HYDROLOGIC REPORT OF THE SOUTHWESTERN OKLAHOMA GROUNDWATER BASIN IN CADDO, KIOWA AND JACKSON COUNTIES

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By

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INTRODUCTION

The hydrogeologic report of the minor alluvial and bedrock groundwater basins in Caddo, Kiowa, and Jackson Counties was conducted by the Oklahoma Water Resources Board (Board) under the authority of Oklahoma Statute 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 determining the maximum annual yield and equal proportionate share of the minor groundwater basin within the study area.

BACKGROUND

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 basin- wide if from a bedrock basin, and 150 gallons per minute if from an alluvial and terrace basin.

One minor Permian bedrock groundwater basin was identified within the study area. The minor bedrock groundwater basin, named the Southwestern Oklahoma Groundwater Basin (SOGB), underlies portions of Caddo and Jackson Counties and all of Kiowa County. Figure 1 shows the boundaries of the SOGB in the study area super-imposed on the public land survey system in Caddo, Kiowa and Jackson Counties. The alluvium adjacent to the smaller streams in the study area is believed to be too thinly saturated to support long-term non-domestic uses. However, locally it may be an important source of groundwater. For the purposes of this report, these minor alluvial resources are considered to be in hydraulic communication with the underlying minor Permian

bedrock basin (SOGB) and will be considered as part of that basin.

PHYSICAL SETTING

Location

This report is limited to the minor groundwater basin underlying all or portions of Caddo, Kiowa and Jackson Counties. The three counties contain approximately 1,969,280 acres or 3,077 square miles. Figure 2 shows the limits of the study area. This figure depicts the area's surface drainage features, primary roadways and principal incorporated towns and cities. The SOGB underlies approximately 1,593 square miles or 1,019,834 acres of the study area (Fig. 1).

Spatial Distribution of the SOGB and Other Resources

The SOGB underlies only the far southwestern corner of Caddo County. Immediately adjacent and northeast of the SOGB are formations of the El Reno Group, a potential major groundwater basin. The Rush Springs Sandstone and Marlow Formation, which together comprise a major groundwater basin, underlie the remainder of the county. The El Reno Group in Caddo County and the Rush Springs-Marlow unit will be excluded from this report. However, the El Reno Group is included as part of the SOGB in Kiowa and Jackson Counties.

The SOGB underlies all of Kiowa County and the approximate east half of Jackson County. The western boundary of the SOGB in Jackson County is defined by the eastern boundary of the Blaine Gypsum Aquifer, a major groundwater basin excluded from this report. The Salt Fork of the Red River, which traverses north-south through the approximate center of Jackson County and its associated alluvium and terrace deposits, are considered to be a potential major groundwater basin and have been excluded from this report.

The Jackson and Kiowa County boundary is formed by the North Fork of the Red River. The alluvium and terrace deposits associated with the North Fork constitute a major groundwater basin and are excluded from this report.

Also excluded are the gabbros and granites that are exposed as isolated barren hills ranging in height from a few feet to more than a thousand feet above the surrounding plain (See Figure 1). These units are highly fractured and, although springs are common at the intersection of the joints, the total yield of water from these units is small.

Setting

The land encompassed within Caddo, Kiowa and Jackson Counties is in the Red Bed Plains Region of the southern great plains. With the exception of the Wichita Mountains, the terrain is a gently rolling plain underlain by weakly consolidated reddish clays, shales and sandstones and unconsolidated alluvium.

