Updated Water-Quality Evaluation of the Ogallala Aquifer Including Selected Metallic and Non-Metallic Inorganic Constituents

November, 1998

By Steven Schriver and Janie Hopkins

More than 700 wells completed in the Ogallala aquifer were sampled from 1994 through 1997 as part of the TWDB=s systematic sampling of major and minor aquifers in Texas. This monitoring is undertaken to characterize the ambient or background quality of ground water in the aquifers as well as to determine if any and what changes may have occurred over time. Field measurements, including conductivity, pH, and temperature, were taken during sampling, which was conducted in accordance with the methods described in the *TWDB Field Manual for Ground-Water Sampling* (Nordstrom and Beynon, 1991). Adhering to procedures started in 1988, samples were analyzed for major cations, anions, nitrate, and minor inorganic elements. In this latest sampling season, however, six additional trace metals were also added to the list.

The map in **Figure 1** serves two functions: to illustrate location of wells sampled as well as to provide a quick look at water quality from the standpoint of total dissolved solids content. Consistent with findings in previous reports on the Ogallala, salinity in the southern part of the study area is poorer than in the northern. The stiff diagrams in **Figure 2** reveal that the Ogallala typically contains calcium bicarbonate to mixed-cation-bicarbonate water in the north, with greater amounts of chloride and sulfate in the south. In the *Water-Quality Evaluation of the Ogallala Aquifer, Texas* (Payne, 1992), maps of total dissolved solids, chloride, sulfate, fluoride, selenium, nitrate, and radioactive constituent content also corroborate this trend of poorer water quality in the south.

The averages and ranges of concentrations of major anions and cations, nitrate, and trace metallic and non-metallic constituents listed in **Tables 1** and **2** reveal little significant difference in the results of the 1992 and 1997 sampling seasons. ASouth" in the tables refers to that same area defined in the most recent TWDB Ogallala water-quality report (Payne, 1992), or counties to the south of and including Parmer, Castro, Swisher, and Briscoe counties. In the southern part of the Texas Ogallala, nitrate as NO_3 and fluoride are in excess of their primary MCLs of 44.3 and 4.0 milligrams/liter in 18 and 77 percent of the wells, respectively. Several anions--chloride, sulfate, and fluoride--are also in excess of their secondary Maximum Constituent Levels (MCLs) in relatively significant amounts in the southern Ogallala, including the overall water quality indicator, or total dissolved solids, averaging slightly more than 1,000 milligrams/liter (Table 1). Table 2 lists the *number* of wells with constituents detected in excess of their primary MCLs of 50 micrograms/liter for arsenic and selenium and of 5 micrograms/liter for lead. Iron, manganese and aluminum are in excess of their secondary MCLs of 300, 50 and 50 micrograms/liter, respectively, in negligible amounts, with the exception of iron found in 21% of the samples in the northern part of the study area.

Figure 1.

Figure 1. TDS values for wells sampled in the Ogallala from 1994 - 1997 corroborate earlier findings of poorer water quality in the southern part of the aquifer.

