1996

Regional Analysis of Rural Domestic Well-water Quality – Northern Panhandle Tablelands

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Rural Domestic Well-water Quality in the *Northern Panhandle Tablelands*

Groundwater Region 6 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 6 is located north of the North Platte River and south of the Pine Ridge in the Nebraska Panhandle (Figure 1). The base of the principal groundwater-bearing units is usually considered the Brule Formation, composed of relatively impermeable siltstone. Coarser grained units of the Brule Formation are present locally and can produce significant amounts of water. Overlying the Brule Formation is the Arikaree Group, which consists of interlayered fine-grained sandstone and siltstone. It is as much as 600 feet thick and contains local occurrences of uncemented sand and gravel. Overlying the Arikaree is the Ogallala Group, which is up to 500 feet thick and consists of interbedded clays, silts, sands, sandstones, and gravel, with various degrees of cementation. The Ogallala generally occurs as channel deposits trending west to east. Overlying the Ogallala Group are river-deposited (alluvial) sands and gravel, generally less than 100 feet thick. These materials primarily underlie the valleys of major drainages such as the Niobrara River. (Geologic cross sections for Region 6 are available at the Conservation and Survey Division; Figure 1.)

The Arikaree Group is heavily developed as source of groundwater for irrigation in Box Butte County and, to a lesser degree, in northern Sheridan County (Table 1). The Ogallala Group is also an important source of groundwater in Box Butte County and Sheridan counties. Alluvium is developed as a source of water primarily along the Niobrara River. The thickness of the primary groundwater-bearing units ranges from about 100 feet or less to about 500 feet or more. Depth to the regional water table is mostly 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 in the bottomlands of the principal valleys. Total dissolved solids in the groundwater vary from 200 to 500 parts per million (ppm).

Results*

Well Characteristics

Characteristics of the wells sampled during the 1994-1995 study are summarized in Table GW6.1. The average year of installation was 1964; less than 50 percent of the wells were installed between 1960 and 1979. The oldest well was installed in 1890. Available information indicates more than 94 percent of the wells were drilled and constructed using either PVC or steel casing. Only 80 percent have sanitary seals. The depth of the wells averaged 150 feet and ranged from 12 to 580 feet. Sixty-six percent of the wells had depths between 50 and 199 feet. Of the 67 wells for which information was available, the average well diameter is nearly 6 inches, and more than 37 percent have diameters greater than 6 inches. The minimum diameter was 3 inches, and maximum was 48 inches. Each well was used by an average of three individuals. Nitrate was used at nearly 69 percent of 67 sites. Pesticides were used at 70 percent of the locations.

Nitrates

Nitrate data for the 69 wells sampled during the 1994-1995 study are summarized in Table GW6.1. Their locations are shown in Figure GW6.1 The nitrate-nitrogen concentrations ranged from less than 0.1 ppm to a maximum of 24.3 ppm. Nearly 45 percent of the wells had concentrations less than 3 ppm (Figure GW6.2), indicating that the other 55 percent are affected by nitrate contamination. Nearly 19 percent of the wells exceeded the 10 ppm maximum contaminant level (mcl) for nitrate. The average value for all samples is 5.6 ppm, and the median value is 3.7 ppm.

Figure GW6.2 shows a nearly 9-percent increase in wells with nitrate-nitrogen concentrations greater than 10 ppm from 1985-1989 to 1994-1995. Although the analytical results indicate a general increase, the Wilcoxon Signed Rank Test indicates that the increase was not statistically significant for the 63 wells that had different concentrations between the two sampling periods.

