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Regional Analysis of Rural Domestic Well-water Quality – East Central Dissected Plains

D. C. Gosselin
University of Nebraska - Lincoln

X- H. Chen

S. E. Summerside

Rural Domestic Well-water Quality in the *East Central Dissected Plains*

Groundwater Region 8 from *Domestic Water-well Quality in Rural Nebraska*
(A data-analysis report for the Nebraska Department of Health compiled by D. C. Gosselin and others, 1996)

Geology and Hydrogeology

Groundwater Region 8 occupies the area known as the East Central Dissected Plains (Figure 1). In this region, the base of the principal groundwater-bearing units is the eroded surface of the Cretaceous Pierre Shale. Overlying this unit is the Tertiary Ogallala Group, composed of fine- to medium-grained silty sand and sandstone, siltstone, sandy and clayey silt, and lesser amounts of volcanic ash. As much as 400 feet thick in the western part of the region, the Ogallala Group thins eastward until it is virtually absent in south-central Madison County, most of Platte County and a small area in eastern Buffalo County. The Ogallala Group is overlain by a complex series of Quaternary deposits consisting of river- and wind-deposited gravel, sand and silt that are thickest where they fill ancient valleys (paleovalleys). These deposits are mantled by wind-blown silt (loess). (Geologic cross sections for Region 8 are available at the Conservation and Survey Division; Figure 1.)

The Quaternary deposits and the Ogallala Group are the primary units from which groundwater is pumped (Table 1). The thicknesses of the primary groundwater-bearing units range from about 100 feet or less to about 500 feet or more. Depth to the regional water table varies as a function of topographic location. In upland areas, depth to water may be greater than 200 feet, whereas it may be less than 50 feet below the bottomlands in the principal valleys. The general water quality is good; natural dissolved solids range from 200 to 500 parts per million (ppm).

Results*

Well Characteristics

Characteristics of the wells sampled in 1994-1995 are summarized in Table GW8.1. Average year of installation was 1970; nearly 70 percent of the wells were installed between 1960 and 1979. The oldest well was installed in 1888. Available information indicates 95 percent of 220 wells were drilled. Steel or PVC casing was used in nearly all of them, and 88 percent had sanitary seals. The average depth of the wells was 181 feet and ranged from 16 to 380 feet. Forty-seven percent of the wells had depths greater than 200 feet. Of the 120 wells for which information was available, the average well diameter was 4.3 inches; 91 percent of the 120 wells had diameters between 4 and 5 inches. The minimum diameter was 1 inch, and the maximum was 24 inches. Wells were used by an average of 3.3 individuals per well. Nitrate was used at 85 percent of 208 sites. Pesticides were used at slightly more than 87 percent of the same sites.

Nitrates

Nitrate data for the 216 wells sampled during the 1994-1995 study are summarized in Table GW8.1. Their locations are shown in Figure GW8.1. The nitrate-nitrogen concentrations ranged from less than 0.1 ppm to a maximum of 37.4 ppm. Nearly 70 percent of the wells had concentrations less than 3 ppm (Figure. GW8.2), indicating that about 30 percent of the wells have been affected by nitrate contamination. Only 8 percent of the wells exceeded the 10 ppm maximum contaminant level (mcl) for nitrate. The average for all samples is 3.4 ppm, and the median value is 1.7 ppm.

Figure GW8.2 shows a nearly 8-percent decrease in wells having nitrate-nitrogen concentrations less than 3 ppm. However, there is a nearly 5- and 3-percent increase, respectively, between 1985-1989 and 1994-1995 in wells with nitrate-nitrogen concentrations from 3 to 4.9 and 5 to 7.5 ppm. The shift in the number of wells to generally higher concentrations is supported by the Wilcoxon Signed Rank Test. The 189 wells that had a change in their concentrations from one period to the other had a statistically significant increase in their concentrations between the two sampling periods.

