# HYDROLOGIC REPORT OF THE MINOR GROUNDWATER BASINS IN GARFIELD, GRANT AND KAY COUNTIES

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# INTRODUCTION

The hydrologic report of the minor groundwater basins in Garfield, Grant and Kay 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 basin(s). This determination is to 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 basins 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 basinwide if from a bedrock basin and less than 150 gallons per minute if from an alluvial and terrace basin.

One minor bedrock and one minor alluvial groundwater basin were identified within the study area. The minor bedrock groundwater basin, named the North Central Groundwater Basin (NCGB) underlies most of the area contained within Garfield, Grant and Kay Counties. The alluvial and terrace deposits associated with the lower reach of the Chikaskia River within the study area constitute a minor alluvial groundwater basin (CRGB). This basin lies entirely within the confines of Kay County. Several major groundwater basins and other important sources of groundwater exist within the study area which will be excluded from consideration in this report. Figure 1 shows the boundaries of the minor, major and potential major groundwater basins superimposed upon the public land survey system in Garfield, Grant and Kay Counties.

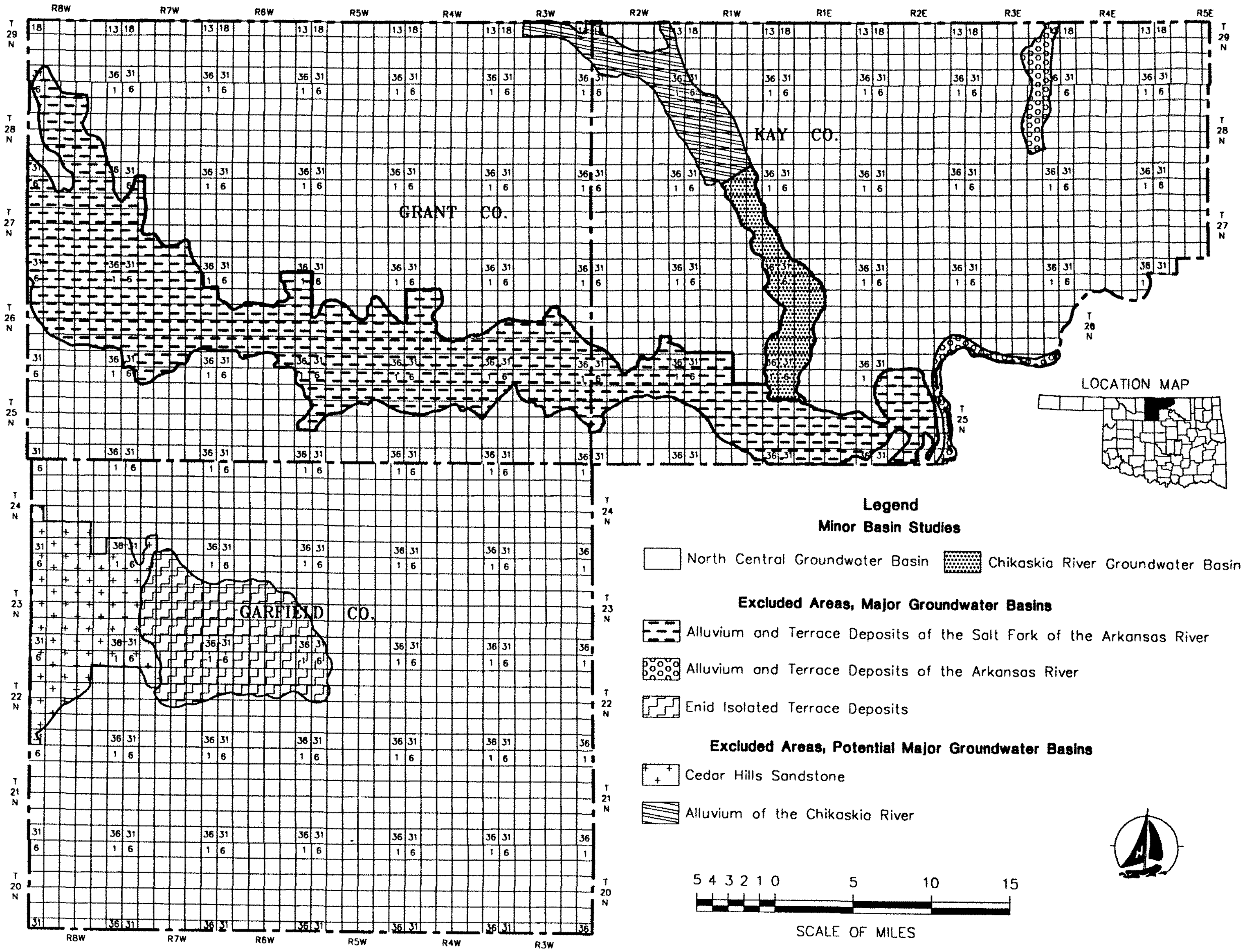


**Figure 1. Groundwater Basins in Study Area**

## Major and Potential Major Groundwater Basins in the Tri-County Study Area

Groundwater resources that are stored in the alluvium and terrace deposits of the Salt Fork of the Arkansas and Arkansas River constitute major groundwater basins and will not be considered in this report. In addition, the Enid Isolated Terrace Aquifer in Garfield County is a major groundwater basin for which a maximum annual determination has already been made. The Cedar Hills Sandstone, a Permian formation outcrops in western Garfield County and will be omitted from consideration in this study. Morton (1980) indicates that a significant portion of the Cedar Hills Sandstone has the potential to yield in excess of 50 gallons per minute.

