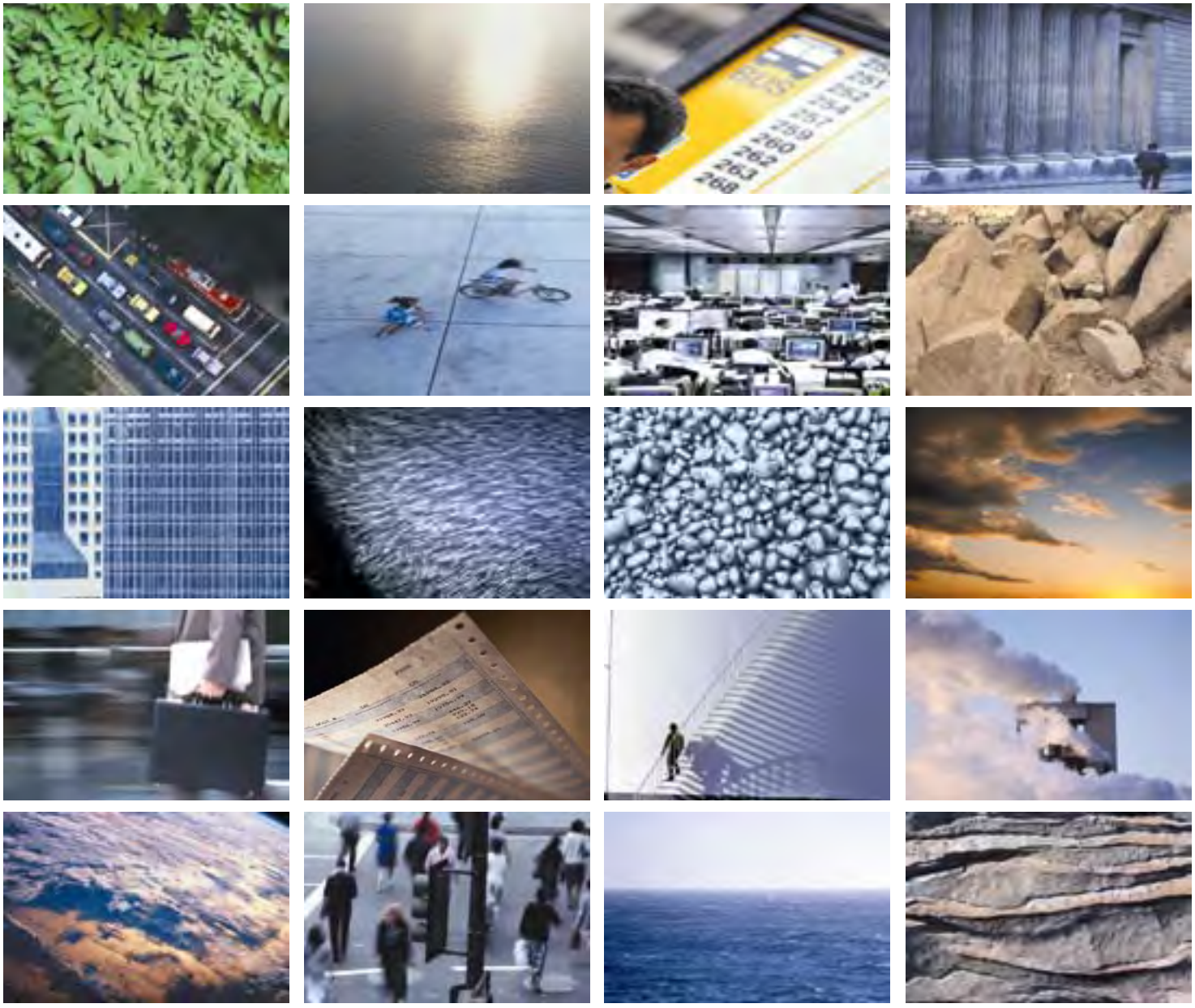

Water Availability and Use in the Woodford Shale Play (Arkoma Basin)

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June 10, 2009

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Project No. 0097954

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EXECUTIVE SUMMARY

ERM conducted a study of water resources in the Woodford shale play study area of Atoka, Coal, Hughes, and Pittsburg counties in the Arkoma Basin of southeast Oklahoma, as it relates to gas well development and fraccing. This study includes a survey of water availability, quality and use in the study area. In addition, regulations as they relate to water use and post-frac produced water disposal or reuse were reviewed. ERM contacted industry and regulatory persons and reviewed industry and academic publications regarding current and best practices for the disposal, treatment, or reuse of post-frac produced water in the study area. The results of this investigation are detailed in a table of management practice alternatives.

The survey of water availability and use in Atoka, Coal, Hughes, and Pittsburg Counties, Oklahoma determined the following:

- The predominant source of water available within the study area is surface water, although some ground water resources are present.
- As follows, the majority of water use in the study area is of surface water resources. The majority of long-term permitted surface water use is for public supply; most of this is to supply the city of Oklahoma City. The majority of long-term permitted ground water use is for irrigation. The majority of 90-day water permits are for oil and gas use.

The review of water rights, permitting, and regulations in Oklahoma, as pertains to shale gas well development and fraccing, determined the following:

- Surface water in Oklahoma is publically owned, while ground water is considered private property that belongs to the overlying property owner. Use of either surface water or ground water requires a permit application to the Oklahoma Water Resources Board (OWRB).
- Provisional temporary permits (90-day permits) are available for both surface water and ground water use. These permits do not require public notice or board approval, and can be granted by the executive director.
- Disposal, treatment, and reuse of post-frac produced water are primarily overseen by the Oklahoma Corporation Commission (OCC). Disposal of post-frac produced water can occur via injection or by surface disposal. Underground injection requires protection of underground sources of drinking water, defined by the base of treatable water. Maps of the base of treatable water are available from the OCC and provided in this report.

Results of the investigation of development water alternatives and current practices are described in a table of management practice alternatives and summarized below.

- Disposal options are underground injection or surface disposal (land application or evaporation).
- Minimization could reduce cost of disposal or treatment.

- Various treatment technologies exist, or are in development. These technologies are not stand-alone treatments for post-frac produced water. Treatment trains combining various technologies are being developed.
- Various reuse/recycling options can be considered, though some are not feasible for the study area. Reuse for frac water or enhanced oil recovery has been practiced in the Woodford shale play.

1.0 INTRODUCTION

Unconventional shale gas production, via horizontal drilling and fracturing techniques, has brought increased activity and attention to shale gas plays throughout North America. The Woodford shale, particularly within the Arkoma Basin of southeast Oklahoma, is one of these shale gas plays. Oil and gas exploration and production has long been a major component of Oklahoma's development and economy. Advances in oil and gas production technology and changes in global and regional energy markets have contributed to additional opportunities for gas production in the Woodford shale of the Arkoma Basin. Along with these opportunities come additional resource requirements, which should be balanced with other development and environmental needs within the region.

This study focuses on the water resource requirements and management practices associated with fracturing (frac process, or fraccing) of the Woodford shale for gas production. Atoka, Coal, Hughes, and Pittsburg counties define the study area (Figure 1) for the purpose of maps and resource surveys presented in this report, though many of the practices, regulations and issues discussed here pertain to areas of the Woodford outside of these counties, and in some cases are applicable to other shale plays in North America.

Water availability is a critical component of shale gas development, as water needs for each well, at least in the short term, are significant. In Atoka County, 42 Woodford shale gas wells were drilled in 2008, at an average depth of 12,279 feet (Appendix A). In that same year, 74 Woodford shale gas wells were drilled in Coal County (average 11,929 feet deep), 165 wells in Hughes County (average 9,526 feet deep), and 182 wells in Pittsburg County (average 9,164 feet deep) (Appendix A). Estimates for maximum water use associated with drilling and cementing of these wells is 21,000 barrels (bbls) in Atoka, 21,000 in Coal, 8,000 in Hughes, and 8,000 in Pittsburg. Estimated maximum water use for completion activities is estimated at 150,000 barrels per well.

Water resource management is a key component of Oklahoma's growth and development, and agencies within Oklahoma are working with municipalities, citizens, industry, and other groups to develop strategies for water use into the future. Water issues include ground water availability, surface water and watershed management, water use and permitting, water quality protection and waste water disposal, beneficial reuse, among others. This report discusses these issues as they pertain to the fraccing of shale gas wells and gas production in the Woodford shale.

2.0 WATER AVAILABILITY AND WATER USE SURVEY FOR FOUR COUNTIES IN THE WOODFORD SHALE DEVELOPMENT AREA

Water availability is a critical issue for shale gas development, due to the requirement for water during various stages of well installation, especially during the fraccing process. The study area counties (Atoka, Coal, Hughes, and Pittsburg) are located near the southern and eastern portion of Oklahoma, within the Arkoma Basin and just northeast of the Ouachita uplift. Much of this region is rural, and dominated by surface water features ranging from small creeks and ponds to large reservoirs (such as Eufaula Lake and Atoka Reservoir). Major ground water resources are less prevalent, though shallow ground water is available, and major Oklahoma aquifers lie to the north, south, and west of the study area.

2.1 WATER AVAILABILITY SURVEY

Surface water is the predominant water resource within the study area (Table 1, Figure 2). Ground water resources are available, though these are limited in yield, and higher yield resources are at the edge or outside of the study area.

2.1.1 Surface Water Resources

The water bodies in Oklahoma are identified by stream systems (Table 1). The stream systems in the study area are the following:

- Muddy Boggy Creek;
- Lower North Canadian River;
- Canadian River to North Canadian River;
- Lower Canadian River;
- Little River; and
- Kiamichi River.

Canadian River, which provides the northern boundary of Pittsburg County and crosses through Hughes County, is a significant source of water for the region. The mean stream flow of Canadian River is 1,783 cubic feet per second (cfs) with maximum stream flow of 174,000 cfs (as measured at the stream gauge at Calvin, OK) (USGS 2008a). Northern Canadian River flows into Eufaula Lake at the northern boundary of Pittsburg County. It has a mean stream flow of 834 cfs and 80% of the flow conditions are between the range of 74 and 1850 cfs (USGS 2008a).

Eufaula Lake is the largest lake in Oklahoma, with a surface area of 105,500 square miles and storage capacity of over 2.3 million acre-feet. Eufaula Lake is formed by the Eufaula Dam on the Canadian River and is used for flood control, water supply, and hydroelectric power (OWRB 2007).

Atoka Reservoir is formed from a dam located on the North Boggy Creek in Atoka County. Atoka Reservoir has a capacity of 225,000 acre-ft, with a range of 99,100 to 142,200 acre-ft of water storage in the 2008 water year (USGS 2008c). Atoka Lake is the water supply for Oklahoma City. Water is transported from Atoka Lake to Lake Stanley Draper, and then to Oklahoma City.

McGee Creek Reservoir in Atoka County has a total storage capacity of 199,237 acre-ft and has a maximum capacity at its outlet of 6,500 cfs (USGS 2008b, USBR 2009). The McGee Creek Reservoir provides 11 cfs minimum flow to McGee Creek for fish, wildlife, and recreation (USBR 2009). McGee Creek is used as a municipal water supply source and for flood control.

Storage capacities and drainage areas of all major lakes and reservoirs in the study area are presented in Table 2, and stream systems drainage areas and stream flows are presented in Table 3.

2.1.2 Surface Water Quality

Surface water in Oklahoma has been monitored by the OWRB under the Beneficial Use Monitoring Program (BUMP) (ODEQ 2008) from 1998 to the present. The summary of water quality data collected in the Woodford study area under this program is presented in Table 4.

According to BUMP data, the average salinity and total dissolved solids (TDS) of water bodies in the study area range from 0.0 parts per trillion (ppt) salinity and 19.6 milligrams per liter (mg/L) TDS at McGee Lake to 0.11 ppt and 155.2 mg/L at Holdenville Lake.

Sampling was conducted at the Blue Creek, Canadian River, Clear Boggy Creek, Muddy Boggy River, and North Canadian River. The average TDS ranged from 127.9 mg/L at Blue Creek in Haileyville to 632 mg/L in the Canadian River in Calvin.

Two stream reaches within the study area on the North Canadian and Canadian River have been identified by the Oklahoma Department of Environmental Quality (ODEQ) in the "Water Quality in Oklahoma 2008 Integrated Report" as Category 5a stream reaches (ODEQ 2008, OWRB 2007). Category 5a stream reaches are stream sections where water quality standards are exceeded and therefore require Total Daily Maximum Load (TDML) limits to protect water quality. The two stream reaches, Canadian River near Calvin and North Canadian River near Wetumka, have high levels of lead, turbidity, and dissolved solids.

The impairment and potential source of impairment for these two stream reaches is summarized below.

Stream Section	Cause of Impairment	Impaired Use	Potential Sources
North Canadian River (near Wetumka)	Lead	Fish Consumption Warm Water Aquatic Community	Highway/Road/Bridge Runoff (Non-construction related)
			Municipal Point Source Discharges
			Source Unknown
	Turbidity	Warm Water Aquatic Community	Grazing in Riparian or Shoreline Zones
			Municipal Point Source Discharges
			Non-irrigated Crop Production
			Rangeland Grazing
			Source Unknown
			Unknown Sources
Canadian River (Near Calvin)	Total Dissolved Solids	Agriculture	Highway/Road/Bridge Runoff (Non-construction related)
			Source Unknown
	Turbidity	Warm Water Aquatic Community	Grazing in Riparian or Shoreline Zones
			Municipal Point Source Discharges
			Non-irrigated Crop Production
			Rangeland Grazing
			Source Unknown
	Lead	Fish Consumption Warm Water Aquatic Community	Highway/Road/Bridge Runoff (Non-construction related)
			Municipal Point Source Discharges
			Source Unknown

2.1.3 Ground Water Resources

The Antlers Aquifer, a bedrock aquifer, is located on the southern border of the study area and is one of the primary sources of ground water for Atoka County. The Antlers Aquifer consists of sand, clay, conglomerate, and limestone. Saturated thickness ranges from 0 feet to 400 ft in the study area. Recharge for the aquifer is 0.32 to 0.96 inches per year (USGS 1992). Hydraulic conductivity ranges from 0.87 to 3.75 feet per day (USGS 1992). Yields in the Antlers aquifer usually are 100-500 gpm, but yields have been recorded up to 1,700 gpm. (Osborn and Hardy, 1999).

A second bedrock aquifer, the Arbuckle-Simpson Aquifer, is located at the western edge of Coal County. This aquifer is considered a "sensitive sole source aquifer" as authorized by Section 1424(e) of the Safe Drinking Water Act of 1974 (Public Law 93-523, 42 U.S.C. 300 et. seq); EPA defines a Sole Source Aquifer as

one which supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer. In 2003, Oklahoma legislature put a moratorium on issuance of 90-day permits in sensitive Sole Source Aquifers (82 O.S. § 1020.9A (OSCN 2009); 2006 OK 34, 148 P.3d 842). The Arbuckle-Simpson is the only aquifer in Oklahoma with the Sole Source Aquifer designation. The OWRB has undertaken the Arbuckle-Simpson Hydrology Study (2003 to 2008) in collaboration with the USGS. Although the outcropping Arbuckle-Simpson aquifer does not overlap significantly with the study area, and the issuance of permits in the aquifer is restricted, it is likely that more saline water (brine) exists in the formation adjacent to the area defined as the aquifer, though exact depth and extent has not been determined (USGS, 2009).

Two alluvial aquifers in the study are the Northern Canadian River Alluvial Aquifer and the Canadian River Alluvial Aquifer. Both aquifers are unconfined aquifers composed of alluvium and terrace deposits of sand and gravel, with silt and clay lenses. The deposits range in thickness from a few feet to 200 ft. Yields from these aquifers range from 10-500 gpm, but can yield up to 1,000 gpm in coarse sand and gravel layers (Osborn and Hardy 1999).

The Pennsylvanian Hydrogeologic Basin, as defined by the OWRB, includes all of the Pennsylvanian outcrops in Oklahoma, excluding the Vamoosa-Ada and Ouachita Mountains (Osborn and Hardy 1999). The Pennsylvanian Hydrogeologic Basin includes the majority of the aquifers that provide ground water to the region, which include the following geologic units:

Seminole Formation,

Wetumka Shale,

Wewoka Formation,

McAlester Shale,

Calvin Sandstone,

Senora Formation,

Boggy Formation, and

Atoka Formation.

The Pennsylvanian Basin consists of sandstone, shale, siltstone, and limestone. Ground water sources in the basin are primarily in the sandstone layers with yields up to 25 gpm (Osborn and Hardy 1999). Along with the Antlers Aquifer, the Pennsylvanian Hydrogeologic Basin is a primary source of ground water to Atoka County. Detailed aquifer information is provided in Table 5.

2.1.3 Ground Water Quality

Ground water resources in the study area are not highly utilized, and therefore, ground water quality data is limited in the study area counties (Personal Communication, Noel Osburn, OWRB). Data for ground water quality was gathered from the USGS National Water Information System and is presented in Table 6 (USGS 2009). Available water quality data for the study area was limited to that collected between 1975 and1982.

The BUMP also evaluates ground water in Oklahoma. From the ground water survey conducted, the DEQ identified water quality issues with the Antlers Sandstone and the Alluvium and Terrace Deposits of the Canadian River, where elevated nitrate levels were detected in some of the wells (ODEQ 2008).

TDS range from 157 mg/L in the McAlester Shale in Coal County to a maximum of 2000 mg/L in the Boggy Formation in Pittsburg County. Figures 3 and 4 show TDS distribution in the Antlers Aquifer and the alluvium terraces of the Canadian River.

2.1.4 Base of Treatable Water

The depth to the base of treatable water is determined by drillers when drilling oil and gas or commercial underground injection wells. This data is then reported to the Oklahoma Corporation Commission (OCC). The OCC has created maps of the base of treatable water, which are provided in Figures 5 through 9. These maps are contoured in feet below sea level, although data points are not provided. Information from these maps should be considered qualitative. Woodford shale gas wells in the study area are drilled to depths greater than 4,000 feet below the surface.

2.2 WATER USE SURVEY

Evaluation of water use in the study area was conducted using OWRB permit databases, as provided by Bob Sandbo of the OWRB from 2008 data. The reported water allotments were provided in two databases: long-term permits and 90-day permits (permits issued from April 21, 2008 to April 21, 2009). The long-term water permits database provided water user name and address, county, amount of water allotted, water source information (i.e. stream system or aquifer), location of the well or the intake point, and water use type. The 90-day permits database provided the water user name and address, county, amount of water allotted, water source (i.e. ground water or surface water), location of the well or the intake point, and water use type.

Water use in the Woodford study area is primarily surface water use, as shown in Figure 10 and Table 7, due to the presence of three major reservoirs and two major rivers in the study area, and limited ground water aquifers. Ninety-three

percent (93%) of the total permitted water allotment in the study area was from surface water.

In the study area, 72% of the total surface water use is for public water supply (Figure 11). The second greatest surface water use in the study area is for power generation (13% of all long term permitted water use). The primary sources of surface water for the study area are within the Muddy Boggy River Stream System, including the Atoka Reservoir, McGee Creek Reservoir, and Coalgate Reservoir (Table 8). The areal extent of this stream system includes both Atoka and Coal counties. Oklahoma City has a permitted water use for public water supply of 131,667 acre-ft, which is 81% of the water use from the Muddy Boggy River stream system in Atoka County and 46% of total permitted water use in the study area (Figure 12).

Ground water is primarily used for irrigation (61%) and public supply (22%), as shown in Figure 13. The Canadian River Alluvial Aquifer and Antlers Aquifer provide 36% and 13%, respectively, of the long-term permitted ground water use for the study area (based on 2008 data) (Table 9). Minor aquifers provide 49% of the ground water for the region. Minor aquifers include formations such as the Seminole Formation, Wetumka Shale, and the Wewoka Formation as shown in Figure 14.

Water use for mining (which includes water use for oil and gas exploration) consists of 10% of total permitted water use (in 2008), yet 99% of the 90-day permitted water use, as reported for April 22, 2008 to April 22, 2009. Additionally, 97% of the water use for 90-day permits is from surface water sources. Table 10 shows the top five water users in the study area from the 90-day permits in 2008.

Overall, the top water users in the study area are public water supply for Oklahoma City and McAlester and power generation by the Public Services Commission of Oklahoma and the Juniper Water Company LLC.

Water use surveys have been conducted by the USGS for the OWRB for water data from 1995 and 2000 (USGS 1999, 2004). The study for 2005 is currently being developed. Raw data has been obtained from the USGS and the ORWB but a complete study has not been released to the public (Personal communication with Stan Paxton, USGS, April 2009 and Terri Sparks, OWRB, April 2009).

3.0 SUMMARY OF WATER RIGHTS, PERMITTING AND REGULATIONS PERTAINING TO WATER USE FOR SHALE GAS DEVELOPMENT

Water use for shale gas development includes water supply, waste water disposal and water reuse/recycling issues that are at least in part, regulated by the state of Oklahoma. Water supply regulations pertain to the use of fresh water from either surface or subsurface sources. Waste water disposal and reuse/recycling regulations pertain to the ultimate disposition of produced or flow back water from frac operations. Information on water regulations was obtained from published Oklahoma laws, rules and guidance provided by the OWRB. OWRB rules are codified in Oklahoma Administrative Code (OAC) Title 785. Appendix B includes a sample of permit forms or permitting guidance associated with the regulations described below. The collection in Appendix B is not complete, and included for example only; current permit applications should be obtained from the appropriate agency as needed.

3.1 WATER SUPPLY

Oklahoma recognizes three classes of water: stream water, ground water and diffused water. Stream water includes all surface water contained within a watercourse in a defined, natural channel with defined beds and banks, originating from a definite sources of water (OAC 785:20-1-2). Stream water includes lakes, creeks, rivers and ponds. Ground water is defined as "fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut bank of any definite stream (OAC 785:30-1-2)." Diffused water is sheet flow runoff prior to the water entering a defined channel or basin. Diffused water is typically not a significant source of water for the oil and gas industry. Each class of water has its own set of water rights and water use regulations.

Other potential stakeholders in water use decisions include river or lake authorities, conservation districts, and tribal entities. No tribal reservation lands exist within the study area counties [Bureau of Indian Affairs (nationalatlas.gov)]. Lake authorities include the Lake Atoka Reservation Association (LARA) and the McGee Creek Authority. These authorities are made up of multiple stakeholders, including the City of Oklahoma City, the City of Atoka, and Atoka County. These groups typically meet twice a year to discuss and manage water use and utility service from the associated water body. The Oklahoma Conservation Commission provides assistance to Oklahoma's 88 conservation districts to accomplish conservation of renewable natural resources through soil and water conservation, land use planning, small watershed upstream flood control, abandoned mine land reclamation, water quality monitoring, environmental education and wetlands conservation. Each county has its own conservation district.

3.1.1 Surface Water Supply Regulations

In Oklahoma, stream water is publicly owned and subject to appropriation by the OWRB. Surface water regulations are codified in OAC Title 785, Chapter 20. Appropriation takes the form of permitted water rights, assigned by the OWRB. The regular permit process is described by an OWRB flowchart (Figure 15). There are exemptions from permitting for domestic use by riparian owners and for the capture and storage of diffused water on the landowner's property.

A permit must be obtained from the OWRB prior to diverting any stream water. The applicant must make application to the OWRB to obtain a permit. Per the OWRB, there are four conditions that must be met in order to qualify for a permit.

1. The amount of unappropriated water applied for must be available;
2. The intended use must be beneficial;
3. The proposed use must not interfere with existing appropriate uses or exempt domestic use; and
4. If the water is intended for use outside of the area where the water originates, the use must not interfere with beneficial uses within the stream system.

The OWRB can issue five types of stream water permits.

1. "Regular" permits allow the permit holder to appropriate water year around. The permit holder must use the entire annual allocation at least once every seven years or lose the unused portion of the allocation;
2. "Seasonal " permits allow for the diversion of water during specified periods of time during the year;
3. "Temporary" permits authorize water use for up to three months;
4. "Term" permits allow for appropriate water use for a specified number of years; and
5. "Provisional Temporary" permits allow for appropriation for up to 90 days and is non-renewable.

For regular, seasonal, temporary and term permits, notice of application must be published in local, county newspapers where the diversion will take place and in the adjacent downstream county. Parties whose interests could be affected by the proposed water use may protest the issuance of the permit. The OWRB would hold an administrative fact finding hearing on the permit.

Provisional temporary permits do not require public hearing, publication of application or notification of downstream users. The executive director may summarily and immediately approve a provisional temporary permit application.

In addition to permitting for surface water use, any works or construction activities that occur in the nation's waters, including wetlands and navigable waters, are subject to review and permitting by the Army Corp of Engineers (ACE). During personal communication, ACE stated that if a facility was constructed on a surface water body that impacted the navigability of the body, then a Section 10 permit might need to be filed. Furthermore, the ACE suggested that a Section 404 permit might need to be filed if the intake facility or conveyance (pipeline) were to be constructed in or near federally designated wetlands.

3.1.2 Ground Water Supply Regulations

Ground water in Oklahoma is considered private property that belongs to the overlying property owner. Even though the resource is considered to be privately owned, ground water is subject to reasonable regulation by the OWRB. Ground water regulations are codified in OAC Title 785, Chapter 30.

As with surface water, a permit must be obtained from the OWRB prior to actual use (Figure 15). Domestic uses are exempt from the permitting process. Applicants for a ground water permit must publish notice in the local newspaper. In addition, all landowners within one quarter mile of the proposed well site must be notified via certified mail.

Four conditions must be met prior to the OWRB issuing a permit.

1. Applicant owns or leases the land;
2. Land lies atop a fresh ground water basin or sub-basin;
3. Water use is beneficial; and
4. Waste by depletion or pollution will not occur.

The amount of water allocation granted in a permit is based the amount of land owned or leased. In basins where maximum annual yields have not been determined, the permits grant ground water withdrawal rates of two acre-ft/year per acre of land. In basins where the annual yield has been determined, slightly more or less water is typically allocated.

There are four types of ground water permits.

1. "Regular" permits are permits issued in basins where the maximum annual yield has been determined. The amount of water permitted is based on the percentage of land owned or leased by the applicant;
2. "Temporary" permits are issued prior the OWRB determining the maximum sustainable annual yield of the basin. These permit are issued for two acre-ft/year per acre of land owned or leased;
3. "Special "permits are an authorization by the OWRB to pump ground water in lieu of or in addition to a regular or temporary permit. Permit

duration must not exceed six months, though special permits may be renewed up the three times; and

4. "Provisional temporary" permits may be approved for up to 90 days, but may be cancelled at anytime.

As with provisional temporary surface water permits, the executive director may summarily and immediately approve a provisional temporary permit application. Provisional temporary permit holders are required to notify the OWRB in writing of the disposition of the well(s) within 30 days of permit expiration.

Both surface water and ground water can be stored in surface pits or reservoirs on owned or leased land, as long as the surface water diversion or ground water use is permitted as described above. Some operators in the area have been able to make use of abandoned open pit coal mines to create pits for backup water supply.

3.2 SUMMARY OF REGULATIONS RELATING TO PRODUCED WATER FROM FRAC OPERATIONS: DISPOSAL AND REUSE/RECYCLING

The OCC has developed rules for the oil and gas industry. The OCC regulates surface storage, reuse and underground injection associated with the oil and gas industry. OCC rules can be found in OAC Title 165. Per OAC 165:10-7-24, produced water must be reclaimed and/or recycled, used in underground injection (disposal or enhanced oil recovery) or discharged in accordance with OAC 165:10-7-17 & 18 relating to surface discharge.

3.2.1 Surface Storage

Pits are typically used on a temporary basis to collect and store produced water. A noncommercial pit (OAC 165:10-7-16) is an earthen pit which is located either on-site or off-site and is used for the handling, storage, or disposal of drilling fluids and/or other substances produced, obtained, or used in connection with the drilling and/or operation of a well or wells, and is operated by the generator of the waste. This includes completion/fracture/workover pits, recycling/reuse pits, converted pits, and offsite pits.

Pits holding water-based fluids are required to have a geomembrane liner if the water table is within 10 feet of the surface, or the pit is located in a wellhead protection area. A soil or geomembrane liner is required if located above terrace deposits or if stored fluids exceed 5,000 mg/L chloride concentration. Any pit used to contain oil-based fluids is required to have a geomembrane liner. Liners must be certified.

A minimum 24" of freeboard is required for these pits and they must limit fluids from a single well if the pit will be used for reserve/circulation pit. If the pit will

be used for recycle/reuse, the pit may contain fluids from multiple wells being developed by the same operator. All pits must utilize protection measures against flooding or runoff entering pit. Offsite pits must be permitted and have signage; must be spaced greater than 600 feet from any other pit; and may not be constructed at a spacing closer than one pit per quarter section.

Produced water may be stored in tanks for reclamation or recycling. This water must be permitted (initial notification of the district office is required). The tank must be labeled "recycle"; the water must be <5,000 mg/L TDS and <1,000 mg/L oil and grease; and the generator must maintain record of load tickets from wells that the water was obtained.

3.2.2 Surface Discharge of Produced Water

Surface discharge of produced water requires permitting, regular sampling, annual reporting, and is subject to the following site and water quality restrictions (OAC 165:10-7-17).

(1) Site restrictions – discharge of produced water shall only occur on land having an Exchangeable Sodium Percentage (ESP) no greater than 15, and all of the following characteristics:

(A) Maximum slope of five percent,

(B) Depth to bedrock at least 20 inches, and

(C) Slight salinity (defined as an electrical conductivity less than 4,000 microhms/cm) in the topsoil or upper six inches of the soil.

(2) Water quality limitations – a surface discharge permit shall not be issued if the produced water to be discharged exceeds either of the following concentrations:

(A) Total Dissolved Solids (TDS) or Total Soluble Salts (TSS) - 5000 mg/L, or

(B) Oil and Grease - 1000 mg/L.

Water discharge to surface water bodies is prohibited unless the owner has a valid national pollution discharge Elimination Permit issued by U.S. EPA (OAC 165:10-7-18)

3.2.3 Burial (Noncommercial Pits)

Burial of drilling-related solids requires liner, specific construction, operation, and closure requirements (OAC 165:10-7-16). Burial is limited to solids associated with water. Free liquids must be physically removed or chemically solidified with non-hazardous material or removed by evaporation or dewatering for surface discharge.

3.2.4 Underground Injection Wells

Upon application and permitting, produced water may be injected into the subsurface. The following are classifications of underground injection wells regulated by the OCC (OAC 165:10-5-1).

