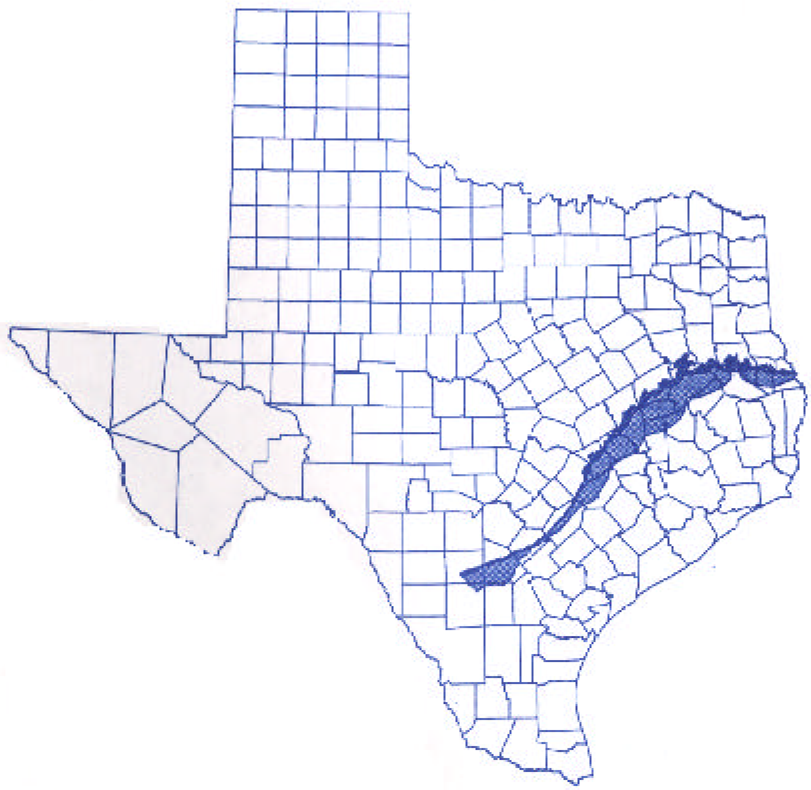
Hydrologic Atlas No. 5

Water Quality in the Sparta Aquifer



by

Merrick Biri

1997

Texas Water Development Board

Water Quality in the Sparta Aquifer

by Merrick Biri, Environmental Quality Specialist
February 1997

INTRODUCTION

The Sparta aquifer covers approximately all or part of 25 counties in south and southeast Texas. Fifty-five wells were sampled in the aquifer from 1993 to 1995 by the Texas Water Development Board (TWDB) as part of its program to monitor ambient water quality and any changes that have occurred over time in the state's aquifers. The author thanks and acknowledges the landowners who permitted their wells to be sampled; the TWDB environmental quality specialists who collected the samples: John Asensio, Dennis Jones, Ron Mohr, and Robbie Ozment; and geologists Phil Nordstrom and Janie Hopkins who edited the atlas. TWDB graphics specialist Alison Omo created the illustrations using ArcView.

The Sparta aquifer crops out in a linear belt extending southwestward from Sabine County in the east to Frio County in the south. The map in Figure 1 illustrates the extent of the aquifer's outcrop, subsurface downdip portion, and location of sampled wells. The formation is typically 300 to 500 feet thick in east Texas, thins to 100 to 200 feet thick in Fayette and Gonzales counties, and maintains a fairly uniform thickness of 100 to 150 feet to the southwest (Payne, 1968).

