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Regional Analysis of Rural Domestic Well-water Quality – Republican River Valley and Dissected Plains

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Rural Domestic Well-water Quality in the *Republican River Valley and Dissected Plains*

Groundwater Region 9 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 9 occupies the Republican River valley and dissected plains of south- central Nebraska (Figure 1). The principal groundwater-bearing units in this region are the Tertiary Ogallala Group and the overlying Quaternary sand and gravel deposits. The Ogallala Group is underlain by the relatively impermeable consolidated deposits of chalk and shale of the Cretaceous Niobrara and Pierre formations and the siltstone and clay of the Tertiary White River Group.

The Ogallala Group has been removed by erosion along the Republican River valley and also in the lower reaches of its tributaries. Consisting of a poorly sorted mixture of clays, silts, sands, sandstones, and gravels, the Ogallala Group is cemented in part by calcium carbonate and silica. Quaternary deposits consisting of loess (wind-deposited silt and clay) that are up to 200 feet thick, and also terrace deposits (lenses of gravel, sand, silt, and clay as much as 90 feet thick) overlie the Ogallala Group. (Geologic cross sections for Region 9 are available at the Conservation and Survey Division; Figure 1.)

Because of its areal extent, accessibility, and extent of saturation, the Ogallala Group is the major source of groundwater in this region (Table 1). Alluvium and terrace deposits are an important source of groundwater, yielding small to large quantities of water in the Republican River valley and its major tributaries. Sand and gravel of Pliocene and Pleistocene age also fill some ancient valleys (paleovalleys). Depth to the regional water table ranges from about 50 feet or less in the Republican River valley to about 200 feet or more in the uplands. The saturated thickness of the principal groundwater-bearing units ranges from about 100 feet or less to about 300 feet or more.

Results*

Well Characteristics

The characteristics of the wells sampled during 1994-1995 are summarized in Table GW9.1. The average year of installation was 1964; nearly 62 percent of the wells were installed between 1960 and 1979. The oldest well was installed in 1880. Available information indicates that 88 percent of 129 wells were drilled. Steel or PVC casing was used in nearly all the wells, and 72 percent had sanitary seals. The depth of the wells averaged 134 feet and ranged from 10 to 400 feet. Sixty-seven percent of the wells had depths between 50 and 200 feet. Of the 70 wells for which there was information, the well diameter averaged 7.2 inches and ranged from 2 to 72 inches. Nitrate fertilizers were used at 85 percent of 116 sites. The incidence of pesticides application was lower, being used at 77 percent of the locations.

Nitrates

Nitrate data for the 131 wells sampled during this study are summarized in Table GW9.1. Their locations are shown in Figure GW9.1. The nitrate-nitrogen concentrations ranged from less than 0.1 parts per million (ppm) to a maximum of 53.3 ppm. Only about 30 percent of the wells had concentrations less than 3 ppm (Figure GW9.2), so nearly 70 percent of the wells had been affected by nitrate contamination. More than 23.5 percent of the wells had water that exceeded the 10 ppm Maximum contaminant level (mcl) for nitrate. The average value for all samples was 5.8 ppm, and the median value was 2.8 ppm.

Figure GW9.2 shows a general shift in the number of wells with lower concentrations to those with higher concentrations. There is a nearly 6-percent increase in the number of wells with nitrate-nitrogen concentrations greater than 10 ppm from 1985-1989 to 1994-1995. The observed change to generally higher concentrations is supported by the Wilcoxon Signed Rank Test, which indicates that for the 118 wells where concentrations changed, there was a significant increase.

