HYDROLOGIC REPORT OF THE MINOR GROUNDWATER BASINS IN NOWATA AND ROGERS COUNTIES

Technical Report 96-4

by

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INTRODUCTION

The hydrologic report of the minor groundwater basins in Nowata and Rogers Counties was conducted by the Oklahoma Water Resources 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 basins. 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 is report will be to provide the hydrologic data necessary to determine or estimate the above mentioned criteria which will provide the basis for determining the maximum annual yield and equal proportionate share of the minor groundwater basins within the study area. The maximum annual yield determinations and equal proportionate share results are subject of an accompanying report.

This report will include a review, assessment, and evaluation of 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.

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 basinwide, if from a bedrock basin and less than 150 gallons per minute, if from an alluvial and terrace basin.

One minor bedrock and two minor alluvial and terrace groundwater basins were identified within the study area. The bedrock groundwater basin includes all Pennsylvanian aged rock units that have not been previously identified as a major or potential major

groundwater basin in Nowata and Rogers Counties. This minor bedrock basin, the Cherokee Group Groundwater Basin (CGGB), is named for the geologic formations that comprise the Cherokee Group.

The alluvial and terrace deposits associated with the Verdigris and Caney Rivers in the study area constitute two groundwater basins separated by Lake Oologah. One of the basins designated VRGB, Reach I, is comprised of alluvium and terrace deposits of the Verdigris River above Lake Oologah in Nowata County. The second basin, VRGB, Reach II, is comprised of alluvium and terrace deposits of the Verdigris and Caney Rivers below Lake Oologah in Rogers County. Figure 1 shows the boundaries of the respective groundwater basins superimposed upon the public land survey system in Nowata and Rogers County.

PHYSICAL SETTING

Location

This report is limited to the minor groundwater basins in Nowata and Rogers Counties in northeast Oklahoma. The two counties contain approximately 825,000 acres or 1,289 square miles (Figure 2).

The principal groundwater basin for this study in terms of surface area is the CGGB. It is comprised solely of Pennsylvanian aged rocks which underlie the entire study area. The alluvial deposits in the study area are associated with the Verdigris River, and its primary tributary, the Caney River, as well as other smaller feeder streams in the two counties. The Caney's confluence with the Verdigris River occurs approximately six miles below Lake Oologah in west-central Rogers County.

Both the Caney and Verdigris rivers enter Oklahoma from the State of Kansas. The Caney enters the state in Washington County and flows south-southeast through Washington and Tulsa Counties until its confluence with the Verdigris. The Verdigris enters the state in Nowata County with a southerly flow and deposits its waters into Oologah Lake in Nowata and Rogers Counties. The dam site exists near the center of Rogers County. Below the dam, the Verdigris flows south-southeast, picking up the Caney waters until it exits the study area to the south into Wagoner County.

A portion of one potential major groundwater basin exists in extreme northwest Nowata County. The Chanute Formation with the Noxie Sandstone located near its base has been classified in some reports as a potential major groundwater basin. Therefore, for the purposes of this report, it will be excluded from consideration as a minor bedrock basin (See Figure 1).