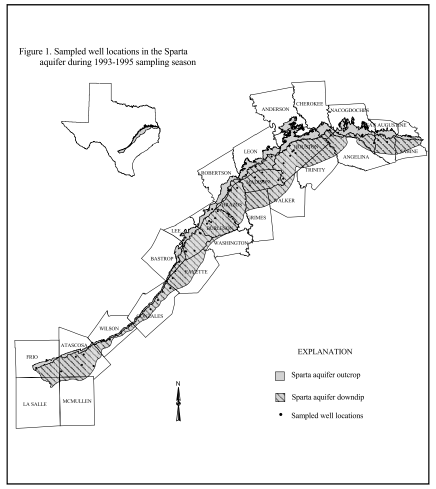


Figure 1. Sampled well locations in the Sparta aquifer during 1993-1995 sampling season

Deposited during the Tertiary as part of the Claiborne Group, the Sparta consists of fine- to medium-grained sandstone and interbedded clay in a pattern parallel to the Eocene Gulf Coast shoreline. This pattern was probably created by offshore or near-shore bar deposition. By contrast, the thicker sand units of the Sparta in Louisiana, Arkansas, and Mississippi, with long axes of sand-bodies normal to the postulated Sparta strand line, are interpreted as channel deposits of anastomosing streams deposited in a large deltaic-fluvial plain. In Louisiana, the distance from outcrop to the limits of continuous sand, or "shale-out" line, is 50 to 200 miles as measured normal to regional dip; from Grimes County to McMullen County, this distance is 14 to 50 miles, due to less extensive sand deposition and differences in degree of regional dip and thickness of the formation (Payne, 1968).

The presence of the Sabine Arch in northeast Texas accounts for the formation's dip to the south and south-southwest at about 100 feet per mile from Angelina to Tyler counties (Payne, 1968); from Houston County southward to Webb County, the regional dip is to the southeast at different rates. In Houston County, the formation dips at 50 feet per mile from the outcrop and 100 feet per mile in the southern part of the county (Tarver, 1966). In Gonzales County, the dip is 200 feet per mile (Shafer, 1965); and in Frio County, only 30 feet per mile (Alexander and White, 1966).

The ground-water potentiometric surface generally reflects the geological structure and the regional dip of the base of the Tertiary formations. The direction of flow varies in areas of artificial discharge toward pumping wells and in areas of natural discharge toward major streams and drainage courses. In the east, ground water moves to the Sabine, Neches, and Trinity rivers; in the central part of the study area, to the San Jacinto, Brazos, Colorado, and Lavaca rivers; and in the south, to the Guadalupe, San Antonio, and Nueces rivers. Depositional history, however, has also affected the hydraulic gradient. As regional flow is normal to the orientation of the sand bars, flow is retarded by the rapid pinchout of permeable beds; and discharge through upward leakage starts within short distances from the outcrop area (Payne, 1968).

WATER QUALITY

Samples were taken from municipal, industrial, and irrigation wells where possible. These wells, because of their constant pumping and high yield, draw water from larger areas in the aquifer and thereby ensure a representative sample. Environmental quality specialists took field measurements and used appropriate sampling techniques as described in the TWDB's *A Field Manual for Ground Water Sampling* (Nordstrom and Beynon, 1991) for dissolved inorganic constituents, nutrients, and radioactivity. Sample analysis was conducted by the Texas Department of Health Laboratory. During the 1993-1995 sampling period, 55 wells were sampled in 25 counties (Figure 1). This atlas discusses the range and average of constituents and provides areas in which key constituents are in excess of maximum contaminant levels (MCLs) where appropriate. Table 1 lists the primary and secondary MCLs as set by the Texas Natural Resource Conservation Commission (TNRCC)

Primary Constituent Levels		
Constituent	**Symbol**	**MCL**
Arsenic	As	0.05 mg/l
Barium	Ba	2.0 mg/l
Cadmium	Cd	0.005 mg/l
Chromium	Cr	0.10 mg/l
Fluoride	F	4.0 mg/l
Lead	Pb	0.015 mg/l
Mercury	Hg	0.002 mg/l
Nitrate (as N)	NO_3 (N)	10.0 mg/l
Selenium	Se	0.05 mg/l
Gross Alpha	α	15 pCi/l
Gross Beta	ß	50 pCi/l
Radium	Ra^{226} + Ra^{228}	5 pCi/l

Table 1. Drinking water standards for selected inorganic constituents and radioactive species as set by the TNRCC. *(continued)*

Secondary Constituent Levels		
Chloride	Cl	300 mg/l
Copper	Cu	1.0 mg/l
Fluoride	F	2.0 mg/l
Iron	Fe	0.3 mg/l
Manganese	Mn	0.05 mg/l
pH		$\geq$7.0
Silver	Ag	0.10 mg/l
Sulfate	SO_4	300 mg/l
Dissolved Solids	TDS	1,000 mg/l
Zinc	Zn	5.0 mg/l

Table 1. Drinking water standards for selected inorganic constituents and radioactive species as set by the TNRCC.

