SENSITIVITY OF THE ALLUVIAL AND TERRACE-ALLUVIAL AQUIFER OF THE SALT FORK OF THE ARKANSAS RIVER TO INDUCED INFILTRATION

By

EDWARD ECKENSTEIN

Bachelor of Science

University of Arkansas

Fayetteville, Arkansas

1979

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1995

SENSITIVITY OF THE ALLUVIAL AND TERRACE-

ALLUVIAL AQUIFER OF THE SALT FORK

OF THE ARKANSAS RIVER TO

INDUCED INFILTRATION

Thesis Approved:

Wayne Pettyjohn

Thesis Adviser

AAHounslow

Gary F. Stewart

Thomas C. Collins

Dean of the Graduate College

ACKNOWLEDGMENTS

I would especially like to thank Dr. Wayne Pettyjohn, my thesis adviser for his sage advice and constructive criticism. My thanks also to Dr. Gary Stewart and Dr. Arthur Hounslow for their editorial and technical comments in reviewing the thesis.

I would like to thank my employer, the Oklahoma Water Resources Board (OWRB) for its support. Much of my research was performed as part of an OWRB study which partially funded by an EPA Grant. Special thanks to all those employees at OWRB who worked with me on this project: Bob Fabian and Noel Osborn whose moral support and technical input has been invaluable; Danny Spiser, Gene Doussett, Ira Smith and Gavin Brady who collected field data; and Brad Nesom and James Leewright who provided drafting support.

Finally, I wish to thank my wife, Ruth and my son Nick for their support, patience, and understanding.

TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION	1
Location of the Study Area	1
Objectives	4
Previous Work	4
Methodology	5
Results	5
II. BACKGROUND	7
Geographic Information System	7
Geography	9
Geology	9
Quaternary Alluvial and Terrace-alluvial Deposits	10
Bedrock	10
Permian	12
Cedar Hills Formation	12
The Salt Plains Formation	12
Harper Formation	13
Lower Cimarron Salt	13
Hennessey Shale / Garber Sandstone	14
Wellington Formation	14
Pennsylvanian	15
Oscar Group	15
III. DATA REVIEW	16
Precipitation	16
Aquifer-bottom Elevations	18
Water Level Measurements	18
Selection of Wells	18
Water-level Trend	19
Hydrogeology	19
Water-table Maps	19
Groundwater Flow	19
Groundwater Divide	21
Hydraulic Gradient	21

Chapter | Page

Saturated Thickness 22
Bedrock Potentiometric Head. 22
Stream Flow Measurements 22
Low-flow Measurements. 22
Stream-gauge Measurements 23
Water Use 23
Water Quality 24
Surface Water 24
Groundwater 27
Alfalfa County 28
Kay, Grant, and Noble Counties . . 28
Hydraulic Conductivity 29
Published and Unpublished Reports. . . 29
Short-term Well-acceptance Tests . . . 29
Analysis of Transmissivity. 30
Grain-Size-Specific Method 32
Average Hydraulic Conductivity Method . 33
Comparison of Methods. 33

IV. GROUNDWATER-SURFACE WATER INTERACTION. 35

V. SENSITIVITY ANALYSIS 36

Sensitivity to Induced Infiltration. 36
Zone-of-Contribution Determination . . 36
Sensitivity Grid 39
Simulations 39
Sensitivity Classes 41
Effect of Limited Saturated Thickness . 42
Upgradient Sources. 43
Duration of Pumping 43
Sensitivity Map 43
Sensitivity Distances for Pump Rates
Above 100 gpm. 43
Sensitivity Patterns 44
Transmissivity, Gradient, and
Distribution of Classes. 45
Geographic Distribution of Classes. 45

VI. SUMMARY AND CONCLUSIONS 48

Chapter Page

Results 48
Conclusions 49

REFERENCES 51

APPENDIXES

A 53

B 55

C 58

LIST OF FIGURES

Figure		Page
1.	Map of the Study Area.	2
2.	Example of Induced Infiltration	8
3.	Stratigraphic Nomenclature of the Study Area	11
4.	Well Hydrograph.	20
5.	Water Use, Alfalfa County, 1991	25
6.	Water Use, Grant & Kay Counties, 1991	26
7.	Graph Showing Shift in Calculated Hydraulic Conductivity After 5 Hours of Pumping	31
8.	Pumping Well and Zone-of-Contribution	37
9.	Transmissivity and Zone-of-Contribution	40

LIST OF TABLES

Table		Page
1.	Rainfall (Inches) From NOAA Gauges	17
2.	Total Area, Percent Area, Transmissivity, and Gradient by Class	46

LIST OF PLATES

Plate		Page
1.	Aquifer Bottom Map	pocket
2.	Contour Map, Top of Water Table, July 1992 . . .	pocket
3.	Contour Map, Top of Water Table, December 1992	pocket
4.	Aquifer Sensitivity Map	pocket

SYMBOLS AND ABBREVIATIONS

EPA	Environmental Protection Agency
GIS	Geographic Information System
gpd	gallons per day
gpm	gallons per minute
K	Hydraulic Conductivity
NOAA	National Oceanic and Atmospheric Administration
OWRB	Oklahoma Water Resources Board
T	Transmissivity
TOT	Time of Travel
USACOE	United States Army Corps of Engineers
USGS	United States Geological Survey
XL	Downgradient null or stagnation point
YL	Stagnation point 90^0 to Downgradient
ZOC	Zone of Contribution
mg/L	milligrams per liter
TDS	Total Dissolved Solids

CHAPTER I

INTRODUCTION

The Alluvial and Terrace-alluvial[1] Aquifer of the Salt Fork of the Arkansas River is a fresh-water aquifer used for agricultural, municipal, and domestic purposes. Water wells located close to the Salt Fork River or to other bodies of surface water that contain elevated levels of chloride, are sensitive to induced infiltration. As pumping wells induce infiltration, degraded water quality will be produced from those wells, and the quality of water from the alluvial and terrace-alluvial aquifer will be affected as well.

Location of the Study Area

The study area is located largely in north-central Oklahoma, primarily in Alfalfa, Grant, and Kay counties; a small portion lies in the northwest corner of Noble County (Figure 1). The western edge is Range 12 West in Alfalfa County, while the eastern edge is the confluence of the Salt Fork and the Arkansas River in Kay County in Range 2 East.

---

[1] The term terrace-alluvial is used because paleo-sediments on terraces were originally deposited by alluvial systems.

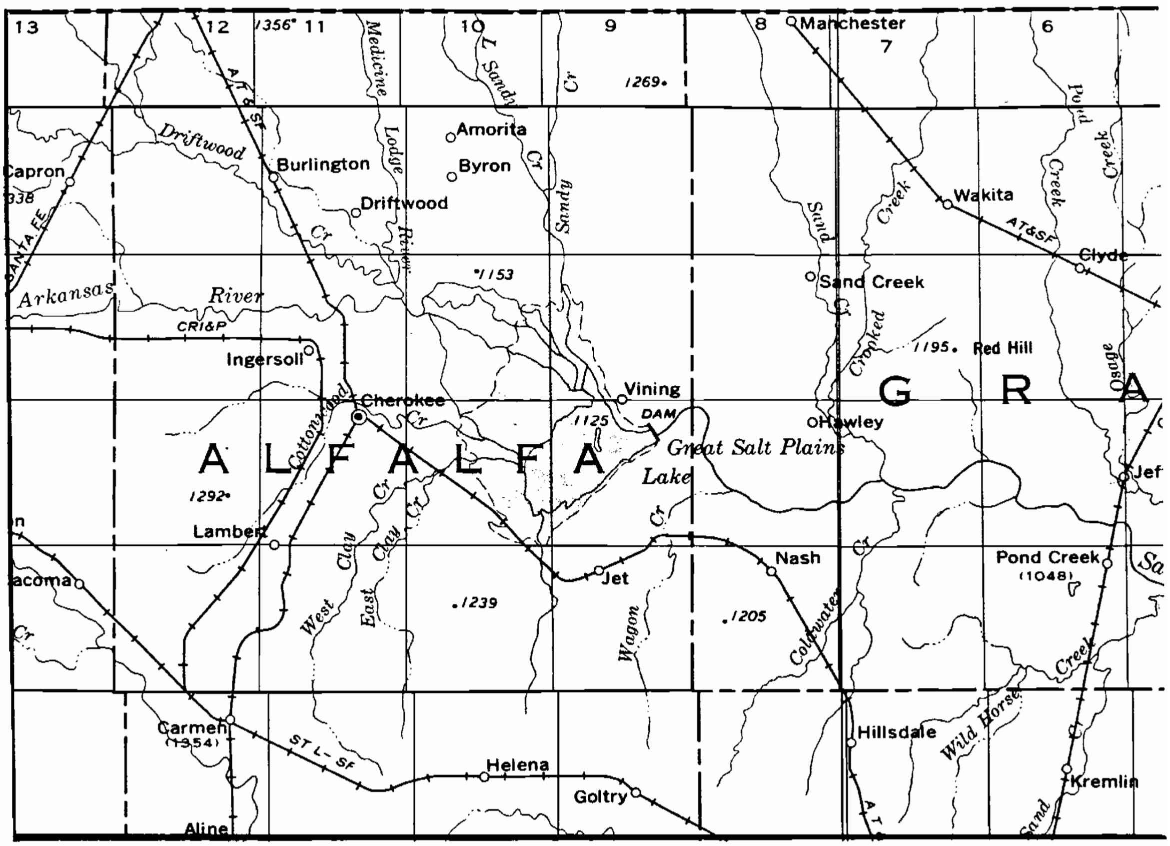
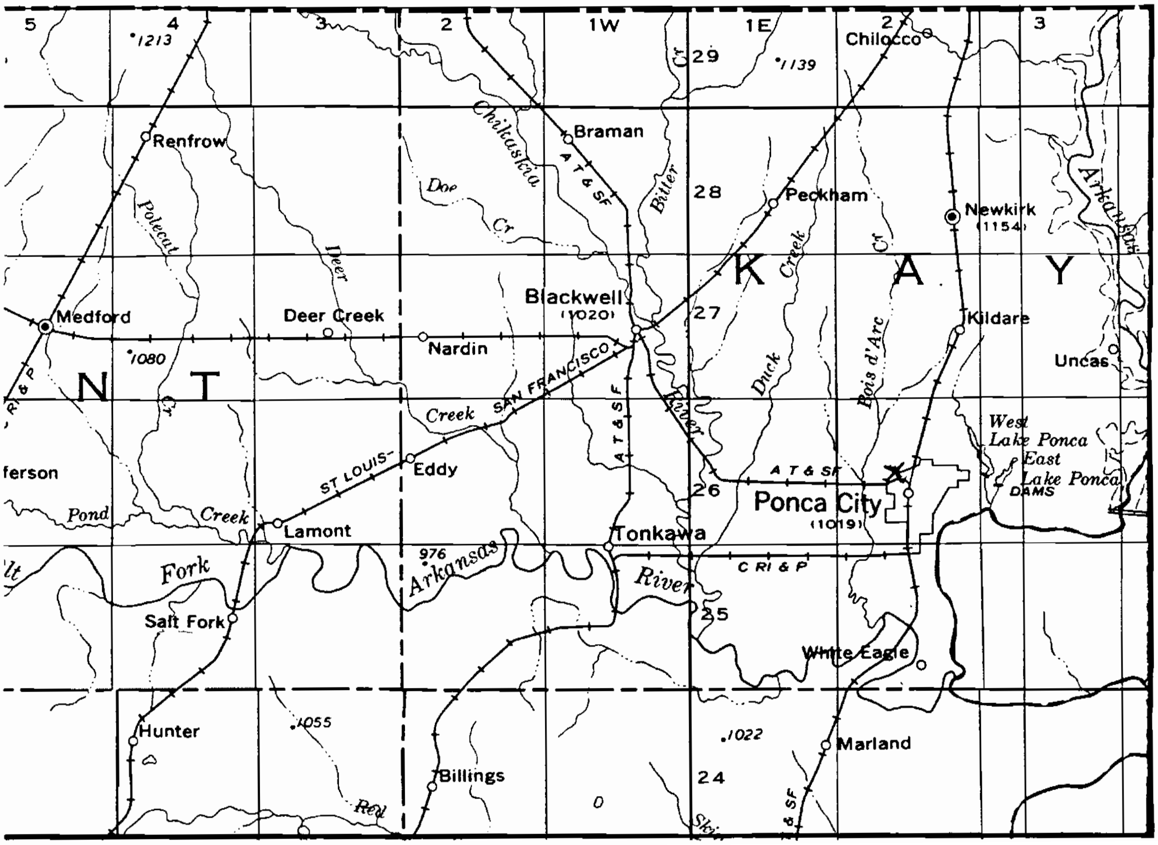


Figure 1. Map of the Study Area. (from USGS)
Scale: 1:500000


5
4
3
2
1W
1E
2
3
29
28
27
26
25
24
1213
1139
1080
976
1055
1022
Chilocco
Renfrow
Braman
Peckham
Newkirk
(1154)
Medford
Deer Creek
Nardin
Blackwell
(1020)
Kildare
Uncas
K
A
Y
N
T
ferson
Eddy
Lamont
Tonkawa
Ponca City
(1019)
Salt Fork
White Eagle
Hunter
Marland
Billings
West
Lake Ponca
East
Lake Ponca
DAMS
Polecat
Cr
Deer
Chikaskia
Doe
Bitter
Creek
Duck
Bois d'Arc
River
Pond
Fork
Arkansas
A T & SF
C RI & P
ST LOUIS-SAN FRANCISCO
Red

Objectives

The purpose of the study was to (1) develop insight into the groundwater-surface water interactions and their effects on water quality, and (2) to identify areas where well pumping could induce infiltration and degrade aquifer water quality.

Previous Work

The majority of geological and hydrogeological research in the study area has been in Alfalfa County, whereas Grant, Kay, and Noble counties have received less attention. Much of the work in Alfalfa County is attributable to the presence of the locally unique Great Salt Plains.

Theis (1934) studied the geology of the Great Salt Plains Reservoir (Figure 1) site prior to its construction. The earliest study of groundwater resources was done in the area around the city of Cherokee (Figure 1) by Schoff (1950). Permian salt and other evaporites of the area were studied by Jordan and Vosburg (1963). The majority of the research done in the area was conducted by the U.S. Army Corps of Engineers as part of the Great Salt Plains Reservoir and chloride control studies.

Fader and Morton (1972) evaluated the groundwater resources of Alfalfa, Grant, Kay, and Noble counties, which formed part of an investigation on the Middle Arkansas River Basin in Kansas and Oklahoma. Bingham, Bergman, and Morton

(1980) prepared hydrologic atlases showing both the geology and water resources of the area.

Methodology

A geographic information system (GIS) was utilized in producing two water-table maps, an aquifer-bottom map, and a map identifying areas sensitive to induced infiltration. Hydraulic gradient, transmissivity, and pumping rate were used to estimate the sensitivity distance. These data were used to determine the zone of contribution of a pumping well. The results were grouped into six classes based on the minimum safe-pumping distance.

Results

A review of the data on groundwater - surface water interactions revealed that the reach of the Salt Fork River, extending from the Great Salt Plains dam to eight miles downstream, is a losing stream. In this area the alluvial and terrace-alluvial aquifer would be impacted by chloride-laden stream water. In addition, groundwater from the bedrock in the vicinity of the Great Salt Plains Reservoir moves upward. It mixes with fresh groundwater and surface water, which results in a degradation of water quality.

Transmissivity of the Aquifer and position of a well relative to groundwater chloride plumes are the more important factors in determining sensitivity. The higher the transmissivity, the lower the sensitivity. All other factors being equal, areas located upgradient from sources of chloride are less sensitive than areas located downgradient. For a given pumping rate, the more sensitive areas are those with a low hydraulic gradient and low transmissivity.

In most of the study area, the aquifer has no sensitivity or low sensitivity to induced infiltration. Large areas of the aquifer are usable for municipal, industrial, or irrigation water without concern for inducing infiltration to pumping wells or degrading the aquifer water quality with chloride.

Locating wells beyond the minimum sensitivity distances would not only protect the water quality of the well, it would also prevent degradation of aquifer water quality.

CHAPTER II

BACKGROUND

Groundwater from the Alluvial and Terrace-alluvial Aquifer of the Salt Fork of the Arkansas River is used by irrigators, municipalities, and individual households. Surface water in the area has elevated chloride levels. Where wells are located close to the river or to other salt-impacted surface waters, the aquifer is sensitive to induced infiltration. Induced infiltration occurs when a pumping well creates head differences between the water-table and a surface water body, resulting in flow of surface water into the well (Figure 2).

Geographic Information System

All data collected for this project were input into computer databases, which allowed the use of a geographic information system (GIS) to produce maps specifically for this project. Oklahoma Water Resources Board (OWRB) databases, digitized United States Geological Survey (USGS) topographic maps and Oklahoma Geological Survey hydrologic atlases (Bingham, Bergman, and Morton, 1980) were also used. Legal descriptions from the OWRB well-inventory database

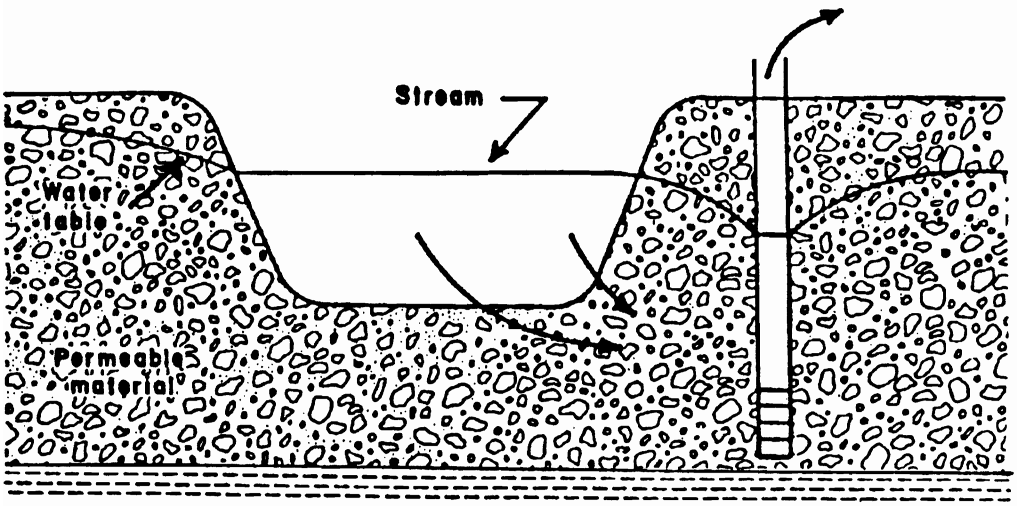


Figure 2. Example of Induced Infiltration. (after Pettyjohn and White, 1986)

were converted to a global reference system by the Oklahoma City office of the USGS, Water Resources Division.

Geography

The study area consists of approximately 800 square miles underlain by alluvial and terrace-alluvial deposits along the Salt Fork of the Arkansas River in Alfalfa, Grant, Kay, and Noble counties, Oklahoma (Figure 1).

The area consists of gently rolling prairie plains that are dissected and drained by the Salt Fork and its major tributaries: the Chikaskia and Medicine Lodge Rivers, Deer, Polecat, Bois d'Arc, Sand, Sandy, Pond, Crooked, and Driftwood Creeks (Figure 1).

The Great Salt Plains, a 10,000-acre saltflat, is located in the western portion of the study area (Figure 1). The saltflats surround the Great Salt Plains Lake, which was constructed by the U.S. Army Corps of Engineers in 1941. The lake covers 8,690 acres and has a conservation pool of 31,420 acre-feet.

Geology

Most of the geologic investigations in Alfalfa County in the vicinity of the Great Salt Plains were done by the USACOE. During their investigations hundreds of core holes were drilled through the Quaternary deposits and into bedrock to depths as great as 300 feet.