Based on a preliminary review of well data, the alluvium and terrace deposits along Chikaskia River beginning approximately 3 miles north-northwest of the City of Blackwell northward to the Kansas state line will be omitted. Along that reach of the river, well yields ranging from 150 to 300 gallons per minute have been reported (Bingham and Bergman, 1980).

# PHYSICAL SETTING

## Location

This report is limited to the minor groundwater basins in Garfield, Grant and Kay Counties in north-central Oklahoma. The three counties contain approximately 1,926,000 acres or 3009 $mi^2$ (Figure 2).

The principal groundwater basin for the study area in terms of surface area is the NCGB. It is comprised of Permian and Pennsylvanian-aged formations. The minor alluvial basin identified in the study area is comprised of the Quaternary sediments deposited within and adjacent to the Chikaskia River.

The Chikaskia River enters Oklahoma from the State of Kansas in far northeastern Grant County. The Chikaskia flows primarily in a south-southeast direction crossing into Kay County a few miles south of the Kansas-Oklahoma border. It follows this general direction until its confluence with the Salt Fork of the Arkansas, a total distance of about 32 miles. From this junction, approximately 11 miles east, the Salt Fork of the Arkansas joins the Arkansas River.

## Setting

The study area for the most part is located within the Central Rolling Red Prairies major land resource area, excepting for eastern Kay County which is in the Bluestem Hills land resource area (OWRB, 1972). For all but eastern Kay County, the terrain can be characterized as ranging from nearly flat to undulating. In eastern Kay County, where streams have cut fairly deep drainageways, relief can be significant, exposing precipitous limestone ledges. Relief in the study area varies from 1,410 feet in the dunal areas of northwest Grant County to 950 feet in the eastern part of the study area near the junction of the Arkansas and Salt Fork of the Arkansas Rivers.