**** Where associations, relationships, increases or decreases are discussed, our analyses have determined them to be statistically significant. If the relationship between contaminant concentrations and various factors are not discussed, it can be assumed that they have not been demonstrated to be statistically significant.***

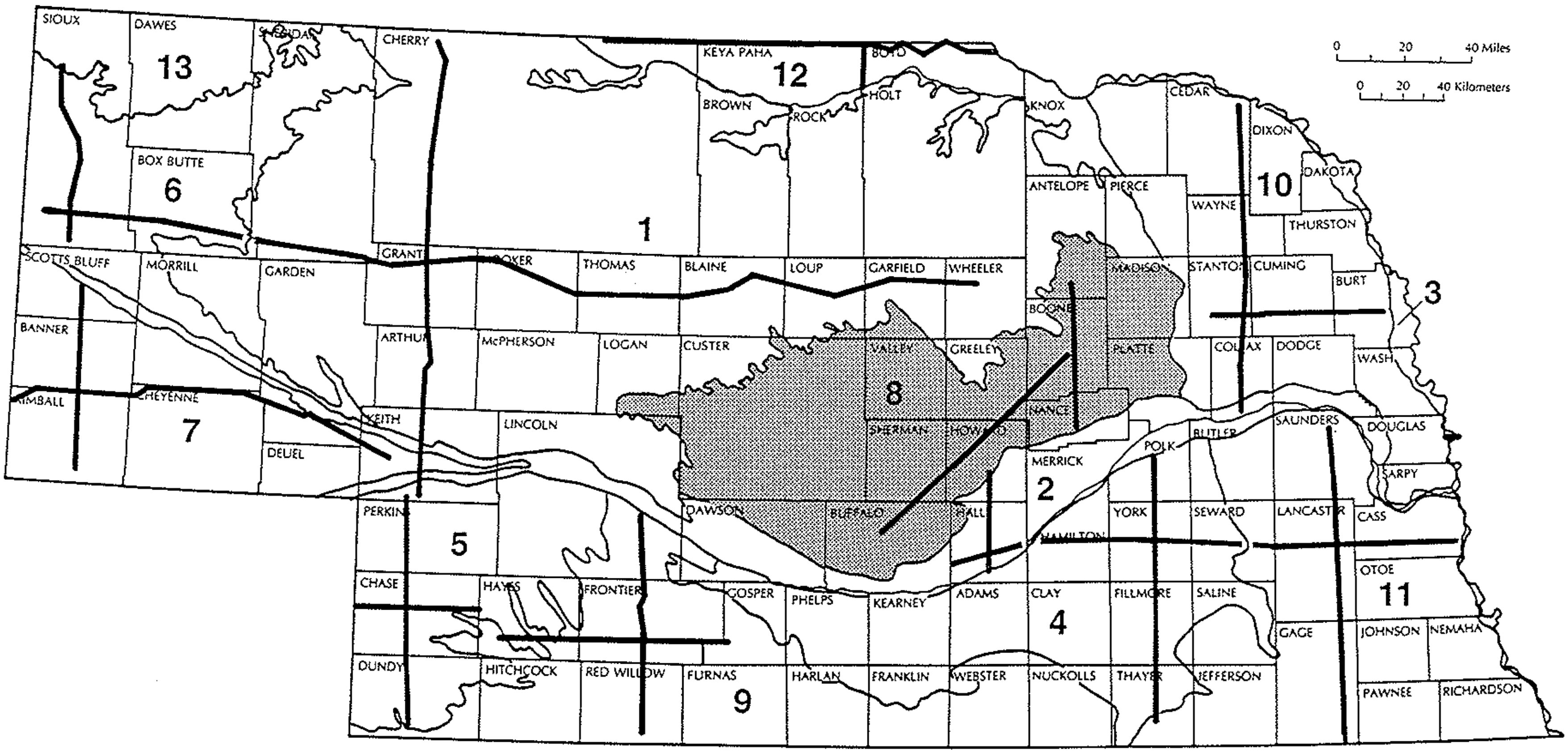

Fig. 1—*Locations of geologic cross sections* (Region 8 in gray)

Water-bearing Properties of Major Rock Units in Nebraska

From *The Groundwater Atlas of Nebraska* — Conservation and Survey Division, University of Nebraska-Lincoln