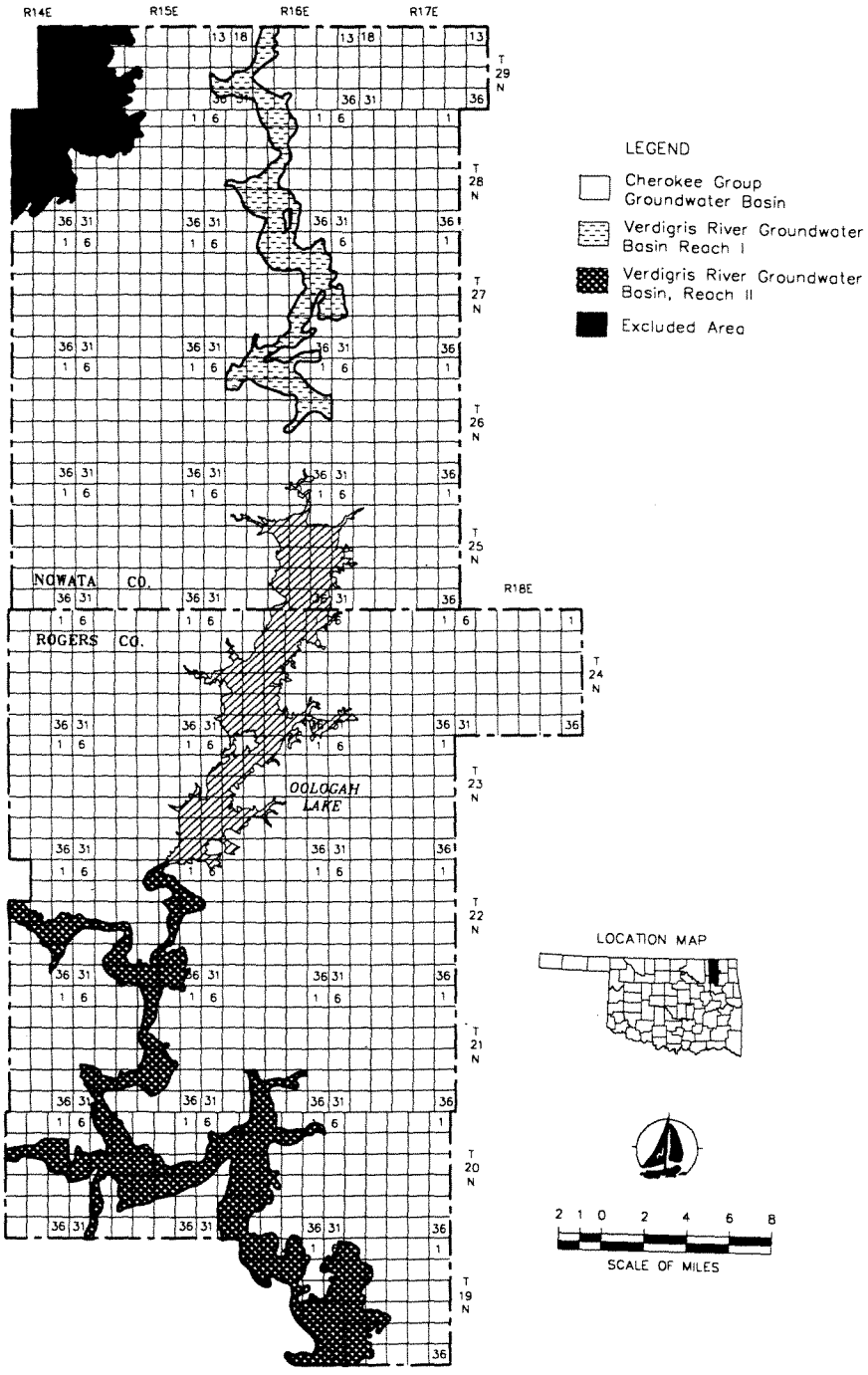

Figure 1. Physical Boundaries of the Cherokee Group and Verdigris River Groundwater Basins