***** *Where associations, relationships, increases or decreases are discussed, we have determined 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.***

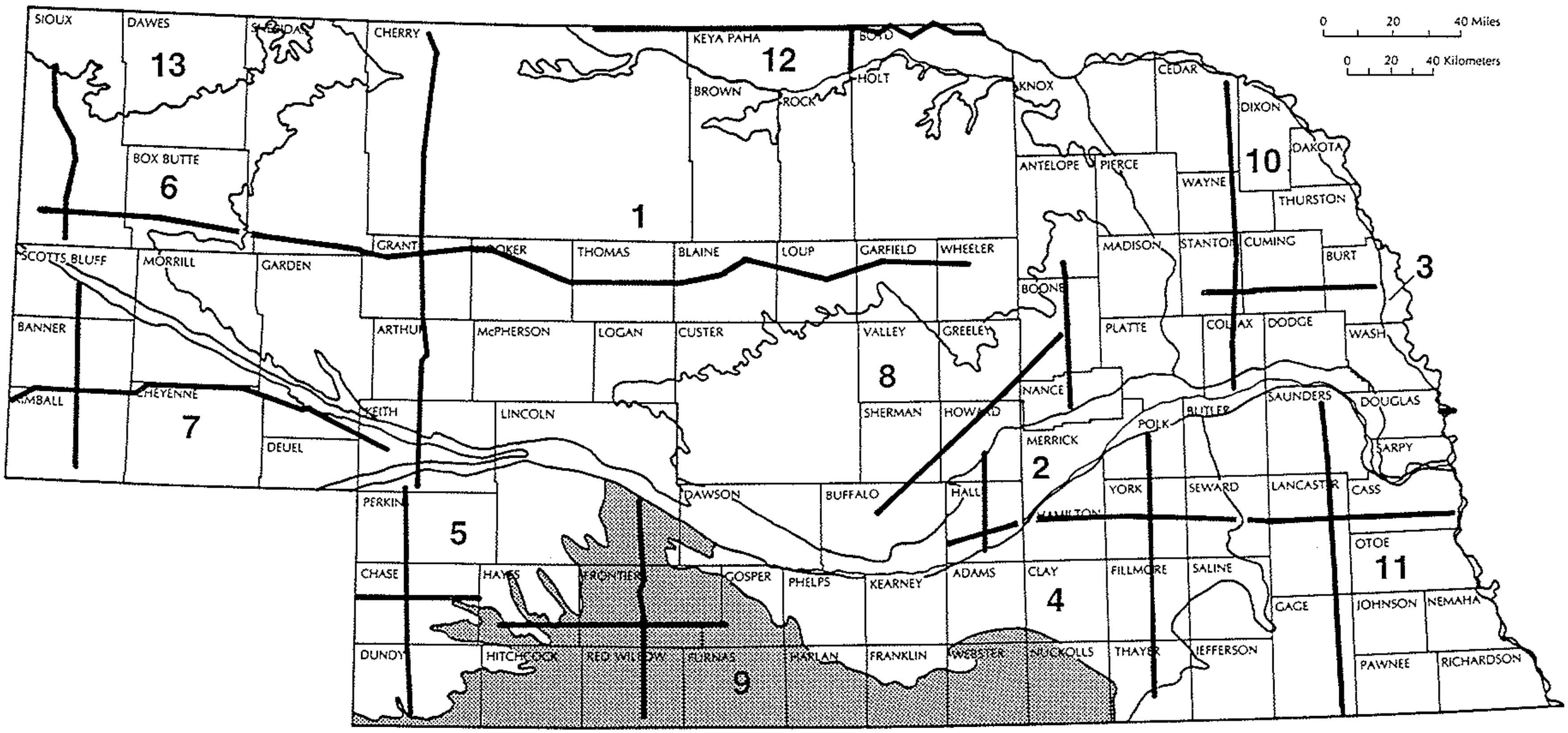

Fig. 1—*Locations of geologic cross sections* **(Region 9 in gray)**

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 GW9.1. 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	118	1964	1880	1986	19
	<1940	11				
	1940-1969	17				
	1960-1979	72				
	1980-present	17				
Well Depth (feet)						
	All	111	134	10	400	91
	<50	16				
	50-99	32				
	100-199	42				
	>200	21				
Well Diameter (inches)						
	All	70	7.2	2	72	11.9
	<2	0				
	2-3	4				
	4-5	51				
	6-7	8				
	>8	7				
Number of Well Users		71	3.0	1	8	1.6
Distance to Contaminant Source (feet):						
	cesspool	18	198	40	600	152
	septic	99	149	16	2000	222
	waste lagoon	8	1063	150	2600	1042
	barnyard	95	207	5	2400	347
	pasture land	65	306	5	2600	471
	cropland	59	278	5	2100	392
Well Type:						
	drilled	114				
	driven	6				
	dug	5				
	other	2				
Casing Material:						
	steel	53				
	plastic	62				
	concrete	0				
	brick	1				
	tile	1				
	other	0				
Sanitary Seal:						
	yes	91				
	no	25				
Casing in Pit:						
	yes	35				
	no	91				
Nitrate Used:						
	yes	98				
	no	18				
Pesticide Used:						
	yes	93				
	no	28				

Water Quality Data

		Number of wells	Mean	Median	Minimum	Maximum	Standard deviation	Detections
Nitrate as Nitrogen (ppm NO3-N)								
1994-1995		131	7.8	5.1	0.1	53.3	8.2	
Bacteria (colonies per 100 ml)								
1994-1995		116			0	100		28
Pesticides (ppb)								
1994-1995								
	Atrazine	131			0	2.9		5

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Nitrate Sampling Locations - Region #9

