HYDROLOGIC REPORT

OF THE

WOODBINE, MARIETTA, AND TEXOMA MINOR BEDROCK

GROUNDWATER BASINS

AND THE

HAWORTH TERRACE AND LITTLE RIVER ALLUVIAL AND TERRACE

MINOR GROUNDWATER BASINS

TECHNICAL REPORT
99-2

by
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OKLAHOMA WATER RESOURCES BOARD
Planning & Management Division

July 1998

ACKNOWLEDGMENTS

The author is grateful to Mark Belden, Noel Osborn and Robert Fabian in the Planning and Management Division for their technical support and review of the report.

Appreciation is also extended to James Leewright and Mike McGaugh of our Mapping and Drafting Section of the Administrative Services Division for the drafting of the figures in the report; Lou Klaver, Assistant Chief of the Planning and Management Division for her legal review of the document; and Mary Whitlow and Susan Birchfield for their review and editing of the report for final preparation for publication.

This publication is prepared, issued and printed by the Oklahoma Water Resources Board. 75 copies were prepared at a cost of $57.40. Copies have been deposited with the Publications Clearinghouse at the Oklahoma Department of Libraries.

INTRODUCTION

The hydrogeologic report of the minor groundwater basins in portions of Bryan, Choctaw, Love, Marshall and McCurtain Counties was conducted by the Oklahoma Water Resources Board (Board) under the authority of Oklahoma Statutes Title 82, Sections 1020.4 and 1020.5. Section 1020.4 authorizes the Board to conduct hydrologic surveys and investigations of fresh groundwater basins to characterize the availability, extent and natural hydrologic conditions of the resource. The Board is further directed by Section 1020.5, upon completion of the hydrologic survey, to determine the maximum annual yield of fresh water to be produced from each groundwater basin, as well as the equal proportionate share of the maximum annual yield to be allocated to each acre of land overlying the basin(s). This determination is to be based on the following criteria:

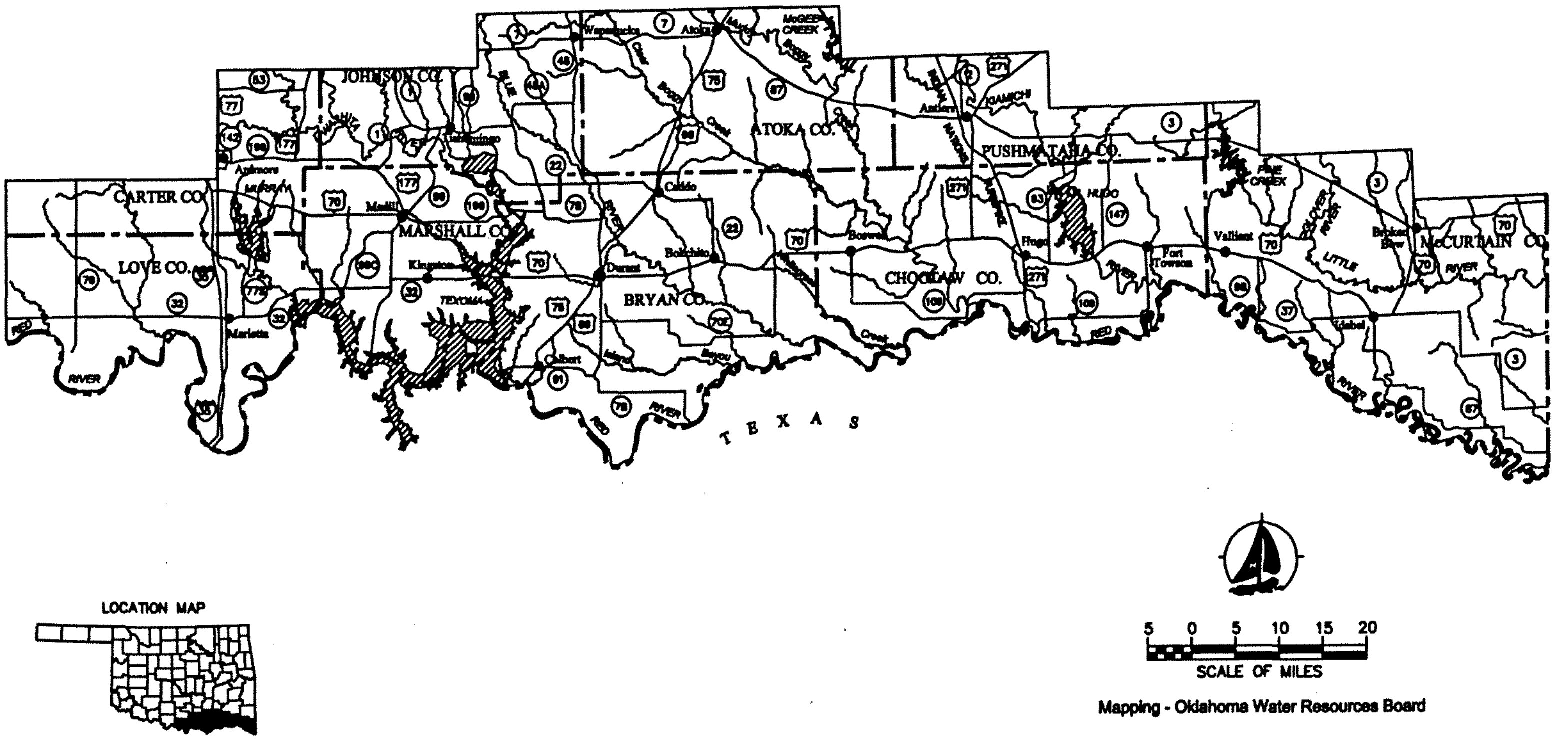
1) The total land area overlying the basin or subbasin;
2) The amount of water in storage in the basin or subbasin;
3) The rate of recharge to the basin or subbasin and total discharge from the basin or subbasin;
4) Transmissivity of the basin or subbasin; and
5) The possibility of pollution of the basin or subbasin from natural sources.

The purpose of this report is to review, assess and evaluate hydrologic data pertaining to the groundwater resources in the study area. Data sources include records maintained by the Board, existing hydrogeologic reports and references which assess the study area and hydrologic reports or texts which evaluate hydrogeologic settings similar to the study area.

This report will provide the hydrologic data necessary to determine or estimate the above criteria which will provide the basis for setting the maximum annual yield and equal proportionate share of the minor groundwater basins within the study area. The maximum annual yield determination and equal proportionate share results are subject of a future report.

A minor groundwater basin is defined as a distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which the groundwater wells yield less than 50 gallons per minute on the average basinwide, if from a bedrock basin and 150 gallons per minute, if from an alluvial and terrace basin.