Quaternary Alluvial and Terrace-alluvial Deposits

The alluvial and terrace-alluvial deposits of the Salt Fork of the Arkansas River are of Quaternary age. They are comprised of gravel, sand, silt, and clay. Dune sands are present in parts of the area. The deposits are quite broad in Alfalfa County, blanketing a large portion of the county and beyond into Kansas. In that county, these sand deposits extend south from the Kansas border for a distance of about 23 miles. From western Grant to Kay and Noble counties the deposits narrow and extend along the river, where they range from one to five miles wide. The thickness of the deposits range from a few feet up to 120 feet.

Bedrock

The bedrock formations underlying the Quaternary deposits primarily are siltstones and shales of Permian age. A small area at the eastern-most portion of the study area, near the confluence of the Salt Fork River and the Arkansas River, is underlain by shales and limestones of the Oscar Group of Pennsylvanian age. Bedrock in the eastern half of the study area dips west to southwest, while in the western half, the dip is south and southwest. Older formations are exposed in the eastern portion of the study area, and younger rocks crop out in the western portion (Bingham and Bergman, 1980; Morton, 1980). The younger rocks are early Permian in age and contain salt beds (Figure 3). The Lower

Quaternary	Alluvial and Terrace Deposits
Permian	Cedar Hills Formation
	Salt Plains Formation
	Harper Formation Kingman Member Chikaskia Member
	Lower Cimarron Salt
	Hennessey Shale / Garber Sandstone
	Wellington Formation
Pennsylvanian	Oscar Group

Figure 3. Stratigraphic Nomenclature of the Study Area. (after USACOE, 1981 and Morton, 1980)

Cimarron Salt underlies a portion of Alfalfa County, whereas the Lower Wellington Salt appears to underlie a large portion of the study area (Jordan and Vosburg, 1963).

Permian

Clastic rocks of Permian age primarily are composed of siltstone and shale with some sandstone. Evaporites sequences containing halite and anhydrite are also present.

Cedar Hills Formation. The Cedar Hills Formation crops out only in the western part of the study area west of Cherokee (Figure 1). The Cedar Hills contains units that range in thickness from 3 to 30 feet. These consist of red-brown to orange-brown coarse-grained siltstone and very fine-grained sandstone. The siltstones and sandstones are interbedded with red brown shales, which range from 1 to 10 feet in thickness. The Cedar Hills sandstone which ranges in thickness from 170 to 180 feet (USACOE, 1981), is the youngest bedrock unit exposed in the study area. It serves as an aquifer in the western part of Alfalfa County.

The Salt Plains Formation. The Salt Plains Formation is primarily a red-brown siltstone, although it also contains a few beds of very fine-grained sandstone and red-brown shale. Test drilling indicated that it is present in the area west of the Great Salt Plains Reservoir and that the thickness is about 250 feet (USACOE, 1981).

Harper Formation. The Corps of Engineers divides the Harper Formation into the Kingman and the Chikaskia Members[2].

The Kingman Member is the younger of the two members. It largely contains pale reddish-brown to orange-brown coarse-grained siltstones that range from 3 to 20 feet thick. Some interbeds of fine-grained sandstone also occur. Thickness of the Kingman ranges from 70 to 90 feet (USACOE, 1981). "The Kingman Member is of special importance because its siltstone and sandstone beds are the main aquifers carrying high salinity brine [sic] upwards into the overlying alluvial and lacustrine deposits of Great Salt Plains" (USACOE, 1981, p. A5-8).

The Chikaskia Member can be divided into three submembers. At the bottom is a siltstone with some interbedded shale that ranges from 70 to 120 feet thick. The middle subunit is a red-brown shale with gray-green spots. It is around 25 feet thick, and informally is called the speckled shale. At the top are interbedded layers of shale and siltstone that range from 25 to 30 feet thick. The siltstones have been described as having relatively high permeability (USACOE, 1981).

Lower Cimarron Salt. The Lower Cimarron Salt is present at shallow depths under the western part of the saltflats near the Great Salt Plains Reservoir. It ranges

---

[2] Informal usage, the Code of Stratigraphic Nomenclature requires a lithology type be part of the member name.

in thickness from 80 to 120 feet in the western part of Alfalfa County. In some test core holes under the saltflats, the rock unit is as thin as ten feet. It is not present east of the reservoir. This unit is mainly composed of red-brown and gray shale with siltstone. It contains salt layers with stringers of anhydrite in the western part of Alfalfa County and salt veins and nodules near the Great Salt Plains. The Lower Cimarron Salt is the logical source of chloride that discharges near the Great Salt Plains (USACOE, 1981).

Hennessey Shale / Garber Sandstone. Shales of the Hennessey Group overlie the Wellington Formation. Clastic units overlying the Wellington are called the Hennessey Shale in western Oklahoma and Garber Sandstone in central Oklahoma (Jordan and Vosburg, 1963). Bingham, Bergman, and Morton (1980) include the Fairmont Shale within the lower part of the Hennessey Group. The Fairmont is red-brown blocky shale with some siltstone. The Garber is largely an orange-brown, fine- to medium-grained quartzose sandstone and conglomerate grading to the northward into shale and siltstone (Morton, 1980).

Wellington Formation. In the area of this investigation, the Wellington Formation is the oldest Permian rock-stratigraphic unit. The Wellington overlies the Pennsylvanian age Oscar Group. Strata of the Wellington contain halite and anhydrite in the lower part. These evaporites have been shown to underlie Alfalfa and Grant counties (Jordan and Vosburg, 1963). At the surface, the Wellington is red-brown shale that grades southward into a fine-grained sandstone and mudstone conglomerate (Bingham and Bergman, 1980).

Pennsylvanian

In the easternmost part of the study area, the Permian section is not present. In this area Quaternary alluvial deposits overlie the Oscar Group of Pennsylvanian age.

Oscar Group. The Oscar Group consists of shale and abundant limestone. This group crops out along the easternmost part of the study area near the confluence of the Salt Fork River and the Arkansas River.

CHAPTER III

DATA REVIEW

Precipitation

Precipitation data in a digital format were obtained from the NOAA rain gauges at Cherokee, Jefferson, Great Salt Plains Dam, and Ponca City (Figure 1). During 1992 and 1993, generally precipitation was greater than normal (Table 1). In 1992 the Ponca City gauge recorded the greatest amount of rain (43.1 inches) of all the gauges, which represented a 6.7- inch increase over 1991. The Great Salt Plains Dam station recorded the lowest total rainfall with 33.5 inches, an increase of 9.1 inches over 1991. During 1993 precipitation ranged from 34.8 inches at Jefferson to 41 inches at Ponca City. In general, precipitation in 1992 and 1993 was greater than both 1991 and the 30-year averages for these rain gauges, except for the Jefferson gauge where the 1992 and 1993 totals were below the 30-year average (39 inches). The 30-year annual average is 34.6 inches for Ponca City and 28 inches for Great Salt Plains Dam. Increases in precipitation over the 1991 totals appear to be reflected by higher groundwater levels, as discussed below.

TABLE 1.

RAINFALL (INCHES) FROM NOAA GAUGES.

Station Name	1991	1992	1993	30 yr. AVG
Ponca City	36.4	43.1	41.0	34.6
Cherokee	26.9	37.0	38.6	27.7
G. Salt Plains	24.4	33.5	39.1	28.0
Jefferson	24.2	34.7	34.8	39.0

Runoff ranged from approximately 0.5 inches in the western part of the study area to 4 inches in the east during the period 1970 to 1979 (Pettyjohn and White, 1986).

Aquifer-bottom Elevations

Sufficient data were available from drillers' logs to determine the altitude of the aquifer base (top of bedrock) in 423 wells in the study area (Plate 1). Low areas of bedrock occur in two places, the first of which is along the river bed, and this is due to erosion. A second low area, which is a large bowl-shaped depression, is located in Alfalfa County, and within this low lies the Great Salt Plains Reservoir.

Water Level Measurements

Selection of Wells

The OWRB has nine network wells in the groundwater basin for which water levels have been measured annually since 1975. Forty-five additional wells were added to the network for this study. These wells were selected by conducting a record search of drillers' logs and a field survey. Well depth, screened interval, spatial distribution, and accessibility were evaluated in selecting the wells. Locations of selected wells are shown on the water-table maps (Plates 2 and 3), and data are listed in Appendix B. Water levels were measured in these wells monthly for over a year, except during intervals when weather conditions made roads impassible.

Water-level Trend

Water levels generally rose during the period from April 1992 to April 1993, and the rise averaged four feet. The average rise ranged from 4.69 feet in Grant County to 3.7 feet in Alfalfa County. These changes in levels reflect the increase in precipitation and groundwater recharge coupled with a decrease in water use. A typical well hydrograph is shown in Figure 4.

Hydrogeology

Water-table Maps

Two water-table maps were prepared, using water levels from the OWRB network of wells (Appendix B) to represent winter (December 1992) and summer (July 1992) conditions (Plates 2 and 3). These months were selected because they differ seasonally and therefore were expected to show the greatest deviation. The summer map shows the effects of irrigation and evapotranspiration, while in December these stresses are negligible.

Groundwater Flow

The water-level maps (Plates 2 and 3) show little evidence of seasonal variation in the hydraulic gradient. Both maps indicate that groundwater in Kay and Grant

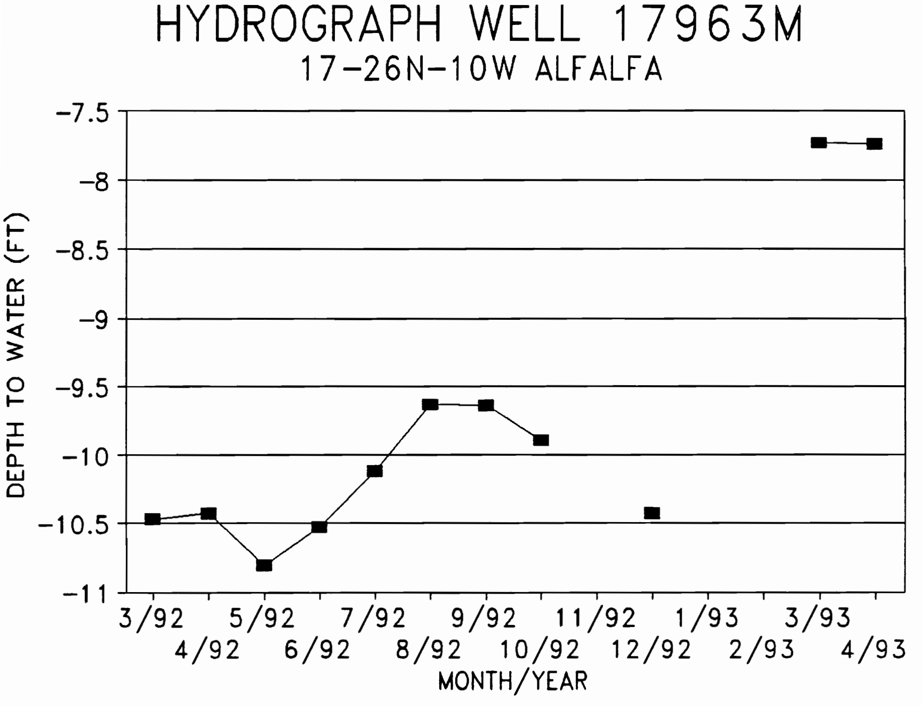


Figure 4. Well Hydrograph.

counties discharges into the river. Where contours point upstream, the river gains in discharge. The water-level maps (Plates 2 and 3) show a bowl-shaped groundwater basin in Alfalfa County centering on the Great Salt Plains Reservoir. Because this groundwater basin is a closed system, all groundwater discharges into streams that flow into the Great Salt Plains reservoir, except for any minor amounts that might seep into bedrock.

Groundwater Divide

The water-table maps (Plates 2 and 3) indicate that the alluvial and terrace-alluvial deposits of the Salt Fork of the Arkansas River, consist of two hydrologically separate groundwater basins. A groundwater divide occurs on the eastern edge of the Great Salt Plains reservoir, where hills provide the eastern limits of the reservoir. This divide coincides closely with the Alfalfa - Grant countyline at Range 8 West, as can be seen on Plates 2 and 3. One groundwater basin is in Alfalfa County and the other is in Grant, Kay, and Noble counties.

Hydraulic Gradient

In general, flow direction in Kay and Grant counties is toward the river, and in Alfalfa County toward the Great Salt Plains Reservoir. The average hydraulic gradient varies from 0.002 in Grant County to 0.0034 in Alfalfa County.

Saturated Thickness

The average saturated thickness of the aquifer is 22 feet. The average saturated thickness by county, is 26 feet in Alfalfa, 25 feet in Grant, and 15 feet in Kay. The total saturated thickness ranges from a few feet to 110 feet.

Bedrock Potentiometric Head

The Corps of Engineers, as part of the Chloride Control Project, drilled numerous borings and core holes into bedrock in the area of the Great Salt Plain Reservoir. They found that the potentiometric surface of the bedrock aquifer is above the lake bottom as well as the water table in the surrounding area. In one area south of the lake, the head in the bedrock is as much as 18 feet above the water table. This indicates that water is discharging upward from the bedrock into the lake and into the alluvial and terrace-alluvial deposits (USACOE, 1981).

Stream Flow Measurements

Because stream flow measurements can provide indications of groundwater - surface water interaction, total discharge measurements from USGS gauging stations, and available low-flow discharge measurements were reviewed.

Low-flow Measurements

Winter stream-flow measurements were taken along the Salt Fork of the Arkansas River and its tributaries, as part of the Arkansas River Chloride Control Project.

Measurements along the stretch from Ingersoll (Figure 1) to the Great Salt Plains Reservoir indicated that the river was neither gaining nor losing. From below the dam to eight miles downstream, the Salt Fork River was losing. It then became a gaining stream and remained that way up to its confluence with the Arkansas River (SYN-AN, 1975).

Stream-gauge Measurements

Discharge records for calendar years 1991 and 1992 from USGS gauges on the Salt Fork of the Arkansas were reviewed. The Jet gauge recorded a total discharge of 107,314 acre-ft of water in 1991 and 305,538 acre-ft of water in 1992. The Tonkawa gauge indicated a total discharge of 210,350 acre-ft of water in 1991 and 762,080 acre-ft of water in 1992. The threefold increase in discharge reflects the increase in precipitation.

Water Use

OWRB reported water use data were reviewed for calendar years 1991 and 1992. The OWRB groups water use into five categories: irrigation; public water supply; mining; commercial; and recreation, fish, and wildlife. Since there are two groundwater basins in the area studied, the water use was divided by basin.

Figures 5 and 6 show that public water supply category had the largest reported use of groundwater in both basins.

Data for 1991 were chosen for Figures 5 and 6 because they were judged to be more representative of average water use than data from 1992. Usage in 1992 for some categories, such as irrigation, was reduced due to the high rainfall. The reported public water supply use for 1991 exceeded 575 million gallons in Alfalfa County, whereas Kay and Grant counties' combined use exceeded 683 million gallons. Use of groundwater in Alfalfa County was reported in the irrigation category; and the recreation, fish and wildlife category. Kay and Grant counties had much less use in these categories than Alfalfa County.

Water Quality

Surface Water

The Great Salt Plains Reservoir has high chloride levels, and discharge from this reservoir is the major source of chloride in the river. Generally, better quality water is found in tributaries of the Salt Fork of the Arkansas. In Alfalfa County, groundwater is affected by saline water discharge from the bedrock, especially in the vicinity of the Great Salt Plains Reservoir. In areas where the potentiometric surface is above the top of bedrock, saline water moves upward to mix with fresh water in the overlying alluvial and terrace-alluvial deposits. Groundwater also discharges to streams in these areas of upward leakage, degrading the streams with chloride. In other areas of the county upgradient of the discharges, the water generally is lower in chloride.

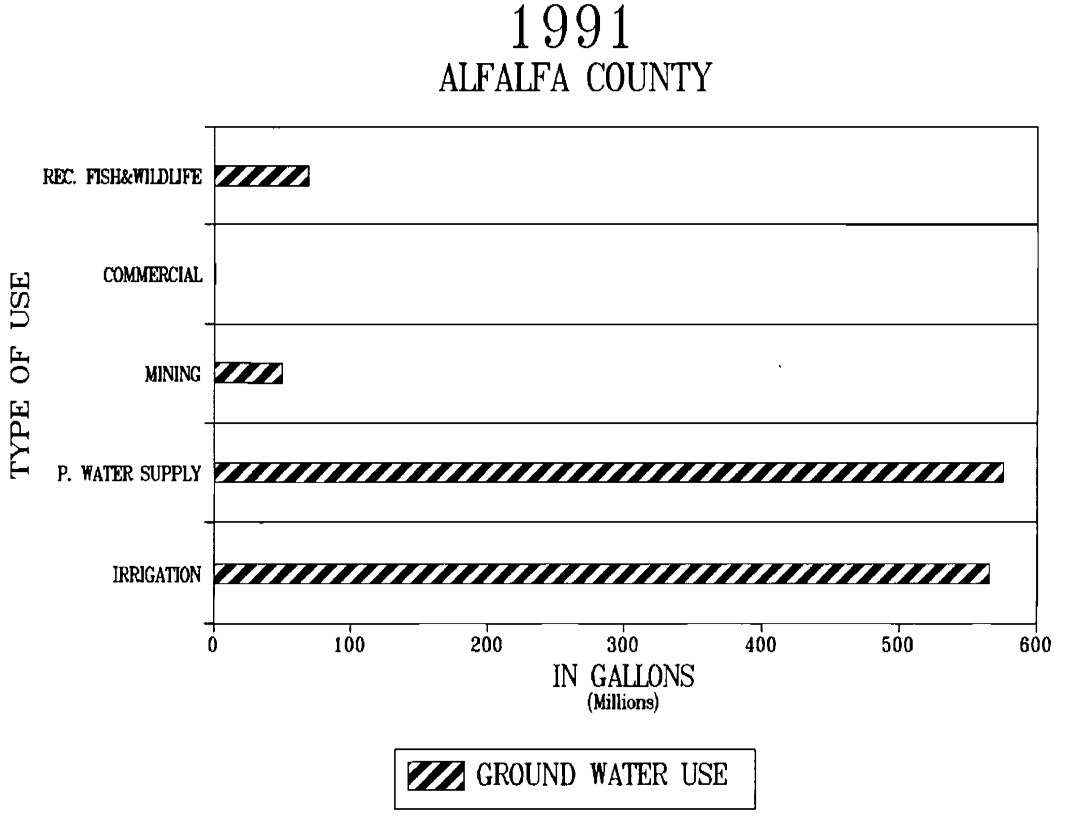


Figure 5. Water Use, Alfalfa County, 1991

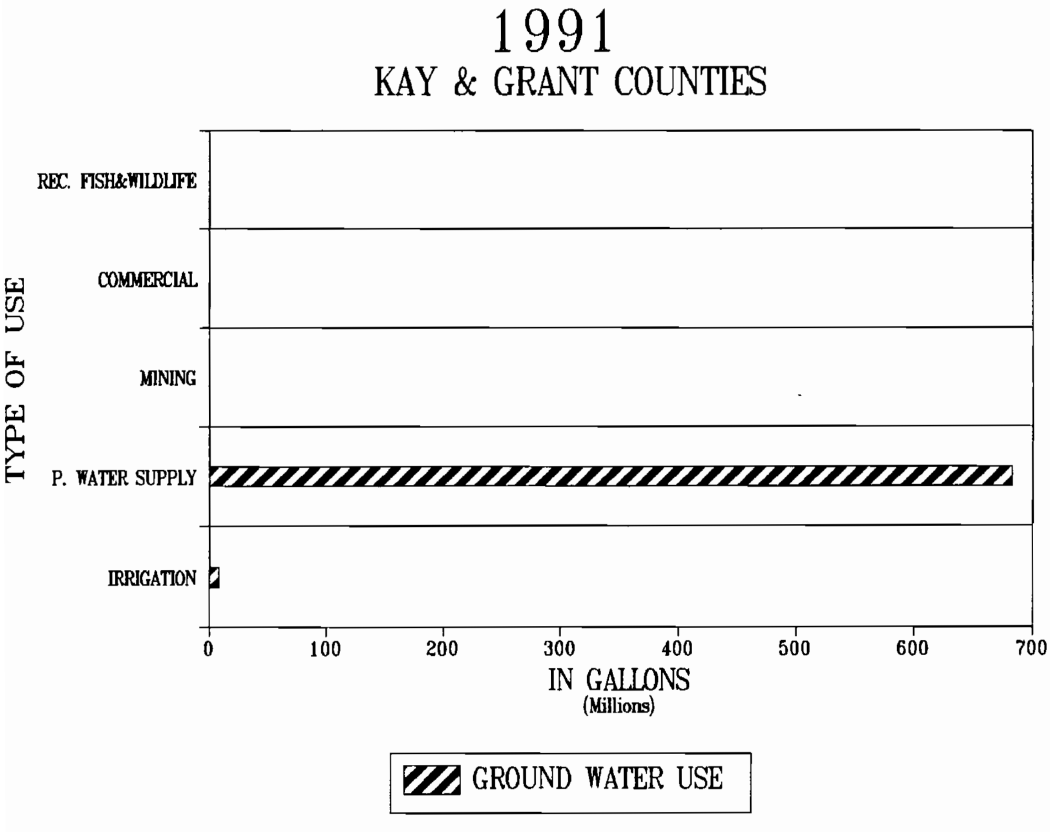


Figure 6. Water Use, Grant & Kay Counties, 1991

A sample of water taken near Ingersoll (Figure 1) in section 14 of T27N, R11W near the western edge of the study area, showed a chloride concentration of 220 mg/L. Farther east in Alfalfa County where the potentiometric head in bedrock is above the water table, groundwater discharge to streams is saline. Chloride concentrations in samples from this area ranged from 205 to 29,300 mg/L (SYN-AN, 1975). This chloride-laden surface water flows into the Great Salt Plains Reservoir and degrades the lake's water quality.

