
0707	CF	Blank	19950719	1212	<.05	--	--	--	--

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (μS/cm)	Water temperature (°C)
0707	CF	Duplicate	19950719	1217	1.4	.2	7.1	646	14
0707	CF	Environmental	19960709	1515	3.6	.5	6.6	964	13.5
0707	CF	Environmental	19960717	1602	2.0	5.6	7.1	777	15
0708	CF	Environmental	19950726	1617	2.5	.1	7.0	701	13.5
0708	CF	Environmental	19960717	1513	3.4	.2	7.1	726	15
0709	CF	Environmental	19950721	1622	6.2	14	7.1	647	13
0709	CF	Blank	19950721	1627	<.05	--	--	--	--
0709	CF	Duplicate	19950721	1632	6.1	14	7.1	647	13
0709	CF	Environmental	19960717	1705	*11	3.0	7.0	729	13.5
0709	CF	Environmental	19970722	1503	7.2	2.5	6.8	609	12
0710	CF	Environmental	19960719	1535	6.0	2.9	7.1	1,300	13
0711	CF	Environmental	19960718	841	2.4	6.7	7.4	553	14.6
0712	CF	Environmental	19950725	1325	1.5	.4	7.1	521	13
0712	CF	Environmental	19960710	0900	1.3	.4	6.9	538	13
0713	CF	Environmental	19960710	0825	*12	1.6	6.7	761	13.5
0714	CF	Environmental	19950721	1435	<.05	.1	7.1	500	15
0714	CF	Blank	19960719	1616	.07	--	--	--	--
0714	CF	Environmental	19960719	1621	.10	.4	7.1	504	15
0714	CF	Duplicate	19960719	1626	.10	.4	7.1	504	15
0715	UF	Environmental	19960719	1433	6.3	7.4	6.9	590	14
0716	UF	Environmental	19950726	1515	4.5	6.8	6.9	762	13.5
0716	UF	Environmental	19960716	1128	4.6	6.8	7.0	738	12.5
0717	CF	Environmental	19950725	1635	2.7	1.4	7.4	605	13.5
0717	CF	Environmental	19960716	1020	*18	8.6	7.0	837	12.5
0717	CF	Environmental	19970722	1401	6.8	4.9	6.9	641	12.5
0718	UF	Environmental	19950724	0833	7.0	10	8.0	615	13.5
0718	UF	Environmental	19960712	1215	7.3	9.0	6.9	609	13
0719	UF	Environmental	19950717	1728	2.8	6.7	6.9	430	13
0719	UF	Environmental	19960712	1405	3.1	7.7	6.5	424	13
0801	UF	Environmental	19950726	1024	2.9	4.5	7.0	490	12.5
0801	UF	Environmental	19960709	1710	2.6	5.1	6.7	535	12.5
0801	UF	Environmental	19960718	1338	5.0	5.6	7.1	392	13
0802	UF	Environmental	19950718	0905	*11	6.1	7.0	788	12.5
0802	UF	Environmental	19960718	1403	9.3	7.0	7.0	487	13
0803	UF	Environmental	19960710	1520	2.6	.9	6.5	781	12.5
0804	CF	Environmental	19960717	1020	.13	1.0	7.2	555	13.5
0805	CF	Environmental	19950830	1415	.14	.4	7.4	520	13
0806	CF	Environmental	19950718	1053	.66	.1	7.3	557	13
0806	CF	Blank	19950718	1058	<.05	--	--	--	--
0806	CF	Duplicate	19950718	1103	.75	.1	7.3	557	13
0806	CF	Environmental	19950718	1340	2.0	.2	7.0	677	13
0806	CF	Environmental	19960710	1300	1.5	.1	6.8	583	13
0806	CF	Duplicate	19960710	1305	1.4	.1	6.8	583	13
0806	CF	Blank	19960710	1310	<.05	--	--	--	--

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (μS/cm)	Water temperature (°C)
0806	CF	Environmental	19960710	1350	2.7	.2	6.8	690	12.5
0807	CF	Environmental	19950718	1230	<.05	.1	7.1	616	13
0807	CF	Environmental	19960717	0857	.12	.5	7.2	616	14
0808	UF	Environmental	19950727	1217	2.5	2.9	7.0	558	13.5
0808	UF	Environmental	19960718	1048	3.6	3.2	7.2	583	13
0809	UF	Environmental	19950718	1430	8.0	6.8	6.8	550	13
0809	UF	Environmental	19960718	1137	*16	8.4	6.8	655	13.5
0809	UF	Blank	19960718	1142	.08	--	--	--	--
0809	UF	Duplicate	19960718	1147	*16	8.4	6.8	655	13.5
0809	UF	Environmental	19970722	1620	*10	8.2	6.9	560	12
0810	UF	Environmental	19950718	1550	3.5	9.3	7.4	500	13.5
0811	CF	Environmental	19950727	1510	4.4	6.4	7.8	591	13
0811	CF	Environmental	19960711	1320	4.8	4.6	6.8	590	12.5
0812	UF	Environmental	19950801	0830	5.3	.4	7.1	907	13.5
0812	UF	Environmental	19960718	1231	5.6	.1	6.9	915	13.5
0813	UF	Environmental	19950718	1755	2.2	1.9	7.1	539	13
0813	CF	Environmental	19960709	0915	1.7	1.7	7.0	533	13
0814	UF	Environmental	19950718	1045	.09	.3	7.2	501	13.5
0814	UF	Environmental	19960709	0945	.10	.1	7.2	503	13.5
0815	UF	Environmental	19950718	1145	1.0	3.7	6.8	335	13.5
0815	UF	Environmental	19960709	1030	1.1	3.8	6.9	317	13
0816	CF	Environmental	19950725	1435	3.9	6.9	7.6	612	14.5
0816	CF	Environmental	19960719	1050	4.1	5.6	6.9	597	14
0817	UF	Environmental	19960719	1135	.38	.5	6.9	645	14
0901	CF	Environmental	19950725	0930	1.4	1.9	--	581	--
0901	CF	Environmental	19960730	1130	0.4	0.6	7.2	579	14
0902	UF	Environmental	19960719	1030	.50	.7	7.3	646	12.5
0902	UF	Environmental	19970731	1425	.31	1.1	7.0	556	12
0903	UF	Environmental	19960719	1200	*12	7.6	7.2	690	12
0904	CF	Environmental	19950725	1130	8.2	4.3	--	627	--
0905	CF	Environmental	19960730	1200	6.0	--	6.9	622	12.5
0905	CF	Environmental	19960904	1400	9.9	6.7	6.9	580	13
0906	UF	Environmental	19950727	1030	<.05	<.1	7.3	529	12.5
0906	UF	Duplicate	19950727	1035	<.05	<.1	7.3	529	12.5
0906	UF	Blank	19950727	1040	<.05	--	--	--	--
0906	UF	Environmental	19960722	1230	.09	.6	7.1	526	12.5
0907	CF	Environmental	19950727	0930	.08	.2	7.4	550	13.5
0907	CF	Environmental	19960730	1600	3.6	2.5	7.1	689	12.5
0908	CF	Environmental	19950725	1230	.15	<.1	7.3	555	13
0909	CF	Environmental	19950726	1230	1.6	.6	7.0	931	12.5
0909	CF	Environmental	19960730	1330	1.9	.8	6.9	925	12.5
0910	UF	Environmental	19950726	1400	4.2	2.6	6.9	693	12.5
0910	UF	Environmental	19960722	1200	6.9	2.4	6.9	701	12.5
0911	CF	Environmental	19950726	1300	1.2	3.3	6.9	533	13