The study area for this report includes portions of Bryan, Choctaw, Love, Marshall and McCurtain Counties as shown in Figure 1. Three minor bedrock groundwater basins and three minor alluvial and/or terrace groundwater basins were identified in the study area. The bedrock groundwater basins include all Cretaceous-aged units deposited stratigraphically above the Antlers Formation. These basins have been named the



Mapping - Oklahoma Water Resources Board

Figure 1. General Area of Study which includes portions of Bryan, Choctaw, Love, Marshall and McCurtain Counties in Southern Oklahoma

Woodbine Minor Groundwater Basin (WMGB), Marietta Minor Groundwater Basin (MMGB), and Texoma Minor Groundwater Basin (TMGB). Two minor isolated terrace deposits located near the Town of Haworth have been designated as the Haworth Isolated Terrace Groundwater Basins (HITGBs) 1 & 2 and the alluvial and terrace deposits along the Little River have been designated as the Little River Groundwater Basin (LRGB). Figures 2, 3 and 4 show the boundaries of the respective groundwater basins superimposed on the public land survey for the study area.

PHYSICAL SETTING

Location

This report will be limited to the minor groundwater basins in Bryan, Choctaw, Love, Marshal and McCurtain Counties located from south-central to southeastern Oklahoma. The study area contains approximately 1,550,000 acres. The area for this report was selected on the basis of similar groundwater resources and geologic deposits and structure. The principal groundwater basin for this study in terms of surface area stretches from McCurtain County to Marshall County and consists of Cretaceous-aged rocks with some minor alluvial and terrace deposits. Two smaller basins located in Marshall and Love Counties that are not contiguous with the principal basin have also been included in this report because they exhibit similar aquifer and geologic characteristics.

Also included as separate basins for the study are two isolated terrace deposits located near the Town of Haworth and the alluvial and terrace deposits along the Little River in southeastern McCurtain County. These basins are positioned just north of the Red River, but are not contiguous with the alluvial and terrace deposits associated with the Red River.

The alluvial and terrace deposits associated with the Red River system along the southern border of Oklahoma are a potential major basin and will not be considered in this report. Also excluded from this report is the Antlers Groundwater Basin which is a major basin.

Setting

The land encompassed by the study area lies within the dissected Coastal Plain Province of Oklahoma, a portion of the Gulf Coastal Plain (Huffman et al, 1978). The region slopes gently southward toward the Red River. Topographic differences range from less than 350 feet above sea level along the Red River in the southern section of the study area to nearly 900 feet above sea level in the northern section (Hart, Jr. 1974 and Marcher and Bergman, 1983). Land use varies from farm and rangeland areas to forest areas. Southward dipping sedimentary strata give rise to a cuesta and dip-slope type of topography where the more resistant formations are present (Huffman et al, 1978). The area is drained by the Red River and its tributaries Little River, Kiamichi River, Muddy Boggy River, Clear Boggy River, Blue River and the Washita River (Hart and Davis, 1981).

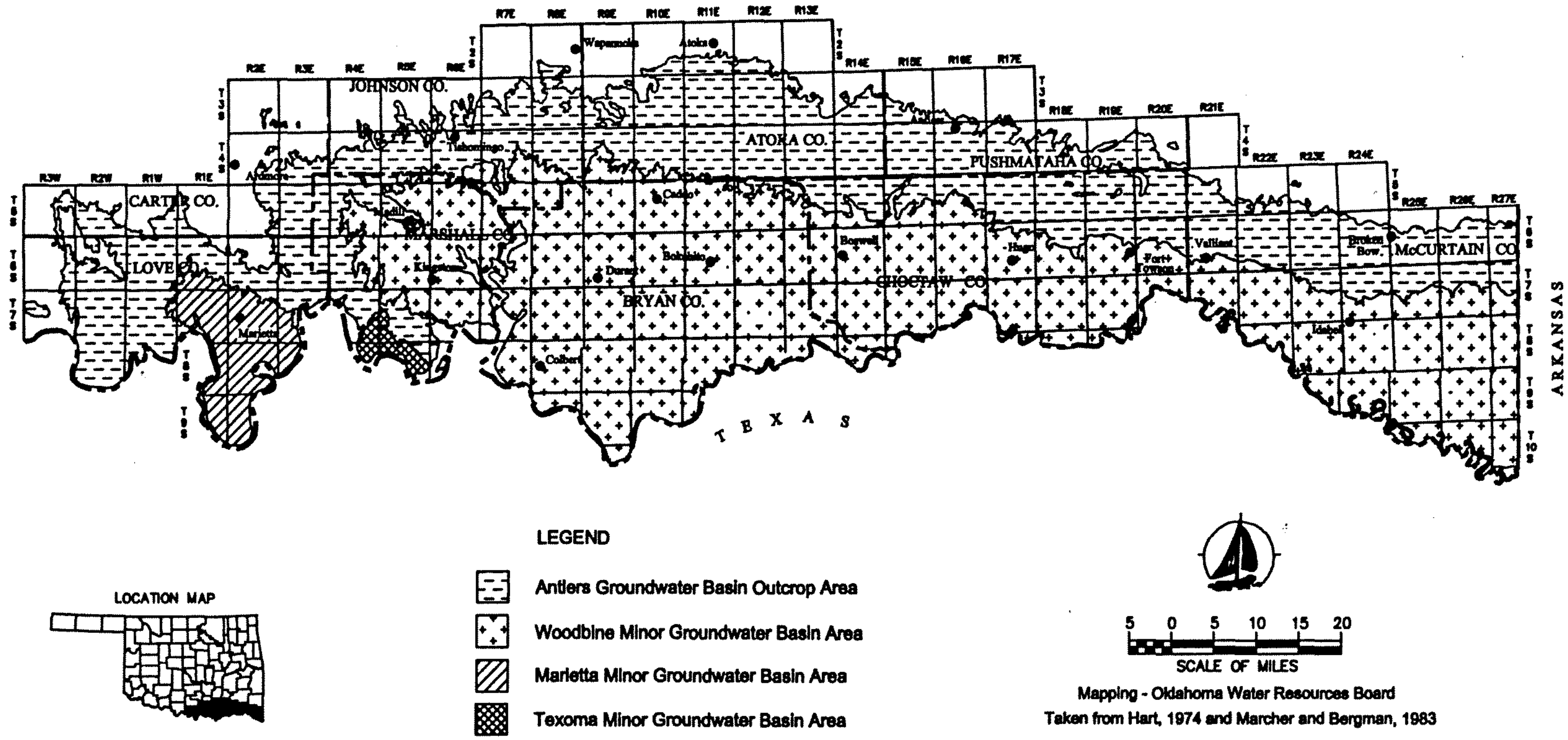


Figure 2. Groundwater Basin Boundary Map for Woodbine, Marietta and Texoma Minor Bedrock Basins

