Texas Water Development Board
LP - 210

Ground-Water Quality

in Garden City, Texas

By

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INTRODUCTION

Garden City, the county seat of Glasscock County, is a small, unincorporated community with a population of approximately 300 (Figure 1). The town, which occupies about one half of a square mile, is primarily residential and contains only a few small businesses and government offices which mostly serve a farming and ranching economy. The semiarid climate in the area is characterized by low rainfall (average of less than 16 inches per year) and a high rate of evaporation (more than five times the average annual rainfall).

Being unincorporated, the community comes under the jurisdiction of the county government with the county judge and the commissioners court responsible for decisions relating to the daily operation of the town. Also, the Glasscock County Underground Water Conservation District (GCUWCD) serves the community in an advisory capacity.

The citizens of Garden City are currently dependent on water wells for their water supply; however, a majority of the households purchase bottled water for cooking and drinking purposes. The Glasscock County Independent School District operates wells in the northwest part of town which supply water to the school facilities and several houses adjacent to the school property.

For several years, the local citizens have been concerned about possible contamination of and any subsequent health risk from the local underground water supply. As a result, water samples have been collected periodically from several local wells by the GCUWCD and analyzed for coliform content. A number of these samples were determined to have dangerously high levels. Acting on a request from the GCUWCD, the Texas Water Development Board agreed to work with the District in an effort to determine the seriousness and extent of the water-quality problem. The findings are to be presented to the Glasscock County Commissioners Court and the citizens of Garden City so that necessary remedial action can be considered.

The project involved a complete inventory of both active and abandoned water wells in town and a survey of septic tanks and cesspools. Land-surface elevations and 31 water-level depths were measured to determine the ground-water flow direction. And finally, samples from 28 wells were analyzed for various constituents including dissolved minerals, selected heavy metals, and the nitrogen cycle by the Texas Department of Health Laboratory in Austin.

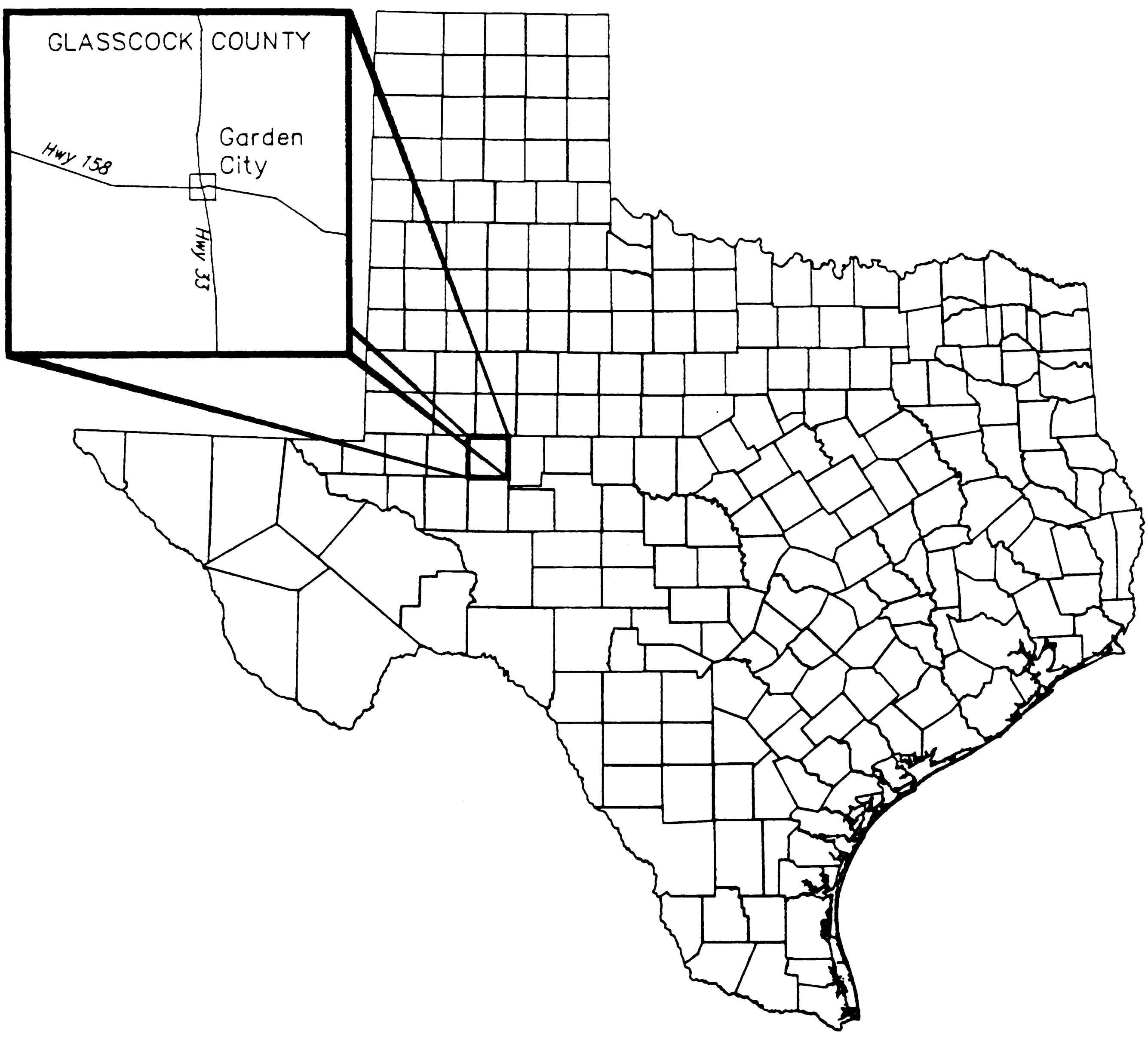


Figure 1

LOCATION OF GARDEN CITY, TEXAS

WATER SUPPLY

Geohydrology of the Aquifer

Wells in Garden City draw water from the Antlers Sand of Lower Cretaceous age which is part of the more extensive Edwards-Trinity (Plateau) aquifer. Locally, the formation is 100 to 150 feet thick and consists of gray, brown, yellow, and white, fine- to coarse-grained sand, sandstone, and gravel, interbedded with usually three to five layers of gray, brown, or red clay ranging in thickness up to 25 feet each.

The Antlers Sand overlies red, maroon, and blue shales of the Triassic Dockum Formation which is commonly referred to as the "redbed." Overlying the Antlers Sand is the light gray to yellowish brown Edwards Limestone which extends to near the surface. Conduits in the limestone, created by joint fracturing, allow for rapid infiltration of water percolating downward from the surface. The Edwards Limestone ranges in thickness from 160 feet in the northwest part of town to about 70 feet in the southern part. Both the Edwards Limestone and the Antlers Sand gently dip toward the southeast.