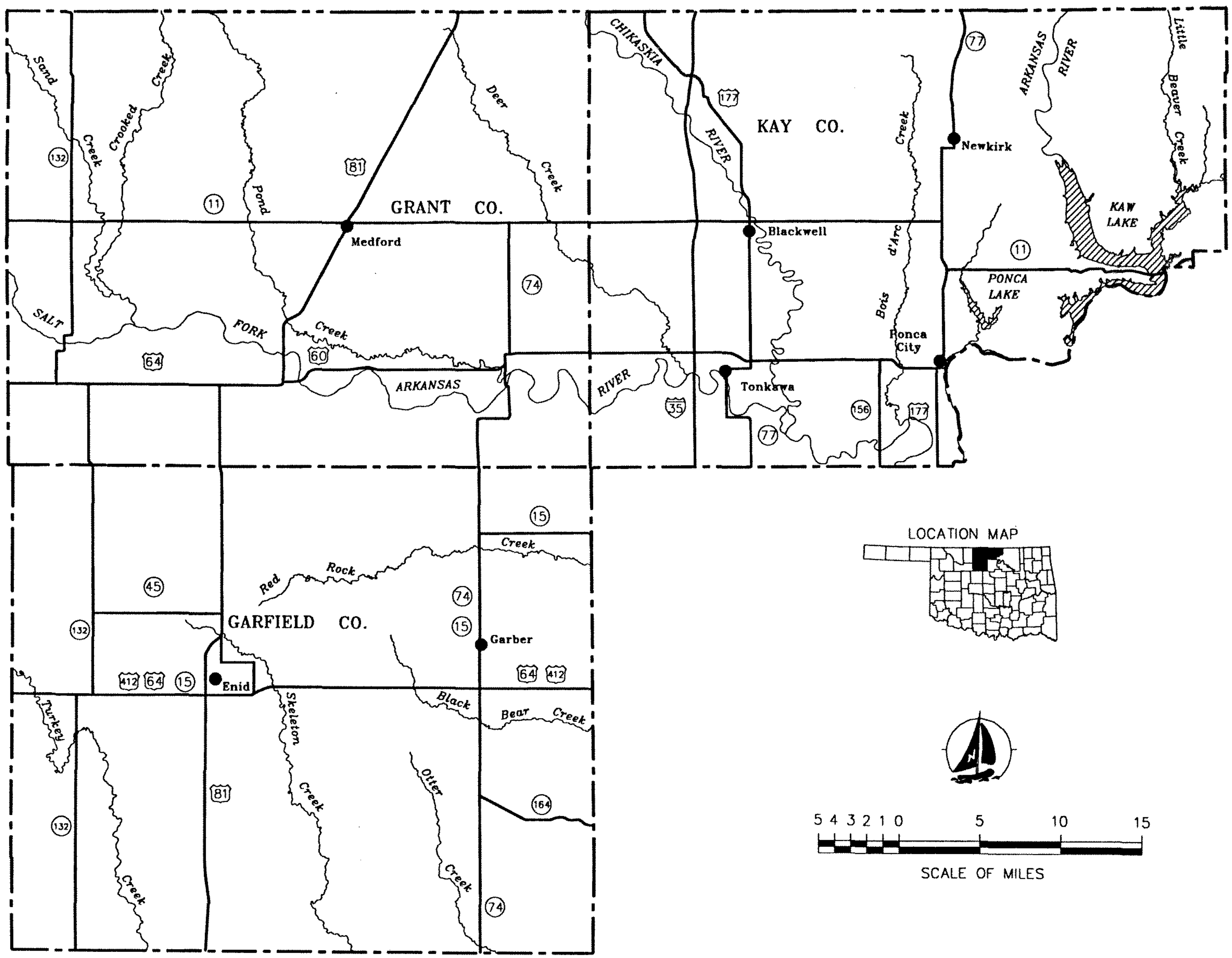


Figure 2. Study Area Showing Surface Drainage Areas, Towns and Primary Road Ways

The major tributaries to the Salt Fork and Arkansas Rivers in Grant and Kay Counties are Sand, Crooked and Pond Creeks which drain western and central Grant County, Deer Creek which drains eastern Grant and southwestern Kay County and Chikaskia River and Bois d'Arc Creek which drain western and central portions of Kay County. No major rivers cross Garfield County but the following streams drain the county: Turkey, Skeleton, and Otter Creeks which discharge to the Cimarron River; and Black Bear and Red Rock Creeks which feed the Arkansas River.

**Climate**

The climate is continental, temperate, and subhumid. Dominated by the flow of warm, moist air masses from the Gulf of Mexico, significant changes in temperature, precipitation and wind occur quickly when these air masses collide with cooler and drier air masses from the northern regions. Seasons are well defined but, but changes between seasons are gradual. Winters are usually short and mild. Periods of cold and snow are short lived, lasting only a few days. Spring, the most variable season is characterized by frequent precipitation, severe storms and tornadoes. The summers are normally hot, but the longer warm periods are eased by cool nights, pleasant breezes, and occasional heavy showers. The mean annual temperature for the study area is approximately 61 degrees. The mean annual rain fall for the study area is approximately 30 inches with seventy percent of the rain fall occurring from April through September ( Swafford, 1967, Garfield County; Williams, Horn, and White, 1985 Grant County; Culver, 1967, Kay County).

**Regional Geology**

Outcropping rock formations consist of Pennsylvanian-aged (Oscar Group) limestones and shales in eastern Kay County and Permian-aged shales, siltstones, sandstones in western Kay, Grant and Garfield Counties (Bingham and Bergman, 1980). Others, have placed the geologic units of the Oscar Group in the Permian system and assigned them to the Chase, Council Grove and Admire Groups (Culver, et al, 1967 and Parkhust, Christenson and Breit, 1996). For this report, following Bingham and Bergman (1980), the Oscar Group will be used when referring to the limestones and shales of eastern Kay County as well as for those same units where they occur in central portions of Oklahoma.

Both fluvial and marine deposits comprise the sandstone, shale and limestone formations in the study area. This resulted as the depositional environment shifted back and forth between river, delta, and shallow sea. Fluvial sediments (sand, silt and clay) were eroded form low lying areas in northeastern Oklahoma and eastern Kansas and transported by westward flowing streams which deposited their sediments into a large inland sea whose shoreline was in proximity to the study area. At other times, precipitation and deposition of marine (limestone) deposits occurred in the shallow sea environment. In Grant County, as a result of extended periods of evaporation of saline sea water, significant beds of rock salt and gypsum were precipitated which occur at depths ranging from 500 to 1,500 feet (Johnson, 1985).

