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Prepared in cooperation with the Republican River Management Districts and the Southwest Nebraska Resource Conservation and Development Area

Distribution of Nitrate in Ground Water in the Republican River Basin, Southwest Nebraska, 1996-98

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INTRODUCTION

Ground water is the primary source of drinking water in the Republican River Basin. Hydrogeologic conditions, at least in some areas, are such that the potential exists for ground-water contamination by agricultural chemicals dissolved in infiltrating water. No study of nitrate concentrations in the Nebraska part of the Republican River Basin has been done recently using uniform collection and analysis techniques. For these reasons, the U.S. Geological Survey (USGS), in cooperation with the Nebraska Republican River Management Districts (the Upper Republican, Middle Republican, Lower Republican, and Tri-Basin Natural Resources Districts (NRDs) and the Frenchman-Cambridge, Frenchman Valley, Hitchcock and Red Willow, and Nebraska Bostwick Irrigation Districts) and the Southwest Nebraska Resource Conservation and Development Area, conducted a study of nitrate concentrations in the Nebraska part of the Republican River Basin.

Purpose and Scope

The primary purpose of this report is to describe the general distribution of nitrate in ground water in the Nebraska part of the Republican River Basin. The secondary purpose is to examine the relation between nitrate concentrations in ground water and hydrogeologic and land-use variables in the study area. To document the occurrence and magnitude of nitrate concentrations in the study area, 283 ground-water samples were collected from irrigation wells during the summers of 1997 and 1998. Additional water-quality information from two similar studies conducted between 1996 and 1998 in the study area was used to augment the data. The two similar studies were conducted by the USGS in the Upper Republican NRD area and by the Nebraska Department of Environmental Quality (NDEQ) in the Lower Republican NRD area.

Description of Study Area

The study area encompasses 9,612 square miles in southwest Nebraska (fig. 1). It is bordered by Colorado on the west, Kansas on the south, and the Republican River drainage basin boundary on the north and east. Precipitation varies between about 26 inches per year in the eastern part of the study area to about 17 inches per year in the west. Between 1991 and 1993, about 50 percent of the study area was used for row crop or small grain production, with approximately 32 percent of that area being irrigated cropland. Forty-seven percent of the study area was designated as mixed grass, sandhills prairie, or sand-sage shrubland. The remaining 3 percent was classified as

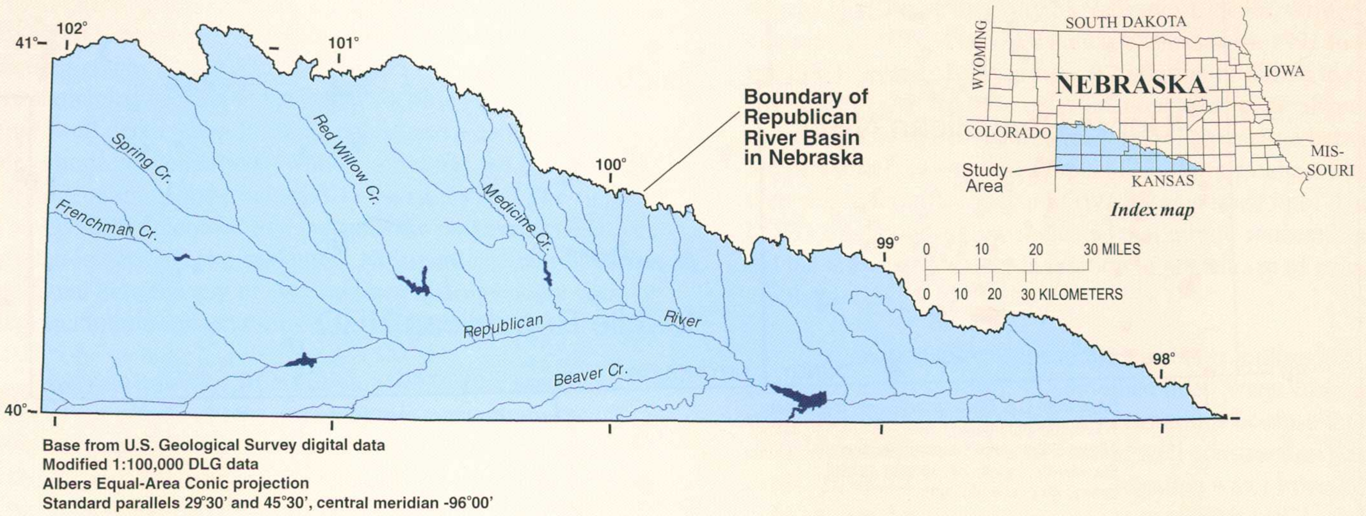

Figure 1. Location of the Nebraska part of the Republican River Basin.