(1) Enhanced recovery injection well. An enhanced recovery injection well (ERIW) is a well which injects fluids to increase the recovery of hydrocarbons.

(2) Disposal well. A disposal well is a well which injects, for purposes other than enhanced recovery, those fluids brought to the surface in connection with oil or natural gas production.

(3) Storage well. A storage well is a well used to inject, for storage purposes, hydrocarbons which are liquid at standard temperature and pressure.

(4) Simultaneous injection well. A well that injects or disposes of salt water at the same time it is producing oil and/or gas to the surface.

The permitting requirements are similar for ERIW and disposal wells. The permitting, testing, monitoring and reporting requirements of the OCC are included in OAC 165:10-5-2, 3, 4, 5, 6 & 7.

There are many commercial injection wells in the area that will accept produced water (Table 11). These facilities are discussed in Section 4.

3.2.5 Additional Water Use Regulations

Additional information/documents are required for permit applications pertinent to enhanced recovery of oil and gas using fresh water as the injection fluid. The OCC regulations provide for the permitting of all ERIWs and injection wells (OAC 165:10-5). The OWRB has additional requirements for the use of fresh water for EOR depending on whether stream or ground water is used. These rules can be found in OAC 785:20-3-4 for surface water and OAC 785:30 3-2 for ground water. In general, both the surface water rule and ground water rule require very similar information be submitted with an application.

4.0 DEVELOPMENT WATER ALTERNATIVES AND CURRENT PRACTICES

The installation and development of a shale gas well, along with subsequent production, requires water and produces wastewater as various steps (Figure 16). This study investigates the management of water at the stage of fraccing and post-frac produced water. After review of the available resources, applicable regulations, current practices, and developing technology, various water management practice alternatives can be considered for shale gas well post-frac produced water. ERM contacted industry and regulatory persons and reviewed industry and academic publications regarding current and best practices for the disposal, treatment, or reuse of post-frac produced water in the study area. The results of this investigation are provided as a table of management practice alternatives (Table 12). This matrix includes information on cost, risk, current use in the Woodford shale play, advantages and disadvantages.

4.1 SURVEY OF CURRENT PRACTICES FOR WATER USE IN SHALE GAS WELL DEVELOPMENT AND HYDROFRACTURING

ERM engaged in verbal communications with regulatory and industry stakeholders in order to obtain information on water rights, use, reuse and disposal regulations and current and alternative management of post-frac produced water. A list of those contacted and their affiliation is included below:

- Tim Baker, OCC, Oil and Gas Pollution Abatement
- Charles Lord, OCC, Underground Injection Control
- Dennis Niskern, OCC, Base of Treatable Water Expert
- Bob Griffith, OCC, ISS Coordinator (GIS Mapping and OCC Databases)
- Julie Cunningham and Bob Sandbo, OWRB, Planning and Management Division, Water Permitting
- Angie Burckhalter, Oklahoma Independent Petroleum Association, Industry Practices in Water Use and Disposal for Woodford
- Noel Osborn, OWRB, Water Resources Geologist
- Terri Sparks, OWRB, Water Use Information
- Jay Wright, ODEQ, Ground Water Quality Division
- Stan Paxton, USGS, Water Science Center, Chief
- John Veil, Argonne National Labs, Produced Water Management Practices and Costs
- Chuck Wilson, EastOK, Water Sourcing and Transfer
- Rex Cathey, Big Mac Trucking, Post-frac Produced Water Transport and Disposal
- John Walker, National Coal County, Catchment Disposal and Recycling of Post-frac Produced Water

Information collected from these persons was used to compile and evaluate current and alternative management practices for the Woodford shale play, as described below.

4.2 AVENUES FOR WATER REUSE OR DISPOSAL INSIDE AND OUTSIDE OF WOODFORD SHALE DEVELOPMENT AREA

This study focuses on post-frac produced water (water that is recovered from down-well during/after the fracture sequences are completed). End use of post-frac produced water can be grouped into two general categories: underground injection and surface discharge. Even if a certain portion of the water is treated or re-used, some portion will be considered wastewater and need disposal, which is typically done either through a permitted injection well or a permitted land treatment or surface discharge alternative. Depending on the location of the production well and various other factors, several post-frac produced water best management practices are viable for the Woodford shale play.

Water may be treated prior to discharge or disposal to facilitate beneficial reuse. Selection of water treatment options should be based on the water quality of post-frac produced water; several possibilities are reviewed in Table 12, a matrix of viable alternatives. Table 12 evaluates common end use alternatives that are available in the Woodford shale play, additional alternatives that are used in other shale plays, and additional potentially feasible alternatives. Current practices within the Woodford play are indicated in the table. The remainder of this section summarizes the alternatives for post-frac produced water end use listed in Table 12.

4.2.1 Disposal Via Underground Injection

Underground injection wells are divided into various classes based on use, including those listed below. Disposal by Class I, Class II or Class V injection is an option for disposal of post-frac produced water, though only Class II is practiced in the Woodford, as described in Table 12.

- Class I Injection Wells
  - Oklahoma has less than 10 permitted hazardous wastewater Class I injection wells.
- Class II Injection Wells
  - Oklahoma has 22,000 permitted Class II injection wells.
  - Class IIR injection wells are used for "waterflood" operations.
  - Class IID injection wells exploit unused aquifer units with poor water quality (typically >10,000 mg/L TDS).
- Class V Injection Wells
  - Class V wells include other less conventional subsurface disposal options such as Subsurface Drip Irrigation (SDI), a beneficial use for nearby agricultural land. SDI applicability would be linked to water

quality and the type of crop; for example, grasses and alfalfa are tolerant of some salt concentration in the water.

- An application and OCC approval is required prior to construction of an injection well. During construction and completion, requirements include approved cement bond log, initial and regular testing, monitoring and annual reporting.

General considerations for evaluating feasibility of an injection well disposal alternative include the following.

- Formation characteristics must be suitable to receive injectate safely:
  - Geographic location, depth and stratigraphy in relation to confining layers, aquifers, other porous zones, faulting, and vicinity wells;
  - Isolation from aquifers and other porous zones or penetrations, and location in relation to the base of treatable water or underground storage of drinking water (USDW) (refer to Figures 5 - 9);
  - Porosity;
  - Permeability; and
  - Storage capacity, with or without perforations or fractures in the unit to increase permeability.
- Reservoir pressure must also be estimated to evaluate maximum rate of injectate and maximum volume.
- Water quality of the formation and of the injectate must be considered; a compatibility test is often performed to evaluate feasibility. Compatibility tests require cores of the reservoir and consider whether or not clay or other mineral grains can react, swell or become mobile in the presence of the injectate.

In Oklahoma, the Pollution Abatement/Underground Injection Control Department of the OCC permits Class II Wells. Class II Wells, also referred to as Underground Injection Control (UIC) Wells, are used to inject fluids from oil and gas recovery into geologic formations. In Oklahoma, there are 11, 365 UIC wells as of July 2006 (EPA 2006). A complete listing of all commercial UIC wells in Oklahoma is maintained by the OCC (OCC 2008). In the study area, there are two UIC wells in Atoka County, 61 in Coal County, 513 in Hughes County, and 28 in Pittsburg County as of December 2008 (OCC 2008, Table 11). Data was also obtained from the OCC (Griffith 2009) for compiling maps of the Commercial and Oil and Gas Injection Wells (Figure 17 and 18). There are additional well listings in Table 11 as compared to the map produced from the GIS database provided by the OCC, as the GIS database was based on data from up to December 2007.

4.2.2 *Disposal Via Surface Discharge*

Disposal by land application and to evaporation pits/ponds (on-site and off-site) is an option for disposal of post-frac produced water. Both options are practiced in the Woodford, as described in Table 12.

- Discharge to evaporation pond (surface impoundment).
  - On-site impoundments can be built, lined and permitted for relatively low cost; sludge is generated and must be disposed of intermittently.
  - Off-site, 3rd party facility exists for disposal via surface impoundment/ settling ponds; water can be withdrawn from the impoundments and re-used in fracturing operations.
  - Off-site livestock watering is a similar application that is a beneficial re-use option (pre-treatment may be necessary to achieve TDS < 10,000 mg/L).
- Discharge directly to surface soil.
  - Depending on water quality or pre-treatment, land irrigation or land farming may be a possible discharge option.
  - Dust control and crop irrigation are beneficial re-uses within this disposal option.
  - Constructed wetlands is another beneficial re-use alternative.

Discharge to a stream or river is potentially an alternative, although pre-treatment would likely be needed. Piping infrastructure may also be needed and permitting is required; permitting of discharge of post-frac produced water to streams is unlikely.

4.2.3 *Minimization*

Minimization of post-frac produced water can reduce costs and impacts of water transport, storage, treatment and/or disposal. Strategies for produced water minimization are still in development, such as use of a downhole gas/water separator (Table 12).

4.2.4 *Reuse/Recycle*

Reuse or recycling can be an attractive option for post-frac produced water because it reduces resource consumption and can potentially reduce costs. Various reuse/recycling end uses are listed in Table 12, including vehicle/equipment washing (at the well site for example), cooling water (e.g., at power generation facilities), or emergency fire water (Table 12).

Based on ERM's research and conversations with various stakeholders, including Tim Baker in Pollution Abatement at the OCC, there are three main practices currently in use in Oklahoma for water reuse and recycling:

- Temporary storage in a permitted, onsite catchment/pit for reuse in a subsequent frac.
    - Best suited for small projects of 1-3 wells, using about 100,000 barrels of water per well for frac; otherwise, the volumes can become too large to effectively deal with onsite; and
    - Water typically can be reused for 2-3 frac jobs before the chloride concentration becomes too high for effective friction-reducing qualities; and divalent cations iron, barium and calcium concentrations become too high and create the potential for scaling (Horn, 2009).
- Storage, treatment and reuse at a third party, permitted, large-scale catchment/pit.
    - Post-frac produced water must be trucked to the facility, where solids are settled out in an initial pit, analyzed for quality, and then transferred to another pit for storage and re-use;
    - Re-use involves trucking of treated water back to the development site;
    - The pits are large, often greater than 10 acres in size;
    - Permits often require testing of water upon entry to the facility and after treatment to meet minimum quality requirements for reuse; and
    - National Coal County is operating a catchment of this type in Tupelo and Centrahoma, Oklahoma (Figure 17).
- Development site treatment and reuse.
    - Post-frac produced water is run through an onsite treatment train to bring water quality into a sufficient range for reuse, either as potable water or for a subsequent frac;
    - Technologies often employed in treatment trains are discussed in Table 12;
    - Multiple vendors have treatment processes for post-frac produced water;
    - Newfield Exploration and Ecosphere have conducted pilot tests near Coalgate, Oklahoma of a treatment process using filtration, oxidation, electro-precipitation, centrifuge and reverse osmosis (Table 12);
    - Devon and Fountain Quail are utilizing evaporation/distillation units to treat and recycle post-frac produced water in the Barnett Shale in the Fort Worth area; and
    - According to the OCC, Devon is preparing to run a treatment technology pilot test for produced water in the Anadarko Basin in Oklahoma in the near future, but has not yet applied for the necessary permits.

- Unique reuse options may also be possible; one operator has coordinated with an abandoned mine reclamation project, to reuse produced water / flowback water as part of the mine reclamation efforts.

4.2.5 Treatment

Some level of treatment is usually involved in conjunction with the waste water management alternatives described above. The treatment approach is influenced by the water quality required for the end use and transport mechanism, and risk associated with these alternatives.

One of the challenges of treatment of post-frac produced water (including slick water) is that this water includes both hydrocarbon and organics along with metals, naturally occurring radioactive material (NORM), and elevated salinity or TDS. Instead of one alternative to address all of these concerns, it's more likely that multiple treatment alternatives will be employed in concert to achieve the desired water quality. In general, the available and potential treatment technologies can be grouped according to the water quality issue addressed or the treatment mechanism. The following treatment alternatives are detailed in Table 12:

- De-oilers/organics removal
  - Corrugated plate separator
  - Centrifuge
  - Hydroclone
  - Gas flotation
  - Extraction
  - Oxidation
  - Adsorption
- Disinfection
  - Chlorination to kill microbes that may cause biofouling
  - Electrochemical activation (also aids desalinization)
- Desalinization
  - Lime softening
  - Ion exchange
  - Electrodialysis
  - Electrodeionization
  - Capacitive deionization
  - Electrochemical activation (also used in disinfection)
  - Rapid spray evaporation
  - Freeze-thaw evaporation

- Filtration
  - Microfiltration
  - Ultrafiltration
  - Nanofiltration
  - Reverse osmosis
  - Trickling filter

As discussed in Section 4.2.4, treatment trains involving one or more of these technologies are being developed by various groups, including Texas A&M University and private companies such as Aqua-Pure; and some of these technologies are being pilot tested in shale plays such as the Barnett Shale.

5.0 CONCLUSIONS

ERM conducted a study of water resources in the Woodford shale play study area of Atoka, Coal, Hughes, and Pittsburg counties in the Arkoma Basin of southeast Oklahoma, as it relates to gas well development and fraccing. The following findings are a result of this study:

Water Availability and Use

- The predominant water resource within the study are is surface water, present in the many creeks and streams that feed into Muddy Boggy Creek, Canadian River, North Canadian River, and Little River, as well as major reservoirs such as Eufaula Lake, Atoka Reservoir, Wewoka Lake, and Lake Wetumka, among others.
- Ground water is also available, although less prevalent. Major aquifers exist at the boundaries of the study area (Canadian River Aquifer, Antlers Aquifer, and Arbuckle-Simpson Aquifer). Throughout the study area, local, shallow ground water bearing units (included in the Pennsylvanian Basin) are also used as water sources, primarily for domestic or agricultural use.
- Most water use is of surface water; much of that is from Muddy Boggy Creek, which feeds Atoka Reservoir. The majority of long-term permitted surface water use is for public supply; most of this is to supply the city of Oklahoma City. The majority of long-term permitted ground water use is for irrigation. The highest ground water use in the study area is from the Canadian river terrace deposits (Canadian River Aquifer).
- The majority of 90-day water permits are for oil and gas use. The top five users by 90-day permitted allocation are Newfield Exploration, Devon Energy, Antero Resources, Pablo Energy II, and XTO Energy.

Water Rights, Permitting, and Regulations

- Surface water in Oklahoma is publically owned, while ground water is considered private property that belongs to the overlying property owner. Use of either surface water or ground water requires a permit application to the OWRB (domestic uses are exempt). Permitting of regular water permits involves application, review, public notification, and board approval.
- Provisional temporary permits (90-day permits) are available for both surface water and ground water use. These permits do not require public notice or board approval, and can be granted by the executive director.
- Disposal, treatment, and reuse of post-frac produced water are primarily overseen by the OCC. Disposal of post-frac produced water can occur via injection or by surface disposal. Permits are required for both, as well as for surface storage (pits). Underground injection requires protection of underground sources of drinking water, defined by the base of treatable water. Maps of the base of treatable water are available from the OCC and provided herein.

Development Water Alternatives and Current Practices

- ERM spoke with representatives from various agencies, industry groups, and industry professionals to gather information about current practices in the Woodford and similar shale plays.
- ERM reviewed industry and academic publications to gather information about potential development water management alternatives.
- After compiling and reviewing this information, ERM developed a matrix of management practices for post-frac produced water using an understanding of available resources, applicable regulations, current practices, and developing technology. This matrix includes information on cost, risk, current use in the Woodford shale play, advantages and disadvantages.
- Disposal options are underground injection or surface disposal (land application or evaporation).
- Minimization could reduce cost of disposal or treatment.
- Various treatment technologies exist, or are in development. These technologies are not stand-alone treatments for post-frac produced water. Treatment trains combining various technologies are being developed.
- Various reuse/recycling options can be considered, though some are not feasible for the study area. Reuse for frac water or enhanced oil recovery has been practiced in the Woodford shale play.

6.0 REFERENCES

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Tables

TABLE 1
Water Resources
Woodford Hydrology Study
Oklahoma, USA

Oklahoma Counties in the Woodford Study Area	
Atoka	Hughes
Coal	Pittsburg

Ground Water Resources		
Aquifer Name	**Minor/Major Aquifer**	**Location in Study Area (Counties)**
East-Central Oklahoma	Minor	Hughes
Kiamichi	Minor	Atoka
Pennsylvanian	Minor	Coal, Pittsburg
Woodbine	Minor	South Atoka
Canadian River	Major	Hughes, Pittsburg
Arbuckle-Simpson	Major	East Coal
Antlers Aquifer	Major	Atoka

Surface Water Resources						
Counties	**River Drainage Basins**	**Stream System Designation**	**Major Water Body Name**	**Reservoirs in Stream System**	**Drainage Area (sq mile)**	**Total Estimated Available Water (acre-ft)**
Atoka, Coal	Red River	1-4	Muddy Boggy Creek	McGee Creek Reservoir, Atoka Reservoir, Coalgate Reservoir	2551	1,957,143
Pittsburg, Hughes	Arkansas River	2-5-1	Lower North Canadian River	Lake Wetumka	1865	537,546
Hughes		2-6-1	Lower Canadian River	Eufaula Lake	2456	516,610
		2-8	Little River	Holdenville Lake	980	321,192

Source: Johnson, K.S. and KV Luza (OGS). 2008. "Rivers, Streams, and Lakes of Oklahoma. Pg.12 Educational Publication 9

TABLE 2
Reservoirs and Lakes in the Woodford Study Area
Woodford Hydrology Study
Oklahoma, USA

County	Water Body	Drainage Area (sq. miles)	Surface Area (acres)	Total Capacity (acre-ft)
Atoka	McGee Creek Reservoir	171	3,709	199,237
	Atoka Reservoir	172	5,537	225,000
Coal	Coalgate City Lake	14	352	3,437
Pittsburg	Eufaula Lake	47,522*	105,500	2,314,600
	Lake McAlester	31	1,521	13,398
Hughes	Holdenville Lake	9	550	11,000
	Wetumka Lake	4	169	1,839

* Includes drainage areas outside of study area.

Sources: OWRB. 2007a. “2007 Report of the Oklahoma Beneficial Use Monitoring Program – Lakes Report.
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TABLE 3
Stream Flow
Woodford Hydrology Study
Oklahoma, USA

County	Steam Name	Basin	Sub-Basin	Gage Location	Period of Record	Drainage Area (sq. mi.)	Avg. Flow (cfs)	Maximum Peak Flow (cfs)	Annual 7-Day Min. Flow (cfs)	10% Flow Exceeds (cfs)	50% Flow Exceeds (cfs)	90% Flow Exceeds (cfs)
Atoka	Muddy Boggy Creek[1,2]	Red-Little Basin	Muddy Boggy Subbasin	Farris	1988-1999	1,087	2,002	49,800	9.2	2,370	102	18
				Unger	1983-1999	2,273	2,002	767,000	2.6	6,100	397	46
Hughes	Canadian River[3]	Lower Canadian River	Lower Canadian-Walnut Subbasin	Calvin	1906-2008	27,952	1,783	174,000	0	4,010	429	28
Atoka	Clear Boggy Creek[4]	Red-Little Basin	Clear Boggy Subbasin	Caney		720	498	53,500	0	1,130	90	11
Hughes	North Canadian River[5]	Lower North Canadian Basin	Lower North Canadian Basin	Wetumka	1938-2008	14,290	834	66,000	0	1,850	324	74

Notes:
cfs = cubic feet per second

Sources:
[1] USGS. 2008. "Water-Data Report 2008: 07334000 Muddy Boggy Creek Near Farris, OK."
[2] USGS. 2008. "Water-Data Report 2008: 07335300 Muddy Boggy Creek Near Unger, OK."
[3] USGS. 2008. "Water-Data Report 2008: 07231500 Canadian River at Calvin, OK."
[4] USGS. 2008. "Water-Data Report 2008: 07335000 Clear Boggy Creek Near Caney, OK"
[5] USGS. 2008. "Water-Data Report 2008: 07242000 North Canadian River near Wetumka, OK."

TABLE 4
Surface Water Quality Summary
Woodford Hydrology Study
Oklahoma, USA

County	Water Body	Date Range	Sample Count		Temperature	Cl	NO_3 as N	SO_4	pH	DO	TDS	Total Alkalinity	Hardness	SC	Salinity	Source
					(C)	(mg/L)	(mg/L)	(mg/L)	(s.u.)	(mg/L)	(g/L)	(mg/L)	(mg/L as $CaCO_3$)	(uS)	(ppt)	--
Atoka	Atoka Lake	2007	20	average	15.2	<10	0.18		7.30	7.88	41.0	33		64.1	0.02	OWDB
				min	4.7	<10	0.05		6.73	2.23	31.1	18		48.6	0.01	OWDB
				max	28.2	<10	0.32		7.58	12.04	59.7	45		93.2	0.04	OWDB
	McGee Creek Lake	2007	20	average	16.0	<10	0.22		6.59	5.16	19.6	19		30.7	0.00	OWDB
				min	6.9	<10	<0.05		6.00	1.31	6.3	14		10.5	-0.01	OWDB
				max	26.1	<10	0.30		7.05	9.76	34.2	30		53.4	0.02	OWDB
	Clear Boggy Creek, Off US 69, Caney	1998-2008	up to 92	average		26.6	0.130	31.8	7.93		274.2	162.2	198.7	429.8		OWDB
				min		5.0	0.050	13.7	7.07		75.0	45.0	63.0	117.0		OWDB
				max		233.0	1.030	100.5	9.32		717.0	287.0	320.0	1119.0		OWDB
	Muddy Boggy River, US 69, Atoka	1998-2008	up to 90	average		21.4	0.116	52.9	7.32		156.6	65.2	83.5	245.4		OWDB
				min		3.6	0.050	5.0	6.67		39.6	12.0	24.0	61.9		OWDB
				max		148.0	0.440	134.0	8.25		484.6	214.0	197.0	757.1		OWDB
Coal	Coalgate Lake	2007+	15	average	14.9	<10	0.37		7.23	7.11	35.5	46		55.5	0.01	OWDB
				min	4.5	<10	0.19		6.51	1.70	31.6	36		49.4	0.01	OWDB
				max	28.2	<10	0.54		7.73	11.57	40.4	57		63.2	0.02	OWDB
Hughes	Holdenville Lake	2007++	15	average	21.1	25	0.07		7.53	5.59	155.2	69		242.5	0.11	OWDB
				min	15.5	16	<0.05		6.41	1.16	112.6	59		175.9	0.08	OWDB
				max	29.3	31	0.07		8.21	8.76	198.6	76		310.3	0.15	OWDB
	Wetumka Lake	2007	12	average	18.8	16	0.05		7.25	6.27	75.9	35		118.6	0.05	OWDB
				min	7.3	<10	<0.05		6.66	1.59	62.5	30		97.6	0.03	OWDB
				max	26.6	17	0.07		7.67	9.69	89.7	40		140.1	0.05	OWDB
	Canadian River, US 270,Calvin	1998-2008	up to 93	average		130.1	0.184	178.6	8.21		632.3	167.9	328.2	980.6		OWDB
				min		5.0	0.050	42.2	6.53		195.0	70.0	99.0	301.0		OWDB
				max		241.0	1.410	473.0	8.80		1119.0	511.0	727.0	1749.0		OWDB
	North Canadian River, US 75, Wetumka	1999-2008	up to 84	average		105.2	0.613	101.7	8.33		481.0	159.4	253.6	745.0		OWDB
				min		20.2	0.050	39.2	6.06		158.0	53.0	60.0	244.0		OWDB
				max		260.0	2.670	247.0	9.87		780.0	296.0	2500.0	1208.0		OWDB
Pittsburg	McAlester Lake	2008	25	average	18.2	<10	0.08		7.42	8.21	65.5	32		102.4	0.03	OWDB
				min	6.6	<10	<0.05		6.89	4.02	55.4	21		86.6	0.00	OWDB
				max	27.6	<10	0.17		7.76	11.54	74.6	41		116.7	0.05	OWDB
	Talawanda Lake	2008	12	average	18.2	<10	0.05		7.48	8.08	68.6	33		107.1	0.03	OWDB
				min	7.3	<10	<0.05		7.07	3.87	65.8	21		102.7	0.00	OWDB
				max	27.4	<10	0.50		7.78	11.68	75.1	48		117.3	0.04	OWDB
	Blue Creek, SH 63, Haileyville	2001-2003	up to 10	average			0.275		7.33		127.9	69.2	99.3	189.4		OWDB
				min			0.050		6.69		72.6	30.0	70.0	121.0		OWDB
				max			1.290		8.11		177.0	157.0	146.0	249.0		OWDB
	Blue Creek, US 270, Haileyville	2001-2003	up to 10	average			0.382		7.23		159.0	67.2	96.2	248.8		OWDB
				min			0.050		6.68		82.0	37.0	65.0	129.0		OWDB
				max			1.260		7.99		282.0	127.0	113.0	441.0		OWDB
	Brushy Creek, Off US 270, Haileyville	1998-2008	up to 93	average		27.4	0.159	69.8	7.35		193.6	58.1	100.4	309.1		OWDB
				min		3.4	0.050	16.0	6.31		11.0	14.0	18.0	18.0		OWDB
				max		178.0	0.760	369.0	8.57		826.0	131.0	693.0	1291.0		OWDB

Notes:
+ Fall not sampled
++ Winter not sampled

1. Surface water data were obtained from the Oklahoma Water Resources Board
2. Lake data are averaged from a maximum of five stations per lake, sampled quarterly throughout the year. Please note that the lakes are stratified with depth and parameters may vary greatly with season and depth.
3. Stream data are averaged for the most recent 10 years of data.

TABLE 5
Ground Water Sources
Woodford Hydology Study
Oklahoma, USA

Groundwater Aquifer	Description	Location	Avg Hydraulic Conductivity (K)(ft/day)	Avg Saturated Thickness (ft)	Avg Transmissivity (ft^2/day)	Avg Recharge (inches)	Initial Storage (acre-feet)	Yield (gpm)	Basin Type
North Canadian River[1,2]	Unconfined alluvial aquifer consisting of sand and gravel with silt and clay	Hughes	59	30-80	60,000 gal/day/ft	1-4	NA	10-500	Alluvium
Canadian River [3]	Unconfined alluvial aquifer consisting of sand and gravel with silt and clay	Hughes, Pittsburg	134	50-80	NA	<8	NA	10-500	Alluvium
Antlers [4,5]	Sand, clay, conglomerate and limestone	Atoka	0.87-3.75	0-400	NA	0.32-0.96	NA	100-500	Bedrock
Pennsylvanian [7,8,9]	Shale, siltstone, coal, thin limestone, and widely separated sandstone units (1)	Coal, Pittsburg	0.4	350	130	1.1	21,105,000	<25	Bedrock

Sources:
(1) Groundwater Atlas of the United States, Oklahoma, Texas HA 730-E
(2) Schoff, S.L, and E.W. Reed. 1951 "Ground water in Alluvial Deposits in Oklahoma." Economic Geology. No. 1. pp. 76-83.
(3) Values for the Canadian River is based up on a study conducted in Norman, OK (Oklahoma County)
(4) USGS. Digital hydraulic conductivity values of the Antlers aquifer in southeastern Oklahoma.
(5) Morton, R.B. 1992. Simulations of Groune-Water Flow in the Antlers Aquifer in Southeastern Oklahoma and Northeastern Texas.
(7) Data gathered from Oklahoma Water Development Board Water Information Mapping System (WIMS) for minor aquifers: http://www.owrb.ok.gov/maps/server/wims.php
(8) Wilkins, K. 1997. Hydrogeologic Report of the Pennsylvanian Minor Groundwater Basin and the Ashalnd Isolated Terrace Groundwater Basin in Coal, Pittsburg and Haskell Counties.
(9) Osborn, N. and R.H. Hardy. 1999. "Statewide Groundwater Vulnerability Map of Oklahoma." Oklahoma Water Resources Board Technical Report 99-1.

Table 6
Ground Water Quality
Woodford Shale Study
Oklahoma, USA

County	Aquifer		Sampling Date	No. of Samples	Sampling depth (feet bgs)	Water Temperature (oC)	Turbidity (NTU)	Sp. Cond. (uS/cm @ 25oC)	pH (s.u.)	CO2 (mg/L)	Hardness (mg/L as CaCO3)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	TDS (mg/L)
Atoka	Boggy Formation	Min	1977-1981	4	-	18	-	120	5.6	-	-	-	-	-	4	9	-	-
		Average			-	21	-	290	6.5	-	-	-	-	-	12	23	-	-
		Max			-	25	-	690	7.0	-	-	-	-	-	31	58	-	-
	McAlester Shale	Min	1977-1978	5	-	15	-	310	6.9	-	-	-	-	-	8	12	-	-
		Average			-	18	-	1584	7.1	-	-	-	-	-	321	50	-	-
		Max			-	21	-	5400	7.3	-	-	-	-	-	1390	88	-	-
	Savanna Sandstone	Min	1977	4	-	17.5	-	245	6.3	-	-	-	-	-	5	10	-	-
		Average			-	20	-	638	6.7	-	-	-	-	-	58	57	-	-
		Max			-	21	-	1010	6.9	-	-	-	-	-	136	165	-	-
Coal	Boggy Formation	Min	1977	3	-	18	-	1200	7.2	-	-	-	-	-	100	190	-	-
		Average			-	21	-	3200	7.3	-	-	-	-	-	597	378	-	-
		Max			-	27	-	5500	7.5	-	-	-	-	-	1240	747	-	-
	Hartshorne Sandstone	Min	1977-1982	4	-	12	2.4	335	8.3	-	43	5.4	7.1	18	49	37	0.4	199
		Average			-	18	2	578	8.3	-	43	5	7	18	56	45	0	199
		Max			-	21	2.4	780	8.3	-	43	5.4	7.1	18	63	53	0.4	199
	McAlester Shale	Min	1977-1982	59	-	13.5	0.2	80	5.1	1.6	32	6.7	3.6	8.7	5	2	0.1	157
		Average			-	19.0	3.5	704.2	7.8	9.4	86.7	18.2	9.8	89.5	70	76	0.2	307.2
		Max			-	25.5	26	2500	8.9	32	210	49	21	220	655	869	0.4	617
	Savanna Sandstone	Min	1977	7	-	19	-	120	5.5	-	-	-	-	-	5	1	-	-
		Average			-	21	-	1205	6.8	-	-	-	-	-	96	184	-	-
		Max			-	27	-	2500	8.1	-	-	-	-	-	319	842	-	-
Hughes	Calvin Sandstone	Min	1977-1979	3	-	20	-	1030	6.9	-	-	-	-	-	111	38	-	-
		Average			-	22	-	1625	6.9	-	-	-	-	-	264	404	-	-
		Max			-	24	-	2220	6.9	-	-	-	-	-	511	983	-	-
	Senora Formation	Min	1977-1979	7	-	20	-	1430	7.2	-	-	-	-	-	16	10	-	-
		Average			-	20	-	1430	7.2	-	-	-	-	-	89	173	-	-
		Max			-	20	-	1430	7.2	-	-	-	-	-	211	800	-	-
Pittsburg	Alluvium	Min	1979	11	-	16	-	110	5.1	-	-	-	-	-	7	5	-	-
		Average			-	18.2	-	1244.5	6.9	-	-	-	-	-	173	84	-	-
		Max			-	25.5	-	4500	8.0	-	-	-	-	-	1100	347	-	-
	Boggy Formation	Min	1976-1979	34	30	16.5	0.4	70	5.9	0.7	12	2.6	0.7	61	1	4	0.3	297
		Average			74	21	2	1269	7.4	35	278	51	36	134	80	267	0	691
		Max			123	29	9.1	6200	9.5	69	790	120	120	330	539	2340	0.6	2010
	Hartshorne Sandstone	Min	1977	7	-	17.5	-	200	6.0	-	-	-	-	-	11	3	-	-
		Average			-	19.1	-	1177.1	6.6	-	-	-	-	-	156	108	-	-
		Max			-	22	-	3300	7.3	-	-	-	-	-	534	355	-	-
	McAlester Shale	Min	1977	68	-	15	-	80	5.5	-	-	-	-	-	4	3	-	-
		Average			-	19	-	1306	6.9	-	-	-	-	-	86	373	-	-
		Max			-	28	-	16000	8.8	-	-	-	-	-	1430	12500	-	-
	Savanna Sandstone	Min	1977-1980	29	-	12	-	58	5.0	-	-	-	-	-	5	7	-	-
		Average			-	20	-	1373	6.7	-	-	-	-	-	262	172	-	-
		Max			-	28	-	5900	7.8	-	-	-	-	-	2760	1760	-	-
	Atoka Formation	Min	1977-1980	8	-	16.5	-	150	6.0	-	-	-	-	-	12	1	-	-
		Average			-	18.45	-	556.125	7.1	-	-	-	-	-	55	62	-	-
		Max			-	20.6	-	1060	9.1	-	-	-	-	-	114	153	-	-

Notes:
All data was collected from the USGS National Water Information System (NWIS), 2009.