The geologic formations present in the study area outcrop in bands ranging from a few miles to 25 miles in width and extend southward well beyond the study boundaries into south-central

Oklahoma. The oldest geologic formation in the study area is the Oscar Formation. The youngest formation in the study area is the Cedar Hills Sandstone. Where the entire stratigraphic sequence is present in the same locale, the maximum thickness would approach 2000 feet (See Table 1 for stratigraphic column). In general, the shale and limestone layers are thicker northward with sandstone layers thickening toward the south. The rock formations generally dip to the west at approximately 40 feet per mile (Bingham and Bergman, 1980).

The Nemaha ridge, a buried structural feature extending from southern Oklahoma County up through the center of the study area and into Kansas was formed during the late Pennsylvanian. The younger Permian rocks which overlie the Nemaha Ridge show little indication of the structural relationships associated with it, but rocks broken by parallel faults as result of its uplift occur eastward of the study area (Luza, K. V., 1985).

**TABLE 1. PERMIAN AND PENNSYLVANIAN-AGE STRATA IN THE STUDY AREA (Bingham and Bergman, 1980)**

| System | Series | Group | Formation |
|---|---|---|---|
| Permian | Cimarron | El Reno | Cedar Hills Sandstone |
| | | Hennessey | Bison Formation |
| | | | Salt Plains Formation |
| | | | Kingman Siltstone |
| | | | Fairmont Shale |
| | | Sumner | Garber Sandstone |
| | | | Wellington Formation |
| Pennsylvanian | Gearyan | Oscar | Oscar Group Undifferentiated |

## GROUNDWATER RESOURCES

### North Central Groundwater Basin

Approximately 2914 $mi^2$ or 1,865,000 acres of land overlies the NCGB. The areal extent of the the basin includes all lands within the three-county study area except for those lands underlying Kaw Lake and those lands underlain by the Cedar Hills Sandstone (figure 1). The alluvium associated with the smaller tributary streams in the three county area will not be treated as separate groundwater basins because the deposits are thought to be too thin to store significant quantities of water. The alluvial deposits associated with these smaller streams are considered to be in hydraulic communication with the underlying Permian formations and will be treated as a part of the NCGB.

The NCGB is comprised of formations that contain varying thicknesses and percentages of shales, sandstones and limestones. Shale is the predominate rock type throughout the basin. In eastern Kay County, limestone beds, mostly absent from the Permian formations in the western two-thirds of the study area are present.

Occurrence of groundwater is controlled primarily by the amount of precipitation that enters into the groundwater environment. The movement of groundwater through the basin is controlled by its geologic framework (porosity and permeability). The size and abundance of the openings in the rock and the relative connection between the openings determine those aquifer characteristics. Groundwater movement in the study area is from uplands (where recharge occurs) toward streams. Potential groundwater recharge to the NCGB is limited by the clayey nature of the study area's soils derived from the underlying tight shale, sandstone, and limestone formations. Seepage to streams and evapotranspiration account for most of the groundwater discharge (groundwater pumping accounts for a small fraction of the groundwater discharge). Groundwater discharge maintains base flow in the streams during dry periods. However, small streams often go dry because the formations that comprise the NCGB are fine-grained, having a limited capacity to absorb and transmit groundwater (Bingham and Bergman, 1980).

### 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 using a table of representative specific yield ranges for earth materials (Walton, 1970). For limestone and shale, specific yield typically ranges between 0.5 and 5 percent. For siltstone and sandstone, specific yield typically ranges between 5 and 15 percent. As a result of a greater percentage of the basin being comprised of shale versus sandstone, more weight was given to the lower end of the specific yield range. Consequently, specific yield is estimated to be 3 percent or 0.03 for the NCGB.

From a review of water well drillers' logs, the average depth to water in the NCGB is 22 feet. Most of the completed wells in the basin are domestic wells drilled to depths ranging from 30 to 60 feet. The mean well depth for the basin is 50 feet.

A base of "treatable" water map was completed for the state (Oklahoma Corporation Commission, 1982) which shows the depth below land surface in which groundwater has concentrations of total dissolved solids (TDS) of 10,000 milligrams per liter (mg/L). In the study area, the average base of treatable water is approximately 250 feet. Fresh groundwater by definition has less than 5,000 mg/l TDS. Groundwater with TDS concentrations greater than 5,000 mg/l is by definition "salt water" and not regulated by the OWRB.

The relative concentration of dissolved solids in groundwater is typically a function of the amount of time the percolating water (precipitation that enters into the groundwater flow system) has been in contact with the rocks and the solubility of the mineral constituents of the rock. Therefore, as a general rule of thumb, dissolved solids concentrations typically increase with depth.

The base of NCGB, which will coincide with the estimated average base of fresh water, is determined to be 200 feet or approximately 20% shallower than the average base of treatable water.

The saturated thickness for the NCGB, equivalent to the difference between the average depth to fresh water and mean aquifer base is determined to be 180 feet.