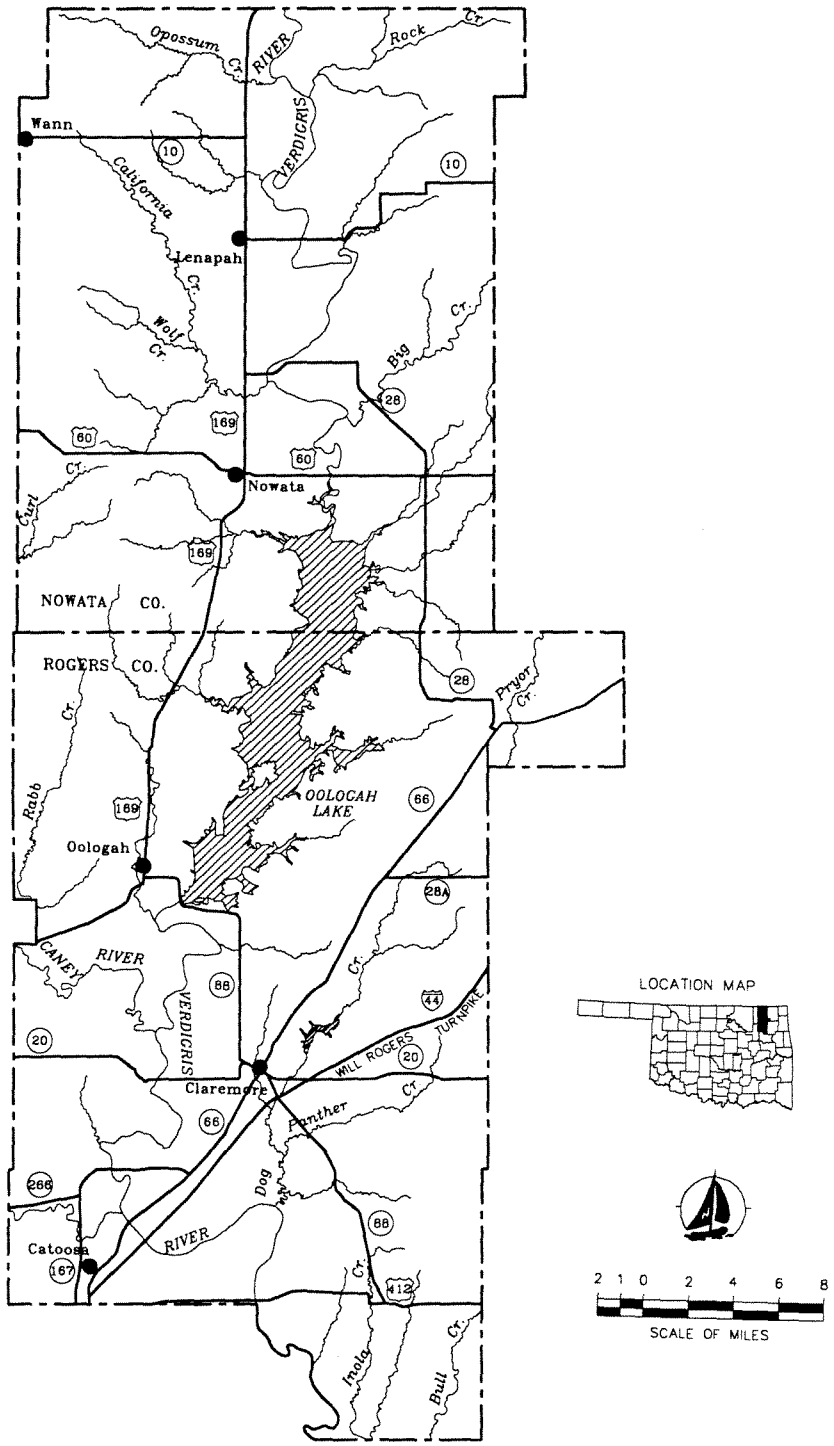

Figure 2. Study Area Showing Surface Drainage Features, Towns and Primary Roadways

Setting

The land encompassed within the study area is in the prairie plains of northeastern Oklahoma. Generally, the terrain consists of level to gently sloping, broad grass-covered valleys underlain by shale. In the eastern part of the study area, the valleys are more pronounced and are separated by prominent, timbered, east-facing cuestas capped by sandstone and limestone. This topography results from differential erosion as a result of streams which carved out the soft, thick sections of shale while leaving behind the more resistant sandstone and limestone layers. The elevation above mean sea level ranges from 1110 feet in northwestern Nowata County near the Kansas-Oklahoma border to 520 feet in southern Rogers County near the Verdigris River.