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

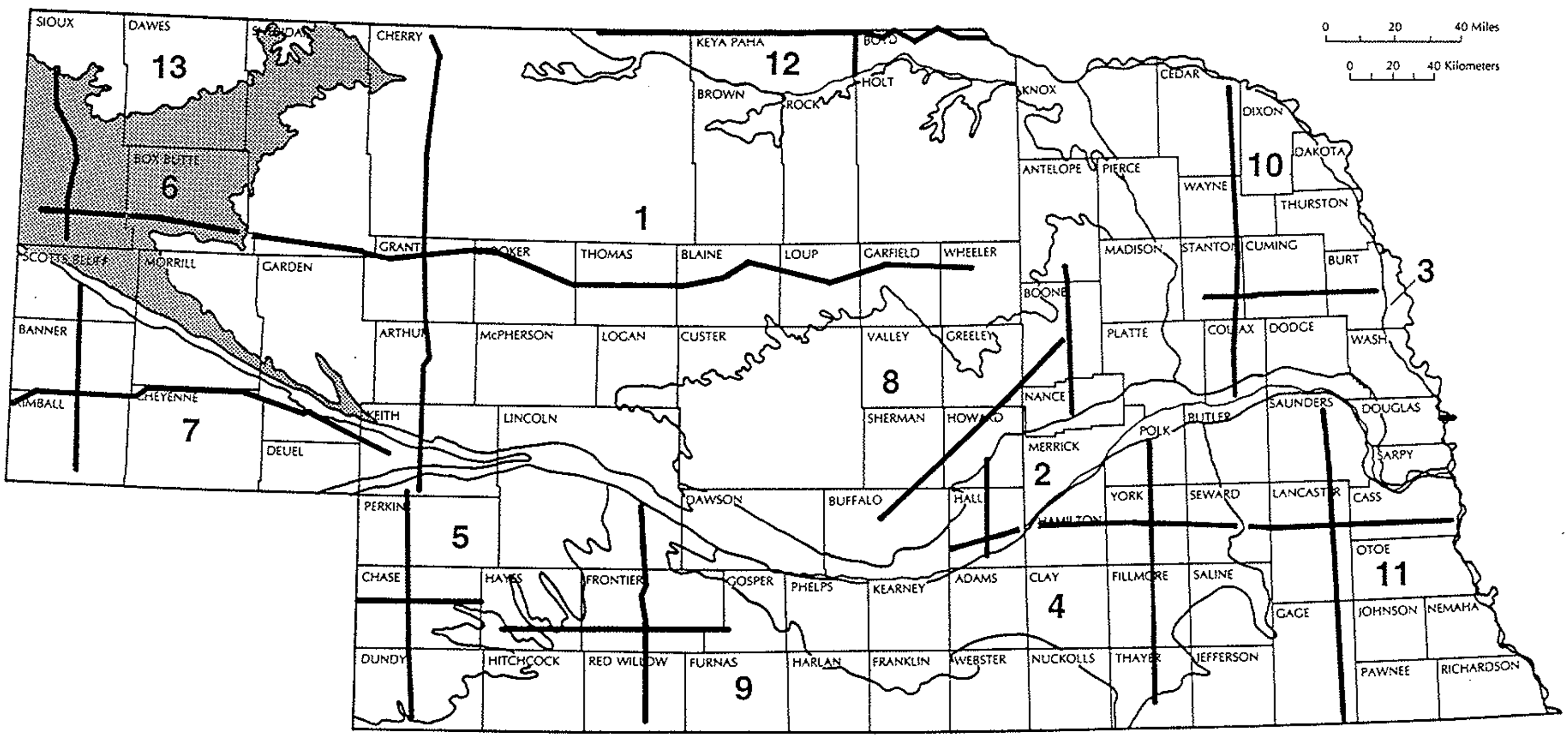

Fig. 1—*Locations of geologic cross sections* **(Region 6 in gray)**

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 GW6.1. 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	58	1964	1890	1988	21
	<1940	5				
	1940-1969	13				
	1960-1979	28				
	1980-present	12				
Well Depth (feet)						
	All	61	149	12	580	110
	<50	5				
	50-99	19				
	100-199	21				
	>200	16				
Well Diameter (inches)						
	All	67	5.9	3	48	5.4
	<2	0				
	2-3	1				
	4-5	41				
	6-7	17				
	>8	8				
Number of Well Users		66	3.1	1	8	1.6
Distance to Contaminant Source (feet):						
	cesspool	6	137	50	240	30
	septic	64	149	10	1120	186
	waste lagoon	1	1300	1300	1300	-
	barnyard	51	313	5	2600	478
	pasture land	53	839	4	6500	1331
	cropland	63	728	5	7800	1272
Well Type:						
	drilled	63				
	driven	3				
	dug	1				
	other	0				
Casing Material:						
	steel	28				
	plastic	35				
	concrete	0				
	brick	0				
	tile	0				
	other	0				
Sanitary Seal:						
	yes	53				
	no	14				
Casing in Pit:						
	yes	35				
	no	32				
Nitrate Used:						
	yes	46				
	no	21				
Pesticide Used:						
	yes	47				
	no	20				