The Garber Sandstone and Wellington Formations comprise about 60% of the of the NCGB. The lithology of these two formations is generally representative of the remainder of the basin except for the absence of limestone. In central Oklahoma, the geographical area which includes southern Logan, Oklahoma, Cleveland, and portions of western Lincoln and Pottawatomie Counties, is underlain by the Central Oklahoma Aquifer (COA), a major bedrock groundwater basin. The principal components of the COA are the Garber Sandstone and Wellington Formations. The basal member of the COA is the Oscar Group.

The median sandstone percentage in the COA was estimated at 60 percent (Parkhurst, Christenson, and Breit, 1996). From their examination of specific capacity data on drillers logs, hydraulic conductivities (K) for the Garber Sandstone and Wellington Formations were calculated which ranged from 0.09 - to 60 ft/day with a median value of 3 ft/day. The median K value calculated for the Oscar Group in this area was 1.3 ft/day (Parkhurst, Christenson and Breit, 1996).

As previously discussed, these formations extend northward to the Kansas-Oklahoma line and beyond. However, beyond the stated boundaries of the COA, the percentage of sand sharply decreases and shale increases .

From a review of lithologic data from well completions in the NCGB, shale comprises between 60 to 75 percent of the formation thicknesses. Taking into account the relative proportions of shale, sandstone, siltstone and limestone reported on water well log completion reports as compared to the relative sand percentages reported for the COA and utilizing representative K values for consolidated and unconsolidated aquifers (Freeze and Cherry, 1979) the hydraulic conductivity of the NCGB is estimated at 0.7 ft/day. Transmissivity, a product of the hydraulic conductivity and saturated thickness is 125 $ft^2$/day.

The median recharge rate for the Central Oklahoma Aquifer in Logan, Oklahoma, Cleveland, Lincoln, and Pottawatomie Counties is 1.6 inches (Parkhurst, Christenson, and Breit, 1996) or approximately 5 percent of the average annual precipitation.

In the study area, the soils are derived from bedrock which a higher clay content than in central Oklahoma. This would tend to lead to a lower rate of infiltration of rain water in the study area as compared to the recharge areas of the COA. However, quantifying the degree of impact on recharge rates resulting from soil type differences is not possible without more data. Consequently, the recharge rate of the NCGB is determined to be 1.6 inches per year or approximately 5 percent of the annual precipitation.

A summary of the aquifer parameters determined for this NCGB 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/Acre/Year) |
|---|---|---|---|---|
| 1,865,000 | 178 | 0.03 | 125 | 1.6 |

### 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 of NCGB is estimated at approximately 9,960,000 acre-feet.

From a review of OWRB multipurpose completion reports (drillers logs) the maximum reported yield for wells completed in the basin is 50 gallons per minute with an average reported yield of 12 gallons per minute.

### Water Use

A majority of the towns and rural water systems located in the study area obtain their water from groundwater resources. However, most of the groundwater supply for these communities is obtained from two major groundwater basins underlying the study area. The Enid Isolated Terrace Deposit underlying the City of Enid in Garfield County and the Alluvium and Terrace Deposits of the Salt Fork of the Arkansas in Grant and Kay Counties supply the majority of the drinking water in the study area (Figure 1).

Public water systems which obtain all or a portion of their drinking water from the NCGB include Deer Creek, Fairmont, Garber, Hunter Rural Water Corporation, and Waukomis (Department of Environmental Quality, 1996).

Permit or prior right holders in the NCGB total 26. In addition to public water supply, the basin supports some irrigated agriculture as well as non-irrigated agriculture. Other permitted uses include commercial, industrial and mining (Table 3). There are also hundreds of private water wells which meet domestic and stock needs.

**TABLE 3. WATER RIGHTS AND USES FOR THE NCGB**

| Purpose | Permits and Prior Rights | Allocated Amounts | Report Water Use (1995) |
|---|---|---|---|
| Agriculture | 15 | 1921 Acre-feet | 85 Acre-feet |
| Public Water Supply | 7 | 934 Acre-feet | 286 Acre-feet |
| Commercial/Industrial/Mining | 4 | 615 Acre-feet | 0 Acre-feet |
| Total | 26 | 3470 Acre-feet | 371 Acre-feet |

### Prior Ground Water Rights

Groundwater rights established within the NCGB prior to July 1, 1973 and recognized by Board Order total 815 acre-feet.

### Chikaskia River Groundwater Basin

The CRGB comprises approximately 33.50 $mi^2$ or 21,500 acres of Quaternary alluvium and terrace deposits that occur as channel and flood plain deposits and overlie the Permian Wellington Formation. These unconsolidated deposits consist of silt, clay, and fine sand with coarse sand and gravel at the base in places. Based on reported well yields and a review of drillers logs, this gravel is not always present or is thin along portions of this reach of river (CRGB) whereas northward from Blackwell, coarse sand & gravel associated with the alluvium is more prevalent where higher yields have been reported (Bingham and Bergman, 1980).