Era	Period	Epoch	Millions of years	Group or Formation	Lithology	Water-bearing Properties
Cenozoic	Quaternary	Holocene	0.01		Sand, silt, gravel and clay	Principal groundwater reservoir; Ogallala is absent in east and northwest. Arikaree is present primarily in west.
		Pleistocene	~2.0			
		Pliocene	5		Sand, gravel and silt	
		Miocene	24	Ogallala	Sand, sandstone, siltstone and some gravel	
		Oligocene		Arikaree	Sandstone and siltstone	
			37	White River	Siltstone, sandstone and clay in lower part	Secondary aquifer in west; water may be highly mineralized.
		Eocene	58	Rocks of this age are not identified in Nebraska.		
		Paleocene	67			
Mesozoic	Cretaceous	Late Cretaceous		Lance	Sandstone and siltstone	Generally not an aquifer; yields water to few wells in west.
				Fox Hills		
				Pierre	Shale and some sandstone in west	Generally not an aquifer; sandstones in west yield highly mineralized water to few industrial wells.
				Niobrara	Shaly chalk and limestone	Secondary aquifer where fractured and at shallow depths, primarily in east.
				Carlile	Shale; in some areas contains sandstones in upper part	Generally not an aquifer; sandstones yield water to few wells in northeast.
			98	Greenhorn-Graneros	Limestone and shale	Generally not an aquifer, yields water to few wells in east.
		Early Cretaceous	144	Dakota	Sandstone and shale	Secondary aquifer, primarily in east; water may be highly mineralized.
	Jurassic		208		Siltstone and some sandstone	Not an aquifer
	Triassic		245		Siltstone	Not an aquifer
Paleozoic	Permian		286		Limestone, dolomites, shales and sandstone.	Some sandstone, limestone and dolomites are secondary aquifers in east. Water may be highly mineralized.
	Pennsylvanian		320			
	Mississippian		360			
	Devonian		408			
	Silurian		438			
	Ordovician		505			
	Cambrian		570			
Precambrian						

Table 1—Hydrostratigraphic chart (showing water-bearing rock units) of Nebraska
Time divisions are not to scale.

Table GW8.1. Summary of Domestic Well Characteristics and Water Quality Data (1994-95)

Well characteristics

		Number of wells	Mean	Minimum	Maximum	Standard deviation
Well Installation Date	All	209	1970	1888	1987	15
	<1940	6				
	1940-1969	16				
	1960-1979	146				
	1980-present	41				
Well Depth (feet)	All	196	181	16	380	80
	<50	9				
	50-99	20				
	100-199	75				
	>200	92				
Well Diameter (inches)	All	120	4.3	1	24	2.1
	<2	2				
	2-3	4				
	4-5	109				
	6-7	1				
	>8	4				
Number of Well Users		120	3.3	1	12	2.1
Distance to Contaminant Source (feet):						
	cesspool	25	193	30	1900	363
	septic	165	135	15	1850	169
	waste lagoon	5	1090	150	2900	1122
	barnyard	179	184	5	2600	267
	pasture land	85	404	5	2600	545
	cropland	120	286	5	1700	298
Well Type:						
	drilled	208				
	driven	7				
	dug	0				
	other	1				
Casing Material:						
	steel	75				
	plastic	124				
	concrete	0				
	brick	0				
	tile	0				
	other	1				
Sanitary Seal:						
	yes	176				
	no	24				
Casing in Pit:						
	yes	44				
	no	176				
Nitrate Used:						
	yes	177				
	no	31				
Pesticide Used:						
	yes	181				
	no	36				

Water Quality Data

	Number of wells	Mean	Median	Minimum	Maximum	Standard deviation	Detections
Nitrate as Nitrogen (ppm NO3-N)							
1994-1995	226	3.4	1.7	0.1	37.4	5.2	
Bacteria (colonies per 100 ml)							
1994-1995	217			0	100		36
Pesticides (ppb)							
1994-1995							
Atrazine	226			0	0.7		4

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Nitrate Sampling Locations - Region #8