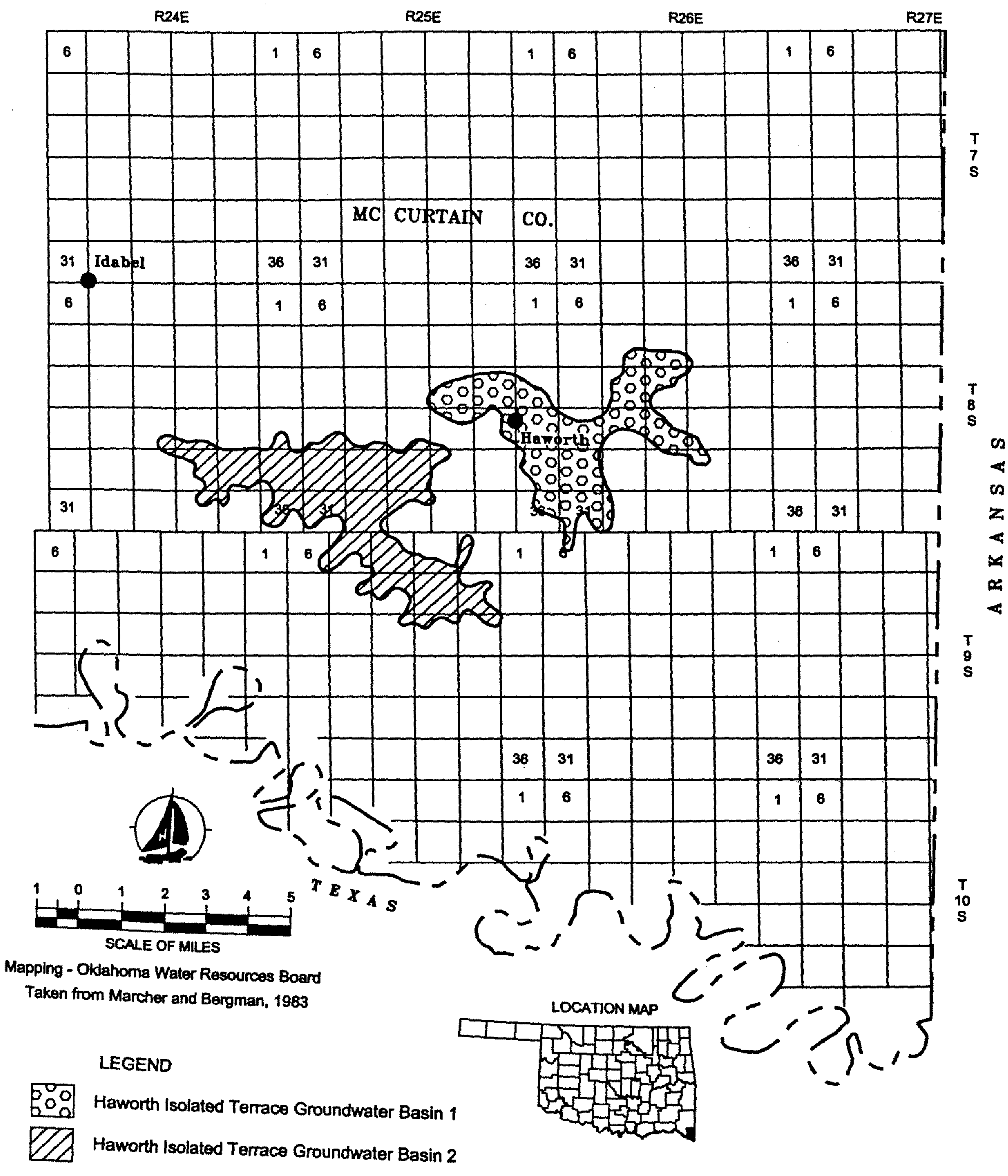


Figure 3. Groundwater Basin Boundary Map for Haworth Isolated Terrace Deposits HITGB 1 and HITGB 2