Downstream from the reservoir, the river's water quality improves with distance from the dam, due to fresh-water dilution by the tributaries, by surface runoff, and by groundwater discharge from the alluvial and terrace-alluvial deposits. Chloride concentrations of the river ranged from 1,190 mg/L at the highway bridge north of Nash (Figure 1), in section 11, T26N, R9W to 540 mg/L in section 31, T25N, R2E a few miles above the confluence with the Arkansas River. Dilution is the greatest from the Chikaskia River, the largest tributary (SYN-AN, 1975).

Groundwater

Until 1992, the OWRB maintained a network of wells monitored for ambient water quality in this aquifer. From 1986 to 1991, sixty-eight samples were collected from 34 wells and submitted for laboratory analysis. Chloride concentrations had a mean value of 118 mg/L and a median value of 24 mg/L. The chloride samples had values that ranged from 10 to 2,266 mg/L. The mean concentration of total dissolved solids was 842 mg/L, and the median concentration was 544 mg/L. The range in concentrations for these samples extended from 86 to 6,934 mg/L (OWRB, 1993). The EPA secondary drinking water standard is 250 mg/L for chloride and 500 mg/L for TDS.

Alfalfa County

The USACOE identified a large groundwater chloride plume in Alfalfa County that mainly surrounds the Great Salt Plains Reservoir. The highest chloride concentrations are adjacent to the lake where they exceed 100,000 mg/L. Although concentrations decrease rapidly away from the reservoir, there are large areas where the 250 mg/L secondary drinking water standard is exceeded (Plate 4).

Kay, Grant, and Noble Counties

In Kay, Grant, and Noble counties, groundwater quality in areas immediately adjacent to the river is degraded by chloride. As part of the Chloride Control Project, a series of monitor wells was installed in directions generally transverse to the river at three locations in Grant and Kay counties. In general, chemical analysis of water from these wells adjacent to the river showed the highest chloride levels, with the concentrations decreasing with distance (EEI, 1987).

Hydraulic Conductivity

Two sources of hydraulic conductivity data were reviewed for this report. The first included published and unpublished reports. The second was short-term well-acceptance data.

Published and Unpublished Reports

Fader and Morton (1972) published estimates of hydraulic conductivity values of 130 to 400 ft/day (970-3000 gpd/ft^2) in alluvial deposits and 65 to 200 ft/day (490-1500 gpd/ft^2) in terrace deposits in Alfalfa, Grant, and Kay counties. Allison (1974), in a published report, referred to a series of pump tests conducted by USACOE in Alfalfa County which produced values of hydraulic conductivities ranging from 3 to 100 ft/day (20-750 gpd/ft^2).

Results from an unpublished report documenting a series of pump tests conducted at the City of Medford's wellfield in Grant County, indicate hydraulic conductivity values there range from 125-451 ft/day (940-3370 gpd/ft^2) (RJ Systems, 1985).

Short-term Well-acceptance Tests

A review of drillers' logs found 91 wells with short-term well-acceptance tests in which the data were sufficiently complete for use. Test data for wells that lacked essential information or that partially penetrated the aquifer were rejected. Data for the acceptable wells were input into the OWRB's T-O-T computer program, which calculates hydraulic conductivity and transmissivity from well-acceptance test data (OWRB, 1992).

Hydraulic conductivities calculated range from 2 to 1004 ft\day (15-7500 gpd/ft^2), with an average value of 210 ft/day (1570 gpd/ft^2). A graph of hydraulic conductivity (using the values generated by the T-O-T program) versus pumping time is shown in Figure 7. The graph shows a distinct increase in hydraulic conductivity values when pumping exceeds five hours. Virtually all wells with acceptance tests of less than five hours have a calculated hydraulic conductivity that is less than 100 ft/day (750 gpd/ft^2), and all wells with longer pumping times have conductivities over 100 ft/day. This shift indicates data from tests with pumping times less than five hours could produce underestimates of hydraulic conductivity.

Of the original 91 wells, only 36 were pumped for pumping times that exceeded five hours. These had conductivities ranging from 55 to 1,004 ft/day (410-7500 gpd/ft^2), with an average value of 323 ft/day (2420 gpd/ft^2). Overall, values calculated from the short-term well-acceptance test data fall within the range of values from the published and unpublished data mentioned above (Appendix A).

Analysis of Transmissivity

Because aquifer test and well acceptance test data were limited, information about saturated thickness and lithology from 423 drillers' logs was used to expand the number of

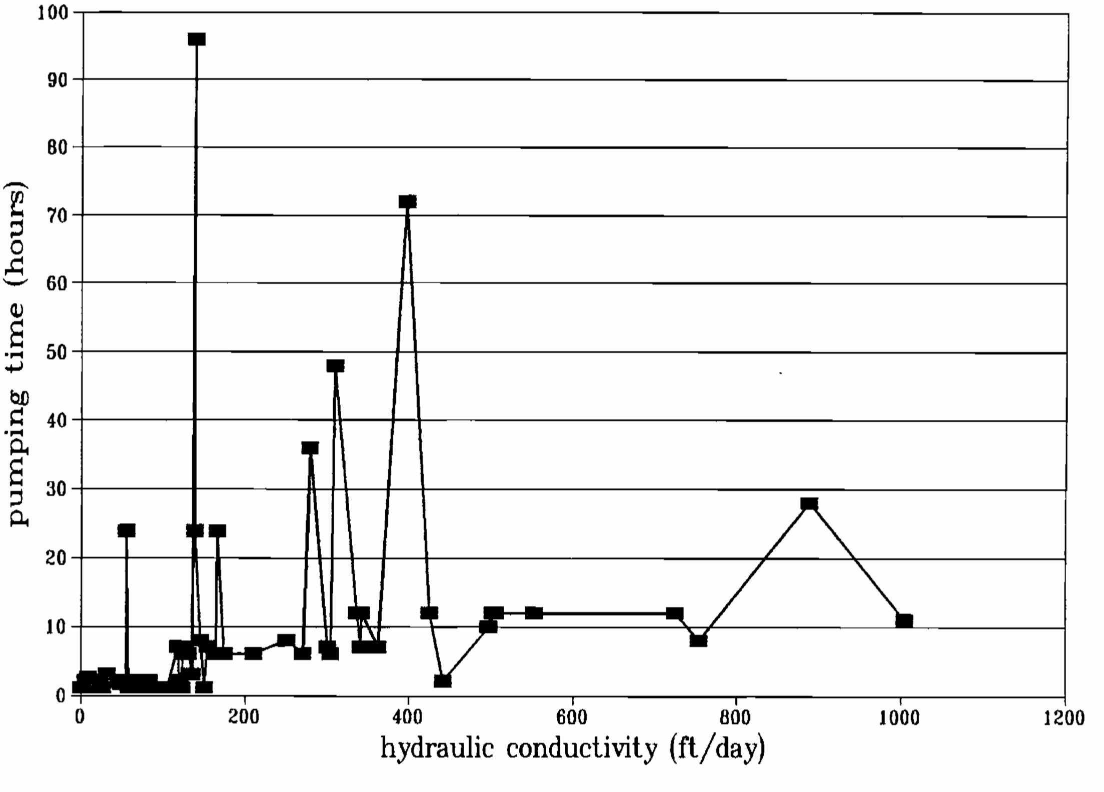


Figure 7. Graph Showing Shift in Calculated Hydraulic Conductivity After 5 Hours of Pumping.

data points. Two approaches to calculating transmissivity (T) were considered and evaluated. The first method applies grain-size-specific hydraulic conductivity values for different unconsolidated materials of the saturated interval in a well, whereas the second uses a single hydraulic conductivity for the entire saturated thickness, regardless of grain-size changes.

Grain-Size-Specific Method

Method one, modified from Kent and others (1973 and 1982), describes an approach to estimating hydraulic conductivities from a grain-size envelope. The envelope is developed from laboratory and pump-test data. This envelope can be used to estimate hydraulic conductivity from grain-size descriptions recorded on drillers' logs.

Sample descriptions from all available drillers' logs were reviewed, and saturated lithology was divided into three groups based on grain-size description. Coarse sand and gravel were assigned to Class 1, fine to medium sand to Class 2 and silt, silty clay and clay to Class 3. Total saturated thickness of each class was recorded.

Hydraulic conductivities for Classes 1 and 2 were determined using the acceptance-test data described above. Wells were selected in which the entire saturated thickness was composed of materials of Class 1. Hydraulic conductivities of this set were averaged. The same procedure was followed for the materials of Class 2. Based on the averages, Class 1 was assigned a hydraulic conductivity of 455 ft/day (3400 gpd/ft^2), and Class 2 was assigned a hydraulic conductivity of 30 ft/day (220 gpd/ft^2). Since none of the wells had only materials of Class 3, this class was assigned a hydraulic conductivity of 0.5 ft/day (4 gpd/ft^2) based on the value used by Kent and others (1982).

Transmissivity for each well was then calculated using the following formula:

$$T_{lith} = \text{(K * total saturated thickness Class 1)} + \text{(K * total saturated thickness Class 2)} + \text{(K * total saturated thickness Class 3)}.$$

Average Hydraulic Conductivity Method

The second method was simply to take an average hydraulic conductivity for the aquifer and multiply it by the saturated thickness:

$$T_{avg} = K_{avg} * \text{saturated thickness.}$$

Comparison of Methods

The set of wells with acceptance-test data that produced a known transmissivity value ($T_{acctest}$) was used as a benchmark to test against the two methods described above.

Comparison of the two methods revealed that the T_{lith} value more closely approached the benchmark value 55 percent of the time. Because this method produced a slightly better result, hydraulic conductivities generated by this method were used in the determination of the sensitivity of the aquifer to induced infiltration as described below.

CHAPTER IV

GROUNDWATER-SURFACE WATER INTERACTION

In studying groundwater-surface water interactions, base-flow measurements are useful. As mentioned above, measurements taken in 1975 by SYN-AN indicated that the Salt Fork of the Arkansas River is a gaining stream from the Great Salt Plains Reservoir to eight miles below the dam, but the resolution of the water table maps is not sufficient to verify this.

A losing stretch of river in the area below the dam, where chloride is high, would allow salt water to infiltrate into the aquifer and contaminate it. This could have an impact on the sensitivity distance since the chlorides in groundwater could extend well beyond the river banks. No analyses were found that could help detect and delineate this possible groundwater contamination.

The impact of chlorides along this losing stretch is not taken into account in the sensitivity analysis below. Operators installing wells in the losing stretch should exercise extra caution, and they should use a distance greater than that recommended below. Other aspects of groundwater - surface water interactions, such as the impact of chloride-laden groundwater on surface water, are described in other sections of the report.

CHAPTER V

SENSITIVITY ANALYSIS

Sensitivity to Induced Infiltration

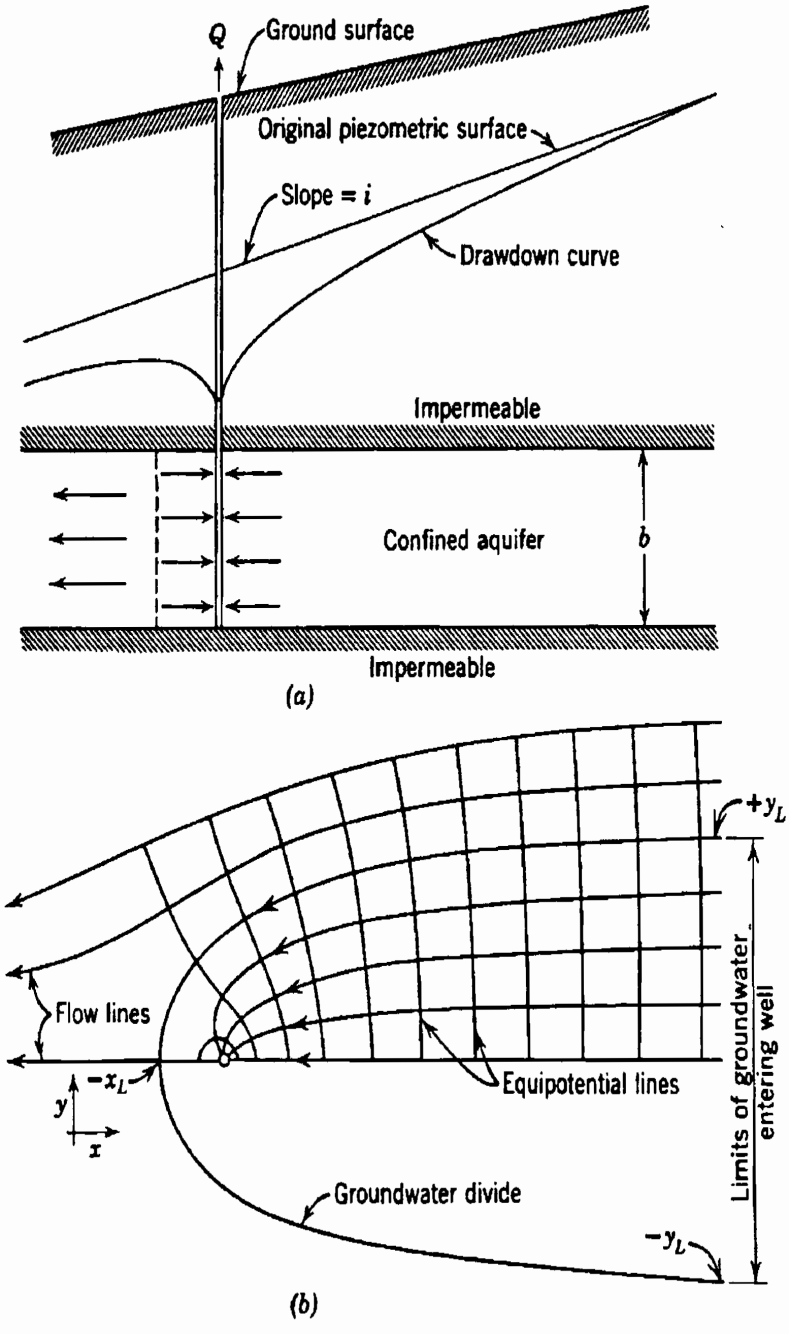
The sensitivity of a particular well to induced infiltration is dependent on the size and shape of the zone-of-contribution of the pumping well and the distance from the source. Figure 8 shows the zone-of-contribution formed by a pumping well.

Zone-of-Contribution Determination

In Grant and Kay counties, it is not necessary to determine the entire capture zone of a well because the source, the river, is located downgradient to any potential wells. Only the downgradient extent is needed to establish the sensitivity. The sensitivities of wells to induced infiltration were calculated using the formula for the downgradient null point of a pumping well. The formula is:

$$X_L = -\frac{Q}{2\pi Kbi}$$

where X_L is the downgradient null or stagnation point, Q is the pumping rate in ft^3/day, K is the hydraulic conductivity in ft/day, b is the aquifer thickness in feet, and i is the hydraulic gradient (Todd, 1980). This formula assumes a



SOURCE: TODD, 1980

Figure 8. Pumping Well and Zone-of-Contribution

stabilized cone of depression. No induced infiltration of chloride-laden water at locations beyond the null point could occur.

Groundwater and lake water are sources of chloride in Alfalfa County. Here it is necessary to consider the entire capture zone because sources can be upgradient or cross-gradient to a potential well. The maximum distance perpendicular to the flow direction (Y_L) can be determined by the formula (Todd, 1980):

$$Y_L = \pm \frac{Q}{2Kbi}$$

Where salt water contamination is located upgradient of a well, the time-of-travel (TOT) must be considered since the upgradient water is moving toward the cone of depression. The time-of-travel can be calculated by the following formula:

$$TOT = (v_r)\ (t) + (v_p)\ (t)$$

where v_r is the regional velocity of groundwater in ft/day, v_p is the velocity of groundwater due to pumping in ft/day, and t is the length of time in days for which the TOT is being calculated (USEPA, 1987). TOT is the distance the groundwater will have traveled in a given period of time.

Differences in transmissivity produce changes in the shape of the zone of contribution formed by pumping wells.

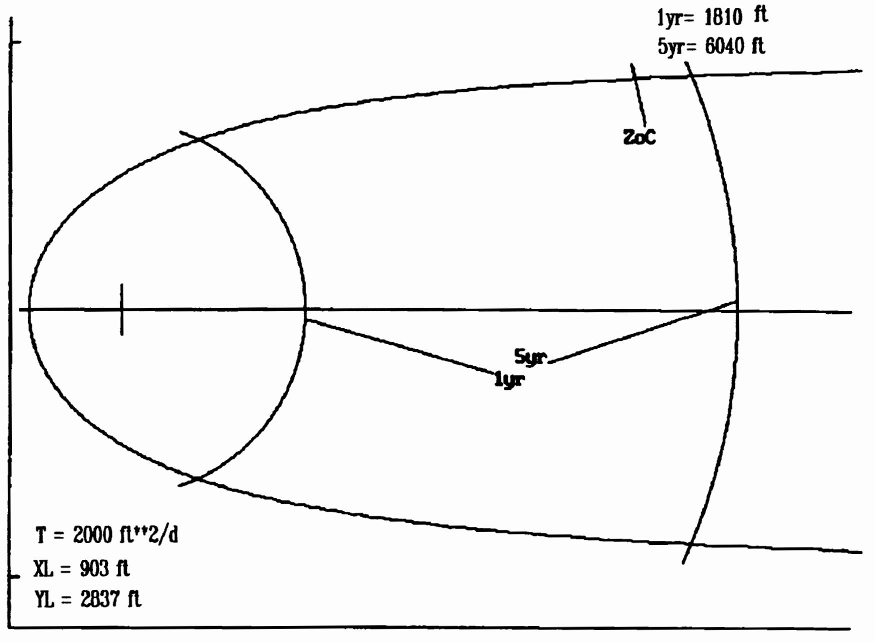
Where wells are located in high transmissivity materials, the zones of contribution tend to be longer and narrower than those produced by wells located in low transmissivity materials (Figure 9).