Field Measurements

The average ground-water temperature of the Sparta samples was 25°C and ranged from 16.2°C to 42.3°C. Seven samples had a pH less than 7.0, and average pH of all analysis was 7.7. Secondary drinking water standards indicate that the pH should be greater than 7.0 because acidic water (less than 7.0) will act as a solvent to release metal ions to the water. The specific conductance averaged 1,083 micromhos and ranged from 97 to 5,960 micromhos. Ground water with higher specific conductance, and therefore higher dissolved-solids content, is more common in the downdip limits of the aquifer. The average total alkalinity as determined in the field was 240 mg/l (range: 2 - 1,200 mg/l) as $CaCO_3$; average bicarbonate ion concentration, calculated from mean total alkalinity, was 288 mg/l. Thirteen samples with a pH of 8.3 or greater had an average phenol alkalinity of 2.1 mg/l (range: 0 to 30 mg/l). The Eh averaged -10.5 mV (range: -332 to +245 mV).

Dissolved Inorganic Constituents

The dissolved solids content is the main factor limiting or determining the use of ground water. These solids primarily consist of mineral constituents dissolved from the host rock, although other natural sources, such as adjacent aquifers or man-affected sources, such as oil field brines, can also contribute certain dissolved constituents. Table 2 describes four classes of ground water classified according to dissolved-solids content, as defined by the Texas Groundwater Protection Committee.

Class	Quality *	Examples of Use
Fresh	0 - 1,000	Drinking and all other uses
Slightly Saline	>1,000 - 3,000	Drinking if fresh unavailable; for livestock, irrigation, and industrial use
Moderately Saline	>3,000 - 10,000	Industrial, mineral extraction, oil and gas production; potential/future drinking and limited livestock watering and irrigation if fresh or slightly saline water is unavailable
Very Saline to Brine	>10,000	Mineral extraction, oil and gas production

* Concentration range of dissolved-solids in milligrams/liter

Table 2. Ground-water classification system.

The maps in Figures 2 through 6 were constructed from all water-quality data available in the TWDB database. Information listed in Tables 3, 4, and 5, however, only reflects data from samples collected after 1992 (of which 51 were balanced). The average for each constituent was calculated only for those values in balanced samples above detection limits.

Table 3 lists ranges and average concentrations of dissolved solids and other inorganic constituents from the Sparta aquifer. The average dissolved-solids content of 740 mg/l reflects the influence of slightly saline waters predominantly in the south and downdip part of the study area, as seen in the map in Figure 2. This map illustrates the location of the 55 wells with dissolved-solids content in excess of 1,000 mg/l. The 357 wells with dissolved-solids content of 1,000 mg/l or less are not shown individually. Twelve wells sampled after 1992 contained dissolved-solids in excess of 1,000 mg/l; two of these were in excess of 3,000 mg/l.

Constituent	Range*	Average*	# > MCL
Silica	10 - 91	20	
Calcium	<1 - 210	37	
Magnesium	<1 - 89	14	
Potassium	1 - 21	6.4	
Sodium	2.5 - 1,590	319	
Strontium	0.2 - 6.0	0.9	
Bicarbonate	2.4 - 1,464	288	
Sulfate	2.0 - 800	152	3**
Chloride	8.0 - 1,524	160	6**
Fluoride	0.1 - 3.3	0.5	2**
Dissolved solids	72 - 3,845	740	12**
Hardness	<1 - 765	132	

* Milligrams/liter ** Secondary MCL

Table 3. Major cations and anions in Sparta aquifer ground water (nitrate discussed later), 1993-1995 sampling period.