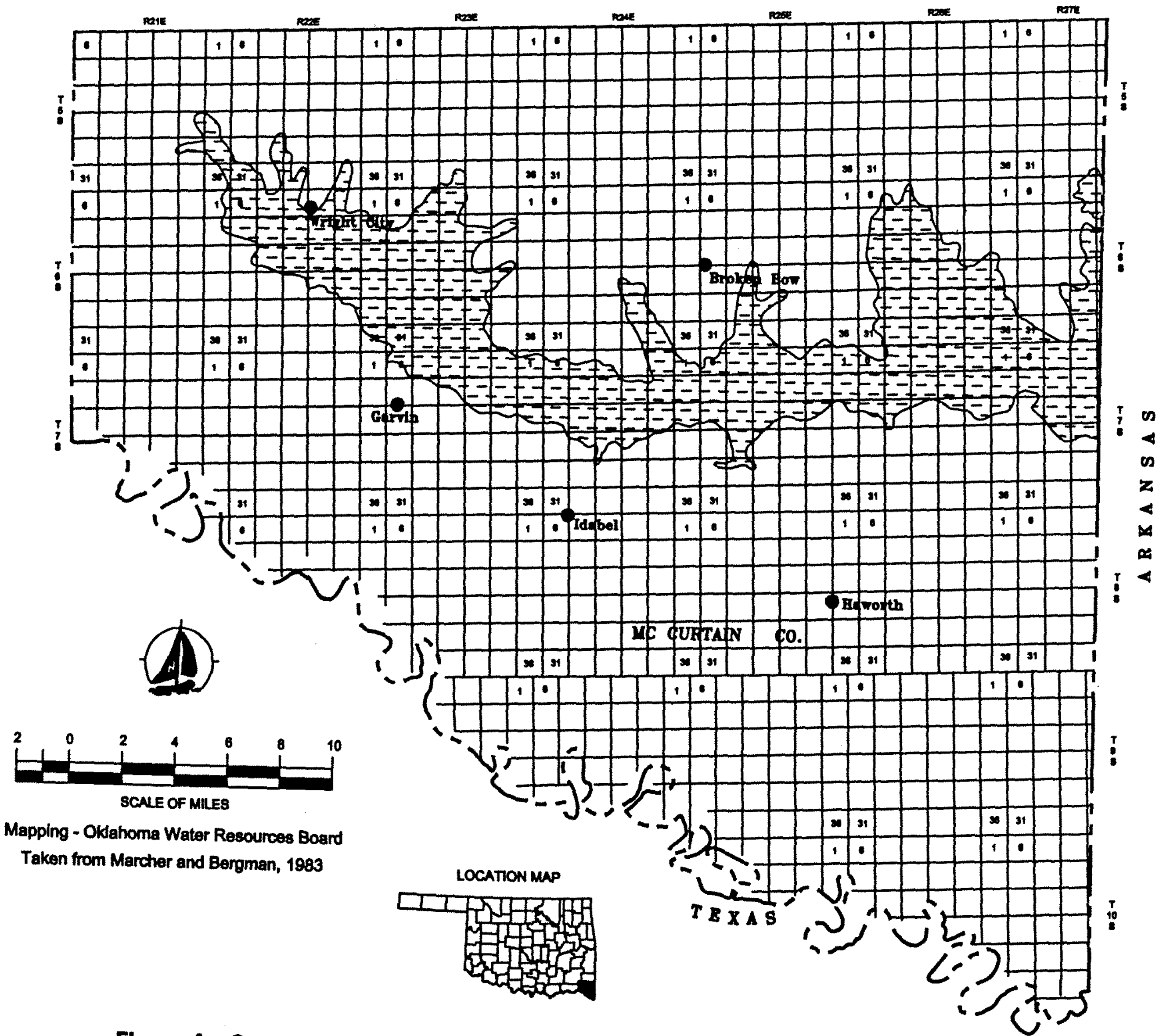


Figure 4. Groundwater Basin Boundary Map for Little River Alluvial and Terrace Deposits

Climate

Climates in the study area range from a temperate, continental climate in the west to a warm, subtropical climate in the east. Seasonal changes are gradual, but the characteristics of each season are well defined. The spring and autumn months are mild, with cool nights and warm days. Summers are hot with high humidity. Winters are comparatively mild with infrequent long periods of severe cold (Coal and Steers, 1978; Swafford and Reasoner, 1979; Reasoner, 1974; Maxwell and Reasoner, 1966).

The average yearly precipitation is sufficient for most field crops commonly grown in the area. Rainfall is typically distributed uniformly throughout the year, reaching a slight peak in spring. The mean annual precipitation ranges from 36 inches per year in Love County to 48 inches in McCurtain County (OWRB, 1990). The mean annual precipitation for the study area was determined to be 43 inches. The minimum and maximum annual precipitation values have been 28 and 79 inches, respectively, in the study area. (Coal and Steers, 1978; Swafford and Reasoner, 1979; Reasoner, 1974; Maxwell and Reasoner, 1966).

In winter the average temperature is 44 degrees and in summer the average temperature is 81 degrees. The prevailing direction of the wind is from the south. Snowfall is infrequent and averages about 3.0 inches per year across the area. Average wind speed is highest, 12 to 14 miles per hour, in March and April (Coal and Steers, 1978; Swafford and Reasoner, 1979; Reasoner, 1974; Maxwell and Reasoner, 1966).

Regional Geology

The area of study lies within the dissected Coastal Plain Province of Oklahoma, a portion of the Gulf Coast Plain. The regional structure of the Coastal Plain Province is homoclinal, with a general east-southeast strike and a gentle southward dip. Rates of dip were estimated to range from 50 to 125 feet per mile. Generally, progressively younger formations outcrop from north to south (Huffman et al, 1975).

Formations outcropping at the surface range from the early Cretaceous (Goodland Limestone) to late Cretaceous (Woodbine and Eagle Ford Formations). These are overlain in places by extensive deposits of terrace and alluvium of Pleistocene and Recent age (See Table 1). The lower Cretaceous formations are divided into the Fredericksburg and Washita Groups. The Fredericksburg Group is represented by the Goodland Limestone, Walnut Clay and the Kiamichi Formation. The Washita Group is represented by the Caddo Formation, Bokchito Formation, Bennington Limestone and the Grayson Marlstone. All of which, according to Hart (1974), yield only limited amounts of water of poor quality.

TABLE 1. QUATERNARY AND CRETACEOUS-AGED STRATA IN THE STUDY AREA.

SYSTEM	SERIES	GROUP	FORMATION	MEMBER
Quaternary	Holocene			Alluvium
	Pleistocene			Terrace
Cretaceous	Gulfian		Eagle Ford Formation	
			Woodbine Formation	Templeton Member
				Lewisville Member
				Red Branch Member
				Dexter Member
	Comanchean	Washita Group	Grayson Formation	
				Bennington Limestone
			Bokchito Formation	Pawpaw Sandstone
				McNutt Limestone
				Weno Clay
				Soper Limestone
				Denton Clay
				Caddo Limestone
		Fredricksburg Group	Kiamichi Formation	
				Goodland Limestone

Taken from Huffman et al, 1978 and Huffman et al, 1975

Unconformably overlying the Grayson Marl and Bennington Limestone is the Woodbine Formation (Upper Cretaceous). The Woodbine Formation consists of brown to tan, fine to coarse-grained, conglomeratic, ferruginous, moderately to weakly indurated, crossbedded sandstone with interbedded gray shale and lignite and has a total thickness of about 400 feet. The Woodbine is subdivided into four units: Dexter Member (indurated sandstone, shale and lignite); Red Branch Member (indurated sandstone, shale, coal and siltstone); Lewisville Member (shale and indurated sandstone); and the Templeton

Member (blue-gray to black fissile shale and sandstone). The Woodbine Formation produces small amounts of poor to good quality water (Hart, 1974). Overlying the Woodbine Formation is the Eagle Ford Formation which consists of blue-gray to yellow, platy, calcareous siltstone, silty limestone and silty shale. The Eagle Ford Formation yields only limited amounts of poor quality water (Hart, 1974).

The Cretaceous deposits in the study area consist of approximately 60 percent shale, 20 percent sandstone and 20 percent limestone and other types (Huffman et al, 1975 and Huffman et al, 1978). Shale units typically are 50-100 feet thick and limestone and sandstone units range from 1-50 feet thick, with the exception of the Dexter Sandstone in the Woodbine Formation which can reach 90 feet in thickness.

Unconformably overlying the Eagle Ford Formation are the Quaternary alluvium and terrace deposits. These deposits are discontinuous layers of gravel, sand, silt and clay along the tributaries of the Red River. They vary in thickness from 5 to 100 feet, but generally are less than 30 feet (Davis, 1960). Because of the predominantly shale bedrock in most of the area, the alluvium and terrace deposits are probably too silty and clayey to yield large quantities of water.

GROUNDWATER RESOURCES

Woodbine, Marietta, and Texoma Minor Groundwater Basins

The minor bedrock basins of the five-county area comprise a total of approximately 1,550,000 acres of Cretaceous and Quaternary deposits that occur as shale, sandstone, siltstone, coal, marl, limestone, clay and sand units. Because the deposits are not contiguous, the basins have been separated into three distinct areas. The boundaries for the three basins are shown in Figure 1.