Sensitivity Grid

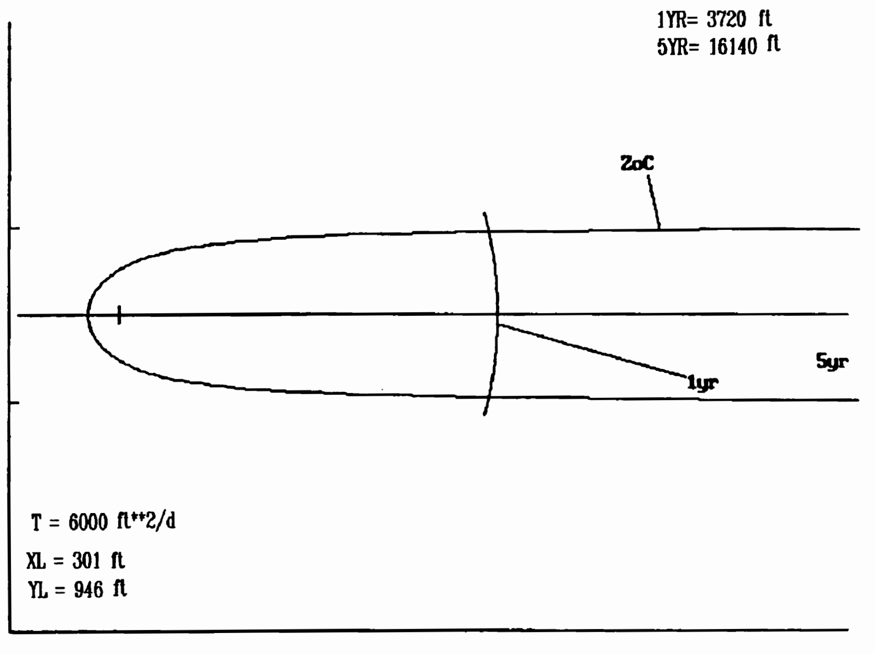
Preliminary sensitivity analysis indicated that a one-mile distance would not be exceeded in most cases. A grid for the sensitivity map was made by utilizing the one-square-mile grid of the Public Land Survey System. Sections included in the grid were those that would touch on a line projected a distance of one mile from the Salt Fork of the Arkansas River in Grant and Kay counties. In Alfalfa County upgradient of the Great Salt Plains Dam, sections were selected that would touch on a line projected one mile from the outer edge of areas where chloride concentrations in groundwater exceeded 250 mg/L. The chloride concentration map of Alfalfa County was taken from USACOE (1976). Each section in a township within the selected areas was treated as a cell and a value for each variable in the formula assigned to each cell. This produces an average sensitivity for each square-mile section.

Simulations

The null point (X_L) and cross-gradient extent (Y_L) were calculated for simulated pumping rates of 100, 250, 500, and 1000 gallons per minute (gpm) (Appendix C). A transmissivity (T) map was prepared using values determined



(a)



(b)

Figure 9. Transmissivity and Zone-of-Contribution:
(a) Low Transmissivity.
(b) High Transmissivity.

as described above, and an average transmissivity value was assigned for each section. The minimum transmissivity value used was 500 ft^2/day, unless available well data indicated that a smaller value should be used. The hydraulic gradient was estimated by examining the December water-table map because that month would not likely be influenced by irrigation pumping. For areas beyond the well network or in areas with limited well control, hydraulic gradient was assigned by examining the slope of the land surface and the regional hydraulic gradient. The values of transmissivity and hydraulic gradient used in the simulations are given in Appendix C.

Sensitivity Classes

A determination was made as to which direction, X_L, Y_L, or upgradient, would be the most sensitive in relation to the source. Sensitivity-distance calculations were grouped into six classes based on the 100-gpm pumping rate. That rate was chosen because it would be achievable more often than the higher pumping rates. The sensitivity classes are:

Class:	Sensitivity Distance:	
1	< or = 500 feet	Least sensitive
2	501 -1000 feet	
3	1001-2000 feet	
4	2001-3000 feet	
5	3001-4000 feet	
6	> 4000 feet	Most sensitive

A well pumping 100 gpm in a Class 1 (least sensitive) area would not induce infiltration of water with elevated chloride as long as it was located more than 500 feet from the source. A Class 5 well that would remain uncontaminated would have to be located at a distance in excess of 4000 feet from a chloride plume. For a given pumping rate, the more sensitive areas are those with low hydraulic gradients and low transmissivities.

Keeping wells located beyond the minimum sensitivity distance would not only protect the water quality of the well, it would also avoid degrading aquifer quality. Salt water contamination induced into a well's zone-of-contribution could remain in the aquifer for years after the contaminated well was abandoned.

Effect of Limited Saturated Thickness

The yield of a well is dependent on saturated thickness and transmissivity. For instance, a well with a transmissivity of 500 ft^2/day would, in a 100 percent efficient well, require a theoretical minimum 43 feet of saturated thickness to maintain a continuous pumping rate of 100 gpm. If that thickness was available, the null point could extend more than 3000 feet downgradient from the well and the cross-gradient extent could be as much as 9400 feet. If the minimum thickness was not available, then the pumping rate would have to be reduced, and the calculated sensitivity distance would reduce as well.

Upgradient Sources

Wells with chloride sources located upgradient to them are the more sensitive. If time-of-travel in the upgradient direction is a consideration, then chloride contamination will move into the well at some point in time. Sections that were considered to have an upgradient source were placed into Class 6 (most sensitive) for this reason.

Duration of Pumping

Since the zone-of-contribution formulas used in the sensitivity simulations assume continuous pumping, and well operators rarely pump continuously, the sensitivity distance would not often be reached.

Sensitivity Map

The sensitivity map is based on a simulated well pumping continuously at 100 gpm (Plate 4). For ease of display, the sensitivity distances were grouped into classes as mentioned above.

Sensitivity Distances for Pump Rates Above 100 gpm

Shown in Appendix C are the values for transmissivity and hydraulic gradient used in the analysis, as well as the sensitivity distance calculated for all sections in the study at pumping rates of 100, 250, 500, and 1000 gpm. Pumping rate is proportional to the null point distance (X_L) and the cross-gradient distance (Y_L). Doubling the pumping rate doubles the sensitivity distance. Although the sensitivity distance changes with differences in discharge, the relative sensitivity at any selected pumping rate does not.

Also included in Appendix C is the theoretical minimum thickness necessary to pump at those rates. The thickness was calculated using the formula for specific capacity for unconfined aquifers:

$$\frac{Q}{s} = \frac{T}{1500}$$

where Q is the pumping rate in gpm, s is the drawdown in feet, and T is the transmissivity in gpd/ft (Driscoll, 1986). Since the saturated thickness of the aquifer rarely exceeds 50 feet, values are not shown for those cases where more than 50 feet of saturated thickness would be necessary to obtain the simulated pumping rate.

Sensitivity Patterns

In general the map shows no specific pattern to sensitivity except that Classes 5 and 6 sensitivities tend to be located near the edge of the aquifer where thin, low-transmissivity material is suspected to occur. However, a greater proportion of Class 6 sensitivities occur in Alfalfa County because the positions of potential wells relative to chloride plumes require that the entire zone-of-contribution be taken into account.

Transmissivity, Gradient, and Distribution of Classes

Outside of Alfalfa County, transmissivity has the greatest effect on the manner in which classes are distributed. Average transmissivity ranges from 4250 ft^2/day for Class 1 to 720 ft^2/day for Class 6 (Table 2). Gradient has little effect on class distribution. The average gradient ranges from 0.002 for Classes 3, 4, 5, and 6 to 0.004 for Class 1. This indicates that for the study area, transmissivity is a more important factor in determining the distribution of classes than is hydraulic gradient.

Geographic Distribution of Classes

Table 2 shows the total area, in square miles, and percent total of each class by county. Also shown is the area of the aquifer beyond (outside) the sensitivity grid, described above, where the aquifer is not considered to be sensitive due to the distance from the various sources. This outside area also includes the alluvial deposits in tributaries to the Salt Fork of the Arkansas River.

Noble County has the greatest percentage of areas in the least sensitive classes with 69 percent of the area in Class 1 or Class 2. However, the county contains only a relatively small (6.5 mi^2) portion of the aquifer. No areas of Classes 5 or 6 (most sensitive) are located in the county.

TABLE 2.

TOTAL AREA, PERCENT AREA, TRANSMISSIVITY, AND GRADIENT BY CLASS

Sensitivity Class	1	2	3	4	5	6	Outside[1]	Total Mi^2/Co.
Alfalfa Co. mi^2/Class	49.1	17.5	11.9	9.8	5.6	67	115.5	277[2]
Pct. of Total Area	17.7	6.3	4.3	3.5	2.0	24.2	41.7	N/A
Grant Co. mi^2/Class	25.1	21.8	27.3	18.4	10.1	6.5	222.4	332
Pct. of Total Area	7.6	6.6	8.2	5.5	3.0	1.9	66.9	N/A
Kay Co. mi^2/Class	30.2	29.5	7.1	3.4	0.5	0	118.6	189
Pct. of Total Area	15.9	15.6	3.8	1.8	0.3	0	62.7	N/A
Noble Co. mi^2/Class	1.69	2.8	0.07	0	0	0	1.9	6.5
Pct. of Total Area	26	43.1	1.1	0	0	0	29.5	N/A
All Co.'s mi^2/Class	106.1	71.6	46.4	31.6	16.2	7.35	458	804.5
Pct. of Total Area All Co.'s	13.2	8.9	5.8	3.9	2.0	0.9	56.9	N/A
Average Transmissivity	4250	2630	1820	1460	720	3000	ND	N/A
Average Gradient	.004	.003	.002	.002	.002	.002	ND	N/A

1. Outside refers to the area outside the area analyzed but within the aquifer boundaries. This area is not considered to be sensitive because of the distances from known sources.
2. Does not include area of the aquifer impacted by chloride

N/A Not Applicable.

ND Not Determined - outside of area analyzed.

Kay County has the second greatest percentage of areas in the least sensitive classes. In this county, Class 1 and 2 sensitivities totaled 31.5 percent of the area. Adding that to the 62.7 percent of outside areas totals 94.2 percent or 178 mi^2 of the aquifer that is either not sensitive or slightly sensitive to induced infiltration of high chloride surface water. Only 0.3 percent of the area is in the two more sensitive classes.

Alfalfa County has the third largest percentage of areas in Classes 1 and 2 (24 percent). When combined with the 45 percent outside areas, the area of not sensitive to slightly sensitive totals 65 percent or 182 mi^2. However, this county has the greatest percentage of most sensitive areas with Classes 5 and 6 totaling 26.2 percent or 72.6 mi^2.

Grant County had the lowest percentage of Classes 1 and 2 (14.2 percent). The outside area was 66.9 percent, and when added to the Class 1 and 2, it totaled 81.1 percent of the aquifer (269.3 mi^2) which is either not sensitive or only slightly sensitive to induced infiltration. This county had only 4.9 percent of the total area in the 5 and 6 sensitivity classes.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The Alluvial and Terrace-alluvial Aquifer of the Salt Fork of the Arkansas River is a fresh-water aquifer used for agricultural, municipal, and domestic purposes. Saline water from bedrock in the vicinity of the Great Salt Plains Reservoir is moving upward and mixing with fresh groundwater and lake water. The chloride-impacted groundwater discharges into streams and into the lake. Discharge from the reservoir has elevated levels of chloride that degrade the water quality of the river. Water wells located close to the river or other sources of chloride-laden water are sensitive to induced infiltration.

Results

Hydraulic gradient, transmissivity, and pumping rate were used to determine the sensitivity distance, using the formulas for calculating the zone-of-contribution of a pumping well.

Although the hydraulic gradient and transmissivity have equal effects on the sensitivity distance, hydraulic gradient did not vary enough to be a significant factor in the study area. Transmissivity of the aquifer and well location relative to groundwater chloride plumes were the most important factors in determining sensitivity. The higher the transmissivity, the lower the sensitivity. All other factors being equal, wells located upgradient to chloride sources are less sensitive to induced infiltration than wells located downgradient or cross gradient.

Most of the area has no sensitivity or low sensitivity to induced infiltration. Of the 804.5 mi^2 of the aquifer in Alfalfa, Grant, Kay, and Noble Counties, 22.1 percent are in Classes 1 and 2 (least sensitive), and 2.9 percent are in Classes 5 and 6 (most sensitive). Alfalfa County has the largest area (72.6 mi^2) of Class 5 and 6 sensitivity classes. Large areas (635.7 mi^2) of the aquifer are of no or low sensitivity and are usable for municipal, industrial, or irrigation use without concern for inducing infiltration to pumping wells or degrading aquifer water quality with salt water.

Conclusions

Locating wells beyond the minimum sensitivity distance would not only protect the water quality of the well, but also would avoid degrading aquifer quality. For a given pumping rate, the more sensitive areas are those with low hydraulic gradients and low transmissivities.

The information contained in this report can be used by industry, agriculture, and municipalities in maintaining water quality, in aquifer management, and in wellhead protection.

This report could be used as a preliminary guide to locating new wells. Interpolations and assumptions are made in areas where no well data were available. Site-specific results will vary and can best be determined by drilling and testing. These simulations are based on a very conservative approach. The null-point formula is for a stabilized cone-of-depression. However, a stabilized cone could take weeks or months to develop, and water users would rarely pump for that long. Some areas will be self-limiting, because of their limited saturated thickness. Saturated-thickness changes over time can increase or reduce the sensitivity distance. This analysis does not take into account multiple pumping wells.

REFERENCES

Allison, L. E. et. al., 1974, Effect of Great Salt Plains Reservoir and Proposed Impoundment on the Agricultural Lands in Alfalfa County, Oklahoma, Division Research Report No. 426: USDA Southern Plains Watershed Research Center, Chickasha, OK.

Bingham, R.H., and Bergman, D.L., 1980, Reconnaissance of the Water Resources of the Enid Quadrangle, North-Central Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 7, 4 sheets, scale 1:250,000.

Driscoll, Fletcher G., 1986, Groundwater and Wells, Second Ed: Johnson Filtration Systems Inc., St. Paul Minnesota.

Engineering Enterprises Inc., 1987, Groundwater Flow Evaluation for Cimarron River, Salt Fork River, Arkansas River; Chloride Control Project, Oklahoma: Unpublished Report.

Fader, Stuart W. and Morton, Robert B., 1972, Ground Water in the Middle Arkansas River Basin: U. S. Geological Survey, Administrative Report.

Jordan, L. and Vosburg, D.L., 1963, Permian Salt and Associated Evaporites in the Anadarko Basin of the Western Oklahoma-Texas Panhandle Region: Oklahoma Geological Survey, Bulletin 102.

Kent, D.C., Naney, J.W., and Barnes, B.B., 1973, An Approach to the Hydrogeologic Investigation of River Alluvium by the Use of Computerized Data Techniques: Groundwater Vol. 11 no. 4 pp. 30-41.

Kent, D.C., Beausoleil, Y.J., and Witz, F. E., 1982, Evaluation of the Aquifer Performance and Water Supply Capabilities of the Enid Isolated Terrace Aquifer in Garfield County, OK: Oklahoma Water Resources Board.

Morton, R.B., 1980, Reconnaissance of the Water Resources of the Woodward Quadrangle, Northwestern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 8, 4 sheets, scale 1:250,000.

Oklahoma Water Resources Board, 1992, T-O-T, A Computer Program for the Delineation of Wellhead Protection Areas: OWRB Technical Report 92-3.

Oklahoma Water Resources Board, 1993, Statistical Summary of Groundwater Quality Data in Oklahoma 1986 - 1991 for the Major Groundwater Basins in Oklahoma: Unpublished Report

Pettyjohn, Wayne A., and White, H.A., 1986, Introduction to Water Resources and Domestic Water Supply in Oklahoma: School of Geology Oklahoma State University for Oklahoma Water Resources Board.

R. J. Systems Inc., 1985, Investigation of Aquifer System and Management Plan; City of Medford: Unpublished Report.

SYN-AN, 1975, Inventory of Mineral Pollution Areas: Chloride Control Project: Oklahoma and Kansas Final Report: Unpublished Report.

Todd, D.K., 1980, Groundwater Hydrology, Second Edition: John Wiley and Sons, New York.

U.S. Army Corps of Engineers, 1981, Chloride Control, Arkansas River Basin, Executive Summary and Vol. 4: USACOE General Design Memorandum No. 32.

U.S. Army Corps of Engineers, 1976, Arkansas and Red River Water Quality Control Studies, Memo Report FM 76-1: Unpublished Report.

U.S. Environmental Protection Agency, 1987, Guidelines for Delineations of Wellhead Protection Areas, EPA 440/6-87-010.

Ward, Porter E., 1961, Geology and Ground-Water Features of Salt Springs, Seeps, and Plains in the Arkansas and Red River Basins of Western Oklahoma and Adjacent Parts of Kansas and Texas: U. S. Geological Survey, Open File Report.

APPENDIX A

Appendix A
Hydraulic Conductivity Data

<u>Source:</u> Well-acceptance test from drillers' logs total of 91.

All 91 wells:

- Average K for all wells with acceptance test data is 210 ft/day or 1570 gpd/ft^2.
- Average K for 6 wells with only gravel is 475 ft/day or 3550 gpd/ft^2
- Average K for sand from 6 tests is 30 ft/day or 220 gpd/ft^2.

Wells with pumping times 5 hours or greater:

- Throwing out the high value the average K of 4 wells with pumping time of 5 hours or greater is: 450 ft/day or 3400 gpd/ft^2.
- Average K for all 36 wells with pumping times of 5 hours or greater was 323 ft/day or 2420 gpd/ft^2.
- Average K for 13 wells with pumping times of 5 hours or greater and only sand or gravel in lithology is 336 ft/day or 2510 gpd/ft^2.

<u>Source:</u> Published and Unpublished Reports.

Grant County:

1. City of Medford wells, K range from 451 ft/day or 3370 gpd/ft^2 to 125 ft/day or 940gpd/ft^2.
2. Fader and Morton (1972, p. 35) estimated hydraulic conductivity range from 130-360 ft/day or 970-2690 gpd/ft^2 for alluvial deposits and from 65-130 ft/day or 490-970 gpd/ft^2 for terrace deposits.

Kay County:

1. Fader and Morton (1972, p. 37) estimated hydraulic conductivity range from 130-400 ft/day or 970 gpd/ft^2 for alluvial deposits.

Alfalfa County:

1. Allison (1974 p. 6) Referenced a series of 12 pump tests made by USACOE. Tests showed permeability range from 3 to 100 ft/day or 20-750 gpd/ft^2. Average was 25 ft/day or 190gpd/ft^2.
2. Fader and Morton (1972, p. 33) estimated hydraulic conductivity range from 130-360 ft/day or 970-2690 gpd/ft^2 for alluvial deposits and from 65-200 ft/day or 490-1500 gpd/ft^2 for terrace deposits.