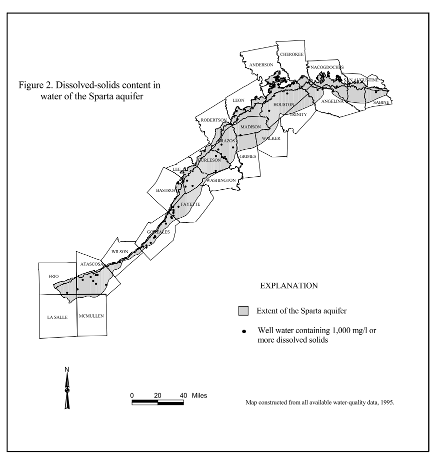


Figure 2. Dissolved-solids content in water of the Sparta aquifer

Chloride, naturally dissolved from rocks and soils, can also be introduced into ground water by human activities, as it is present in sewage, oil field brines, industrial brines, and seawater (a possible contaminant of fresh-water aquifers in areas of heavy pumpage). In large amounts in combination with sodium, chloride gives a salty taste to drinking water and can increase the corrosiveness of the water. The map in Figure 3 indicates the 37 out of a total of 412 wells where the chloride content is greater than the secondary MCL of 300 mg/l; water from six of the wells sampled after 1992 had chloride levels greater than 300 mg/l.

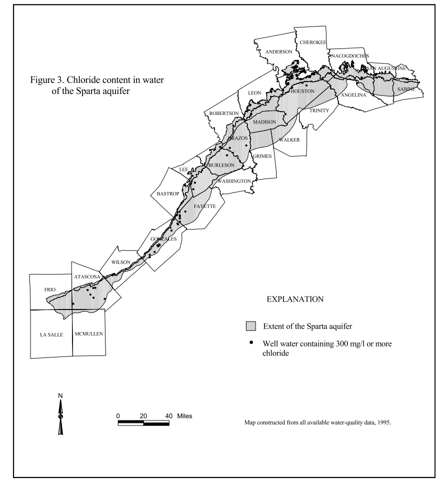


Figure 3. Chloride content in water of the Sparta aquifer

Sulfate is dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Sulfate in large amounts and in combination with other ions imparts a rotten-egg odor to water. When combined with calcium, sulfate can be conducive to hard scale forming in steam boilers. The map in Figure 4 illustrates 36 wells (out of a total of 412) where the sulfate content is greater than 300 mg/l. Since 1992, only three wells were determined to contain sulfate greater than the secondary MCL of 300 mg/l.

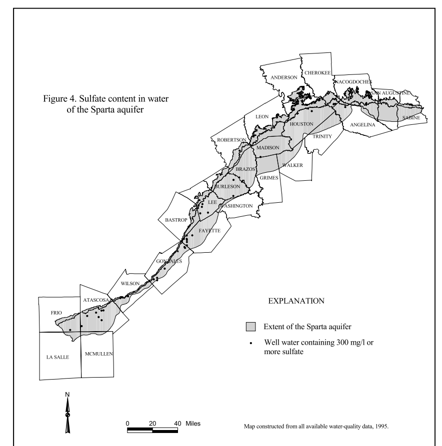


Figure 4. Sulfate content in water of the Sparta aquifer

The Stiff diagrams in Figure 5 illustrate the major constituents of dissolved solids in Sparta ground water from a representative sampling of wells in the aquifer. Dissolved solids are commonly lower in the northeast and along the outcrop, as indicated by the shorter axes for both anions and cations. Sodium is the dominant cation throughout. Bicarbonate is the dominant anion in the northeast and some distance from the outcrop; sulfate and chloride are more commonly the dominant anions farther to the southwest. Considering all historical data, water quality is best in Houston County and poorest in Gonzales and Atascosa counties.