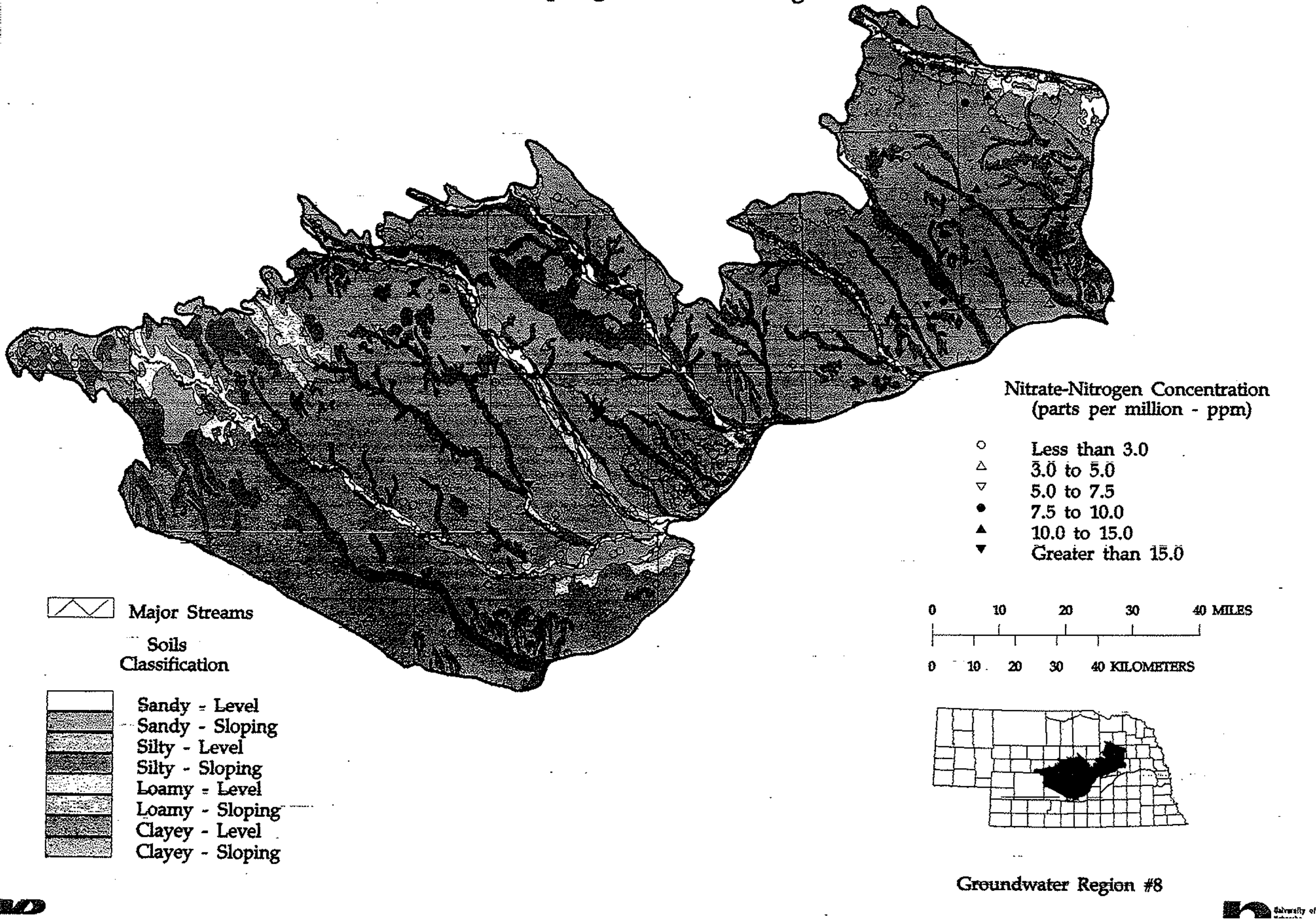

Figure GW8.1

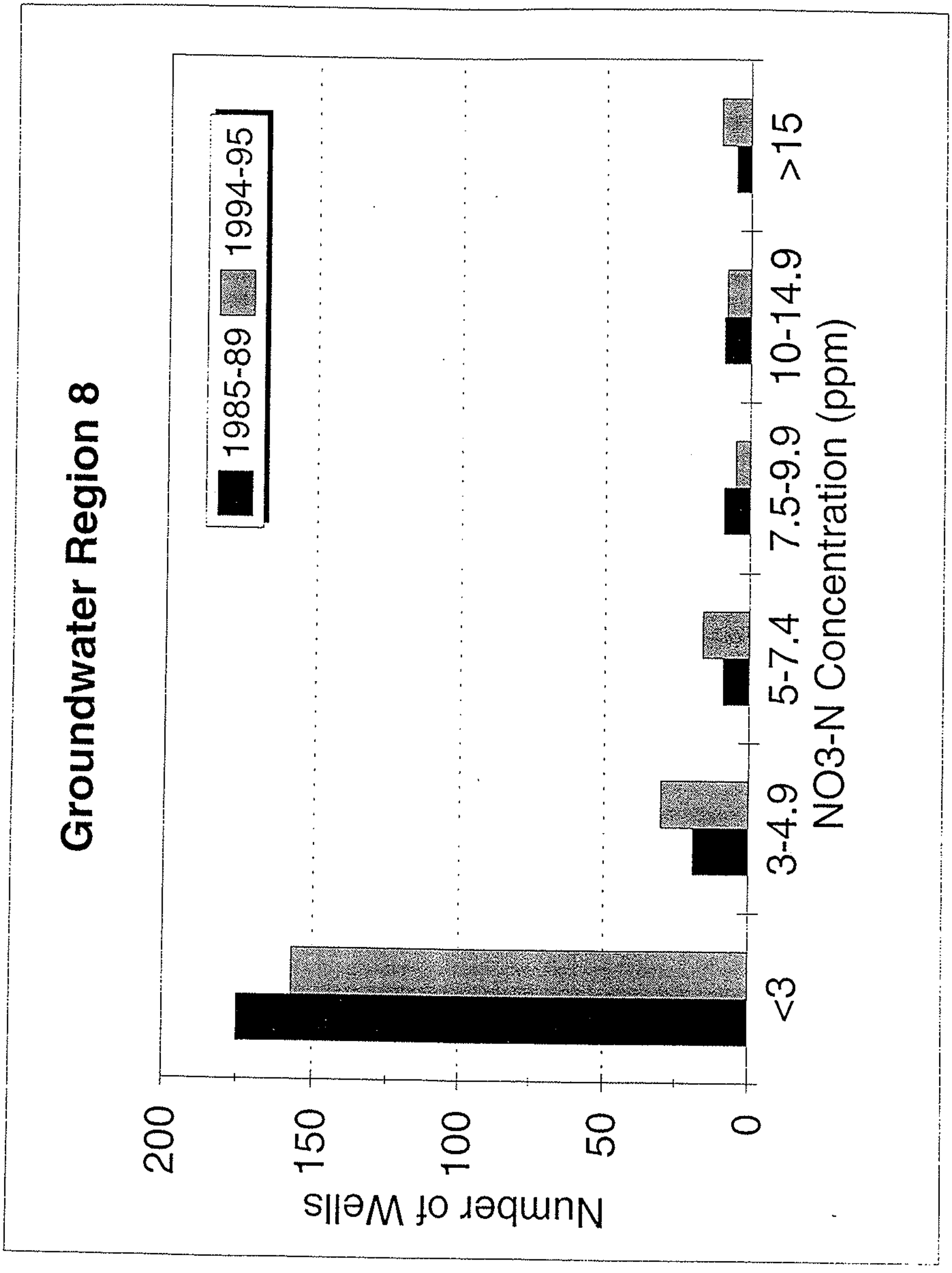
Groundwater Region 8
1985-89
1994-95
Number of Wells
0
50
100
150
200
<3
3-4.9
5-7.4
7.5-9.9
10-14.9
>15
NO3-N Concentration (ppm)

Figure GW8.2

The factors that may influence the nitrate-nitrogen concentrations in rural domestic wells are divided into three groups: 1) well-construction factors: casing type, age, diameter, well completed in or out of a pit, sanitary seal, and well type; 2) distance factors: distance to cesspools, septic systems, waste lagoons, barnyards, pasture, and cropland; and 3) hydrogeologic and site factors: well depth, depth to water, landscape and soil characteristics (Figure GW8.1), and agricultural chemical use.

Well-construction factors

The Mann-Whitney Rank Sum Test indicated no statistically significant differences in nitrate-nitrogen concentrations related to the grouping of well-construction factors; these factors were casing type (steel or PVC), sanitary seal (yes or no), casing completion (in or out of a pit), and well type (drilled or not). The Kruskal-Wallis Test showed a statistically significant difference between the nitrate concentrations associated with the individual age groups. Further analysis using the Mann-Whitney Test indicated that wells installed between 1940 and 1960 had median concentrations (0.45 ppm) statistically lower than wells installed from 1960-1980 (2.0 ppm) or from 1980-present (1.5 ppm).

Distance factors

The Spearman Test did not indicate any significant relationships between nitrate-nitrogen and distance factors.