Water Quality Data

		Number of wells	Mean	Median	Minimum	Maximum	Standard deviation	Detections
Nitrate as Nitrogen (ppm NO3-N)								
1994-1995		69	5.6	3.7	0.1	24.3	5.6	
Bacteria (colonies per 100 ml)								
1994-1995		58			0	100		5
Pesticides (ppb)								
1994-1995								
	Atrazine	69						0

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Nitrate Sampling Locations - Region #6

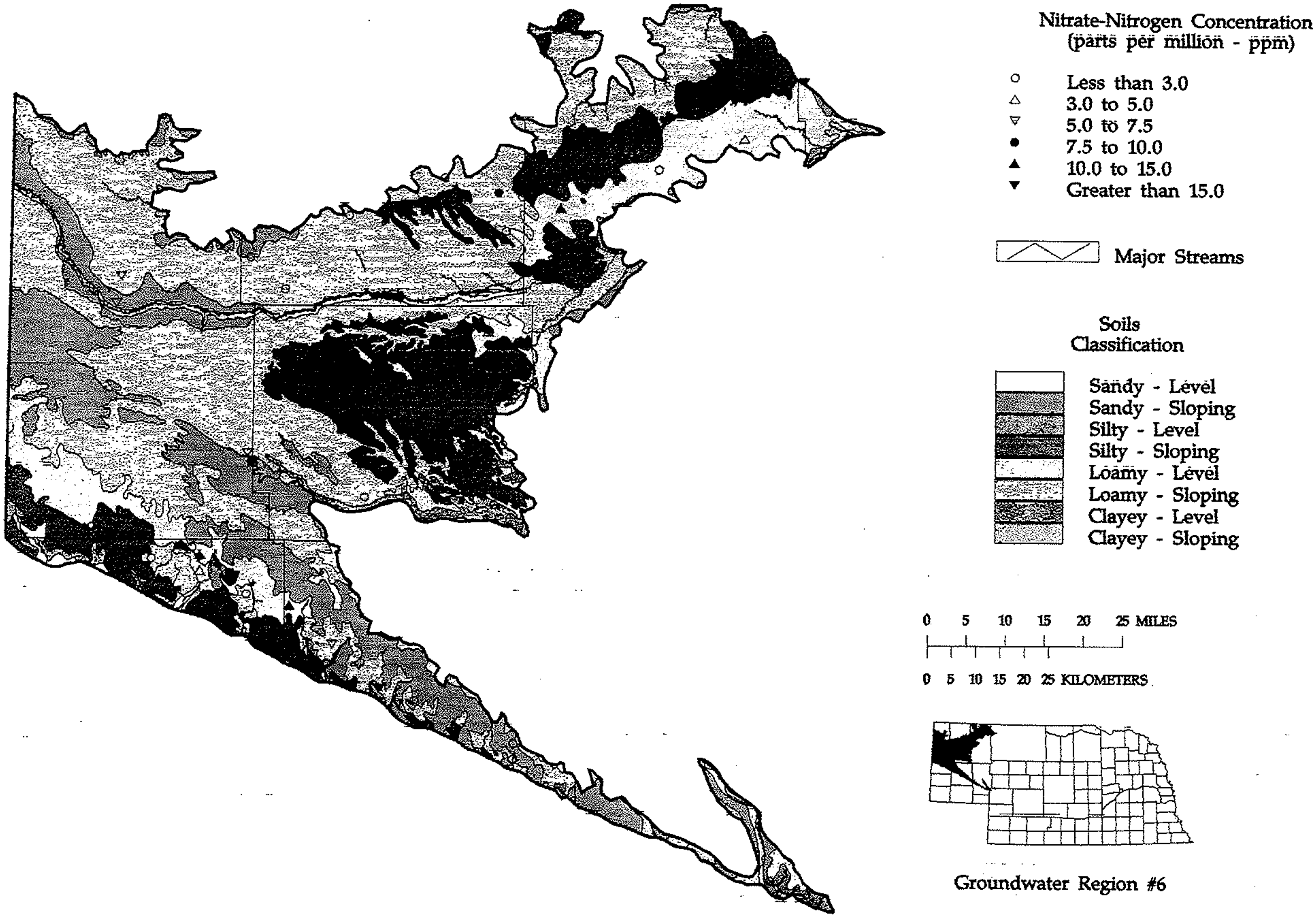