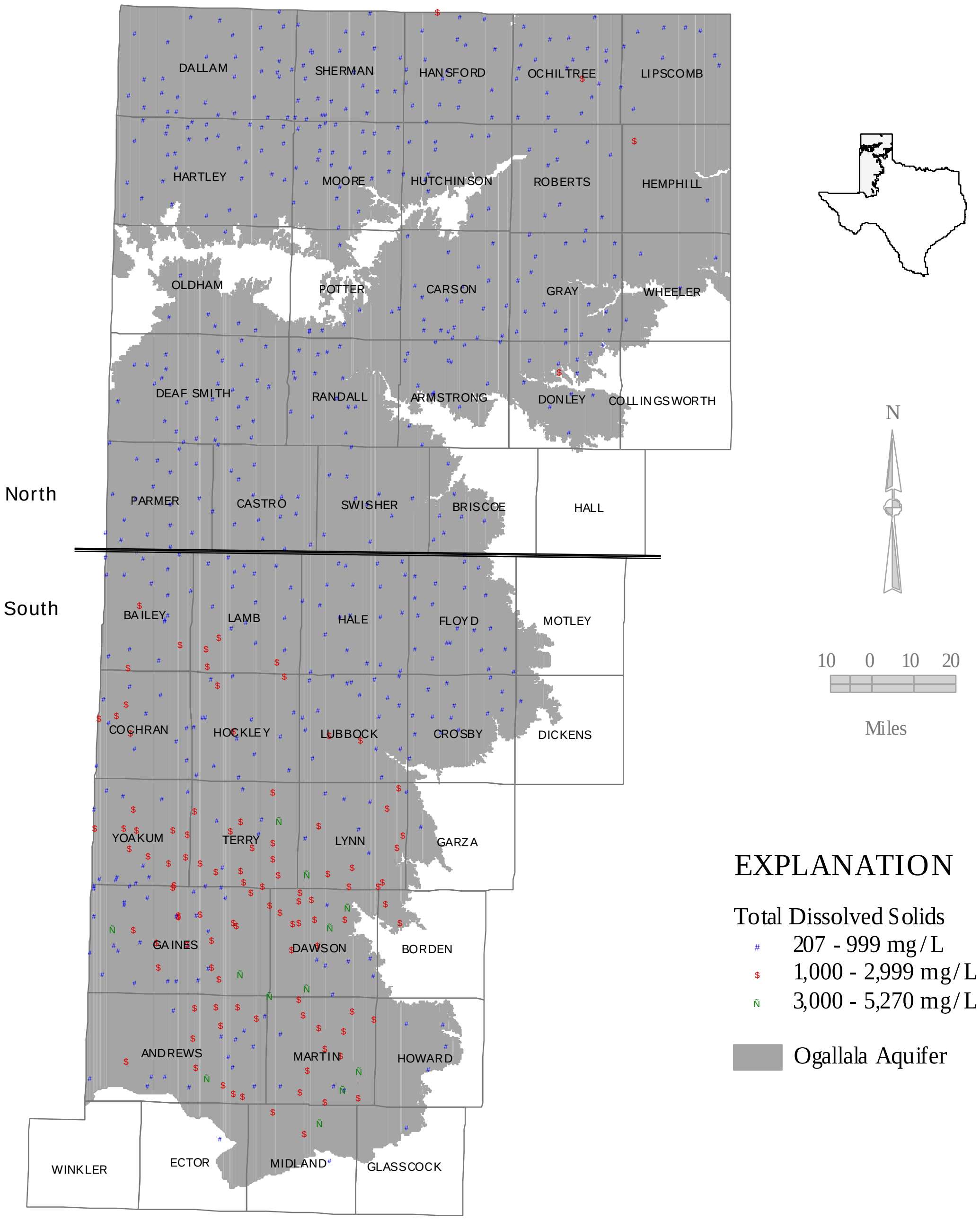
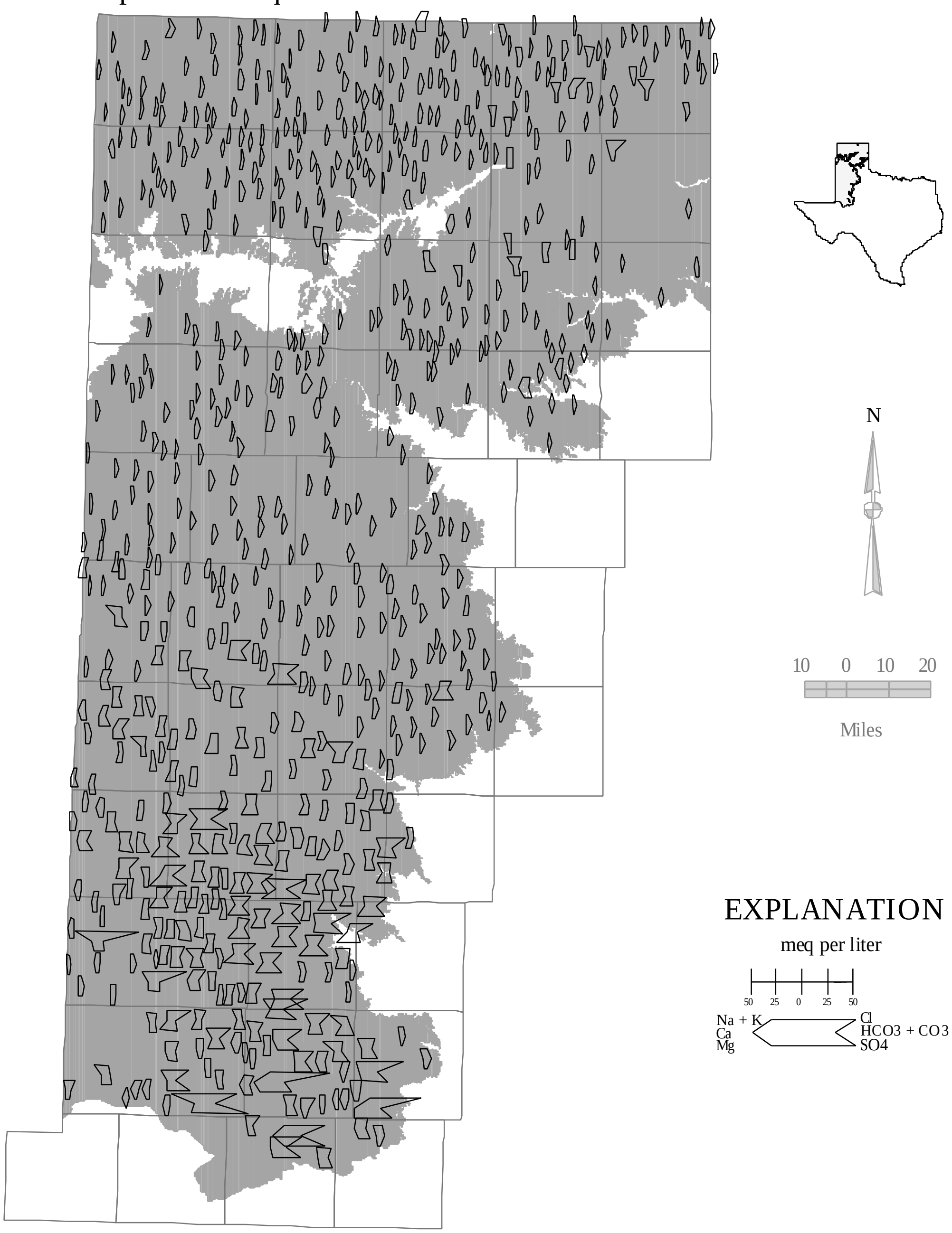