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (µS/cm)	Water temperature (°C)
0911	CF	Environmental	19960730	1300	1.5	3.2	6.8	534	13.5
0912	CF	Environmental	19960712	1112	4.5	.4	7.2	820	13
0913	CF	Environmental	19960712	1507	4.2	5.9	7.1	1,380	13
1001	CF	Environmental	19950728	1100	<.05	<.1	8.2	780	14
1001	CF	Environmental	19960718	1415	.76	--	7.0	1,070	12.5
1002	UF	Environmental	19950728	1130	*7.5	4.6	6.9	1,050	12
1002	UF	Environmental	19960718	1400	*.11	--	8.3	771	14.5
1003	CF	Environmental	19950727	900	*1.5	--	7.5	605	14.5
1003	CF	Environmental	19960712	1340	*17	2.3	7.1	947	12
1004	CF	Environmental	19950725	1400	5.5	<.1	7.1	1,110	14.5
1004	CF	Environmental	19960722	1300	6.1	<.1	7.0	1,140	14.5
1005	CF	Environmental	19950726	0930	1.7	5.4	7.3	630	12.5
1005	CF	Environmental	19960730	1400	1.4	4.8	7.1	639	12.5
1006	CF	Environmental	19960730	1500	1.8	6.0	7.1	752	12.5
1006	CF	Duplicate	19960730	1505	1.8	6.0	7.1	752	12.5
1006	CF	Blank	19960730	1510	.10	--	--	--	--
1101	UF	Environmental	19950724	1115	9.2	6.7	7.0	615	13
1101	UF	Environmental	19960716	1200	*11	6.9	7.0	616	13.5
1102	CF	Environmental	19950718	1500	.05	.5	7.5	571	15
1102	CF	Environmental	19960716	1100	.12	.2	7.3	570	15
1102	CF	Duplicate	19960716	1105	.09	.2	7.3	570	15
1102	CF	Blank	19960716	1110	.13	--	--	--	--
1103	UF	Environmental	19950718	1615	5.4	8.3	7.1	517	13
1103	UF	Environmental	19960717	1630	5.6	6.2	6.8	509	14
1104	UF	Environmental	19960717	1500	*18	--	8.8	712	14
1105	UF	Environmental	19960717	1530	8.8	6.7	7.1	609	14
1106	UF	Environmental	19950727	1430	*11	--	7.0	514	13
1106	UF	Environmental	19960715	1500	*10	8.2	6.7	544	13.5
1107	CF	Environmental	19950719	1115	3.0	3.1	7.0	573	13
1107	CF	Duplicate	19950719	1120	2.9	3.1	7.0	573	13
1107	CF	Blank	19950719	1125	.05	--	--	--	--
1108	UF	Environmental	19950719	1530	*23	5.5	6.6	1,510	12
1108	UF	Environmental	19960718	1000	*22	--	6.7	1,430	12.5
1109	CF	Environmental	19960716	1430	*21	.8	7.2	1,060	13
1110	UF	Environmental	19950718	1700	*14	13	7.0	1,030	12
1110	UF	Duplicate	19950718	1705	*13	13	7.0	1,030	11
1110	UF	Blank	19950718	1710	<.05	--	--	--	--
1110	UF	Environmental	19960716	0800	*17	9.4	6.9	1,040	12
1111	UF	Environmental	19960904	1500	8.7	7.6	6.8	572	12
1112	UF	Environmental	19950718	1745	5.1	4.0	7.0	809	12.5
1112	UF	Environmental	19960703	1700	5.2	--	6.7	603	12.5
1113	CF	Environmental	19950719	1400	<.05	<.1	7.6	568	14.5
1113	CF	Environmental	19960719	1400	.09	<.1	7.4	557	14

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature (°C)
1113	CF	Duplicate	19960719	1405	.09	<.1	7.4	557	14
1113	CF	Blank	19960719	1416	.16	--	--	--	--
1114	UF	Environmental	19950726	1745	5.0	6.5	6.9	508	13.5
1114	UF	Environmental	19960730	1100	4.9	6.0	6.9	505	14
1115	UF	Environmental	19950720	1330	6.1	6.9	7.0	451	13.5
1115	UF	Environmental	19960719	1300	5.0	7.1	6.8	449	13.5
1116	UF	Environmental	19950724	1430	9.0	7.0	6.8	569	13
1116	UF	Environmental	19960715	1230	*12	--	7.2	576	13
1117	UF	Environmental	19950724	1330	9.6	--	7.2	602	13
1117	UF	Environmental	19960718	1200	9.4	--	6.6	602	13
1118	CF	Environmental	19950725	0830	6.1	9.0	--	457	--
1118	CF	Environmental	19960715	1130	5.9	8.9	6.8	467	13
1119	UF	Environmental	19950724	1230	5.7	--	7.1	539	13
1119	UF	Duplicate	19950724	1235	5.5	--	7.1	539	13
1119	UF	Blank	19950724	1240	.06	--	--	--	--
1119	UF	Environmental	19960715	1600	7.8	--	6.1	549	13.5
1120	UF	Environmental	19950728	1600	*14	5.0	6.9	1,260	12.5
1121	UF	Environmental	19950724	1540	5.8	6.6	7.1	530	12
1121	UF	Environmental	19960718	1300	6.7	--	6.9	552	12.5
1122	UF	Environmental	19960730	0930	*12	11	6.7	691	13
1123	UF	Environmental	19950724	1730	3.3	5.6	6.9	560	13
1123	UF	Environmental	19960715	1400	3.9	5.7	6.8	562	12.5
1124	CF	Environmental	19950726	0745	1.6	1.5	7.2	862	14
1124	CF	Environmental	19960715	1000	.37	.3	6.9	834	13.5
1125	UF	Environmental	19950724	1615	5.7	7.1	6.9	705	13.5
1125	UF	Environmental	19960719	1500	4.6	7.9	7.1	687	13
1126	CF	Environmental	19960717	0800	.12	1.2	8.0	835	14.5
1127	UF	Environmental	19950721	1000	1.7	.2	7.0	540	12.5
1127	UF	Environmental	19960717	1730	1.9	--	6.7	557	13
1201	CF	Environmental	19950727	1300	.11	16	8.1	508	16
1201	CF	Environmental	19960717	1300	.13	.1	7.3	512	13.5
1201	CF	Duplicate	19960717	1305	.13	.1	7.3	512	13.5
1201	CF	Blank	19960717	1310	.08	--	--	--	--
1202	CF	Environmental	19950717	1710	2.4	1.8	7.8	510	13
1202	CF	Duplicate	19950717	1715	2.5	1.8	7.8	510	13
1202	CF	Blank	19950717	1720	<.05	--	--	--	--
1202	CF	Environmental	19960711	0955	.21	.3	6.9	560	13
1203	CF	Environmental	19950718	0915	.61	.4	7.2	646	14
1203	CF	Environmental	19960711	0920	1.1	.29	6.7	625	13.5
1204	CF	Environmental	19960717	1200	2.7	1.1	7.2	572	13.5
1205	UF	Environmental	19950719	0845	*16	11	7.1	990	12.5
1205	UF	Environmental	19960717	1030	9.6	4.4	7.0	793	13.5
1205	UF	Environmental	19970805	1344	*15	10	6.8	895	12.5
1206	CF	Environmental	19960717	1100	3.5	6.0	6.9	475	13

Table 8. Nitrate concentrations and field measurements for water samples from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1997--Continued

Well identification number[1] (fig. 8)	Hydro-geologic condition	Sample type	Sample date	Sample time	Nitrate and nitrite as nitrogen, dissolved (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conduct-ance, field (μS/cm)	Water temperature (°C)
1207	UF	Environmental	19950717	1504	.25	.4	7.0	893	13
1207	UF	Environmental	19960711	1120	.42	.4	6.6	902	12.5
1208	UF	Environmental	19950724	0845	.14	.1	7.4	611	13
1209	UF	Environmental	19950717	1830	5.4	7.3	7.1	565	12.5
1209	UF	Environmental	19960722	1100	5.9	1.2	--	--	14
1210	UF	Environmental	19950718	1045	1.4	4.7	7.2	447	13.5
1210	UF	Environmental	19960722	1000	1.6	4.5	7.0	450	14
1211	UF	Environmental	19950727	1230	1.9	--	7.6	558	15
1211	UF	Environmental	19960716	1500	.33	1.1	7.1	563	12
1212	CF	Environmental	19950719	0930	*8.6	5.6	7.0	483	12.5
1212	CF	Environmental	19960718	0830	.83	--	7.2	499	13.5
1212	CF	Environmental	19970729	1053	.75	1.2	6.9	463	13
1213	UF	Environmental	19950718	1300	*20	13	7.0	1,200	13
1213	UF	Environmental	19960716	1230	*20	7.8	6.9	1,230	13
1214	CF	Environmental	19950721	1425	<.05	<.1	7.6	539	15.5
1214	CF	Environmental	19960718	1100	.08	--	7.3	548	16
1215	CF	Environmental	19960717	1400	6.4	6.4	7.1	622	13
1216	CF	Environmental	19950720	1010	.10	3.4	7.5	601	14
1216	CF	Environmental	19960719	0900	.12	--	7.4	583	13.5

[1] Well identification number was assigned using management-zone number as the first two numbers; the second two numbers indicate the sequential well number.