Climate

Climate is temperate and continental of the moist, subhumid type. This transitional area receives the warmer, moisture-laden air from the Gulf of Mexico, which is regularly penetrated by the cooler, drier air moving from the north. Rapid penetration of cool air sometimes results in significant variations of temperature, precipitation, cloudiness, and wind velocity. Changes between seasons are gradual. Winters are mostly moderate and sunny. The cold periods usually last only a few days. Spring and Fall bring the most significant opportunities for rain. Summers are usually hot. The mean annual temperature is around 60 degrees. The mean monthly temperature varies from 38 degrees in January to 82 degrees in July (Polone, Dock J., 1966, 1979).

According to data from the National Weather Service rain gauge located in Nowata Oklahoma, annual precipitation has varied from a low of 22.34 inches to a high of 62.49 inches (period of record 1948-1992). The mean annual precipitation for the study area is approximately 39 inches (OWRB, 1990).

Regional Geology

The geologic formations which occur in the two-county area are of Pennsylvanian age. The beds of these units form a predominantly sand-shale sequence with thin beds of limestone and coal. The exception to this is a 200 foot thick sequence of limestone beds which are separated by thin layers of shale. This limestone province constitutes the Marmaton Group within the study area.

The Pennsylvanian strata of eastern Oklahoma include five Series. From youngest to oldest they are the Virgillian, Missourian, Desmoinesian, Atokan, and Morrowan. In the study area, only formations of Desmoinesian and Missourian age outcrop (See Stratigraphic Section, Table 1). Formations of the Missouri Series have been assigned to the Ochelata and Skiatook Groups. These units occupy the western one-third of Nowata County and northwest

corner of Rogers County. Formations of the Desmoinesian have been assigned to the Marmaton and Cherokee Groups. These units outcrop in the eastern two-thirds of Nowata County and all but the northwest corner of Rogers County. The youngest (Pennsylvanian-aged) sediments in the study area belong to the Tallant Formation, assigned to the Ochelata Group located in northwest Nowata County; the oldest lithologic unit, the Savanna Formation (Cherokee Group), outcrops in extreme southeastern Rogers County.

The general strike of the formations in the study area is NE-SW, and the regional dip is 25-40 feet per mile W-NW. Pennsylvanian-age formations thicken from east to west across the study area. From a feather edge at the western margin of the Ozark Plateau, Pennsylvanian sediments obtain a thickness of about 2,000 feet in Washington and Tulsa Counties (Marcher and Bingham, 1971).

Table 1.

Middle Pennsylvanian-aged Strata in Study Area

Series	Group	Formation
Missourian	Ochelata	Tallant
		Barnsdall
		Wann
		Iola
		Chanute
	Skiatook	Dewey
		Nellie Bly
		Hogshooter
		Coffeyville
		Checkerboard
		Seminole
Desmoinesian	Marmaton	Holdenville
		Lenapah
		Nowata
		Oologah
		Labette
		Fort Scott Limestone
	Cherokee	Senora
		Boggy
		Savanna

The formations of middle-upper Pennsylvanian were deposited on the Northeast Oklahoma Platform. This platform was a depositional shelf during this period of geologic time. Prior to the deposition of the Marmaton limestones, mud and sand were deposited from streams flowing southward from the craton. When this sedimentation

pattern halted, a shallow sea formed over the area and thick limestone banks were deposited (Marmaton limestone). Deposition of the limestone banks was halted not by the return of sedimentation from the north, but by the northward growth of a distributary system of the ancestral Ouachita mountains whose muds and sands overrode the limestone banks (Krumme, 1981).

The associated structural features include the buried north-south running Nemaha Ridge to the west, the Ozark uplift to the east, the McAlester and Ouachita basins to the southeast, and the Seminole uplift to the south. The Seminole uplift is a structural saddle separating the Anadarko Basin from the McAlester Basin, which is itself, the western portion of the much larger Arkoma Basin.

Quaternary alluvium along the Verdigris and its tributaries are the youngest sediments in the study area. The thickness of the alluvium varies between 15 and 70 feet. The alluvium is comprised of clay and silt in the upper part grading downward into a few feet of coarse sand and gravel (Marcher and Bingham, 1971).