woodland, wetland, and other land uses (Julie G. Giandinoto, CALMIT/Conservation and Survey Division, University of Nebraska-Lincoln, written commun., 1999).

Three primary water-bearing geologic units are present in the Nebraska part of the Republican River Basin: (1) alluvial deposits (stream deposited sand and gravel), (2) paleovalley (buried river valley) deposits, and (3) the Ogallala Formation. The extents of these units have been described by Waite, Reed, and Jones (1944); Johnson (1960); Cardwell and Jenkins, (1963); Dreeszen and others (1973); and Eversoll and others (1988). The alluvial deposits are found throughout the study area in present-day river valleys, generally are less than 60 ft (feet) thick, and are primarily composed of sand and gravel deposited by recent streams during the Holocene Epoch (last 10,000 years). The water table in the alluvial deposits generally is closer to the land surface (normally less than 60 ft below land surface), and therefore may be more susceptible to nitrate contamination, than the other water-bearing units in the study area.

The paleovalley deposits are present primarily in parts of Franklin, Harlan, Kearney, Nuckolls, Phelps, and Webster Counties. These deposits have a variable thickness (0 to more than 300 ft) (Johnson, 1960), and consist of sand and gravel that was deposited by streams during the most recent glaciations (between 10 thousand and 1.6 million years ago). They overlie the Ogallala Formation where the formation is present and are buried by younger deposits.

The Ogallala Formation is found throughout the entire study area except where it has been completely removed by erosion in the Republican River valley and in parts of Franklin, Harlan, Nuckolls, and Webster Counties. It usually is a plentiful source of ground water and has a variable thickness (0 to about 500 ft) that generally thins toward the eastern part of the study area (Johnson, 1960; Cardwell and Jenkins, 1963). It consists of unconsolidated sand, gravel, and clay along with layers of limy sandstone and siltstone deposited during the Miocene Epoch (about 1.6 to 5 million years ago).

DATA COLLECTION

Water samples were collected from 283 irrigation wells in the study area during the summers of 1997 and 1998. The water samples collected from these wells were analyzed for total nitrite plus nitrate as nitrogen concentrations (herein referred to as nitrate) at Olsen's Agricultural Laboratory in McCook, Nebraska, using standard methods described by the American Public Health Association (1995).

The wells sampled for this project were chosen from all irrigation wells on file with the Nebraska Department of Water Resources (NDWR) using a modified random selection