The CRGB northern boundary begins approximately 3 miles north-northwest of the City of Blackwell and terminates approximately 2 miles above the confluence of the Chikaskia and Salt Fork Arkansas Rivers. The distance between these two points is approximately 13 miles. Along this reach of the Chikaskia, the alluvium forms a band on either side of the river reaching a maximum width of about 3 ½ miles and averaging about 2 miles across. All of this basin lies within Kay 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 (T). For unconfined aquifers like the CRGB, storage coefficient and specific yield are nearly equivalent. Specific yield for clay, silt, sand and gravel ranges from 1 percent for clay to 30 percent for gravel (Walton, 1970). Specific yield for other alluvial and terrace aquifers in Oklahoma has been estimated to range from 15-20 percent. Bingham and Bergman (1980) infer from their reporting of potential well yields that along this lower reach of the Chikaskia, the basal gravel is thin or sometimes absent and that the aquifer contains a higher proportion of fines than the upper reach of the Chikaskia. Specific yield of the CRGB is determined to be 0.15 (fifteen percent).

The alluvium of the CRGB may be as much as sixty feet thick (Bingham and Bergman, 1980), but review of well records indicates the average basin thickness to be 44 feet. From well records, the average depth to water in CRGB is determined to be 22 feet. The average saturated thickness of the basin is 22 feet corresponding to the difference between the average basin thickness (44 feet) and average depth to water (22 feet).

Based on the limited information regarding the relative proportions of clay, silt, sand and in some cases gravel in the basin, hydraulic conductivity (K) for the basin is estimated from Freeze and Cherry (1979). For these types of sediments, K can range from 1000 ft/day for fine gravel $10^{-7}$ ft/day for unweathered clay. Hydraulic Conductivity is estimated at 100 ft/day with sand, silt, and clay being the majority sediment types comprising the basin. Transmissivity, a product of the hydraulic conductivity and saturated thickness is 2200 $ft^2$/day.

The recharge rate of the basin is estimated at 15 percent of the mean annual precipitation of the study area or 4.5 inches per year. The estimate for the CRGB is correlated to Reed's (1952) recharge rate for the Cimarron Terrace Aquifer, located west of the study area. Bingham and Bergman (1980) reported that recharge to other terrace and alluvium deposits within the Enid quadrangle may be about the same because the surface soils are sandy and capable of absorbing large amounts of water and because the lithologies of the aquifers are similar.

A summary of the aquifer parameters determined for this basin is provided in Table 4.

**TABLE 4. AQUIFER PARAMETERS**

| Area of Basin (Acres) | Saturated Thickness (Feet) | Specific Yield | Transmissivty $Ft^2$/Day | Recharge Rate (Inches/Acre/Year) |
|---|---|---|---|---|
| 21,500 | 22 | 0.15 | 2200 | 4.5 |

### 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 for the CRGB is approximately 71,000 acre-feet.

Well yields range from 50 to 150 gallons per minute (Bingham and Bergman, 1980).

## Water Use

Water use within this basin is mostly limited to household and stock use. One municipality obtains its water from the basin. The 1995 reported water use for the basin was 154,000,000 gallons or 472 acre-feet.

## Prior Groundwater Rights

Groundwater rights established within the CRGB prior to July 1, 1973 and recognized by Board Order total 1,036 acre-feet.

# GROUNDWATER QUALITY

In north-central Oklahoma, chemical characteristics of the groundwater differ considerably within short distances. Groundwater in the NCGB can be characterized as a sodium-calcium-magnesium-bicarbonate type with many variations in water type (Bingham and Bergman, 1980 and Parkhurst etal, 1996). In most places, the water is hard (121-180 mg/l) to very hard (> 180 mg/l hardness). Reported concentrations of total dissolved solids (TDS) range from 429 to 6080 mg/l (Bingham and Bergman, 1980).

In Kay County, the groundwater underlying the area contained within Townships 26N-29N, and Ranges 2WIM-2EIM typically have TDS greater than 1,000 mg/l. This area is mostly underlain by the Permian Wellington Formation as well as the alluvium and terrace deposits of the Chikaskia River (Bingham and Bergman, 1980).

Although proportionately minor compared to the percentage of the NCGB comprised of shale, siltstone, sandstone and limestone, evaporites such as gypsum, anhydrite and halite occur as seams and nodules throughout much of the shallow, near surface Permian strata (McMahan, 1977). Thicker, bedded, evaporite deposits occur at depth in Grant County such as the Cimarron and Wellington evaporites (McMahan, 1977). The presence of these relatively minor amounts of gypsum and halite in the upper Permian are the likely source of the high TDS, sulfate and locally high chloride in the NCGB.