The Cretaceous formations conformably overly the Antlers Formation from eastern McCurtain County in southeastern Oklahoma to Love County in south-central Oklahoma (Huffman et al, 1978). The deposits dip south-southeasterly and are tilted at the surface exposing bedding plane openings between the layers of sandstone, shale and limestone (Hart, Jr. 1974). Recharge entering the basin is derived mainly from precipitation falling on the outcrop. Recharge also occurs from discharge from the underlying Antlers Formation. Most discharge is by evaporation, although some water is discharged to streams during periods of high water levels. A small quantity of water is discharged by pumping domestic and municipal water wells (Davis, 1960).

Groundwater in the upper portions of the aquifer is generally unconfined, whereas water in the deeper portions of the aquifer can be confined. In shallow unconfined portions of the aquifer, the slope of the potentiometric surface coincides with the slope of the land so the local direction of water movement is toward the streams and valleys (Davis, 1960).

Aquifer Parameters

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be represented in terms of storage coefficient and transmissivity. For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. For these basins, specific yield is estimated to be 0.05. This number represents an approximate mean of the range of values given by Driscoll (1986) for the type of formations which comprise the three basins. Typical deposits in the basins consist of a sequence of shale, sandstone, siltstone and limestone units. Water is derived in small quantities from thin sandstone units and from cracks and solution openings in limestone units. The water table is close to the surface during wet periods, but can rapidly decline during dry periods. The formations have relatively very little primary porosity and their ability to store and transmit water is limited (Davis, 1960).

Figure 5 is a structure contour map derived from Hart and Davis (1981) showing the base of the three basins. This figure indicates that the base dips toward the south in the Woodbine basin and toward the southeast in the Marietta and Texoma basins. OWRB Multi-Purpose Completion Reports, which provide lithologies and depths to water in wells, indicate that groundwater in the Woodbine basin is generally encountered within 100 feet of land surface. Average formation thickness is estimated to be 350 feet and the average saturated thickness is estimated at approximately 250 feet. In the Marietta and Texoma basins, average formation thickness is estimated to be 150 feet, depth to water is estimated at 50 feet, and the average saturated thickness is estimated at 100 feet.

Hydraulic conductivity (K) is estimated for the three basins based on the mean K derived from hydrogeologic texts which provide ranges of possible K values for different consolidated aquifers (Heath, 1983). Formations which consist primarily of shale, sandstone and limestone are reported to have K values ranging from 10×10^{-1} ft/day to 10×10^{-3} ft/day. For this study, an average K value of 0.5 ft/day was estimated for the basins. Transmissivity, a product of the saturated thickness and K, is estimated to be 125 ft^2/day for the Woodbine basin and 50 ft^2/day for the Marietta and Texoma basins.

Recharge can occur where slopes are gentle, soils are thick and the bedrock is permeable. The amount of annual recharge is estimated to be 2.15, 1.6 and 1.8 inches per year for the Woodbine, Marietta and Texoma basins, respectively, which is 5 percent of the average annual precipitation for each basin (Marcher and Bergman, 1983).

Aquifer Storage and Yield Capabilities

Initial storage for the Woodbine, Marietta and Texoma basins is estimated at approximately 17,900,000, 500,650 and 81,000 acre-feet of groundwater, respectively for the three basins. These values are obtained by multiplying the area of the basins by the specific yield and the estimated saturated thickness of the basins.

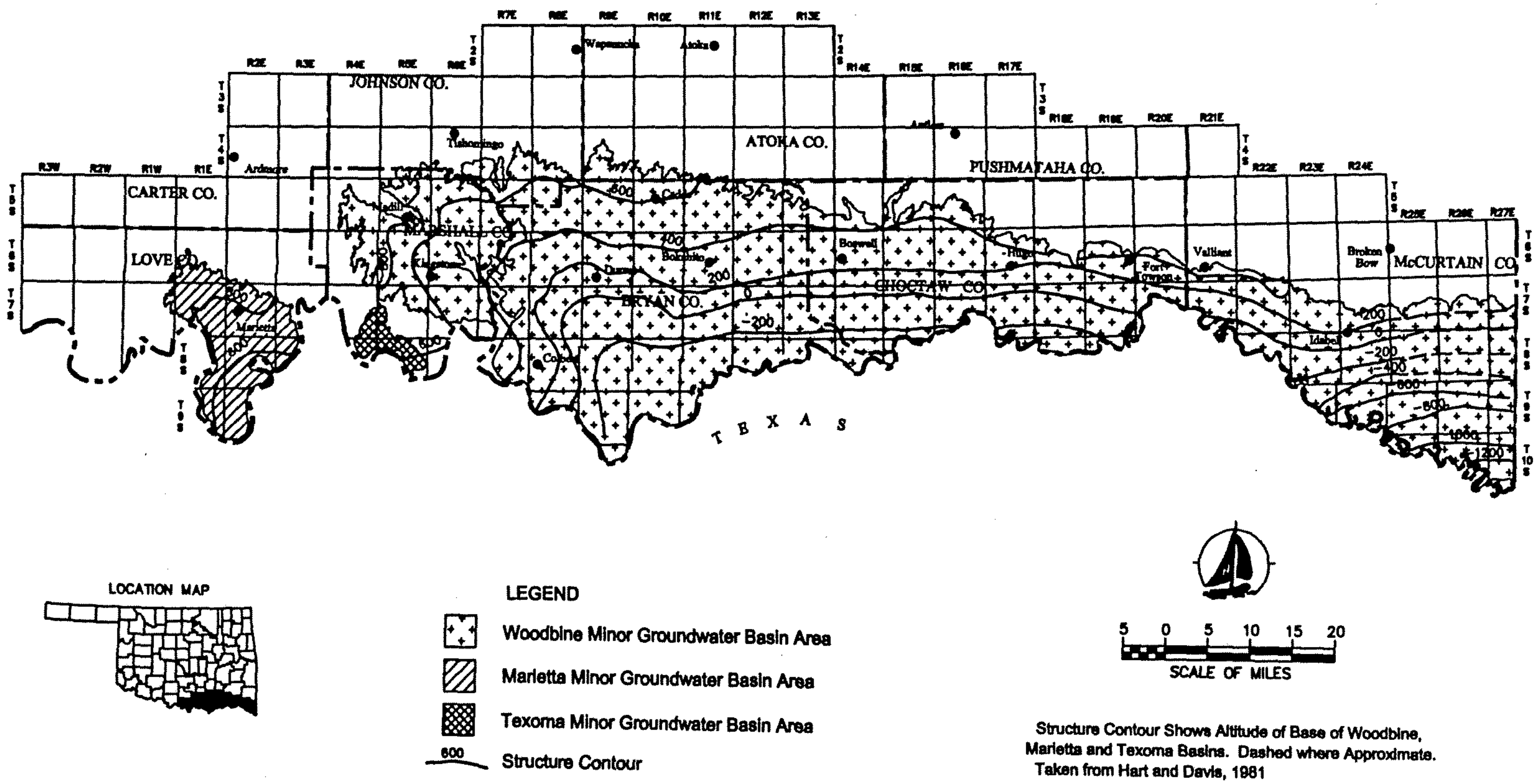


Figure 5. Structure Contour Map Showing Base of Woodbine, Marietta and Texoma Groundwater Basins

Groundwater availability ranges from limited to readily available. The mean well yield for all three basins, as determined from OWRB well records, is approximately 14 gallons per minute. Locally, yields of 40 to 60 gallons per minute have been obtained from wells penetrating thicker sandstone units (OWRB, 1997A). Table 2 summarizes the aquifer parameters and aquifer storage for the basins.