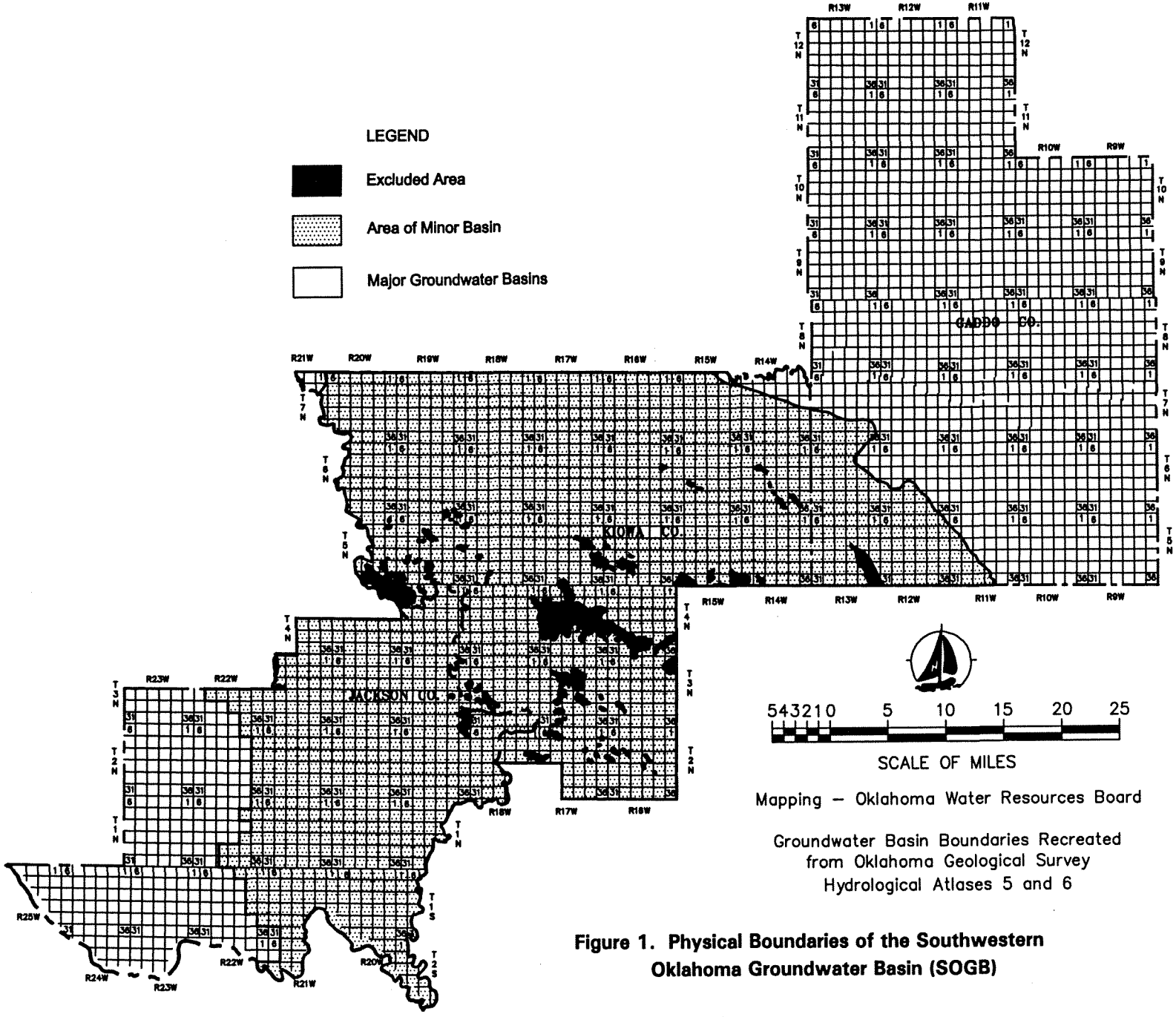

Figure 1. Physical Boundaries of the Southwestern Oklahoma Groundwater Basin (SOGB)