Figure 2.

Figure 2. Stiff diagrams for wells sampled in the Ogallala from 1994 - 1997 indicate higher salinity in the southern part of the aquifer.



Constituent*	**Range** *South*	**Avg.** *South*	**Med.** *South*	**% > MCL+**	**Range** *North*	**Avg.** *North*	**Med.** *North*	**% > MCL+**
Silica	6.1-79	53	53	-	1.0-85	37	33	-
Calcium	8.8-740	105	81	-	7.1-561	50	46	-
Magnesium	2.3-356	82	61	-	3.7-95	28	28	-
Potassium	2.1-39	12	10	-	0.7-13	5.5	5.4	-
Sodium	12-1,058	140	94	-	1.9-258	38	32	-
Strontium	0.3-21	3.7	2.6	-	0.02-8.7	1.1	1.1	-
Bicarbonate	143 - 548	279	272	-	48 - 474	256	247	-
Sulfate	13 - 2,197	279	187	33	4.1 - 169	49	35	0.6
Chloride	4.2 -2,017	254	153	25	2.2 - 516	30	16	0.6
Fluoride	0.1 - 9.3	3.5	3.3	41; 77	0.01 -16	1.7	1.6	2.2; 29
Dissolved Solids	273-5,270	1,094	813	38	207-2,648	366	337	0.6
Hardness ($CaCo_3$)	32 - 3,220	602	456	-	39 – 1,757	241	229	-
Nitrate as NO_3	0.04 - 315	27	17	18	0.04 – 72	9.7	8.8	0.4

* Milligrams/liter + Primary MCLs for nitrate and fluoride (41% of total sampled > 4.0 mg/l in the South; 2.2% >4.0 mg/l in the North); secondary MCLs for dissolved solids, sulfate, chloride, and fluoride (77 % > 2.0 mg/l in the South; 29% > 2.0 mg/l in the North)

Table 1. Major anions, major cations, hardness, and nitrate in Ogallala aquifer ground water.