Figure GW6.1

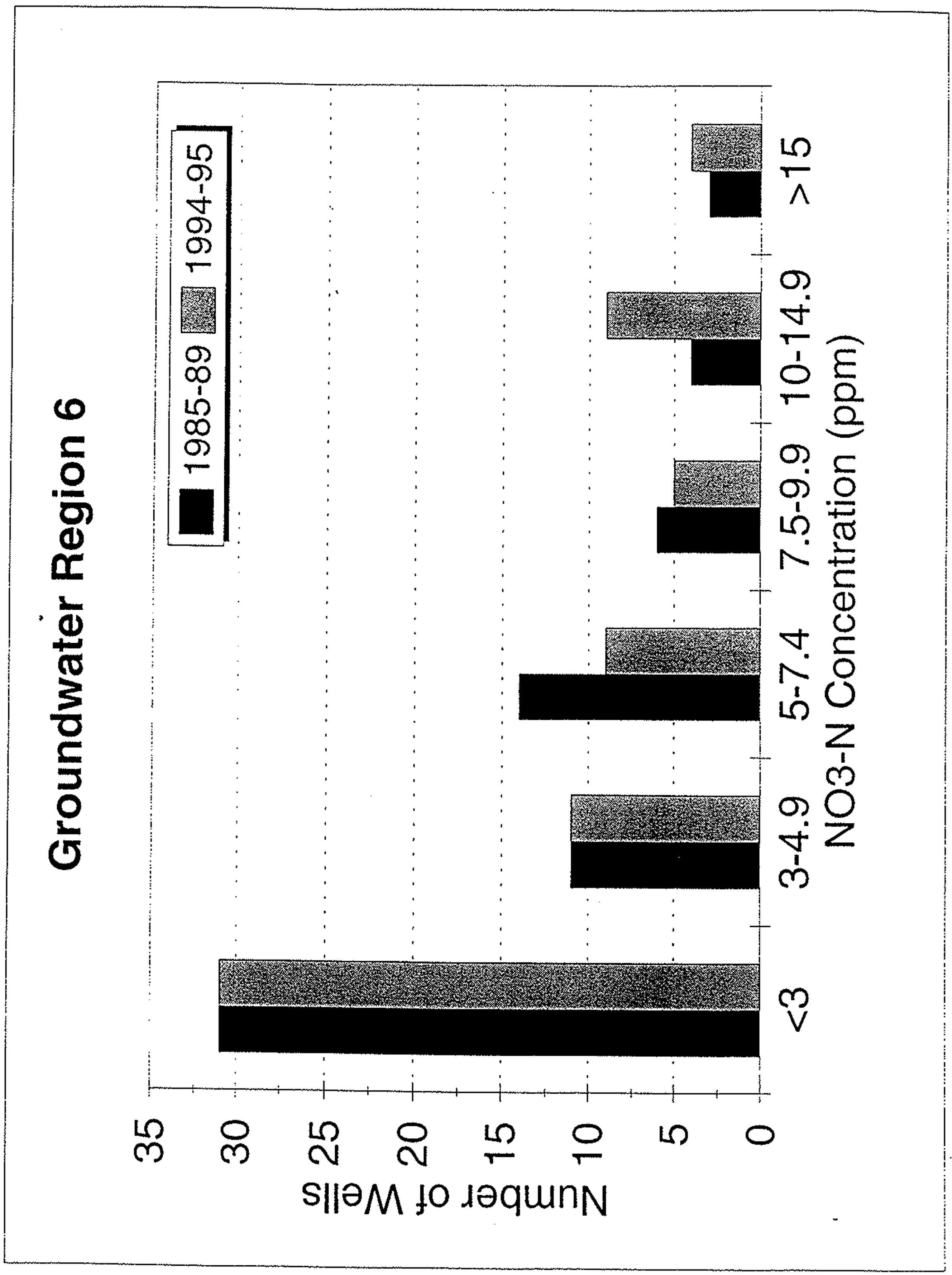
Groundwater Region 6
1985-89
1994-95
Number of Wells
0
5
10
15
20
25
30
35
<3
3-4.9
5-7.4
7.5-9.9
10-14.9
>15
NO3-N Concentration (ppm)

Figure GW6.2

The factors that may influence the nitrate-nitrogen concentrations in rural domestic wells were 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 GW6.1), and agricultural chemical use.