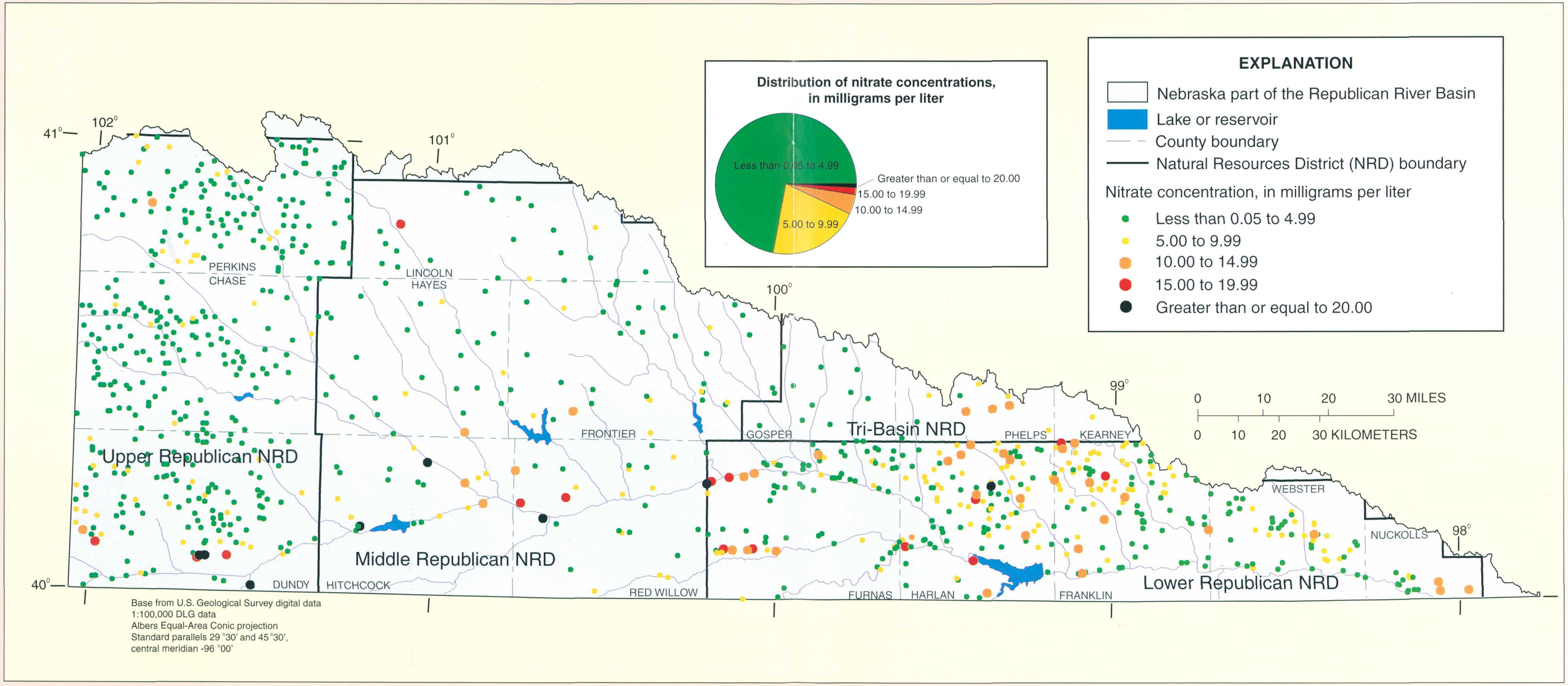

Figure 2. Nitrate concentrations in the Republican River Basin, southwest Nebraska, 1996-98.

method in which one or two irrigation wells were selected randomly in every township of the study area. The selected wells then were evaluated further to establish their suitability for sampling. A well was considered suitable for sampling if (1) no site conditions, such as point-source pollutants, were evident that might make the sample unrepresentative of the ground water in the surrounding area, and (2) permission was obtained from the well owner to sample. In most cases, wells had a driller's geologic log and construction information on record. Alternate wells were chosen in the event that a randomly selected well could not be sampled. An alternate well was either a well that was owned by the same landowner or the nearest well to the originally selected well. In some townships, ground-water availability was minimal and no irrigation wells were found suitable for sampling.

Water samples were collected using sampling methods modified from Kolpin and Burkart (1991). Samples were collected only after the well had been pumping for at least 20 minutes and after field parameters (pH, specific conductance, water temperature, and dissolved oxygen) had stabilized to assure that the sample water represented ground-water conditions. Sample bottles were filled directly from the nearest access point to the wellhead. Water was not collected from any well that was chemigating (using an irrigation system to deliver agricultural chemicals to a crop or field) at the time of sampling or any well that had a chemigation apparatus attached above the sampling point. For each well, the water-bearing unit contributing water to the well was determined using driller's geologic logs and comparisons with previously published reports about the local geology (Waite, Reed, and Jones, 1944; Johnson, 1960; Cardwell and Jenkins, 1963; Dreeszen and others, 1973; Eversoll and others, 1988). The contributing water-bearing unit could not be determined at 20 of the wells.

To verify the quality of the data, duplicate samples were collected at 10 percent of the sites, prepared samples of known nitrate concentrations were sent to the laboratory for 3 percent of the sites, and prepared blank samples with nitrate concentration values of zero were sent to the laboratory for 1 percent of the sites. Analytical results from the duplicate and prepared quality-control samples indicated that the data were reliable.