APPENDIX B

Appendix B

SEC	TWP	RGE	DEPTH TO WATER	DATE	ELEVATION
10	25N	01EIM	9.90	22-Jul-92	959.10
10	25N	01EIM	06.73	03-Dec-92	962.27
12	25N	01EIM	22.98	22-Jul-92	944.02
12	25N	01EIM	20.08	03-Dec-92	946.92
21	25N	01EIM	20.35	22-Jul-92	944.65
21	25N	01EIM	19.16	03-Dec-92	945.84
4	25N	01WIM	15.10	03-Dec-92	962.90
7	25N	01WIM	19.55	22-Jul-92	943.45
7	25N	01WIM	18.46	03-Dec-92	944.54
9	25N	01WIM	17.02	22-Jul-92	932.98
9	25N	01WIM	18.06	03-Dec-92	931.94
1	25N	02WIM	10.50	22-Jul-92	957.50
1	25N	02WIM	10.40	03-Dec-92	957.60
14	25N	02WIM	8.92	21-Jul-92	967.08
14	25N	02WIM	5.74	03-Dec-92	970.26
18	25N	02WIM	16.10	22-Jul-92	951.90
18	25N	02WIM	16.00	03-Dec-92	952.00
6	25N	03WIM	10.27	22-Jul-92	980.73
6	25N	03WIM	10.08	03-Dec-92	980.92
1	25N	04WIM	16.83	21-Jul-92	983.17
1	25N	04WIM	17.57	03-Dec-92	982.43
13	25N	04WIM	15.55	21-Jul-92	968.45
13	25N	04WIM	15.46	03-Dec-92	968.54
6	25N	05WIM	7.17	21-Jul-92	1026.83
6	25N	05WIM	7.79	02-Dec-92	1026.21
8	25N	05WIM	9.86	21-Jul-92	1019.14
8	25N	05WIM	10.63	02-Dec-92	1018.37
32	26N	02WIM	6.27	03-Dec-92	984.73
31	26N	03WIM	10.06	22-Jul-92	989.94
31	26N	03WIM	9.03	03-Dec-92	990.97
31	26N	05WIM	16.95	21-Jul-92	1031.05
31	26N	05WIM	14.74	02-Dec-92	1033.26
32	26N	05WIM	19.10	21-Jul-92	1015.90
32	26N	05WIM	17.36	02-Dec-92	1017.64
34	26N	05WIM	20.78	21-Jul-92	1009.22
34	26N	05WIM	20.13	02-Dec-92	1009.87
22	26N	06WIM	24.72	21-Jul-92	1025.28
22	26N	06WIM	18.09	02-Dec-92	1031.91
24	26N	06WIM	11.79	21-Jul-92	1028.21
24	26N	06WIM	0.00	02-Dec-92	0.00
7	26N	07WIM	7.54	21-Jul-92	1073.46
7	26N	07WIM	5.70	02-Dec-92	1075.30
15	26N	07WIM	10.89	21-Jul-92	1062.11
15	26N	07WIM	09.93	02-Dec-92	1063.07
22	26N	07WIM	5.58	21-Jul-92	1058.42
22	26N	07WIM	5.27	02-Dec-92	1058.73
16	26N	08WIM	5.97	21-Jul-92	1097.03
16	26N	08WIM	6.90	02-Dec-92	1096.10
27	26N	08WIM	20.64	21-Jul-92	1062.36
27	26N	08WIM	20.84	02-Dec-92	1062.16
23	26N	09WIM	26.35	20-Jul-92	1154.65
23	26N	09WIM	25.61	02-Dec-92	1155.39
29	26N	09WIM	8.22	21-Jul-92	1175.78
29	26N	09WIM	6.71	02-Dec-92	1177.29
17	26N	10WIM	10.12	20-Jul-92	1142.88
17	26N	10WIM	10.43	01-Dec-92	1142.57
33	26N	10WIM	24.90	20-Jul-92	1174.10
33	26N	10WIM	24.29	01-Dec-92	1174.71

Appendix B

SEC	TWP	RGE	DEPTH TO WATER	DATE	ELEVATION
5	26N	11WIM	19.22	20-Jul-92	1184.78
5	26N	11WIM	19.05	01-Dec-92	1184.95
11	26N	11WIM	14.63	20-Jul-92	1162.37
11	26N	11WIM	14.46	01-Dec-92	1162.54
18	27N	07WIM	13.38	21-Jul-92	1105.62
12	27N	08WIM	7.83	21-Jul-92	1115.17
12	27N	08WIM	6.55	02-Dec-92	1116.45
32	27N	08WIM	6.93	21-Jul-92	1166.07
32	27N	08WIM	6.23	02-Dec-92	1166.77
8	27N	09WIM	5.52	21-Jul-92	1142.48
8	27N	09WIM	4.54	02-Dec-92	1143.46
9	27N	09WIM	3.10	21-Jul-92	1226.90
9	27N	09WIM	4.35	02-Dec-92	1225.65
16	27N	09WIM	16.65	21-Jul-92	1181.35
24	27N	09WIM	7.45	21-Jul-92	1309.55
24	27N	09WIM	6.98	02-Dec-92	1310.02
2	27N	10WIM	0.56	21-Jul-92	1144.44
18	27N	10WIM	4.53	20-Jul-92	1159.47
18	27N	10WIM	3.99	01-Dec-92	1160.01
14	27N	11WIM	6.89	20-Jul-92	1166.11
14	27N	11WIM	0.00	01-Dec-92	0.00
23	27N	11WIM	8.36	20-Jul-92	1167.64
23	27N	11WIM	0.00	01-Dec-92	0.00
31	27N	11WIM	22.65	20-Jul-92	1212.35
31	27N	11WIM	18.48	01-Dec-92	1216.52
26	27N	12WIM	18.78	20-Jul-92	1232.22
26	27N	12WIM	17.84	01-Dec-92	1233.16
11	28N	10WIM	8.45	20-Jul-92	1181.55
11	28N	10WIM	7.63	01-Dec-92	1182.37
10	28N	11WIM	8.67	20-Jul-92	1202.33
10	28N	11WIM	7.78	01-Dec-92	1203.22
19	28N	11WIM	13.40	20-Jul-92	1197.60
19	28N	11WIM	12.98	01-Dec-92	1198.02
31	28N	11WIM	4.92	20-Jul-92	1201.08
31	28N	11WIM	2.89	01-Dec-92	1203.11
29	28N	12WIM	0.00	20-Jul-92	0.00
29	28N	12WIM	0.00	01-Dec-92	0.00
18	29N	09WIM	6.27	20-Jul-92	1202.73
18	29N	09WIM	6.43	01-Dec-92	1202.57
30	29N	10WIM	22.39	20-Jul-92	1213.61
30	29N	10WIM	0.00	10-Dec-92	0.00

APPENDIX C

Explanation of Legend for Appendix C

XL - Downgradient capture zone or null point.

YL - Extent of capture zone cross gradient.

Q/S - Specific Capacity in gallons/ft of drawdown.

DD - Drawdown.

Direction - specifies the direction in relation to gradient that was considered most sensitive in determining sensitivities based on the site specific conditions based on location of the source. The three abbreviations listed below apply.

XL - As explained above.
YL - As explained above.
UG - Upgradient

Appendix C.

SEC	TWP-RGE	TRANS. Ft_2/ day	GRAD-IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC-TION	SENS CLASS
3	24N-01E	2500	0.0025	490	1540	1225	3850	2451	7700	*	*	12.0	8	20	40	*	XL	1
4	24N-01E	2500	0.0025	490	1540	1225	3850	2451	7700	*	*	12.0	8	20	40	*	XL	1
5	24N-01E	2500	0.0025	490	1540	1225	3850	2451	7700	*	*	12.0	8	20	40	*	XL	1
3	24N-02E	1500	0.0023	888	2790	2220	6975	*	*	*	*	7.5	13	33	*	*	XL	2
4	24N-02E	1925	0.0023	692	2174	1730	5435	*	*	*	*	9.6	10	26	*	*	XL	2
5	24N-02E	2525	0.0023	528	1657	1319	4143	2638	8287	*	*	13.0	8	20	40	*	XL	2
6	24N-02E	2400	0.0023	555	1744	1388	4359	2775	8718	*	*	12.0	8	21	42	*	XL	2
8	24N-02E	2000	0.0023	666	2092	1665	5231	3330	10462	*	*	10.0	10	25	50	*	XL	2
9	24N-02E	1800	0.0023	740	2325	1850	5812	*	*	*	*	9.0	11	28	*	*	XL	2
10	24N-02E	900	0.0023	1480	4650	*	*	*	*	*	*	4.5	22	*	*	*	XL	3
7	25N-01E	2400	0.0047	272	853	679	2133	1358	4266	*	*	12.0	8	21	42	*	XL	1
17	25N-01E	1700	0.0030	601	1887	1502	4718	*	*	*	*	8.5	12	29	*	*	XL	2
18	25N-01E	1825	0.0047	357	1122	893	2805	*	*	*	*	9.1	11	27	*	*	XL	1
19	25N-01E	1900	0.0030	538	1689	1344	4222	*	*	*	*	9.5	11	26	*	*	XL	2
20	25N-01E	1800	0.0030	567	1782	1418	4456	*	*	*	*	9.0	11	28	*	*	XL	2
21	25N-01E	1675	0.0025	732	2299	1829	5746	*	*	*	*	8.4	12	30	*	*	XL	2
23	25N-01E	2800	0.0025	438	1375	1094	3438	2188	6875	*	*	14.0	7	18	36	*	XL	1
24	25N-01E	2400	0.0025	511	1604	1277	4010	2553	8021	*	*	12.0	8	21	42	*	XL	2
25	25N-01E	5500	0.0025	223	700	557	1750	1114	3500	2228	7000	27.0	4	9	18	36	XL	1
26	25N-01E	4750	0.0025	258	811	645	2026	1290	4053	2580	8105	24.0	4	11	21	42	XL	1
27	25N-01E	3600	0.0025	340	1069	851	2674	1702	5347	*	*	18.0	6	14	28	*	XL	1
28	25N-01E	2625	0.0025	467	1467	1167	3667	2334	7333	*	*	13.0	8	19	38	*	XL	1
29	25N-01E	1925	0.0025	637	2000	1592	5000	*	*	*	*	9.6	10	26	*	*	XL	2
30	25N-01E	2400	0.0025	511	1604	1277	4010	2553	8021	*	*	12.0	8	21	42	*	XL	2
31	25N-01E	2675	0.0025	458	1439	1145	3598	2291	7196	*	*	13.0	7	19	37	*	XL	1
32	25N-01E	2300	0.0025	533	1674	1332	4185	2664	8370	*	*	11.0	9	22	44	*	XL	2
33	25N-01E	2225	0.0025	551	1730	1377	4326	2754	8652	*	*	11.0	9	23	45	*	XL	2
34	25N-01E	2975	0.0025	412	1294	1030	3235	2060	6471	*	*	15.0	7	17	34	*	XL	1
35	25N-01E	4000	0.0025	306	963	766	2406	1532	4813	3064	9625	20.0	5	13	25	50	XL	1
36	25N-01E	4330	0.0025	283	889	708	2223	1415	4446	2830	8892	22.0	5	12	23	46	XL	1
3	25N-01W	1600	0.0015	1277	4010	3191	10026	*	*	*	*	8.0	13	31	*	*	XL	3
4	25N-01W	1875	0.0015	1089	3422	2723	8556	*	*	*	*	9.4	11	27	*	*	XL	3
5	25N-01W	2550	0.0015	801	2516	2002	6291	4005	12582	*	*	13.0	8	20	39	*	XL	2
6	25N-01W	2625	0.0015	778	2444	1945	6111	3890	12222	*	*	13.0	8	19	38	*	XL	2
7	25N-01W	2575	0.0015	793	2492	1983	6230	3966	12460	*	*	13.0	8	19	39	*	XL	2
8	25N-01W	2350	0.0015	869	2731	2173	6826	4346	13652	*	*	12.0	9	21	43	*	XL	2
9	25N-01W	1400	0.0035	625	1964	1563	4911	*	*	*	*	7.0	14	36	*	*	XL	2
10	25N-01W	2275	0.0035	385	1209	962	3022	1924	6044	*	*	11.0	9	22	44	*	XL	1
11	25N-01W	3250	0.0035	269	846	673	2115	1347	4231	*	*	16.0	6	15	31	*	XL	1
12	25N-01W	1750	0.0047	373	1170	931	2926	*	*	*	*	8.7	11	29	*	*	XL	1
13	25N-01W	1450	0.0047	450	1412	1124	3531	*	*	*	*	7.2	14	35	*	*	XL	1
14	25N-01W	3450	0.0035	254	797	634	1993	1269	3986	*	*	17.0	6	15	29	*	XL	1
15	25N-01W	4200	0.0035	208	655	521	1637	1042	3274	2084	6548	21.0	5	12	24	48	XL	1
16	25N-01W	1650	0.0035	531	1667	1326	4167	*	*	*	*	8.2	12	30	*	*	XL	2
17	25N-01W	750	0.0020	2042	6417	*	*	*	*	*	*	3.7	27	*	*	*	XL	4
18	25N-01W	1250	0.0020	1225	3850	3064	9625	*	*	*	*	6.2	16	40	*	*	XL	3
20	25N-01W	500	0.0025	2451	7700	*	*	*	*	*	*	2.5	40	*	*	*	XL	4
21	25N-01W	1325	0.0025	925	2906	2312	7264	*	*	*	*	6.6	15	38	*	*	XL	2
22	25N-01W	1750	0.0025	700	2200	1751	5500	*	*	*	*	8.7	11	29	*	*	XL	2
23	25N-01W	2200	0.0025	557	1750	1393	4375	2785	8750	*	*	11.0	9	23	46	*	XL	2
24	25N-01W	3650	0.0025	336	1055	839	2637	1679	5274	*	*	18.0	5	14	27	*	XL	1

Appendix C.

SEC	TWP-RGE	TRANS. Ft_2/ day	GRAD-IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC-TION	SENS CLASS
25	25N-01W	6250	0.0025	196	616	490	1540	980	3080	1961	6160	31.0	3	8	16	32	XL	1
36	25N-01W	2725	0.0025	450	1413	1124	3532	2249	7064	*	*	14.0	7	18	37	*	XL	1
15	25N-02E	2105	0.0023	633	1988	1582	4970	3164	9940	*	*	10.0	10	24	48	*	XL	2
16	25N-02E	1075	0.0023	1239	3893	3098	9732	*	*	*	*	5.4	19	47	*	*	XL	3
17	25N-02E	1275	0.0023	1045	3282	2612	8206	*	*	*	*	6.4	16	39	*	*	XL	3
18	25N-02E	1100	0.0023	1211	3804	3027	9511	*	*	*	*	5.5	18	46	*	*	XL	3
19	25N-02E	2875	0.0023	463	1456	1158	3639	2317	7278	*	*	14.0	7	17	35	*	XL	1
20	25N-02E	3225	0.0023	413	1298	1033	3244	2065	6488	*	*	16.0	6	16	31	*	XL	1
21	25N-02E	1325	0.0023	1005	3158	2513	7896	*	*	*	*	6.6	15	38	*	*	XL	3
22	25N-02E	1550	0.0023	859	2700	2148	6750	*	*	*	*	7.7	13	32	*	*	XL	2
27	25N-02E	2550	0.0023	522	1641	1306	4103	2612	8206	*	*	13.0	8	20	39	*	XL	2
28	25N-02E	3425	0.0023	389	1222	972	3055	1945	6109	*	*	17.0	6	15	29	*	XL	1
29	25N-02E	5300	0.0023	251	790	628	1974	1257	3948	2513	7896	26.0	4	9	19	38	XL	1
30	25N-02E	3875	0.0023	344	1080	859	2700	1719	5400	*	*	19.0	5	13	26	*	XL	1
31	25N-02E	4150	0.0023	321	1008	802	2521	1605	5042	3210	10084	21.0	5	12	24	48	XL	1
32	25N-02E	4400	0.0023	303	951	757	2378	1514	4755	3027	9511	22.0	5	11	23	46	XL	1
33	25N-02E	4900	0.0023	272	854	680	2135	1359	4270	2719	8540	24.0	4	10	20	41	XL	1
34	25N-02E	1895	0.0023	703	2208	1757	5521	*	*	*	*	9.4	11	26	*	*	XL	2
1	25N-02W	5250	0.0020	292	917	730	2292	1459	4583	2918	9167	26.0	4	10	19	38	XL	1
2	25N-02W	1875	0.0020	817	2567	2042	6417	*	*	*	*	9.4	11	27	*	*	XL	2
3	25N-02W	1625	0.0020	943	2962	2357	7404	*	*	*	*	8.1	12	31	*	*	XL	2
4	25N-02W	2850	0.0020	538	1689	1344	4222	2687	8443	*	*	14.0	7	18	35	*	XL	2
5	25N-02W	1575	0.0020	973	3056	2432	7639	*	*	*	*	7.9	13	32	*	*	XL	2
7	25N-02W	2100	0.0020	730	2292	1824	5729	3647	11458	*	*	10.0	10	24	48	*	XL	2
8	25N-02W	1750	0.0020	875	2750	2188	6875	*	*	*	*	8.7	11	29	*	*	XL	2
9	25N-02W	4825	0.0020	318	997	794	2494	1587	4987	3175	9974	24.0	4	10	21	42	XL	1
10	25N-02W	4000	0.0020	383	1203	957	3008	1915	6016	3830	12031	20.0	5	13	25	50	XL	1
11	25N-02W	2700	0.0020	567	1782	1418	4456	2837	8912	*	*	13.0	7	19	37	*	XL	2
12	25N-02W	2200	0.0020	696	2188	1741	5469	3482	10938	*	*	11.0	9	23	46	*	XL	2
13	25N-02W	1500	0.0020	1021	3208	2553	8021	*	*	*	*	7.5	13	33	*	*	XL	3
17	25N-02W	1500	0.0020	1021	3208	2553	8021	*	*	*	*	7.5	13	33	*	*	XL	3
18	25N-02W	670	0.0020	2286	7183	*	*	*	*	*	*	3.3	30	*	*	*	XL	4
19	25N-02W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
1	25N-03W	3000	0.0020	511	1604	1277	4010	2553	8021	*	*	15.0	7	17	33	*	XL	2
2	25N-03W	1500	0.0020	1021	3208	2553	8021	*	*	*	*	7.5	13	33	*	*	XL	3
3	25N-03W	2500	0.0020	613	1925	1532	4813	3064	9625	*	*	12.0	8	20	40	*	XL	2
4	25N-03W	1825	0.0020	839	2637	2098	6593	*	*	*	*	9.1	11	27	*	*	XL	2
5	25N-03W	2450	0.0020	625	1964	1563	4911	3126	9821	*	*	12.0	8	20	41	*	XL	2
6	25N-03W	4750	0.0020	323	1013	806	2533	1612	5066	3225	10132	24.0	4	11	21	42	XL	1
7	25N-03W	3300	0.0020	464	1458	1161	3646	2321	7292	*	*	16.0	6	15	30	*	XL	1
8	25N-03W	1430	0.0020	1071	3365	2678	8414	*	*	*	*	7.1	14	35	*	*	XL	3
9	25N-03W	1350	0.0020	1135	3565	2837	8912	*	*	*	*	6.7	15	37	*	*	XL	3
10	25N-03W	1350	0.0020	1135	3565	2837	8912	*	*	*	*	6.7	15	37	*	*	XL	3
11	25N-03W	2000	0.0020	766	2406	1915	6016	3830	12031	*	*	10.0	10	25	50	*	XL	2
12	25N-03W	4175	0.0020	367	1153	917	2882	1835	5764	3669	11527	21.0	5	12	24	48	XL	1
13	25N-03W	5000	0.0020	306	963	766	2406	1532	4813	3064	9625	25.0	4	10	20	40	XL	1
14	25N-03W	2400	0.0020	638	2005	1596	5013	3191	10026	*	*	12.0	8	21	42	*	XL	2
15	25N-03W	1000	0.0020	1532	4813	3830	12031	*	*	*	*	5.0	20	50	*	*	XL	3
16	25N-03W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
17	25N-03W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
18	25N-03W	1000	0.0020	1532	4813	3830	12031	*	*	*	*	5.0	20	50	*	*	XL	3

Appendix C.