Well-construction factors

The Mann-Whitney Rank Sum Test indicated that for nitrate-nitrogen concentrations grouped by casing type (steel or PVC), sanitary seal (yes or no), casing completed in or out of a pit, and well type (drilled or not), the only factor to show any statistically significant difference was the casing completion. Wells ending in a pit were statistically different and had a higher median value (5.1 ppm) than those in which the casing did not (2.3 ppm). Further evaluation using the Fisher Exact Test supported the Mann-Whitney results and indicated a greater likelihood for a well ending in a pit to have concentrations greater than 5 ppm.

No statistical associations were indicated between nitrate-nitrogen concentrations and installation date (age) or well diameter, using either the Spearman or Kruskal-Wallis tests.

Distance factors

The Spearman Test did not indicate any significant relationships between nitrate-nitrogen and possible point sources of contamination that were related to distance factors.

Hydrogeologic and site factors

Nitrogen was used on the premises in nearly 70 percent of the 67 wells for which this information was available. The Mann-Whitney Test indicated that use of nitrogen did not necessarily relate to differences in nitrate-nitrogen concentrations observed in wells. The Spearman Test indicated a significant association between shallow wells and water levels with higher nitrate concentrations. Use of the Kruskal-Wallis Test and the well-depth groups in Table GW6.1, followed by the Mann-Whitney Test, indicated that wells with depths less than 100 feet had generally higher nitrate-nitrogen concentrations than wells with depths greater than 100 feet.

More than 81 percent of the area in which wells occur is dominated by soils in class 3 (silty-level), class 5 (loamy-level), and class 6 (loamy-sloping) (Figure. GW6.1). Using the Chi-Square Test and the Fisher Exact Test to analyze soil characteristics and nitrate-nitrogen concentrations groups (<3, ≥ 3 to <5, ≥ 5 to < 10, ≥ 10) indicated no statistical difference in nitrate occurrence related to soil type and landscape position.

Pesticides

Of the 69 wells analyzed, pesticides were not detected in any of the wells (Figure GW6.3). In the 1985-1989 study, there were three detections of atrazine; the highest value was 0.8 ppb.

Bacteria

Coliform-bacteria data for the 58 wells sampled during the 1994-1995 study are summarized in Table GW6.1. Their locations are shown in Figure GW6.4. The bacteria data expressed in colonies per 100 ml of water range from 0 to greater than 100. More than 91 percent of the wells had no detectable coliform bacteria, indicating that less than 9 percent of the wells have been affected by bacterial contamination and exceed the mcl for bacteria. Only one of these wells exceeded the mcl for nitrate-nitrogen.

The Wilcoxon Signed Rank Test indicated no statistical difference between the 1994-1995 and 1985-1989 sampling periods for the 10 wells that had different counts during the two periods.

No statistical relationships were indicated between coliform bacteria and distance to any of the possible point sources, such as barnyards or septic systems. One well was installed in 1900. Two others are less than 20 feet from a barnyard and have depths less than 50 feet. These wells could have benefitted from the regulatory distances.

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Pesticide Sampling Locations - Region #6