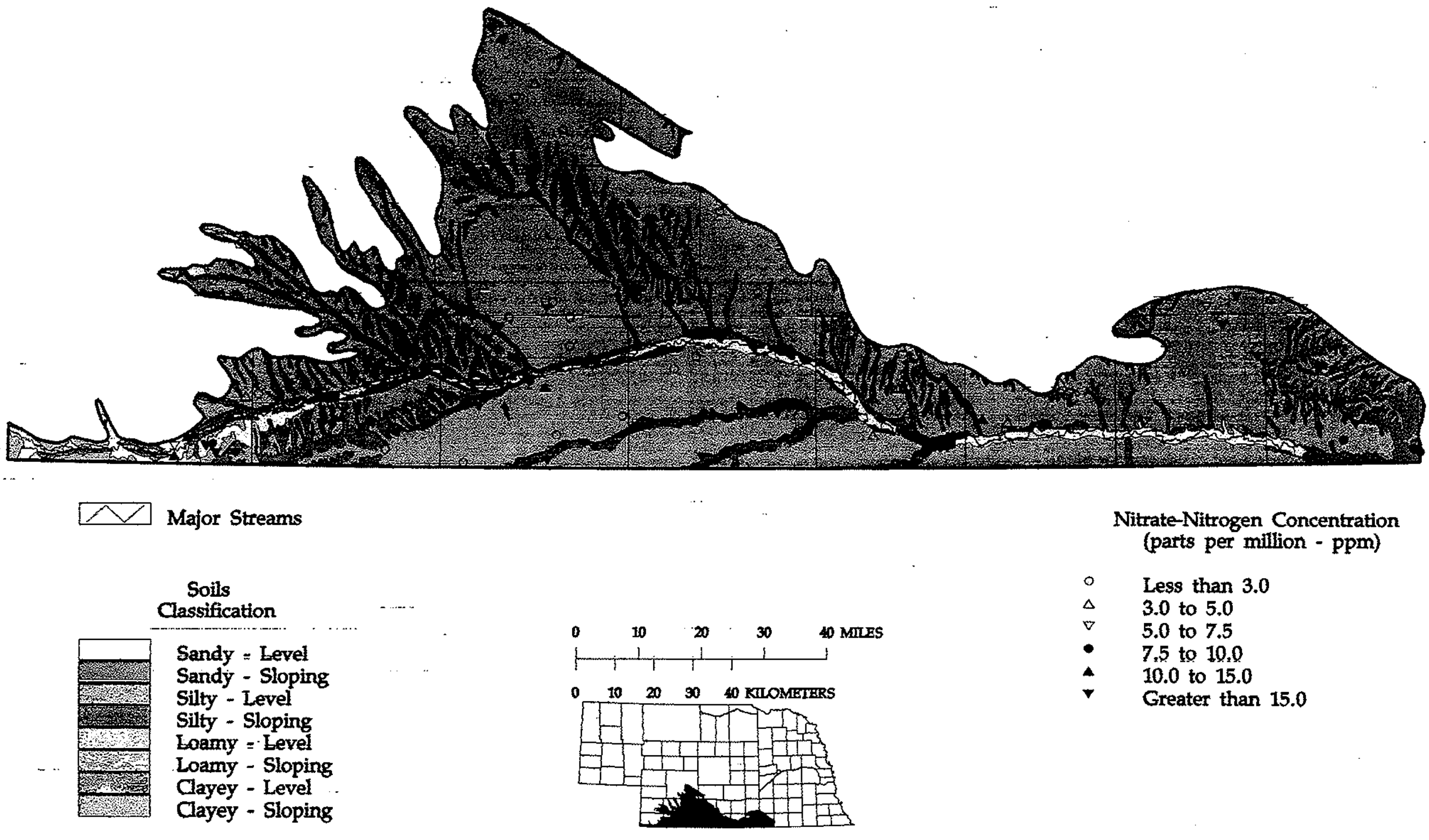

Figure GW9.1

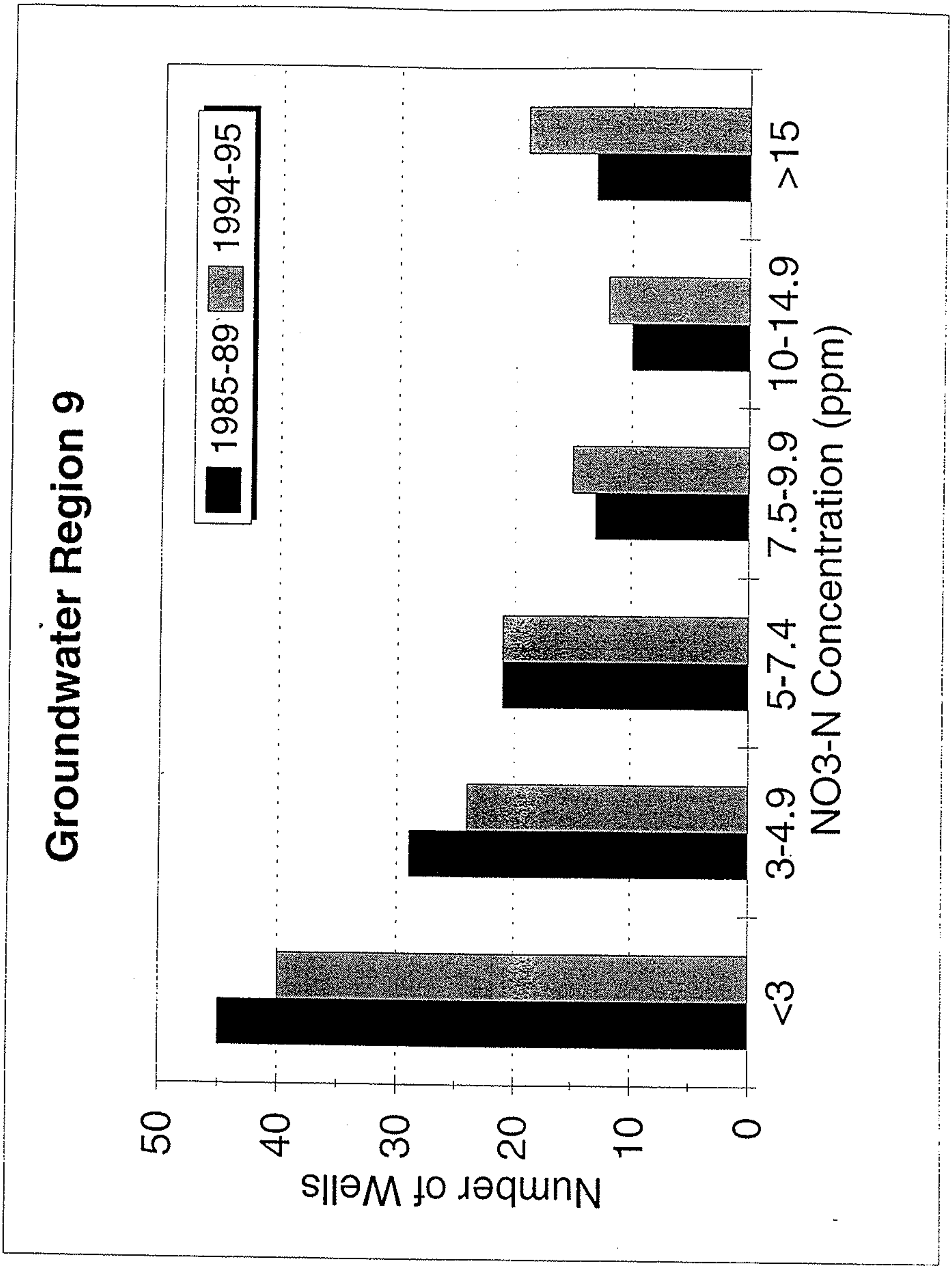
Groundwater Region 9
1985-89
1994-95
Number of Wells
50
40
30
20
10
0
<3
3-4.9
5-7.4
7.5-9.9
10-14.9
>15
NO3-N Concentration (ppm)