TABLE 7
Water Use by County and Type
Woodford Shale Study Area
Oklahoma, USA

	Ground Water Use Survey								
	Agriculture	**Commercial**	**Industrial**	**Irrigation**	**Mining**	**Power**	**Public Supply**	**Recreational**	**Total Use**
Atoka	0	2,346	0	483	0	0	787	20	**3,636**
Coal	4	0	0	30	0	0	783	0	**817**
Hughes	502	0	0	10,524	130	0	2,307	20	**13,484**
Pittsburg	0	103	8	1,064	0	0	380	0	**1,555**
Study Area	**506**	**2,449**	**8**	**12,101**	**130**	**0**	**4,257**	**40**	**19,491**

	Surface Water Use Survey								
	Agriculture	**Commercial**	**Industrial**	**Irrigation**	**Mining**	**Power**	**Public Supply**	**Recreational**	**Total Use**
Atoka	0	0	12,000	1,670	110	285	146,769	535	**161,369**
Coal	35	0	0	1,756	1,851	0	3,566	1	**7,209**
Hughes	1,382	3	20	8,641	62	0	5,400	465	**15,973**
Pittsburg	0	30	779	6,942	27	33,040	37,787	400	**79,005**
Study Area	**1,417**	**33**	**12,799**	**19,009**	**2,050**	**33,325**	**193,522**	**1,401**	**263,556**

Notes:
units = acre-ft
Data based on permitted water allocations by the OWRB (2008)
Includes long-term and 90-day permits

TABLE 8
Surface Water Use by Source
Woodford Shale Study Area
Oklahoma, USA

Stream System	Atoka	Coal	Hughes	Pittsburg	Total Study Area
Muddy Boggy River	161,259	7,209	1,007	15	**169,490**
Kiamichi	110	0	0	300	**410**
Lower Canadian River	0	0	2,121	77,690	**79,811**
Lower North Canadian River	0	0	7,009	--	**7,009**
Little River	0	0	5,836	--	**5,836**
Canadian River to North Canadian River	0	0	0	1,000	**1,000**

Notes:
units = acre-ft
Data based on permitted water allocations by the OWRB (2008)
Includes long-term and 90-day permits
-- = Not reported

TABLE 9
Ground Water Use by Source
Woodford Shale Study Area
Oklahoma, USA

	Atoka	Coal	Hughes	Pittsburg	Study Area
Canadian - Isolated Terrace Deposits	--	--	7,816	952	8,768
Seminole Formation	3,636	--	48	--	3,684
Antlers Formation	3,132	--	--	--	3,132
Wetumka Shale	--	--	2,463	--	2,463
Wewoka Formation	--	--	1,989	80	2,069
McAlester Shale	--	562	--	210	772
Calvin Sandstone	--	--	556	--	556
Atoka Formation	504	--	--	--	504
Senore Formation	--	--	403	--	403
Boggy Formation	--	255	--	53	308
Beaver-North Canadian Alluvium Deposits	--	--	157	--	157
Other	0	255	713	53	1,021

Notes:
units = acre-ft
Data based on permitted water allocations by the OWRB (2008)
Includes long-term and 90-day permits
-- = Not reported

TABLE 10
Highest Water Users from 90-Day Permits
Woodford Hydrology Study
Oklahoma, USA

Short Term Top Water Users	Permitted Water Use (acre-ft)
Newfield Exploration	2,269.50
Devon Energy	727.5
Antero Resources	330.5
Pablo Energy II	235.8
XTO Energy	108.0

For period of April 2008-April 2009

TABLE 11
Oil and Gas Wells and Commercial Disposal Wells
Woodford Shale Study
Oklahoma, USA

County	Formation	API Number	Operator	Commerical Disposal Well	Top of Formation Depth (ft bgs)	Bottom of Formation Depth (ft bgs)	Maximum Injection Pressure (psi, surface)	Maximum Injection Rate (bbls/day)
Atoka	STANLEY UP	20189	KAL ENERGY INC		411	864	1500	
	STANLEY UP	20322	KAL ENERGY INC		372	780	1000	
Coal	UNKNOWN	13	SOUTHERN RESOURCES INC		0	0	600	150
	UNKNOWN	0	GEONATURAL RESOURCES INC					
	UNKNOWN	20003	OTC/OCC NOT ASSIGNED		0	0	0	0
	UNKNOWN	20122	OTC/OCC NOT ASSIGNED		0	0	0	0
	UNKNOWN	20207	PAYNE EXPLORATION COMPANY		0	0	0	0
	ARBUCKLE	20422	D & E OIL CO	Yes	7153	8750	1000	10000
	ARBUCKLE GROUP	0	DEVON ENERGY PRODUCTION CO LP		8115	9665	2500	50000
	ARBUCKLE GROUP	20411	TRUEVINE GAS COMPANY	Yes	12016	13252	3000	14000
	ARBUCKLE GROUP	20422	D & E OIL CO	Yes	7170	8750	1000	10000
	ARBUCKLE GROUP	20856	TEXAS TRANSCO INC	Yes	8500	8600	1000	5000
	ARBUCKLE GROUP	20856	TEXAS TRANSCO INC	Yes	8500	10000	2000	30000
	ARBUCKLE GROUP	20890	CLARITA OPERATING LLC	Yes	2380	4500	1000	5760
	ARBUCKLE GROUP	20890	CLARITA OPERATING LLC	Yes	2535	3192	1250	45000
	ARBUCKLE GROUP	20898	LEWIS OIL PROPERTIES		9300	11900	2000	70000
	ARBUCKLE GROUP	20898	LEWIS OIL PROPERTIES			11900	2000	70000
	ATOKA	162	COAL OIL & GAS COMPANY		1525	1560	0	0
	ATOKA /LM/	60015	BLANCHARD HENRY		2066	2103	600	150
	ATOKA SAND	303	BLANCHARD HENRY		2016	2048	0	120
	ATOKA SAND	60035	WEATHERLY NELL M ESTATE		850	854	500	100
	BASAL MCLISH SAND	247	TRIPOWER RESOURCES INC		6551	6630	1000	4000
	BASAL MCLISH SAND	247	TRIPOWER RESOURCES INC		6551	6630	1000	4000
	CROMWELL	222	SOUTHERN RESOURCES INC		5366	5498	1500	1000
	CROMWELL	20037	ARROW ENERGY INC		4200	4642	1000	900
	CROMWELL	20041	ARROW ENERGY INC		4178	4320	600	900
	CROMWELL	20080	ARROW ENERGY INC		3832	3944	1000	900
	CROMWELL	20298	ARROW ENERGY INC		3776	3892	400	900
	CROMWELL	20543	GUNGOLL CARL E EXPLORATION LLC		4196	4285	1500	1200
	CROMWELL	20571	ARROW ENERGY INC		4150	4280	1000	900
	CROMWELL	30005	ARROW ENERGY INC		3920	4042	1000	900
	CROMWELL	30005	ARROW ENERGY INC		3922	4050	1000	900
	CROMWELL	30007	ARROW ENERGY INC		3740	3866	600	900
	CROMWELL SAND	159	GRAHAM ROYALTY LTD		4850	5050	800	4200
	DEESE	20078	PALUCA PETROLEUM INC		610	986	800	400
	GILCREASE	280	CANTRELL BILL G		1083	1094	300	200
	GILCREASE	20462	GUNGOLL CARL E EXPLORATION LLC		2220	2420	1000	1000
	GILCREASE LOW	20396	AMES OIL & GAS CORPORATION		2778	2787	500	100
	GILCREASE UP	20396	AMES OIL & GAS CORPORATION		2315	2323	500	100
	HARSHORNE	187	SANTA FE MINERALS INC		2100	2300	1000	500
	HARTSHORNE	13	SOUTHERN RESOURCES INC		2553	2575	600	150
	HARTSHORNE	268	BLANCHARD HENRY		1795	1840	400	1000
	HARTSHORNE	291	LARKIN ENERGY INC		1662	1692	500	200
	HARTSHORNE	291	LARKIN ENERGY INC		1662	1692	1500	300
	HARTSHORNE	20088	TENNECO OIL COMPANY		2184	2370	600	600
	HARTSHORNE	20277	GOMACO OPERATING COMPANY		1604	1631	1000	600
	HARTSHORNE	20501	ROBERSON OIL COMPANY INC		696	870	340	500
	MCALESTER SAND	304	BHP PETROLEUM (AMERICAS) INC		1675	1710	0	0
	MCLISH BASAL JONES	20060	WENTWORTH OPERATING COMPANY	Yes	6625		1000	6000
	MCLISH-ARBUCKLE	20060	WENTWORTH OPERATING COMPANY	Yes	6614	7651	2000	15000
	MCLISH-OIL CREEK	0	ANTERO RESOURCES CORPORATION		1804	2095	900	20000
	OIL CREEK	243	COAL OIL & GAS COMPANY		7500	7512	0	0
	OIL CREEK	330	COAL OIL & GAS COMPANY		7506	7509	0	0
	OIL CREEK	349	COAL OIL & GAS COMPANY		7348	7500	1000	2000
	OIL CREEK	20898	LEWIS OIL PROPERTIES		8550	8650	2000	70000
	OIL CREEK	20898	LEWIS OIL PROPERTIES		8550		2000	70000
	OIL CREEK BASAL	20403	DUNN'S TANK SERVICE INC	Yes	1926	2260	800	5000
	OIL CREEK BASAL ARBUCKLE	20060	WENTWORTH OPERATING COMPANY	Yes		7725	1000	6000
	PENNSYLVANIAN SAND	224	GOMACO INC		1130	1150	0	0
	SAVANNA	286	SOUTHERN RESOURCES INC		1697	1835	800	1500
	SAVANNA	20557	OEXCO INC		1520	1526	0	10
	VIOLA-SIMPSON-ARBUCKLE	20411	TRUEVINE GAS COMPANY	Yes	10935	14095	2000	30000
	WAPANUEKA	20146	ARROW ENERGY INC		1974	2117	200	100
Hughes	UNKNOWN	20723	M M & M RESOURCES INC				250	3,000
	UNKNOWN	0	MORAN PIPE & SUPPLY CO INC		0	0	0	0
	UNKNOWN	0	ARIES EXPLORATION CO INC		0	0	0	0
	UNKNOWN	0	ARIES EXPLORATION CO INC		0	0	0	0
	UNKNOWN	0	ARIES EXPLORATION CO INC		0	0	0	0
	UNKNOWN	0	ARIES EXPLORATION CO INC		0	0	0	0
	UNKNOWN	0	CENTRAL OKLA OIL & GAS CORP					
	UNKNOWN	881	CHEVRON USA INC				0	0
	UNKNOWN	887	BHP PETROLEUM (AMERICAS) INC				0	0
	UNKNOWN	916	ALEXANDER PROPERTIES					
	UNKNOWN	998	CIRCLE C OILFIELD SUPPLY INC				0	0

TABLE 11
Oil and Gas Wells and Commercial Disposal Wells
Woodford Shale Study
Oklahoma, USA

County	Formation	API Number	Operator	Commerical Disposal Well	Top of Formation Depth (ft bgs)	Bottom of Formation Depth (ft bgs)	Maximum Injection Pressure (psi, surface)	Maximum Injection Rate (bbls/day)
Hughes (cont'd)	UNKNOWN	1139	TIDE WEST OIL COMPANY		0	0	0	0
	UNKNOWN	1579	PETRO SPEED INC		0	0	0	0
	UNKNOWN	1626	WILSHIRE ENTERPRISES INC					
	UNKNOWN	1796	R S P OIL OPERATORS		1,740	2,348	400	1,000
	UNKNOWN	1978	ARIES EXPLORATION CO INC		0	0	0	0
	UNKNOWN	2623	RICE WILLIAM C & NORMA J					
	UNKNOWN	3863	COX ELMER N					
	UNKNOWN	4491	R W PRODUCTION COMPANY INC				0	0
	UNKNOWN	4532	PRYOR JR VICTOR W					
	UNKNOWN	20093	RWIT COMPANY INC				0	0
	UNKNOWN	20273	TREPCO PRODUCTION COMPANY INC					
	UNKNOWN	20366	KAHN GEORGE		0	0	0	0
	UNKNOWN	20600	AMERICAN TRADING & PROD CORP					
	UNKNOWN	20632	CROWN ENERGY COMPANY					
	UNKNOWN	20656	HILL OIL COMPANY INC					
	UNKNOWN	21083	GILBERT OIL PROPERTIES					
	UNKNOWN	21168	PUMPING SERVICES INC					
	UNKNOWN	21673	SWADLEY ROY W & JUDITH I				0	0
	UNKNOWN	21864	PRENTICE BRADLEY L		0	0	0	0
	UNKNOWN	22715	FLEET FRANK T INC				0	0
	UNKNOWN	23427	CENTRAL OKLA OIL & GAS CORP					
	1ST & 2ND ALLEN	20922	LUCKY ACE PETROLEUM LLC		555	632	330	100
	1ST CROMWELL SAND	3055	DESHIELDS OIL & GAS INC		3,872	3,878	0	0
	2ND CROMWELL SAND	1213	CHASTAIN DIANE		3,018	3,080	0	0
	2ND WILCOX	20968	X-BAR LIMITED PARTNERSHIP		4,367	4,415	350	2,000
	2ND WILCOX SAND	30299	JAY PETROLEUM INC		4,123	4,173	400	1,000
	3RD CALVIN	23145	SANDY PETROLEUM INC		860	872	430	500
	ALLEN	903	PRENTICE BRADLEY L		738	746	0	0
	ALLEN	904	PRENTICE BRADLEY L		802	808	480	50
	ALLEN	905	PRENTICE BRADLEY L		745	753	425	50
	ALLEN	1697	PRENTICE BRADLEY L		630	820	315	100
	ALLEN	20433	TREPCO PRODUCTION COMPANY INC		712	723	0	0
	ALLEN	20483	TREPCO PRODUCTION COMPANY INC		750	778	500	300
	ALLEN	20905	CHILES JACK WELL SERVICE		720	738	250	50
	ALLEN/DES MOINES/	1625	TREPCO PRODUCTION COMPANY INC		708	727	350	50
	ALLEN /DES MOINES/	20845	LUCKY ACE PETROLEUM LLC		603	644	300	500
	ALLEN/DES MOINES/	23560	MCCOOL JOHN E		850	870	425	200
	ALLEN/DES MOINES/	23561	MCCOOL JOHN E		850	870	425	200
	ALLEN LOWER/DES MOINES/	22581	PERKINS NOVA		930	980	300	100
	ALLEN SAND	1621	WILSHIRE ENTERPRISES INC		707	734	0	0
	ALLEN SAND	1650	WILSHIRE ENTERPRISES INC		765	785	0	0
	ALLEN SAND	4567			676	682	200	25
	ALLEN SAND	20260	TREPCO PRODUCTION COMPANY INC		764	768	0	0
	ALLEN SAND	20282	WILSHIRE ENTERPRISES INC		766	779	0	0
	ALLEN SAND	20283	TREPCO PRODUCTION COMPANY INC		697	715	0	0
	ALLEN SAND	20284	TREPCO PRODUCTION COMPANY INC		708	715	0	0
	ALLEN SAND	20285	TREPCO PRODUCTION COMPANY INC		696	707	0	0
	ALLEN SAND	20479	TREPCO PRODUCTION COMPANY INC		754	780	0	0
	ALLEN SAND	20488	TREPCO PRODUCTION COMPANY INC		747	767	300	300
	ALLEN SAND	20515	TREPCO PRODUCTION COMPANY INC		892	912	300	50
	ALLEN SAND	20588	TREPCO PRODUCTION COMPANY INC		862	882	300	50
	ALLEN SAND	20712	TREPCO PRODUCTION COMPANY INC		874	880	300	50
	ALLEN SAND	20713	TREPCO PRODUCTION COMPANY INC		846	860	300	50
	ALLEN SAND	21939	TREPCO PRODUCTION COMPANY INC		913	929	300	50
	ALLEN SAND	21940	TREPCO PRODUCTION COMPANY INC		880	892	300	50
	ALLEN SAND	21941	TREPCO PRODUCTION COMPANY INC		893	907	300	50
	ALLEN SAND	22720	TREPCO PRODUCTION COMPANY INC		919	923	300	50
	ALLEN SAND	22721	TREPCO PRODUCTION COMPANY INC		902	918	300	50
	ALLEN SAND	22989	TREPCO PRODUCTION COMPANY INC		932	950	300	50
	ALLEN SD	20487	TREPCO PRODUCTION COMPANY INC		754	774	0	0
	ALLEN SD	20517	TREPCO PRODUCTION COMPANY INC		774	794	0	0
	ARBUCKLE	863	OTC/OCC NOT ASSIGNED		4,905	6,144	0	0
	ARBUCKLE	22918	TK DRILLING CORPORATION		4,630	6,113	500	5,000
	ARBUCKLE	22918	TK DRILLING CORPORATION		4,630	6,113	500	5,000
	ARBUCKLE /SILICEOUS/	22376	MARJO OPERATING COMPANY INC		4,066	5,997	1,000	40,000
	ARBUCKLE /SILICEOUS/	23988	PANTHER ENERGY COMPANY LLC		5,400	6,000	500	2,500
	ARBUCKLE GROUP	22984	NORTHBROOK OIL & GAS CO LLC		4,990	5,230	750	1,500
	ARBUCKLE GROUP	23534	MONTGOMERY EXPLORATION COMPANY			6,800	300	20,000
	ARBUCKLE GROUP	24068	SABER INDUSTRIES LP	Yes	8,155	10,200	2,000	50,000
	BARTLESVILLE	4232	C BAR K ENTERPRISES INC		1,600	1,695	500	300
	BARTLESVILLE	20954	K S OIL COMPANY INC		1,850	1,870	300	1,000
	BARTLESVILLE	21113	XANADU EXPLORATION COMPANY		1,855	1,964	720	1,000
	BARTLESVILLE	23384	AMERICAN PETROLEUM & MINERAL CO INC		2,106	2,116	200	300
	BARTLESVILLE	23797	A & A TANK TRUCK CO	Yes	1,800	2,000	1,250	4,000

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Hughes (cont'd)	BARTLESVILLE	30078	CHARRO OPERATING LLC		2,050	2,070	600	1,000
	BARTLESVILLE SAND	1526	TRIDON OIL INC		1,682	1,690	0	50
	BARTLESVILLE SAND	2117	TRIDON OIL INC		1,570	1,710	50	10
	BARTLESVILLE SD	21671	NEWFIELD EXPL MIDCONTINENT INC		1,768	1,810	0	75,080
	BARTLESVILLE-SAVANA	829	FUGO SERVICES LLC	Yes	1,570	1,845	785	3,000
	BARTLEVILLE	21060	TREPCO PRODUCTION COMPANY INC		1,872	1,954	300	440
	BAS. PENN.UNCONFORM.	21277	LEMA PETROLEUM INC		3,364	3,414	750	2,000
	BOGGY	23436	YALE OIL ASSOCIATION INC		1,354		300	1,000
	BOGGY	23735	MARBET LLC		1,800	2,070	300	3,000
	BOGGY (RED FORK)	23436	YALE OIL ASSOCIATION INC		1,354	1,364	300	1,000
	BOGGY CREEK	806	SWADLEY ROY W & JUDITH I		1,925	1,955	0	0
	BOOCH	0	ARIES EXPLORATION CO INC		2600	0	0	0
	BOOCH	802	X-BAR RESOURCES INC		2,872	2,890	500	1,000
	BOOCH	911	KRUMME OIL COMPANY LLP		2,717	2,730	0	0
	BOOCH	939	PERKINS NOVA		2,727	2,839	0	0
	BOOCH	1062	LUNAR INVESTMENTS INC		2,850	2,915	500	600
	BOOCH	1553	MILNE LEWIS JOEL		2,820	2,846	0	0
	BOOCH	1594	NORTHBROOK OIL & GAS CO LLC		2,768	2,787	300	800
	BOOCH	1594	NORTHBROOK OIL & GAS CO LLC		2,768	2,787	800	800
	BOOCH	1594	NORTHBROOK OIL & GAS CO LLC		2,768	2,787	1,200	1,000
	BOOCH	1650	WILSHIRE ENTERPRISES INC		765	785	350	50
	BOOCH	1654	PALUCA PETROLEUM INC		2,861	2,877	0	0
	BOOCH	1654	PALUCA PETROLEUM INC		2,861	2,877	500	1,500
	BOOCH	1654	PALUCA PETROLEUM INC		2,861	2,877	500	1,500
	BOOCH	2390	SEMINOLE TANK SERVICE		2,893	2,915	0	500
	BOOCH	2410	WALKER RANDY & JAN OIL COMPANY LLC		2,956	2,966	300	200
	BOOCH	2957	X-BAR LIMITED PARTNERSHIP		3,039	3,060	0	0
	BOOCH	2964	X-BAR LIMITED PARTNERSHIP		2,883	2,929	0	0
	BOOCH	2965	X-BAR LIMITED PARTNERSHIP		2,902	2,947	0	0
	BOOCH	2969	X-BAR LIMITED PARTNERSHIP		2,960	2,990	0	0
	BOOCH	2970	X-BAR LIMITED PARTNERSHIP		3,067	3,100	0	0
	BOOCH	3515	TILFORD PINSON EXPLORATION LLC		2,675	2,782	1,337	150
	BOOCH	3516	SIX "E" TRADING COMPANY		2,750	2,760	0	0
	BOOCH	4472	X-BAR LIMITED PARTNERSHIP		3,013	3,052	0	0
	BOOCH	4478	X-BAR RESOURCES INC		2,902	2,952	0	0
	BOOCH	20090	KAHAN & ASSOCIATES INC		2,810	2,840	500	1,000
	BOOCH	20199	TEXACO INC		2,662	3,362	1,000	3,000
	BOOCH	20261	TREPCO PRODUCTION COMPANY INC		734	744	350	50
	BOOCH	20262	TREPCO PRODUCTION COMPANY INC		711	713	350	50
	BOOCH	20282	WILSHIRE ENTERPRISES INC		716	733	350	50
	BOOCH	20285	TREPCO PRODUCTION COMPANY INC		696	707	350	50
	BOOCH	20333	TREPCO PRODUCTION COMPANY INC		2,315	2,324	0	0
	BOOCH	20334	TREPCO PRODUCTION COMPANY INC		2,323	2,334	0	0
	BOOCH	20353	TREPCO PRODUCTION COMPANY INC		2,350	2,366	0	0
	BOOCH	20435	TREPCO PRODUCTION COMPANY INC		2,442	2,458	650	100
	BOOCH	20788	RDT PROPERTIES INC		2,844	2,850	1,000	2,500
	BOOCH	20946	RDT PROPERTIES INC		2,796	2,806	1,000	2,500
	BOOCH	20950	RDT PROPERTIES INC		2,812	2,976	1,000	2,500
	BOOCH	20950	RDT PROPERTIES INC		2,950	2,976	1,000	2,500
	BOOCH	20990	PRYOR JR VICTOR W		2,560	2,600	500	1,000
	BOOCH	21050	RDT PROPERTIES INC		2,772	2,786	1,000	2,500
	BOOCH	21083	GILBERT OIL PROPERTIES		2,650	2,670	0	100
	BOOCH	21098	RDT PROPERTIES INC		2,802	2,818	1,000	2,500
	BOOCH	21118	RDT PROPERTIES INC		2,772	2,777	1,000	2,500
	BOOCH	21121	RDT PROPERTIES INC		2,795	2,805	100	2,500
	BOOCH	21122	RDT PROPERTIES INC		2,781	2,806	1,000	2,500
	BOOCH	21136	RDT PROPERTIES INC		2,901	2,918	1,000	2,500
	BOOCH	21233	RDT PROPERTIES INC		2,768	2,780	1,000	2,500
	BOOCH	21256	MASSAD JOHN M		2,924	2,932	200	350
	BOOCH	21409	AMERICAN TRADING & PROD CORP		3,050		0	0
	BOOCH	21455	POTEET AND HARRIS	Yes	2,912	3,006	400	2,000
	BOOCH	21455	POTEET AND HARRIS	Yes	2,912	3,006	400	7,000
	BOOCH	21455	POTEET AND HARRIS	Yes	2,912	3,006	400	7,000
	BOOCH	21556	SHARBER BILLY JACK OPERATING LLC		2,659	2,675	0	300
	BOOCH	21814	CENTREX OPERATING COMPANY		2,345	2,680	500	5,000
	BOOCH	21942	TERRY JACK		2,574	2,590	500	150
	BOOCH	22165	LIBERTY OPERATING INC		2,826	2,840	200	300
	BOOCH	22190	LIBERTY OPERATING INC		2,824	2,828	1,000	300
	BOOCH	22205	KLO LLC		2,836	2,842	135	500
	BOOCH	22238	PALUCA PETROLEUM INC		2,914	2,942	500	1,500
	BOOCH	22243	LIBERTY OPERATING INC		2,830	2,838	1,000	300
	BOOCH	22281	LAIRD BILL OIL COMPANY		2,716	2,738	300	500
	BOOCH	22323	LOFTIS BOB L		2,810	2,834	400	500
	BOOCH	22325	LIBERTY OPERATING INC		2,812	2,837	1,000	300