Hydrogeologic and site factors

Nitrogen was used on the premises in 85 percent of the 208 wells where this data was provided. The Mann-Whitney Test indicates that the use of nitrogen did not necessarily relate to nitrate-nitrogen concentrations observed in the wells. Use of the Spearman Test indicated no relationship between nitrate-contamination and well depth. For the 50 wells that had depth-to-water estimates, a significant association was indicated between higher nitrate concentrations and greater depths to water. This is similar to what is observed in Groundwater Region 4.

Ninety-five percent of the area in which the wells occur is dominated by soils in class 2 (11 percent; sandy-level), class 3 (34 percent; silty-level), and class 4 (50 percent; silty level) (Figure. GW8.1). The Chi-Square Test and the Fisher Test did not indicate any relationships between nitrate-nitrogen concentrations and soil characteristics.

Pesticides

Of the 226 wells analyzed for pesticides, only four wells had detectable atrazine (Figure GW8.3; Table GW8.1). The highest reported value was 0.7 parts per billion (ppb). During the 1985-1989 sampling period, these same wells had two atrazine detections, with the highest concentration being 0.35 ppb. There was also one detection of Treflan at 0.42 ppb.

Average nitrate-nitrogen concentrations for these wells is 14.5 ppm, with two exceeding 21 ppm. Two of these wells are within 45 feet of cropland, whereas the other two were less than 50 feet deep.

Bacteria

Coliform-bacteria data for the 217 sites sampled during the 1994-1995 study are summarized in Table GW8.1. Their locations are shown in Figure GW8.4. The bacteria data expressed in colonies per 100 ml of water ranged from 0 to greater than 100. More than 83 percent of the wells had no detectable coliform bacteria, indicating that less than 17 percent of the wells have been affected by bacterial contamination and exceeded the mcl for bacteria. Only two of these wells have nitrate-nitrogen concentrations greater than 10 ppm.

The Wilcoxon Signed Rank Test indicated no differences between the 1994-1995 and 1985-1989 data for the 54 wells that had different counts between the two periods.

The Spearman Test did not indicate any statistical relationship between the occurrence of coliform bacteria and distance to any possible point sources such as barnyards or septic systems. However, 30 percent of the wells were less than 100 feet from a barnyard. Another 23 percent were less than 50 feet from septic systems.