Water in the aquifer is unconfined and thus occurs under water-table conditions. Depth to the water table from the land surface ranges from about 145 feet in the northwest part of town to about 90 feet in the south. The water table generally occurs less than 25 feet below the top of the Antlers Sand and dips toward the southeast (Figure 2). Movement of the ground water is also generally toward the southeast at a rate of only a few feet per year. Considering an average net saturated sand thickness of 70 feet and an average specific yield of 0.074, there is an estimated 1,700 acre-feet (554 million gallons) of water contained in the aquifer below Garden City.

Water Wells

Because there is not a central water distribution system in Garden City, most households are supplied from individual wells with the exception of several houses owned by the school district which are supplied from a common system operated by the district. The few businesses and government offices either have individual wells or share common wells. A well inventory conducted in the town in 1989 located 104 wells currently in use and 15 abandoned or unused wells (Figure 3).

A majority of the abandoned wells were found to be either open at the surface or covered by an easily removable object. In either case, these wells pose both a safety and health hazard. Wells drilled in the past 10 years appear to comply with construction rules set forth by the Texas Water Well Drillers Board and the Texas Department of Health. Numerous older wells were either poorly constructed or their condition has deteriorated and may no longer prevent contaminants from entering the well from the surface or shallow depths. More recently drilled wells have cement between the borehole and the casing from the surface down 10 to 15 feet. Depth of cement is uncertain in the older wells and may not occur at all in some.

SEWAGE DISPOSAL

The disposal of sewage in Garden City is accomplished by septic tanks and cesspools. Cesspools are more of a health problem than septic tank systems because they allow raw sewage to enter the soil zone. Although an actual count was not

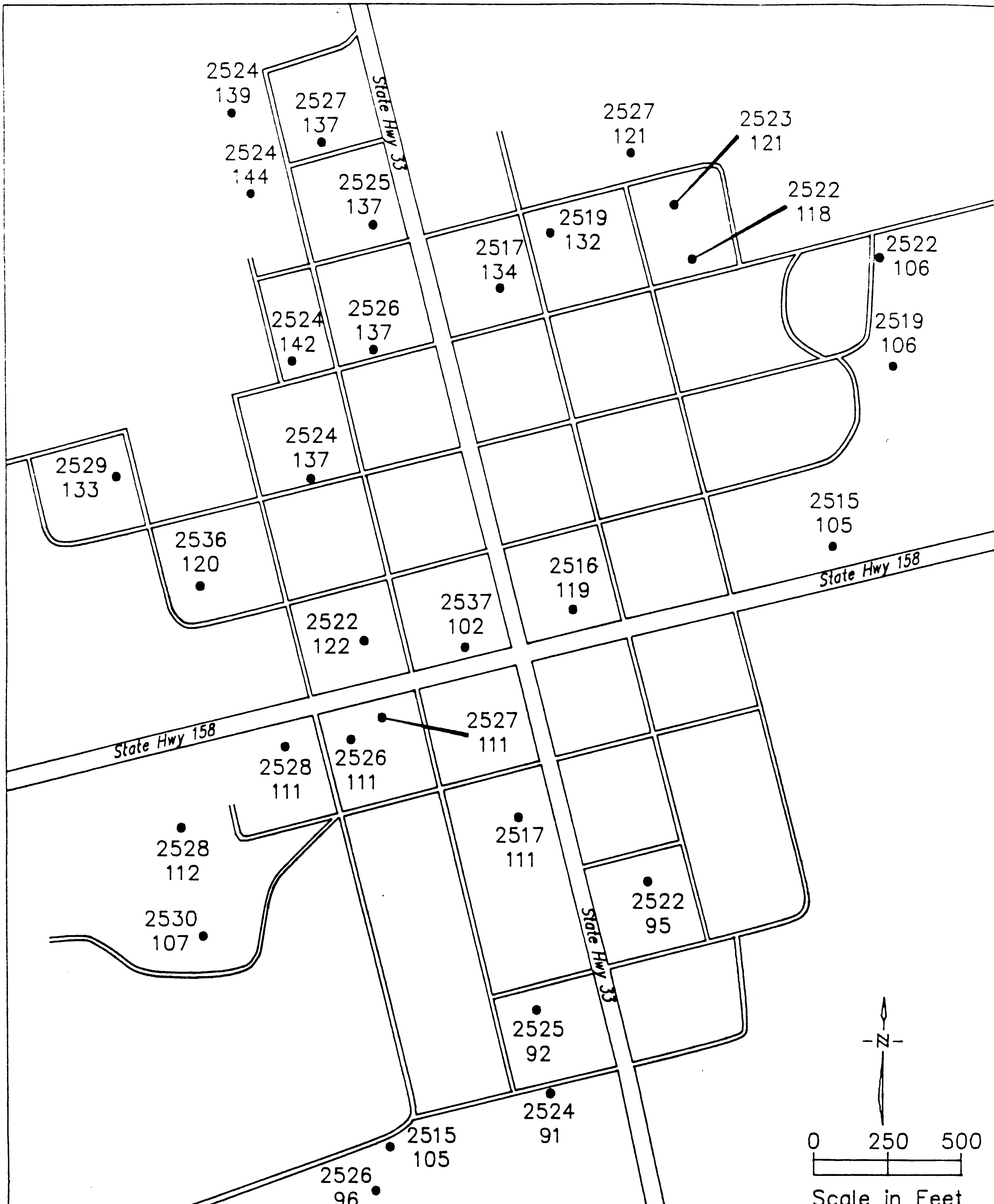


Figure 2

ELEVATION OF AND DEPTH TO THE WATER LEVEL IN WELLS (MEASUREMENTS WERE MADE IN APRIL AND MAY OF 1989)