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Hughes (cont'd)	BOOCH	22331	BETTIS BOYLE & STOVALL		2,864	2,892	300	250
	BOOCH	22334	LIBERTY OPERATING INC		2,795	2,806	1,000	300
	BOOCH	22350	LIBERTY OPERATING INC		2,806	2,818	1,000	300
	BOOCH	22373	LOFTIS BOB L		2,798	2,824	400	500
	BOOCH	22427	ROGERS DAN R		2,724	2,736	300	150
	BOOCH	22462	LIBERTY OPERATING INC		2,848	2,860	1,000	300
	BOOCH	22581	PERKINS NOVA		2,607	2,611	1,500	100
	BOOCH	22659	DAVCO PRODUCTIONS INC		2,788	2,802	300	300
	BOOCH	22664	MESA EXPLORATION CO INC		2,572	2,590	400	500
	BOOCH	22759	LIBERTY OPERATING INC		2,785	2,800	1,000	300
	BOOCH	22809	LIBERTY OPERATING INC		2,806	2,818	1,000	300
	BOOCH	23048	COLUMBUS OIL COMPANY		2,950	2,976	1,000	10,000
	BOOCH	23048	COLUMBUS OIL COMPANY		2,950		1,000	10,000
	BOOCH	23240	BETTIS BOYLE & STOVALL		2,845	2,862	1,000	500
	BOOCH	23305	ARCHIBALD OIL & GAS OPERATING INC		2,990	3,010	450	450
	BOOCH	23481	RKR EXPLORATION INC		2,150	2,166	500	1,000
	BOOCH	23657	WALKER RANDY & JAN OIL COMPANY LLC		2,886	2,893	500	1,000
	BOOCH	24238	STEELE VICTOR PATTERSON		2,883	2,930	150	200
	BOOCH	26679	LUNAR INVESTMENTS INC		2,851	2,859	0	1,000
	BOOCH	26679	LUNAR INVESTMENTS INC		2,851	2,859	300	1,000
	BOOCH GILCREASE	20112	JAY PETROLEUM INC		2,625	3,322	600	2,500
	BOOCH SAND	1542	B & R OIL		2,732	2,741	500	300
	BOOCH SAND	2573	MORAN OIL ENTERPRISES LLC		2,871	2,917	100	50
	BOOCH SAND	2605	DAVIS EARL A		2,900	2,924	0	0
	BOOCH SAND	2607	STEELE VICTOR PATTERSON		2,876	2,980	400	150
	BOOCH SAND	2608	WMW OIL PRODUCTION		2,914	2,938	0	0
	BOOCH SAND	20120	STOVER COMPANY		2,261	2,312	200	600
	BOOCH SAND	30102	MONTGOMERY EXPLORATION COMPANY		2,572	2,598	400	750
	BOOCH-HARTSHORNE	21307	FUGO SERVICES INC		1,586	5,655	793	3,000
	BOUCH	2972	X-BAR LIMITED PARTNERSHIP		3,079	3,120	0	0
	CALVIN	0	B & R OIL		1165	1185	150	500
	CALVIN	810	WALKER RANDY & JAN OIL COMPANY LLC		1,161	1,171	590	400
	CALVIN	1580	MOSLEY CURTIS D		1,198	1,223	0	0
	CALVIN	1606	ROBERTS ANDERINE		794	805	150	200
	CALVIN	1802	WALKER RANDY & JAN OIL COMPANY LLC		855	899	200	120
	CALVIN	1802	WALKER RANDY & JAN OIL COMPANY LLC		855	899	250	150
	CALVIN	1802	WALKER RANDY & JAN OIL COMPANY LLC		825	900	400	350
	CALVIN	2515	PARKINSOL OIL COMPANY		1,176	1,184	590	400
	CALVIN	2540	KLO LLC		1,181	1,205	0	0
	CALVIN	2544	KLO LLC		1,186	1,197	0	0
	CALVIN	2672	LAIRD BILL OIL COMPANY		1,145	1,160	0	100
	CALVIN	2679	SMITH OLEN A		1,150	1,200	0	0
	CALVIN	2837	OLIPHANT GERTRUD		1,013	1,017	0	0
	CALVIN	2849	KLO LLC		881	911	0	0
	CALVIN	4342	TAYLOR PETROLEUM LLC		859	864	250	400
	CALVIN	4515	PARKS BILL M ESTATE		855	866	300	300
	CALVIN	4588	KLO LLC		896	915	0	0
	CALVIN	4589	SWADLEY ROY W & JUDITH I		844	864	0	0
	CALVIN	4831	MONTEGO RESOURCES INC		2,150	2,178	0	50
	CALVIN	5852	X-BAR RESOURCES INC		793	825	100	100
	CALVIN	16717	PARKINSOL OIL COMPANY		1,187	1,205	0	100
	CALVIN	20202	SWADLEY ROY W & JUDITH I		882	909	0	0
	CALVIN	20448	LUNAR INVESTMENTS INC		870	880	400	50
	CALVIN	20704	LOFTIS BOB L		788	796	395	600
	CALVIN	20737	B & R OIL		1,175	1,200	150	500
	CALVIN	20862	SHALLOW ENERGY INC		1,204	1,376	200	400
	CALVIN	20936	TWO GEMS COMPANY		300	320	350	150
	CALVIN	21032	GENESIS INC		300	320	400	80
	CALVIN	21065	GENESIS INC		270	300	400	80
	CALVIN	21066	GENESIS INC		264	284	300	40
	CALVIN	21068	GENESIS INC		299	313	400	80
	CALVIN	21069	GENESIS INC		302	322	400	80
	CALVIN	21072	GENESIS INC		320	335	300	40
	CALVIN	21080	MEIER MARK A		950	960	250	100
	CALVIN	21080	MEIER MARK A		1,064	1,074	250	100
	CALVIN	21113	XANADU EXPLORATION COMPANY		1,439	1,468	720	1,000
	CALVIN	21252	KLO LLC		806	950	500	200
	CALVIN	21397	ROBINSON DEAN		800	1,030	200	200
	CALVIN	21539	LUNAR INVESTMENTS INC		800	1,000	300	600
	CALVIN	21539	LUNAR INVESTMENTS INC		800	1,000	500	500
	CALVIN	21539	LUNAR INVESTMENTS INC		800	1,000	600	1,000
	CALVIN	21713	U S DRILLING COMPANY INC		1,200	1,208	700	400
	CALVIN	21731	KIMCO OIL AND GAS CO		934	992	100	100
	CALVIN	22248	PARKS BILL M ESTATE		842	860	420	150

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Hughes (cont'd)	CALVIN	22715	FLEET FRANK T INC		645	666	300	100
	CALVIN	22752	KLO LLC			1,504	1,000	2,000
	CALVIN	23017	LUNAR INVESTMENTS INC		898	903	300	100
	CALVIN BTLSVL SAVANN	21113	XANADU EXPLORATION COMPANY		1,440	2,040	720	1,000
	CALVIN SAND	0	SWADLEY ROY W & JUDITH I		854	909	0	40
	CALVIN SAND	0	ONTEX OIL CO		530	798	0	0
	CALVIN SAND	4	SWEARINGEN ROBERT E		860	870	0	0
	CALVIN SAND	312	BETTIS BOYLE & STOVALL		445	511	200	50
	CALVIN SAND	1304	M M & M RESOURCES INC		874	890	200	125
	CALVIN SAND	1870	BROWN L C COMPANY		779	787	190	60
	CALVIN SAND	2424	WOLVERINE PETROLEUM CORP.		1,030	1,050	200	200
	CALVIN SAND	2491	B & R OIL		1,165	1,185	0	250
	CALVIN SAND	2682	MASSAD OIL COMPANY		950	1,250	720	600
	CALVIN SAND	2697	WOLVERINE PETROLEUM CORP.		1,200	1,208	200	200
	CALVIN SAND	2839	OLIPHANT GERTRUD		1,024	1,031	300	200
	CALVIN SAND	2864	OLIPHANT GERTRUD		985	1,010	0	50
	CALVIN SAND	2865	OLIPHANT GERTRUD		985	1,010	0	0
	CALVIN SAND	2873	PICKENS L A		874	902	0	10
	CALVIN SAND	2876	PARKS BILL M ESTATE		800	875	300	100
	CALVIN SAND	3863	COX ELMER N		940	1,000	0	0
	CALVIN SAND	4072	PARKS BILL M ESTATE		860	870	350	200
	CALVIN SAND	4768	ENNIS BILL H		1,230	1,320	0	50
	CALVIN SAND	21105	BRADY PRODUCTION		850	860	300	200
	CALVIN SAND	23229	SIGNATURE EXPLORATION INC		882	890	300	500
	CALVIN SAND	25007	COLUMBUS OIL COMPANY		1,386	1,433	100	100
	CALVIN SD	2868	PARKS BILL M ESTATE		850	890	300	0
	CHANNEL BOOCH	20286	C & C TANK TRUCK SERVICE INC	Yes	2,282	2,331	300	1,000
	CHANNEL BOOCH	20286	C & C TANK TRUCK SERVICE INC	Yes	2,282	2,331	1,000	1,000
	CROMWELL	0	STARGAS CO		32853	3305	0	0
	CROMWELL	0	TEXOLA DRILLING CO		3112	3141	0	1250
	CROMWELL	268	X-BAR LIMITED PARTNERSHIP		3,790	3,797	375	1,000
	CROMWELL	885	WOLFEN ENERGY CORP		3,401	3,419	0	300
	CROMWELL	888	TEXAS ENERGY ASSOCIATES		0	0	0	0
	CROMWELL	1206	GENERAL PETROLEUM CORPORATION		3,130	3,160	500	5,000
	CROMWELL	1378	CANTRELL J G DRILLING CO		3,110	3,124	0	0
	CROMWELL	1432	GENERAL PETROLEUM CORPORATION		3,128	3,166	1,200	3,000
	CROMWELL	1473	CHAPMAN LETA M ESTATE				0	0
	CROMWELL	1494	GLENCO OIL & GAS CORPORATION		3,338	3,345	0	0
	CROMWELL	1586	DAYCON EXPLORATION		3,149	3,286	1,000	600
	CROMWELL	3029	X-BAR RESOURCES INC		3,760	3,782	100	200
	CROMWELL	4057	CONOCOPHILLIPS COMPANY		3,285	3,305	0	0
	CROMWELL	20104	CHERMAC ENERGY CORPORATION		3,334	3,372	0	50
	CROMWELL	20112	JAY PETROLEUM INC		0	0	600	2,500
	CROMWELL	20254	C & C TANK TRUCK SERVICE INC	Yes	3,367	3,421	1,000	3,000
	CROMWELL	20256	RAINBOW OIL & GAS LLC		3,530	3,550	300	150
	CROMWELL	20256	RAINBOW OIL & GAS LLC		3,530	3,550	300	150
	CROMWELL	20495	TEXACO EXPLORATION & PROD INC		4,392	4,404	500	1,500
	CROMWELL	20525	TOKLAN OIL & GAS CORPORATION		3,027	3,130	500	750
	CROMWELL	20723	M M & M RESOURCES INC		3,126	3,210	250	3,000
	CROMWELL	20940	TIDE WEST OIL COMPANY		3,308	3,332	30	150
	CROMWELL	20990	PRYOR JR VICTOR W		4,490	4,545	500	1,000
	CROMWELL	20990	PRYOR JR VICTOR W		4,490	4,555	500	1,000
	CROMWELL	21104	LIBERTY OPERATING INC		3,378	3,418	100	300
	CROMWELL	21158	KLO LLC		3,888	3,898	600	3,000
	CROMWELL	21313	UNITED PRODUCTION CO LLC		4,365	4,590	250	400
	CROMWELL	21313	UNITED PRODUCTION CO LLC		4,365	4,590	1,000	400
	CROMWELL	21451	GOMACO OPERATING COMPANY		3,665	3,708	500	900
	CROMWELL	21564	MCQUEEN ED & COMPANY INC		3,055	3,095	500	1,000
	CROMWELL	21585	PRYOR JR VICTOR W		3,397	3,463	300	500
	CROMWELL	21700	RUFFEL LANCE OIL AND GAS CORP		3,234	3,240	250	400
	CROMWELL	21819	CUESTA PETROLEUM INC		3,356	3,371	500	500
	CROMWELL	21819	CUESTA PETROLEUM INC		3,435	3,505	500	1,500
	CROMWELL	21872	GOLDEN GAS SERVICE COMPANY		3,426	3,430	700	10
	CROMWELL	21886	FLINT DOUGLAS J		3,580	3,592	200	100
	CROMWELL	21902	YALE OIL ASSOCIATION INC		3,840	3,854	500	500
	CROMWELL	21902	YALE OIL ASSOCIATION INC		3,840	3,854	500	500
	CROMWELL	21929	P A ENERGY INC		4,473	4,529	750	1,000
	CROMWELL	21929	P A ENERGY INC		4,473	4,529	1,500	15,000
	CROMWELL	21933	LANDERS OIL & GAS INC		3,310	3,370	800	1,000
	CROMWELL	21947	OAKLAND PETROLEUM OPERATING CO INC		3,178	3,180	0	1,500
	CROMWELL	22210	OAKLAND PETROLEUM OPERATING CO INC		3,548	3,556	700	
	CROMWELL	22261	KAHAN & ASSOCIATES INC		3,365	3,400	200	2,500
	CROMWELL	22263	PALUCA PETROLEUM INC	Yes	4,519	4,534	400	1,000
	CROMWELL	22263	PALUCA PETROLEUM INC	Yes	4,519	4,575	1,000	10,000

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Hughes (cont'd)	CROMWELL	22369	WILLIAMS REID OPERATING INC		4,434	4,458	0	325
	CROMWELL	22422	CROWN ENERGY COMPANY		4,558	4,640	0	300
	CROMWELL	22814	KLO LLC		5,500	6,162	300	1,000
	CROMWELL	22814	KLO LLC		5,500	6,162	300	1,000
	CROMWELL	22899	SOUTHERN RESOURCES INC		3,358	3,388	500	1,000
	CROMWELL	23048	COLUMBUS OIL COMPANY		3,448	3,563	1,000	10,000
	CROMWELL	23048	COLUMBUS OIL COMPANY			3,564	1,000	10,000
	CROMWELL	23440	BC OPERATING INC		3,398	3,406	0	85
	CROMWELL	23581	CHESAPEAKE OPERATING INC		2,498	2,506	500	300
	CROMWELL	23581	CHESAPEAKE OPERATING INC		4,006	4,016	500	300
	CROMWELL	23812	CONTINENTAL RESOURCES INC		4,478	4,638	2,200	10,000
	CROMWELL	24003	RKR EXPLORATION INC		3,400	3,550	500	5,000
	CROMWELL	30043	HOWELL BILL J		4,400	4,585	400	850
	CROMWELL	30304	LAIRD BILL OIL COMPANY		3,320	3,330	200	400
	CROMWELL SAND	0	EARNHARDT WILLIAM R COMPANY		2,836	2,975	0	0
	CROMWELL SAND	69	CHERMAC ENERGY CORPORATION		3,370	3,400	0	300
	CROMWELL SAND	430	KLO LLC		3,587	3,590	250	50
	CROMWELL SAND	820	SINCLAIR OIL & GAS COMPANY		3,300	3,322	0	0
	CROMWELL SAND	899	KLO LLC		4,770	4,890	600	1,000
	CROMWELL SAND	998	CIRCLE C OILFIELD SUPPLY INC		3,140	3,145	300	480
	CROMWELL SAND	1103	KLO LLC		3,876	3,882	0	1,000
	CROMWELL SAND	1358	GENERAL PETROLEUM CORPORATION		3,160	3,165	500	200
	CROMWELL SAND	1375	PRYOR JR VICTOR W		3,116	3,125	200	100
	CROMWELL SAND	1447	GRAHAM ROYALTY LTD		3,427	3,443	0	150
	CROMWELL SAND	2133	TK DRILLING CORPORATION		3,242	3,320	0	1,500
	CROMWELL SAND	3077	RESEARCH OIL COMPANY INC		3,272	3,301	300	200
	CROMWELL SAND	3540	JACKSON JR L B		3,342	3,394	0	50
	CROMWELL SAND	20077	FERGUSON OIL CO		4,860	4,880	0	100
	CROMWELL SAND	20167	SELLERS O N		3,466	3,590	300	300
	CROMWELL SAND	20321	ROXANNA OIL COMPANY		2,993	2,999	0	100
	CROMWELL SAND	20701	GENERAL PETROLEUM CORPORATION		3,182	3,215	500	300
	CROMWELL SAND	20778	PAR OIL COMPANY INC		3,330	3,360	0	100
	CROMWELL SAND	20890	C & C TANK TRUCK SERVICE INC	Yes	3,157	3,174	300	2,000
	CROMWELL SD	0	RDT PROPERTIES INC		3,292	3,366	800	1,000
	CROMWELL SD	22062	RDT PROPERTIES INC		3,290	260	800	1,000
	CROMWELL SD	22063	LANDERS & MUSGROVE OIL CO INC		3,290	3,370	800	1,000
	CROMWELL SD	22064	LANDERS & MUSGROVE OIL CO INC		3,290	3,370	800	1,000
	CROMWELL SD	22065	LANDERS & MUSGROVE OIL CO INC		3,290	3,370	800	1,000
	CROMWELL SD	22066	LANDERS & MUSGROVE OIL CO INC		3,290	3,370	800	1,000
	CROMWELL SD	22067	RDT PROPERTIES INC		3,290	3,370	800	1,000
	CROMWELL SD	22068	LANDERS & MUSGROVE OIL CO INC		3,290	3,370	800	1,000
	CROMWELL SD	22069	RDT PROPERTIES INC		3,290	3,370	800	1,000
	CROMWELL SD	22070	RDT PROPERTIES INC		3,290	3,370	800	1,000
	CROMWELL-WILCOX 2	21749	FOUNDATION ENERGY MANAGEMENT LLC		3,990	4,084	500	700
	CROMWELL-WILCOX 2	23369	ARVINE ENVIRONMENTAL LLC		3,550	4,950	1,500	3,000
	EARLSBORO	20201	TRIPOWER RESOURCES INC		1,200	1,216	350	350
	EARLSBORO	22137	NORTHBROOK OIL & GAS COMPANY		2,490	2,500	1,000	500
	EARLSBORO SAND	35	WHITSON OIL COMPANY INC.		1,932	1,962	500	1,500
	GILCREASE	1432	GENERAL PETROLEUM CORPORATION		2,721	2,769	1,200	3,000
	GILCREASE	2451	SEMINOLE TANK SERVICE		3,051	3,059	0	50
	GILCREASE	4532	PRYOR JR VICTOR W		2,454	2,554	0	0
	GILCREASE	20090	KAHAN & ASSOCIATES INC		3,110	3,150	500	1,000
	GILCREASE	20495	TEXACO EXPLORATION & PROD INC		3,525	3,565	500	1,500
	GILCREASE	20651	C & C TANK TRUCK SERVICE INC	Yes	2,910	3,074	1,000	2,000
	GILCREASE	20723	M M & M RESOURCES INC		2,605	2,730	0	500
	GILCREASE	21564	MCQUEEN ED & COMPANY INC		2,550	2,554	500	1,000
	GILCREASE	21594	HALLWOOD PETROLEUM INC		3,330	3,350	0	0
	GILCREASE	21733	REED POWER TONGS INC		3,090	3,096	1,500	200
	GILCREASE	22152	PRYOR JR VICTOR W		2,502	2,568	500	350
	GILCREASE	22291	REED POWER TONGS INC		3,052	3,064	1,500	200
	GILCREASE	22362	SOUTHERN RESOURCES INC		2,990	3,180	1,200	1,000
	GILCREASE	22857	BOONE OPERATING INC		3,112		300	100
	GILCREASE	23048	COLUMBUS OIL COMPANY				1,000	10,000
	GILCREASE	23117	SCOTT JERRY DRILLING CO INC		2,865	2,870	0	300
	GILCREASE	23474	SENTINEL PETROLEUM INC		3,029	3,039	1,500	300
	GILCREASE	30057	COLUMBUS OIL COMPANY		3,090	3,220	300	1,000
	GILCREASE 1	22897	BOONE OPERATING INC		3,060	3,066	300	200
	GILCREASE LOW	20651	C & C TANK TRUCK SERVICE INC	Yes	3,033	3,074	0	2,000
	GILCREASE LOW	23048	COLUMBUS OIL COMPANY		3,232	3,280	1,000	10,000
	GILCREASE MID	23048	COLUMBUS OIL COMPANY		3,134	3,251	1,000	10,000
	GILCREASE SAND	810	WALKER RANDY & JAN OIL COMPANY LLC		3,042	3,069	0	0
	GILCREASE SAND	2133	TK DRILLING CORPORATION		2,735	2,903	0	1,500
	GILCREASE SAND	4524	JETSON OPERATING INC		3,045	3,067	0	300
	GILCREASE SAND	22897	BOONE OPERATING INC		3,060	3,066	300	200

TABLE 11
Oil and Gas Wells and Commercial Disposal Wells
Woodford Shale Study
Oklahoma, USA

County	Formation	API Number	Operator	Commerical Disposal Well	Top of Formation Depth (ft bgs)	Bottom of Formation Depth (ft bgs)	Maximum Injection Pressure (psi, surface)	Maximum Injection Rate (bbls/day)
Hughes (cont'd)	GILCREASE SAND	30102	MONTGOMERY EXPLORATION COMPANY		2,854	2,876	400	750
	GILCREASE SD	20559	STAUB LARRY INC		2,882	3,552	350	800
	GILCREASE UP	20651	C & C TANK TRUCK SERVICE INC	Yes	2,910	2,914	0	2,000
	GILCREASE/CROMWELL	22732	CENTREX OPERATING COMPANY		2,732	3,116	500	500
	GILCREASE-CROMWELL	20199	TEXACO INC		2,662	3,363	1,000	3,000
	GILCREASE-CROMWELL	21436	COLUMBUS OIL COMPANY		3,110	3,457	1,000	10,000
	GILCRS U.VALY JEFSON	21552	GENESIS INC		0	0	1,000	800
	HARTSHORNE	2012	CENTRAL OKLA OIL & GAS CORP		3,392	3,498	500	600
	HARTSHORNE	3298	WEEMS BILL WELDING INC		2,600		0	0
	HARTSHORNE	20201	TRIPOWER RESOURCES INC		3,066	3,094	350	350
	HARTSHORNE	20990	PRYOR JR VICTOR W		2,940	2,968	500	1,000
	HARTSHORNE	20990	PRYOR JR VICTOR W		2,940	2,968	500	1,000
	HARTSHORNE	22426	SOUTHERN RESOURCES INC		2,811	2,819	750	500
	HARTSHORNE	22563	PRICE AUBREY		2,553	2,560	300	300
	HARTSHORNE	23581	CHESAPEAKE OPERATING INC		2,498	2,506	500	1,000
	HARTSHORNE	23581	CHESAPEAKE OPERATING INC		2,498	2,506	1,249	3,000
	HARTSHORNE SAND	4522	WEEMS BILL WELDING INC		2,550	2,600	0	0
	HUNTON	0	GENERAL PETROLEUM CORPORATION		3,725	3,840	0	0
	HUNTON	1163	COLUMBUS OIL COMPANY		3,985	4,000	0	400
	HUNTON	20874	M M & M RESOURCES INC		3,800	3,830	0	250
	HUNTON LIME	21385	NEWELL OIL AND GAS INC		3,820	3,948	750	6,000
	JEFFERSON	20225	KLO LLC		4,546	4,570	400	1,000
	JEFFERSON	21961	TOKLAN OIL & GAS CORPORATION		3,300	3,306	100	50
	JEFFERSON	23222	X-BAR RESOURCES INC		3,356	3,371	300	1,000
	JEFFERSON/ARK/ OKLA/	21505	DAYCON EXPLORATION		3,381	3,394	150	100
	JEFFERSON/ARK/ OKLA/	21505	DAYCON EXPLORATION		3,467	3,502	150	100
	JEFFERSON/ARK/ OKLA/	22481	MARBET LLC		5,724	5,745	300	300
	JEFFERSON SAND	22081	JOSIE OIL & GAS INC		3,378	3,392	500	250
	JEFFERSON 2 /ARK/ OKLA/	22857	BOONE OPERATING INC			3,582	300	100
	JEFFERSON SD	21505	DAYCON EXPLORATION		3,467	3,502	100	150
	L CROMWELL	22774	PRIMARY NATURAL RESOURCES INC		3,184	3,200	250	900
	LOWER BOOCH	1561	MILNE LEWIS JOEL		2,860	2,878	900	260
	LOWER BOOCH	1561	MILNE LEWIS JOEL		2,860	2,878	1,400	260
	LOWER CALVIN	3802	C E D LC		1,111	1,121	0	0
	LOWER CALVIN	21308	LEMA PETROLEUM INC		1,028	1,032	400	100
	LOWER CROMWELL	1206	GENERAL PETROLEUM CORPORATION		3,130	3,160	500	5,000
	LOWER CROMWELL	1206	GENERAL PETROLEUM CORPORATION		3,130	3,160	500	5,000
	LOWER CROMWELL	34941	JAY PETROLEUM INC		3,394	3,400	500	700
	LOWER WILCOX	22505	DIAMOND HARRY H INC		4,448	4,474	0	200
	MARSHALL 1ST 2NDWILC	22041	MARJO OPERATING COMPANY INC		3,680	3,842	650	1,200
	MCALESTER	0	FUGO SERVICES INC		1,400	2,200	700	6,000
	MIDDLE CALVIN	1547	B & R OIL		1,009	0	200	500
	MIDDLE CALVIN	21489	KLO LLC		782	806	300	150
	MIDDLE CALVIN SAND	0	PARKINSOL OIL COMPANY		1,166	1,199	0	500
	MIDDLE CALVIN SAND	11383	SWADLEY ROY W & JUDITH I		1,075	1,086	300	75
	MIDDLE CALVIN SAND	20610	SWADLEY ET AL		1,016	1,046	100	75
	MIDDLE CALVIN SAND	53346	SWADLEY ET AL		1,034	1,055	125	90
	MISENER	3879	KAHAN & ASSOCIATES INC		3,128	0	0	0
	MISENER	21158	KLO LLC		4,660	4,664	600	3,000
	MISENER	21322	SCOTT JERRY DRILLING CO INC		4,054	0	0	0
	MISENER	21615	RIVES OWEN H		4,044	4,060	300	950
	MISENER	22081	JOSIE OIL & GAS INC		4,102	4,128	250	250
	MISENER	22081	JOSIE OIL & GAS INC		4,102	4,128	500	250
	ORDOVICIAN	625	CUESTA PETROLEUM INC		4,300	5,100	300	2,000
	PENN	0	DERRICK OPERATING INC		804	834	0	0
	PENN	0	CORNERSTONE E & P COMPANY LP		1,050	2,300	500	8,000
	PENN	23494	P A ENERGY INC		1,236	1,300	1,000	800
	PENN SD	23297	CORNERSTONE E & P COMPANY LP		1,050	2,700	500	8,000
	PENN SD	23494	P A ENERGY INC		1,236	1,300	500	800
	PENN SD	24159	CORNERSTONE E & P COMPANY LP		1,386	2,300	500	10,000
	PENN. SAND	20344	HOWELL BILL J		1,230	1,290	500	500
	RED FORK	3309	LENCO OIL & GAS INC		1,436		150	72
	RED FORK	3309	LENCO OIL & GAS INC		1,498	1,554	200	100
	RED FORK	4357	CONTINENTAL OPERATING CO		1,465	1,490	200	200
	RED FORK	22004	MAJORS EUGENE E		1,840	1,876	150	200
	RED FORK	23436	YALE OIL ASSOCIATION INC			1,400	300	1,000
	RED FORK SAND	897	CHAPMAN LETA M ESTATE		2,370	2,410	700	100
	SAVANA	22165	LIBERTY OPERATING INC		2,566	2,574	200	300
	SAVANA BOOCH GILCRES	21552	GENESIS INC		0	0	1,000	800
	SAVANNA	21113	XANADU EXPLORATION COMPANY		2,032	2,037	720	1,000
	SAVANNA-BOOCH-HARTSHORNE	23708	FUGO SERVICES LLC		2,400	3,525	1,200	10,000
	SECOND CROMWELL	2137	MORAN-K OIL LLC		3,327	3,333	0	0
	SENORA	851	DAYCON EXPLORATION		1,390	1,404	400	150
	SENORA	1604	SCOTT JERRY DRILLING CO INC		1,218	1,224	200	400

TABLE 11
Oil and Gas Wells and Commercial Disposal Wells
Woodford Shale Study
Oklahoma, USA

County	Formation	API Number	Operator	Commerical Disposal Well	Top of Formation Depth (ft bgs)	Bottom of Formation Depth (ft bgs)	Maximum Injection Pressure (psi, surface)	Maximum Injection Rate (bbls/day)
Hughes (cont'd)	SENORA	20304	WINSTON OIL COMPANY		1,088	1,173	400	70
	SENORA	21495	TRANSOK LLC		1,733	1,737	100	40
	SENORA	23096	PETROQUEST OIL & GAS LLC		525	700	300	350
	SENORA	23328	HALL EXPLORATION INC		674	820	120	100
	SENORA/SD/	3309	LENCO OIL & GAS INC			1,554	150	72
	SENORA/SD/	23730	PETRA PETROLEUM MANAGEMENT LLC		356	370	250	400
	SENORA - ALLEN SAND	1719	PRENTICE ED		835	865	300	100
	SENORA - ALLEN SAND	4489	PRENTICE ED		853	864	300	100
	SENORA LOW	23730	PETRA PETROLEUM MANAGEMENT LLC		484	500	250	400
	SENORA LOW	23730	PETRA PETROLEUM MANAGEMENT LLC		484	500	250	400
	SENORA SD	1589	LOFTIS BOB L		900	1,850	800	1,200
	SKIN-BART. SANDS	4216	EARNHARDT WILLIAM R COMPANY		1,457	1,755	700	1,000
	THURMAN	177	TRIPOWER RESOURCES LLC		1,010	1,075	300	300
	THURMAN	177	TRIPOWER RESOURCES LLC		1,010	1,075	500	1,000
	THURMAN	930	PERKINS NOVA		1,680	1,710	1,000	200
	THURMAN	930	PERKINS NOVA		1,680	1,710	1,000	200
	THURMAN	1062	LUNAR INVESTMENTS INC		1,750	1,780	500	600
	THURMAN	4357	CONTINENTAL OPERATING CO		1,205	1,221	200	200
	THURMAN	22009	TRIPOWER RESOURCES LLC		1,153	1,163	300	250
	THURMAN	22717	RICHARDSON BUD II		1,406	1,426	300	300
	THURMAN	23510	MITCHELL CECIL D		1,430	1,464	300	500
	THURMAN SAND	1062	LUNAR INVESTMENTS INC		1,755	1,780	75	100
	THURMAN SAND	1562	PUMPING SERVICES INC		1,725	1,745	500	100
	UN. VALLEY-CROMWELL	4150	GENERAL PETROLEUM CORPORATION		3,070	3,102	200	200
	UNION VALLEY	1447	GRAHAM ROYALTY LTD		3,240	3,246	0	150
	UNION VALLEY	30058	RESEARCH OIL COMPANY INC		4,464	4,477	500	1,000
	UNION VALLEY CROMWEL	30057	COLUMBUS OIL COMPANY		3,404	3,468	300	1,000
	UNION VALLEY SAND	20208	JOHNSON DOYLE T		3,046	3,060	800	1,000
	UNION VALLEY-CROMWELL	21809	OAKLAND PETROLEUM OPERATING CO INC		3,468	3,474	700	7,000
	UNION VALLEY-CROMWELL	22317	FOUNDATION ENERGY MANAGEMENT LLC		4,343	4,426	1,000	1,000
	UNION VALLY	1586	DAYCON EXPLORATION		3,149	3,286	1,000	600
	UNNAMED PENN-PERMIAN	885	WOLFEN ENERGY CORP		1,730	1,735	0	300
	UPPER BOOCH	934	CHILES JACK WELL SERVICE		2,741	2,747	1,000	200
	UPPER WILCOX	22505	DIAMOND HARRY H INC		4,330	4,350	0	200
	VIOLA /LM GROUP/	121	P A ENERGY INC		5,409	5,433	500	1,000
	VIOLA /LM GROUP/	21113	XANADU EXPLORATION COMPANY		4,436	4,484	720	1,000
	VIOLA-WILCOX	23369	ARVINE ENVIRONMENTAL LLC		4,611	4,840	1,000	3,000
	WAPANUCKA	23395	YALE OIL ASSOCIATION INC		3,491	3,501	600	1,200
	WAPANUCKA-CROMWELL	23395	YALE OIL ASSOCIATION INC		3,491	3,850	600	1,200
	WEWOKA	22752	KLO LLC		518		1,000	2,000
	WILCOX	0	GENERAL PETROLEUM CORPORATION		4,035	4,099	0	0
	WILCOX	231	U S DRILLING COMPANY INC		4,431	0	0	0
	WILCOX	21113	XANADU EXPLORATION COMPANY		4,671	4,675	720	1,000
	WILCOX	21158	KLO LLC		4,910	5,100	600	3,000
	WILCOX	21586	JOSIE OIL & GAS INC		4,143	4,196	300	500
	WILCOX	22473	WEEMS BILL OIL INC		3,672	3,925	750	2,000
	WILCOX 1	23534	MONTGOMERY EXPLORATION COMPANY		4,280		300	20,000
	WILCOX 2	2378	MORAN-K OIL LLC		4,262	4,278	1,200	700
	WILCOX 2	23534	MONTGOMERY EXPLORATION COMPANY				300	20,000
	WILCOX SAND	806	SWADLEY ROY W & JUDITH I		5,030	5,125	0	0
	WILCOX SAND	1068	CHADWELL BEN A		5,081	5,095	500	500
	WILCOX SAND	2400	X-BAR LIMITED PARTNERSHIP		4,362	4,436	0	0
	WILCOX SAND	21277	LEMA PETROLEUM INC		4,408	4,409	750	2,000
	WILCOX-ARBUCKLE	23484	SHARBER BILLY JACK OPERATING LLC	Yes	3,880	6,339	750	5,000
	WILCOX-ARBUCKLE	23484	SHARBER BILLY JACK OPERATING LLC	Yes	3,880	6,182	750	20,000
	WILSON SAND	2378	MORAN-K OIL LLC		4,202	4,278	500	700
	WOODFORD /SH/ SD/ NTEX/	22481	MARBET LLC		6,560	6,652	300	300
	WOODFORD-VIOLA	21749	FOUNDATION ENERGY MANAGEMENT LLC			4,793	500	700
Pittsburg	ARBUCKLE GROUP	20221	NEWFIELD EXPL MIDCONTINENT INC		8,630	8,800	2,000	3,000
	BARTLESVILLE	22829	MARBET LLC		1,734	1,752	0	80
	BARTLESVILLE	22829	MARBET LLC		1,710	1,752	300	1,000
	BARTLESVILLE	23619	CHESAPEAKE OPERATING INC		1,325	1,600	500	2,000
	BARTLESVILLE	23619	CHESAPEAKE OPERATING INC		1,364	1,403	682	2,000
	BARTLESVILLE	23619	CHESAPEAKE OPERATING INC		1,384	1,403	1,500	2,500
	BARTLESVILLE-SAVANNA-BOOCH	20966	DAVIS OPERATING COMPANY		900	2,400	250	1,000
	BOOCH	0	A & A TANK TRUCK CO	Yes	1,600	1,800	1,250	4,000
	BOOCH	0	BISHOP GARY	Yes	1,610	1,810	800	4,000
	BOOCH	0	BISHOP GARY	Yes	1,640	1,880	800	5,000
	BOOCH	0	STP CHEROKEE INC		2,540	2,580	1,200	3,000
	BOOCH	20224	CANAAN RESOURCES LLC		1,912	1,936	600	3,000
	BOOCH	23153	FUGO SERVICES LLC	Yes	1,476	1,680	665	4,500
	BOOCH & BOGGY	20646	FUGITT OIL COMPANY INC		1,000	2,720	500	1,000
	BOOCH & BOGGY	20646	FUGITT OIL COMPANY INC		1,000	2,720	500	1,000