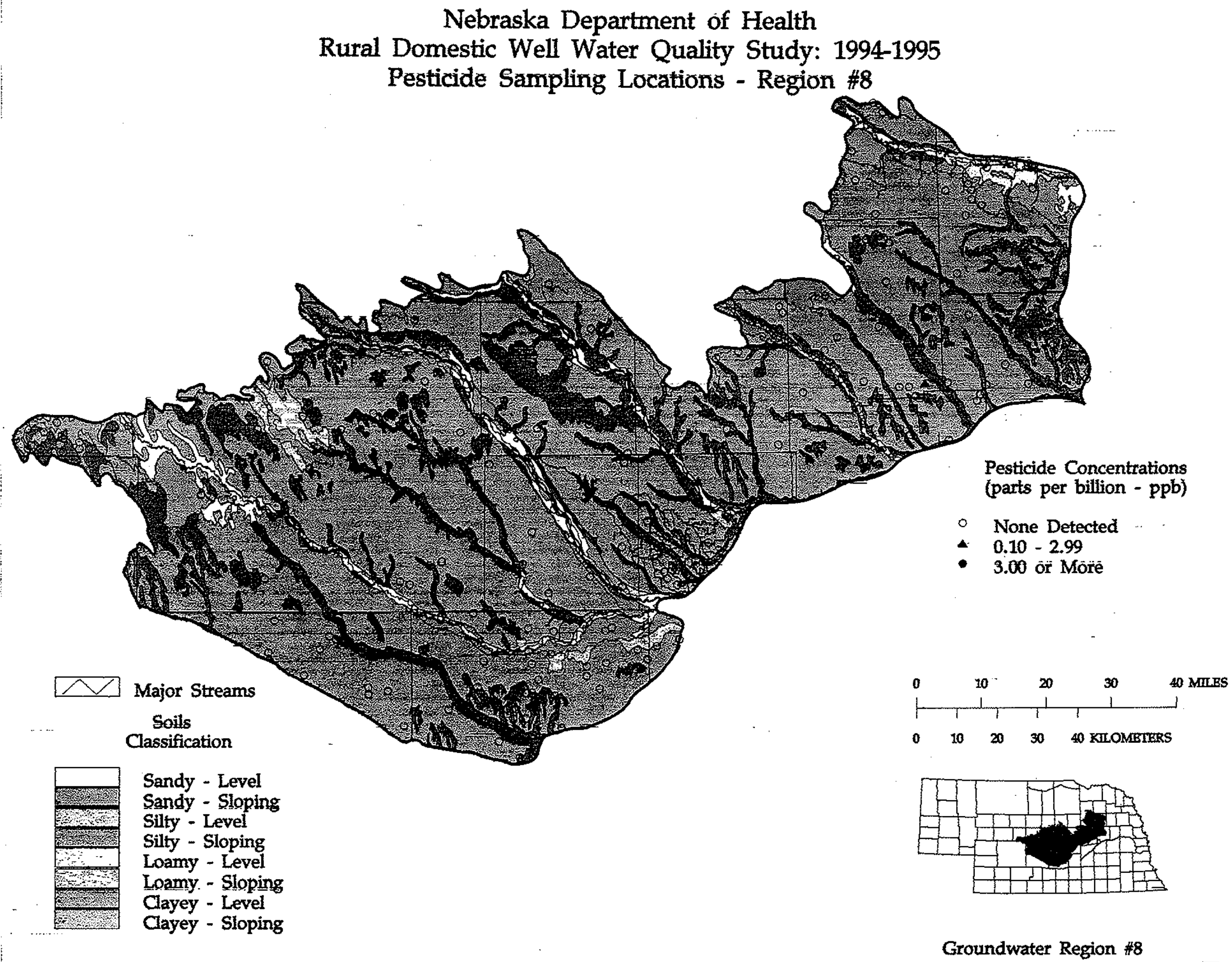
Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Pesticide Sampling Locations - Region #8
Pesticide Concentrations
(parts per billion - ppb)
None Detected
0.10 - 2.99
3.00 or More
Major Streams
Soils
Classification
Sandy - Level
Sandy - Sloping
Silty - Level
Silty - Sloping
Loamy - Level
Loamy - Sloping
Clayey - Level
Clayey - Sloping
0 10 20 30 40 MILES
0 10 20 30 40 KILOMETERS
Groundwater Region #8

Figure GW8.3

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Bacteria Sampling Locations - Region #8