Figure GW9.2

The factors that may influence the nitrate-nitrogen concentrations in these rural domestic wells are divided into three groups: 1) well construction factors: casing type, age, diameter, well completion 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. GW9.1), and agricultural chemical use.

Well-construction factors

We used the Mann-Whitney Rank Sum Test to determine whether differences among the nitrate concentrations were related to the well-construction factors. This required grouping nitrate-nitrogen concentrations by casing type (steel vs. PVC), sanitary seal (yes or no), casing completion (in or out of a pit), and well type (drilled or not; and drilled or driven). Of these groupings, only the presence or absence of a sanitary seal were related to statistically different nitrate-nitrogen concentrations. Furthermore, the Fisher Exact Test demonstrated that those wells without a sanitary seal had a greater likelihood of having nitrate-nitrogen concentrations greater than 5 ppm. No statistical associations were indicated between nitrate-nitrogen and installation date (Spearman Test). However, for wells with nitrate-nitrogen greater than 3 ppm, there was a statistically significant association between higher nitrate-nitrogen concentrations and larger diameter wells.

Distance factors

The Spearman Test indicated no association between nitrate-nitrogen concentrations and the distance factors, which are related to point sources of contamination.

Hydrogeologic and site factors

The Mann-Whitney Test indicated that the use of nitrogen did not necessarily relate to the differences in nitrate-nitrogen concentrations. The Spearman Test supported a statistically significant association of higher nitrate concentrations in wells having shallower depths. The strength of this correlation almost doubled when only wells with nitrate-nitrogen concentrations greater than 3 ppm were considered. This test also indicated a very strong association between higher nitrate-nitrogen concentrations and decreasing depth to the water table.

We evaluated the nitrate-nitrogen concentrations related to the well-depth groups in Table GW9.1 by using the Kruskal-Wallis Test, which indicated statistically significant differences between the groups. The Mann-Whitney Test demonstrated that there were statistical differences among the concentrations of the 50- to 99-foot group (a median of 9.1 ppm), those in the 100- to 199-foot group (a median of 5 ppm), and those greater than 200 feet (a median of 3.3 ppm). This indicates that wells deeper than 100 feet were affected to a much lesser degree by contamination than were the shallower wells.

Virtually all the wells in this region occur in areas with soils in class 3 (31 percent; silty-level), class 4 (60 percent; silty-sloping), and soil class 5 (8 percent; loamy-level) (Figure GW9.1). Use of the Chi-Square Test and the Fisher Exact Test indicated that the wells in silty-level soil had a somewhat greater likelihood of having higher concentrations than those wells on silty-sloping soils. Although not indicated by the Chi-Square Test, the Fisher Exact Test indicated that wells in loamy-level soils have a greater likelihood of having nitrate concentrations greater than 5 ppm relative to those in silty-sloping soil.