Table 2. Summary of Aquifer and Storage Parameters for the WMGB, MMGB & TMGB.

Basin	Area (acres)	Specific Yield	Saturated Thickness (ft)	K (ft/day)	T (ft^2/day)	Recharge (in/yr)	Storage (acre-ft)
WMGB	1,432,416	0.05	250	0.5	125	2.15	17,900,000
MMGB	100,130	0.05	100	0.5	50	1.8	500,650
TMGB	16,200	0.05	100	0.5	50	1.9	81,000

K - Hydraulic Conductivity T - Transmissivity

Water Use

Groundwater use in the study area appears to be limited primarily to household and stock water use and use by two community systems. In some parts of the study area, adequate supplies of suitable groundwater are not available and water districts have been established to meet the domestic, commercial and industrial needs of rural areas. Farm ponds have also been constructed to provide water for livestock.

OWRB records indicate that two permits for a total amount of 1,134 acre-feet of groundwater per year have been issued within the WMGB. Records also show that 537.6 acre feet of water use was reported by permit holders within the WMGB in 1996. No permits have been issued within MMGB or TMGB. Table 3 summarizes the permit and water use data for the basins.

Table 3. Permit and Water Use Information within the WMGB, MMGB and TMGB basins for 1997.

Basin	No. of Permits	Permitted Amount	Reported Use
WMGB	2	1,134.0 ac-ft	537.6 ac-ft
MMGB	0	0.0 ac-ft	0.0 ac-ft
TMGB	0	0.0 ac-ft	0.0 ac-ft
Total	2	1,134.0 ac-ft	537.6 ac-ft

Compiled from unpublished OWRB data

Prior Groundwater Rights

No prior rights were established by the Board within these basins.

Haworth Isolated Terrace Groundwater Basins

The HITGBs comprise approximately 15,900 acres of Quaternary terrace deposits that overlie the Cretaceous-aged Woodbine Formation in the southeastern corner of McCurtain County. The deposits were formed by deposition of sediment from the Red River and presently are isolated just north of the current Red River alluvial and terrace deposits (Marcher and Bergman, 1983). The deposits themselves are separated into two segments and have been designated as the HITGB 1 and HITGB 2 (See figure 3).

The basins typically consist of variable proportions of sand, clay and silt with fine-grained sand near the surface and medium-grained sand at depth (OWRB, 1997A). Marcher and Bingham (1971) reported that the terrace deposits in the area can average 20 to 30 feet in thickness. OWRB well records indicate an average total sand thickness of 25 feet.

Aquifer Parameters

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be described in terms of storage coefficient and transmissivity (T). For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. Specific yield for the HITGBs is estimated at 0.15 which is comparable to other alluvial and terrace basins in Oklahoma. The average saturated thickness, as determined from well records, is 17 feet.

The deposits consist of variable proportions of sand, silt and clay with fine-grained sand near the surface and medium-grained sand at the base. Mean K values for the medium-grained sand interval and the sand, clay and silt interval are approximated at 500 ft/day and 1 ft/day, respectively (Heath (1983). To account for a majority of the saturated interval being fine-to-medium-grained sand, a weighted K value of 50 ft/day was estimated. Transmissivity, a product of the mean saturated thickness and K, is estimated to be 850 ft^2/day for both the HITGB 1 and HITGB 2.

The amount of annual recharge to the basin is estimated to be 10 percent of the average annual precipitation, or approximately 4.8 inches per year. This percentage of recharge was selected by comparison of previous alluvial and terrace deposit studies.

Aquifer Storage and Yield Capabilities

Determination of the initial storage of a groundwater basin is calculated by multiplying the area of the basin by the specific yield and saturated thickness. Initial storage calculations for the HITGB 1 and HITGB 2 are 22,900 acre-feet and 17,550 acre-feet, respectively.

Average well yield in the HITGB is estimated at 25 gallons per minute (OWRB, 1997A). Wells can yield as much as 100 gallons per minute in localized areas where thicker deposits occur (Marcher and Bingham, 1971). Table 4 summarizes the aquifer parameters and storage parameters for the HITGBs.

Table 4. Summary of Aquifer Parameters and Storage for the HITGBs.

Basin	Area (acres)	Specific Yield	Saturated Thickness (ft)	K (ft/day)	T (ft^2/day)	Mean Well Yield (gpm)	Storage (ac-ft)
HITGB 1	8,979	0.15	17	50	850	25	22,900
HITGB 2	6,885	0.15	17	50	850	25	17,550

K - Hydraulic Conductivity T - Transmissivity

Water Use

Groundwater use in the study area of the HITGBs currently appears to be primarily limited to household and stock water use. The Town of Haworth has a prior right permit for 322 acre feet and reported a usage of 70.0 acre feet in 1996. The Town currently uses the well only as a backup source of water. No regular or temporary groundwater permits have been issued by the Board in either of the basins.

Prior Groundwater Rights

Groundwater rights established within this basin prior to July 1, 1973, and recognized by Board Order, total 322 acre-feet per year. This total amount represents the prior right for the Town of Haworth.

Little River Groundwater Basin

The Little River Groundwater Basin comprises approximately 87,680 acres of Quaternary alluvial and terrace deposits that primarily overlie the Cretaceous-aged Antlers Formation in McCurtain County. The deposits were formed by deposition of sediment from the Little River and contain terrace deposits upland from the river and alluvial deposits adjacent to the river (Marcher and Bergman, 1983). Together the deposits have been designated as the LRGB (See Figure 3).

The basin typically consists of variable proportions of gravel, sand, clay and silt with fine-grained and medium-grained sand in the upper portions and some gravel at depth (OWRB, 1997A). Marcher and Bingham (1971) reported that the Little River alluvial deposits can reach a thickness of 50 feet and the terrace deposits can average 20 to 30 feet in thickness. OWRB well records indicate an average formation thickness of 40 feet and an average total sand thickness of 15 feet.