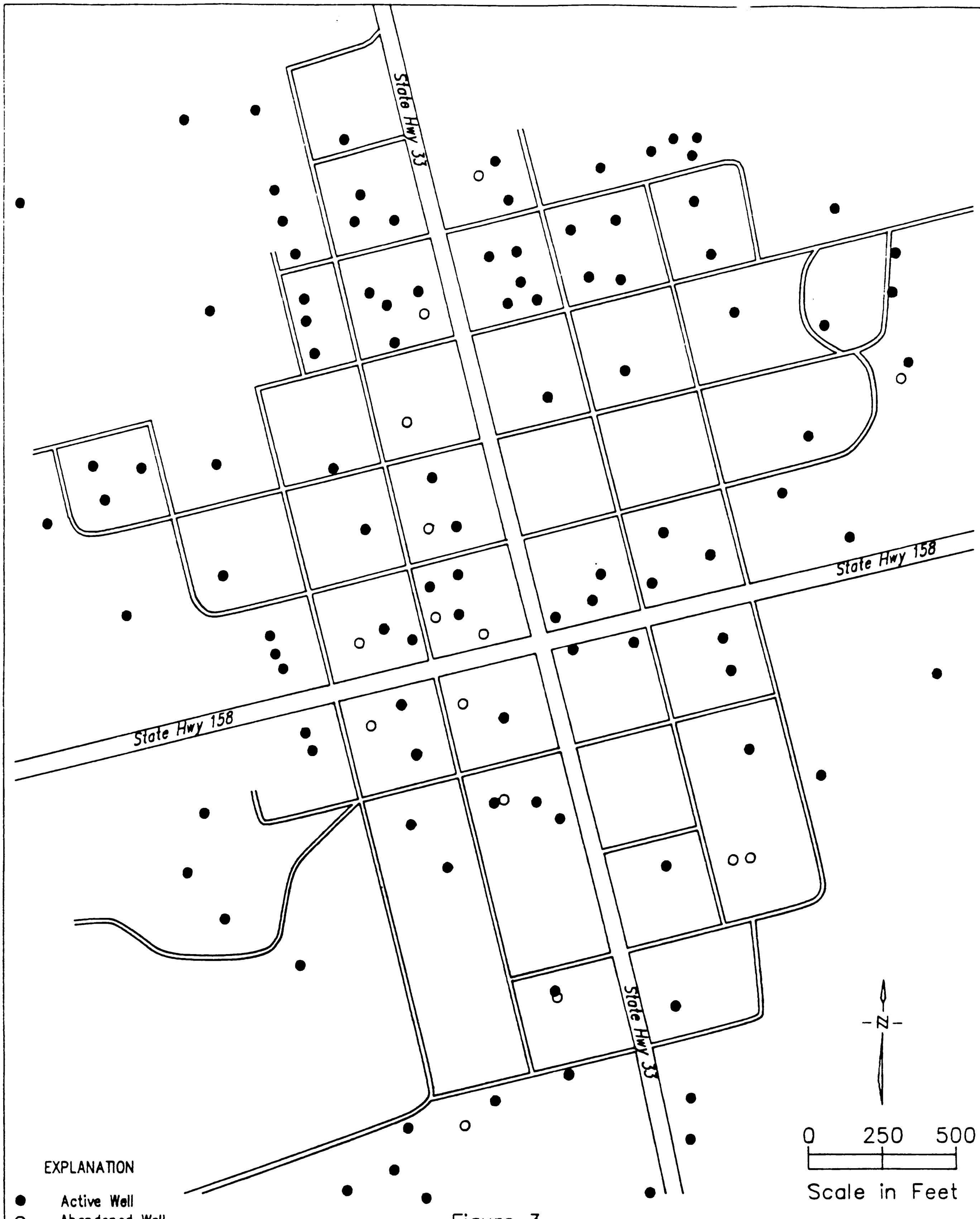


Figure 3

LOCATION OF ACTIVE AND ABANDONED WATER WELLS made, there appears to be more disposal systems in town than there are wells. Every house in town has a disposal system; however, not every house has a water well.

Septic systems are completed in the upper few feet of land surface. Consequently, their ability to function is partially dependent on the permeability of the soil and the nature of the underlying bed rock. Most of the town is underlain by the Reagan soil (Figure 4) which has been classified as having a favorable percolation rate by the U. S. Department of Agriculture Soil Conservation Service. Elsewhere in the town, Angelo, Conger, and Tobosa soils have slow percolation rates (U.S. Soil Conservation Service, 1977).

Underlying the soil zone at variable depths throughout town are massive layers of limestone which tend to cause the septic effluent to travel more horizontally than vertically. This horizontal movement often brings the effluent in contact with nearby wells that are not adequately sealed and thus allow the effluent to travel down into the well.

Rules related to the Water Well Drillers Act dictate that there should be a minimum of 150 feet between a well and a concentrated source of contamination such as a septic system. However, this distance may be decreased provided the total depth of the cement slurry placed around the wells is substantially increased. Most households in Garden City do not appear to meet this standard.

WATER QUALITY

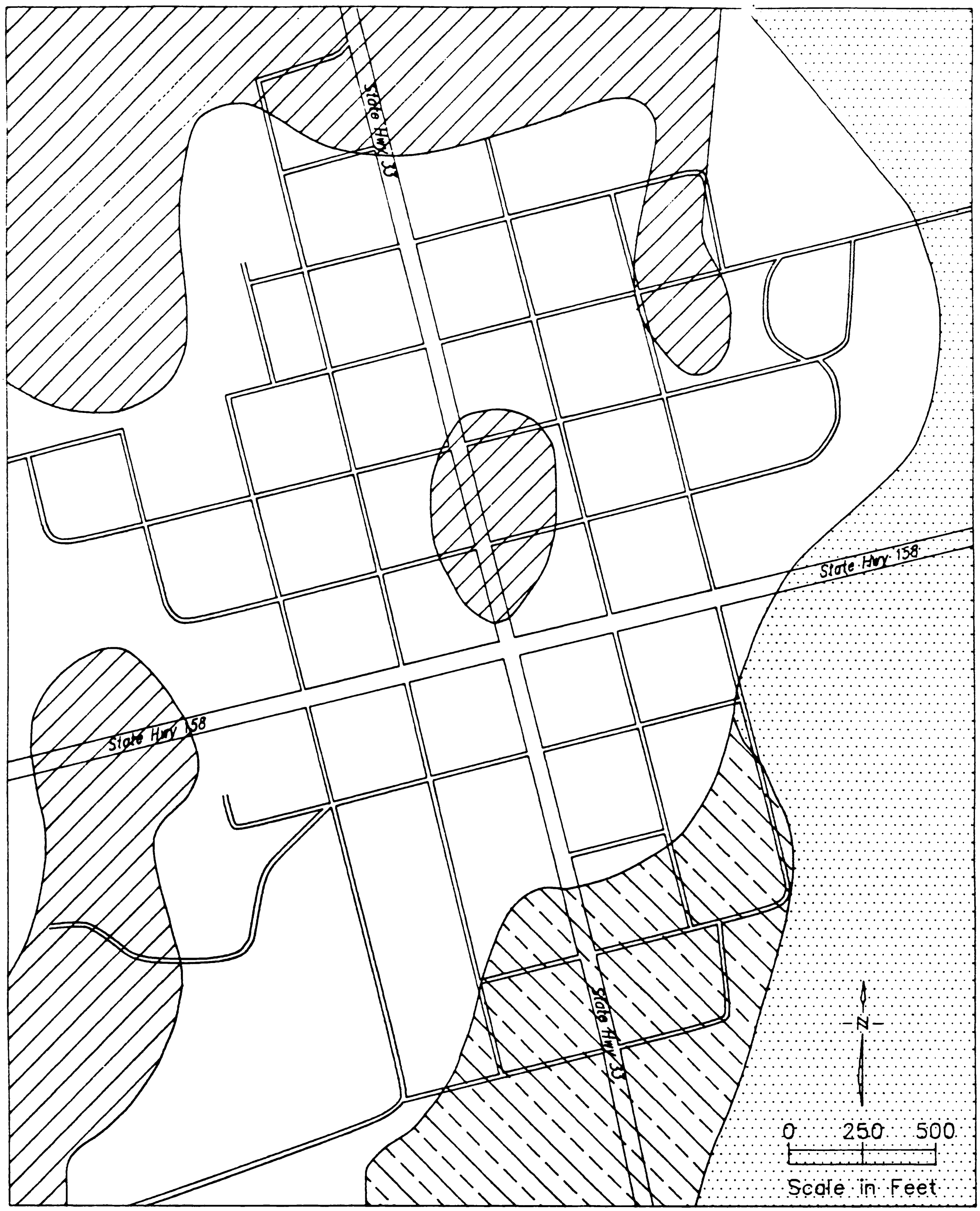
The native chemical quality of ground water in the Antlers Sand aquifer in the Garden City area is acceptable for most uses; a few exceptions will be discussed in the following paragraphs. Twenty eight randomly selected wells were sampled to determine the chemical quality in the aquifer underlying the town. Data collected from this effort was then compared to existing data for the surrounding area to see if any changes in quality have occurred. Ground water in Glasscock County contains concentrations of dissolved solids generally ranging between 400 and 800 milligrams per liter (mg/l) and is very hard. Table 1 shows the average and range of concentration of constituents in water samples from 14 wells. One contaminated well was not included in this table.