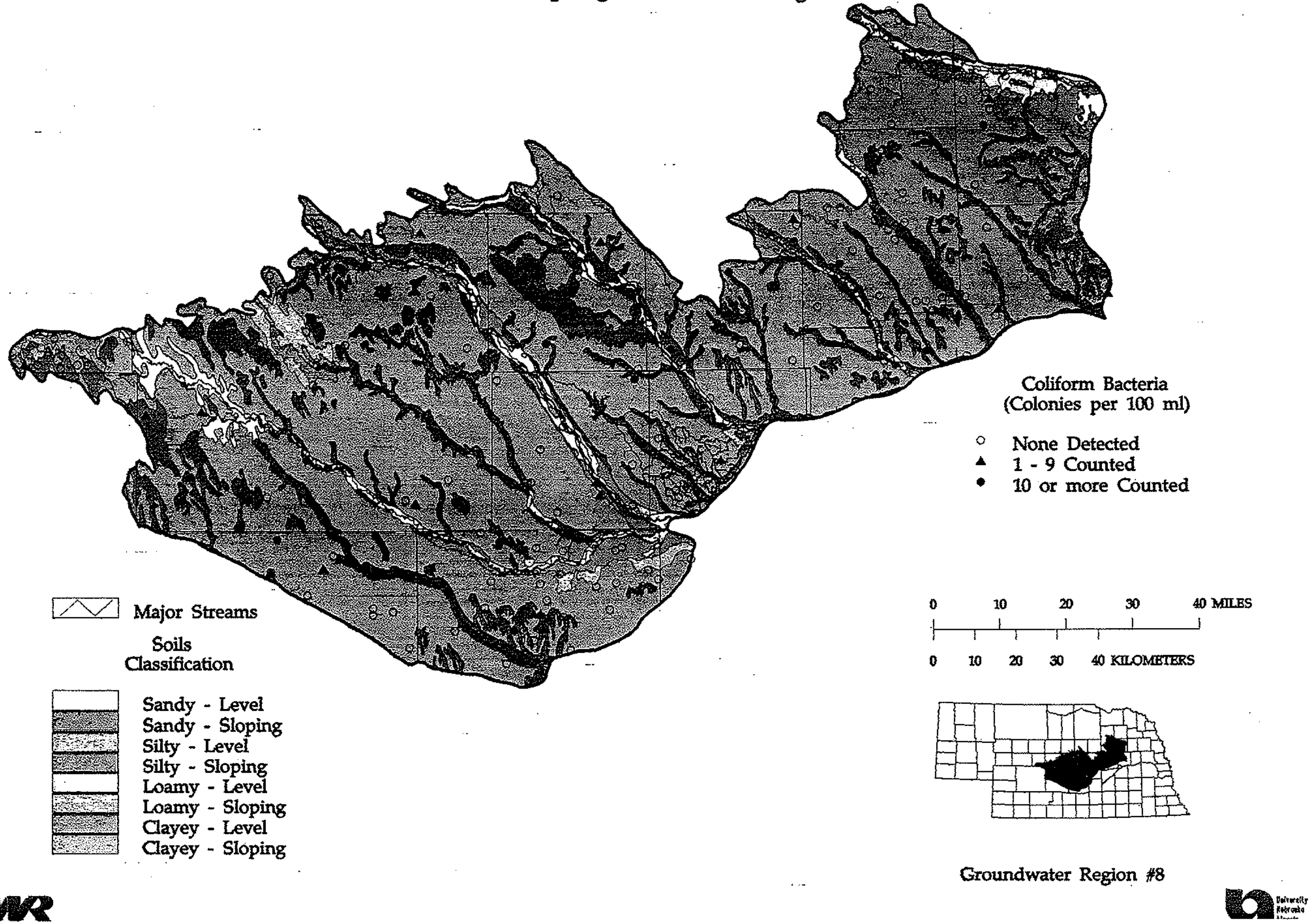

Figure GW8.4

Discussion

Significant associations suggested by the statistical analyses are that higher nitrate-nitrogen concentrations are associated with: 1) wells installed since 1960 and less so to wells installed between 1940 and 1960; and 2) greater depths to the water table. There is also an indication that the occurrence of pesticides is related to higher concentrations of nitrate-nitrogen. Our analyses also indicate that there has been a slight, but significant increase in the nitrate concentrations between the 1985-1989 and 1994-1995 sampling periods.

Differences in the nitrate-nitrogen concentrations between wells installed from 1940 to 1960 (a median of 0.45 ppm) and those installed between 1960 and 1989 (a median of 1.8 ppm) are small. However, the difference is the opposite of what would be expected. Older wells are typically thought to have higher contaminant concentrations. An explanation cannot readily be given for this relationship, but it indicates that the generalization about contamination and well age may not always be correct and that this relationship should be evaluated on a region-by- region basis.

Association of greater nitrate concentrations with greater depths seems contrary to what might be expected, especially if one considers contamination in the Platte River valley, where the opposite is likely to be true. However, in the context of a groundwater flow system, areas that are dominated by net addition of water to the groundwater system (net recharge areas) are typically associated with higher parts of the landscape where depths to water are greater (Gosselin, 1991).

Although distance factors (that is, distance to point sources) do not show any statistical relationships with nitrate-nitrogen contamination, two of the wells with pesticides have nitrate-nitrogen concentrations in excess of 21 ppm and are less than 45 feet from cropland. There is also a possibility that barnyards have affected wells with bacteria, considering that 30 percent of the wells contaminated by bacteria are less than 100 feet from this point source. It should also be noted that distance between a well and a point source of contamination is only one of the factors that determines whether a well will become contaminated. Other factors are the spatial relationship of the well to the point source--that is, whether the well is near or far, upgradient, downgradient, or located laterally from the point source. Furthermore, another important factor is whether the groundwater-bearing units have similar properties. The groundwater-bearing units include stratigraphic layers that affect the direction and rate of local groundwater movement.

References

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Sniegocki, R.T., 1959, Geologic and Ground-Water Reconnaissance of the Loup River Drainage Basin, Nebraska: U.S. Geological Survey, Water-Supply Paper 1493, 105 p.

Svoboda, G.R., 1959, Preliminary Groundwater Study - Boone County, Nebraska University of Nebraska, Conservation and Survey Division, 7 figures.