SEC	TWP-RGE	TRANS. Ft_2/ day	GRAD- IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC- TION	SENS CLASS
22	25N-03W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
24	25N-03W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
1	25N-04W	4500	0.0015	454	1426	1135	3565	2269	7130	4539	14259	22.0	4	11	22	45	XL	1
2	25N-04W	1725	0.0015	1184	3720	2960	9300	*	*	*	*	8.6	12	29	*	*	XL	3
3	25N-04W	3250	0.0015	629	1974	1571	4936	3142	9872	*	*	16.0	6	15	31	*	XL	2
4	25N-04W	3025	0.0015	675	2121	1688	5303	3376	10606	*	*	15.0	7	17	33	*	XL	2
7	25N-04W	1000	0.0015	2042	6417	5106	16042	*	*	*	*	5.0	20	50	*	*	XL	4
8	25N-04W	1500	0.0015	1362	4278	3404	10694	*	*	*	*	7.5	13	33	*	*	XL	3
9	25N-04W	3550	0.0015	575	1808	1438	4519	2877	9038	*	*	18.0	6	14	28	*	XL	2
10	25N-04W	3000	0.0015	681	2139	1702	5347	3404	10694	*	*	15.0	7	17	33	*	XL	2
11	25N-04W	2300	0.0015	888	2790	2220	6975	4440	13949	*	*	11.0	9	22	44	*	XL	2
12	25N-04W	6875	0.0015	297	933	743	2333	1485	4667	2971	9333	34.0	3	7	15	29	XL	1
13	25N-04W	2300	0.0015	888	2790	2220	6975	4440	13949	*	*	11.0	9	22	44	*	XL	2
14	25N-04W	1400	0.0015	1459	4583	3647	11458	*	*	*	*	7.0	14	36	*	*	XL	3
15	25N-04W	1500	0.0015	1362	4278	3404	10694	*	*	*	*	7.5	13	33	*	*	XL	3
16	25N-04W	1600	0.0013	1473	4627	3682	11569	*	*	*	*	8.0	13	31	*	*	XL	3
17	25N-04W	1000	0.0013	2357	7404	5892	18510	*	*	*	*	5.0	20	50	*	*	XL	4
18	25N-04W	500	0.0013	4713	14808	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
20	25N-04W	500	0.0013	4713	14808	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
21	25N-04W	500	0.0013	4713	14808	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
23	25N-04W	500	0.0013	4713	14808	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
24	25N-04W	500	0.0013	4713	14808	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
1	25N-05W	500	0.0015	4085	12833	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
2	25N-05W	875	0.0015	2334	7333	*	*	*	*	*	*	4.4	23	*	*	*	XL	4
3	25N-05W	1725	0.0015	1184	3720	2960	9300	*	*	*	*	8.6	12	29	*	*	XL	3
4	25N-05W	1600	0.0015	1277	4010	3191	10026	*	*	*	*	8.0	13	31	*	*	XL	3
5	25N-05W	1600	0.0015	1277	4010	3191	10026	*	*	*	*	8.0	13	31	*	*	XL	3
6	25N-05W	1575	0.0015	1297	4074	3242	10185	*	*	*	*	7.9	13	32	*	*	XL	3
7	25N-05W	500	0.0015	4085	12833	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
8	25N-05W	700	0.0015	2918	9167	*	*	*	*	*	*	3.5	29	*	*	*	XL	4
9	25N-05W	900	0.0015	2269	7130	*	*	*	*	*	*	4.5	22	*	*	*	XL	4
10	25N-05W	900	0.0015	2269	7130	*	*	*	*	*	*	4.5	22	*	*	*	XL	4
11	25N-05W	700	0.0015	2918	9167	*	*	*	*	*	*	3.5	29	*	*	*	XL	4
12	25N-05W	500	0.0015	4085	12833	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
13	25N-05W	500	0.0015	4085	12833	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
15	25N-05W	600	0.0015	3404	10694	*	*	*	*	*	*	3.0	33	*	*	*	XL	5
16	25N-05W	600	0.0015	3404	10694	*	*	*	*	*	*	3.0	33	*	*	*	XL	5
17	25N-05W	500	0.0015	4085	12833	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
18	25N-05W	500	0.0015	4085	12833	*	*	*	*	*	*	2.5	40	*	*	*	XL	6
1	25N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
12	25N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
13	25N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
4	25N-09W	1225	0.0125	200	629	500	1571	*	*	*	*	6.1	16	41	*	*	XL	1
5	25N-09W	1650	0.0150	124	389	310	972	*	*	*	*	8.2	12	30	*	*	XL	1
6	25N-09W	1500	0.0100	204	642	511	1604	*	*	*	*	7.5	13	33	*	*	XL	1
7	25N-09W	500	0.0100	613	1925	*	*	*	*	*	*	2.5	40	*	*	*	XL	2
8	25N-09W	900	0.0150	227	713	*	*	*	*	*	*	4.5	22	*	*	*	XL	1
9	25N-09W	750	0.0075	545	1711	*	*	*	*	*	*	3.7	27	*	*	*	XL	2
16	25N-09W	500	0.0075	817	2567	*	*	*	*	*	*	2.5	40	*	*	*	XL	2
17	25N-09W	500	0.0150	409	1283	*	*	*	*	*	*	2.5	40	*	*	*	XL	1
18	25N-09W	500	0.0075	817	2567	*	*	*	*	*	*	2.5	40	*	*	*	XL	2

Appendix C.

SEC	TWP-RGE	TRANS. Ft^2/ day	GRAD- IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC- TION	SENS CLASS
1	25N-10W	675	0.0100	454	1426	*	*	*	*	*	*	3.4	30	*	*	*	YL	3
4	25N-10W	3000	0.0070	146	458	365	1146	730	2292	*	*	15.0	7	17	33	*	YL	1
5	25N-10W	4050	0.0050	151	475	378	1188	757	2377	1513	4753	20.0	5	12	25	50	XL	1
6	25N-10W	3000	0.0050	204	642	511	1604	1021	3208	*	*	15.0	7	17	33	*	YL	2
12	25N-10W	500	0.0050	1225	3850	*	*	*	*	*	*	2.5	40	*	*	*	XL	3
1	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
2	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	UG	6
3	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
4	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
5	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
10	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
11	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
12	25N-11W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
31	26N-01W	6025	0.0035	145	456	363	1141	726	2282	1453	4564	30.0	3	8	17	33	XL	1
32	26N-01W	2850	0.0035	307	965	768	2412	1536	4825	*	*	14.0	7	18	35	*	XL	1
33	26N-01W	3150	0.0035	278	873	695	2183	1389	4365	*	*	16.0	6	16	32	*	XL	1
25	26N-02W	3325	0.0020	461	1447	1152	3618	2304	7237	*	*	17.0	6	15	30	*	XL	1
26	26N-02W	1600	0.0020	957	3008	2394	7520	*	*	*	*	8.0	13	31	*	*	XL	2
34	26N-02W	650	0.0020	2357	7404	*	*	*	*	*	*	3.2	31	*	*	*	XL	4
35	26N-02W	1525	0.0020	1005	3156	2511	7889	*	*	*	*	7.6	13	33	*	*	XL	3
36	26N-02W	4500	0.0020	340	1069	851	2674	1702	5347	3404	10694	22.0	4	11	22	45	XL	1
31	26N-03W	1750	0.0013	1347	4231	3367	10577	*	*	*	*	8.7	11	29	*	*	XL	3
32	26N-03W	1625	0.0013	1450	4556	3626	11391	*	*	*	*	8.1	12	31	*	*	XL	3
33	26N-03W	2100	0.0013	1122	3526	2806	8814	5611	17628	*	*	10.0	10	24	48	*	XL	3
34	26N-03W	4175	0.0013	565	1773	1411	4433	2822	8867	5645	17734	21.0	5	12	24	48	XL	2
35	26N-03W	1150	0.0013	2049	6438	5123	16095	*	*	*	*	5.7	17	44	*	*	XL	4
36	26N-03W	1175	0.0013	2006	6301	5014	15753	*	*	*	*	5.9	17	43	*	*	XL	4
30	26N-05W	3125	0.0015	654	2053	1634	5133	3268	10267	*	*	16.0	6	16	32	*	XL	2
31	26N-05W	5000	0.0015	409	1283	1021	3208	2042	6417	4085	12833	25.0	4	10	20	40	XL	1
33	26N-05W	8750	0.0015	233	733	584	1833	1167	3667	2334	7333	44.0	2	6	11	23	XL	1
34	26N-05W	7250	0.0015	282	885	704	2213	1409	4425	2817	8851	36.0	3	7	14	28	XL	1
35	26N-05W	3075	0.0015	664	2087	1661	5217	3321	10434	*	*	15.0	7	16	33	*	XL	2
36	26N-05W	950	0.0015	2150	6754	*	*	*	*	*	*	4.7	21	*	*	*	XL	4
7	26N-06W	750	0.0020	2042	6417	*	*	*	*	*	*	3.7	27	*	*	*	XL	4
8	26N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
17	26N-06W	1400	0.0020	1094	3438	2735	8594	*	*	*	*	7.0	14	36	*	*	XL	3
18	26N-06W	3050	0.0020	502	1578	1256	3945	2511	7889	*	*	15.0	7	16	33	*	XL	2
19	26N-06W	1875	0.0020	817	2567	2042	6417	*	*	*	*	9.4	11	27	*	*	XL	2
20	26N-06W	550	0.0020	2785	8750	*	*	*	*	*	*	2.7	36	*	*	*	XL	4
21	26N-06W	1500	0.0020	1021	3208	2553	8021	*	*	*	*	7.5	13	33	*	*	XL	3
22	26N-06W	8000	0.0020	192	602	479	1504	957	3008	1915	6016	40.0	3	6	13	25	XL	1
23	26N-06W	8500	0.0020	180	566	451	1415	901	2831	1802	5662	42.0	2	6	12	24	XL	1
25	26N-06W	2750	0.0020	557	1750	1393	4375	2785	8750	*	*	14.0	7	18	36	*	XL	2
26	26N-06W	3450	0.0020	444	1395	1110	3487	2220	6975	*	*	17.0	6	15	29	*	XL	1
27	26N-06W	1375	0.0020	1114	3500	2785	8750	*	*	*	*	6.9	15	36	*	*	XL	3
28	26N-06W	1000	0.0020	1532	4813	3830	12031	*	*	*	*	5.0	20	50	*	*	XL	3
29	26N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
30	26N-06W	875	0.0020	1751	5500	*	*	*	*	*	*	4.4	23	*	*	*	XL	3
32	26N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
33	26N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
34	26N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5

Appendix C.

SEC	TWP-RGE	TRANS. Ft₂/ day	GRAD-IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC-TION	SENS CLASS
35	26N-06W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
36	26N-06W	750	0.0020	2042	6417	*	*	*	*	*	*	3.7	27	*	*	*	XL	4
12	26N-07W	3000	0.0020	511	1604	1277	4010	2553	8021	*	*	15.0	7	17	33	*	XL	2
13	26N-07W	5250	0.0020	292	917	730	2292	1459	4583	2918	9167	26.0	4	10	19	38	XL	1
14	26N-07W	6250	0.0020	245	770	613	1925	1225	3850	2451	7700	31.0	3	8	16	32	XL	1
15	26N-07W	1525	0.0020	1005	3156	2511	7889	*	*	*	*	7.6	13	33	*	*	XL	3
16	26N-07W	1425	0.0020	1075	3377	2687	8443	*	*	*	*	7.1	14	35	*	*	XL	3
17	26N-07W	525	0.0020	2918	9167	*	*	*	*	*	*	2.6	38	*	*	*	XL	4
18	26N-07W	3600	0.0020	426	1337	1064	3342	2128	6684	*	*	18.0	6	14	28	*	XL	1
19	26N-07W	4200	0.0020	365	1146	912	2865	1824	5729	3647	11458	21.0	5	12	24	48	XL	1
20	26N-07W	1100	0.0020	1393	4375	3482	10938	*	*	*	*	5.5	18	46	*	*	XL	3
21	26N-07W	975	0.0020	1571	4936	*	*	*	*	*	*	4.9	21	*	*	*	XL	3
22	26N-07W	1750	0.0020	875	2750	2188	6875	*	*	*	*	8.7	11	29	*	*	XL	2
23	26N-07W	5000	0.0020	306	963	766	2406	1532	4813	3064	9625	25.0	4	10	20	40	XL	1
24	26N-07W	4750	0.0020	323	1013	806	2533	1612	5066	3225	10132	24.0	4	11	21	42	XL	1
25	26N-07W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
26	26N-07W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
27	26N-07W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
28	26N-07W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
29	26N-07W	700	0.0020	2188	6875	*	*	*	*	*	*	3.5	29	*	*	*	XL	4
30	26N-07W	1250	0.0020	1225	3850	3064	9625	*	*	*	*	6.2	16	40	*	*	XL	3
31	26N-07W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
5	26N-08W	9000	0.0045	76	238	189	594	378	1188	756	2377	45.0	2	6	11	22	XL	1
6	26N-08W	7000	0.0014	308	968	771	2421	1541	4842	3082	9683	35.0	3	7	14	29	XL	1
7	26N-08W	5000	0.0070	88	275	219	688	438	1375	875	2750	25.0	4	10	20	40	XL	1
8	26N-08W	5250	0.0035	167	524	417	1310	834	2619	1667	5238	26.0	4	10	19	38	XL	1
17	26N-08W	1500	0.0035	584	1833	1459	4583	*	*	*	*	7.5	13	33	*	*	XL	2
18	26N-08W	1250	0.0035	700	2200	1751	5500	*	*	*	*	6.2	16	40	*	*	XL	2
19	26N-08W	500	0.0035	1751	5500	*	*	*	*	*	*	2.5	40	*	*	*	XL	3
20	26N-08W	500	0.0030	2042	6417	*	*	*	*	*	*	2.5	40	*	*	*	XL	4
21	26N-08W	1200	0.0030	851	2674	2128	6684	*	*	*	*	6.0	17	42	*	*	XL	2
22	26N-08W	4750	0.0048	134	422	336	1055	672	2111	1344	4222	24.0	4	11	21	42	XL	1
23	26N-08W	4500	0.0040	170	535	426	1337	851	2674	1702	5347	22.0	4	11	22	45	XL	1
24	26N-08W	4400	0.0020	348	1094	870	2734	1741	5469	3482	10938	22.0	5	11	23	46	XL	1
25	26N-08W	1500	0.0020	1021	3208	2553	8021	*	*	*	*	7.5	13	33	*	*	XL	3
26	26N-08W	600	0.0020	2553	8021	*	*	*	*	*	*	3.0	33	*	*	*	XL	4
27	26N-08W	900	0.0020	1702	5347	*	*	*	*	*	*	4.5	22	*	*	*	XL	3
28	26N-08W	1000	0.0020	1532	4813	3830	12031	*	*	*	*	5.0	20	50	*	*	XL	3
29	26N-08W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
30	26N-08W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
35	26N-08W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
36	26N-08W	500	0.0020	3064	9625	*	*	*	*	*	*	2.5	40	*	*	*	XL	5
1	26N-09W	5600	0.0028	195	614	489	1535	977	3069	1954	6138	28.0	4	9	18	36	XL	1
2	26N-09W	5500	0.0023	242	761	606	1902	1211	3804	2422	7609	27.0	4	9	18	36	XL	1
3	26N-09W	3750	0.0063	130	407	324	1019	648	2037	*	*	19.0	5	13	27	*	XL	1
11	26N-09W	750	0.0030	1362	4278	*	*	*	*	*	*	3.7	27	*	*	*	XL	3
12	26N-09W	450	0.0030	2269	7130	*	*	*	*	*	*	2.2	45	*	*	*	XL	4
13	26N-09W	400	0.0074	1035	3252	*	*	*	*	*	*	2.0	50	*	*	*	XL	3
14	26N-09W	300	0.0030	*	*	*	*	*	*	*	*	1.5	*	*	*	*	XL	5
15	26N-09W	1700	0.0050	360	1132	901	2831	*	*	*	*	8.5	12	29	*	*	XL	1
21	26N-09W	2700	0.0070	162	509	405	1273	811	2546	*	*	13.0	7	19	37	*	XL	1

Appendix C.

SEC	TWP-RGE	TRANS. Ft_2/ day	GRAD- IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC- TION	SENS CLASS
22	26N-09W	2150	0.0050	285	895	713	2238	1425	4477	*	*	11.0	9	23	47	*	XL	1
23	26N-09W	300	0.0050	*	*	*	*	*	*	*	*	1.5	*	*	*	*	XL	4
27	26N-09W	1900	0.0030	538	1689	1344	4222	*	*	*	*	9.5	11	26	*	*	XL	2
28	26N-09W	3000	0.0050	204	642	511	1604	1021	3208	*	*	15.0	7	17	33	*	XL	1
29	26N-09W	1375	0.0070	318	1000	796	2500	*	*	*	*	6.9	15	36	*	*	XL	1
31	26N-09W	2000	0.0030	511	1604	1277	4010	2553	8021	*	*	10.0	10	25	50	*	XL	2
32	26N-09W	2000	0.0030	511	1604	1277	4010	2553	8021	*	*	10.0	10	25	50	*	XL	2
33	26N-09W	3000	0.0030	340	1069	851	2674	1702	5347	*	*	15.0	7	17	33	*	XL	1
6	26N-10W	1050	0.0016	1824	5729	4559	14323	*	*	*	*	5.2	19	48	*	*	YL	6
7	26N-10W	3375	0.0018	504	1584	1261	3961	2522	7922	*	*	17.0	6	15	30	*	UG	6
20	26N-10W	1200	0.0022	1161	3645	2901	9114	*	*	*	*	6.0	17	42	*	*	YL	5
21	26N-10W	1200	0.0022	1161	3645	2901	9114	*	*	*	*	6.0	17	42	*	*	YL	5
27	26N-10W	1925	0.0022	723	2273	1809	5682	*	*	*	*	9.6	10	26	*	*	XL	2
28	26N-10W	2450	0.0022	568	1786	1421	4464	2842	8929	*	*	12.0	8	20	41	*	YL	3
29	26N-10W	1700	0.0022	819	2574	2048	6434	*	*	*	*	8.5	12	29	*	*	YL	4
30	26N-10W	1500	0.0022	928	2917	2321	7292	*	*	*	*	7.5	13	33	*	*	YL	4
31	26N-10W	1500	0.0032	638	2005	1596	5013	*	*	*	*	7.5	13	33	*	*	XL	2
32	26N-10W	3000	0.0027	378	1188	946	2971	1891	5941	*	*	15.0	7	17	33	*	XL	1
33	26N-10W	4025	0.0022	346	1087	865	2717	1730	5435	3460	10870	20.0	5	12	25	50	XL	1
34	26N-10W	2575	0.0024	496	1557	1239	3894	2479	7787	*	*	13.0	8	19	39	*	XL	1
1	26N-11W	1125	0.0014	1945	6111	4863	15278	*	*	*	*	5.6	18	45	*	*	YL	6
2	26N-11W	750	0.0014	2918	9167	*	*	*	*	*	*	3.7	27	*	*	*	YL	6
3	26N-11W	825	0.0014	2653	8333	*	*	*	*	*	*	4.1	24	*	*	*	YL	6
4	26N-11W	1850	0.0022	753	2365	1882	5912	*	*	*	*	9.2	11	27	*	*	YL	4
5	26N-11W	875	0.0022	1592	5000	*	*	*	*	*	*	4.4	23	*	*	*	YL	6
6	26N-11W	300	0.0031	*	*	*	*	*	*	*	*	1.5	*	*	*	*	YL	6
7	26N-11W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
8	26N-11W	100	0.0019	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
9	26N-11W	150	0.0020	*	*	*	*	*	*	*	*	0.7	*	*	*	*	YL	6
10	26N-11W	200	0.0018	*	*	*	*	*	*	*	*	1.0	*	*	*	*	YL	6
11	26N-11W	1250	0.0018	1362	4278	3404	10694	*	*	*	*	6.2	16	40	*	*	YL	6
12	26N-11W	2900	0.0018	587	1844	1467	4610	2935	9219	*	*	14.0	7	17	35	*	UG	6
15	26N-11W	650	0.0018	2619	8227	*	*	*	*	*	*	3.2	31	*	*	*	YL	6
16	26N-11W	125	0.0019	*	*	*	*	*	*	*	*	0.6	*	*	*	*	YL	6
17	26N-11W	100	0.0023	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
18	26N-11W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
19	26N-11W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
30	26N-11W	100	0.0025	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
31	26N-11W	100	0.0025	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
32	26N-11W	100	0.0025	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
35	26N-11W	500	0.0025	2451	7700	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
36	26N-11W	1000	0.0025	1225	3850	3064	9625	*	*	*	*	5.0	20	50	*	*	UG	6
1	26N-12W	90	0.0031	*	*	*	*	*	*	*	*	0.4	*	*	*	*	YL	6
2	26N-12W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
12	26N-12W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	YL	6
13	26N-12W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
24	26N-12W	100	0.0031	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
25	26N-12W	100	0.0025	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
36	26N-12W	100	0.0025	*	*	*	*	*	*	*	*	0.5	*	*	*	*	XL	6
31	27N-08W	2300	0.0075	178	558	444	1395	888	2790	*	*	11.0	9	22	44	*	XL	1
32	27N-08W	6625	0.0075	62	194	154	484	308	969	617	1937	33.0	3	8	15	30	XL	1

Appendix C.