Constituent*	% > detec	Range *South*	Median *South*	# > MCL+	% > detec	Range *North*	Median *North*	# > MCL+
Silver	0	-	-	0	0	-	-	0
Cadmium	0	-	-	0	0	-	-	0
Lead	15	<1 – 4.6	<1	0	14	<1 - 17	<1	4+
Manganese	34	<1 - 1,175	<1	11	36	<1 - 1,100	<1	5
Chromium	50	<2 - 35	19	0	96	<2 - 39	26	0
Copper	91	<1 - 54	3	0	70	<1 - 25	2.1	0
Mercury	50	<0.13 - 0.4	0.3	0	16	<0.2 - 0.6	<0.2	0
Iron	75	<5 - 1,077	11	5	43	<5 - 1,355	16	21
Selenium	91	<5 - 494	19	71+	50	<5 - 40	<5	0
Molybdenum	95	<1 - 119	6.3	NA	87	<1 - 74	3.8	NA
Aluminum	98	<1 - 102	4	4	64	<1 - 86	3.9	2
Bromide	99	<0.05 - 14	1.1	NA	91	<0.001 - 0.9	0.13	NA
Arsenic	100	1.1 - 172	10	12+	71	<1 - 44	<5	0
Boron	100	34 - 3,300	342	NA	98	<1 - 5,155	138	NA
Vanadium	100	2.4 - 589	43	NA	99	<1 - 56	18	NA
Zinc	100	1.2 - 3,696	13	0	94	<1 - 1,300	21	0
Barium	100	11 - 578	43	0	99	<1 -1,100	88	0

* Micrograms/liter + Primary MCLs for cadmium, lead, chromium, mercury, selenium, arsenic and barium; secondary MCLs for silver, manganese, copper, iron, aluminum, and zinc.

Table 2. Dissolved metallic and non-metallic inorganic constituents in Ogallala ground water

Of the six elements listed in **Table 3** sampled for the first time in this latest season, five have been targeted by the EPA for inclusion in primary water standards: antimony, beryllium, cobalt, nickel, and thallium. All but cobalt and lithium have been assigned MCLs. In response to numerous requests from nurses in Texas interested in its distribution in the state's drinking water, lithium content was also analyzed for the first time; lithium as of this writing has not been assigned an MCL. Concentrations of antimony, beryllium, and thallium were below detection limits throughout the study area. Cobalt was detected in relatively insignificant amounts; nickel and lithium were found in virtually all samples throughout the Texas Ogallala. Nickel was detected in excess of its primary MCL of 100 micrograms/liter (0.1 milligram/liter) in a small percentage of the wells, primarily in Midland County in the southern part of the study area.

Constituent	**% > detec**	**Range** *South*	**Med.** *South*	**# > MCL***	**% > detec**	**Range** *North*	**Med.** *North*	**# > MCL***
Antimony	0	-	-	0	0	-	-	0
Beryllium	0	-	-	0	0	-	-	0
Cobalt	16	<1-27	<1	NA	10	<1-14	<1	NA
Nickel	99	<1-528	8.4	6	98	<1-300	4.9	3
Thallium	0	-	-	0	0	-	-	0
Lithium	100	8.3 - 377	88	NA	100	1.8 - 250	54	NA

* Primary MCL

Table 3. Dissolved select trace elements in Ogallala ground water in micrograms/liter.