Table 9. Statistical summary of nitrate concentrations, field measurements, and well depth by aquifer, hydrogeologic condition, and management zone from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996

[mg/L, milligrams per liter; ft; foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; <, less than; --, not applicable]

Grouping	Variable	Unit of measure	Number of observations or samples	Minimum	25th percentile	Median	75th percentile	Maximum	Mean	Standard deviation
All data	Dissolved nitrate and nitrite as nitrogen	mg/L	197	0.06	1.7	4.6	8.9	27	6.0	5.4
	Specific conductance, field	µS/cm	181	320	550	600	690	960	620	120
	Oxygen, dissolved, field	mg/L	172	<.1	2.3	5.9	7.5	17	5.1	3.1
	pH, field	standard units	195	6.1	6.8	7.0	7.1	8.8	--	0.31
	Well depth	ft	196	40	137	184	243	485	194	80
Differentiated by aquifer										
Shallow part of the High Plains aquifer	Dissolved nitrate and nitrite as nitrogen	mg/L	104	.09	3.4	6.3	11	27	7.6	5.7
	Specific conductance, field	µS/cm	95	320	550	610	690	920	620	120
	Oxygen, dissolved, field	mg/L	90	.1	4.5	6.9	7.8	11	6.0	2.6
	pH, field	standard units	103	6.1	6.8	6.9	7.1	8.8	6.9	.32
	Well depth	ft	103	40	106	140	174	364	143	53
Deep part of the High Plains aquifer	Dissolved nitrate and nitrite as nitrogen	mg/L	86	.06	1.1	3.4	5.9	21	4.2	4.3
	Specific conductance, field	µS/cm	80	400	530	580	690	960	620	120
	Oxygen, dissolved, field	mg/L	78	<.1	.8	3.6	6.6	17	4.1	3.4
	pH, field	standard units	85	6.5	6.9	7.0	7.2	8.3	7.0	.30
	Well depth	ft	86	136	201	241	286	462	244	59
Undifferentiated part of the High Plains aquifer	Dissolved nitrate and nitrite as nitrogen	mg/L	3	1.7	1.7	6.4	11	11	6.4	4.7
	Specific conductance, field	µS/cm	3	550	550	580	730	730	620	100
	Oxygen, dissolved, field	mg/L	3	4.5	4.5	7.1	7.9	7.9	6.5	1.8
	pH, field	standard units	3	6.6	6.6	6.7	6.8	6.8	6.7	0.10
	Well depth	ft	3	181	181	190	201	201	191	10

Table 9. Statistical summary of nitrate concentrations, field measurements, and well depth by aquifer, hydrogeologic condition, and management zone from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996--Continued

Grouping	Variable	Unit of measure	Number of observations or samples	Minimum	25th percen-tile	Median	75th percen-tile	Maxi-mum	Mean	Standard deviation
Dakota aquifer	Dissolved nitrate and nitrite as nitrogen	mg/L	4	0.08	0.08	0.11	0.60	0.76	0.26	0.33
	Specific conductance, field	µS/cm	3	550	550	560	570	570	560	11
	Oxygen, dissolved, field	mg/L	1	.2	--	--	--	--	--	--
	pH, field	standard units	4	7.0	7.1	7.3	7.4	7.4	7.3	.17
	Well depth	ft	4	358	361	394	467	485	408	58
Differentiated by hydrogeologic condition										
Unconfined part of the High Plains aquifer	Dissolved nitrate and nitrite as nitrogen	mg/L	123	.09	3.0	6.2	11	27	7.3	5.5
	Specific conductance, field	µS/cm	114	320	550	610	690	920	620	120
	Oxygen, dissolved, field	mg/L	109	.1	4.4	6.7	7.9	17	6.1	2.8
	pH, field	standard units	122	6.1	6.8	6.9	7.1	8.8	7.0	.34
	Well depth	ft	122	40	118	153	195	364	155	56
Confined part of the High Plains aquifer	Dissolved nitrate and nitrite as nitrogen	mg/L	74	.06	.67	2.9	5.0	21	3.7	4.3
	Specific conductance, field	µS/cm	67	400	530	580	680	960	610	130
	Oxygen, dissolved, field	mg/L	63	<.1	.50	2.9	6.3	9.8	3.5	3.1
	pH, field	standard units	73	6.5	6.9	7.1	7.2	8.0	7.0	.30
	Well depth	ft	74	136	204	247	294	485	258	72
Differentiated by management zone										
Management zone 1	Dissolved nitrate and nitrite as nitrogen	mg/L	16	.12	2.3	4.7	13	21	7.9	7.3
	Specific conductance, field	µS/cm	13	350	580	620	740	870	640	130
	Oxygen, dissolved, field	mg/L	15	1.5	3.9	7.1	8.0	9.6	6.2	2.6
	pH, field	standard units	16	6.7	6.9	7.1	7.2	8.3	7.1	0.36
	Well depth	ft	16	125	164	205	255	364	212	61

Table 9. Statistical summary of nitrate concentrations, field measurements, and well depth by aquifer, hydrogeologic condition, and management zone from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996--Continued

Grouping	Variable	Unit of measure	Number of observations or samples	Minimum	25th percentile	Median	75th percentile	Maximum	Mean	Standard deviation
Management zone 2	Dissolved nitrate and nitrite as nitrogen	mg/L	15	0.82	2.6	5.0	11	13	6.2	4.1
	Specific conductance, field	µS/cm	15	360	510	630	690	920	630	150
	Oxygen, dissolved, field	mg/L	13	.9	4.3	6.1	7.5	8.5	5.8	2.1
	pH, field	standard units	15	6.6	6.7	6.8	7.0	7.4	6.9	.22
	Well depth	ft	14	134	144	193	202	221	182	30
Management zone 3	Dissolved nitrate and nitrite as nitrogen	mg/L	21	.40	1.2	3.3	5.3	11	3.8	2.9
	Specific conductance, field	µS/cm	20	430	540	600	670	870	620	120
	Oxygen, dissolved, field	mg/L	21	.1	2.8	5.6	7.3	8.7	5.1	2.6
	pH, field	standard units	21	6.5	6.6	6.7	6.8	7.2	6.8	.22
	Well depth	ft	21	122	163	184	201	228	179	29
Management zone 4	Dissolved nitrate and nitrite as nitrogen	mg/L	20	.06	2.3	4.9	8.6	15	5.7	4.0
	Specific conductance, field	µS/cm	19	470	550	590	680	740	610	86
	Oxygen, dissolved, field	mg/L	19	.9	4.7	6.5	8.2	17	6.7	3.4
	pH, field	standard units	19	6.8	6.9	7.0	7.1	7.5	7.0	.15
	Well depth	ft	20	130	156	232	249	351	214	59
Management zone 5	Dissolved nitrate and nitrite as nitrogen	mg/L	12	.25	5.6	10	13	27	11	7.1
	Specific conductance, field	µS/cm	12	430	500	610	740	870	620	140
	Oxygen, dissolved, field	mg/L	12	.8	6.1	7.1	8.8	9.6	6.5	2.9
	pH, field	standard units	12	6.4	6.9	7.1	7.2	7.4	7.0	0.33
	Well depth	ft	12	80	115	155	177	313	165	72

Table 9. Statistical summary of nitrate concentrations, field measurements, and well depth by aquifer, hydrogeologic condition, and management zone from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996--Continued