TABLE 11
Oil and Gas Wells and Commercial Disposal Wells
Woodford Shale Study
Oklahoma, USA

County	Formation	API Number	Operator	Commerical Disposal Well	Top of Formation Depth (ft bgs)	Bottom of Formation Depth (ft bgs)	Maximum Injection Pressure (psi, surface)	Maximum Injection Rate (bbls/day)
Pittsburg (cont'd)	BOOCH SAND	20695	FUGO SERVICES LLC	Yes	1,370	1,735	700	4,000
	BOOCH-HARTSHORNE	22473	FUGO SERVICES LLC	Yes	1,450	2,328	725	3,000
	HARTSHORNE	0	FUGO SERVICES LLC		3,200	4,000	1,500	7,500
	HARTSHORNE	22070	FUGO SERVICES LLC	Yes	3,168	3,253	1,584	3,600
	HARTSHORNE	22070	FUGO SERVICES LLC	Yes	3,168	3,253	1,584	3,600
	HARTSHORNE	23482	PETROQUEST ENERGY LLC		3,294	3,390	1,500	3,000
	HARTSHORNE SAND	20886	HARDIN W S		3,215	3,250	1,200	4,000
	HARTSHORNE SAND	60057	DEISENROTH M CRAIG		2,498	2,542	0	50
	MCALESTER	20224	CANAAN RESOURCES LLC		1,624	1,628	600	3,000
	SAVANNA	20284	BROWER OIL & GAS CO INC		1,410	1,468	705	1,000
	SAVANNA	23021	FUGO SERVICES LLC	Yes	1,760	1,965	880	4,000
	SIMPSON	20221	NEWFIELD EXPL MIDCONTINENT INC		8,180	8,470	3,000	5,000

Notes:
ft bgs = feet below ground surface
psi = pounds per square inch
bbls/day = barrels per day

1. Data obtained from the Oklahoma Corporation Commission (http://www.occ.state.ok.us/Divisions/OG/newweb/ogdatafiles.htm) and was last updated on 12/23/2008.
2. Oil and gas wells may peforate multiple formations. Wells with the same API Number are the same well.

TABLE 12
Management Practices for Post Frac Produced Water
Woodford Hydrology Study
Oklahoma, USA

Management Category	Type	Description	Cost[a]	Safety Risk[b]	Human Health and Eco Risk[c]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Disposal	Class I Injection	Permitted, technologically sophisticated wells that inject large volumes of hazardous or non-hazardous waste in deep isolated rock formations	High; Class I wells are designed and permitted to dispose of hazardous waste	Moderate; common to truck to disposal site	Low; deep underground sequestration	Only by-products of pre-treatment, if necessary	(1) Can handle large volumes of waste	(1) Pre-treatment often required to prevent formation plugging; (2) trucking often required to reach disposal site; (3) formation permeability, storage capacity, pressure can be limiting factors	No, according to OCC	Used primarily in petroleum refining, metal production, chemical production, pharmaceutical production, commercial disposal and municipal disposal industries
Disposal	Class II Injection	Permitted well, technically similar to a Class I UIC, that is primarily used for disposal of oil and gas exploration and production waste or enhanced recovery	$0.30 to 75/bbl for disposal; $100/hour for transport	Moderate; common to truck to disposal site	Low; deep underground sequestration	Only by-products of pre-treatment, if necessary	(1) Commonly available in oil and gas producing states such as OK; (2) can handle large volumes of waste; (3) can be a beneficial re-use if water used for enhanced recovery	(1) Pre-treatment often required to prevent formation plugging; (2) trucking often required to reach disposal site; (3) formation permeability, storage capacity, pressure can be limiting factors	Yes	Wells are classified as IID (disposal) or IIR (secondary recovery); enhanced recovery wells can be considered a beneficial re-use of post-frac produced water
Disposal	Class V Injection	Permitted well, defined by the EPA as any well not fitting under other four designations; typically shallow, including subsurface drip irrigation, septic systems, aquifer storage wells	Unknown	Moderate; common to truck to disposal site	Moderate; potential to affect shallow ground water quality	Only by-products of pre-treatment, if necessary	(1) Can be a beneficial re-use if water used for irrigation of crops or for municipal water	(1) Pre-treatment often required to prevent plugging of equipment or formation, or to reach potable water standards; (2) trucking often required to reach disposal site; (3) formation permeability, storage capacity, pressure can be limiting factors	No	Treatment must ensure that salt levels in the post-frac produced water do not have adverse effects on soil for growing, or on shallow drinking water
Disposal	Land application	Discharge of water directly to soil in a permitted facility; water is stored in lined pits for settling; application hinges on water and soil analysis to ensure permit limitations are met	Moderate; specific vendor could not be contacted; expected to be less than or comparable to pit disposal; $100/hour for transport	Moderate; common to truck to disposal site	Moderate; metals and salt could effect shallow GW	Sludge	(1) Can handle large volumes of waste	(1) Creates salt accumulation in soil; (2) use is limited in many states if ground is saturated, frozen or precipitation is imminent; (3) sludge to dispose of; (4) size of operation may create opposition from residents; (6) pre-treatment of water generally required	Yes	Treatment must ensure that salt levels in the post-frac produced water do not have adverse effects on soil for growing, or on shallow drinking water
Disposal	Settling pits/ponds - 3rd party, off-site	Permitted, lined pits/ponds that hold water for settling, and sometimes treatment and re-use	$0.75 to 0.99/bbl for disposal; $100/hour for transport	Moderate; trucking required	Moderate; potential for exposure from pit & release to shallow GW	Sludge	(1) May be able to treat and re-use post-frac flowback for subsequent frac; (2) can handle large volumes of waste	(1) Large footprint needed to make economically viable; (2) potential for release to shallow GW; (3) sludge to dispose of; (4) sheer size may create opposition from residents	Yes	None

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Management Category	Type	Description	Cost[(a)]	Safety Risk[(b)]	Human Health and Eco Risk[(c)]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Disposal	Settling pits/ponds - at well pad	Permitted, lined pits/ponds that hold water for settling, and sometimes treatment and re-use	Low; cost to dig, line and permit pit	Low; no trucking required	Low; potential for exposure from pit	Sludge	(1) May be able to treat and re-use post-frac flowback for subsequent frac; (2) can handle large volumes of waste	(1) potential for release to shallow GW; (2) sludge to dispose of	Yes	None
Minimization	Downhole Gas/Water Separator	Separation of water and hydrocarbon downhole, and subsequent injection of water into a non-producing formation above or below the gas producing formation, so minimal water comes to the surface	Moderate; equipment is somewhat expensive	Low; equipment operates downhole	Low; minimal risk of exposure	Waste water; generally process is not 100% efficient	(1) Minimizes disposal need; (2) water never comes to the surface	(1) Formations for downhole injection need to have suitable porosity, permeability and isolation from USDW; (2) unit plugging can be an issue from suspended solids or precipitates; (3) process not 100% efficient and some water usually comes to the surface	Unknown	Bypass tools may be appropriate for rates of 25-250 barrels/day (bpd) and depths of 2,000 to 8,000 feet below ground surface (bgs); modified plunger rod pumps good for rates of 250-800 bpd at depths of 2000 to 8000 ft bgs; electric submersible pumps good for rates above 800bpd and depths greater than 6,000 ft bgs.
Treatment	Corrugated plate separator	De-oiler; separation of phase-separated oil under gravity effects enhanced by flocculation on corrugated plates	Low; equipment & energy costs low	Low; minimal explosive hazard from hydrocarbon vapors	Low; potential exposure in maintenance	Slurry	(1) No energy required; (2) effective for bulk oil and suspended solids removal; (3) equipment resistant to breakdowns; (4) treats oil & grease in excess of 1000 ppm	(1) Inefficient for fine particles; (2) long residence time required; (3) not a commonly utilized, mobile technology; (4) would require additional technology to treat salt content of post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; oil content in post-frac produced water expected to be minimal
Treatment	Centrifuge	De-oiler and suspended particles removal; separation under centrifugal force from spinning	High; maintenance & energy costs	Moderate; moving parts, energy hook up, hydrocarbon vapors	Low; potential exposure in maintenance	Slurry	(1) Efficient removal of fine oil particles; (2) short retention time; (3) capable of large throughput; (4) treats oil & grease in excess of 1000 ppm; (5) more commonly utilized mobile technology	(1) Spinning is energy intensive; (2) high maintenance cost; (3) would require additional technology to treat salt content of post-frac produced water	Yes	Technology is not a stand alone treatment for post-frac produced water; oil content in post-frac produced water expected to be minimal
Treatment	Hydroclone	De-oiler; separation of phase-separated oil under centrifugal force generated by pressurized, tangential input of influent stream	High; maintenance & energy costs	Moderate; moving parts, energy hook up, hydrocarbon vapors	Low; potential exposure in maintenance	Slurry	(1) Equipment is compact; (2) high efficiency and throughput for fine oil particles; (3) treats oil & grease in excess of 1000 ppm; (4) more commonly utilized mobile technology	(1) Inlet pressure requirement is energy intensive; (2) no solid separation; (3) fouling can be an issue; (4) higher maintenance cost; (5) would require additional technology to treat salt content of post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; oil content in post-frac produced water expected to be minimal

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Management Category	Type	Description	Cost[(a)]	Safety Risk[(b)]	Human Health and Eco Risk[(c)]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Treatment	Gas flotation	De-oiler; oil particles attach to induced gas bubbles and float to surface	Low; equipment & energy costs low	Low; minimal explosive hazard from hydrocarbon vapors	Low; potential exposure in maintenance	Oil skim and lumps	(1) No moving parts; (2) efficiency due to coalescence; (3) simple operation; (4) low maintenance; (5) treats oil & grease in excess of 1000 ppm	(1) Generates large quantities of air; (2) longer retention time, so throughput lower; (3) would require additional technology to treat salt content of post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; oil content in post-frac produced water expected to be minimal
Treatment	Extraction	De-oiler; removal by use of hydrocarbon solvent that is less dense than water	Moderate; solvent costs	Moderate; potential explosive hazard from solvent	Moderate; potential exposure to solvent	Solvent regeneration waste	(1) No moving parts; (2) minimal energy; (3) removes dissolved oil; (4) simple operation; (5) treats oil & grease less than 1000 ppm	(1) Solvent has safety and exposure risks; (2) extract handling and solvent regeneration; (3) would require additional technology to treat salt content of post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; technology may be suitable for removal of trace hydrocarbons present in post-frac produced water
Treatment	Oxidation	Organics and metals removal; may include ozone, peroxide or oxygen; strong oxidizer reacts with organic material or with inorganics and precipitates to remove from solution	Moderate; oxidizer material costs, waste	Moderate; potential reactivity from oxidizer	Moderate; potential exposure to oxidizer	Precipitate slurry	(1) Simple operation; (2) efficient with high throughput for primary treatment of soluble constituents; (3) treats ionic constituents as well as organics; (4) mobile technology available	(1) Must handle and store oxidizer; (2) higher maintenance and waste disposal costs; (3) would require additional technology to treat post-frac produced water	Yes	Technology is not a stand alone treatment for post-frac produced water; technology is suitable for gross removal of trace hydrocarbons, NORM, and metals present in post-frac produced water, but requires polishing to produce potable water
Treatment	Adsorption	Organics removal; includes granular activated carbon (GAC); porous media adsorbs influent stream	Low; material & disposal costs are low	Low; minimal explosive hazard from hydrocarbon vapors	Low; potential exposure in maintenance	Used adsorbent media	(1) Equipment is compact; (2) high efficiency; (3) equipment is cheaper; (4) more commonly utilized mobile technology	(1) High retention time, so throughput less; (2) efficiency less with higher influent concentration; (3) maintenance associated with media regeneration or disposal; (4) fouling can be an issue; (5) would require additional technology to treat post-frac produced water	Yes	Technology is not a stand alone treatment for post-frac produced water; technology is suitable for polishing removal of dissolved organics in post-frac produced water
Treatment	Chlorination	Disinfection; kills many microbes that may cause biofouling	Low; material costs	Low; commonly used chemical	Low; potential exposure to oxidizer	Small volumes of suspended solids	(1) Cheap; (2) simple; (3) helps protect piping and surface equipment from fouling; (4) mobile technology available	(1) Not effective on all microbes; (2) doesn't affect a wide range of constituents; (3) must handle and store oxidizer; (4) would require additional technology to treat post-frac produced water	Likely, but not confirmed	Technology is not a stand alone treatment for post-frac produced water
Treatment	Lime softening	Desalinization; addition of lime to remove bicarbonate, carbonate and hardness	Low; material & disposal costs	Low; commonly used chemical	Low; chemical exposure unlikely	Precipitates	(1) Cheap; (2) simple; (3) mobile technology available	(1) Chemical cost; (2) only suitable for TDS between 1000 and 10,000 ppm; (3) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; water would likely need additional treatment for dissolved and/or phase-separated hydrocarbon

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Management Category	Type	Description	Cost[(a)]	Safety Risk[(b)]	Human Health and Eco Risk[(c)]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Treatment	Ion exchange	Desalinization; dissolved salts are ionized and removed with ion exchangers	Moderate; resin, regeneration chemical, disposal costs	Low; resins are not harmful	Low; resins are not toxic	Spent regeneration chemicals	(1) Low energy requirement; (2) efficient; (3) mobile technology available	(1) Pre- and post-treatment required for high efficiency; (2) only suitable for TDS between 1000 and 10,000 ppm; (3) produce effluent concentrate; (4) would require additional technology to treat post-frac produced water	Likely, but not confirmed	Technology is not a stand alone treatment for post-frac produced water; water would likely need additional treatment for dissolved and/or phase-separated hydrocarbon; not suitable for brines
Treatment	Electrodialysis	Desalinization; ionized salts attracted to oppositely charged electrodes passing through ion exchange membranes	Moderate; membrane regeneration	Low; passive technology	Low; membranes are safe	Regeneration waste	(1) No energy requirement; (2) no chemical addition; (3) little pre-treatment required; (4) mobile technology available	(1) Less efficient with high concentration influent; (2) membrane regeneration required; (3) only suitable for TDS between 1000 and 10,000 ppm; (4) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS
Treatment	Electro-deionization	Desalinization; similar to electrodialysis, but enhanced due to presence of ion exchange resins between the ion exchange membranes	Moderate; resin regeneration	Low; resins are not harmful	Low; resins are not toxic	Regeneration waste; filtrate waste from post-treatment	(1) Low energy requirement; (2) removes weakly ionized species; (3) high removal rate; (4) mobile technology available	(1) Regeneration of resins required; (2) pre- and post-treatment required for high efficiency; (3) only suitable for TDS between 1000 and 10,000 ppm; (4) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; water would likely need additional treatment for dissolved and/or phase-separated hydrocarbon; not suitable for brines
Treatment	Capacitive deionization	Desalinization; ionized salts are adsorbed by oppositely charges electrodes	High; electrodes expensive	Low; electrodes present little risk	Low	Regeneration waste	(1) Low energy requirement; (2) higher throughput than other desalinization treatments; (3) mobile technology available	(1) Regeneration of electrodes; (2) fouling can be an issue; (3) only suitable for TDS between 1000 and 10,000 ppm; (4) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS
Treatment	Electrochemical activation	Desalinization and disinfection; ionized water reacts with chloride ion to form chlorite that kills microbes and precipitates salt	High; electrodes expensive	Low; electrodes present little risk	Low	Regeneration waste	(1) Low energy requirement; (2) simultaneous removal of salt and microbes; (3) can help reduce fouling	(1) Regeneration of electrodes; (2) expensive electrodes; (3) only suitable for TDS between 1000 and 10,000 ppm; (4) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS
Treatment	Rapid spray evaporation	Desalinization; injecting water at high velocity into heated air to evaporate water, which is condensed to obtain treated water	High; high energy requirement	Moderate; heated air	Low; some potential for exposure to vapor	Sludge	(1) Produces high quality water; (2) high efficiency	(1) High energy requirement; (2) waste solid disposal; (3) only suitable for TDS between 1000 and 10,000 ppm; (4) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS

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Management Category	Type	Description	Cost[a]	Safety Risk[b]	Human Health and Eco Risk[c]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Treatment	Freeze-thaw evaporation	Desalinization; utilize natural temperature cycles to freeze water into pure crystals, which can be thawed to produce pure water, leaving behind salty water	Low	Low; natural process	Low; natural process	Concentrated brine and solids	(1) Low energy requirement; (2) less expensive; (3) natural process	(1) Not practical for much of the year in Oklahoma; (2) low efficiency; (3) long operation cycle; (4) would require additional technology to treat organics in post-frac produced water	No	Technology is not a stand alone treatment for post-frac produced water and would not be applicable in warmer months in Oklahoma
Treatment	Microfiltration	Membrane filtration; water under pressure to remove constituents at the 10 - 0.1 micron size	High; high energy requirement	Low; potential for exposure during maintenance	Low; potential for exposure during maintenance	Concentrated waste during membrane cleaning	(1) Compact; (2) mobile technology available; (3) high recovery of fresh water; (4) capable of removing bacteria, viruses and suspended solids	(1) High energy requirement; (2) less efficient for monovalent and divalent salts; (3) would require additional technology to treat post-frac produced water	Likely, but not confirmed	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS
Treatment	Ultrafiltration	Membrane filtration; water under pressure to remove constituents at the 0.05 - 0.005 micron size	High; high energy requirement	Low; potential for exposure during maintenance	Low; potential for exposure during maintenance	Concentrated waste during membrane cleaning	(1) Compact; (2) mobile technology available; (3) high recovery of fresh water; (4) capable of removing microfiltration constituents plus proteins, starch, organics, dyes, fats etc	(1) High energy requirement; (2) less efficient for salts and low MW organics; (3) fouling can be an issue; (4) would require additional technology to treat post-frac produced water	Likely, but not confirmed	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS
Treatment	Nanofiltration	Membrane filtration; water under pressure to remove constituents at the 0.005 - 0.0005 micron size	High; high energy requirement	Low; potential for exposure during maintenance	Low; potential for exposure during maintenance	Concentrated waste during membrane cleaning	(1) Compact; (2) mobile technology available; (3) high recovery of fresh water; (4) capable of removing ultrafiltration constituents plus sugar, pesticides, herbicides, divalent ions, BOD, COD, surfactants etc.	(1) High energy requirement; (2) less efficient for monovalent salts and low MW organics; (3) fouling can be an issue; (4) would require additional technology to treat post-frac produced water	Likely, but not confirmed	Technology is not a stand alone treatment for post-frac produced water; brines would need additional pre-treatment to lower TDS
Treatment	Reverse osmosis (RO)	Membrane filtration; water under pressure to remove constituents at the 0.0005 - 0.00005 micron size	High; high energy & pressure requirement	Moderate; high pressures, but contained	Low; potential for exposure during maintenance	Concentrated waste during membrane cleaning	(1) Compact; (2) mobile technology available; (3) high recovery of fresh water; (4) capable of removing nanofiltration constituents plus metal ions, monovalent salts, acids, other ions etc	(1) High energy/pressure requirement; (3) fouling can be an issue with even trace oil & grease; (4) would require additional technology to treat post-frac produced water	Yes	Technology is not a stand alone treatment for post-frac produced water; water would require pre-treatment to remove oil, grease and other hydrocarbons that could lead to membrane fouling
Treatment	Trickling filter	Organics removal; a film of microbial material formed on the surface of packed material to degrade contaminants	Low	Low; potential for exposure during maintenance	Low; potential for exposure during maintenance	Sludge	(1) Cheap; (2) simple operation	(1) Large oxygen requirement; (2) filter has large dimensions, tough for portable use; (3) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; post-treatment is usually required to remove biomass and precipitate

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Management Category	Type	Description	Cost[a]	Safety Risk[b]	Human Health and Eco Risk[c]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Treatment	Thermal distillation	Desalinization; utilizing heat to turn water containing high TDS to steam; the steam is then distilled to create clean water, leaving behind a lower volume of high concentration brine	High; high energy requirement	Moderate; high temps and pressures, but contained	Low; potential for exposure during maintenance	Concentrated brine and solids	(1) Mobile technology available; (2) creates high quality clean water	(1) High energy requirement; (2) Not effective for volatile organics; (3) would require additional technology to treat post-frac produced water	Unknown	Technology is not a stand alone treatment for post-frac produced water; pre- or post-treatment is usually required to remove volatile organics
Treatment	Texas A&M treatment train 1	(1) CINC centrifuge - remove large suspended particles; (2) organoclay - remove smaller suspended particles; (3) GAC - remove dissolved organics; (4) 5-micron backwashable filter - suspended particle polishing; (5) RO - remove salts	$0.50 to $1.50/bbl	Moderate; moving parts, energy hook up, hydrocarbon vapors	Low; potential exposure in maintenance	Sludge, spent adsorbent	(1) Mobile technology available; (2) creates agricultural quality clean water; (3) process has been shown to work effectively on TDS up to 50,000 ppm	(1) Fouling can occur at TDS over 15,000 ppm; (2) only about 50% of produced water can be treated; (3) other technologies may be required to more efficiently remove hydrocarbons	Unknown; pilot testing done in the Barnett	Treatment pilot verified influent with hydrocarbons at 200 ppm reduced to 29 ppm, and TDS influent at 45,000 ppm reduced to 500 ppm; units test had maximum throughput of 15,000 gallons per day with 50% recovery
Treatment	Texas A&M treatment train 2	(1) CINC centrifuge; (2) tubular ultrafiltration - remove smaller suspended particles; (3) RO	$0.50 to $1.50/bbl	Moderate; moving parts, energy hook up, hydrocarbon vapors	Low; potential exposure in maintenance	Sludge, spent adsorbent	(1) Mobile technology available; (2) creates agricultural quality clean water; (3) process has been shown to work effectively on TDS up to 50,000 ppm	(1) Fouling can occur at TDS over 15,000 ppm; (2) only about 50% of produced water can be treated; (3) other technologies may be required to more efficiently remove hydrocarbons	Unknown; pilot testing done in the Barnett Shale	Treatment pilot verified influent with hydrocarbons at 200 ppm reduced to 29 ppm, and TDS influent at 45,000 ppm reduced to 500 ppm; units test had maximum throughput of 15,000 gallons per day with 50% recovery
Treatment	Ecosphere treatment train	(1) solid settling in frac tank; (2) larger particulate filtration; (3) oxidation - ozonated water mixed by cavitation; (4) electro-precipitation of salts; (5) coagulation with aluminum sulfate; (6) centrifuge; (7) GAC; (8) RO, if briney.	<$4.00/bbl	Low; oxidizing compounds and electrical; potential for reduced trucking	Low; potential for exposure during maintenance	Sludge, precipitates, spent adsorbent	(1) Mobile technology available; (2) creates high quality clean water; (3) reduces trucking transport of waste; (4) effective for TDS and organics	(1) High energy and equipment costs; (2) 75% efficiency for potable-quality water, 25% concentrated brine stream; (3) Not effective at very high TDS levels; (4) units are untested over long periods of time.	Yes	Capable of treating about 100 bbls/hour; some states do not allow discharge of post-frac produced water, even if it is potable-quality; process would not work to obtain potable-quality water on most, briney produced fluids
Treatment	Aqua-Pure treatment train	(1) Flocculant chemicals; (2) inclined plate separator; (3) preheat exchangers; (4) de-aerator; (5) steam draw (energy from compressor) and distillation (MVR evaporation)	High; anecdotally more expensive than trucking, UIC and purchasing new water	Moderate; pressurized piping and vapors	Low; potential for exposure during maintenance	Precipitates	(1) Mobile technology; (2) capable of treating water up to 80,000 ppm TDS; (3) reduces water volume requiring disposal	(1) High energy and equipment costs; (2) must be transported in three truck mounted units; (3) scaling can be an issue	Unknown; currently used at full-scale in the Barnett Shale	Capable of treating about 2500 bbls/day, producing about 2000 bbls of fresh distilled water; direct-fired distillation can require up to 1000 BTU/lb of heat energy, while MVR only required 30 BTU/lb; Fountain Quail Water Management installs and administers the systems in Texas; they charge a per barrel processing fee
Recycle and Reuse	Constructed wetland	Multi-constituent removal; natural oxidation, decomposition and uptake of constituents by plants	Moderate to high; construction and maintenance costs	Moderate; construction equipment risk	Low; potential for air or drinking exposure	None	(1) Natural treatment, without moving parts and equipment; (2) serves as a wildlife habitat; (3) return water to natural cycle instead of consumptive use	(1) Difficult to ensure water quality of nearby features or ground water won't be affected; (2) not widely accepted by regulatory community for post-frac produced water	No. Not an acceptable management option in Oklahoma	None

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Management Category	Type	Description	Cost[a]	Safety Risk[b]	Human Health and Eco Risk[c]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Recycle and Reuse	Frac water	Store post-frac produced water in a permitted reservoir and reuse for the subsequent frac	Low, assumes no trucking or pre-treatment	Low; same methods used in original frac	Low; potential for exposure to vapor	Sludge; settled solids	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) Potential to impact shallow ground water; (2) pit liner required in many states; (3) water can only be recycled a finite number of times before quality forces disposal or treatment	Yes	None
Recycle and Reuse	Enhanced oil recovery	Store post-frac produced water in a permitted reservoir and truck to adjacent oil field for water flooding	Moderate; assumes trucking required ($2-4/bbl depending on distance)	Low; common method in oilfield	Low; potential for exposure to vapor and ground water impact	Sludge; settled solids	(1) Reuse of water to recover oil resource; (2) sustainable approach that conserves water resource; (3) save money on disposal and water supply	(1) Some states don't allow this reuse; (2) trucking costs and carbon emissions are high	Yes	None
Recycle and Reuse	Drilling fluid	Store post-frac produced water in a permitted reservoir and reuse as drilling fluid for the subsequent well	Low, assumes no trucking or pre-treatment	Low; common method in oilfield	Low; potential for exposure to vapor and ground water impact	Sludge; settled solids	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) Potential to impact shallow ground water; (2) pit liner required in many states; (3) some states don't allow this reuse	Unknown	None
Recycle and Reuse	Mine reclamation	Produced water and flowback water is mixed with fresh water and fly ash in reclamation operations	Low	Low	Low to moderate: assumes reused water does not pose a threat to human health or ecology	None	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource; (3) contribures to reclamation efforts	(1) Scenario not widely available; (2) likely restriction on water quality	Unknown	Description of this operation related by Tim Baker of OCC
Recycle and Reuse	Injection and storage	Inject water into salty water-bearing unit for subsequent oil field, industrial or agricultural use	Moderate; cost to permit and drill injection well	Moderate; common to truck to injection site	Low; underground sequestration	None	(1) Water can be stored for future use; (2) save money on disposal and water supply; (3) sustainable approach that conserves water resource	(1) Difficult to permit if not for disposal only; (2) potential for impact to potable water supply, depending on depth; (3) some states don't allow this reuse; (4) some pretreatment may be required; (5) subsurface formation can become plugged	No	Generally considered Class V UIC; some modeling may be required to show that post-frac produced water quality won't impair or significantly worsen the formation water
Recycle and Reuse	Livestock watering	For water between 1000 and 10,000 TDS, transport post-frac produced water for consumption by livestock	Moderate; transport costs, potential treatment costs	Moderate; common to transport by truck	Moderate; some potential for exposure through ingestion	Sludge in stock ponds	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) Transport cost; (2) most cattle operators will already have water, so produced water must be cheap; (3) some pre-treatment could be required to lower TDS and remove organics; (4) some states don't allow this reuse	No	Water between 0 and 5,000 ppm TDS generally safe for all classes of livestock; from 5,000 to 7,000 ppm TDS, safe for larger livestock, not recommended for pregnant animals; between 7,000 and 10,000 ppm TDS, not recommended, but use still possible for adult animals