Additional water-quality information from two other sampling efforts conducted in the study area was assembled with the analysis results from this study, bringing the total number of samples used for this report to 907. These supplementary data pertain to 291 ground-water samples collected from irrigation wells by USGS personnel in the Upper Republican NRD during the summer of 1998 (Jill D. Frankforter, USGS, written commun., 1998) and 333 samples collected from irrigation wells by NDEQ personnel in the Lower Republican NRD during the summers of 1996 and 1997 (Inman, 1998). Both of these studies had similar sampling and analysis methods.

DISTRIBUTION OF NITRATE

Nitrate concentrations of samples collected in the study area (fig. 2; table 1) ranged from less than 0.05 to 26.90 mg/L (milligrams per liter; one milligram per liter is equal to one part per million), with a median concentration of 3.20 mg/L. Water

Table 1. Nitrate concentrations in the Republican River Basin, southwest Nebraska, 1996-98

[mg/L, milligrams per liter; NRD, Natural Resources District; <, less than]

Sample area or water-bearing unit	Number of samples	Minimum (mg/L)	1st Quartile[1]	Mean[2] (mg/L)	Median[3] (mg/L)	3rd Quartile[4] (mg/L)	Maximum
Republican River Basin	907	<0.05	2.20	4.39	3.20	5.33	26.90
			NRD				
Upper Republican NRD	394	<.05	2.04	3.34	2.50	3.78	25.13
Middle Republican NRD	108	.07	2.71	5.55	3.68	6.54	26.90
Lower Republican NRD	383	<.05	2.48	5.09	4.29	6.78	25.20
Tri-Basin NRD	22	2.58	3.00	5.39	4.18	6.40	13.85
			Water-bearing unit				
Alluvial deposits	136	<.05	.65	5.40	3.07	8.22	26.90
Paleovalley deposits	134	1.29	3.52	5.54	5.13	7.12	15.40
Ogallala Formation	617	.14	2.17	3.90	2.89	4.59	25.20

[1]The first quartile is the value that is greater than 25 percent of the concentrations and less than 75 percent of the concentrations.

[2]The mean, or average, value is the sum of the concentrations divided by the total number of samples.

[3]The median concentration is the value that is greater than 50 percent of the concentrations and less than 50 percent of the concentrations.

[4]The third quartile is the value that is greater than 75 percent of the concentrations and less than 25 percent of the concentrations.

from 493 of the 907 wells (54 percent) had nitrate values of 3 mg/L or greater. In a national study evaluating the occurrence of nitrate, concentrations of more than 3 mg/L were considered to be human induced (Madison and Brunett, 1985). Water from 63 wells (7 percent) had nitrate concentrations of more than 10 mg/L, the U. S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for drinking water (U.S. Environmental Protection Agency, 1996). The USEPA has determined that nitrate concentrations greater than 10 mg/L may present potential health risks to humans and livestock (National Research Council, 1978). One possible health risk is a blood disorder called methemoglobinemia, or blue baby syndrome. Nitrate-contaminated water principally causes this illness in children under the age of 6 months and in young livestock.

Using the Wilcoxon rank-sum statistical test at the 99-percent confidence interval (Wilcoxon, 1945), median nitrate concentrations in water samples from the paleovalley deposits were determined to be significantly greater than water samples from the other two water-bearing units (fig. 3). In the alluvial deposits, concentrations ranged from less than 0.05 to 26.90 mg/L, with a median of 3.07 mg/L. In the Ogallala Formation, concentrations varied from 0.14 to 25.20 mg/L, with a median of 2.89 mg/L. Nitrate concentrations in the paleovalley deposits ranged from 1.29 to 15.40 mg/L, with a median of 5.13 mg/L. Nitrate concentrations exceeded the USEPA MCL in 18 percent of samples from the alluvial deposits, 8 percent of samples from the paleovalley deposits, and 4 percent of samples from the Ogallala Formation.

Hydrogeologic variables other than water-bearing unit also may influence nitrate concentrations in ground water. The other variables considered for this study were water-table depth, well depth, and well-screen depth. The relation of each of these variables to nitrate concentrations was examined by creating a scatterplot graph of each variable with its nitrate concentration values and then superimposing a LOcally WEighted Scatterplot Smoothing (LOWESS) line on the resulting graph. A LOWESS-smoothed line visually enhances the relation between an independent variable (water-table depth, well depth, or well-screen depth) and a dependent variable (nitrate concentrations) while minimizing the influence of outlying, or anomalous, values (Cleveland, 1979). The slope of a LOWESS-smoothed line indicates the positive or negative correlation between two variables. No significant correlation was found between any of the examined hydrogeologic variables and nitrate concentration using this method.