Grouping	Variable	Unit of measure	Number of observations or samples	Minimum	25th percentile	Median	75th percentile	Maximum	Mean	Standard deviation
Management zone 6	Dissolved nitrate and nitrite as nitrogen	mg/L	15	1.7	4.5	6.2	12	15	7.5	4.4
	Specific conductance, field	µS/cm	15	530	550	590	690	780	620	80
	Oxygen, dissolved, field	mg/L	15	2.1	5.9	7.2	8.9	11	7.1	2.3
	pH, field	standard units	15	6.5	6.7	6.9	7.1	7.5	6.9	.26
	Well depth	ft	15	63	106	171	181	230	153	51
Management zone 7	Dissolved nitrate and nitrite as nitrogen	mg/L	19	.10	2.4	4.7	7.3	18	5.7	4.6
	Specific conductance, field	µS/cm	17	400	500	610	730	960	640	140
	Oxygen, dissolved, field	mg/L	18	.2	.5	3.0	7.0	9.0	3.6	3.2
	pH, field	standard units	19	6.5	6.8	7.0	7.1	7.4	7.0	.21
	Well depth	ft	19	50	185	273	299	351	239	75
Management zone 8	Dissolved nitrate and nitrite as nitrogen	mg/L	17	.10	.26	2.6	4.5	16	3.4	4.1
	Specific conductance, field	µS/cm	17	320	510	580	630	920	580	130
	Oxygen, dissolved, field	mg/L	15	.1	.5	3.2	5.6	9.3	3.5	3.1
	pH, field	standard units	17	6.5	6.8	6.9	7.2	7.4	7.0	.25
	Well depth	ft	17	70	138	205	239	260	185	63
Management zone 9	Dissolved nitrate and nitrite as nitrogen	mg/L	13	.09	.45	3.6	6.5	12	4.0	3.8
	Specific conductance, field	µS/cm	12	530	560	630	700	930	660	120
	Oxygen, dissolved, field	mg/L	12	<.1	.6	1.6	5.2	7.6	2.6	2.7
	pH, field	standard units	13	6.8	6.9	7.1	7.2	7.3	7.1	.17
	Well depth	ft	13	40	118	243	278	304	207	85

Table 9. Statistical summary of nitrate concentrations, field measurements, and well depth by aquifer, hydrogeologic condition, and management zone from the ground-water-quality monitoring network of domestic and registered wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through September 1996--Continued

Grouping	Variable	Unit of measure	Number of observations or samples	Minimum	25th percen-tile	Median	75th percen-tile	Maxi-mum	Mean	Standard deviation
Management zone 10	Dissolved nitrate and nitrite as nitrogen	mg/L	6	0.11	0.60	1.6	8.8	17	4.5	6.5
	Specific conductance, field	µS/cm	4	640	670	760	900	950	780	130
	Oxygen, dissolved, field	mg/L	3	2.3	2.3	4.8	6.0	6.0	4.4	1.9
	pH, field	standard units	6	7.0	7.0	7.1	7.4	8.3	7.3	.51
	Well depth	ft	6	95	172	263	384	430	269	120
Management zone 11	Dissolved nitrate and nitrite as nitrogen	mg/L	27	.09	3.9	6.7	12	22	8.1	6.2
	Specific conductance, field	µS/cm	23	450	550	570	620	840	600	98
	Oxygen, dissolved, field	mg/L	18	.2	2.6	6.5	8.0	11	5.7	3.3
	pH, field	standard units	27	6.1	6.7	6.9	7.1	8.8	7.0	.49
	Well depth	ft	27	42	95	128	215	462	168	115
Management zone 12	Dissolved nitrate and nitrite as nitrogen	mg/L	16	.08	.16	.97	5.3	20	3.3	5.3
	Specific conductance, field	µS/cm	14	450	510	570	620	900	590	120
	Oxygen, dissolved, field	mg/L	11	.3	.4	1.2	6.0	7.8	3.0	2.8
	pH, field	standard units	15	6.6	6.9	7.1	7.3	7.4	7.1	.24
	Well depth	ft	16	65	123	175	261	485	198	106

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C ; °C, degrees Celsius; UF, unconfined part of the High Plains aquifer; CF, confined part of the High Plains aquifer; sampling date, yyyymmdd; --, no data; Con., continued]

Nested moni-toring well number	Hydro-geo-logic condi-tion	Sampling date	Sample type	Dissolved nitrate and nitrite con-centration as nitrogen (mg/L)	Oxygen, dis-solved, field (mg/L)	pH, field (stan-dard units)	Specific conduc-tance, field (µS/cm)	Water temper-ature, field (°C)
1A	UF	19951108	Environmental	12	10	7.9	844	12
		19960109	Environmental	14	9.2	7.1	845	12.5
		19960312	Environmental	14	8.9	7.1	800	12.5
		19960422	Environmental	14	8.9	7.6	795	11.5
		19960508	Environmental	16	7.7	7.6	920	13.5
		19960612	Environmental	16	11	7.7	814	12.5
		19960724	Environmental	16	11	7.0	984	13.5
		19960910	Environmental	17	9.7	7.1	760	14
		19961112	Environmental	18	8.5	6.9	926	12
		19970121	Environmental	19	8.2	7.0	922	12
		19970317	Environmental	20	8.7	6.0	971	10.5
		19970519	Environmental	21	--	7.3	986	12.5
1B	CF	19951108	Environmental	<.05	.2	8.4	511	13
		19960109	Environmental	.1	.3	7.3	540	13
		19960206	Environmental	--	6.9	7.2	840	12.5
		19960312	Environmental	<.05	.3	7.6	515	13.5
		19960422	Environmental	<.05	1.6	7.9	500	12
		19960508	Environmental	.1	.5	7.9	544	12
		19960612	Environmental	.14	.6	7.4	477	13
		19960724	Environmental	.12	.5	7.3	558	14
		19960910	Environmental	.14	.3	7.3	541	14
		19961112	Environmental	.10	.4	7.2	532	13
		19970121	Environmental	.10	1.1	7.3	522	13
		19970317	Environmental	.07	1.1	6.3	516	11
		19970519	Environmental	.08	--	7.6	509	13
2A	UF	19951108	Environmental	6.4	12	7.8	622	12.5
		19960109	Environmental	6.7	8.3	6.9	620	13
		19960206	Environmental	6.2	10	7.0	600	13
		19960312	Environmental	6.6	8.4	6.9	580	13
		19960422	Environmental	6.1	11	7.4	545	12
		19960508	Environmental	6.8	9.2	7.5	630	13
		19960612	Environmental	6.6	11	7.5	559	13
		19960724	Environmental	7.1	10	6.9	646	13.5
		19960910	Environmental	7.4	10	7.0	570	14.5
		19961112	Environmental	6.9	8.0	6.8	615	12.5
		19970121	Environmental	6.3	8.0	7.0	614	12

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997--Continued

Nested monitoring well number	Hydrogeologic condition	Sampling date	Sample type	Dissolved nitrate and nitrite concentration as nitrogen (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature, field (°C)
2A Con.	UF	19970317	Environmental	6.5	11	6.8	643	11
		19970519	Environmental	6.1	--	6.9	574	13
2B	UF	19951108	Environmental	2.6	3.8	7.9	472	13
		19960109	Environmental	3.1	4.0	7.0	515	13
		19960206	Environmental	3.0	4.1	7.0	500	13
		19960312	Environmental	2.8	4.0	6.9	490	13
		19960422	Environmental	2.8	4.1	7.4	470	12
		19960612	Environmental	3.0	4.7	7.5	452	13
		19960724	Environmental	3.0	4.3	7.9	516	13.5
		19960910	Environmental	3.0	4.8	6.9	241	14
		19961112	Environmental	3.7	3.8	6.8	522	13
		19970121	Environmental	3.6	4.8	7.1	515	12.5
		19970317	Environmental	3.1	5.0	6.9	518	10
		19970519	Environmental	2.9	--	7.0	495	13
3A	UF	19951107	Environmental	9.2	9.2	7.4	575	12
		19960109	Environmental	8.5	4.2	6.5	585	12.5
		19960207	Environmental	8.1	4.5	6.6	585	12.5
		19960312	Environmental	8.8	5.4	6.5	570	12.5
		19960423	Environmental	7.9	8.3	6.8	560	11
		19960509	Environmental	9.0	9.2	6.9	615	12.5
		19960612	Environmental	9.2	9.8	6.5	550	14.5
		19960724	Environmental	--	11	6.4	625	13
		19960910	Environmental	7.4	9.3	6.5	531	14
		19961112	Environmental	7.8	7.3	6.3	580	12
		19970122	Environmental	8.3	6.1	6.5	624	11.5
		19970318	Environmental	8.7	9.5	6.4	625	12
		19970519	Environmental	8.6	--	6.5	640	13
3B	UF	19951107	Environmental	1.0	3.2	7.9	641	13
		19960109	Environmental	1.1	2.9	7.0	680	13.5
		19960207	Environmental	1.0	3.0	7.0	670	13.5
		19960312	Environmental	1.1	3.2	6.9	640	13.5
		19960423	Environmental	1.0	8.0	7.4	640	12
		19960509	Environmental	1.1	3.4	7.4	695	13
		19960612	Environmental	1.1	3.6	7.0	619	15
		19960724	Environmental	1.1	3.5	6.8	680	14.5
		19960910	Environmental	1.0	3.5	6.9	672	14
		19961112	Environmental	1.1	11	6.8	691	12.5
		19970122	Environmental	1.1	3.8	7.1	689	12