TABLE 1

Average and Range of Concentration of Constituents

Constituent	Average (mg/l)	Range (mg/l)
Calcium	105	62 - 198
Magnesium	29	17 - 54
Sodium	113	67 - 236
Potassium	6	4 - 10
Silica	14	11 - 17
Alkalinity	228	184 - 400
Sulfate	200	83 - 487
Chloride	98	29 - 229
Fluoride	1.5	1.3 - 2.1
Dissolved Solids	733	422 - 1465
Hardness as CaCO3	385	225 - 716

Wells were sampled in accordance with the Board's Field Manual for Ground Water Sampling (1990). Sampled wells (Table 3) were purged (pumped) until the temperature, specific conductance, and pH stabilized, insuring that the sample results were reflective of the representative water quality of the aquifer with as little interference from the well construction as possible. Samples were obtained at or as



EXPLANATION Soil Name	Septic Tank Absorption Field Characteristics
Angelo	Slow percolation rate
Conger	Cemented pan
Reagan	Favorable percolation rate
Tobosa	Slow percolation rate

Figure 4

SURFACE SOIL TYPES AND THEIR ABILITY TO FUNCTION AS A SEPTIC TANK ABSORPTION FIELD

Source: U.S. Soil Conservation Service

close to the well head as possible. Total alkalinity was determined at the well site by field titration. Water pumped from the well was passed through a 0.45 *u*m filter; hence, analysis results will be in dissolved constituents. Subsamples (individual samples from the same well) from each well were preserved as applicable and chilled on ice. Samples were then delivered to the Texas Department of Health (TDH) laboratory for analysis within one week so that holding times for constituents could be observed. Table 2 shows the primary and secondary maximum concentration level (MCL) as recommended by the TDH for human consumption.

TABLE 2

Standards of Chemical Quality
(TDH, 1988)

Primary Constituent Levels

Constituent	MCL in mg/l
Arsenic	0.05
Fluoride	4.00
Nitrate (as N)	10.00

Recommended Secondary Levels

Constituent or Property	Level
Chloride	300 mg/l
Fluoride	2 mg/l
Iron	0.3 mg/l
pH	>7.0 units
Sulfate	300 mg/l
Total dissolved solids	1000 mg/l

Subsamples were collected from 15 wells to determine anion (sulfate, chloride, and fluoride) and silica content. No preservative was necessary, but the subsamples were chilled on ice to 4° C until delivered to the lab. The TDH's recommended secondary constituent levels applicable to all public water systems (see Table 2) in mg/l is sulfate (300), chloride (300), and fluoride (2.0). One contaminated well (44-13-138) exceeded the recommended limits for all three anions. Sulfate levels were high in several other wells (see Table 4). The average constituent concentration from the other 14 anion subsamples was sulfate (200), chloride (98), and fluoride (1.5) in mg/l. There is no MCL established for dissolved silica, which had an average concentration of 14 mg/l.

Subsamples from the same 15 wells were collected to determine cation concentrations. The filtered water was collected in one liter polyethylene containers to which 5 ml of concentrated nitric acid was added as a preservative. At this point the subsamples were put on ice and delivered to the laboratory. Analysis of the cations was completed within an established 28 day holding time. Subsamples were analyzed for calcium, magnesium, sodium, arsenic, potassium, iron, and strontium.

Excluding the aforementioned contaminated well, averages and evaluations of the constituents determined in the remaining 14 cation subsamples are as follows:

1. Average concentrations for calcium, magnesium, and strontium were 105, 29, and 3.25 mg/l, respectively. From these values, hardness as calcium carbonate was calculated to be 385 mg/l. The property of water known as hardness is associated primarily with reactions of water with soap. As hardness increases, so does the soap-consuming ability of water. Hardness in excess of 180 mg/l is considered very hard. Obviously, the ground water in this area falls in this category. For general domestic use, hardness of water is not particularly objectionable until it attains about 100 mg/l.

2. Average concentrations for sodium and potassium were 113 and 6.2 mg/l, respectively. MCLs have not been established for either of these constituents; however, as compared to analyses of most public water supply systems (TDH files), both averages are relatively low.

3. Subsamples of water from 13 wells were analyzed for arsenic and iron. All analyses indicated that arsenic concentrations were below the detection limit of 10 micrograms per liter (ug/l). Only two cation samples had results above the detection limit of 20 ug/l for iron. These were only 28 and 23 ug/l. MCLs established for arsenic and iron are 50 and 300 ug/l, respectively.