Cobalt is generally of low toxicity, however the toxic mechanism is not well understood; and although it is considered an essential element (it is the core component of vitamin B_{12}), concentrations higher than 1 mg/kg of body weight may be considered a health hazard to humans. (De Zuane, 1990). It is often associated with nickel, silver, lead, copper, and iron ores, although its presence in ground water is generally negligible. No MCL has yet been assigned. Minute amounts of cobalt are present in green leafy vegetables, and soils containing certain amounts of it are considered essential for proper animal nutrition. Cobalt is used in alloys, metal electroplating, and for centuries in the production of brilliant blue colors in glass, porcelain, pottery, and enamels. In this study only 16 and 10 percent of samples collected in the southern and northern parts of the study area, respectively, contained amounts above detection limits as indicated on the map in **Figure 3**.

Nickel is not commonly found as a pure metal in nature--it typically occurs in combination with sulfur, arsenic, antimony, silica, and oxygen--nor is it found in any appreciable amounts in uncontaminated ground water. Most meteorites contain nickel. Nickel is an essential element for animals that appears to be adequately satisfied at a dietary intake of about 50 micrograms a day, although nickel nutritional deficiency has not been recognized in humans (De Zuane, 1990). Recently a MCL of 100 micrograms/liter has been proposed for drinking water standards. The map in **Figure 4** illustrates the location of the five wells in Midland County, one in Glasscock, two in Hale, and one in Donley in which nickel was found above its MCL.

Lithium is the lightest of all metals and does not occur free in nature; it behaves much like other alkaline metals sodium and potassium, but is much rarer. It is combined in small amounts in nearly all igneous rocks (Hammond, 1995). Its association with volcanism, whether current or ancient, accounts for its common occurrence in the water of many mineral springs. Lithium has no established standards. Lithium compounds such as lithium carbonate are used to treat manic-depressives. As seen on the map in **Figure 5**, well water concentrations are higher in the southern part of the study area. The underlying Dockum may act as a source of lithium, as although it is fluvial sandstone, it is composed of reworked igneous sediments.

Figure 3.

Figure 3. Dissolved cobalt content found below and above detection limits in wells sampled in the Ogallala aquifer from 1994 - 1997.