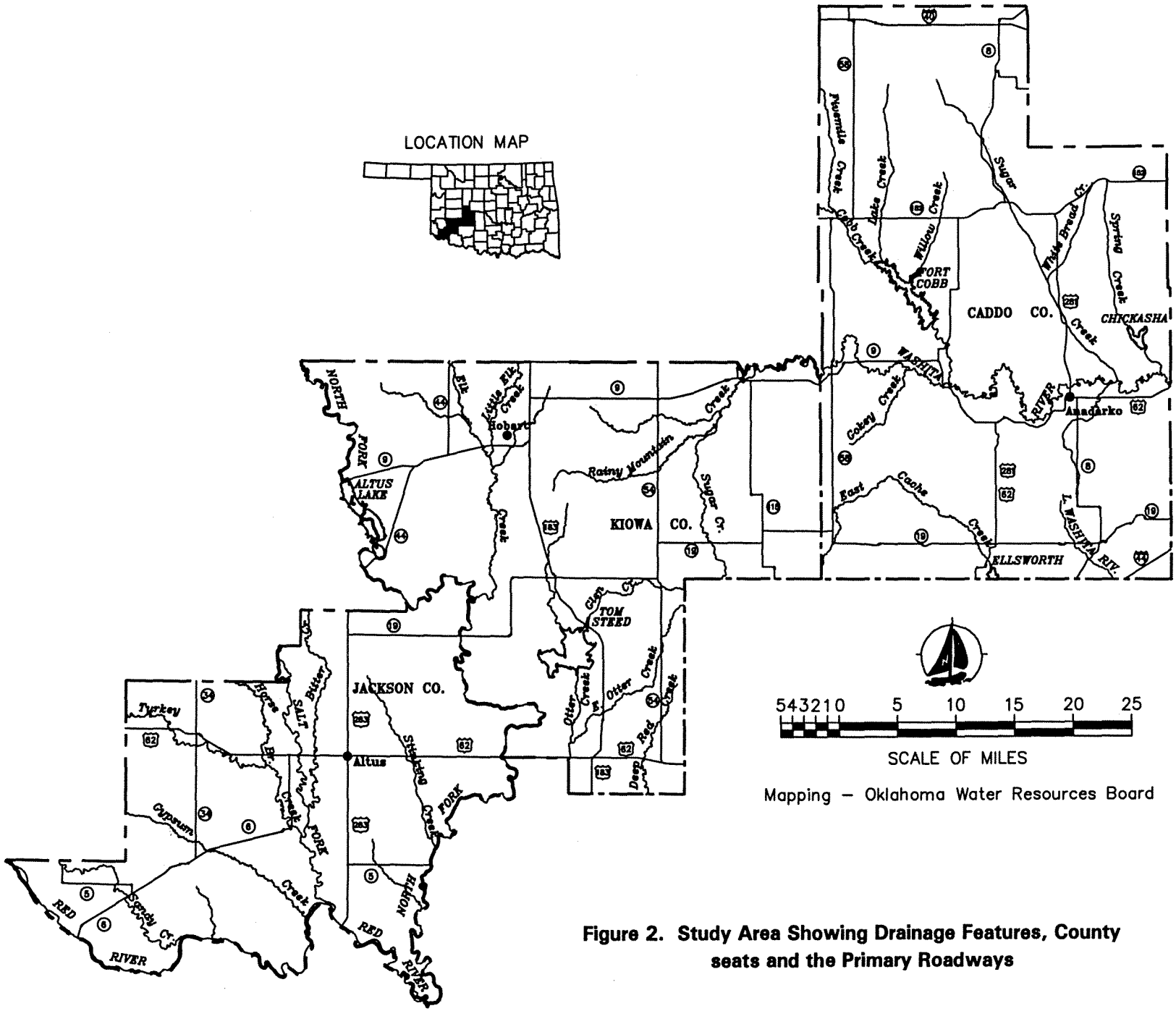

Figure 2. Study Area Showing Drainage Features, County seats and the Primary Roadways

The Wichita Mountains constitute a drainage divide between the Washita River drainage basin to the northeast and the North Fork of the Red River to the west and southwest. The North Fork of the Red River and its principal tributaries; Elk Creek, Glen Creek, West and East Otter Creeks, drain the western two-thirds of Kiowa County. Northeast Kiowa County is drained by Rainy Mountain and Sugar Creeks which flow northeast to the Washita River. The southwestern corner of Caddo County is drained by East Cache Creek. It flows northeastward out of the study area and eventually flows into Lake Ellsworth, which is a City of Lawton water supply lake. Jackson County is drained largely by the North Fork of the Red River, the Salt Fork of the Red River and its tributaries. With the exception of the area northeast of the Wichita Mountains, all surface water in the study area eventually winds up in the Red River. The highest elevation in the study area is in the Wichita Mountains, probably at Tepee Mountain in Kiowa County with an elevation of 2,259 feet above sea level. The lowest elevation is 1,190 feet above sea level at the confluence of the North Fork of the Red River and the Red River in far southeastern Jackson County.