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997--Continued

Nested monitoring well number	Hydrogeologic condition	Sampling date	Sample type	Dissolved nitrate and nitrite concentration as nitrogen (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature, field (°C)
3B Con.	UF	19970318	Environmental	1.2	3.3	6.1	660	12.5
		19970519	Environmental	1.2	--	6.9	664	13.5
4A	UF	19951108	Environmental	11	10	7.9	619	12
		19960109	Environmental	11	8.8	6.9	635	12
		19960206	Environmental	11	6.0	7.0	650	12.5
		19960313	Environmental	12	5.6	6.8	610	13.5
		19960424	Environmental	11	11	7.4	645	11.5
		19960507	Environmental	13	8.9	7.3	690	11.5
		19960613	Environmental	12	10	7.4	896	14
		19960724	Environmental	11	10	6.9	986	13
		19960911	Environmental	11	9.4	6.8	255	13
		19961112	Environmental	12	8.7	6.7	785	12
		19970121	Environmental	13	10	7.1	881	12
		19970317	Environmental	13	9.0	6.8	995	9.5
		19970519	Environmental	12	--	7.1	997	12.5
4B	UF	19951108	Environmental	3.7	6.5	7.9	579	12.5
		19960109	Environmental	3.8	6.5	6.9	600	12
		19960206	Environmental	3.6	6.2	7.0	590	12.5
		19960313	Environmental	3.8	4.5	6.9	570	12.5
		19960424	Environmental	3.6	6.1	7.0	600	12.5
		19960507	Environmental	3.9	6.3	7.4	560	11.5
		19960613	Environmental	3.6	6.5	7.4	550	14.5
		19960724	Environmental	4.2	7.1	6.8	635	13
		19960911	Environmental	4.1	6.5	6.7	554	13
		19961112	Environmental	3.8	5.4	6.8	600	12
		19970121	Environmental	3.9	5.0	7.1	599	12
		19970317	Environmental	4.1	6.2	6.9	632	9
		19970519	Environmental	3.9	--	7.0	608	12.5
5A	UF	19951108	Environmental	5.4	3.9	7.8	604	12.5
		19960110	Environmental	7.2	6.3	6.9	645	12
		19960207	Environmental	7.8	4.7	6.9	640	13
		19960312	Environmental	9.1	6.3	6.7	640	12.5
		19960424	Environmental	7.1	5.6	7.2	605	13
		19960507	Environmental	7.5	6.6	7.3	575	12
		19960612	Environmental	6.8	6.6	7.4	590	12
		19960724	Envieronmental	7.9	9.2	7.4	671	13
		19960911	Environmental	5.7	7.4	6.7	582	13
		19961113	Environmental	6.9	6.2	6.6	617	12

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997--Continued

Nested monitoring well number	Hydrogeologic condition	Sampling date	Sample type	Dissolved nitrate and nitrite concentration as nitrogen (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature, field (°C)
5A Con.	UF	19970121	Environmental	7.1	6.8	6.9	628	12
		19970319	Environmental	7.1	5.7	6.7	609	13
		19970520	Environmental	7.8	--	6.6	655	13
5B	CF	19951108	Environmental	--	.3	7.4	489	13
		19960110	Environmental	1.1	1.4	7.0	480	13
		19960207	Environmental	1.1	1.1	7.0	485	14
		19960312	Environmental	1.1	.9	6.9	470	13.5
		19960425	Environmental	.77	.7	7.5	465	13.5
		19960507	Environmental	1.0	1.2	7.5	450	12.5
		19960612	Environmental	1.1	.5	7.5	448	12.5
		19960724	Environmental	.79	.9	6.9	498	14
		19960911	Environmental	.96	1.1	6.9	473	13.5
		19961113	Environmental	1.1	1.0	6.8	475	13
		19970121	Environmental	1.1	2.0	7.1	484	12.5
		19970319	Environmental	1.1	1.3	6.8	457	13.5
		19970520	Environmental	1.0	--	6.8	475	13.5
6A	CF	19951107	Environmental	.97	.1	7.6	635	13
		19960109	Environmental	.42	.2	6.4	640	13
		19960207	Environmental	1.1	.1	7.3	680	13.5
		19960312	Environmental	2.3	.1	7.1	730	13.5
		19960423	Environmental	2.7	.4	7.7	740	12.5
		19960508	Environmental	3.5	.2	7.6	820	12.5
		19960612	Environmental	3.4	.7	6.9	765	13
		19960724	Environmental	4.6	1.0	7.0	930	13.5
		19960910	Environmental	3.4	.3	7.0	863	14.5
		19961112	Environmental	1.9	0.6	7.0	706	13
		19970122	Environmental	3.1	.8	7.3	787	12.5
		19970318	Environmental	3.5	.9	6.5	769	12.5
		19970519	Environmental	3.1	--	7.0	758	14
6B	CF	19951107	Environmental	<.05	.1	8.1	554	13
		19960109	Environmental	<.05	.1	7.2	580	13.5
		19960207	Environmental	<.05	.1	7.2	580	13.5
		19960312	Environmental	<.05	.1	7.1	570	13.5
		19960423	Environmental	<.05	.2	7.6	550	12
		19960508	Environmental	.06	.3	7.6	595	12
		19960612	Environmental	.06	.3	6.9	529	13.5
		19960724	Environmental	.06	.4	7.0	585	14
		19960910	Environmental	.05	.1	6.9	549	14

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997--Continued

Nested monitoring well number	Hydrogeologic condition	Sampling date	Sample type	Dissolved nitrate and nitrite concentration as nitrogen (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature, field (°C)
6B Con.	CF	19961112	Environmental	.06	.7	6.9	507	12.5
		19970122	Environmental	.06	.6	7.2	581	12.5
		19970318	Environmental	<.05	.5	5.9	568	12.5
		19970519	Environmental	<.05	--	7.0	568	13.5
7A	UF	19951107	Environmental	1.6	8.0	7.4	640	--
		19960110	Environmental	2.3	7.0	7.1	580	13
		19960206	Environmental	2.1	1.0	7.1	590	12.5
		19960311	Environmental	4.5	1.5	7.0	580	13
		19960423	Environmental	4.2	2.1	7.5	550	12
		19960507	Environmental	4.4	2.0	7.4	565	13
		19960613	Environmental	4.6	2.6	7.5	534	14.5
		19960725	Environmental	4.4	3.5	6.5	595	13
		19960909	Environmental	4.6	3.9	6.8	550	13
		19961113	Environmental	4.4	1.5	6.7	577	12.5
		19970121	Environmental	4.2	2.8	7.0	571	12
		19970318	Environmental	4.4	2.6	6.9	559	12
		19970520	Environmental	4.1	--	6.8	568	13
7B	CF	19951107	Environmental	<.05	.1	7.4	522	13
		19960110	Environmental	<.05	.1	7.2	515	13
		19960206	Environmental	<.05	.1	7.3	510	13
		19960311	Environmental	<.05	.1	7.2	480	13
		19960423	Environmental	.07	3.0	7.7	306	12
		19960507	Environmental	0.12	0.3	7.7	475	12
		19960613	Environmental	.05	.3	7.8	454	14.5
		19960725	Environmental	.08	.7	7.0	501	13
		19960909	Environmental	.06	.1	7.1	421	14
		19961113	Environmental	<.05	.2	7.1	498	12.5
		19970121	Environmental	.06	1.1	7.3	500	12
		19970318	Environmental	<.05	.4	7.1	491	12.5
		19970520	Environmental	<.05	--	7.1	500	13
7C	CF	19951107	Environmental	<.05	.1	7.4	571	--
		19960110	Environmental	<.05	.1	7.2	565	13.5
		19960206	Environmental	<.05	.1	7.3	560	14
		19960311	Environmental	<.05	.1	7.2	530	14
		19960423	Environmental	<.05	.2	7.7	500	13
		19960507	Environmental	.08	.2	7.7	520	13.5
		19960613	Environmental	<.05	.1	7.7	505	16
		19960725	Environmental	.07	.1	7.0	568	14.5
		19960909	Environmental	--	.1	7.1	439	15