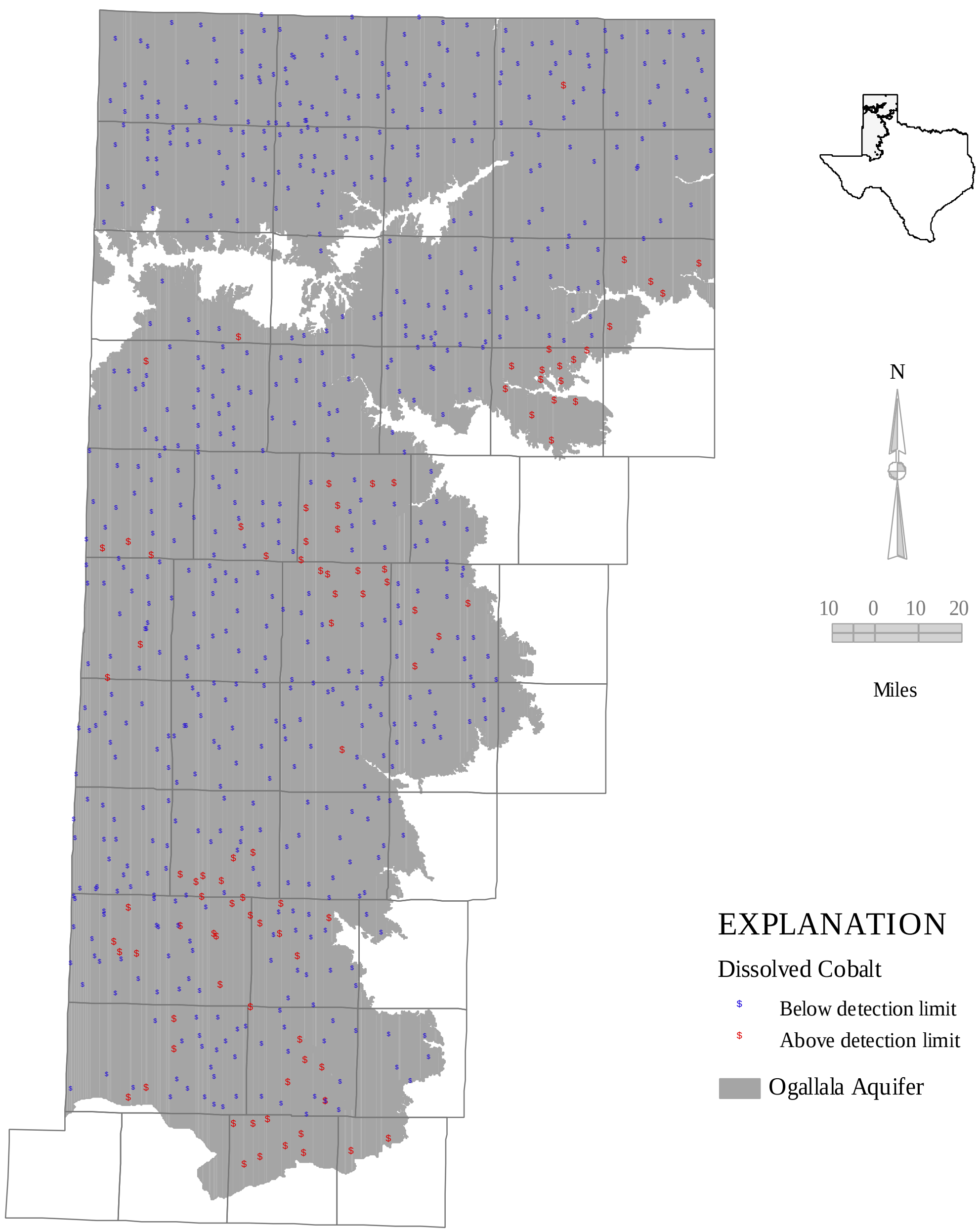


Figure 4.

Figure 4. Dissolved nickel content below and above the primary MCL of 100 micrograms/liter in wells sampled in the Ogallala aquifer from 1994 - 1997.