SEC	TWP-RGE	TRANS. Ft.2/ day	GRAD-IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC-TION	SENS CLASS
4	27N-09W	6825	0.0095	47	148	118	371	236	742	473	1485	34.0	3	7	15	29	XL	1
5	27N-09W	5325	0.0095	61	190	151	476	303	951	606	1903	27.0	4	9	19	38	UG	6
6	27N-09W	5325	0.0020	288	904	719	2259	1438	4519	2877	9038	27.0	4	9	19	38	UG	6
7	27N-09W	2175	0.0050	282	885	704	2213	1409	4425	*	*	11.0	9	23	46	*	XL	1
8	27N-09W	2175	0.0095	148	466	371	1165	741	2329	*	*	11.0	9	23	46	*	YL	1
9	27N-09W	4475	0.0095	72	226	180	566	360	1132	721	2264	22.0	4	11	22	45	XL	1
16	27N-09W	5250	0.0090	65	204	162	509	324	1019	648	2037	26.0	4	10	19	38	XL	1
17	27N-09W	600	0.0090	567	1782	*	*	*	*	*	*	3.0	33	*	*	*	XL	2
18	27N-09W	500	0.0090	681	2139	*	*	*	*	*	*	2.5	40	*	*	*	XL	2
20	27N-09W	6400	0.0085	56	177	141	442	282	885	563	1769	32.0	3	8	16	31	XL	1
21	27N-09W	5500	0.0085	66	206	164	515	328	1029	655	2059	27.0	4	9	18	36	XL	1
27	27N-09W	3400	0.0080	104	325	259	813	518	1626	*	*	18.0	5	14	27	*	XL	1
28	27N-09W	3700	0.0080	104	325	259	813	518	1626	*	*	18.0	5	14	27	*	XL	1
29	27N-09W	6500	0.0080	59	185	147	463	295	925	589	1851	32.0	3	8	15	31	XL	1
33	27N-09W	900	0.0074	460	1445	*	*	*	*	*	*	4.5	22	*	*	*	XL	1
34	27N-09W	2175	0.0074	190	598	476	1495	952	2990	*	*	11.0	9	23	46	*	XL	1
35	27N-09W	5875	0.0074	70	221	176	553	352	1107	705	2214	29.0	3	9	17	34	XL	1
36	27N-09W	4975	0.0070	88	276	220	691	440	1382	880	2764	25.0	4	10	20	40	XL	1
1	27N-10W	3000	0.0015	681	2139	1702	5347	3404	10694	*	*	15.0	7	17	33	*	UG	6
2	27N-10W	1900	0.0015	1075	3377	2687	8443	*	*	*	*	9.5	11	26	*	*	UG	6
6	27N-10W	6000	0.0009	567	1782	1418	4456	2837	8912	5674	17824	30.0	3	8	17	33	UG	6
1	27N-11W	11250	0.0009	303	951	757	2377	1513	4753	3026	9506	56.0	2	4	9	18	UG	6
2	27N-11W	5750	0.0009	592	1860	1480	4650	2960	9300	5920	18599	29.0	3	9	17	35	YL	3
3	27N-11W	1800	0.0009	1891	5941	4728	14853	*	*	*	*	9.0	11	28	*	*	YL	6
4	27N-11W	3225	0.0016	594	1865	1484	4663	2969	9327	*	*	16.0	6	16	31	*	YL	3
5	27N-11W	4250	0.0016	451	1415	1126	3539	2253	7077	4506	14154	21.0	5	12	24	47	YL	3
6	27N-11W	2200	0.0016	870	2734	2176	6836	4352	13672	*	*	11.0	9	23	46	*	YL	4
9	27N-11W	4075	0.0010	752	2362	1880	5905	3759	11810	7518	23620	20.0	5	12	25	49	YL	4
10	27N-11W	1500	0.0010	2042	6417	5106	16042	*	*	*	*	7.5	13	33	*	*	YL	6
11	27N-11W	5875	0.0010	522	1638	1304	4096	2607	8192	5215	16383	29.0	3	9	17	34	YL	3
12	27N-11W	10500	0.0010	292	917	730	2292	1459	4583	2918	9167	52.0	2	5	10	19	UG	6
15	27N-11W	1275	0.0011	2184	6863	5461	17157	*	*	*	*	6.4	16	39	*	*	YL	6
16	27N-11W	2500	0.0018	681	2139	1702	5347	3404	10694	*	*	12.0	8	20	40	*	YL	4
17	27N-11W	3550	0.0018	480	1506	1199	3766	2397	7531	*	*	18.0	6	14	28	*	YL	3
18	27N-11W	3750	0.0018	454	1426	1135	3565	2269	7130	*	*	19.0	5	13	27	*	XL	1
19	27N-11W	4350	0.0028	252	790	629	1976	1258	3951	2515	7902	22.0	5	12	23	46	UG	6
20	27N-11W	4625	0.0020	331	1041	828	2601	1656	5203	3312	10405	23.0	4	11	22	43	UG	6
21	27N-11W	4125	0.0020	371	1167	928	2917	1857	5833	3714	11667	21.0	5	12	24	49	UG	6
22	27N-11W	1800	0.0012	1418	4456	3546	11140	*	*	*	*	9.0	11	28	*	*	UG	6
27	27N-11W	1000	0.0012	2553	8021	6383	20052	*	*	*	*	5.0	20	50	*	*	UG	6
28	27N-11W	3050	0.0024	419	1315	1046	3287	2093	6575	*	*	15.0	7	16	33	*	UG	6
29	27N-11W	3050	0.0024	419	1315	1046	3287	2093	6575	*	*	15.0	7	16	33	*	UG	6
30	27N-11W	3150	0.0031	314	986	784	2464	1569	4928	*	*	16.0	6	16	32	*	UG	6
31	27N-11W	250	0.0031	*	*	*	*	*	*	*	*	1.2	*	*	*	*	YL	6
32	27N-11W	1175	0.0024	1086	3413	2716	8533	*	*	*	*	5.9	17	43	*	*	UG	6
33	27N-11W	1900	0.0024	672	2111	1680	5277	*	*	*	*	9.5	11	26	*	*	UG	6
34	27N-11W	1000	0.0014	2188	6875	5471	17188	*	*	*	*	5.0	20	50	*	*	UG	6
35	27N-11W	1150	0.0014	1903	5978	4757	14946	*	*	*	*	5.7	17	44	*	*	UG	6
13	27N-12W	5750	0.0031	172	540	430	1350	859	2700	1719	5400	29.0	3	9	17	35	XL	1
14	27N-12W	6500	0.0031	152	478	380	1194	760	2388	1521	4777	32.0	3	8	15	31	XL	1
15	27N-12W	6100	0.0031	162	509	405	1273	810	2545	1620	5090	30.0	3	8	16	33	XL	1

Appendix C.

SEC	TWP-RGE	TRANS. Ft_2/ day	GRAD- IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC- TION	SENS CLASS
16	27N-12W	3000	0.0031	329	1035	824	2587	1647	5175	*	*	15.0	7	17	33	*	XL	1
21	27N-12W	3000	0.0031	329	1035	824	2587	1647	5175	*	*	15.0	7	17	33	*	XL	1
22	27N-12W	5750	0.0031	172	540	430	1350	859	2700	1719	5400	29.0	3	9	17	35	YL	2
23	27N-12W	6250	0.0031	158	497	395	1242	791	2484	1581	4968	31.0	3	8	16	32	YL	1
24	27N-12W	6450	0.0031	153	481	383	1203	766	2407	1532	4814	32.0	3	8	16	31	UG	6
25	27N-12W	4000	0.0031	247	776	618	1941	1235	3881	2471	7762	20.0	5	13	25	50	UG	6
26	27N-12W	3750	0.0031	264	828	659	2070	1318	4140	*	*	19.0	5	13	27	*	YL	2
27	27N-12W	3700	0.0031	267	839	668	2098	1336	4196	*	*	18.0	5	14	27	*	XL	1
28	27N-12W	1875	0.0031	527	1656	1318	4140	*	*	*	*	9.4	11	27	*	*	XL	2
34	27N-12W	1500	0.0031	659	2070	1647	5175	*	*	*	*	7.5	13	33	*	*	XL	2
35	27N-12W	530	0.0031	1865	5858	*	*	*	*	*	*	2.6	38	*	*	*	YL	6
36	27N-12W	90	0.0031	*	*	*	*	*	*	*	*	0.4	*	*	*	*	YL	6
16	28N-09W	1500	0.0095	215	675	538	1689	*	*	*	*	7.5	13	33	*	*	XL	1
17	28N-09W	1275	0.0062	388	1218	969	3044	*	*	*	*	6.4	16	39	*	*	XL	1
18	28N-09W	4625	0.0028	237	743	592	1858	1183	3716	2366	7432	23.0	4	11	22	43	YL	2
19	28N-09W	1300	0.0020	1178	3702	2946	9255	*	*	*	*	6.5	15	39	*	*	YL	5
20	28N-09W	1625	0.0047	401	1260	1003	3151	*	*	*	*	8.1	12	31	*	*	XL	1
21	28N-09W	7500	0.0095	43	135	108	338	215	675	430	1351	37.0	3	7	13	27	XL	1
22	28N-09W	14250	0.0095	23	71	57	178	113	355	226	711	71.0	1	4	7	14	XL	1
28	28N-09W	10000	0.0095	32	101	81	253	161	507	323	1013	50.0	2	5	10	20	XL	1
29	28N-09W	3875	0.0050	158	497	395	1242	791	2484	*	*	19.0	5	13	26	*	XL	1
31	28N-09W	4750	0.0020	323	1013	806	2533	1612	5066	3225	10132	24.0	4	11	21	42	UG	6
32	28N-09W	6750	0.0015	303	951	757	2377	1513	4753	3026	9506	34.0	3	7	15	30	YL	2
33	28N-09W	9750	0.0095	33	104	83	260	165	520	331	1039	49.0	2	5	10	21	XL	1
1	28N-10W	8325	0.0018	205	642	511	1606	1022	3212	2045	6423	42.0	2	6	12	24	XL	1
2	28N-10W	5875	0.0018	290	910	724	2275	1449	4551	2897	9102	29.0	3	9	17	34	XL	1
3	28N-10W	3200	0.0020	479	1504	1197	3760	2394	7520	*	*	16.0	6	16	31	*	YL	3
4	28N-10W	2800	0.0024	456	1432	1140	3581	2280	7162	*	*	14.0	7	18	36	*	UG	6
5	28N-10W	4950	0.0024	258	810	645	2026	1289	4051	2579	8102	25.0	4	10	20	41	YL	2
6	28N-10W	4175	0.0024	306	961	764	2401	1529	4803	3058	9606	21.0	5	12	24	48	YL	2
7	28N-10W	5350	0.0024	239	750	597	1874	1193	3748	2386	7496	27.0	4	9	19	37	YL	2
8	28N-10W	6250	0.0024	204	642	511	1604	1021	3208	2043	6417	31.0	3	8	16	32	YL	2
9	28N-10W	5325	0.0024	240	753	599	1883	1199	3766	2397	7531	27.0	4	9	19	38	UG	6
10	28N-10W	4050	0.0024	315	990	788	2476	1576	4951	3152	9902	20.0	5	12	25	50	YL	2
11	28N-10W	4675	0.0018	364	1144	910	2860	1820	5719	3641	11438	23.0	4	11	21	43	XL	1
12	28N-10W	6475	0.0018	263	826	657	2065	1314	4129	2629	8258	32.0	3	8	15	31	XL	1
13	28N-10W	4600	0.0021	317	996	793	2491	1586	4982	3172	9964	23.0	4	11	22	44	YL	2
14	28N-10W	2750	0.0020	557	1750	1393	4375	2785	8750	*	*	14.0	7	18	36	*	UG	6
15	28N-10W	3150	0.0022	442	1389	1105	3472	2210	6944	*	*	16.0	6	16	32	*	UG	6
16	28N-10W	6500	0.0023	205	644	512	1610	1025	3219	2049	6438	32.0	3	8	15	31	YL	2
17	28N-10W	6825	0.0025	180	564	449	1410	898	2821	1796	5641	34.0	3	7	15	29	YL	2
18	28N-10W	6600	0.0025	186	583	464	1458	928	2917	1857	5833	33.0	3	8	15	30	YL	2
19	28N-10W	6850	0.0019	235	740	589	1849	1177	3698	2354	7395	34.0	3	7	15	29	UG	6
20	28N-10W	7800	0.0024	164	514	409	1285	818	2571	1637	5142	39.0	3	6	13	26	YL	2
22	28N-10W	4675	0.0022	298	936	745	2340	1489	4679	2979	9358	23.0	4	11	21	43	UG	6
23	28N-10W	3225	0.0022	432	1357	1080	3392	2159	6783	*	*	16.0	6	16	31	*	UG	6
24	28N-10W	3050	0.0018	558	1753	1395	4383	2790	8766	*	*	15.0	7	16	33	*	YL	3
25	28N-10W	1700	0.0013	1386	4355	3466	10888	*	*	*	*	8.5	12	29	*	*	UG	6
26	28N-10W	2000	0.0022	696	2188	1741	5469	3482	10937	*	*	10.0	10	25	50	*	UG	6
27	28N-10W	1850	0.0020	828	2601	2070	6503	*	*	*	*	9.2	11	27	*	*	UG	6
28	28N-10W	3325	0.0020	461	1447	1152	3618	2304	7237	*	*	17.0	6	15	30	*	UG	6

Appendix C.

SEC	TWP-RGE	TRANS. Ft$_2$/ day	GRAD-IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC-TION	SENS CLASS
29	28N-10W	4800	0.0020	319	1003	798	2507	1596	5013	3191	10026	24.0	4	10	21	42	YL	3
30	28N-10W	7200	0.0015	284	891	709	2228	1418	4456	2837	8912	36.0	3	7	14	28	UG	6
31	28N-10W	6900	0.0012	370	1162	925	2906	1850	5812	3700	11624	34.0	3	7	15	29	UG	6
32	28N-10W	3350	0.0012	762	2394	1905	5986	3811	11971	*	*	17.0	6	15	30	*	UG	6
33	28N-10W	1500	0.0012	1702	5347	4255	13368	*	*	*	*	7.5	13	33	*	*	UG	6
34	28N-10W	1325	0.0018	1285	4036	3211	10089	*	*	*	*	6.6	15	38	*	*	UG	6
35	28N-10W	1650	0.0013	1428	4487	3571	11218	*	*	*	*	8.2	12	30	*	*	UG	6
36	28N-10W	2825	0.0013	834	2621	2086	6552	4171	13104	*	*	14.0	7	18	35	*	UG	6
1	28N-11W	3450	0.0010	888	2790	2220	6975	4440	13949	*	*	17.0	6	15	29	*	YL	4
2	28N-11W	3400	0.0010	901	2831	2253	7077	4505	14154	*	*	17.0	6	15	29	*	YL	4
3	28N-11W	3050	0.0010	1005	3156	2511	7889	5023	15779	*	*	15.0	7	16	33	*	YL	5
4	28N-11W	2675	0.0010	1145	3598	2863	8995	5727	17991	*	*	13.0	7	19	37	*	YL	5
6	28N-11W	4000	0.0010	766	2406	1915	6016	3830	12031	7659	24063	20.0	5	13	25	50	UG	6
7	28N-11W	500	0.0050	1225	3850	*	*	*	*	*	*	2.5	40	*	*	*	UG	6
8	28N-11W	6300	0.0100	49	153	122	382	243	764	486	1528	31.0	3	8	16	32	UG	6
9	28N-11W	5350	0.0160	36	112	89	281	179	562	358	1124	27.0	4	9	19	37	UG	6
10	28N-11W	3550	0.0160	54	169	135	424	270	847	*	*	18.0	6	14	28	*	UG	6
11	28N-11W	4650	0.0010	659	2070	1647	5175	3294	10349	6589	20699	23.0	4	11	22	43	XL	2
15	28N-11W	5875	0.0016	326	1024	815	2560	1630	5120	3259	10239	29.0	3	9	17	34	UG	6
16	28N-11W	5100	0.0016	376	1180	939	2949	1877	5898	3755	11795	25.0	4	10	20	39	UG	6
17	28N-11W	2250	0.0016	851	2674	2128	6684	4255	13368	*	*	11.0	9	22	45	*	XL	2
18	28N-11W	500	0.0016	3830	12031	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
19	28N-11W	500	0.0010	6127	19250	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
20	28N-11W	1600	0.0014	1368	4297	3419	10742	*	*	*	*	8.0	13	31	*	*	YL	6
21	28N-11W	2750	0.0014	796	2500	1989	6250	3979	12500	*	*	14.0	7	18	36	*	UG	6
22	28N-11W	3850	0.0014	568	1786	1421	4464	2842	8929	*	*	19.0	5	13	26	*	UG	6
24	28N-11W	3800	0.0014	576	1809	1440	4523	2879	9046	*	*	19.0	5	13	26	*	UG	6
25	28N-11W	3875	0.0014	565	1774	1412	4436	2824	8871	*	*	19.0	5	13	26	*	UG	6
26	28N-11W	3325	0.0014	658	2068	1645	5169	3291	10338	*	*	17.0	6	15	30	*	UG	6
27	28N-11W	2325	0.0014	941	2957	2353	7393	4706	14785	*	*	12.0	9	22	43	*	UG	6
28	28N-11W	1450	0.0014	1509	4741	3773	11853	*	*	*	*	7.2	14	35	*	*	UG	6
29	28N-11W	1400	0.0014	1563	4911	3908	12277	*	*	*	*	7.0	14	36	*	*	YL	6
30	28N-11W	825	0.0014	2653	8333	*	*	*	*	*	*	4.1	24	*	*	*	YL	6
31	28N-11W	1850	0.0014	1183	3716	2957	9291	*	*	*	*	9.2	11	27	*	*	YL	5
32	28N-11W	3500	0.0014	625	1964	1563	4911	3126	9821	*	*	17.0	6	14	29	*	UG	6
33	28N-11W	1775	0.0014	1233	3873	3082	9683	*	*	*	*	8.9	11	28	*	*	UG	6
34	28N-11W	1825	0.0014	1199	3767	2998	9418	*	*	*	*	9.1	11	27	*	*	UG	6
35	28N-11W	3750	0.0014	584	1833	1459	4583	2918	9167	*	*	19.0	5	13	27	*	UG	6
36	28N-11W	7450	0.0014	294	923	734	2307	1469	4614	2937	9228	37.0	3	7	13	27	UG	6
1	28N-12W	500	0.0010	6127	19250	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
2	28N-12W	400	0.0010	7659	24063	*	*	*	*	*	*	2.0	50	*	*	*	YL	6
13	28N-12W	500	0.0010	6127	19250	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
14	28N-12W	500	0.0030	2042	6417	*	*	*	*	*	*	2.5	40	*	*	*	YL	6
24	28N-12W	250	0.0030	*	*	*	*	*	*	*	*	1.2	*	*	*	*	YL	6
25	28N-12W	400	0.0030	2553	8021	*	*	*	*	*	*	2.0	50	*	*	*	YL	6
36	28N-12W	700	0.0030	1459	4583	*	*	*	*	*	*	3.5	29	*	*	*	YL	6
15	29N-10W	2900	0.0015	704	2213	1761	5532	3522	11063	*	*	14.0	7	17	35	*	XL	2
16	29N-10W	1500	0.0015	1362	4278	3404	10694	*	*	*	*	7.5	13	33	*	*	YL	6
17	29N-10W	1500	0.0015	1362	4278	3404	10694	*	*	*	*	7.5	13	33	*	*	XL	3
18	29N-10W	3000	0.0015	681	2139	1702	5347	3404	10694	*	*	15.0	7	17	33	*	YL	4
19	29N-10W	3000	0.0015	681	2139	1702	5347	3404	10694	*	*	15.0	7	17	33	*	YL	4

Appendix C.