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997--Continued

Nested monitoring well number	Hydrogeologic condition	Sampling date	Sample type	Dissolved nitrate and nitrite concentration as nitrogen (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature, field (°C)
7C Con.	CF	19961113	Environmental	<.05	1.2	7.0	558	14
		19970121	Environmental	.06	1.0	7.2	552	13.5
		19970318	Environmental	<.05	.7	7.1	553	13
		19970520	Environmental	<.05	--	7.1	552	14.5
8A	UF	19951107	Environmental	14	8.8	7.1	777	12
		19960110	Blank	.06	--	--	--	--
		19960110	Environmental	15	5.7	6.6	610	12
		19960207	Environmental	14	5.7	6.6	600	12
		19960207	Blank	<.05	--	--	--	--
		19960207	Duplicate	14	5.7	6.6	600	12
		19960311	Environmental	15	7.5	6.5	560	12.5
		19960311	Blank	.05	--	--	--	--
		19960311	Duplicate	15	7.5	6.5	560	12.5
		19960423	Duplicate	14	9.4	6.7	550	11.5
		19960423	Blank	<.05	--	--	--	--
		19960423	Environmental	14	9.3	6.4	550	11.5
		19960509	Environmental	15	8.7	6.9	610	12.5
		19960509	Blank	.07	--	--	--	--
		19960509	Duplicate	15	8.7	6.9	610	12.5
		19960613	Environmental	13	8.9	7.1	536	14.5
		19960613	Duplicate	13	8.4	7.1	536	14.5
		19960613	Blank	<.05	--	--	--	--
		19960725	Environmental	13	7.1	6.5	620	14
		19960725	Duplicate	13	7.1	6.5	620	14
		19960725	Blank	.07	--	--	--	--
		19960909	Blank	.07	--	--	--	--
		19960909	Environmental	14	10.2	6.5	544	13
		19960909	Duplicate	14	10.2	6.5	544	13
		19961113	Environmental	13	6.8	6.4	609	11.5
		19961113	Duplicate	13	6.8	6.4	609	11.5
		19961113	Blank	<.05	--	--	--	--
		19970122	Environmental	14	7.8	6.6	605	11.5
		19970122	Duplicate	--	7.8	6.6	605	11.5
		19970122	Blank	--	--	--	--	--
		19970318	Environmental	14	8.3	6.4	576	11.5
		19970318	Duplicate	14	8.3	6.4	576	11.5
		19970318	Blank	<.05	--	--	--	--

Table 13. Nitrate concentrations and field measurements in water from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, July 1995 through May 1997--Continued

Nested monitoring well number	Hydrogeologic condition	Sampling date	Sample type	Dissolved nitrate and nitrite concentration as nitrogen (mg/L)	Oxygen, dissolved, field (mg/L)	pH, field (standard units)	Specific conductance, field (µS/cm)	Water temperature, field (°C)
8A Con.	UF	19970520	Environmental	12	--	6.4	576	12.5
		19970520	Duplicate	12	--	6.4	576	12.5
		19970520	Blank	--	--	--	--	--
8B	UF	19951107	Environmental	14	8.7	7.1	777	12
		19951107	Blank	<.05	--	--	--	--
		19951107	Duplicate	22	7.8	7.3	789	12
		19960110	Environmental	21	5.4	6.6	700	12
		19960207	Environmental	20	7.0	6.6	680	12
		19960311	Environmental	--	7.7	6.6	630	13
		19960423	Environmental	18	8.7	7.0	600	11.5
		19960509	Environmental	19	7.5	7.0	683	12.5
		19960613	Environmental	19	7.8	7.1	615	15
		19960725	Environmental	20	8.0	6.4	730	14
		19960909	Environmental	23	8.7	6.5	648	13.5
		19961113	Environmental	23	6.5	6.4	722	12
		19970122	Environmental	21	7.6	6.7	726	11.5
		19970318	Environmental	21	7.2	6.5	698	12
		19970520	Environmental	19	--	6.5	565	13
8C	CF	19951107	Environmental	<.05	.4	7.3	519	14.5
		19960110	Environmental	.23	--	--	--	--
		19960110	Duplicate	.23	--	--	--	--
		19960207	Environmental	.19	.2	7.1	520	13
		19960311	Environmental	.26	.1	7.0	500	14
		19960423	Environmental	.16	2.2	7.5	480	12.5
		19960509	Environmental	.22	.2	7.5	524	14
		19960613	Environmental	.22	.2	7.6	467	16.5
		19960725	Environmental	--	.3	6.9	526	15
		19960909	Environmental	.24	.1	6.9	438	14
		19961113	Environmental	.29	.4	6.9	512	12.5
		19970122	Environmental	.28	.7	7.2	558	10
		19970318	Environmental	.32	.9	7.1	510	12.5
		19970520	Environmental	.27	--	6.9	490	14

Table 14. Summary statistics for nitrate concentrations from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through May 1997

[mg/L, milligrams per liter; --, not applicable; UF, unconfined part of the High Plains aquifer; CF, confined part of the High Plains aquifer; --, not applicable]

Grouping or well number	Hydro-geologic condition	Number of samples	Nitrate concentration (mg/L)			
			Mean	Minimum	Median	Maximum
All data	--	226	5.5	<0.05	3.6	23
Shallow part of High Plains aquifer	--	101	11	1.6	9.2	23
Deep part of High Plains aquifer	--	125	1.2	<.05	.42	4.6
Unconfined part of High Plains aquifer	UF	139	8.6	1.0	7.1	23
Confined part of High Plains aquifer	CF	87	.60	<.05	.10	4.6
1A	UF	12	16	12	16	21
1B	CF	12	.09	<.05	.10	.14
2A	UF	13	6.6	6.1	6.6	7.4
2B	UF	12	3.0	2.6	3.0	3.7
3A	UF	12	8.5	7.4	8.6	9.2
3B	UF	13	1.1	1.0	1.1	1.2
4A	UF	13	12	11	12	13
4B	UF	13	3.8	3.6	3.8	4.2
5A	UF	13	7.2	5.4	7.1	9.1
5B	CF	12	1.0	.77	1.1	1.1
6A	CF	13	2.6	.42	3.1	4.6
6B	CF	13	.05	<.05	.05	.06
7A	UF	13	3.8	1.6	4.4	4.6
7B	CF	13	.06	<.05	.05	.12
7C	CF	12	.06	<.05	.05	.08
8A	UF	13	14	12	14	15
8B	UF	12	20	14	20	23
8C	CF	12	.23	<.05	.24	.32

Table 15. Alkalinity, and major-ion and tritium concentrations in water samples from nested monitoring wells, Upper Big Blue Natural Resources District, central Nebraska, September 1996

[Site ID, nested monitoring well number; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than; --, no data]