Aquifer Parameters

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be described in terms of storage coefficient and transmissivity (T). For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. Specific yield for the LRGB is estimated at 0.15 which is comparable to other alluvial and terrace basins in Oklahoma. The average saturated thickness as determined from well records is 15 feet. The deposits consist of variable proportions of sand, silt and clay with fine and medium-grained sand near the surface and gravel, if present, near the base. Approximate mean K values for the medium-grained sand interval and for the sand, clay, and silt interval range from 500 ft/day and 1 ft/day, respectively (Heath, 1983).

Another method to calculate K and T is available if well acceptance tests (short duration pump tests) have been conducted. As a means to compare the estimated T and K values derived from the grain size analysis, data from two wells with well acceptance tests were input into the OWRB's TOT computer program, which calculates K and T (OWRB, 1992). K values ranged from 30 to 50 ft/day with an average of 40 ft/day. T values derived from this method ranged from 330 to 500 ft^2/day. To account for a majority of the saturated interval being fine to medium-grained sand and from the results of the well acceptance tests, a weighted K value of 40 ft/day was estimated for the basin. Transmissivity, a product of the mean saturated thickness (15 ft) and K (40 ft/day), is estimated to be 600 ft^2/day.

The amount of annual recharge to the basin is estimated to be 10 percent of the average annual precipitation or approximately 4.8 inches per year. This percentage of recharge was selected by comparison of previous alluvial and terrace deposit studies.

Aquifer Storage and Yield Capabilities

Determination of the initial storage of a groundwater basin is calculated by multiplying the area of the basin by the specific yield and saturated thickness. Initial storage calculation for the LRGB is 197,300 acre-feet.

Average well yield in the LRGB is estimated at 15 gallons per minute (OWRB, 1997A). Wells can yield as much as 100 gallons per minute in localized areas where thicker deposits occur (Marcher and Bingham, 1971). Table 5 summarizes the aquifer parameters and storage parameters for the LRGB.

Table 5. Summary of Aquifer Parameters and Storage for the LRGB.

Basin	Area (acres)	Specific Yield	Saturated Thickness (ft)	K (ft/day)	T (ft^2/day)	Mean Well Yield (gpm)	Storage (ac-ft)
LRGB	87,680	0.15	15	40	600	15	197,300

K - Hydraulic Conductivity T - Transmissivity

Water Use

Groundwater use in the study area of the LRGB currently appears to be primarily limited to household and stock water. No regular or temporary groundwater permits have been issued by the Board in the basin.

Prior Groundwater Rights

No prior groundwater rights have been established or recognized by the Board within this basin.

GROUNDWATER QUALITY

Woodbine, Marietta and Texoma Minor Groundwater Basins

The area of study is underlain by Cretaceous shale, siltstone, limestone and sandstone units above the Antlers Formation. The chemical quality differs considerably from location to location, depending on well depth and the geologic formation encountered. Consequently, in local areas, the concentration of some constituents may exceed the EPA recommended limits for drinking water (Marcher and Bergman, 1983).

Typically, the groundwater is a sodium-potassium bicarbonate type, although many variations in water type occur. Concentrations of total dissolved solids range from 76 to 1,900 milligrams per liter (mg/l) and hardness generally ranges from hard to very hard. Table 6 is a summary of selected physical and chemical properties of groundwater sampled from wells within the Cretaceous-age formations. The table shows the minimum, median and maximum concentrations for the selected parameters.

Table 6. Summary of Chemical Analyses of Water from Wells Completed in Undifferentiated Cretaceous-age Formations.

Parameter (mg/l)	Maximum	Median	Minimum	No. of Samples
Hardness	686	124	5	17
Sulfate	778	35	2.9	16
Chloride	845	40	4	17
Nitrate	56	1.0	0.0	17
Total Dissolved Solids	1,900	448	76	17

* Results from McAlester and Texarkana Quadrangles (Marcher and Bergman, 1983)

The water quality within the Cretaceous bedrock basins is probably suitable for most beneficial uses except in localized areas. The major natural sources of pollution in the area that might impact some portions of the basin include hardness, chlorides and total dissolved solids. However, with proper well completion techniques (sealing out lower quality water zones), water treatment techniques and water quality sampling and analysis, negative health effects can be mitigated.

Haworth Isolated Terrace Groundwater Basins

Groundwater quality information regarding the HITGBs is somewhat limited. Marcher and Bergman (1983) reported analytical data from one well completed in the HITGB 1 and the Town of Haworth provided data from a water supply well completed in the HITGB 2. Marcher and Bergman reported that groundwater from terrace deposits is typically a calcium-magnesium bicarbonate type. Analytical results of hardness indicate the groundwater in the HITGBs would be classified as hard, according to Driscoll (1987). Total dissolved solids are low to moderate and well below EPA's maximum contaminant level of 500 mg/l. Sulfate and chloride levels are also low to moderate. Table 7 shows the combined chemical characteristics of groundwater from both wells.

Table 7. Selected Chemical Characteristics of Water from Terrace Deposits in The HITGBs.

Parameter	Value	Units
Total Dissolved Solids+	98	mg/l
Hardness*	143	mg/l as CaCO3
Sodium+	46	mg/l
Chloride+	44	mg/l
Sulfate+	24	mg/l
Phosphate*	0.09	mg/l as PO4
Iron*	ND	mg/l
Nitrite-Nitrate* (range)	0.0 - 2.66	mg/l as N
Manganese*	0.06	mg/l

* Town of Haworth Laboratory Analyses from 1995 and 1996 (Brown, 1998)
+ Marcher and Bergman, 1983
ND - Non Detectable
mg/l - milligrams per liter

The water quality of the HITGBs appears to be suitable for most beneficial uses except possibly in localized areas. The major natural sources of pollution in the area that might impact some portions of the basin include hardness and possibly total dissolved solids. However, with proper well completion techniques (sealing out lower quality water zones), water treatment techniques and water quality sampling and analysis, negative health effects can be mitigated.

Little River Groundwater Basin

Groundwater quality information regarding the LRGB is very limited. Analytical data were obtained from the Choctaw Nation of Oklahoma, Environmental Health Service for two wells completed in the basin. Average analytical results from both wells indicate that the groundwater exceeds recommended maximum contaminant levels for pH, turbidity and iron. Total dissolved solids and nitrate levels are low and well below EPA's maximum contaminant levels of 500 mg/l and 10 mg/l, respectively. Sulfate and chloride levels are also low. Table 8 shows the combined chemical characteristics of groundwater from the wells.

Table 8. Selected Chemical Characteristics of Water from Little River Alluvial and Terrace Deposits.