Climate

The area has a warm, temperate, continental climate. The area receives the warmer, moisture-laden air from the Gulf of Mexico, which is regularly penetrated by the cooler, drier air moving down from the Arctic Zone or approaching from the Pacific. When these two air systems meet, significant changes in temperature, precipitation and wind velocity often occur. The definite seasonal characteristics of the climate generally vary in intensity from year to year, but changes between seasons are gradual. Winters are mostly moderate and sunny. Temperatures often are fairly low and some snow falls, but the cold periods generally only last 2 to 5 days before they are moderated by southerly winds. In spring and fall, the heaviest rains occur, and it benefits growing crops and pastures. Also, rains late in the spring and early summer generally are accompanied by the greatest number of severe local storms. Adequate moisture generally is received in spring for initial plant growth, but some replanting is needed occasionally. Summers generally are long and hot, and the driest month is August. Brisk southerly breezes and low humidity often ease the discomforting effect of the hot spells (Moffatt, 1973).

The average annual temperature at the Lake Altus Dam in Jackson County is 63 degrees F. Prevailing winds are from the southeast at 1 to 12 m.p.h. The average precipitation at the Altus Dam is 23.81 in/yr (Kent, 1980). The average annual rainfall in Caddo County varies from 27 inches in the northwest part of the county to 33 inches in the southeast (Moffatt, 1973). Both Jackson and Kiowa Counties average 25 inches of annual rainfall (Bailey and Graft, 1961, and Lamar, 1979). Since Kiowa and Jackson Counties comprise most of the study area and data are not available for southwestern Caddo County, 25 inches per year is determined to represent the average annual rainfall for the SOGB.

Regional Geology

The rocks exposed within the study area range in age from Pre-Cambrian to Quaternary. The oldest rocks found are the gabbros and granites associated with the Wichita Mountains which were apparently uplifted during the Pennsylvanian era. These rocks are exposed as isolated barren hills ranging in height from a few feet to more than a thousand feet above the surrounding plain. These units are highly fractured and, although springs are common at the intersection of the joints, the total yield of water from these units is small. They have been excluded from the study (See Figure 1).

Large-scale structural features that trend northwest-southeast through the study area include the Hollis basin in the southwest, the Wichita Mountain uplift in the central section, and the Anadarko basin in the northeast. The Permian rocks dip gently west or southwest in the western two-thirds of the area and northeast in the remaining part (Havens, 1977).

A heavily faulted area of Ordovician and Cambrian limestones and dolomites of the Arbuckle Group outcrop in the Slick Hills north of the mountains. The Permian age Post Oak Conglomerate was deposited by small ephemeral streams that eroded and drained the Wichita Mountains (Al-Shaieb et al, 1977). The Post Oak is principally comprised of limestone, granitic debris and sand. Within the study area this formation crops out north and west of the mountains. Away from the mountains this formation becomes finer grained and eventually grades into and becomes interfingered with the Hennessey Shale and Garber Sandstone.

Following the Wichita uplift and removal of overlying early and middle Paleozoic units by erosion, formations were laid down during the Permian era in a shallow sea which apparently advanced from the southwest. Following is a brief description of the Permian formations which were deposited within the study area. Table 1 shows the stratigraphic relationship among the Permian formations within the study area.

The Garber Sandstone is a reddish-brown, fine-grained sandstone and mudstone conglomerate (Havens, 1977). The Hennessey Formation is characterized by reddish-brown argillaceous shales and siltstones. This unit outcrops extensively over large portions of the study area. The Hennessey Formation does not yield significant amounts of water, although low to moderate yields can be obtained locally from isolated sandstone lenses. The Flowerpot Formation overlies the Hennessey Formation and consists of a sandstone and a shale unit. The shale unit consists predominately of a reddish-brown shale, siltstone, gypsum and dolomite with some large deposits of salt. The Duncan Sandstone consists of a very fine-grained, silty lenticular sandstone interbedded with thick reddish-brown shales. The Dog Creek Formation consists of salty, red-brown shales and some thin dolomites and gypsum. The Dog Creek Formation locally yields minor amounts of fair to poor quality water (Kent 1980).