Site ID (table 5)	Date (yyyy mmdd)	Residue on evaporation at 180 °C (mg/L)	Alkalinity, laboratory dissolved, as $CaCO_3$ (mg/L)	Calcium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (µg/L)	Iron, dissolved (µg/L)	Magnesium, dissolved (µg/L)	Manganese dissolved (µg/L)	Potassium dissolved (mg/L)	Silica, dissolved (mg/L)	Sodium dissolved(mg/L)	Sulfate, dissolved (mg/L)	Tritium, (pCi/L)
1A	19960910	601	363	110	17	0.6	6	21	2	7.5	23	58	75	26
1B	19960910	339	140	72	12	.5	44	11	1	4.9	19	21	110	<.3
2A	19960910	415	288	81	10	.3	<3	14	1	7	33	39	29	--
2B	19960910	316	201	69	13	.4	10	10	<1	5.5	30	21	37	--
3A	19960910	394	177	73	25	.2	<3	16	5	11	41	21	64	--
3B	19960910	456	206	100	14	.3	12	14	1	7.8	32	23	130	--
4A	19960911	526	261	110	73	.3	14	16	4	7.2	34	29	24	--
4B	19960911	379	271	89	15	.3	7	13	3	7	33	22	26	--
5A	19960911	401	248	77	8.5	.3	58	15	1	7.7	42	31	50	--
5B	19960911	309	202	69	13	.3	27	10	[1]140	5.4	35	18	33	--
6A	19960910	599	256	120	12	.4	5	26	[1]670	6.2	30	31	190	1.6
6B	19960910	379	183	77	13	.3	140	12	[1]850	4.9	29	26	100	2.5
7A	19960909	369	280	64	5.7	.3	3	14	2	6.8	35	41	21	--
7B	19960909	328	243	73	5.7	.3	83	11	[1]600	8.2	49	13	21	--
7C	19960909	309	202	69	12	.3	27	10	[1]140	5.4	35	18	33	--
8A	19960909	417	154	73	14	.2	51	13	14	6.9	36	31	88	39
8B	19960909	486	155	87	16	.2	10	14	4	6.8	35	34	110	28
8C	19960909	320	241	76	7.7	.3	13	11	10	5	32	17	28	<.3

[1] Exceeded the Secondary Maximum Contaminant Level of 50 µg/L for managanese (U.S. Environmental Protection Agency, 1996).

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997

[Subsite number, DH denotes deep hole, the number denotes the nested monitoring well site number, and the letters denote the respective subsite; Sample site identification number, the number denotes the nested monitoring well site number, the first letter denotes the subsite identification, the two subsequent numbers denote soil sample, and the remaining two numbers denote the sequential sample number which varies by depth]

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
		November-December 1995 sampling		
DH1	1SS01	19951128	0.25	6.9
	1SS02	19951128	1.5	3.5
	1SS03	19951128	3.5	4.5
	1SS04	19951128	5.5	7
	1SS05	19951128	9.5	4.4
	1SS06	19951128	15	4.3
	1SS07	19951128	20	6.3
	1SS08	19951128	30	5.3
	1SS09	19951128	40	5
	1SS10	19951128	50	8.6
	1SS11	19951128	60	14
	1SS12	19951128	65	5
DH2X	2SS01	19951128	1.0	30
	2ASS02	19951128	3.0	11
	2ASS03	19951128	4.5	8
	2ASS04	19951128	10	2.6
	2ASS05	19951128	15	3.2
	2ASS06	19951128	20	4.6
	2ASS07	19951128	25	11
	2ASS08	19951128	35	9.8
	2ASS09	19951128	45	.5
	2ASS10	19951128	54	1.8
	2ASS11	19951128	64	1.7
	2ASS12	19951128	74	1.2
	2ASS13	19951128	85	3.1
DH2Y	2BSS01	19951129	1.0	10
	2BSS02	19951129	3.0	4.8
	2BSS03	19951129	5.0	7.3
	2BSS04	19951129	10	1.8
	2BSS05	19951129	15	4.9
	2BSS06	19951129	20	8.8
	2BSS07	19951129	22	13
	2BSS08	19951129	35	3.9
	2BSS09	19951129	45	3.7
	2BSS10	19951129	50	--
	2BSS11	19951129	55	--
	2BSS12	19951129	65	1.2

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH2Y Con.	2BSS13	19951129	75	1.6
	2BSS14	19951129	85	2.3
DH3X	3ASS01	19951204	1.0	3.2
	3ASS02	19951204	3.0	2.8
	3ASS03	19951204	5.0	7.1
	3ASS04	19951204	10	6.0
	3ASS05	19951204	15	3.6
	3ASS06	19951204	20	3.5
	3ASS07	19951204	25	4.0
	3ASS08	19951204	35	6.0
DH3Y	3BSS01	19951205	1.0	<.05
	3BSS02	19951205	3.0	.93
	3BSS03	19951205	5.0	.93
	3BSS04	19951205	10	1.9
	3BSS05	19951205	14	1.1
	3BSS06	19951205	20	1.1
	3BSS07	19951205	30	.9
	3BSS08	19951205	40	3.1
DH4X	4ASS01	19951128	1.0	4.6
	4ASS02	19951128	3.0	2.0
	4ASS03	19951128	5.0	2.7
	4ASS04	19951128	10	2.0
	4ASS05	19951128	15	2.2
	4ASS06	19951128	20	--
	4ASS07	19951128	25	3.3
	4ASS08	19951128	30	3.1
	4ASS09	19951128	40	2.9
	4ASS10	19951128	50	1.6
	4ASS11	19951128	60	1.1
	4ASS12	19951128	70	1.2
DH4Y	4BSS01	19951130	1.0	5.2
	4BSS02	19951130	3.0	1.2
	4BSS03	19951130	5.0	1.2
	4BSS04	19951130	10	1.4
	4BSS05	19951130	15	7.2
	4BSS06	19951130	20	1.8
	4BSS07	19951130	30	4.4
	4BSS08	19951130	40	1.4
	4BSS09	19951130	50	1.1

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH4Z	4CSS01	19951130	1.0	69
	4CSS02	19951130	3.0	11
	4CSS03	19951130	5.0	5.4
	4CSS04	19951130	10	6.6
	4CSS05	19951130	15	6.5
	4CSS06	19951130	20	7.6
	4CSS07	19951130	29	17
	4CSS08	19951130	40	16
	4CSS09	19951130	50	23
	4CSS10	19951130	60	25
	4CSS11	19951130	69	6.3
DH5	5SS01	19951201	1.0	5.0
	5SS02	19951201	3.0	4.3
	5SS03	19951201	5.0	7.1
	5SS04	19951201	10	1.7
	5SS05	19951201	15	3.3
	5SS06	19951201	20	6.5
	5SS07	19951201	30	3.7
	5SS08	19951201	40	3.7
	5SS09	19951201	50	1.3
	5SS10	19951201	60	1.3
	5SS11	19951201	70	2.1
DH6X	6ASS01	19951204	1.0	1.9
	6ASS02	19951204	3.0	1.5
	6ASS03	19951204	5.0	1.5
	6ASS04	19951204	10	.84
	6ASS05	19951204	15	.95
	6ASS06	19951204	20	.67
	6ASS07	19951204	30	1.3
DH6Y	6BSS01	19951204	1.0	2.7
	6BSS02	19951204	3.0	1.4
	6BSS03	19951204	5.0	3.7
	6BSS04	19951204	10	6.5
	6BSS05	19951204	15	7.2
	6BSS06	19951204	19	1.9
	6BSS07	19951204	30	1.5
	6BSS08	19951204	40	2.6
DH7X	7ASS01	19951130	1.0	11
	7ASS02	19951130	3.0	2.1
	7ASS03	19951130	5.0	2.1