A summary of data on nitrate in groundwater was taken from the Enid Quadrangle (Bingham and Berman, 1980), categorized by the age of the host aquifer (See Table 5).

### TABLE 5. CONCENTRATIONS OF NITRATES IN NORTH-CENTRAL OKLAHOMA

| Age | Aquifer Material | # Samples | Maximum | Median | Minimum |
|---|---|---|---|---|---|
| Quaternary Alluvium | Sand and Gravel | 46 | 300 mg/l | 4 mg/l | 0 mg/l |
| Quaternary Terrace | Sand and Gravel | 27 | 180 mg/l | 25 mg/l | 3 mg/l |
| Permian | Shale, Sandstone, and Siltstone | 25 | 728 mg/l | 21 mg/l | 2 mg/l |
| Pennsylvanian | Shale and Limestone | 42 | 225 mg/l | 2 mg/l | 0 mg/l |

Twenty-five percent of the water samples taken from wells completed in Permian aquifers had nitrate levels greater than 125 mg/l. Nitrate in water is considered to be a final oxidation product of nitrogenous material, and when present in concentrations greater than 45 mg/l, it may be indicative of contamination by sewage or other organic matter. Chemical fertilizers may also be the source of nitrate. The quantity of nitrate present in natural, unpolluted water generally is only a few mg/l (Bingham and Berman, 1980).

Water quality data from 20 wells completed in the NCGB and six wells completed in the CRGB are summarized in Tables 6 and 7 respectively.

### TABLE 6. SUMMARY OF CONCENTRATIONS OF COMMON ANIONS AND CATIONS IN THE NCGB (Bingham and Bergman, 1980)

| Parameter | Maximum | Mean | Median | Minimum |
|---|---|---|---|---|
| TDS (mg/l) | 4020 | 1484 | 1260 | 278 |
| Chloride (mg/l) | 1584 | 264 | 122 | 17 |
| Na+K (mg/l) | 1104 | 255 | 158 | 40 |
| Ca+Mg (mg/l) | 2050 | 611 | 444 | 50 |
| $HCO_3$ (mg/l) | 884 | 373 | 335 | 152 |
| $SO_4$ (mg/l) | 1680 | 425 | 263 | 24 |

(TDS - Total Dissolved Solids, Residue on Evaporation at 180 Degrees Celsius; Na+K - Sodium + Potassium; Ca+Mg - Calcium + Magnesium; $HCO_3$ - Bicarbonate; $SO_4$ - Sulphate; mg/l - milligrams per liter)

### TABLE 7. SUMMARY OF CONCENTRATIONS OF COMMON ANIONS AND CATIONS IN THE CRGB (Bingham and Bergman, 1980)

| Parameter | Maximum | Mean | Median | Minimum |
|---|---|---|---|---|
| TDS | 6080 | 2234 | 1295 | 640 |
| Chloride | 2555 | 689 | 205 | 35 |
| Na+K | 920 | 307 | 225 | 50 |
| Ca+Mg | 2750 | 966 | 725 | 0 |
| $HCO_3$ | 480 | 377 | 380 | 300 |
| $SO_4$ | 720 | 353 | 375 | 50 |

(TDS - Total Dissolved Solids, Residue on Evaporation at 180 Degrees Celsius; Na+K - Sodium + Potassium; Ca+Mg - Calcium + Magnesium; $HCO_3$ - Bicarbonate; $SO_4$ - Sulphate; mg/l - milligrams per liter)

The median values for total dissolved solids (TDS) and sulfates for both minor basins exceeds the maximum recommended levels (500 mg/l and 250 mg/l respectively) for those constituents in drinking water by the Environmental Protection Agency (EPA). The recommended limit for TDS is based mainly on taste thresholds and not physiological effects. Water that greatly exceeds 500 mg/l is generally not palatable.

The source of the sulfate and high TDS water in the CRCB may be attributed to communication with the underlying Permian rocks (NCGB). This would be particularly true if the piezometric surface of the bedrock aquifer is near the base of the alluvial aquifer or if wells in the alluvium were pumped excessively inducing upward groundwater flow from the Permian basin below. In some cases, the water quality of the alluvium may be impacted by inflow from the Chikaskia River (at points adjacent to loosing reaches of the stream). For most of the Chikaskia River and its tributaries, dissolved solids concentrations exceed 1,000 mg/l and specific conductance ranges between 3,000 and 5,000 (Bingham and Bergman, 1980). For both basins, 50% of the chloride analyses were below the EPA maximum concentration level (250 mg/l) for drinking water. A handful of the results had excessive chlorides, greater than 1,000 mg/l. Bingham and Bergman (1980) indicated that these were likely the result of man-made activities.