Deposition of the Hennessey and Garber formations is believed to be contemporaneous with that of the Post Oak Conglomerate but of a different source, occurring primarily in a shallow sea environment (Pate, 1947).

TABLE 1.

QUATERNARY AND PERMIAN-AGED STRATA IN STUDY AREA

SYSTEM	GROUP	FORMATION
Quaternary		Alluvium and terrace deposits
Permian	Whitehorse	Whitehorse Sandstone Rush Springs Sandstone Marlow Sandstone
	El Reno	Dog Creek Shale Flowerpot Shale San Angelo/ Duncan Sandstone
	Hennessey	Hennessey Shale/Post Oak Conglomerate
	Sumner	Garber Sandstone Wellington Formation

GROUNDWATER RESOURCES

Southwestern Oklahoma Ground Water Basin (SOGB)

Approximately 1,593 square miles or 1,019,834 acres overlies the SOGB. The SOGB rock units are principally comprised of interbedded shale and sandstones. As previously stated, the SOGB incorporates the alluvium deposits adjacent to the smaller streams in the study area. It includes all of the formations listed in Table 1 except for the Whitehorse Group for the entire area and the El Reno Group in Caddo County.

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. For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. The specific yield was estimated to be 0.02, which represents an approximate mean of the range of values given for the type of rock formations that comprise the SOGB (Driscoll, 1986). The thickness of the SOGB is defined by a water quality parameter. Using the Oklahoma Corporation Commission's (1982) Base of Treatable Water Maps

(depth to treatable water contours based on 10,000 mg/l total dissolved solids) the average depth to treatable water in the three-county study area is approximately 124 feet. Ninety-one multipurpose completion reports (water well driller's logs) in the SOGB indicate an average depth to water of 16 feet. The average saturated thickness is determined to be approximately 108 feet which is the difference between the average total thickness and the average depth to water in the SOGB.

The driller's logs were also utilized to determine the predominant lithologic units of the SOGB. Generally, the drillers reported that the principal rock units in the SOGB were: 1) shale or clay; and 2) sandstone which varied from fine-to coarse-grained. An estimated 82 percent of the rock is comprised of clay and shale and approximately 18 percent is comprised of sandstone.

The hydraulic conductivity (K) of the saturated portion of the clay and shale interval (89 feet) is estimated to be 0.001 feet/day, which falls within a range of K values given by Heath (1983) for unfractured shales. Kent (1973) developed a methodology for estimating K from lithologic evidence by developing a classification system where he assigned K values based on median grain size. Utilizing the referenced methodology, K for the sandstone portion of the SOGB is determined to be 27 feet/day. An overall weighted K value for the basin was determined by multiplying the saturated thicknesses of the two primary lithologic units, shale/clay (89 feet) and sandstone (19 feet), by their respective K values of 0.001 and 27 feet/day. These results were then summed and subsequently divided by the total saturated thickness (108 feet) to derive a weighted K of 4.75 feet/day. Transmissivity, a product of the saturated thickness and hydraulic conductivity, is 513 ft^2/-day.

Recharge to alluvium and terrace deposits in Tillman County was estimated by Barclay and Burton (1953) to be about 12 percent of the annual precipitation. Runkle and McLean (1995) estimated recharge to the Blaine aquifer to be 1.5 in/year, or 6 percent of the normal annual precipitation of 24 inches. Because most of the study area lies between these two areas, an average of these two figures was applied to the SOGB. Therefore, recharge to the SOGB in the study area is estimated to be 2.25 inches per year, or approximately 9 percent of the mean annual rainfall of 25 inches per year.

A summary of the aquifer parameters determined for the SOGB is provided in Table 2.

TABLE 2. AQUIFER PARAMETERS

Area of Basin (Acres)	Saturated Thickness (Feet)	Specific Yield	Transmissivity Ft^2/Day	Recharge Rate Inches/Year
1,019,834	108	0.02	513	2.25

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 the saturated thickness. Initial storage is estimated at 2,203,000 acre-feet. The average well yield for the SOGB on OWRB driller's logs was approximately 25 gallons per minute (gpm.). A few wells reportedly yield in excess of 100 gpm and one well driller's log reported a yield of 250 gpm.