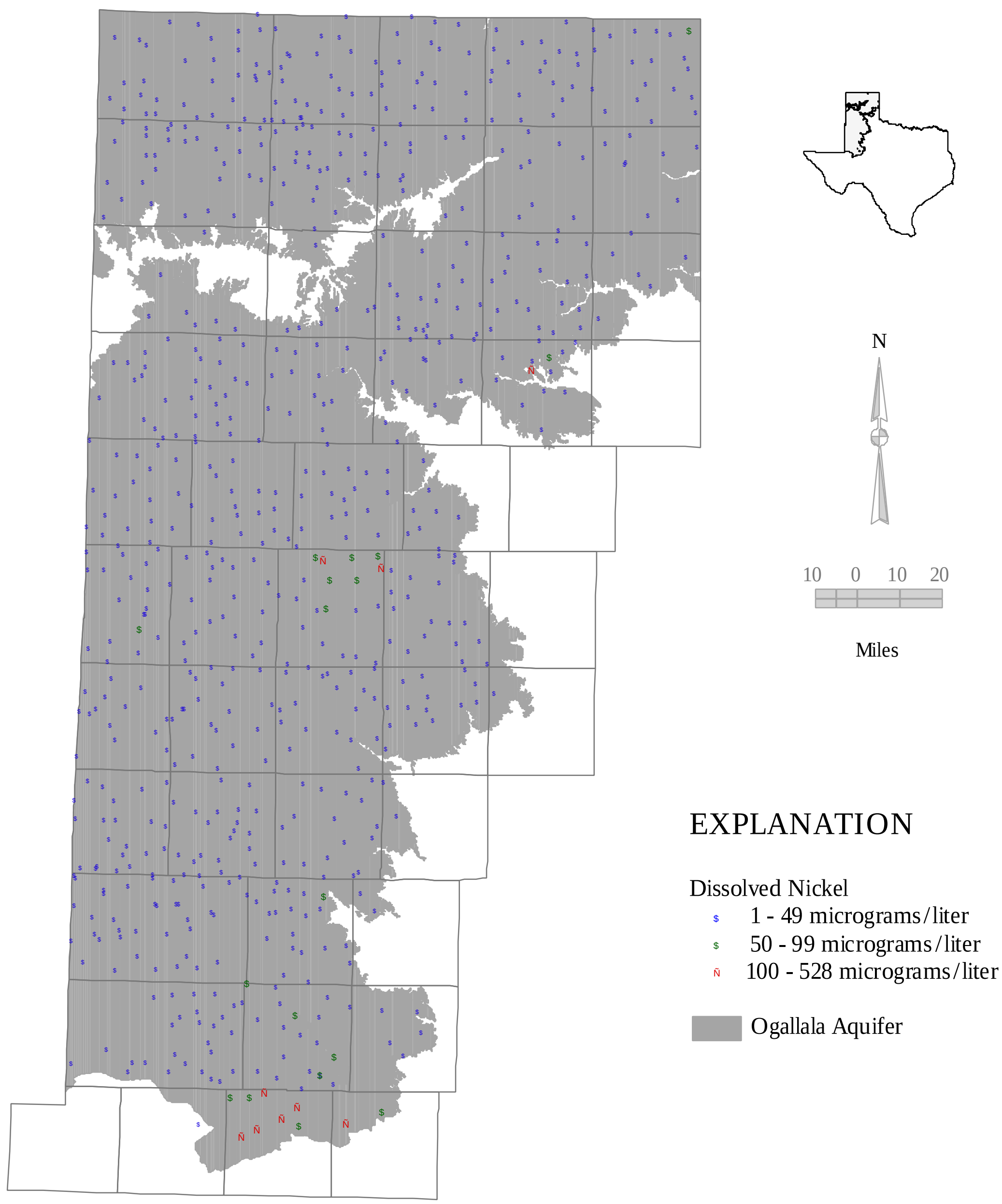
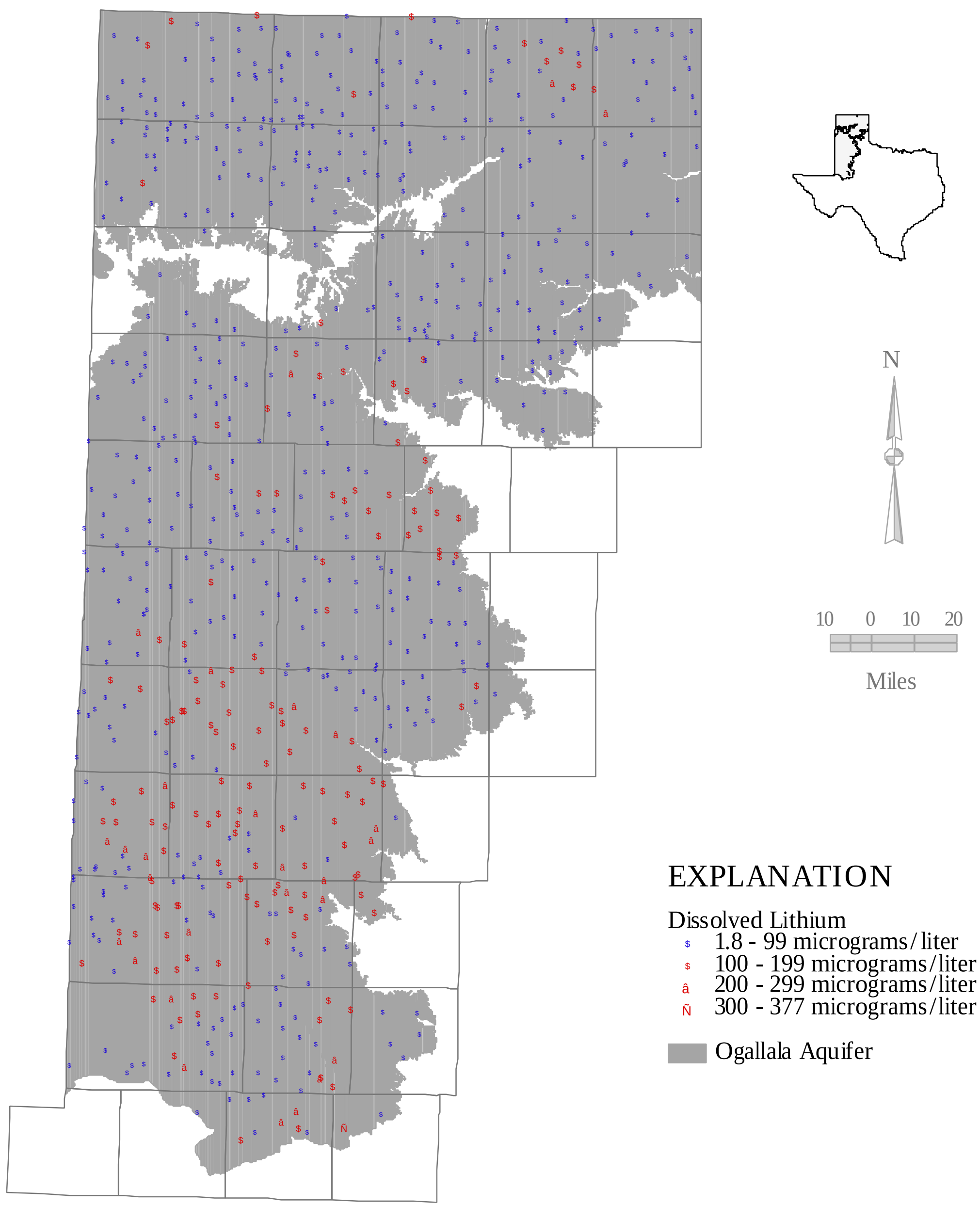