Pesticides

Of the 131 wells analyzed for pesticides, only five wells had detectable atrazine (Figure GW9.3, Table GW7.1). These concentrations ranged from 0.1 to 2.9 parts per billion (ppb). In the 1985-1989 sampling period, these same wells had 10 atrazine detections with the highest concentration being 1.7 ppb.

The nitrate-nitrogen concentrations for these same wells ranged from 3.9 to 36.5 ppm. The well having 36.4 ppm is the only one exceeding the mcl. It was installed in 1908 and is a tile-cased well. Depth to water for four of the five wells is less than 100 feet. Two of the wells are also less than 20 feet from cropland.

Bacteria

Coliform-bacteria data for the 116 sites sampled during the 1994-1995 study are summarized in Table GW9.1. Their locations are shown in Figure GW9.4. The bacteria data expressed in colonies per 100 ml of water ranged from 0 to greater than 100. About 77 percent of the wells had no detectable coliform bacteria, indicating that 23 percent of

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Pesticide Sampling Locations - Region #9

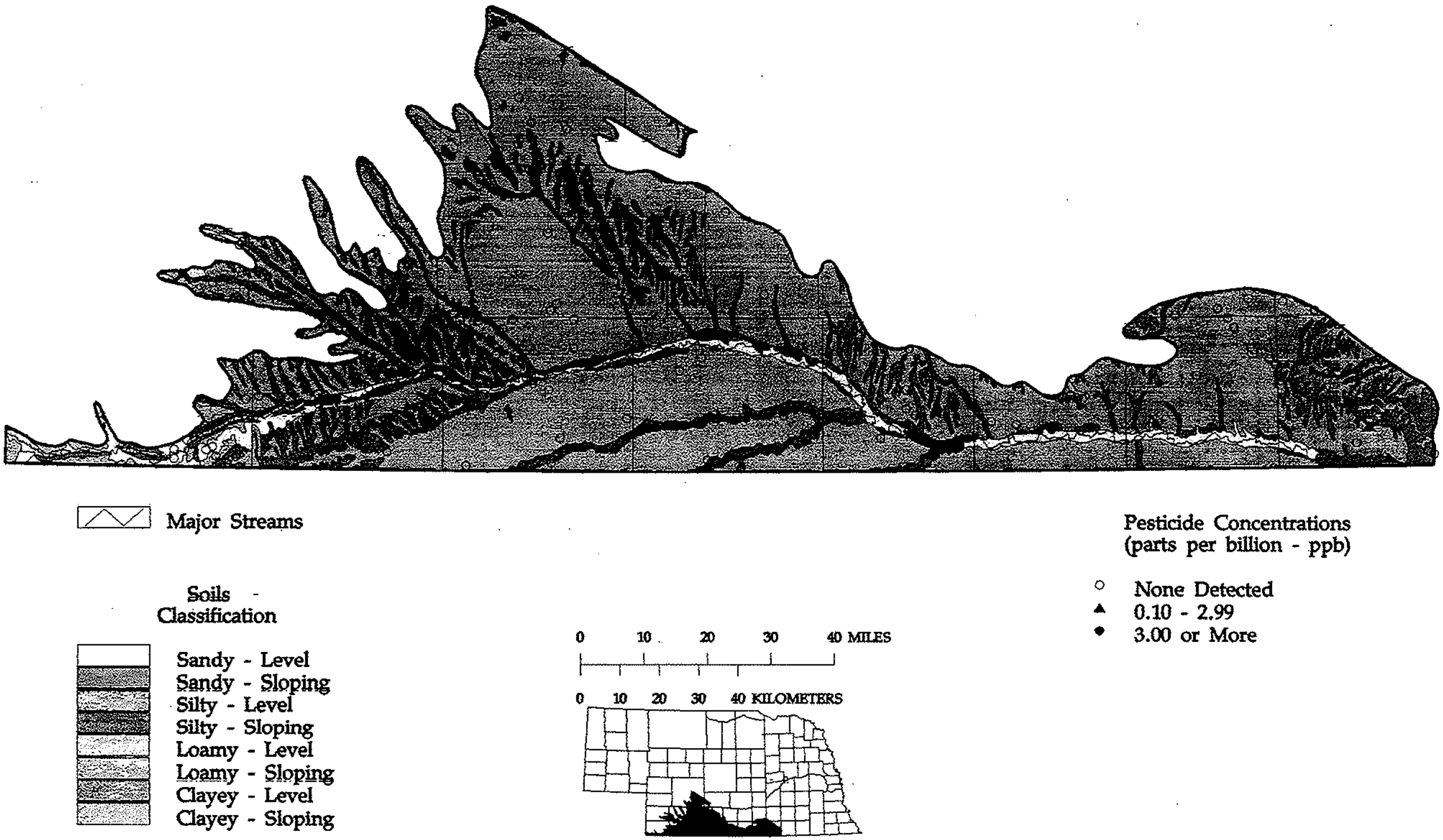

Figure GW9.3

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Bacteria Sampling Locations - Region #9