Water Use

The SOGB is not heavily relied upon to supply agricultural crop water. The Board has issued 25 irrigation permits, 4 industrial permits and 1 public water supply permit. Groundwater from the SOGB is an important source of water for domestic and stock water use for individuals and farms in the outlying areas not served by rural water districts.

Reported water use for 1996 by permit holders within the SOGB totaled 43 acre-feet (OWRB, 1996). Groundwater withdrawals were reported for irrigation, industrial and public water supply. (See Table 3).

TABLE 3.

PERMIT AND WATER USE INFORMATION FOR THE SOGB FOR 1996

Purpose	Number of Permits	Permitted Amount	Reported Use
Irrigation	25*	1676 acre-feet	30 acre-feet
Industrial	4*	949 acre-feet	13 acre-feet
Public water supply	1*	51 acre-feet	no use reported
Totals	30*	2676 acre-feet	43 acre-feet

* - Includes Prior Rights

Prior Groundwater Rights

Groundwater rights established within the SOGB prior to July 1, 1973 and recognized by Board Order total 1897 acre-feet. In 1996, water use of prior rights was 30 acre-feet (OWRB, 1996).

GROUNDWATER QUALITY

The groundwater quality data available for the study are limited and not current. Groundwater usually becomes more mineralized with depth, and for practicable purposes (note discussion on base of treatable water), may become unusable. Also the costs to treat may be too great at depths exceeding 124 feet, on the average, in the SOGB. As previously noted in the geology section, common mineralogic constituents of the formations comprising the SOGB are gypsum, dolomite, and in some cases salt deposits. These constituents, when dissolved by percolating groundwater from the rock, give rise to elevated levels of sulfate, calcium, magnesium and chloride which are directly attributable to higher dissolved solids concentrations. Based on the available groundwater quality data (Havens, 1977), over 50 percent of the samples for wells in the SOGB exceed EPA's secondary drinking water standards for concentrations of sulfate, chloride and dissolved solids. Havens also reported that the median value for nitrates in groundwater in the Permian rocks within the Lawton Quadrangle is 10 mg/l, which is the recommended threshold for drinking water for this constituent. Filtration, water treatment, proper well construction and location can aid in limiting the impacts of these naturally occurring substances. Table 4 summarizes the general chemistry of the SOGB utilizing water samples from 37 wells completed in the SOGB or rock units of similar geologic and mineralogic composition.

TABLE 4. ANIONS AND CATIONS IN THE SOGB

Parameters	**Concentration in mg/l**	**EPA MCL's**
Hardness as Calcium Carbonate	520	N/A
Sulfate (SO4)	295	250
Chloride (Cl)	375	250
Nitrate (NO3) *	10	10
Dissolved solids	1,680	500

* Primary Standards (all others are secondary standards)

SUMMARY

The following data on the SOGB were derived in order to calculate and determine the Maximum Annual Yield and Equal Proportionate Share of the Basin:

1) The total land area overlying the basin is 1,019,834 acres;

2) The amount of water in storage in the basin is approximately 2,203,000 acre-feet;

3) The average rate of recharge is estimated to be 2.25 inches, or 9% of the average annual precipitation with 3,825,000 acre-feet of recharge over the life of the basin (minimum of 20 years). The total amount of groundwater established under prior rights is 1897 acre-feet with total discharge of 37,940 acre-feet over the life of the basin.

4) The transmissivity of the basin is estimated to be 513 ft^2/day.

5) The possibility of pollution of the basin from natural sources is negligible and occurrence can be limited by not drilling into deeper zones which may contain highly mineralized groundwater.

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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 that 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 geologic and hydrologic 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 geologic and hydrologic characteristics and from which groundwater wells yield at least 50 gallons per minute on the average basin-wide if from a bedrock aquifer, and at least 150 gallons per minute on the average basin-wide if from an alluvium and terrace aquifer, or as otherwise designated by the Oklahoma Water Resources Board (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 geologic and hydrologic characteristics and from which groundwater wells yield less than fifty gallons per minute on the average basin-wide if from a bedrock aquifer and less than one hundred fifty gallons per minute on the average basin-wide if from an alluvium and terrace aquifer, or as otherwise designated by the Oklahoma Water Resources Board (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.