Figure 5.

Figure 5. Dissolved lithium content in wells sampled in the Ogallala aquifer from 1994 - 1997; no MCL established yet.



Antimony, a brittle, bluish-white element with a metallic luster, is relatively rare in crustal rocks. It typically occurs with other minerals in some ore deposits and around geothermal geysers. Frequently it occurs as the sulfide compound stibnite, a mineral used for black eye makeup in Biblical times. Today antimony is used as an alloy. It is considered toxic in air at certain concentrations, and antimony compounds cause severe liver damage. Doses of 100 milligrams are lethal and cause symptoms similar to arsenic poisoning. No Ogallala water samples contained antimony in excess of its MCL of 6 micrograms/liter or even above its detection limit of 0.01 micrograms/liter.

Beryllium, a member of the alkaline earth metals, is used commercially as an alloy component to increase strength in metals such as copper and nickel. Concentrations of beryllium are naturally minimal in ground water because of its low solubility and its absorption by clays in the soil strata. Although it is relatively harmless when ingested in food and water (with the exception of large continuing dosages), beryllium dust is an industrial air contaminant causing skin and pulmonary ailments that must be regulated by industrial hygiene officials. The MCL for beryllium is 4 micrograms/liter; none was found above detection limits in the Ogallala.

Thallium, a soft and malleable metal resembling lead in appearance, is highly toxic with a primary standard of 2 micrograms/liter. Levels are normally low in ground water, but can be increased by pollution from coal-burning, metal-smelting, or ore-processing. No longer used as a rodenticide, ant killer, and treatment for ringworm and other skin infections, today thallium is used in making alloys, electronic devices, and glass. It can be absorbed through the skin; its effects are cumulative; and high concentrations affect the nervous system, lungs, heart and kidney. In this study, none was detected above the detection limit of 0.01 micrograms/liter.

REFERENCES

De Zuane, J., 1990, Drinking water quality standards and controls: Van Nostrand Reinhold, New York, 523 p.

Hammond, C.R., 1995, CRC handbook of chemistry and physics: CRC Press, Inc., Boca Raton, Florida.

Nordstrom, P.L., and Beynon, B.B., 1991, A field manual for ground-water sampling: Texas Water Development Board User's Manual-51, 74 p.

Payne, J., 1993, Water-quality evaluation of the Ogallala aquifer, Texas: Texas Water Development Board, 41 p.

Texas Natural Resource Conservation Commission, 1994, Drinking water standards governing drinking water quality and reporting requirements, 73 p.