GROUNDWATER RESOURCES

Cherokee Group Groundwater Basin

Approximately 1,210 mi^2 or 775,000 acres of land overlies the CCGB. The CGGB rock units are principally comprised of interbedded shale and sandstone with thin limestone stringers and thin beds of coal. One section of the Pennsylvanian that contains a thick sequence of limestone occurs in the Marmaton Group. However, on the average, 25% of the CGGB is comprised of sandstone, most of which can be characterized as fine to very fine-grained (Hemmish, 1988 and OWRB Well Records).

The Pennsylvanian sediments of northeast Oklahoma are well known for their fossil fuel reserves: oil, gas and coal (Krumme, 1981 and Hemmish, 1988). Groundwater occurrence and availability in these sediments, by contrast, is limited.

The thickest sandstone units occur in the eastern portion of the basin in the Cherokee Group. The basin name was selected for these rock units because they contain the most important sources of groundwater in the Pennsylvanian strata in the study area. The three principal sandstone bodies within the Cherokee Section of the Pennsylvanian strata are described in the following discussion. These sandstone units have been characterized as being potentially good-water bearing reservoirs (Marcher and Bingham, 1971).

In ascending order (oldest to youngest), the rocks of the undifferentiable Hartshorne, McAlester and Savanna Formations outcrop along the southeastern corner of Rogers County. The basal member, the Warner Sandstone, has been described as a medium to fine-grained sandstone generally six to ten feet thick with a

maximum thickness of 23 feet. Approximately 250 feet above the Warner Sandstone, at the base of the Boggy Formation, lies the Blue Jacket Sandstone. The Blue Jacket Sandstone is 30-50 feet thick, its lower portion is described as fine-grained and massively bedded whereas the upper portion is comprised of interbeds of shale, siltstone, and sandstone. The Chelsea Sandstone, a member of the Senora Formation, lies approximately 200 feet above the Blue Jacket Sandstone. It is approximately 50 feet thick, medium-grained and massively bedded (Lohman Jr., Clarence, 1952). The Boggy and Senora Formations outcrop in approximately 80 percent of Rogers County and in southeastern Nowata 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. For this study, specific yield was estimated to be 0.01. This figure represents an approximate mean of the range of values given for the type of rock formations which comprise the CGGB (Driscoll, 1986). The rock units of the CGGB are dominated by shale, well cemented, fine to very fine-grained sandstones and unjointed limestones characterized as dense to moderately crystalline and thin to massively bedded.

The mean depth to water is estimated at 20 feet and the mean depth of wells completed in the study area is approximately 115 feet (OWRB, 1996, Marcher and Bingham, 1971). Approximately ten percent of the well completions averaged 225 in depth. Two wells were reportedly drilled to depths of 500 feet. It appears, based on water quality considerations, that the two 500-foot deep wells are anomalous to the vast majority of the basin. In most instances, groundwater encountered at depths greater than 250 feet would be highly mineralized, with total dissolved solids concentrations exceeding 10,000 mg/l (OCC, 1982).

The average total thickness of the basin is determined to be 170 feet. This represents the mean of the cluster of wells completed to depths of around 225 feet and the mean reported well depth (115 feet) for the study area.

The saturated thickness of the CGGB is 150 feet, which is the difference between the mean total thickness and the mean depth to water in the CGGB.

Hydraulic conductivity (K) is estimated for the CGGB based on the mean K taken from hydrogeologic texts which provide ranges of possible K values for different consolidated aquifers (Freeze and Cherry, 1979). Formations which consist primarily of shale, siltstone, hard cherty limestone, and sandstone are reported to have K values ranging from 1.3×10^{-3} ft/day to 1.3×10^{-6} ft/day.

For this study, K was estimated at 1.3×10^{-4} ft/day (0.00013 ft/day).

Transmissivity, a product of the basin saturated thickness and K, was estimated at 0.02 ft^2/day.