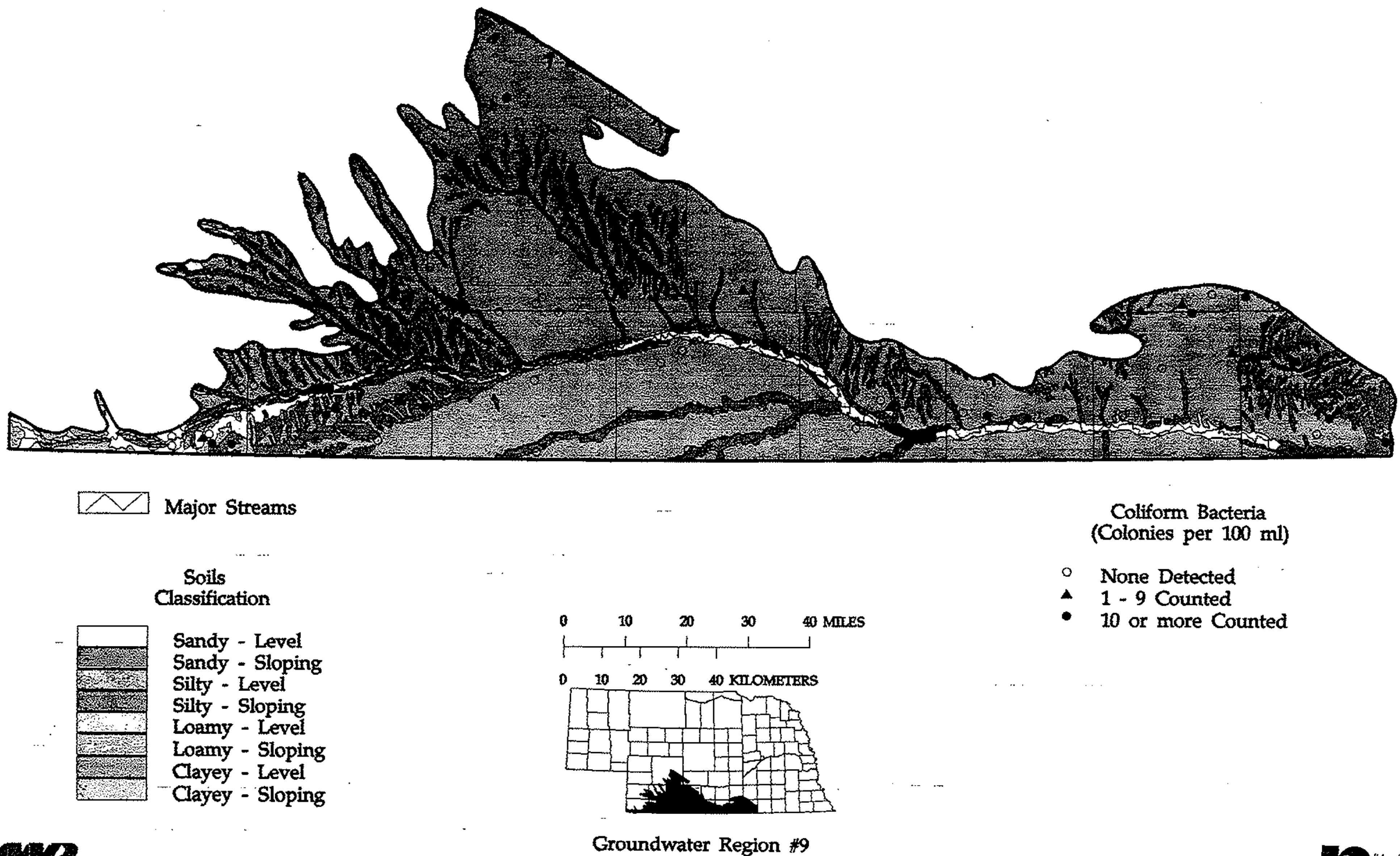

Figure GW9.4

the wells had been affected by bacterial contamination and exceed the mcl for bacteria. Forty percent of the wells had nitrate-nitrogen concentrations greater than 10 ppm.

The Wilcoxon Signed Rank Test was used to assess whether there was any difference between the 1994-1995 and 1985-1989 data and indicated no statistical change in bacteria contamination for the 46 wells that had different counts between the two periods.

A statistical association between the occurrence of coliform bacteria and nitrate-nitrogen concentrations was indicated by the Spearman Test. Thirty-six percent of these wells were installed before 1960, half of which are less than 90 feet deep. Of the remaining wells, nearly 30 percent are less than 100 feet from a barnyard. The closest well is 8 feet from a barnyard, but the water obtained from it had only one coliform colony.

Discussion

Results of our analyses indicated statistically significant associations between higher nitrate-nitrogen concentrations and: 1) wells lacking sanitary seals and having larger diameters; 2) lesser depths to the water table; and 3) silty-level soils and loamy-level soils compared to silty-sloping soils. In addition, a general increase in nitrate concentrations occurred in the wells sampled during both the 1985-1989 and the 1994-1995 sampling periods.

The impact of agricultural chemical contamination of groundwater in Red Willow and Hitchcock counties in the central part of Groundwater Region 9 has been documented by a Special Protection Area study by the Nebraska Department of Environmental Quality (Link, 1991). This study, along with those conducted by the Middle Republican Natural Resources District, concluded that nonpoint-source agricultural chemical contamination is responsible for the degradation of groundwater quality.