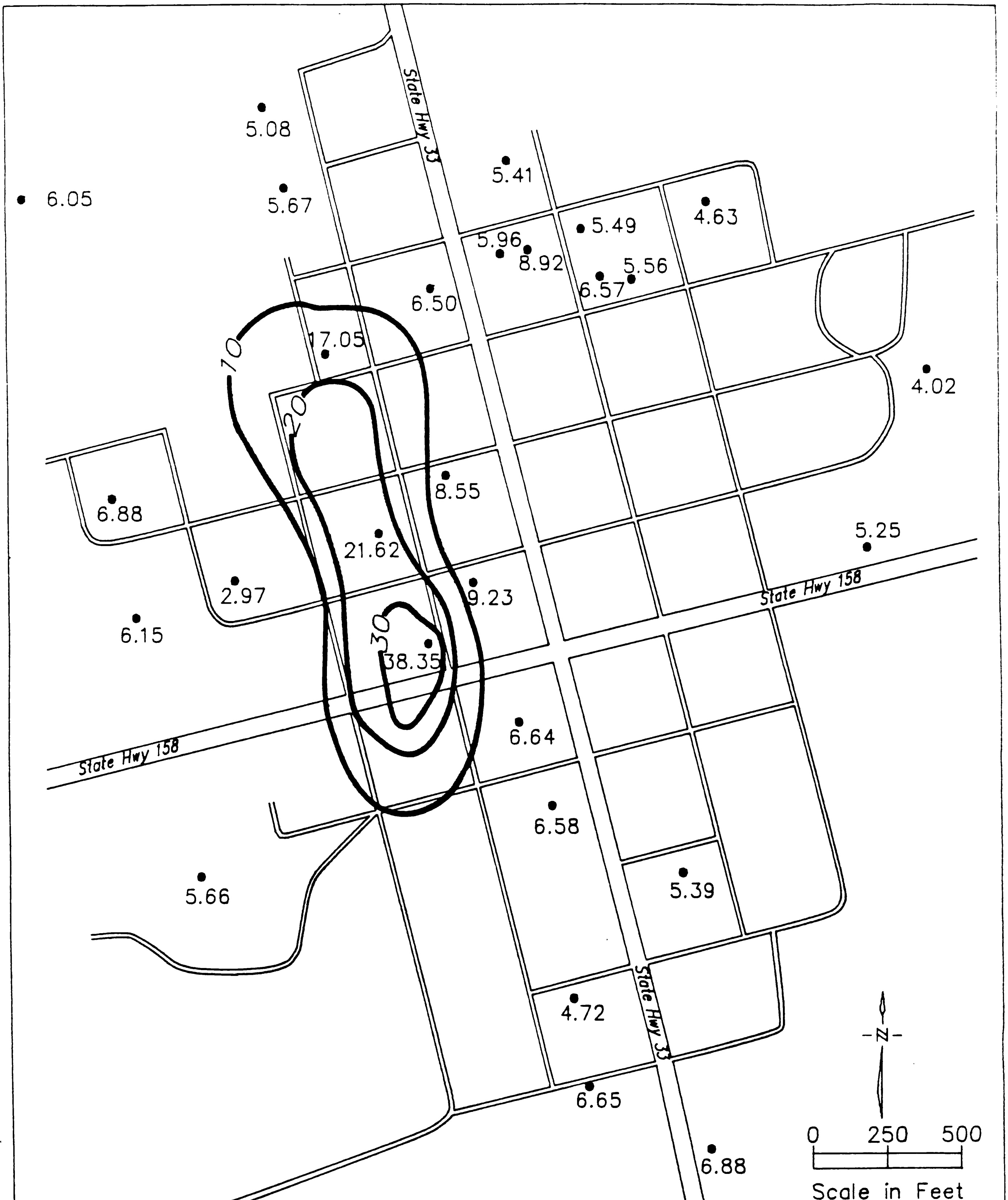
After the wells had been sufficiently purged, values of temperature, pH, and specific conductance were determined. The average temperature of the samples taken was 20.5°C. The pH was relatively neutral with a range in values from 6.7 to 7.8 units, and an average of 7.1 units for 22 measurements. Recommended secondary constituent levels applicable to all public water systems for pH is 7.0 or greater. Specific conductance readings were obtained with a LaMotte conductivity meter and a range of 670 to 3,800 micromhos with an average reading of 1,390 micromhos was obtained from 28 samples. Table 4 presents the pH and conductivity measurements for each well sampled. These are listed by state well number and the date of collection.

Alkalinity of ground water must be determined in the field at the time of sampling if the values determined are to accurately represent those originally present in the water. Since alkalinity is controlled by dissolution and outgassing of carbon dioxide, there may be a shift in the source of alkalinity. Field alkalinity was determined by titration and pH meter. Since pH was well below 8.3 units, phenolphthalein alkalinity, and hence carbonate, was zero. Total alkalinity was determined for 28 water samples. The range was 184 to 400 mg/l with an average of 228 as calcium carbonate. Total alkalinity x 1.22 equals bicarbonate, so the average bicarbonate concentration was 278 mg/l as $CaCO_3$.

Nutrient subsamples were taken from the 28 wells listed on Table 3. Filtered well water was collected in 500 ml opaque containers to which sulfuric acid was added as a preservative. The subsamples were then placed on ice and delivered to the TDH lab so that their analyses could be conducted within the prescribed maximum 7-day holding period. Subsamples were analyzed for nitrate, nitrite, ammonia, Kjeldahl, and orthophosphate.

Results of tests for nitrates can be expressed several ways, and it is important to know which way the laboratory reports nitrate values on the analysis report. If the report expresses results as nitrate-nitrogen (NO_3-N), the drinking water quality standard is 10 mg/l. If the results are expressed as nitrate (NO_3), the standard limit is 44.3 mg/l. Basically, to convert NO_3-N to NO_3, multiply by 4.427. Table 4 lists the values as nitrate, while Table 5 lists the values as nitrate-nitrogen, as received from the lab. The NO_3 value is used in determining dissolved solids (sum of constituents), while NO_3-N values are used in comparing nitrogen quantities with the other nutrient constituents. Figure 5 depicts nitrate-N results from sampled wells.

Contaminated well 44-13-138 contained 169.8 mg/l nitrate. The remainder of the wells sampled had a range in nitrate



EXPLANATION

• Sampled well with NO_3 N Valve

10 Line showing approximate Nitrate–N content

Figure 5

NITRATE CONTENT IN WATER FROM SELECTED WELLS values of 13.2 to 95.7 mg/l with an average concentration of 31.2 mg/l. Only three results exceeded the TDH's maximum contaminant level of 44.3 mg/l. Results of 43 analyses collected previously in the general vicinity of Garden City indicate an average nitrate level of 14 mg/l. Even though wells were not previously sampled with the quality control and quality assurance currently in practice, results indicate that levels of nitrate within the town limits of Garden City are more elevated than in the surrounding area.

Lab analysis results indicate that levels of nitrite, ammonia, and orthophosphate were at or below the detection limit. The Kjeldahl nitrogen values ranged from <0.1 to 0.7 mg/l as N, with an average value of 0.2 mg/l (Table 5). Organic nitrogen is determined by subtracting ammonia from the Kjeldahl nitrogen, and since ammonia was not detected in sample analyses, the Kjeldahl values can be construed to be all organic nitrogen.

The highest concentration of organic nitrogen was determined to be in contaminated well 44-13-138. The remaining 5 wells with values in excess of 0.2 mg/l were found to be in immediate proximity to this well. All six wells were also located within the 1,000 mg/l dissolved-solids contour line on Figure 6 and three of the wells had nitrate-N values exceeding 10 mg/l (Figure 5). Principal sources of organic nitrogen in this area are septic tanks and fertilizers. Since the area of high nitrogen and coliform levels occurs within the city limits and is surrounded by better quality well water, it would appear that contamination in the form of higher concentrations of nitrogen and total dissolved solids is derived from septic tank system fluids entering the aquifer via abandoned and/or improperly completed wells.

Once all the major anions and cations are determined, the values of each constituent, in mg/l, is summed to render the dissolved-solids content. The calculated sum of constituents was determined for 15 well samples. An estimate of total dissolved solids can also be made from specific conductance. Dividing the sum of constituents by specific conductance in the 15 complete water analyses, an average value was determined to be 58.22 percent. Multiplying this factor by the measured specific conductance in the remaining wells yielded a good estimate of total dissolved solids. Figure 6 shows the combination of these two methods plotted on the well location map. Again, the area depicting higher dissolved-solids content immediately surrounds and extends in a north-south axis from contaminated well 44-13-138. Eight of the 28 wells sampled in Garden City had a dissolved-solids content in excess of TDH's secondary recommended limits for drinking water standards of 1,000 mg/l (Table2).