SEC	TWP-RGE	TRANS. Ft$_2$/ day	GRAD- IENT	XL@ 100 gpm	YL@ 100 gpm	XL@ 250 gpm	YL@ 250 gpm	XL@ 500 gpm	YL@ 500 gpm	XL@ 1000 gpm	YL@ 1000 gpm	Q/S	DD@ 100 gpm	DD@ 250 gpm	DD@ 500 gpm	DD@ 1000 gpm	DIREC- TION	SENS CLASS
21	29N-10W	1500	0.0015	1362	4278	3404	10694	*	*	*	*	7.5	13	33	*	*	YL	6
22	29N-10W	2950	0.0015	692	2175	1731	5438	3462	10876	*	*	15.0	7	17	34	*	YL	4
27	29N-10W	3650	0.0015	560	1758	1399	4395	2798	8790	*	*	18.0	5	14	27	*	YL	3
28	29N-10W	1650	0.0015	1238	3889	3095	9722	*	*	*	*	8.2	12	30	*	*	YL	5
29	29N-10W	2800	0.0015	730	2292	1824	5729	3647	11458	*	*	14.0	7	18	36	*	YL	4
30	29N-10W	4300	0.0015	475	1492	1187	3731	2375	7461	4750	14922	21.0	5	12	23	47	YL	3
31	29N-10W	5300	0.0015	385	1211	963	3027	1927	6054	3854	12107	26.0	4	9	19	38	YL	3
32	29N-10W	3400	0.0015	601	1887	1502	4718	3004	9436	*	*	17.0	6	15	29	*	YL	3
33	29N-10W	1500	0.0015	1362	4278	3404	10694	*	*	*	*	7.5	13	33	*	*	YL	6
34	29N-10W	3000	0.0015	681	2139	1702	5347	3404	10694	*	*	15.0	7	17	33	*	YL	4
22	29N-11W	1500	0.0045	454	1426	1135	3565	*	*	*	*	7.5	13	33	*	*	XL	1
23	29N-11W	1500	0.0045	454	1426	1135	3565	*	*	*	*	7.5	13	33	*	*	XL	1
24	29N-11W	1000	0.0045	681	2139	1702	5347	*	*	*	*	5.0	20	50	*	*	XL	2
25	29N-11W	5075	0.0045	134	421	335	1054	671	2107	1342	4215	25.0	4	10	20	40	XL	1
26	29N-11W	3050	0.0045	223	701	558	1753	1116	3506	*	*	15.0	7	16	33	*	XL	1
27	29N-11W	1800	0.0045	378	1188	946	2971	*	*	*	*	9.0	11	28	*	*	XL	1
28	29N-11W	400	0.0045	1702	5347	*	*	*	*	*	*	2.0	50	*	*	*	XL	3
30	29N-11W	400	0.0040	1915	6016	*	*	*	*	*	*	2.0	50	*	*	*	XL	3
31	29N-11W	500	0.0040	1532	4813	*	*	*	*	*	*	2.5	40	*	*	*	XL	3
32	29N-11W	1325	0.0060	385	1211	963	3027	*	*	*	*	6.6	15	38	*	*	XL	1
33	29N-11W	2000	0.0060	255	802	638	2005	1277	4010	*	*	10.0	10	25	50	*	YL	2
35	29N-11W	3300	0.0035	265	833	663	2083	1326	4167	*	*	16.0	6	15	30	*	YL	2
36	29N-11W	8500	0.0035	103	324	258	809	515	1618	1030	3235	42.0	2	6	12	24	YL	1
25	29N-12W	400	0.0030	2553	8021	*	*	*	*	*	*	2.0	50	*	*	*	YL	6
26	29N-12W	400	0.0030	2553	8021	*	*	*	*	*	*	2.0	50	*	*	*	YL	6
35	29N-12W	400	0.0030	2553	8021	*	*	*	*	*	*	2.0	50	*	*	*	YL	6
36	29N-12W	400	0.0030	2553	8021	*	*	*	*	*	*	2.0	50	*	*	*	YL	6

Plates 1, 2, 3, and 4

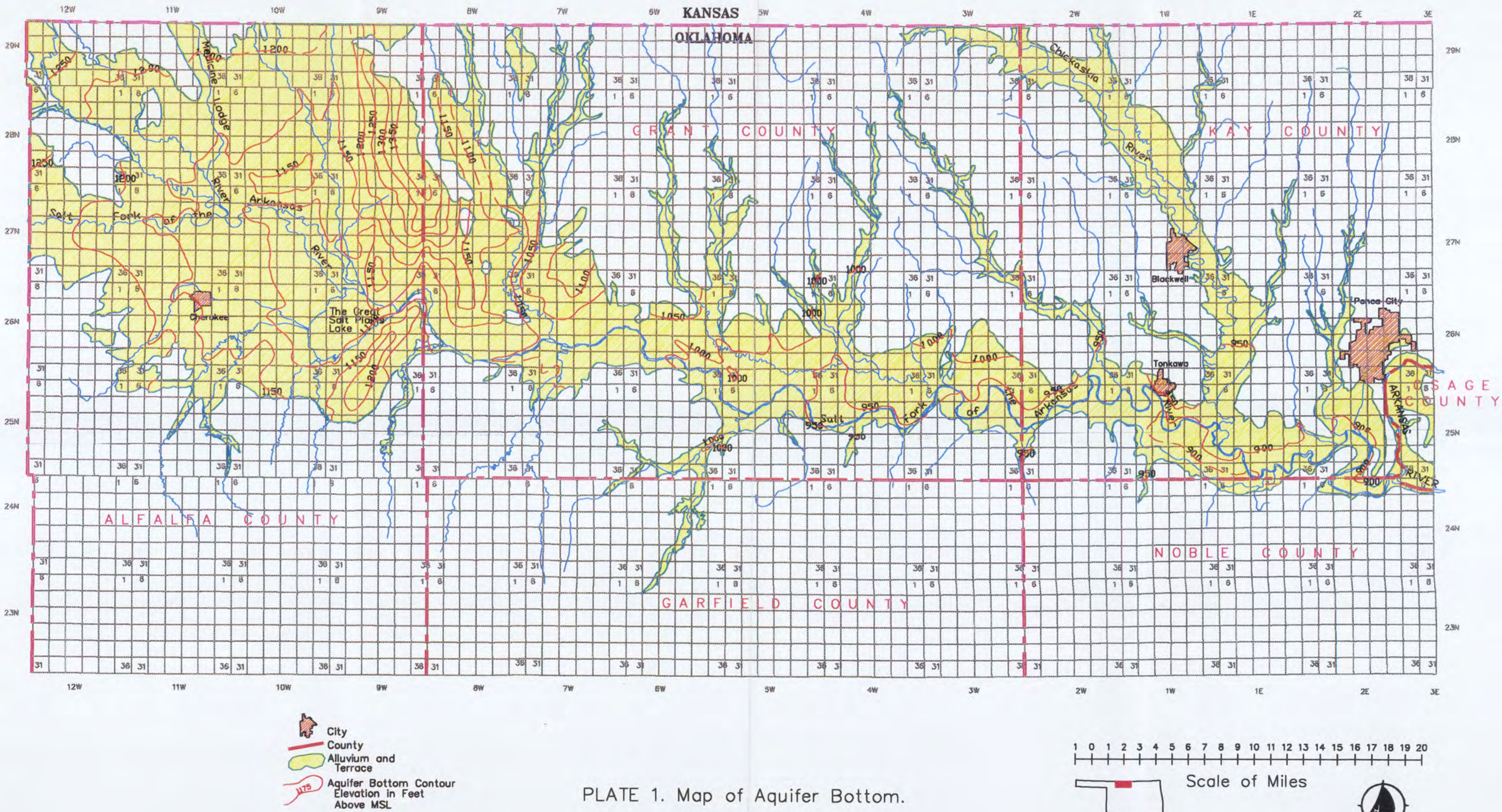


PLATE 1. Map of Aquifer Bottom.

Contour Interval = 50 feet

Map by The Oklahoma Water Resources Board

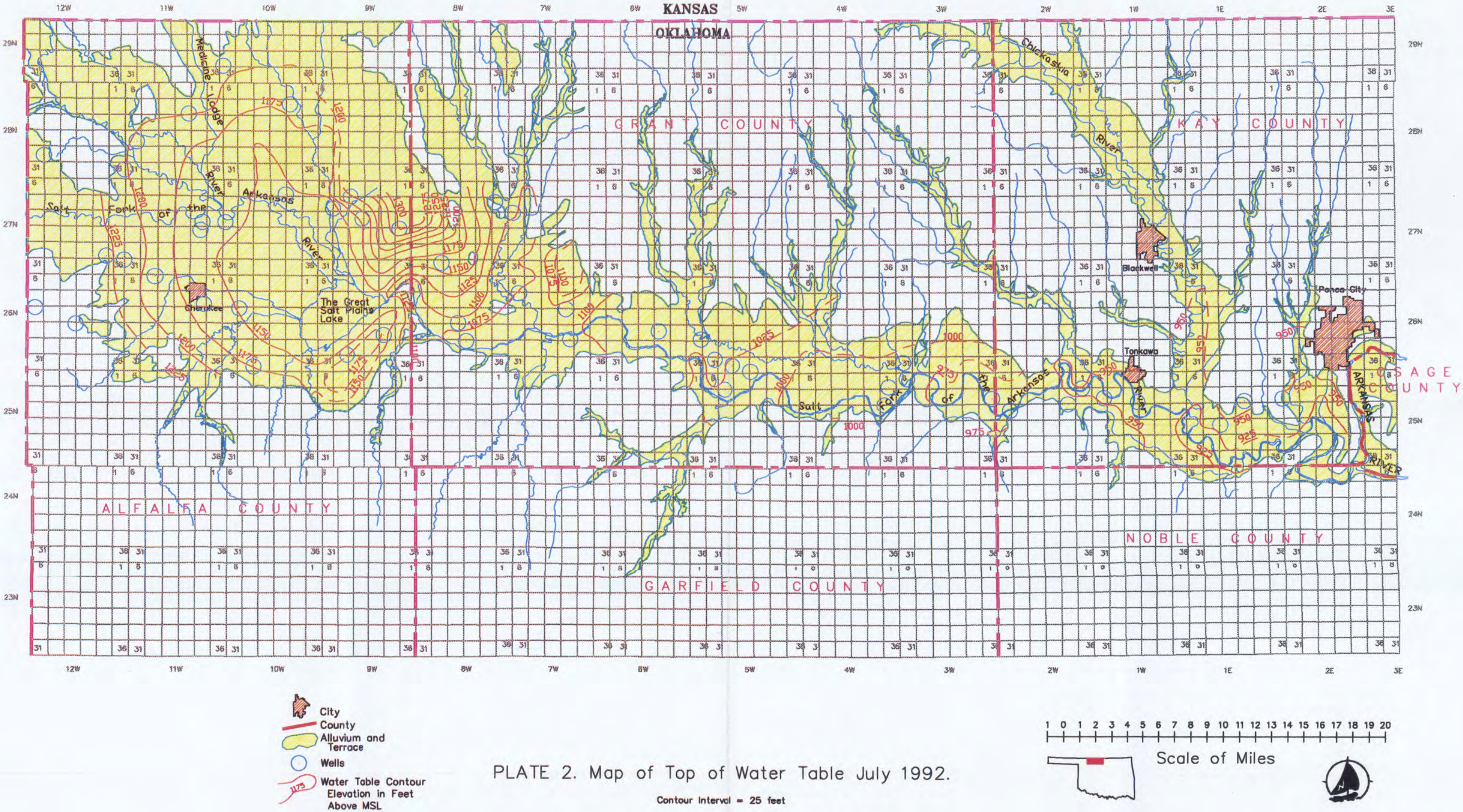
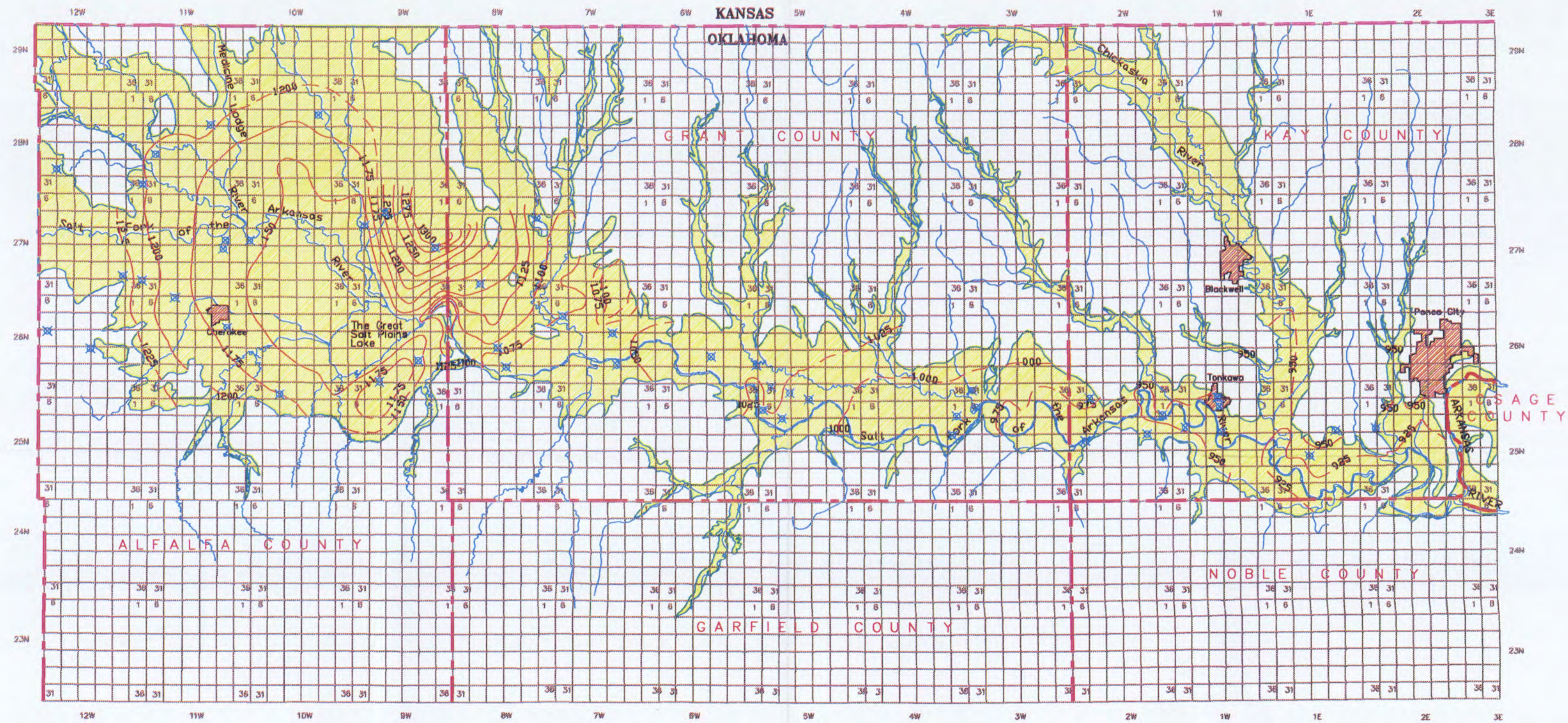


PLATE 2. Map of Top of Water Table July 1992.

Contour Interval = 25 feet

Map by The Oklahoma Water Resources Board



City
County
Alluvium and Terrace
Wells
Water Table Contour Elevation in Feet Above MSL

PLATE 3. Map of Top of Water Table December 1992.

contour interval = 25 feet

Map by The Oklahoma Water Resources Board

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Scale of Miles

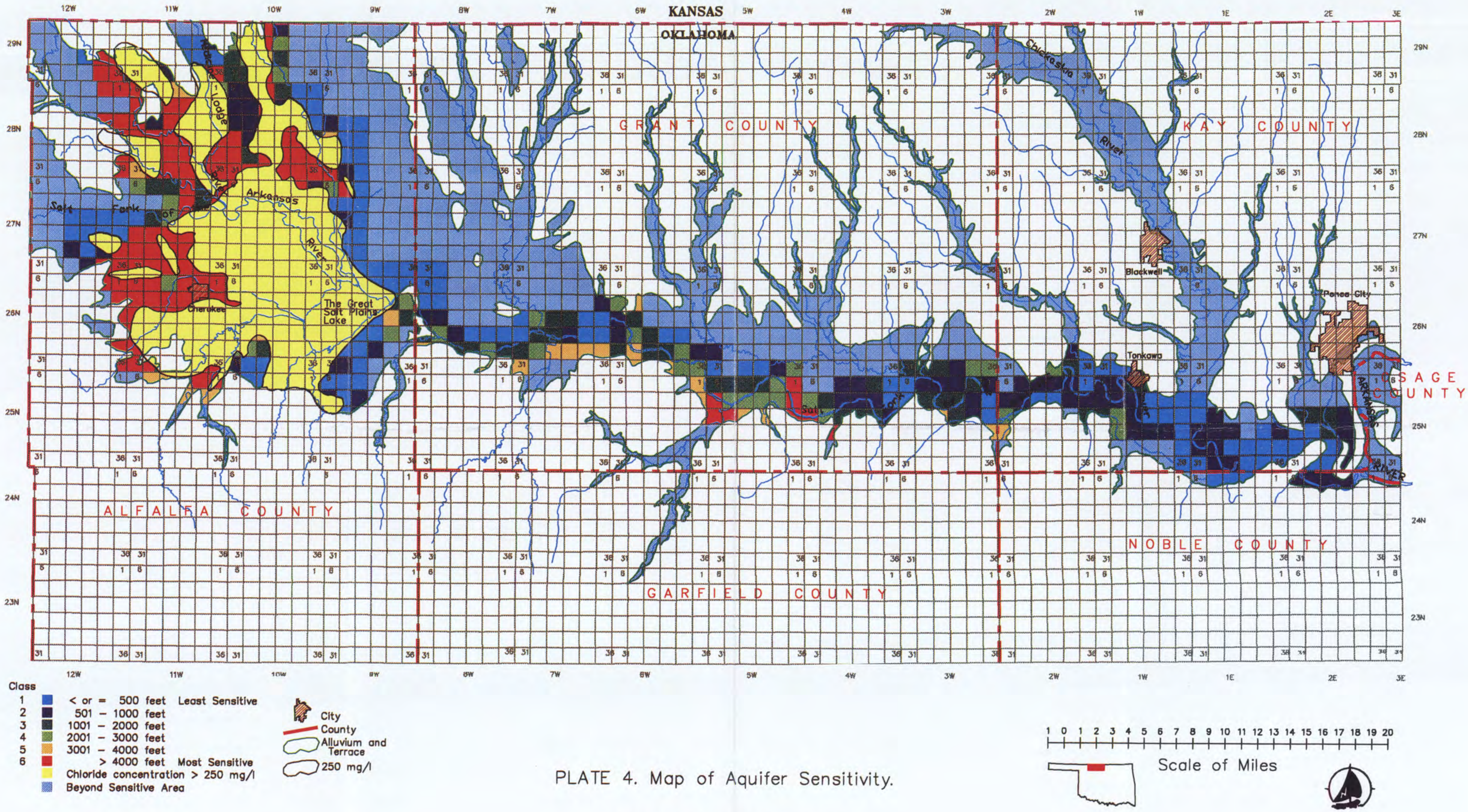


PLATE 4. Map of Aquifer Sensitivity.

Map by The Oklahoma Water Resources Board

VITA

Edward Eckenstein

Candidate for the Degree of

Master of Science

Thesis: SENSITIVITY OF THE ALLUVIAL AND TERRACE-ALLUVIAL AQUIFER OF THE SALT FORK OF THE ARKANSAS RIVER TO INDUCED INFILTRATION

Major Field: Geology

Biographical:

Personal Data: Born in Chicago Illinois, August 10, 1955, the son of John and Dolores Eckenstein.

Education: Graduated from Marist High School, Chicago, Illinois in May 1974; received a Bachelor of Science Degree in Geology in August 1979; completed the requirements for the Master of Science Degree at Oklahoma State University in May, 1995.

Professional Experience: Well-Site Geologist, Geological Logging Co., Oklahoma City, OK, 1979 to 1981; Exploration Geologist, Woods Petroleum Corp., Oklahoma City, OK, 1981 to 1985; Self Employed, Well Site Geologist, Oklahoma City, OK, 1985 to 1987; Geologic Consultant, Accessible Data Co., Oklahoma City, OK, 1988 to 1990; Water Resources Geologist, Oklahoma Water Resources Board, Oklahoma City, OK, 1990 to present.