The relationship between nitrate-nitrogen concentration and the landscape and soil characteristics are consistent with nonpoint-source contamination occurring where the net addition of water to groundwater (net recharge areas) should be more favorable: relatively flat silty-level landscapes compared with silty-sloping areas. The level-silty soils are also more likely to be under agricultural production in this region. Our analyses of the depth-to-water groups indicates that wells should be installed to depths greater than 100 feet to reduce the possibility of future contamination.

The association of higher nitrate concentrations with wells lacking sanitary seals, having larger diameters, and being contaminated with coliform bacteria indicates that point sources are also contributing at times to the contamination of the wells. Barnyards are likely point sources. Therefore it is important to minimize the impact of point sources through both the location of well and the use of proper well construction.

References

Goeke, J.W., J.M. Peckenpaugh, R.E. Cady, and J.T. Dugan, 1992, Hydrogeology of Part of the Twin Platte and Middle Republican Natural Resources Districts, Southwestern Nebraska: Nebraska Water Survey Paper No. 70, Conservation and Survey Division, University of Nebraska - Lincoln, 89 p.

Link, M.L., 1991, A Study of Nonpoint Source Ground Water Contamination in Red Willow and Hitchcock Counties, Nebraska, A Special Protection Area Report: Nebraska Department of Environmental Control, 81 p.