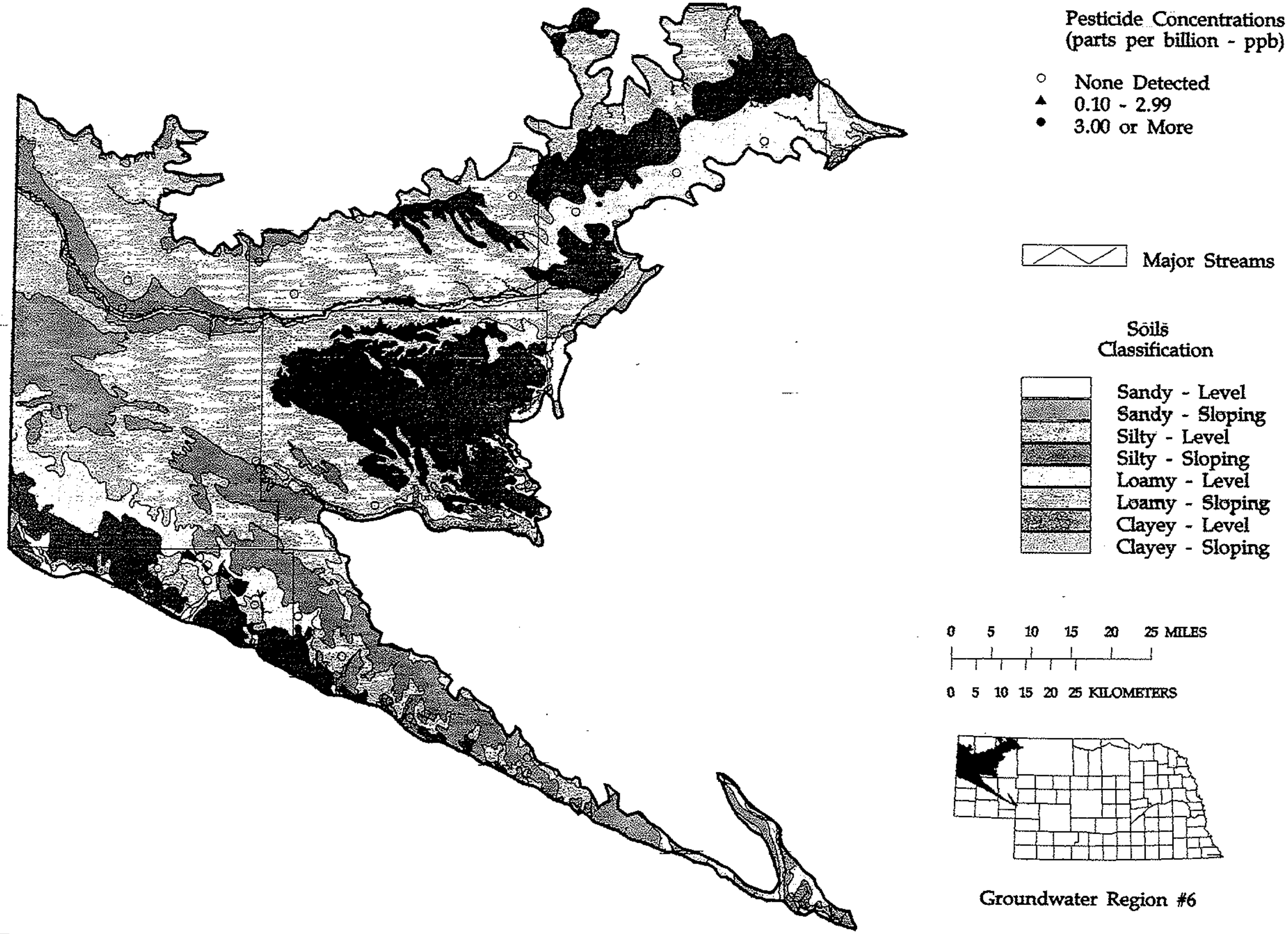

Figure GW6.3

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Bacteria Sampling Locations - Region #6