Parameter (mg/l)	Maximum	Median	Minimum	No. of Samples
*Total Hardness	28	19	10	2
Fluoride	0.64	0.35	0.05	2
*P-Alkalinity	0.0	0.0	0.0	2
*Total Alkalinity	5	3.75	2	2
Sulfate	10	5.16	2	2
Turbidity (NTU)	54	54	54	1
Turbidity (JTU)	15	15	15	1
Manganese	0.06	0.06	0.06	1
Chloride	33	19.5	6	2
Nitrate as N	0.5	0.5	0.5	2
pH	6.2	5.73	5.26	2
Iron	7.6	3.8	0.05	2
Total Dissolved Solids	36.2	34.1	32	2

(Analytical Results from Choctaw Nation of Oklahoma, Environmental Health, 1998) * as CaCO3

The water quality of the LRGB appears to be suitable for most beneficial uses except possibly in localized areas. The major natural sources of pollution in the area that might impact some portions of the basin include turbidity, pH and iron. However, with proper well completion techniques (sealing out zones of lower quality water), water treatment techniques and water quality sampling and analysis, negative health effects can be mitigated.

SUMMARY

The following data on the Woodbine Minor Groundwater Basin, Marietta Minor Groundwater Basin, Texoma Minor Groundwater Basin, Haworth Isolated Terrace Groundwater Basins and Little River Groundwater Basin were derived in order to determine the Maximum Annual Yield and Equal Proportionate Share of the basins:

Woodbine Minor Groundwater Basin

1. The total land area overlying the basin is 1,432,400 acres;
2. The amount of water in storage in the basin on July 1, 1997 was determined to be 17,900,000 acre-feet;
3. The average rate of recharge is estimated at 2.15 inches per year or 5 percent of the average annual precipitation (43 inches) and totals approximately 5,132,800 acre-feet. The total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 125 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment and water quality testing and analysis.

Marietta Minor Groundwater Basin

1. The total land area overlying the basin is 100,130 acres;
2. The amount of water in storage in the basin on July 1, 1997 was determined to be 500,650 acre-feet;
3. The average rate of recharge is estimated to be 1.8 inches per year or 5 percent of the average annual precipitation (36 inches) and totals approximately 300,400 acre-feet. The total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 50 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment and water quality testing and analysis.

Texoma Minor Groundwater Basin

1. The total land area overlying the basin is 16,200 acres;
2. The amount of water in storage in the basin on July 1, 1997 was determined to be 81,000 acre-feet;
3. The average rate of recharge is estimated at 1.9 inches per year or 5 percent of the average annual precipitation (38 inches), and totals approximately 51,300 acre-feet. The total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 50 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment and water quality testing and analysis.

Haworth Isolated Terrace Minor Groundwater Basin 1

1. The total land area overlying the basin is 8,979 acres;
2. The amount of water in storage in the basin on July 1, 1997 was approximately 22,900 acre-feet;
3. The estimated rate of recharge is 4.8 inches per year or 10 percent of the average annual precipitation (48 inches) and totals approximately 71,800 acre-feet. The total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 850 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment and water quality testing and analysis;

Haworth Isolated Terrace Minor Groundwater Basin 2

1. The total land area overlying the basin is 6,885 acres;
2. The amount of water in storage in the basin on July 1, 1997 was approximately 17,550 acre-feet;
3. The estimated rate of recharge is 4.8 inches per year or 10 percent of the average annual precipitation (48 inches) and totals approximately 55,000 acre-feet. The total discharge of the basin is 6440 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 850 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment and water quality testing and analysis;

Little River Groundwater Basin

1. The total land area overlying the basin is 87,680 acres;
2. The amount of water in storage in the basin on July 1, 1997 was approximately 197,300 acre-feet;
3. The estimated rate of recharge is 4.8 inches per year or 10 percent of the average annual precipitation (48 inches) and totals approximately 701,000 acre-feet. The total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 600 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as turbidity, pH and iron can be minimized by proper well construction, water treatment and water quality testing and analysis

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GLOSSARY

Alluvium

A general term for clay, silt, sand and gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or partially sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

Aquifer

A formation, group of formations or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Equal Proportionate Share

That portion of the maximum annual yield of water from a groundwater basin which shall be allocated to each acre of land overlying such basin. The percentage of the maximum annual yield is equal to the percentage of the land overlying the fresh groundwater basin which is owned or leased by an applicant for a regular permit.

Fresh Water

Water which has less than five thousand (5,000) parts per million total dissolved solids. All other water is salt water.

Groundwater

Fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut beds or banks of any definite stream.

Groundwater Basin

A distinct underground body of water overlain by contiguous land having substantially the same geological and hydrological characteristics and yield capabilities. The areal boundaries of a basin can be determined by political boundaries, geological, hydrological or other reasonable physical boundaries.

Hydraulic Conductivity

The volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Life of a Groundwater Basin

That period of time during which pumping of the maximum annual yield for a minimum twenty-year life of such basin will result in a final basin storage which approaches zero. Fifteen feet of saturated thickness is maintained in bedrock aquifers to provide for domestic use.

Major Groundwater Basin

A distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which groundwater wells yield at least fifty gallons per minute on the average basinwide if from a bedrock aquifer and at least one hundred fifty gallons per minute on the average basinwide if from an alluvium and terrace aquifer, or as otherwise designated by the Oklahoma Water Resources Board.

Maximum Annual Yield

A determination by the Board of the total amount of fresh groundwater that can be produced from each basin allowing a minimum twenty-year life of such basin.

Minor Groundwater Basin

A distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which groundwater wells yield less than fifty gallons per minute on the average basinwide if from a bedrock aquifer and less than one hundred fifty gallons per minute on the average basinwide if from an alluvium and terrace aquifer, or as otherwise designated by the Oklahoma Water Resources Board.

Natural Recharge

All flow of water into a groundwater basin by natural processes including percolation from irrigation.

Permeability

The property of a porous medium to transmit fluids under a hydraulic gradient.

Porosity

The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium.

Prior Groundwater Right

The right to use groundwater established by compliance with the laws in effect prior to July 1, 1973, the effective date of the Oklahoma Groundwater Act.

Specific Yield

The ratio of the volume of water which the porous medium, after being saturated, will yield by gravity to the volume of the porous medium.

Storage Coefficient

The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (virtually equal to the specific yield in an unconfined aquifer).

Terrace Deposits

Deposits of older alluvium which occupy positions topographically higher than recent alluvium and mark the former position of a stream.

Total Discharge from the Basin

Shall include but may not be limited to the amount of fresh groundwater withdrawn and placed to beneficial use prior to July 1, 1973, which amount shall be determined from the applicable final orders of the Board determining prior groundwater rights.

Transmissivity

The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.