Methods modified from Kolpin (1997) were used to examine the effects of land use on nitrate concentrations. Samples from 132 wells most likely affected by local land use were selected. The wells were characterized by having a water table no more than 20 ft below land surface and a screened interval no more than 20 ft below the water table and less than 50 ft long. Land use within about a 1.2-mile radius of the selected wells was determined using a modified version of the

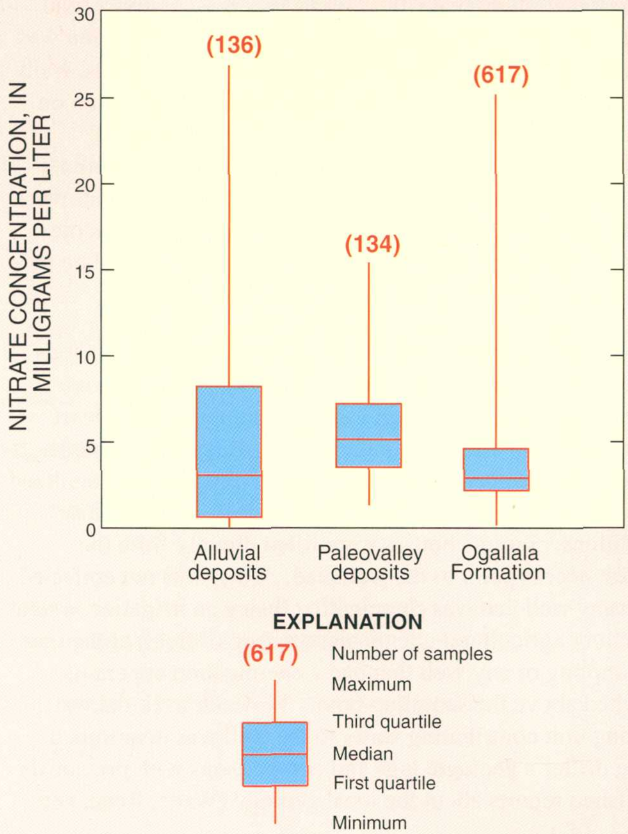

Figure 3. Nitrate concentrations by water-bearing unit in the Republican River Basin, southwest Nebraska, 1996-98.

USGS Geographic Analysis Program (GAP) land-use digital data set (Julie G. Giandinoto, CALMIT/Conservation and Survey Division, University of Nebraska-Lincoln, written commun., 1999). The GAP land use is based on 1991 to 1993 satellite imagery. To determine the relation of nitrate to land use, the 17 GAP land-use classifications were generalized into two classes; irrigated and nonirrigated. The relation between the percentage of irrigated cropland and nitrate concentrations then was determined with a LOWESS-smoothed line. The LOWESS-smoothed line indicated that nitrate concentrations did not vary significantly in relation to percentage of irrigated cropland.

The relation of well age to nitrate concentrations also was examined using a LOWESS-smoothed line. Water from older wells may have greater nitrate concentrations because they often were not installed with current well construction standards. In addition, fertilizers and irrigation water often have been applied for a longer period of time at older well locations. Well age ranged from 1 to 47 years. Data from this study showed that nitrate concentrations did not vary significantly in relation to well age.

SUMMARY

- Nitrate concentrations of ground-water samples collected during 1996-98 in the Nebraska part of the Republican River Basin ranged from less than 0.05 to 26.90 mg/L, with a median concentration of 3.20 mg/L.
- About half of the water samples collected had nitrate concentrations greater than 3 mg/L, indicating that human activities have affected the ground water in large parts of the study area.
- Nitrate concentrations generally were less than the 10 mg/L USEPA MCL. Alluvial deposits had the greatest percentage of samples (18 percent) that exceeded the USEPA MCL.
- Water from the paleovalley deposits had a greater median nitrate concentration than water from the alluvial deposits and the Ogallala Formation.
- Nitrate concentrations did not show significant relations with water-table depth, well depth, well-screen depth, irrigated cropland, or well age.

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