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Management Category	Type	Description	Cost[a]	Safety Risk[b]	Human Health and Eco Risk[c]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Recycle and Reuse	Crop irrigation	Discharge of raw or treated post-frac produced water to the land surface for irrigation of crops via center-pivots, side rolls and fixed or mobile water guns	Moderate; transport costs, potential treatment costs	Moderate; common to transport by truck	Moderate; some potential for exposure through ingestion	Salt build-up on soils	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) Transport cost; (2) most farmers will already have water, so produced water must be cheap; (3) some pre-treatment could be required to lower TDS and remove organics; (4) some states don't allow this reuse; (5) salt content could be too high for some crops, or could make soil unusable in the future; (6) surface runoff to other SW resources could be a problem	Unknown	None
Recycle and Reuse	Dust control	Discharge of raw or treated post-frac reduced water to the land surface for control of fugitive dust at industrial sites such as mining or aggregate operations where truck traffic is high	Moderate; transport costs, potential treatment costs	Moderate; common to transport by truck	Moderate; some potential for exposure through air	Salt build-up on soils	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) Transport cost; (2) some pre-treatment could be required to lower TDS and remove organics; (3) some states don't allow this reuse; (4) surface runoff to other SW resources could be a problem	Unknown	Target industries includes mining, oil & gas, and others
Recycle and Reuse	Vehicle/ Equipment Washing	Store post-frac produced water in a permitted reservoir and reuse as cleaning fluid for heavy machinery	Moderate; transport costs, potential treatment costs	Moderate; common to transport by truck	Moderate; some potential for exposure through air	Sludge, wash water	(1) Sustainable approach that conserves water resource	(1) Wash water still requires disposal; (2) some states don't allow this reuse; (3) some pre-treatment could be required to lower TDS and remove organics; (4) surface runoff to other SW resources could be a problem	Unknown	Target industries includes mining, oil & gas, construction and others
Recycle and Reuse	Power generation	Transport post-frac produced water to adjacent power generating facilities for use as cooling water	Moderate; transport costs, potential treatment costs	Moderate; common to transport by truck	Low; some potential for exposure	Sludge, scale	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) May not supply enough quantity; (2) water quality could cause scaling; (3) transport cost; (4) water must be sufficiently treatable to be discharges via NPDES; (5) some states don't allow this reuse	Unknown	Likely that a consortium of operators may be necessary to make this economically viable, with transport by pipeline

TABLE 12
Management Practices for Post Frac Produced Water
Woodford Hydrology Study
Oklahoma, USA

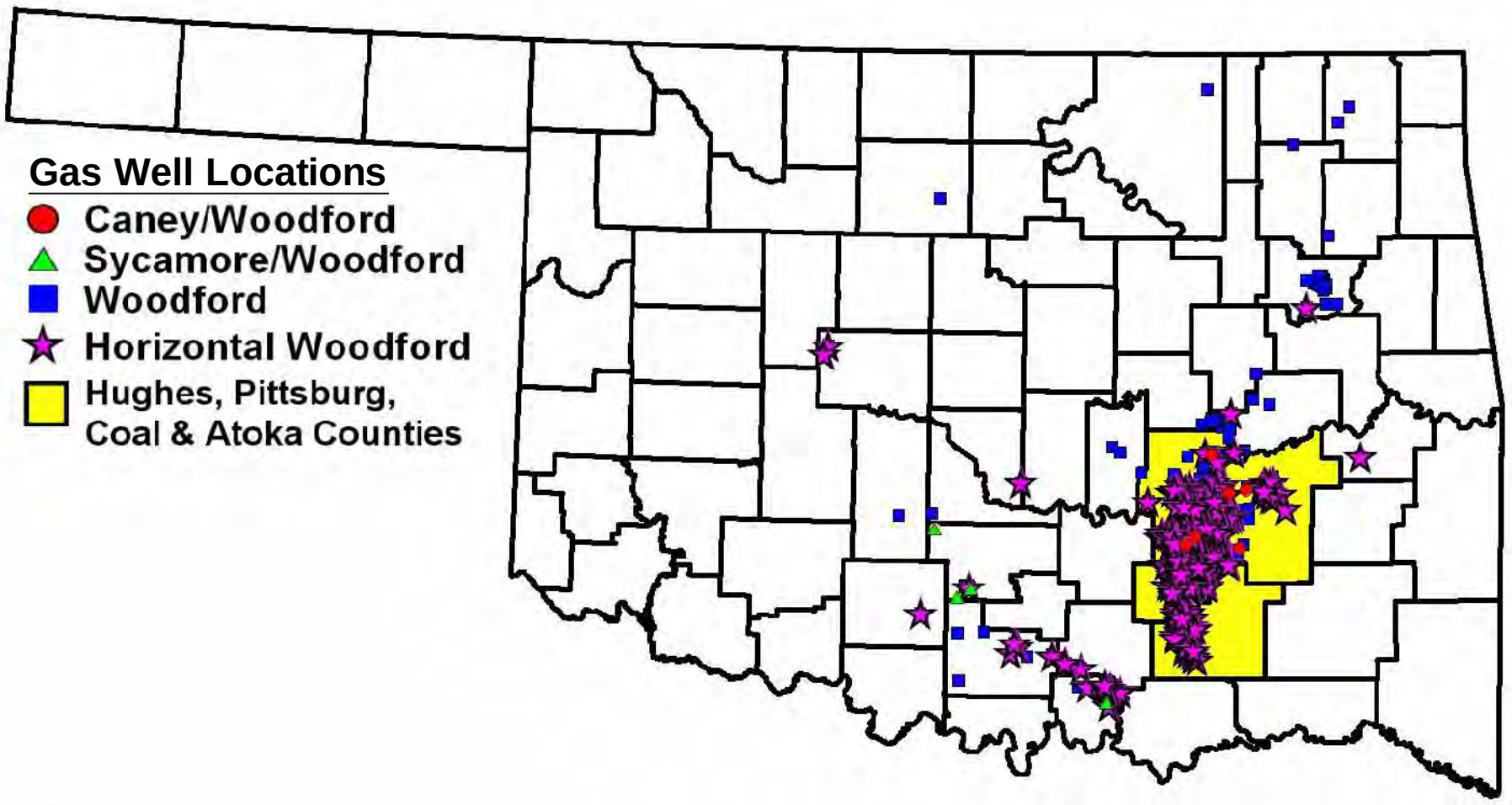
Management Category	Type	Description	Cost[a]	Safety Risk[b]	Human Health and Eco Risk[c]	Waste Produced	Advantages	Disadvantages	Used in the Woodford Play?	General Notes
Recycle and Reuse	Fire water	Store post-frac produced water in a permitted reservoir and reuse to fill air tankers for fighting fires	Moderate; transport costs, potential treatment costs	Moderate; common to transport by truck	Moderate; some potential for exposure through air	Sludge, scale	(1) Save money on disposal and water supply; (2) sustainable approach that conserves water resource	(1) More common use in arid regions with wildfires; (2) water quality could cause scaling; (3) transport cost; (4) some states don't allow this reuse	Unknown	None

Notes:
NA = Information not available
Trucking in Oklahoma is generally done in 110 barrel trucks. Assuming a 2 hour average travel time and $100/hour rate, cost per barrel is $1.82
(a) Specific per barrel costs are provided when information is available, otherwise relative costs of low, moderate or high are assigned based on equipment, energy consumption, transport and other factors, as relevant
(b) Relative safety risk of low, moderate or high is assigned based on factors such as transport, potential flammability, reactivity and other factors, as relevant
(c) Relative human health and ecological risk of low, moderate or high is assigned based on relative toxicity of treatment or byproduct and potential for exposure to receptors..

Sources:

Interstate Oil and Gas Compact Commission and ALL Consulting, 2006, *A Guide to Practical Management of Produced Water from Onshore Oil and Gas Operations in the United States*
Veil, John A. et. al., 2004, Argonne National Laboratory, *A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas and Coal Bed Methane*
Veil, John A., and Puder, M. G., 2006, Argonne National Laboratory, *Offsite Commercial Disposal of Oil and Gas Exploration and Production Waste: Availability, Options and Cost*
Burnett, David B. and Siddiqui, M., 2006, Texas A&M University, *Recovery of Fresh Brine Water Resources from Desalinization of Brine Produced During Oil and Gas Production Operations*
www.aqua-pure.com
Veil, John A., 2008, Argonne National Laboratory, Water Technology Brief #2008-1, *Thermal Distillation Technology for Management of Produced Water and Frac Flowback Water*
Horn, Aaron D., 2009, Newfield Exploration, *Breakthrough Mobile Water Treatment Converts 75% of Fracturing Flowback Fluid to Fresh Water and Lowers CO2 Emissions*, Society of Petroleum Engineers Meeting, San Antonio

Figures



Modified from Oklahoma Geological Survey, "Woodford Shale Gas Well Completions Map, 2003-2008

Environmental Resources Management

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FIGURE 1
WOODFORD STUDY AREA
Woodford Hydrology Study
Oklahoma, USA

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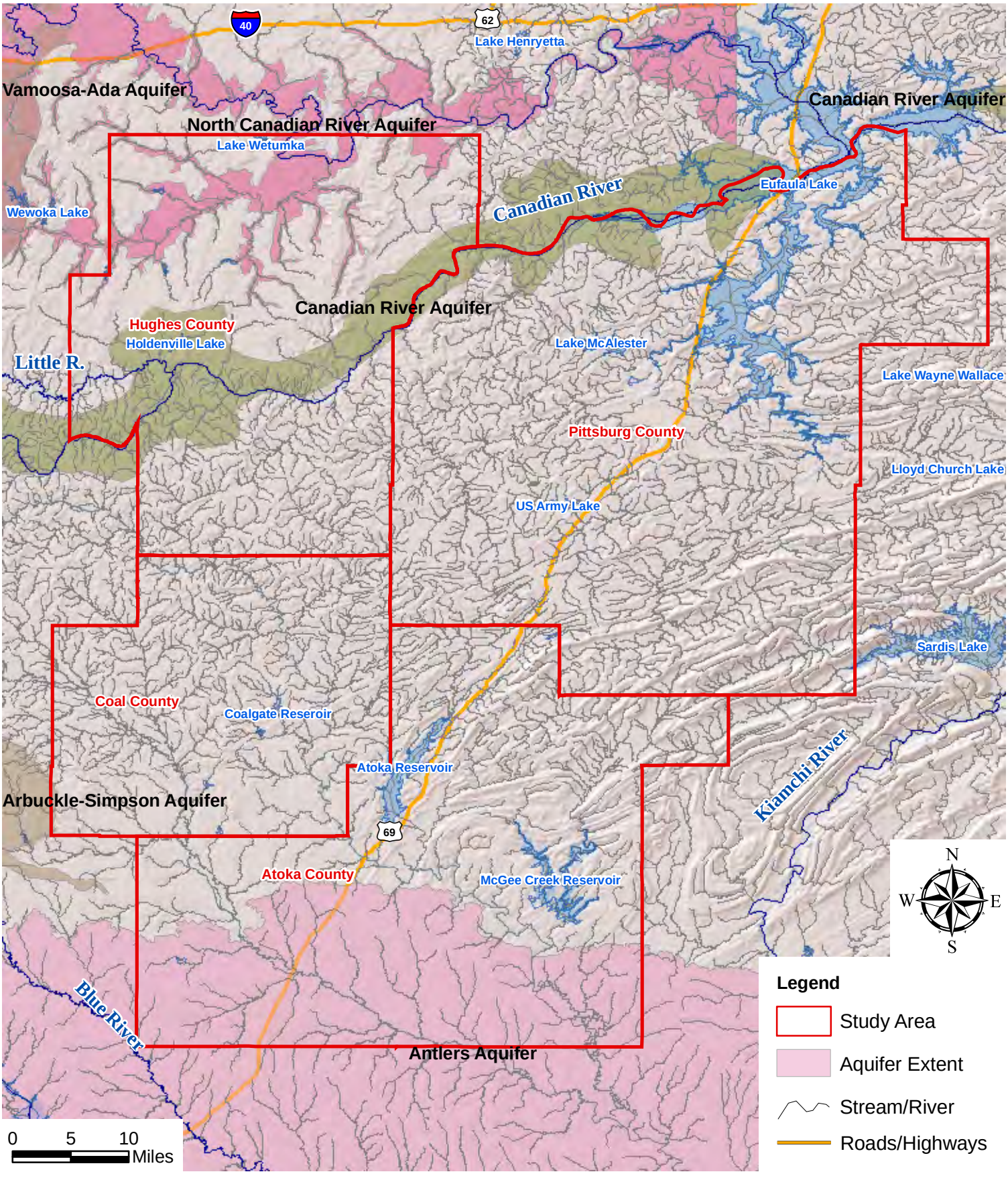

Environmental Resources Management

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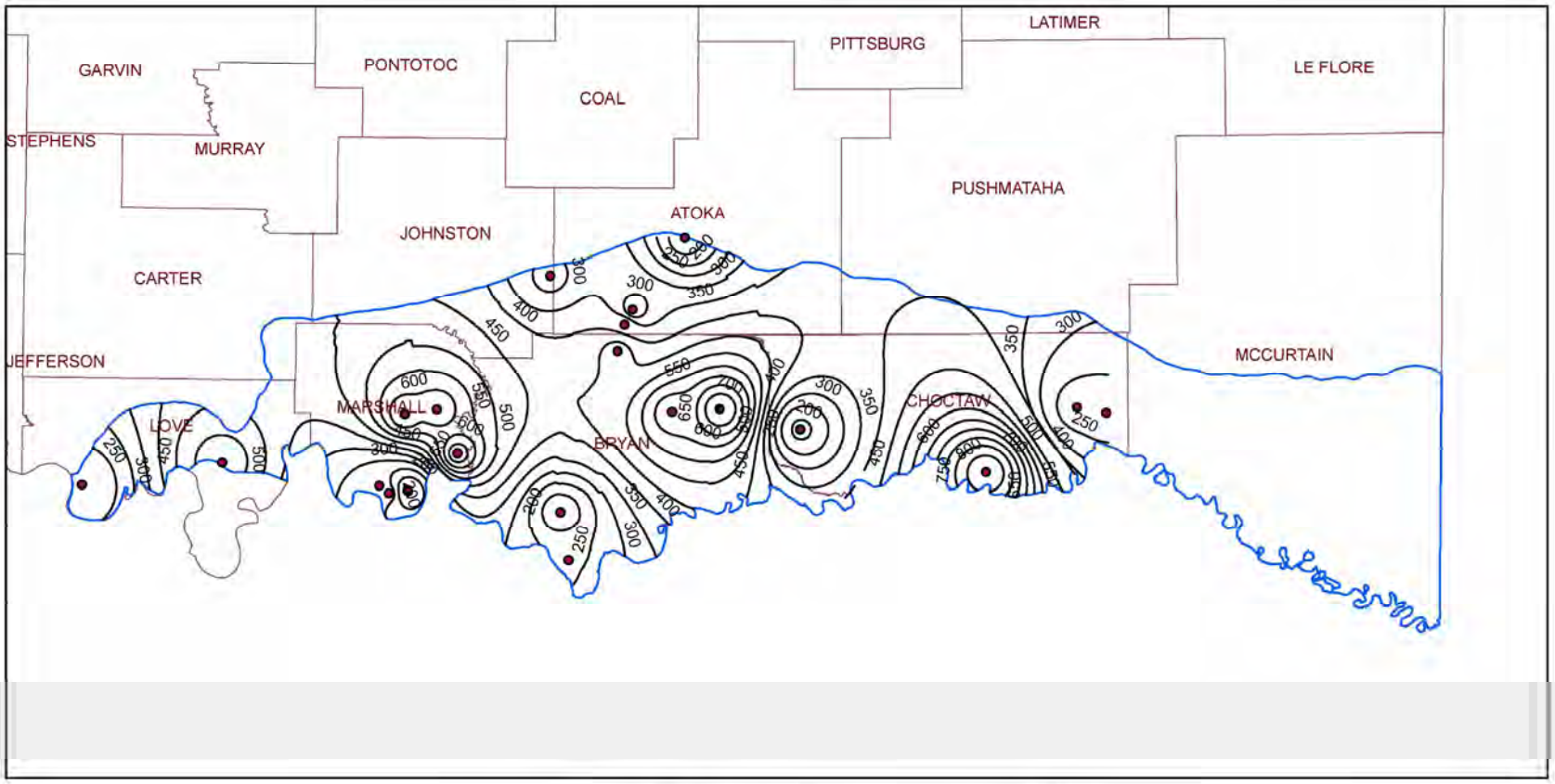
FIGURE 2
WATER FEATURES IN SUBJECT AREA
Woodford Hydrology Study
Oklahoma, USA

ERM



Legend

- Antlers TDS Contours
- Antlers Wells
- Antlers Aquifer Boundary
- County

ArcMap generated 50 mg/L contours

Source: OWRB

Environmental Resources Management

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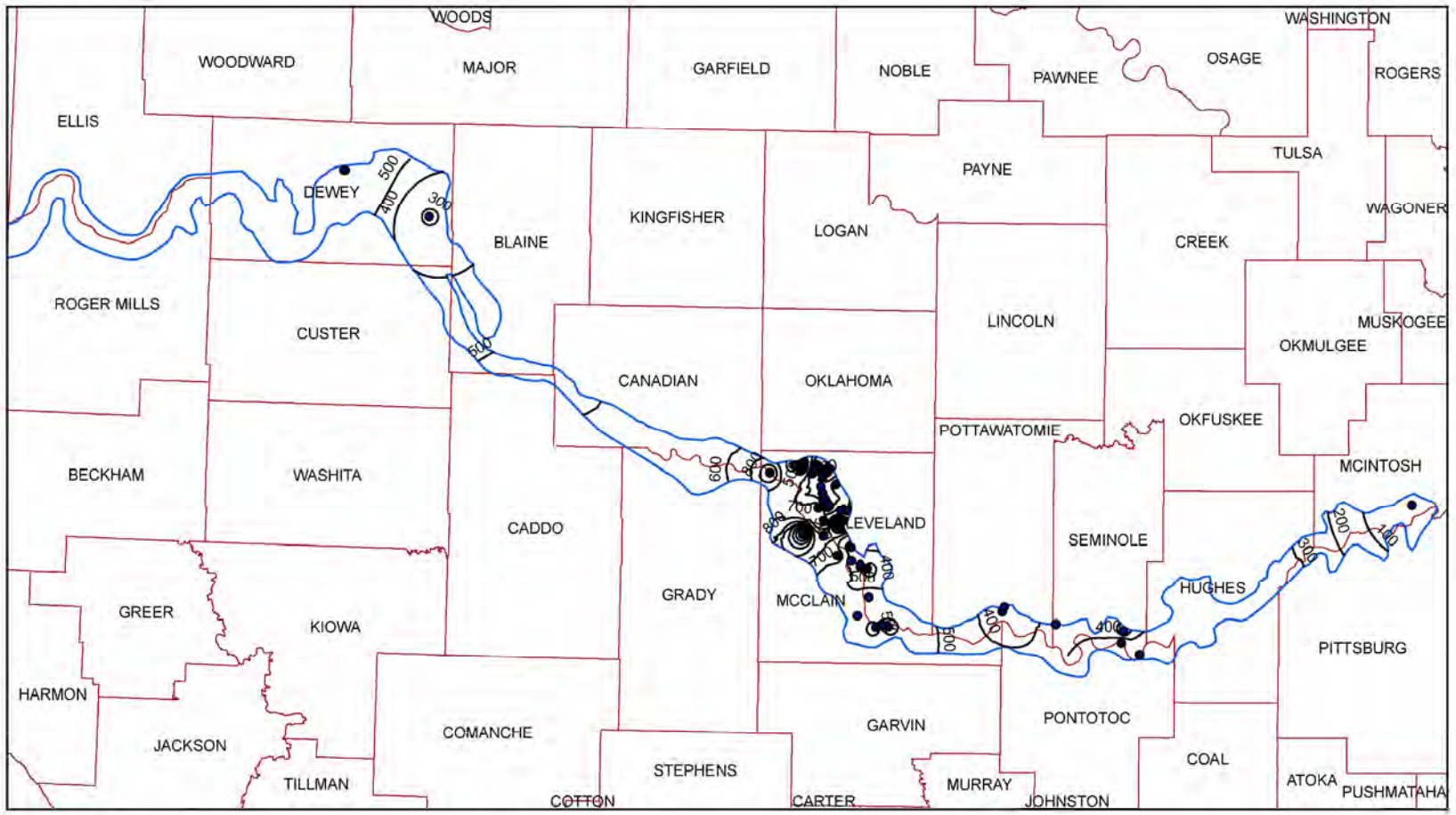
FIGURE 3
ANTLERS AQUIFER TOTAL DISSOLVED SOLIDS CONTOUR MAP
Woodford Hydrology Study
Oklahoma, USA

ERM



Environmental Resources Management

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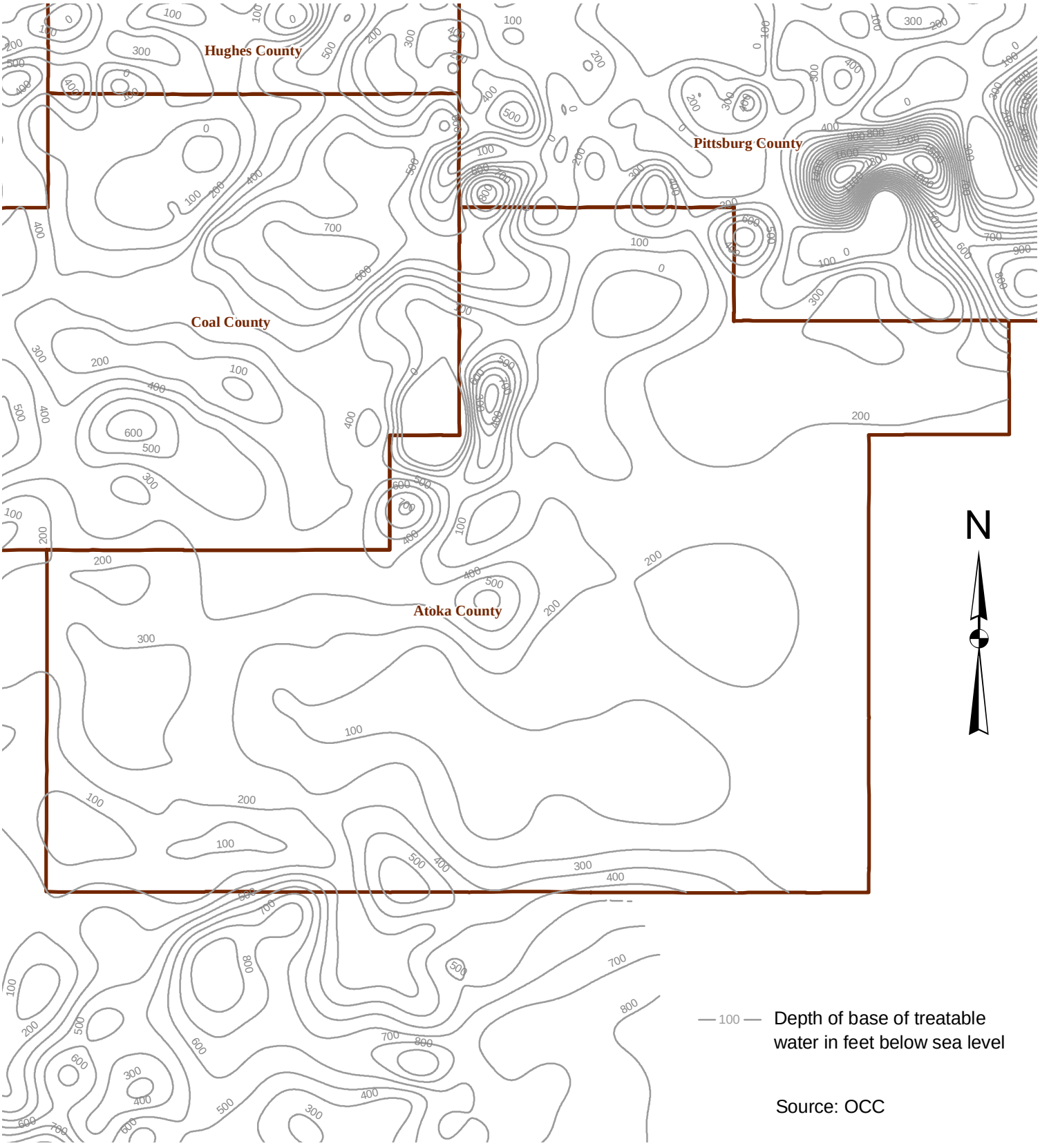
FIGURE 4
CANADIAN TERRACE TOTAL DISSOLVED SOLIDS CONTOUR MAP
Woodford Hydrology Study
Oklahoma, USA

ERM



Environmental Resources Management

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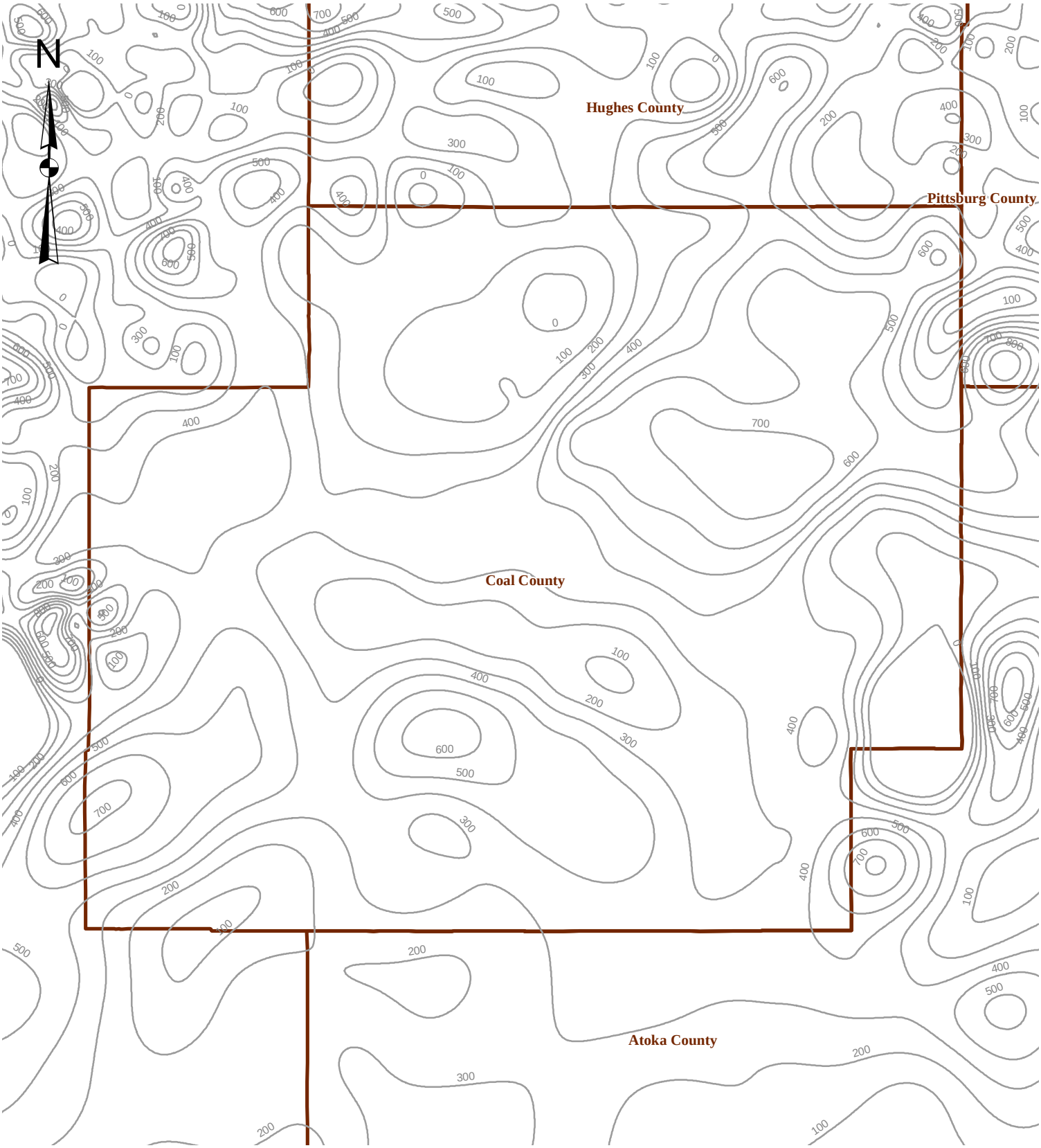
FIGURE 5
BASE OF TREATABLE WATER FOR ATOKA COUNTY
Woodford Hydrology Study
Oklahoma, USA