CONCLUSIONS AND RECOMMENDATIONS

Garden City, like many small unincorporated communities, relies on private water wells for its water supply and septic systems for the disposal of sewage effluent. There are approximately 104 wells currently in use and 15 abandoned or unused wells. Several of those wells are in a state of deterioration in which leakage of contaminants into the well from the surface or near surface is possible. In addition, virtually every home and many of the businesses have septic systems.

Water quality analyses of samples taken from 28 wells indicate that the concentration of water wells and septic

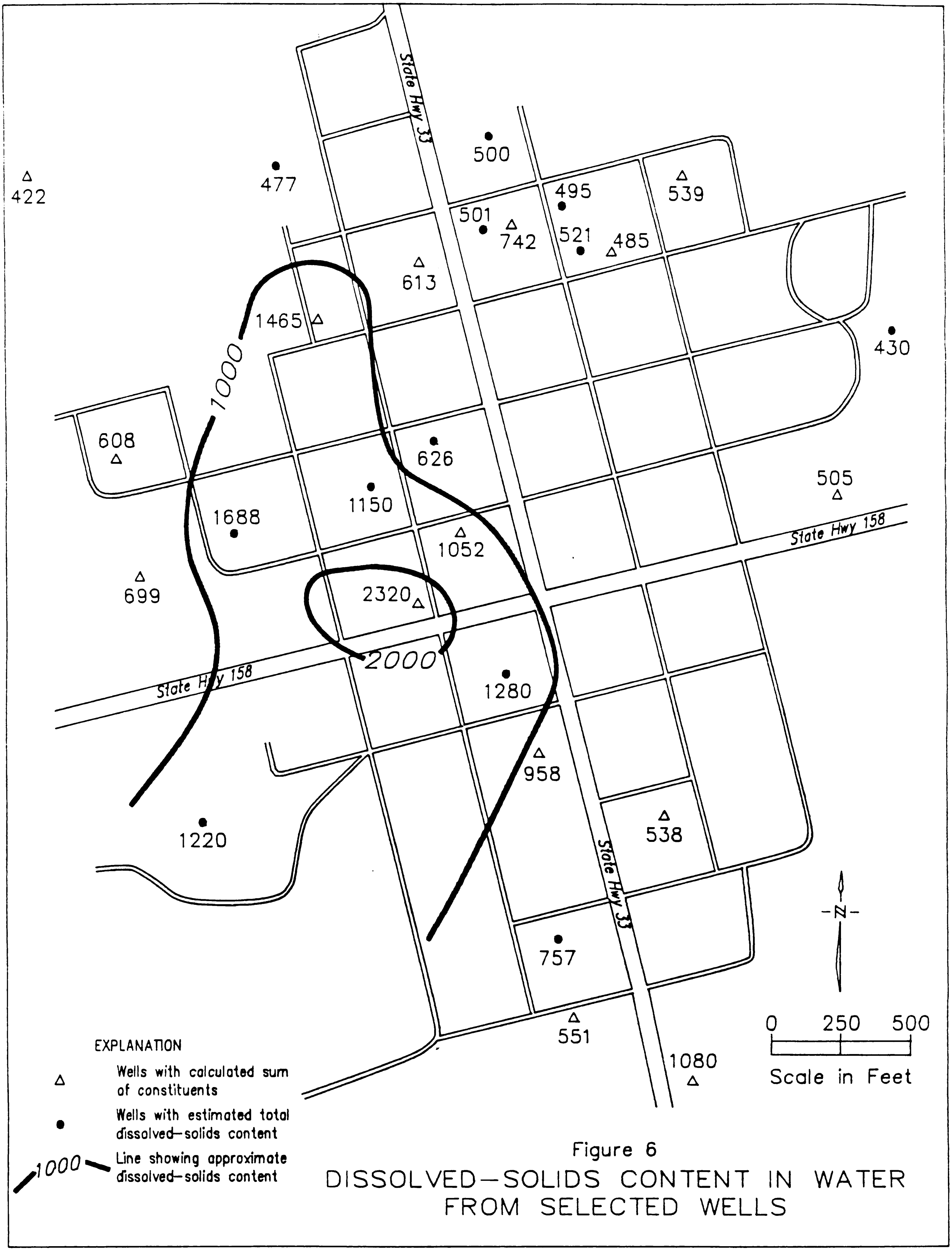


Figure 6
DISSOLVED—SOLIDS CONTENT IN WATER FROM SELECTED WELLS

systems within the half mile square area of the town has resulted in a degradation of the chemical quality of the underlying ground water. Although the quality of the ground water is generally acceptable for human consumption, there were several samples from wells that contained constituent levels in excess of the maximum levels recommended to be safe for drinking by the Texas Department of Health.

The primary solution to the problem of a contaminated or potentially contaminated aquifer would be the establishment of a municipal well field located outside the area of influence of concentrated human activities. However, if this option is not financially feasible, then the following suggestions should be considered:

1. Establish a quality monitoring system in which every well is periodically tested for specific conductivity, nitrates, coliform bacteria, and other suspected contaminants.

2. Identify contaminated wells, determine the source of the contamination, and take remedial action.

3. Eliminate all cesspools and replace with properly installed septic tanks with adequate drain fields.

4. Properly plug all abandoned wells and plug or cap all unused wells.

5. Locate new wells as far away from drain fields as possible and follow all rules set forth by the Texas Water Well Drillers Board.

6. Initiate a public awareness program concerning such topics as well house sanitation, storage of chemicals, overuse of fertilizers and pesticides, etc.