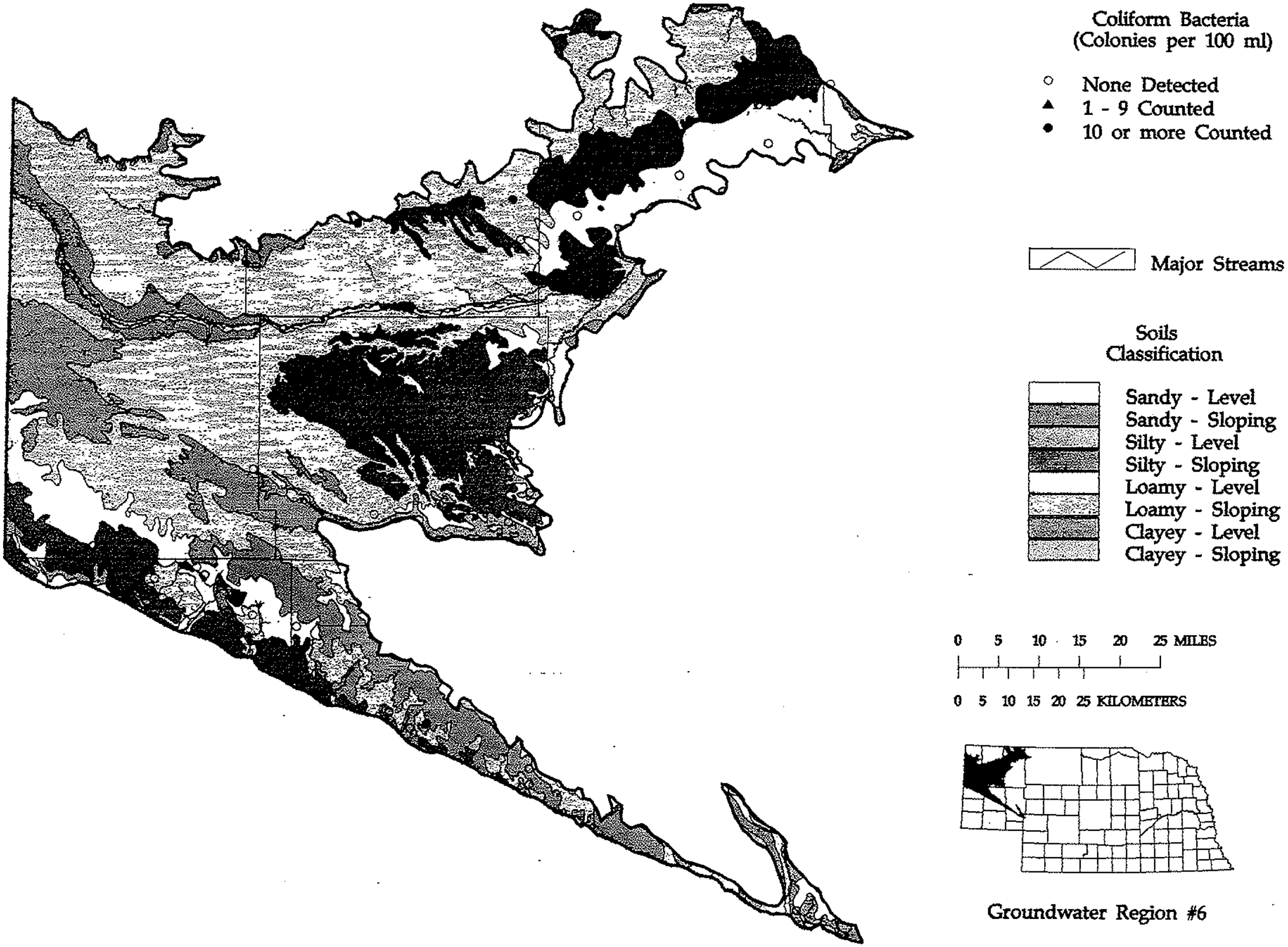

Figure GW6.4

Discussion

The significant associations suggested by the statistical analyses are that higher nitrate-nitrogen concentrations are associated with: 1) wells completed in a pit; and 2) shallow well depth and water tables for wells. Our analyses also indicate that there was no change in nitrate concentrations in these wells from the 1985-1989 sampling period to the 1994-1995 period.

The relationship between generally higher nitrate concentrations and wells completed in a pit clearly indicates that this installation practice should be avoided in this region. As in other areas, decreasing well depth associated with higher nitrate concentrations is expected. Furthermore, we suggest that wells be drilled to depths greater than 100 feet to minimize contamination.

Lack of association of nitrate with distance factors, which are often related to point sources, indicates that these sources have not contributed significantly to variations in the concentration of nitrate-nitrogen in individual wells. However, 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 sitting 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

Swinehart, J.B., V.L. Souders, H.M. DeGraw, and R.F. Diffendal, Jr., 1985, Cenozoic Paleogeography of Western Nebraska, in Flores, R.M. and S.S. Kaplan, eds., Cenozoic Paleogeography of West-Central United States, Denver, Colorado, pp. 209-229.