ERM



Source: OCC

Environmental Resources Management

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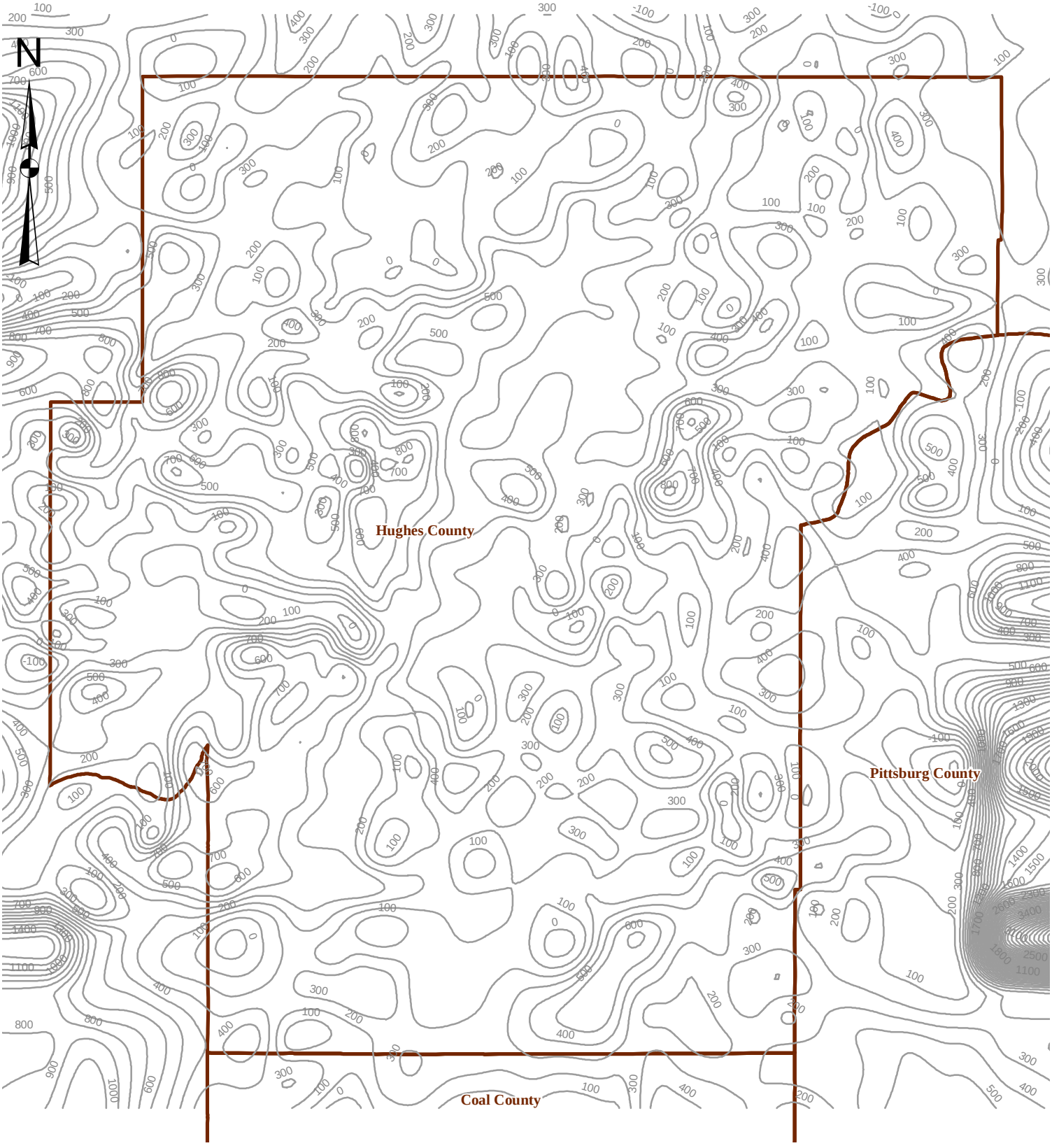
FIGURE 6
BASE OF TREATABLE WATER FOR COAL COUNTY
Woodford Hydrology Study
Oklahoma, USA

ERM



Environmental Resources Management

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DATE: 05-14-2009	SCALE: AS SHOWN	REVISION: 0
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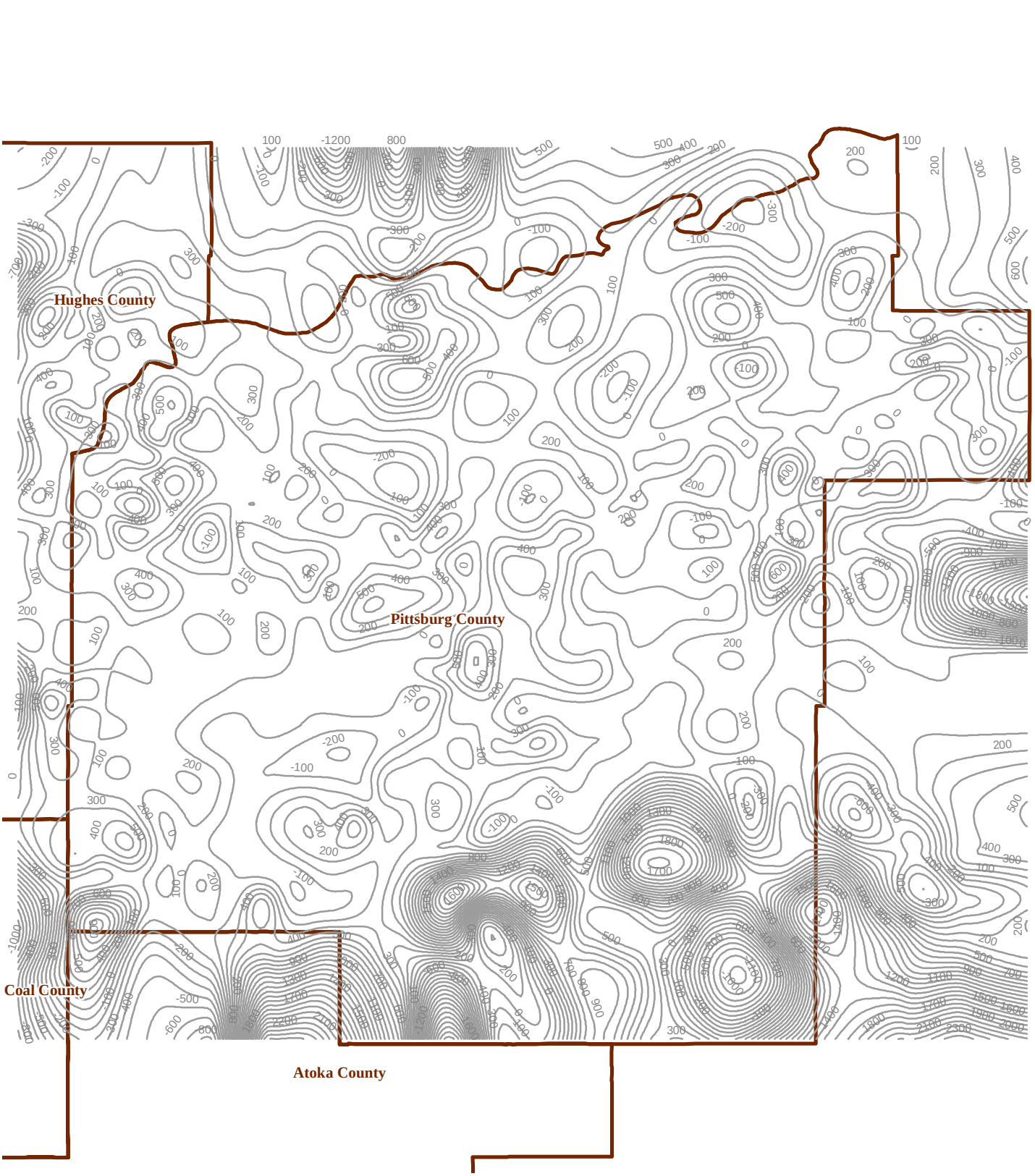
FIGURE 7
BASE OF TREATABLE WATER FOR HUGHES COUNTY
Woodford Hydrology Study
Oklahoma, USA

ERM



Environmental Resources Management

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FIGURE 8
BASE OF TREATABLE WATER FOR PITTSBURG COUNTY
Woodford Hydrology Study

ERM

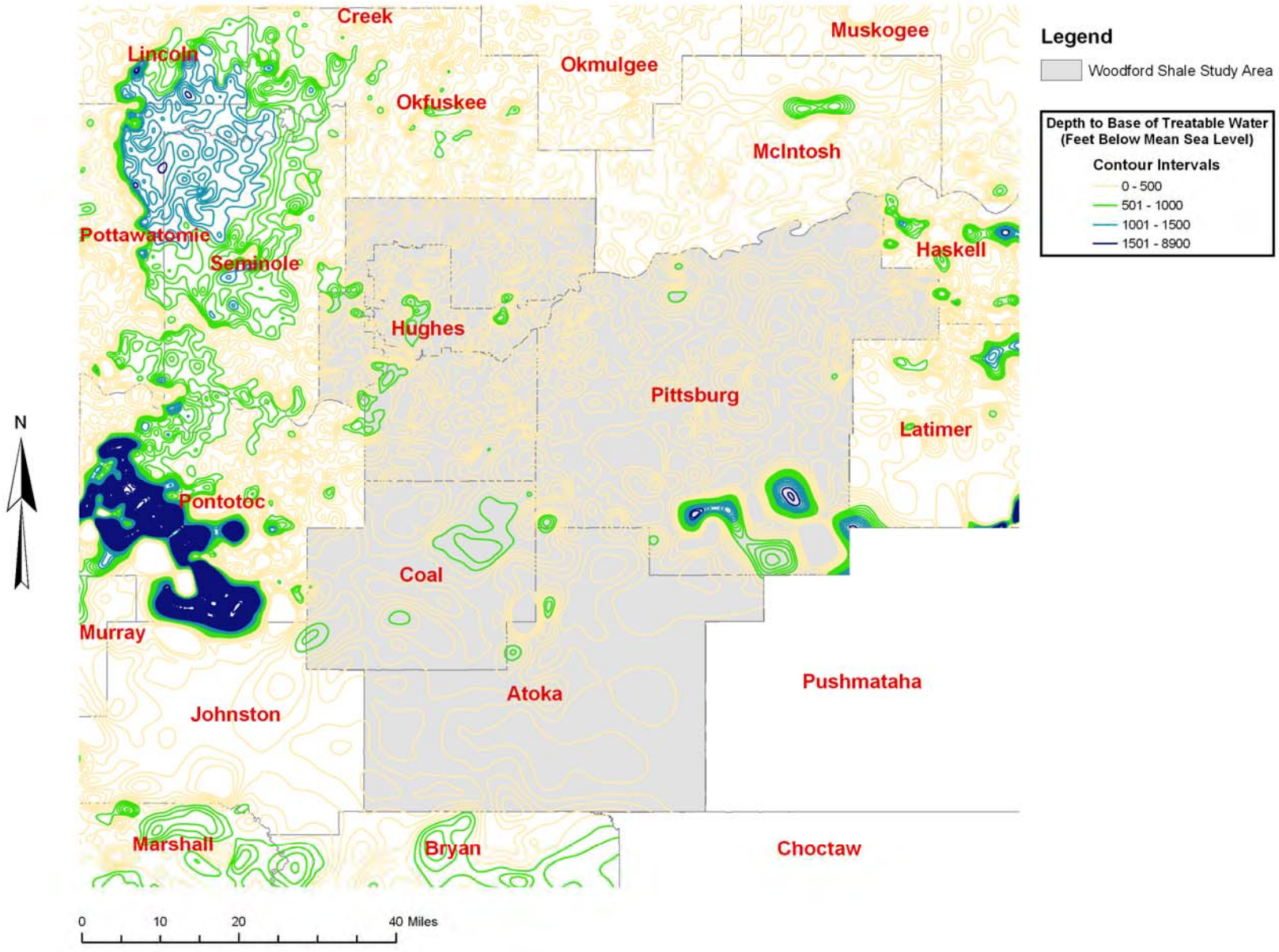

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FIGURE 9
BASE OF TREATABLE WATER FOR THE STUDY AREA
Woodford Hydrology Study
Oklahoma, USA

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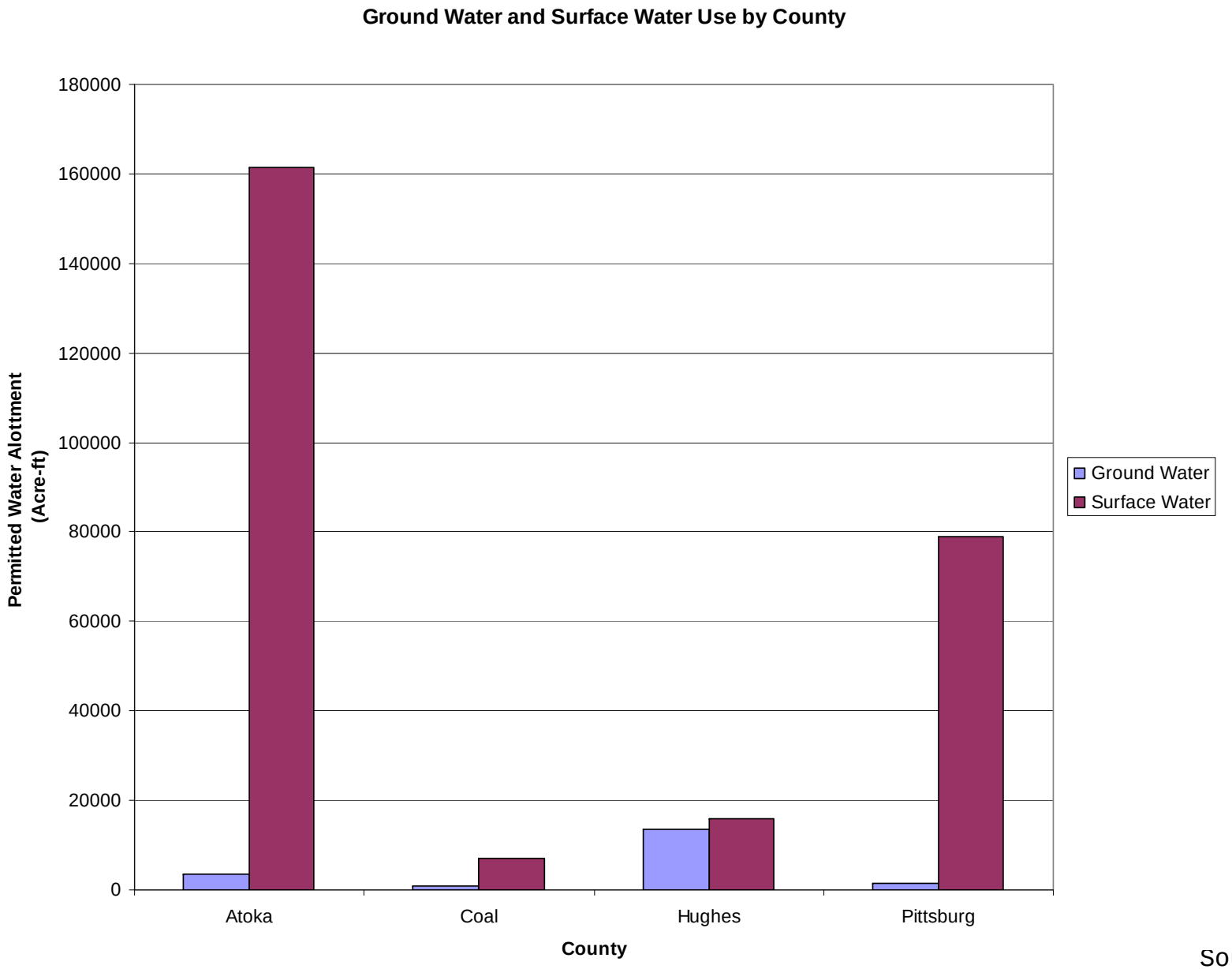

Source: OWRB

Environmental Resources Management		
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FIGURE 10
GROUND WATER AND SURFACE WATER USE BY COUNTY FOR 2008
Woodford Hydrology Study
Oklahoma, USA

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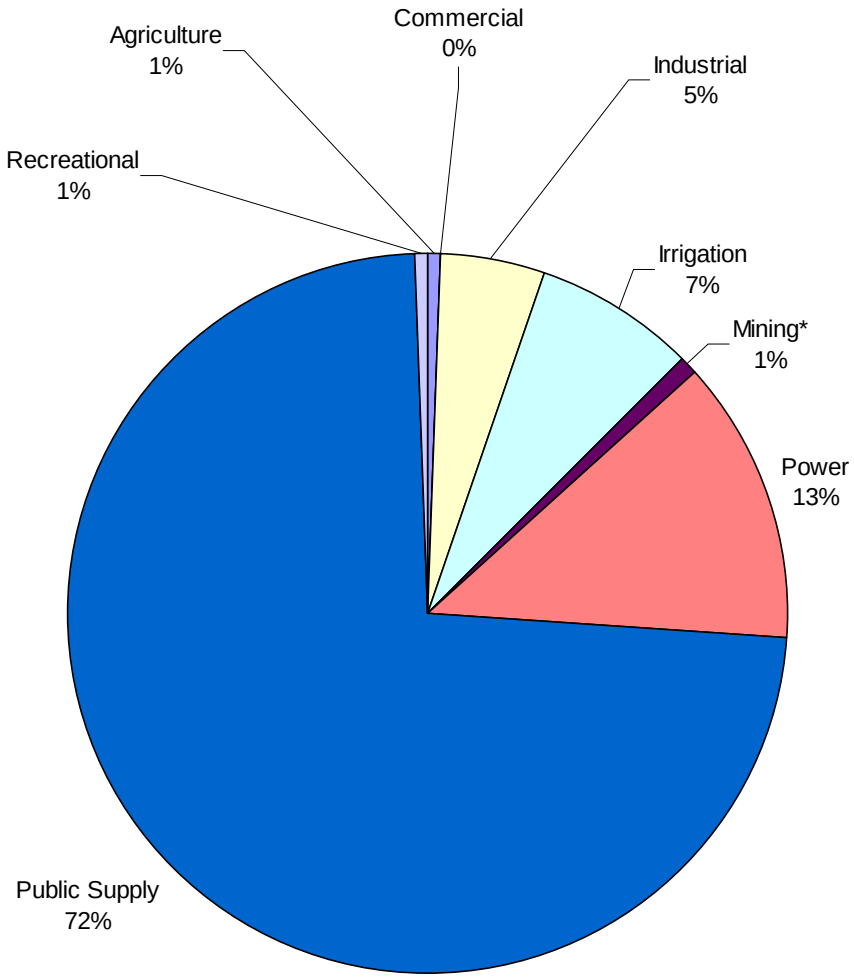

Total Long-Term Permitted Surface Water Use in 2008: 263,556 acre-ft

* Mining includes oil and gas.

Source: OWRB

Environmental Resources Management		
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DATE: 4/15/2009	SCALE: Not to Scale	REV.: 0
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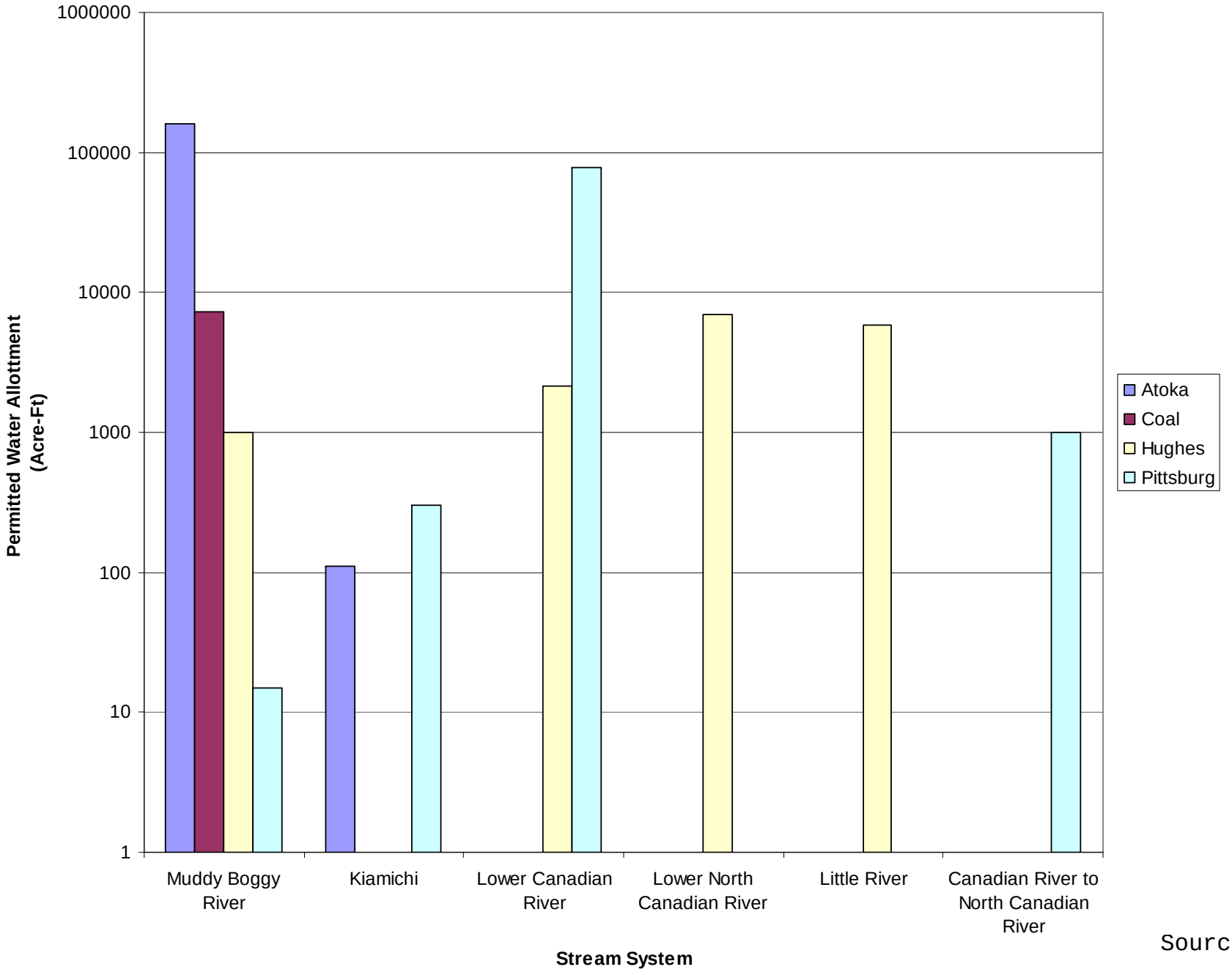
FIGURE 11
LONG-TERM PERMITTED SURFACE WATER USE IN 2008 IN THE WOODFORD STUDY AREA
Woodford Hydrology Study
Oklahoma, USA

ERM®



Source: OWRB

Environmental Resources Management

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FIGURE 12
SURFACE WATER USE BY STREAM SYSTEM PER COUNTY IN THE WOODFORD STUDY AREA IN 2008 (LOGARITHMIC SCALE)
Woodford Hydrology Study
Oklahoma, USA

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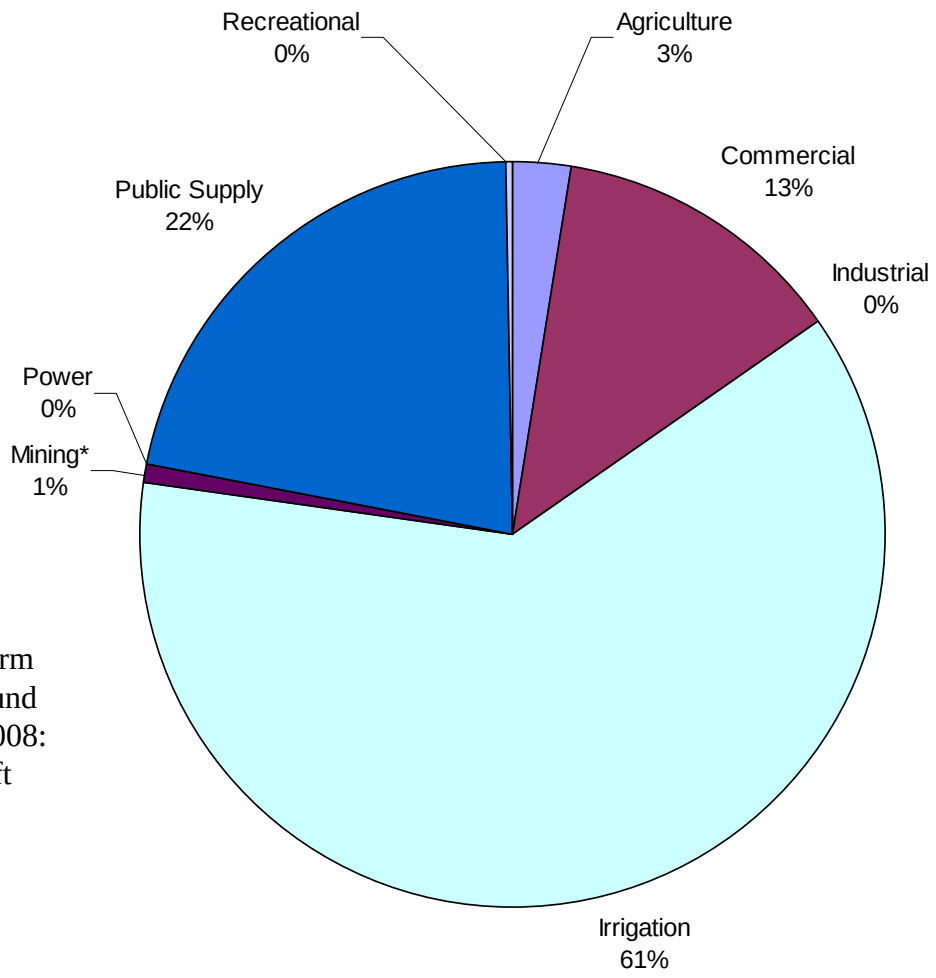

Total Long-Term Permitted Ground Water Use in 2008: 19,491 acre-ft

* Mining includes oil and gas.

Source: OWRB

Environmental Resources Management		
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FIGURE 13
LONG TERM PERMITTED GROUND WATER USE IN 2008 IN THE WOODFORD STUDY AREA
Woodford Hydrology Study
Oklahoma, USA

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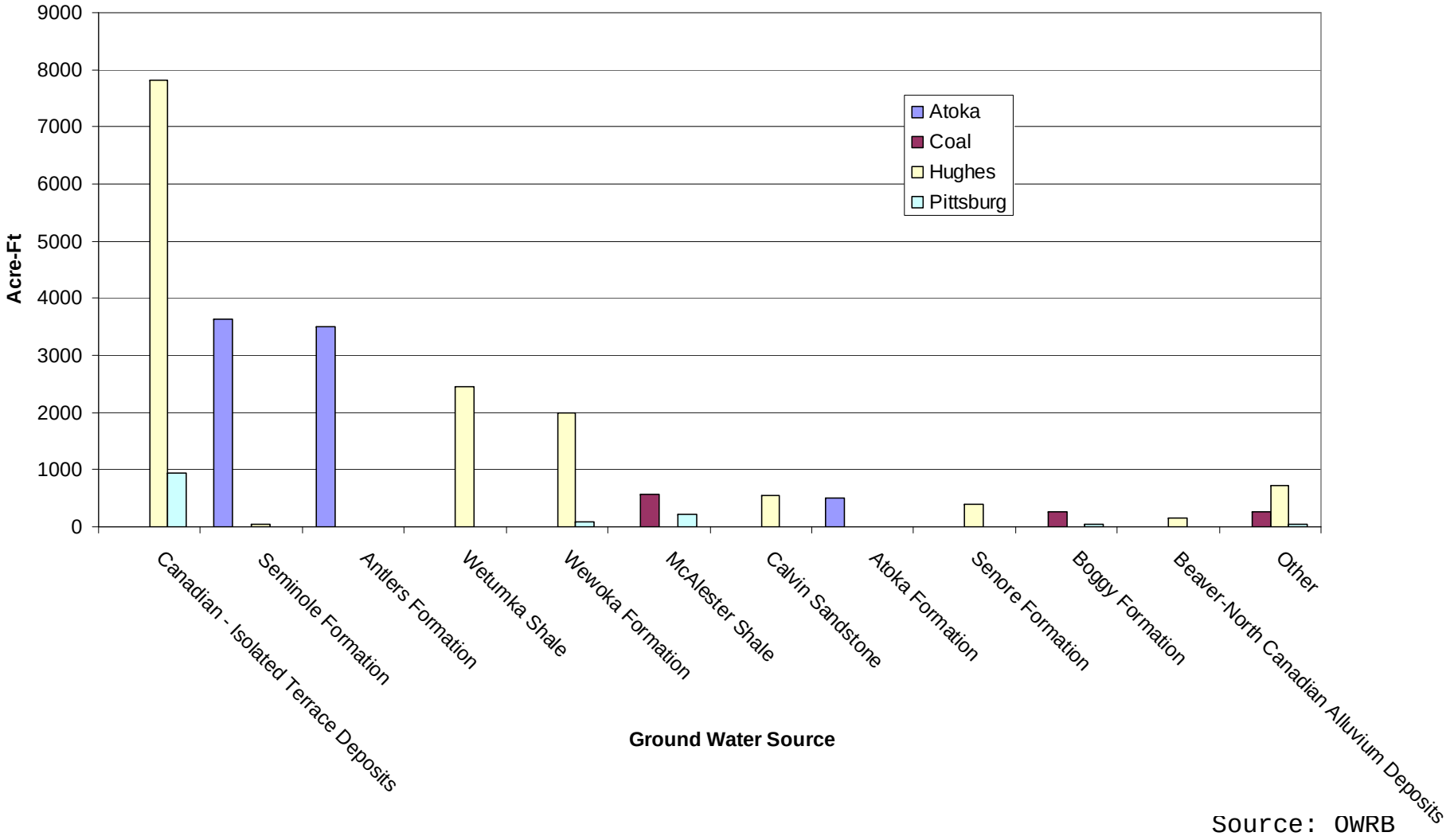
Ground Water Use by Aquifer per County in the Woodford Study Area in 2008



Source: OWRB

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DATE: 4/15/2009	SCALE: Not to Scale	REV.: 0
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FIGURE 14
GROUND WATER USE BY AQUIFER PER COUNTY
IN THE WOODFORD STUDY AREA IN 2008
Woodford Hydrology Study
Oklahoma, USA

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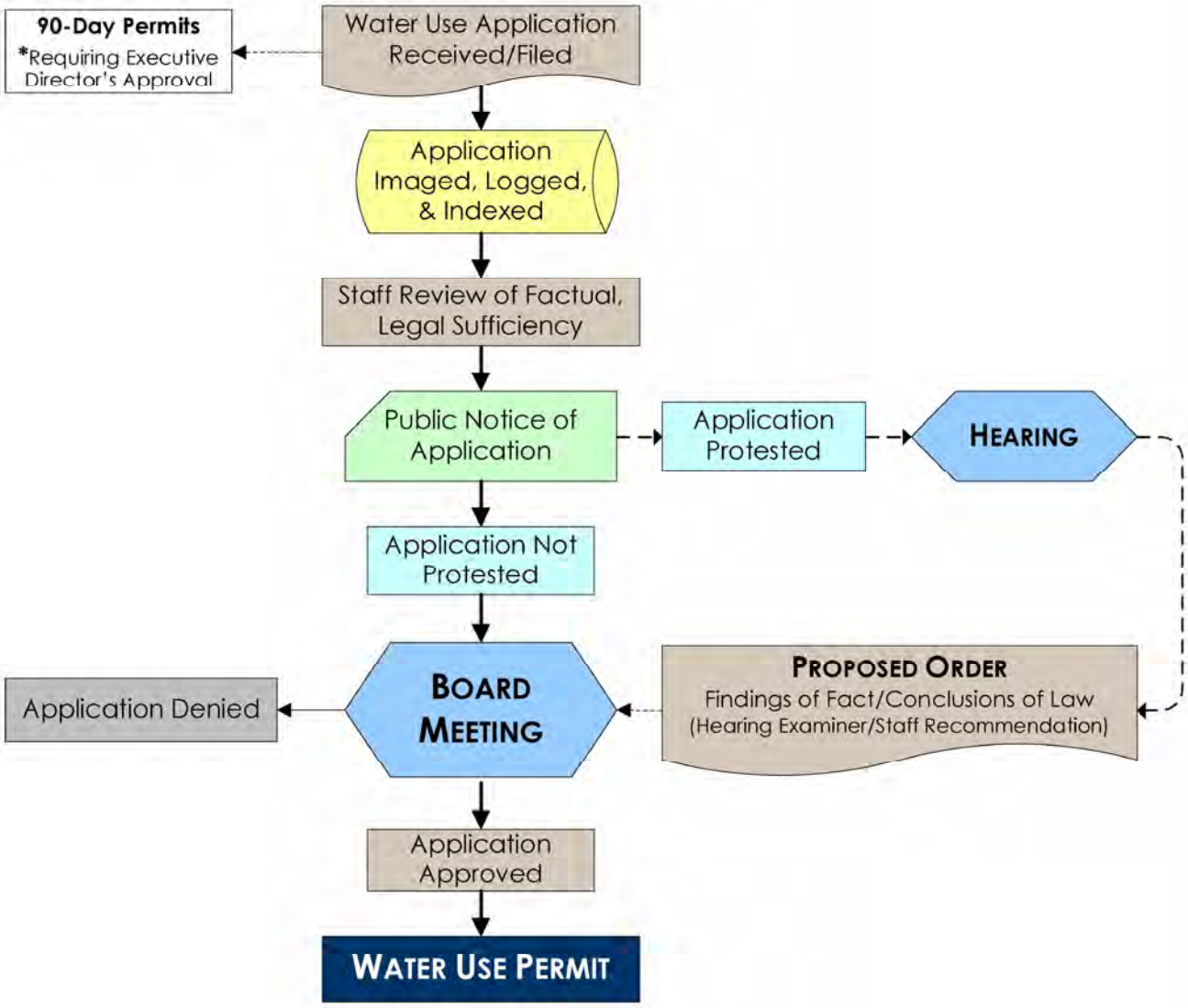

Source: OWRB, 2009.