**Chikaskia River Groundwater Basin**

In concluding, the quality of the groundwater in the CRCB is probably suitable for most beneficial uses except in localized areas. The Town of Tonkawa obtains it water supply from this basin and as described in the general discussion of the basin, dissolved solids, sulfate, and hardness are the most problematic aspects of their water supply. Because of the hardness and amount of dissolved solids in the groundwater, water softening units and some filtration may be required to reduce scale build-up on piping and to improve the palatability of the water. Well construction practices, operation (pump rates and pump duration) and spacing can help reduce the degree of infiltration or capture of more highly mineralized waters originating in either the NCGB or the Chikaskia River.

## North-Central Groundwater Basin

In concluding the water quality section on the NCGB, several communities rely on this groundwater resource in spite of the degree of mineralization of the groundwater. Although there exists a lot variability in the relative concentrations of a particular constituent in the basin, in general, the groundwater can be utilized for most beneficial uses. Water quality testing can help identify the problem areas and proper well construction and operation can reduce the negative impacts.

## SUMMARY

### North-Central Groundwater Basin

The following data on the North-Central Groundwater Basin 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, 865,000 acres;
2) The amount of water in storage in the basin on June 1, 1997 was determined to be 9,960,000 acre-feet;
3) The estimated rate of recharge is five percent of the average annual precipitation (30 inches) and totals approximately 4,700,000 acre-feet with a total discharge from the basin of 16,300 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 TDS and sulfates can be minimized by proper well construction, treatment, and water quality testing and analysis.

### Chikaskia River Groundwater Basin

The following data on the Chikaskia River Groundwater Basin 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 21,500 acres;
2) The amount of water in storage in the basin on June 1, 1997 was determined to be 71,000 acre-feet;
3) The estimated rate or recharge is 15 percent of the average annual precipitation (30 inches) and totals approximately 161,000 acre-feet with a total discharge from the basin of 20,720 acre-feet over the life of the basin (20 years);
4) The transmissivity of the basin is estimated to be 2,200 $ft^2$/day;
5) The possibility of pollution of the basin from natural sources such as TDS and sulfate can be minimized by proper well construction, treatment and water quality testing and analysis.

## REFERENCES


Bingham, Roy H. and Bergman, DeRoy L., 1980, Reconnaissance of the Water Resources of the Enid Quadrangle North-Central Oklahoma, Oklahoma Geological Survey Hydrologic Atlas 7, Four Sheets.

Culver, James R., Soil Survey of Kay County, 1967, Soil Conservation Service, United States Department of Agriculture 85p.

Department of Environmental Quality, 1996, Public Water Supply Data for Communities Using Groundwater in Garfield, Grant, and Kay Counties, 1996.

Driscoll, Fletcher G., 1996, Groundwater and Wells, Second Edition p. 67 and 75.

Freeze, R. A. and Cherry, J. A., 1979, Groundwater, 604 p.

Grant County Conservation District, 1973, Long Range Total Resource Conservation Program, pg 36.

Johnson, Kenneth, 1985, Geology Section For Grant County Soil Survey p. 94-96.

Luza, K. V., 1985, Seismicity and Tectonic Relationships of the Nemaha Uplift and Midcontinent Geophysical Anomaly, Oklahoma Geological Survey, Special Publication 85-2, p.14.

McMahan, Gregory Lee, 1977, A Geochemical and Thermodynamic Investigation of the Great Salt Plains Groundwater Alfalfa County, Oklahoma, University of Tulsa, Masters Thesis, p. 7-16.

Morton, Robert B., 1980, Reconnaissance of the Water Resources of the Woodward Quadrangle, Oklahoma Geological Survey Hydrologic Atlas 8, Four Sheets.

Oklahoma Corporation Commission, 1982, Unpublished County Maps Indicating the Base of Treatable Water in Oklahoma.

Oklahoma Water Resources Board, 1972, Appraisal of the Water and Related Land Resources of Oklahoma, Region 10

Parkhurst, David L., Christenson, Scott, and Breit, George N., 1996, Groundwater Quality Assessment of the Central Oklahoma Aquifer, Oklahoma-Geochemical and Geohydrologic Investigations, 101 p.

Reed, E. W., and others, 1952, Groundwater Resources of the Cimarron Terrace: Oklahoma Planning and Resources Board, Division of Water Resources Bulletin 9.

Swafford, Bill, Soil Survey of Garfield County, 1967, Soil Conservation Service, United States Department of Agriculture p.

Walton, W. C., 1970, Groundwater Resource Evaluation, 664 p.

Williams, Glen E., Horn, Edward E., White, Joe D., Soil Survey of Grant County, 1985, Soil Conservation Service, United States Department of Agriculture, 169 p.

## 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. 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 (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 (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 Capacity

The volume of water a well will yield per unit of drawdown, usually expressed in gallons per minute per foot (gpm/ft).

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.