The rate of groundwater recharge depends on several factors, including precipitation, permeability of the rocks, depth to water table, soil type and moisture conditions, topography, vegetation, and temperature, among others. The recharge rate for the CGGB was inferred from a previous study conducted in Ohio which estimated effective regional recharge rates for different drainage basins (Pettyjohn and Henning, 1979). The hydrogeologic setting for the Hocking River Drainage Basin in eastern Ohio is very similar to that of the CGGB. The geology is comprised of Permian and Pennsylvanian aged rock which consists largely of alternating layers of sandstone and shale with minor amounts of limestone and coal. The topography is generally flat lying to gently rolling. The mean precipitation is 39 inches per year and the typical well yield is generally less than 10 gallons per minute due to the relatively thin nature of the low permeability sandstones. The Ohio study estimated a range of recharge rates between two and four inches per year for the Hocking River drainage basin. For this study, a recharge rate of three inches per year is estimated.

Aquifer Storage and Yield Capabilities

Determination of the initial storage of a groundwater basin was calculated by multiplying the area of the basin by the specific yield and the saturated thickness of the basin. The initial storage for the CGGB is estimated at approximately 1,162,000 acre-feet.

Groundwater availability is limited in the study area. Most wells yield from a fraction of a gallon per minute to a few gallons per minute. The mean well yield as determined from OWRB well records is approximately three gallons per minute. Locally, yields of 20 gallons per minute have been obtained from the thicker sandstone units in the area (Marcher and Bingham, 1971).

Verdigris River Groundwater Basin

The VRGB comprises approximately 107 mi^2 of Quaternary alluvium deposits that occur as channel and floodplain deposits and overlie the Pennsylvanian formations in the area. The upper part of the aquifer is comprised of silts and clays which grade downward into a few feet of fine to coarse sands and gravel at the base.

The thickness of the alluvium along the Verdigris River in Reach I (above Oologah Lake) ranges from 15-40 feet and averages about 20 feet (Marcher and Bingham, 1971). Reach I contains approximately

32 mi^2 or 20,500 acres.

In Reach II (below Oologah Lake), the alluvium associated with the Verdigris River has an average thickness of 40 feet, with a maximum thickness of about 70 feet. The alluvium of the Caney River is also a part of Reach II, and based on limited data, has an average thickness of 20 feet. The alluvium along the Caney River makes up about 10-20 percent of Reach II. Reach II contains approximately 75 mi^2 or 48,000 acres.

Aquifer Parameters

Specific yield, which relates the quantity of water in storage that will yield by gravity drainage, is estimated at 0.15. This value falls within a range reported for other alluvial basins in Oklahoma.

For the two basins, the mean depth to groundwater based on well records and other published data (Havens and Bergman, 1976 and Marcher and Bingham, 1971) is estimated at ten feet. The mean saturated thickness for Reach I is ten feet; and for Reach II is eighteen feet.

Marcher and Bingham, 1971, stated that the alluvial sediments are comprised of clays, silts and fine sands in the upper portion, which grade downward into a few feet of coarse sands and gravel. It is estimated that the coarse sands and gravel comprise approximately 10-20 percent of the saturated sections of the respective alluvial basins. From Freeze and Cherry, 1979, mean K values for the coarse sand and gravel interval and fine sand, silt, and clay interval are approximated at 700 ft/day and 7 ft/day respectively. To account for the greater portion of the saturated interval being fine-grained, a weighted K value was estimated at 80 ft/day. Transmissivity, a product of the mean saturated thickness and K, is estimated to be 800 ft^2/day for Reach I and 1440 ft^2/day for Reach II.

Recharge to the alluvial basins in the study area is estimated to be four inches per year or approximately 10 percent of the mean annual rainfall. This slightly higher value relative to the CGGB is due to its more permeable nature.

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 of Reach I is estimated at 30,750 acre-feet. Initial storage of Reach II is estimated at 129,600 acre-feet.

A typical well yield in Reach I is 5-10 gallons per minute with a maximum of about 25 gallons per minute. In Reach II, yields

ranging from 10-30 gallons per minute are typical, and yields as high as 75 gallons per minute may be obtained.