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH7X Con.	7ASS04	19951130	10	4.4
	7ASS05	19951130	15	1.3
	7ASS06	19951130	20	.94
DH7Y	7BSS01	19951204	1.0	5.6
	7BSS02	19951204	3.0	1.2
	7BSS03	19951204	5.0	2.3
	7BSS04	19951204	10	4.4
	7BSS05	19951204	15	3.4
DH8X	8SS01	19951201	1.0	3.5
	8SS02	19951201	3.0	1.4
	8SS03	19951201	5.0	3.4
	8SS04	19951201	10	11
	8SS05	19951201	15	8.3
	8SS06	19951201	20	6.4
	8SS07	19951201	30	3.0
	8SS08	19951201	39	2.2
	8SS09	19951201	50	3.1
	8SS10	19951201	60	.73
	8SS11	19951201	70	2.9
	8SS12	19951201	80	1.7
	8SS13	19951201	90	5.2
		December 1996-January 1997 sampling		
DH1	1ASS0196	19961205	.50	4.5
	1ASS0296	19961205	1.8	4.3
	1ASS0396	19961205	4.5	6.6
	1ASS0496	19961205	6.0	12
	1ASS0596	19961205	8.0	8.2
	1ASS0696	19961205	13	5.6
	1ASS0796	19961205	19	6.0
	1ASS0896	19961205	27	6.5
DH2X	2ASS0196	19961204	.25	2.7
	2ASS0296	19961204	1.3	3.2
	2ASS0396	19961204	3.0	3.5
	2ASS0496	19961204	5.0	3.9
	2ASS0596	19961204	10	4.0
	2ASS0696	19961204	21	7.7
	2ASS0796	19961204	26	7.9
	2ASS0896	19961204	31	5.7

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH2Y	2BSS0196	19961204	1.0	2.6
	2BSS0296	19961204	3.0	2.8
	2BSS0396	19961204	5.0	3.6
	2BSS0496	19961204	10	3.0
	2BSS0596	19961204	15	6.3
	2BSS0696	19961204	20	8.8
	2BSS0796	19961204	25	8.0
	2BSS0896	19961204	30	5.0
DH3X	3ASS0196	19970102	1.0	4.9
	3ASS0296	19970102	2.5	3.6
	3ASS0396	19970102	6.0	6.3
	3ASS0496	19970102	10	6.5
	3ASS0596	19970102	12	5.7
	3ASS0696	19970102	15	4.4
DH3Y	3BSS0196	19970102	.25	3.4
	3BSS0296	19970102	1.3	2.4
	3BSS0396	19970102	5.5	3.9
	3BSS0496	19970102	10	5.3
	3BSS0596	19970102	14	4.3
	3BSS0696	19970102	20	3.2
	3BSS0796	19970102	23	2.6
DH4X	4ASS0196	19961206	.50	4.0
	4ASS0296	19961206	1.5	2.9
	4ASS0396	19961206	3.0	2.9
	4ASS0496	19961206	5.0	2.1
	4ASS0596	19961206	10	1.5
	4ASS0696	19961206	15	--
	4ASS0796	19961206	21	3.9
	4ASS0896	19961206	27	5.4
DH4B	4BSS0196	19961206	.50	3.4
	4BSS0296	19961206	1.5	1.7
	4BSS0396	19961206	4.0	1.7
	4BSS0496	19961206	11	1.8
	4BSS0596	19961206	15	2.9
	4BSS0696	19961206	21	2.0
	4BSS0796	19961206	31	5.5
	4BSS0896	19961206	40	8.0

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH4Z	4CSS0196	19961206	.30	5.6
	4CSS0296	19961206	.80	10
	4CSS0396	19961206	1.5	4.8
	4CSS0496	19961206	3.0	3.9
	4CSS0596	19961206	5.0	5
	4CSS0696	19961206	10	5
	4CSS0796	19961206	15	--
	4CSS0896	19961206	20	8.4
	4CSS0996	19961206	25	8.7
	4CSS1096	19961206	30	6.2
DH5	5SS0196	19961205	.50	3.9
	5SS0296	19961205	1.3	5.1
	5SS0396	19961205	2.3	8.5
	5SS0496	19961205	3.5	7.0
	5SS0596	19961205	6.5	3.8
	5SS0696	19961205	8.5	3.0
	5SS0796	19961205	12	4.9
	5SS0896	19961205	16	4.5
	5SS0996	19961205	21	3.0
	5SS1096	19961205	30	2.5
DH6X	6ASS0196	19961231	.50	3.1
	6ASS0296	19961231	1.3	1.9
	6ASS0396	19961231	3.0	1.7
	6ASS0496	19961231	5.0	1.8
	6ASS0596	19961231	9.0	1.6
	6ASS0696	19961231	15	1.6
	6ASS0796	19961231	21	1.7
DH6Y	6BSS0196	19961231	.50	4.6
	6BSS0296	19961231	1.5	2.4
	6BSS0396	19961231	3.0	2.4
	6BSS0496	19961231	9.0	5.6
	6BSS0596	19961231	15	8.5
	6BSS0696	19961231	19	9.7
DH7X	7ASS0196	19961230	0.50	4.1
	7ASS0296	19961230	1.5	3.8
	7ASS0396	19961230	3.0	2.7
	7ASS0496	19961230	6.5	3.0
	7ASS0596	19961230	10	3.1
	7ASS0696	19961230	16	6.6
	7ASS0796	19961230	20	14

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH7Y	7BSS0196	19961230	.50	4.5
	7BSS0296	19961230	1.5	3.3
	7BSS0396	19961230	3.0	4.1
	7BSS0496	19961230	5.5	3.8
	7BSS0596	19961230	10	2.6
	7BSS0696	19961230	14	3.1
DH8X	8ASS0196	19970103	.50	6.0
	8ASS0296	19970103	1.5	6.4
	8ASS0396	19970103	3	2.5
	8ASS0496	19970103	6	4.5
	8ASS0596	19970103	10	7.8
	8ASS0696	19970103	16	7.5
	8ASS0796	19970103	21	7.4
	8ASS0896	19970103	25	3.8
		March 1997 sampling		
DH4X	4ASS0196	19970324	.50	4.6
	4ASS0296	19970324	1.5	3.0
	4ASS0396	19970324	3.0	2.5
	4ASS0496	19970324	5.0	1.9
	4ASS0596	19970324	10	2.3
	4ASS0696	19970324	15	3.3
	4ASS0796	19970324	21	3.0
	4ASS0896	19970324	27	--
DH4Y	4BSS0196	19970324	.50	1.7
	4BSS0296	19970324	1.5	1.3
	4BSS0396	19970324	4.0	1.1
	4BSS0496	19970324	11	3.8
	4BSS0596	19970324	15	4.5
	4BSS0696	19970324	21	1.8
	4BSS0796	19970324	31	2.8
DH4Z	4CSS0196	19970324	0.30	15
	4CSS0296	19970324	.80	8.3
	4CSS0396	19970324	1.5	6.6
	4CSS0496	19970324	3.0	7.7
	4CSS0596	19970324	5.0	5.3
	4CSS0696	19970324	10	4.0
	4CSS0796	19970324	15	7.9
	4CSS0896	19970324	20	11
	4CSS0996	19970324	25	3.9
	4CSS1096	19970324	30	7.2

Table 16. Nitrate concentrations in unsaturated-zone sediment samples collected from selected subsites, Upper Big Blue Natural Resources District, central Nebraska, November 1995 through March 1997--Continued

Subsite number	Sample site identification number	Date of sample collection (yyyymmdd)	Depth of sample collection (feet)	Total nitrate concentration (milligrams per kilogram)
DH6X	6ASS0196	19970325	.50	4.9
	6ASS0296	19970325	1.3	1.6
	6ASS0396	19970325	3.0	1.6
	6ASS0496	19970325	5.0	1.3
	6ASS0596	19970325	9.0	1.3
	6ASS0696	19970325	15	.83
	6ASS0796	19970325	21	--
DH6Y	6BSS0196	19970325	.50	5.7
	6BSS0296	19970325	1.5	2.8
	6BSS0396	19970325	3.0	2.9
	6BSS0496	19970325	9.0	5.6
	6BSS0596	19970325	15	14
	6BSS0696	19970325	19	--
DH7X	7ASS0196	19970325	.50	5.8
	7ASS0296	19970325	1.5	5.7
	7ASS0396	19970325	3.0	4.2
	7ASS0496	19970325	6.5	5.1
	7ASS0596	19970325	10	12
	7ASS0696	19970325	16	14
	7ASS0796	19970325	20	12
DH7Y	7BSS0196	19970325	.50	11
	7BSS0296	19970325	1.5	6.3
	7BSS0396	19970325	3.0	2.8
	7BSS0496	19970325	5.5	1.6
	7BSS0596	19970325	10	2.6
	7BSS0696	19970325	14	--

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