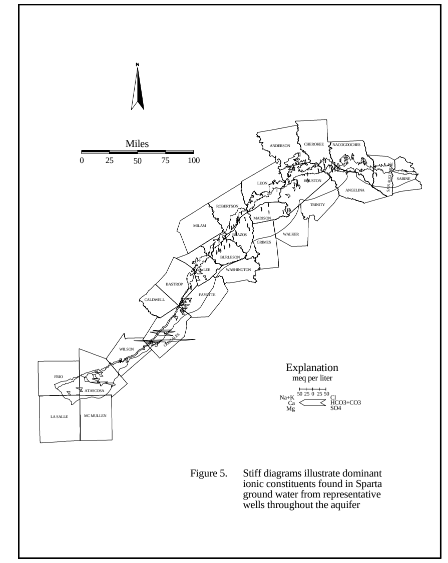


Figure 5. Stiff diagrams illustrate dominant ionic constituents found in Sparta ground water from representative wells throughout the aquifer

Fluoride is dissolved in small to minute quantities from most rocks and soils. Fluoride in drinking water reduces the incidence of tooth decay; however, it may cause mottling of the teeth when concentrations are greater than 2 mg/l. The map in Figure 6 indicates eight well locations where the fluoride level is greater than the MCL of 2 mg/l and two well locations where the fluoride content is greater than 4 mg/l. During the 1993-1995 sampling period, two well water samples had fluoride levels greater than 2 mg/l.

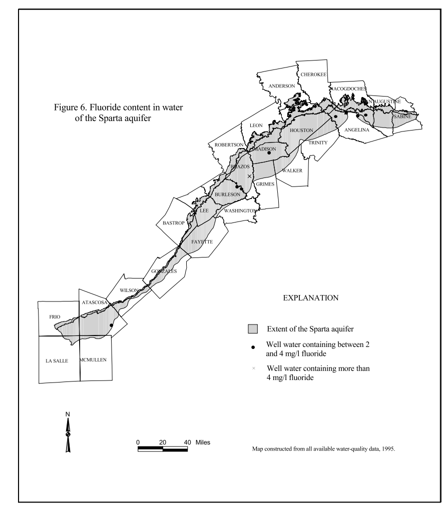


Figure 6. Fluoride content in water of the Sparta aquifer

Most of the dissolved trace metal constituents whose ranges and averages (of amounts above detection) are listed in Table 4 were detected at low levels. Iron, which is dissolved from practically all rocks and soils, may also may be introduced into well water by pipes, pumps, and other equipment. On exposure to air, iron in ground water oxides to a reddish-brown precipitate. If above 300 micrograms/liter, it may cause an unpleasant taste and promote iron bacteria growth. Eight wells contained iron in excess of the secondary standard of 300 mg/l (Figure 7); all had been sampled in the 1993-1995 season.

Constituent	% Above Detection	Range*	Average*	# > MCL
Arsenic	6	<1.0 - 16	2.1	
Barium	86	<4.0 - 121	30.5	
Boron	100	350 - 1,410	957	
Cadmium	2	1 sample at 2.2		
Chromium	2	1 sample at 6.9		
Copper	12	<2.0 - 20	9.3	
Iron	94	20 - 2,690	245	8**
Lead	2	1 sample at 3.8		
Manganese	73	<0.5 - 431	40	6**
Molybdenum	11	<20 - 29	24.7	
Silver	0			
Vanadium	0			
Zinc	71	<5.0 - 602	97.7	
Aluminum	12	<20 - 91	73.0	
Selenium	6	<2.0 - 4.4	2.9	
Mercury	11	<.13 - .71	.24	

*Expressed in micrograms/liter **Secondary MCL

Table 4. Dissolved trace metal constituents in Sparta ground water, 1993-1995 sampling period.

Concentrations of manganese in ground water are usually low. Manganese is dissolved from many metamorphic and igneous minerals, with small amounts originating from some limestones and dolomites. Manganese is an essential element for humans. The map in Figure 7 indicates the six wells (all sampled after 1992) where the manganese content is greater than the secondary MCL of 50 micrograms/liter.