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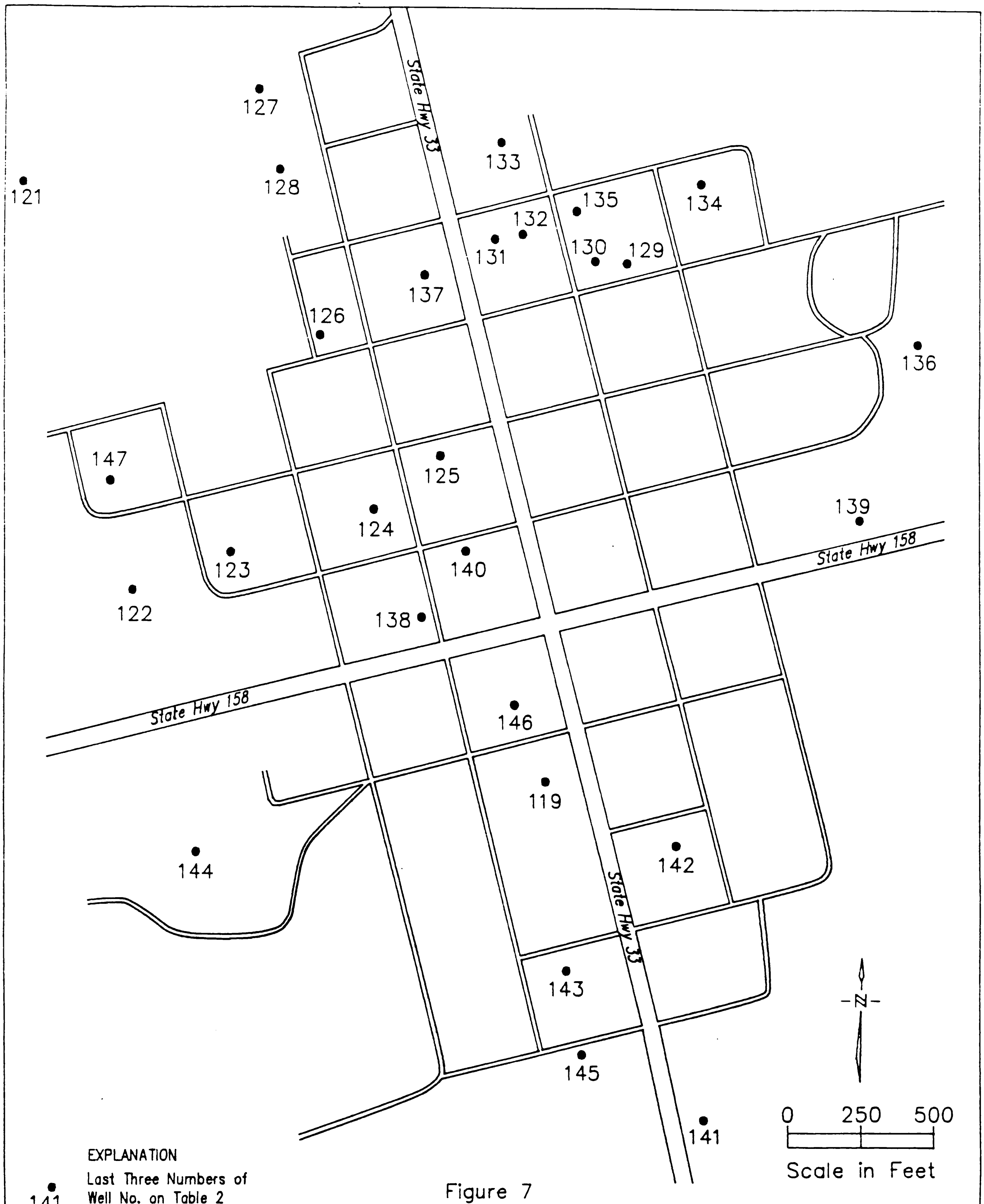

Figure 7

LOCATION OF WATER WELLS

Table 3 -- Records of Selected Wells

WELL	OWNER	DRILLER	DATE COMPLETED	CASING & SCREEN DATA DEPTH OF WELL (FT.)	CASING OR SCREEN	DIAMETER (IN.)	WATER LEVEL TOP DEPTH	BOT DEPTH (FT.)	WATER BEARING UNIT	ALTITUDE OF LAND SURFACE (FT.)	MEASUREMENT FROM LSD (FT.)	DATE	METHOD OF LIFT AND POWER	USE OF WATER	REMARKS
44-13-119	Church of Christ								218ALRS	2629	-111.80	4/6/89	S E	H	
44-13-121	Glasscock County ISD	Choat Well Service, Inc.							218ALRS	2675	-159.55	4/5/89	S E	P	Supplies water to school and to several homes.
44-13-122	Jimmy Bednar	John Robinson	1971						218ALRS	2654			S E	H	
44-13-123	Jose Lopez								218ALRS	2656	-119.55	4/4/89	S E	H	
44-13-124	Steve Livingston	Jim Brown	1978	210	C	5	0	190	218ALRS	2654	-120.00	7/15/78	S E	H	
					S	5	190	210							
44-13-125	Daniel Kujawski	Hickerson Drilling & Pump Co.	1987	205					218ALRS	2656			S E	H	
44-13-126	Curtis Palmer								218ALRS	2666	-141.70	4/5/89	S E	H	
44-13-127	Ruth Cook								218ALRS	2663	-138.65	4/5/89	S E	H	
44-13-128	Donald Cypert	O. W. Coleman	1985	280	C	5	0	139	218ALRS	2667	-142.60	4/5/89	S E	H	
					S	5	139	280							
44-13-129	Rory Buchanan								218ALRS	2643			S E	H	
44-13-130	Cook								218ALRS	2647			S E	H	
44-13-131	James Cypert			175					218ALRS	2657	-50.00	8/6/71	S E	H	

Table 3 -- Records of Selected Wells

WELL	OWNER	DRILLER	DATE COM- PLETED	CASING & SCREEN DATA DEPTH OF WELL (FT.)	CASING OR SCREEN	DIAM- ETER (IN.)	WATER LEVEL TOP DEPTH	BOT DEPTH (FT.)	WATER BEARING UNIT	ALTITUDE OF LAND SURFACE (FT.)	MEASURE- MENT FROM LSD (FT.)	DATE	METHOD OF LIFT AND POWER	USE OF WATER	REMARKS
													0.75		
44-13-132	Wanda Forbis								218ALRS	2656			S E	H	
44-13-133	Stewart Dalton	O. W. Coleman	1982	280	C	5	0	140	218ALRS	2656	-130.00	7/23/82	S E	H	
					S	5	140	280							
44-13-134	Glen Kingston								218ALRS	2642	-119.40	5/4/89	S E	H	
44-13-135	Wayne Montgomery								218ALRS	2650	-130.60	5/4/89	S E	H	
44-13-136	R. C. Schafer	Gene Braden	1977	197	C	6	0	121	218ALRS	2625	-105.80	5/4/89	S E	H	Currently unused.
					S	6	121	197							
44-13-137	First Methodist Chruch	O. W. Coleman	1987	290	C	6	0	190	218ALRS	2660	-150.00	10/19/87	S E	H	
					S	6	190	290							
44-13-138	Vier S	T. I. Green	1969	160					218ALRS	2643			S E	H	
44-13-139	Larry Wheat								218ALRS	2620	-105.00	5/4/89	S E	H	
44-13-140	Glen Riley	Walton O'Neil Loftis	1978	196	C	6	0	196	218ALRS	2646	-110.00	6/19/78	S E	H	
44-13-141	Pat Munn	O. W. Coleman	1983	235	C	6	0	134	218ALRS	2612	-210.00	5/19/83	S E	H	
					S	6	134	235							

Table 3 -- Records of Selected Wells

					CASING & SCREEN DATA		WATER LEVEL			ALTITUDE					
WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (FT.)	CASING OR SCREEN	DIAMETER (IN.)	TOP DEPTH	BOT DEPTH (FT.)	WATER BEARING UNIT	OF LAND SURFACE (FT.)	MEASUREMENT FROM LSD (FT.)	DATE	METHOD OF LIFT AND POWER	USE OF WATER	REMARKS
44-13-142	Vernon Gill			150					218ALRS	3617	-95.40	5/3/89	S E	H	Converted shot hole.
44-13-143	Royce Pruitt								218ALRS	2617	-91.60	4/6/89	S E	H	
44-13-144	Ervin Wooten			265	C	0	0	265	218ALRS	2640			S E	H I	
44-13-145	Gerald Wooten	O. W. Coleman	1981	247	C	8	0	147	218ALRS	2616	-110.00	9/25/81	S E	H I	
					S	8	147	247							
44-13-146	Alex Fry								218ALRS						
44-13-147	Michael Hoch	O. W. Coleman	1985	290	C	6	0	149	218ALRS	2657	-140.00	9/21/85	S E	H	
					S	6	149	290			-133.70	5/23/89			