Water Use

Groundwater use in the two-county study area appears to be limited to household and stock water use. For Nowata County, no groundwater rights permits have been issued by the Board. In Rogers County, only two groundwater rights permits exist and no use of groundwater has been reported.

Prior Groundwater Rights

No prior groundwater rights have been established within the two-county study area for the subject groundwater basins.

GROUNDWATER QUALITY

The groundwater quality data available for the study area are limited and not very recent. Groundwater in the Pennsylvanian rocks becomes increasingly mineralized with depth, and for practicable purposes, becomes unusable at depths exceeding 250 feet. Concentrations of total dissolved solids and chlorides exceed EPA's recommended thresholds for many of the reporting wells. Table 1 summarizes the general chemistry of the study area based on the sampling an analyses of twenty four wells in the late 1960's (Bingham and Marcher, 1971). The table shows mean concentrations for the parameters and EPA's maximum concentration levels (MCL'S) for drinking water, where applicable.

Table 1. Anions and Cations in the CGGB

Parameters	Concentration in mg/l	EPA MCL'S
Total Dissolved Solids	890	500
Sodium/Potassium	220	N/A
Nitrate	1.4	10
Chloride	217	250
Hardness	268	N/A
Bicarbonate	354	N/A
Sulfate	129	250

Sample results for the alluvial basins are minimal. The few analysis that are available indicate that groundwater from the alluvium is less mineralized (lower TDS concentrations) and generally not as hard.

SUMMARY

The following data on the Cherokee Group Groundwater Basin and Verdigris River, Reaches I and II Groundwater Basins were derived in order to calculate and determine the Maximum Annual Yield and Equal Proportionate Share of the basins:

Cherokee Group Groundwater Basin

1) The total land area overlying the basin is 775,000 acres;
2) The amount of water in storage in the basin on September 1, 1996 is approximately 1,162,000 acre-feet;
3) The average rate of recharge is estimated to be three inches or 7.5 percent of the average annual precipitation with 3,875,000 acre-feet of recharge over the life of the basin (a minimum of twenty years). The total amount of groundwater established under prior rights is 0 acre-feet with a total discharge of 0 acre-feet over the life of the basin.
4) The transmissivity of the basin is estimated at 0.02 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 groundwaters.

Verdigris River Groundwater Basin, Reach I

1) The total land area overlying the basin is 20,500 acres;
2) The amount of water in storage in the basin on September 1, 1996 is 30,750 acre-feet;
3) The average rate of recharge is estimated to be four inches per year or 10 percent of the average annual precipitation with 137,000 acre-feet of recharge over the life of the basin (twenty years). The total amount of groundwater established under prior rights is 0 acre-feet with a total discharge determined to be 0 acre-feet over the life of the basin.
4) The transmissivity of the basin is 800 ft^2/day;
5) The possibility of pollution from natural sources appears to be negligible.

Verdigris River Groundwater Basin, Reach II

1) The total land overlying the basin is 48,000 acres;
2) The amount of water in storage in the basin on September 1, 1996 is 129,600 acre-feet
3) The average rate of recharge is estimated to be 4 inches per year or 10 percent of the average annual precipitation with 320,000 acre-feet of recharge over the life of the basin (twenty years). The total amount of groundwater established under prior rights is 0 acre-feet with a total discharge determined to be 0 acre-feet over the life of the basin.
4) The transmissivity of the basin is 1,400 ft^2/day;
5) The possibility of pollution from natural sources appears to be negligible.

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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 stream or other body of running water as a sorted or partially sorted sediment in the bed of the stream or on its flood plain 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.

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 and banks of any definite stream.

Groundwater Basin
: A distinct underground body of water overlain by contiguous land and 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 the complete depletion of the basin with the exception of maintaining five feet of saturated thickness in alluvium and terrace aquifers and 15 feet of saturated thickness in bedrock aquifers 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 (Board).

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

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

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.