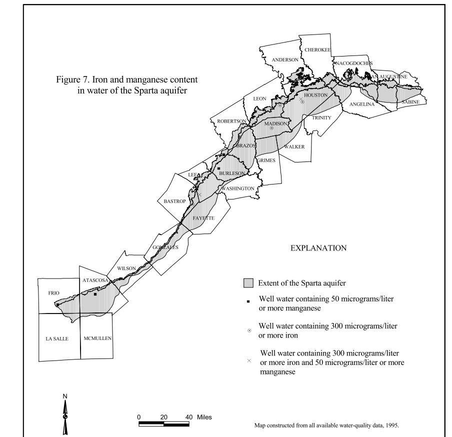


Figure 7. Iron and manganese content in water of the Sparta aquifer

Nutrients

The percents above detection, ranges, and averages of sample values (above detection) for the four nutrients analyzed in each well are listed in Table 5. Nitrate and nitrite are the only nutrients that have drinking water standards set by the TNRCC. Nitrate, an end product of the aerobic stabilization of nitrogen, particularly organic nitrogen, is a potential pollutant in any agricultural area; it is to be expected at higher concentrations where fertilizers are used and in decayed animal and vegetable matter. Ground-water concentrations are also typically higher in leachates from sludge and refuse disposal and in industrial discharges. In this study, 67 percent of the samples analyzed contain detectable amounts of nitrate, although none contained nitrate (as NO_3) in excess of 44.3 mg/l, the primary MCL.

Constituent	Range *	Average *	% Above Detection
Ammonia	<0.01 -1.98	0.63	98
Nitrite	<0.01 - 0.17	0.01	34
Nitrate (NO_3)	<0.01 - 12.50	0.81	66
Kjeldahl	<0.10 - 3.50	0.91	96

* Expressed in milligrams/liter

Table 5. Dissolved nutrients in Sparta ground water, 1993-1995 sampling period.

Nitrite, formed by the action of bacteria upon ammonia and organic nitrogen, when detected in potable water in considerable amounts, is an indication of sewage/bacterial contamination and inadequate disinfection (De Zuane, 1990). In such reducing environments, nitrite is not oxidized to nitrate. In this study, 33 percent of the samples analyzed were above detection, but none were found to be above the primary MCL.

Radioactivity

Gross alpha (α) radiation consists of the emissions of positively charged helium nuclei having high atomic weight. This radioactive decay is measured as gross α in units of picocuries per liter (pCi/l). Alpha-emitting isotopes in natural waters are primarily isotopes of Ra_{226} and Ra_{228}, Ra_{226} being the disintegration product of uranium (U_{238}), and Ra_{228} the disintegration product of thorium (Th_{232}). Ra_{226} decays to radon gas (Rn_{226}), which is also an α-emitter. Gross beta (ß) radiation consists of the emission of high energy electrons and positrons from the nucleus of atoms having high atomic weight. Natural ß-emitting isotopes occur in the uranium and thorium disintegration series, among other natural sources. In these analyses, gross alpha and gross beta ranged from 2 to 10 and 4 to 15 pCi/l and averaged 3.2 and 6.2 pCi/l, respectively; none were in excess of their primary MCLs.

COMPARISON TO PREVIOUS WORK

Few investigations have done little more than briefly mention water quality in the Sparta aquifer with the exception of Payne's 1968 report. Here he discusses the control of the depositional environment on hydrology. In summary, the thick deltaic sand bodies oriented parallel to dip in Louisiana and Arkansas are more permeable, have experienced higher rates of ground-water movement, and contain lower dissolved solids than the smaller, thinner, strandline sand bodies oriented parallel to the paleo- and present-day shoreline but normal to regional dip in Texas.