Aquifer: 218 ALRS - Antlers Sand

Method of Lift and Power: S-submersible, E-electric

Use of Water: H - household, I - irrigation, P - public supply

Table 4 -- Results of Standard Water-Quality Analyses

Well	Date of Collection	pH	Silica (SiO2) MG/L	Calcium (Ca) MG/L	Magnesium (Mg) MG/L	Sodium (Na) MG/L	Potassium (K) MG/L	Carbonate (CO3) MG/L	Bicarb. (HCO3) MG/L	Sulfate (SO4) MG/L	Chloride (Cl) MG/L	Fluoride (F) MG/L	Nitrate (NO3) MG/L	Dissolved Solids MG/L	Spec. Cond. (micromhos)	Hardness as CaCO3	Percent Sodium
44 13 119	5/25/89		13	120	38	167	7	0	273	293	151	1.4	29.1	954	1250	455	44
44 13 121	5/23/89	7.3	11	62	17	69	5	0	238	83	29	1.4	26.8	422	670	225	39
44 13 122	5/23/89	7.0	13	99	28	112	6	0	253	192	96	1.6	27.2	699	1300	360	39
44 13 123	5/23/89	6.9						0	420				13.2		2900		
44 13 124	5/23/89	7.8						0	277				95.7		1975		
44 13 125	5/23/89	7.2						0	262				37.9		1075		
44 13 126	5/23/89	6.8	13	198	54	236	10	0	328	487	229	1.3	75.5	1465	2600	716	41
44 13 127	5/23/89	7.2						0	488				22.5		770		
44 13 128	5/23/89	7.0						0	232				25.1		820		
44 13 129	5/24/89	7.2	13	76	21	70	5	0	232	117	43	1.6	24.6	485	790	276	35
44 13 130	5/24/89	7.0						0	249				29.1		895		
44 13 131	5/24/89	7.0						0	225				26.4		860		
44 13 132	5/24/89	7.1	17	96	27	113	6	0	256	188	88	2.1	39.5	742	1250	350	40
44 13 133	5/24/89	7.1							234				24.0		860		
44 13 134	5/24/89	7.1	15	88	21	76	4	0	268	113	67	1.8	20.5	539	890	306	34

Table 4 – Results of Standard Water-Quality Analyses

Well	Date of Collection	pH	Silica (SiO2) MG/L	Calcium (Ca) MG/L	Magnesium (Mg) MG/L	Sodium (Na) MG/L	Potassium (K) MG/L	Carbonate (CO3) MG/L	Bicarb. (HCO3) MG/L	Sulfate (SO4) MG/L	Chloride (Cl) MG/L	Fluoride (F) MG/L	Nitrate (NO3) MG/L	Dissolved Solids MG/L	Spec. Cond. (micromhos)	Hardness as CaCO3	Percent Sodium
44 13 135	5/24/89	7.2							234				24.3		850		
44 13 136	5/24/89	7.2							232				17.8		740		
44 13 137	5/24/89	7.1	14	89	25	94	6	0	254	157	73	1.7	28.8	613	1200	325	38
44 13 138	5/25/89	6.7	24	256	69	431	12	0	454	659	466	2.1	169.8	2320	3800	923	49
44 13 139	5/25/89	7.1	16	88	20	67	5	0	254	101	58	1.4	23.2	505	840	302	32
44 13 140	5/25/89	7.0	15	144	40	166	8	0	337	288	177	1.3	40.9	1052	1900	524	40
44 13 141	5/25/89		14	148	44	159	8	0	264	370	171	1.3	30.5	1080	1900	550	38
44 13 142	5/25/89		15	95	22	68	5	0	244	123	62	1.3	23.9	538	920	328	30
44 13 143	5/25/89	7.0					0	225				20.9		1300			
44 13 144	5/23/89						0	254				25.1		2100			
44 13 145	5/25/89		14	79	22	86	6	0	259	129	55	1.6	29.4	551	1400	288	38
44 13 146	5/26/89							0	303				29.4		2200		
44 13 147	5/23/89	7.2	14	88	23	98	6	0	244	156	71	1.5	30.5	608	890	314	39

Table 5 --Results of Analyses for Nitrate-N, Kjeldahl-N, and Strontium

STATE WELL NUMBER	DATE	SAMPLE #	STORET CODE	DESCRIPTION	FLAG	VALUE
44-13-119	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.58
44-13-121	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.05
44-13-122	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.15
44-13-123	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		2.97
44-13-124	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		21.62
44-13-125	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		8.55
44-13-126	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		17.05
44-13-127	5/22/83	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.08
44-13-128	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.67
44-13-129	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.56
44-13-130	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.57
44-13-131	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.96
44-13-132	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		8.92
44-13-133	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.41
44-13-134	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		4.63
44-13-135	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.49
44-13-136	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		4.02
44-13-137	5/23/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.50
44-13-138	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		38.35
44-13-139	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.25
44-13-140	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		9.23
44-13-141	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.88
44-13-142	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.39
44-13-143	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		4.72
44-13-144	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		5.66
44-13-145	5/24/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.65
44-13-146	5/25/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.64
44-13-147	5/22/89	1	00618	NITRATE NITROGEN, DISSOLVED (MG/L AS N)		6.88
44-13-119	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.2
44-13-121	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)	<	0.1
44-13-122	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1

Table 5 --Results of Analyses for Nitrate-N, Kjeldahl-N, and Strontium

STATE WELL NUMBER	DATE	SAMPLE #	STORET CODE	DESCRIPTION	FLAG	VALUE
44-13-123	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.6
44-13-124	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.3
44-13-125	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-126	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.3
44-13-128	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-129	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-130	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.2
44-13-131	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.2
44-13-132	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-133	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.2
44-13-134	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-135	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-136	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-137	5/23/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-138	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.7
44-13-139	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-140	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.3
44-13-141	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.2
44-13-142	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-143	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-144	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-145	5/24/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-146	5/25/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.3
44-13-147	5/22/89	1	00623	NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)		0.1
44-13-119	5/24/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		3640
44-13-122	5/22/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		2990
44-13-129	5/23/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		2330
44-13-132	5/23/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		3510
44-13-137	5/23/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		2890
44-13-138	5/24/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		8400
44-13-141	5/24/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		3730

Table 5 --Results of Analyses for Nitrate-N, Kjeldahl-N, and Strontium

STATE WELL NUMBER	DATE	SAMPLE #	STORET CODE	DESCRIPTION	FLAG	VALUE
44-13-142	5/24/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		1980
44-13-145	5/24/89	1	01080	STRONTIUM, DISSOLVED (UG/L AS SR)		2080