Payne describes three chemical provinces based on the relationship between the anions. His bicarbonate water province occurs in the updip part of the Sparta; the chloride water province includes all of the Sparta except for limited areas in and short distances downdip from the outcrop; and the sulfate water province includes the water downdip from the outcrop and extends from Burleson County to Frio County. A majority of the Stiff diagrams plotted in Figure 5 correspond to these three provinces.

Change in water quality over time in the Sparta aquifer is best assessed by examining analyses from wells sampled more than once. Seventy-three wells throughout the aquifer were sampled at least twice at intervals of at least five years; many were first sampled in the sixties and again in the seventies or eighties, or in the seventies and again later; four were sampled in the thirties and forties. The water quality in 30 of these wells (40%) appears to have improved over time, as indicated by an average decrease in dissolved solids of 142 mg/l from the initial sampling event to the most recent. However, water quality in 45 of these (60%) appears to have decreased, as indicated by a larger average increase of 176 mg/l dissolved solids, particularly in Burleson, Lee, Gonzales, and Atascosa counties. Comparisons of chloride and sulfate follow suit: average increases of 103 and 71 mg/l had occurred in 35 and 37 wells, respectively, whereas smaller average decreases in chloride and sulfate of 39 and 43 mg/l had occurred in 32 wells each, with no change in the remaining eight and six wells, respectively.

The change in Sparta water quality can also be assessed, although less accurately, by querying all wells in the database analyzed for water quality, regardless of which have multiple samples. Query language was used to calculate averages of specific constituents during three time periods, arbitrarily chosen, as listed in Table 6. With the exception of sulfate during the two latest time intervals, the increase in all constituents during the past 28 years suggests a slight deterioration in water quality.

Time Period (# of analyses)	Dissolved Solids	Chloride	Sulfate	Hardness
1967 - 1976 (138)	578	99	106	91
1977 - 1988 (97)	728	147	151	115
1989 - 1995 (51)	776	157	151	142

Table 6. Comparison of averages of dissolved constituents, in milligrams/liter, in Sparta aquifer water over time.

REFERENCES

Alexander, W.H. Jr., and White, D.E., 1966, Ground-water resources of Atascosa and Frio Counties, Texas: Texas Water Development Board Rept. 32, 211 p.

Anders, R.B., 1957, Ground-water geology of Wilson County, Texas: Texas Board of Water Engineers Bull. 5710, 66 p.

Baker, E.T. Jr., Follett, C.R., McAdoo, G.D., and Bonnet, C.W., 1974, Ground-water resources of Grimes County, Texas: Texas Water Development Board Rept. 186, 34 p.

Beynon, B.E., 1992, Ground-water quality monitoring results in the Winter Garden area, 1990 Texas Water Development Board Rept. 335, 56 p.

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

Guyton, W.F., and Associates, 1972, Ground-water conditions in Anderson, Cherokee, Freestone, and Henderson counties, Texas: Texas Water Development Board Rept. 150, 80 p.

Harris, H.B., 1965, Ground-water resources of La Salle and McMullen counties, Texas: TWC Bull. 6520, 96 p.

McCoy, T.W., 1991, Evaluation of the ground-water resources of the western portion of theWinter Garden area, Texas: Texas Water Development Board Rept. 334, 64 p.

Nordstrom, P.L., and Beynon, B., 1991, A field manual for ground-water sampling: Texas Water Development Board User's Manual-51, 49 p.

Payne, J.N., 1968, Hydrologic Significance of the Lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas, United States Geological Survey Professional Paper 569-A, 17 p.

Rogers, L.T., 1967, Availability and quality of ground water in Fayette County, Texas: Texas Water Development Board Rept. 56, 117 p.

Shafer, G.H., 1965, Ground-water resources of Gonzales County, Texas: Texas Water Development Board Rept. 4, 89 p.

Tarver, G.E.,1966, Ground-water resources of Houston County, Texas, Texas Water Development Board Rept. 18, 86 p.

Texas Natural Resource Conservation Commission, 1994, Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements, 73 p.

Thompson, G.L., 1966, Ground-water resources of Lee County, Texas: Texas Water Development Board Rept. 20, 62 p.