Environmental Resources Management		
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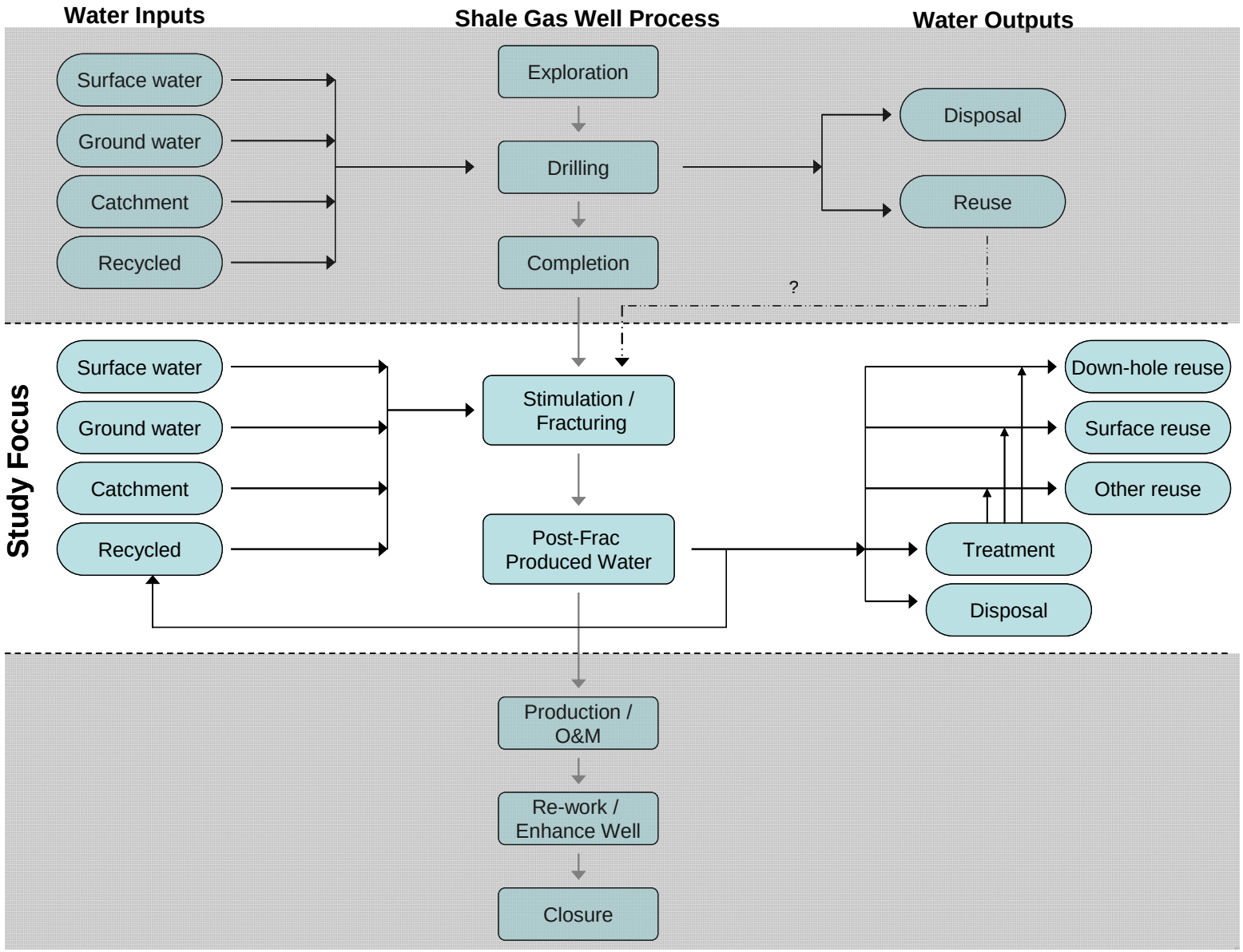
FIGURE 15
OWRB WATER USE PERMITTING PROCESS
Woodford Hydrology Study
Oklahoma, USA

ERM



Environmental Resources Management

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FIGURE 16
SHALE GAS WELL WATER CYCLE
Woodford Hydrology Study
Oklahoma, USA

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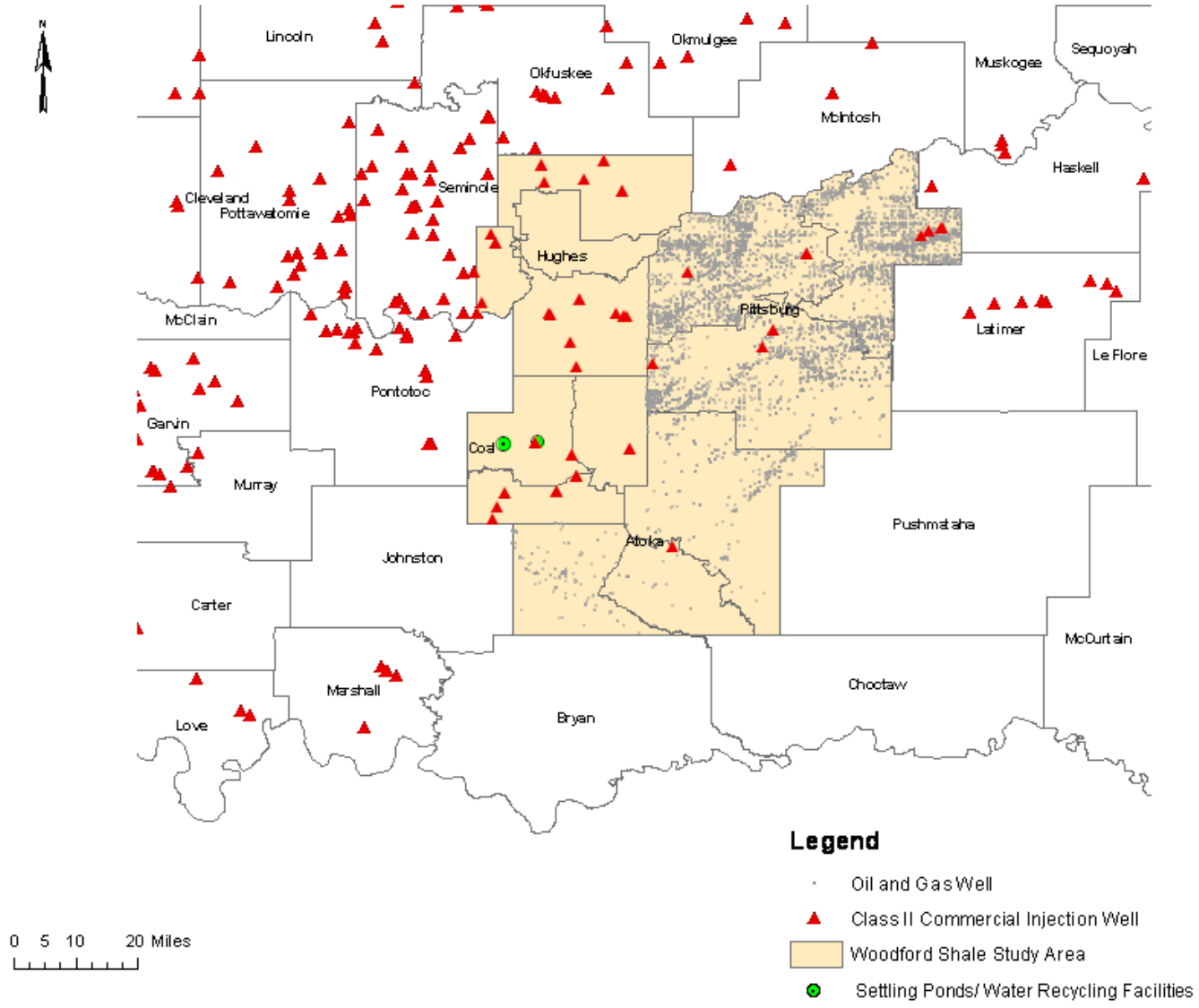

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DATE: 6/09/2009	SCALE: Not to Scale	REV.: 0
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FIGURE 17
CLASS II COMMERCIAL INJECTION WELLS
IN THE STUDY AREA
Woodford Hydrology Study
Oklahoma, USA

ERM®

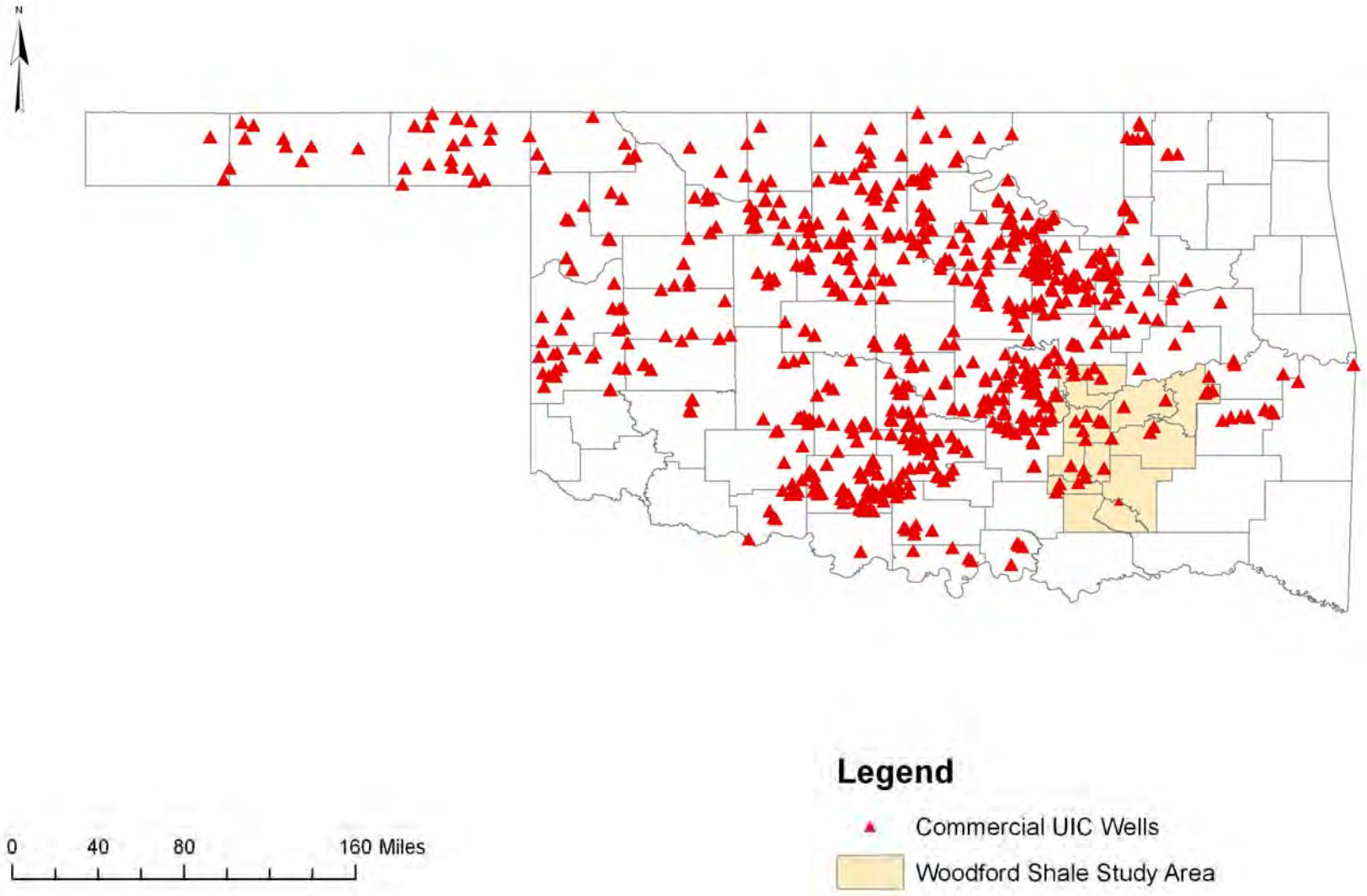

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FIGURE 18
CLASS II COMMERCIAL INJECTION WELLS
IN OKLAHOMA
Woodford Hydrology Study
Oklahoma, USA

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Oil and Gas Well Completion Summary

Appendix A

June 10, 2009
Project No. 0097954

Environmental Resources Management Southwest, Inc.
206 E. 9th St., Suite 1700
Austin, Texas 78701
(512) 459-4700

OKLAHOMA CORPORATION COMMISSION
OIL & GAS CONSERVATION DIVISION
TECHNICAL SERVICES DEPARTMENT

ANNUAL SUMMARY OF COMPLETIONS BY COUNTIES
FOR THE YEAR OF 2008

COUNTY	OIL	GAS	DRY	TOTAL	FOOTAGE	AVERAGE DEPTH	SUCCESS RATIO
ADAIR	0	0	0	0	0	0	0.00%
ALFALFA	18	24	2	44	316,976	7,204	95.45%
ATOKA	0	42	1	43	527,994	12,279	97.67%
BEAVER	10	80	0	90	693,170	7,702	100.00%
BECKHAM	5	44	2	51	698,602	13,698	96.08%
BLAINE	5	16	1	22	207,921	9,451	95.45%
BRYAN	1	1	3	5	35,185	7,037	40.00%
CADDO	13	44	3	60	953,949	15,899	95.00%
CANADIAN	10	62	0	72	891,278	12,379	100.00%
CARTER	111	12	5	128	558,391	4,362	96.09%
CHEROKEE	0	0	0	0	0	0	0.00%
CHOCTAW	0	0	0	0	0	0	0.00%
CIMARRON	1	7	2	10	45,689	4,569	80.00%
CLEVELAND	7	0	1	8	61,652	7,707	87.50%
COAL	2	74	3	79	942,430	11,929	96.20%
COMANCHE	9	7	2	18	145,057	8,059	88.89%
COTTON	0	0	0	0	0	0	0.00%
CRAIG	3	1	0	4	1,674	419	0.00%
CREEK	23	12	4	39	124,564	3,194	89.74%
CUSTER	3	43	1	47	620,772	13,208	97.87%
DELAWARE	0	0	0	0	0	0	0.00%
DEWEY	14	17	1	32	337,959	10,561	96.88%
ELLIS	43	43	5	91	966,540	10,621	94.51%
GARFIELD	10	9	2	21	135,266	6,441	90.48%
GARVIN	52	17	8	77	592,522	7,695	89.61%
GRADY	9	44	0	53	672,559	12,690	100.00%
GRANT	16	9	1	26	140,628	5,409	96.15%
GREER	0	0	0	0	0	0	0.00%
HARMON	0	0	0	0	0	0	0.00%
HARPER	26	39	2	67	458,579	6,844	97.01%
HASKELL	0	16	1	17	123,827	7,284	94.12%
HUGHES	12	165	5	182	1,733,768	9,526	97.25%
JACKSON	2	0	0	2	3,628	1,814	0.00%
JEFFERSON	0	0	0	0	0	0	0.00%
JOHNSTON	3	0	0	3	31,740	10,580	0.00%
KAY	44	3	2	49	211,133	4,309	95.92%
KINGFISHER	20	20	3	43	405,129	9,422	93.02%
KIOWA	0	2	2	4	65,896	16,474	50.00%
LATIMER	0	89	1	90	896,413	9,960	98.89%
LEFLORE	1	103	4	108	737,011	6,824	96.30%
LINCOLN	9	41	2	52	410,539	7,895	96.15%

OKLAHOMA CORPORATION COMMISSION
OIL & GAS CONSERVATION DIVISION
TECHNICAL SERVICES DEPARTMENT

ANNUAL SUMMARY OF COMPLETIONS BY COUNTIES
FOR THE YEAR OF 2008

COUNTY	OIL	GAS	DRY	TOTAL	FOOTAGE	AVERAGE DEPTH	SUCCESS RATIO
LOGAN	8	10	5	23	140,575	6,112	78.26%
LOVE	2	1	0	3	25,040	8,347	100.00%
MCCLAIN	19	7	0	26	245,090	9,427	100.00%
MCCURTAIN	0	0	0	0	0	0	0.00%
MCINTOSH	0	67	2	69	280,457	4,065	97.10%
MAJOR	68	99	0	167	1,399,178	8,378	100.00%
MARSHALL	5	7	4	16	144,186	9,012	75.00%
MAYES	0	3	0	3	1,623	541	0.00%
MURRAY	7	0	0	7	29,834	4,262	100.00%
MUSKOGEE	2	2	0	4	9,604	2,401	100.00%
NOBLE	44	17	3	64	235,827	3,685	95.31%
NOWATA	16	27	5	48	57,450	1,197	89.58%
OKFUSKEE	9	7	1	17	74,547	4,385	94.12%
OKLAHOMA	22	8	1	31	238,904	7,707	96.77%
OKMULGEE	23	3	0	26	48,711	1,874	100.00%
OSAGE	0	0	0	0	0	0	0.00%
OTTAWA	0	0	0	0	0	0	0.00%
PAWNEE	6	0	2	8	25,778	3,222	75.00%
PAYNE	10	7	0	17	85,650	5,038	100.00%
PITTSBURG	0	182	4	186	1,704,444	9,164	97.85%
PONTOTOC	20	0	0	20	84,840	4,242	100.00%
POTTAWATOMIE	7	1	2	10	57,596	5,760	80.00%
PUSHMATAHA	0	4	0	4	25,756	6,439	100.00%
ROGER MILLS	7	88	1	96	1,272,310	13,253	98.96%
ROGERS	20	4	4	28	18,048	645	85.71%
SEMINOLE	34	16	2	52	227,048	4,366	96.15%
SEQUOYAH	0	13	0	13	61,139	4,703	100.00%
STEPHENS	105	26	6	137	831,899	6,072	95.62%
TEXAS	47	30	18	95	583,305	6,140	81.05%
TILLMAN	4	0	0	4	17,104	4,276	100.00%
TULSA	8	5	1	14	22,466	1,605	92.86%
WAGONER	12	83	1	96	103,136	1,074	98.96%
WASHINGTON	18	36	1	55	83,774	1,523	98.18%
WASHITA	9	79	5	93	1,440,405	15,488	94.62%
WOODS	76	145	3	224	1,473,951	6,580	98.66%
WOODWARD	8	138	0	146	1,062,780	7,279	100.00%
TOTAL	1,098	2,201	140	3,439	26,860,896	7,811	95.93%
AVG./COUNTY	14	29	2	45	348,843		

Source: Oklahoma Corporation Commission

Copies of Select Permit Forms and Permitting Guidance

Appendix B

June 10, 2009
Project No. 0097954

Environmental Resources Management Southwest, Inc.
206 E. 9th St., Suite 1700
Austin, Texas 78701
(512) 459-4700

Surface Water Use

APPLICATION FOR A PERMIT TO USE SURFACE OR STREAM WATER

OKLAHOMA WATER RESOURCES BOARD
3800 N. CLASSEN BLVD.
OKLAHOMA CITY, OK 73118 (405) 530-8800
website: www.owrb.ok.gov

Office Use Only

Application No. _____ Type of Permit_____
Stream System Code_____Reservoir Code_____
Hydrologic Unit Code_____

FILING FEE MUST ACCOMPANY APPLICATION

Amount applied for	Fee
0 - 320 acre-feet	$190.00
321 - 640 acre-feet	$300.00
641 - 1500 acre-feet	$375.00
Over 1500 acre-feet	$375.00

Plus $150.00 for each 500 acre-feet (or any increment thereof) over 1500 acre-feet.
(Maximum Fee $3,000.00)

1. NAME AND ADDRESS

a. Print the applicant's full name and mailing address, complete with zip code. If the applicant is a corporation, use the name and business address of the corporation.

Applicant Name _____ **Phone** (____) ____ - _____
FAX# (____) ____ -_____
Address _____

City _____ State_____Zip_____

b. If the contact during the application process is someone other than the applicant listed above, print the name and mailing address of the contact person.

Contact Name _____ **Phone** (____) ____ - _____
FAX# (____) ____ - _____
Address _____

City _____ State_____Zip_____

2. TYPE OF SURFACE WATER PERMIT REQUESTED (Check one)

☐ **Regular Permit** - authorizes diversion and use of water on a year-round basis.
☐ **Seasonal Permit** - authorizes diversion and use of water for specified time periods during the calendar year.
☐ **Term Permit** - valid for a term of years and does not vest the holder with any permanent right.
(Provide ending date for term permit _____).

DATE OF RECEIPT OF APPLICATION
(FOR OFFICE USE ONLY)

3. AMOUNT OF WATER TO BE APPROPRIATED

State total amount of water applied for in acre-feet per calendar year. One acre-foot of water will cover one acre of land one foot deep and is equal to 325,851 U.S. *gallons. The diversion rate is the maximum rate of withdrawal, in gallons per minute, of water from the pond, lake, spring or other definite stream.*

Application is made to take and use _____ acre-feet of surface water annually at a rate not to exceed _____gallons per minute.

4. PURPOSE(S) FOR WHICH WATER WILL BE USED

a. List the purpose or purposes for which the water would be used if the permit is granted and list the number of acre-feet for each purpose. Be sure that the sum of the amounts listed below equals the total acre-feet in #3 above. If the water is to be used to irrigate crops, list IRRIGATION as the purpose and list the sum total acre-feet for all crops.

OFFICE USE ONLY
SIC CODES

_____ acre-feet of water will be used for _____

_____ acre-feet of water will be used for _____

_____ acre-feet of water will be used for _____

_____ acre-feet of water will be used for _____

b. *If the water requested is for irrigation purpose, state the total number of acres that will be irrigated. The land to be irrigated must be shown on plat(s) attached to the application. The amount of water requested should be based on types of crops to be grown and cropping patterns proposed. The Board will use appropriate publications and information the applicant submits in determining amount of water needed.*

_____ acres of land are proposed to be irrigated. The proposed crops are_____

_____.

5. DIVERSION(S) OF WATER: Source, Location and Method of Diversion

a. If the water is to be used in a pond, lake or reservoir and will not be pumped or moved from one location to another, check here. ☐

b. For each diversion point, state the amount of water, in acre-feet, to be diverted annually and give the legal description to the nearest ten (10)-acre tract. Also show the point(s) of diversion on the plat, as shown on the sample provided. If you are applying for more than one diversion point, then a photocopy of Section 5 shall be filled out completely for each additional diversion point and attached to the application. If the water is to be used in a pond, lake or reservoir and will not be pumped or moved from one location to another, then use the location of the dam or spillway as the point of diversion.

_____ acre-feet of water will be diverted from:

____ 1/4 of ____ 1/4 of ____1/4 of Sec. _____ Twp. _____ N ☐ S ☐ Rge. _____ EIM ☐ WIM ☐ ECM ☐ in _____ County

(1) *If the water will be taken from a stream or spring, enter the stream or spring name. If the stream or spring is unnamed, enter as tributary of a named stream, such as "Unnamed tributary of Wolf Creek."*

Direct diversion from stream: _____
Name of Stream

(2) *If the water will be taken from a Soil Conservation Service (S.C.S.) Detention Reservoir, enter the number of the site and the watershed name:*

S.C.S. Site No. ____________ Watershed Name ____

(3) *if the water will be taken from some other public or private reservoir, enter the name of the stream dammed and name of the reservoir if available. If the stream is unnamed, enter it as a tributary of a named stream, such as "Unnamed tributary of Wolf Creek."*

Name of reservoir ____ on ______________________________________
Name of Stream

Reservoir is ☐ Existing (Date completed ____________) ☐ Under Construction ☐ Planned

Storage of the reservoir: ______ acre-feet Average water depth: ________

Surface acres: ________ Yield:___________________

(4) *Method of Diversion:*
If by gravity, enter the size and carrying capacity of the main canal or conduit and the size of headgate.
If by pump, enter the size, type and number of pumps, kind and horsepower of engine or motor, inlet and outlet size and the maximum capacity of each pump, in gallons per minute.

Method of diversion will be by: ☐ Gravity ____
Size, etc.

☐ Pump ____
Size, Type of pump, etc.

(5) Do you own or lease the land on which the point of diversion will be located? ☐ Yes ☐ No *If available, attach a copy of the deed, lease, etc. showing the right to use the point of diversion. If not available, the permit, if issued, will contain a condition requiring submittal of a copy of the right before water use begins.*

(6) Will water lines cross public right-of-ways or another landowner's property? ☐ Yes ☐ No *If yes, attach a copy of the easement. If not available, the permit, if issued, will contain a condition requiring submittal of a copy of the easement before water use begins.*

6. LEGAL DESCRIPTION OF AREA OF USE

a. *Describe the legal description of the area of use below. Please do not use lots or blocks but convert to the nearest legal description. Also show this area on a plat as shown on the sample attached. Your local ASCS or NRCS office may provide you with an aerial photograph of your land.* ***(Municipal and rural water entities refer to #8 below)***.

______ acres ______ 1/4 ______ 1/4 of Sec. ______ Twp. ______ N ☐ S ☐ Range ______ EIM ☐ WIM ☐ ECM ☐ of ______________________ County

______ acres ______ 1/4 ______ 1/4 of Sec. ______ Twp. ______ N ☐ S ☐ Range ______ EIM ☐ WIM ☐ ECM ☐ of ______________________ County

______ acres ______ 1/4 ______ 1/4 of Sec. ______ Twp. ______ N ☐ S ☐ Range ______ EIM ☐ WIM ☐ ECM ☐ of ______________________ County

______ acres ______ 1/4 ______ 1/4 of Sec. ______ Twp. ______ N ☐ S ☐ Range ______ EIM ☐ WIM ☐ ECM ☐ of ______________________ County

b. FOR IRRIGATION ONLY Do you own or lease this land? ☐ Yes ☐ No *If yes, attach a copy of the deed or lease. If no, application should be made by the owner or the permit, if issued, will require that a deed or lease be submitted before use of water begins.*

 Application_____

7. PLATS A plat must be completed and submitted with the application showing the following:

a. *The information requested in items 4b, 5 and 6 of this form.*
b. *The appropriate location and extent of the proposed storage and diversion works.*
c. *The location of the headgate, intake, pumping plant and point of diversion.*
d. *The course and name of river, stream or other source of water.*
e. *The position and area of all lakes, reservoirs or basins intended to be used or created, and the water lines thereof (if known); and*
f. *All other ditches, canals, conduits, laterals, lakes or reservoirs (or other works or improvements affected) which the proposed works will intersect, or with which connection will be made.*

8. JUSTIFICATION OF PRESENT AND FUTURE NEED

a. ***Irrigation*** *- Completion of #4b. serves as justification of need for amounts requested for irrigation for common*
b. *crops grown in Oklahoma.*
b. ***Municipal and rural water entities*** *- Submit population projection figures and all other methodologies, calculations, and additional information used to determine amount of water requested. Submit a map of the municipal or rural water entity boundaries or service areas and the water line locations. The map must show points of reference or scale.*
c. ***Industrial, Commercial and Agriculture (non-irrigation)*** *- Submit methodology, calculations, and additional information used to determine amount of water requested.*

SIGNATURES The application must be signed as follows:

a. *If the applicant is an individual, the application shall be signed by the applicant, or his duly appointed agent who shall present evidence of authority to act as agent with the application.*
b. *A joint application shall be signed by each applicant or his duly authorized agent, provided that a joint application by husband and wife may be signed by either party. (Joint applicants are required to select one among them to act for and represent the others in dealing with the Board.)*
c. *If the application is by a partnership, the applicant shall be designated by the firm name followed by the word "a Partnership," and the application shall be signed by each of the general partners or, if signed by one partner or other agent, a written statement of that person's authorization to make the application, signed by the other parties in interest, shall be attached to the application.*
d. *In the case of an estate or guardianship, the application shall be signed by the duly appointed guardian or representative of the estate, and a certified copy of the letters issued by the court shall be attached to the application.*
e. *In the case of a water district, count, municipality, etc., the application shall be signed by a duly authorized official, and a certified copy of the resolution or other authorization to make the application shall be attached.*
f. *In the case of a private corporation, the application shall be signed by a duly authorized person and , if not attested by the secretary or assistant secretary, a copy of the authorization shall be attached to the application;*

An attorney duly licensed to practice law in Oklahoma may sign an application for an applicant he or she represents. The Oklahoma Bar Association number must be indicated.

Subscribed and sworn before me

this _____ day of _____ 20___

_____
Notary

My commission expires on: _____
(seal)

I swear and verify that the above information is true and accurate to the best of my knowledge, and that I will comply with all applicable laws and regulations of the State of Oklahoma.

_____
Signature of Applicant

_____
Print Name

_____
Title (if applicable)

Application #_____

APPLICATION SUBMISSION AND PROCESSING

To be deemed complete, the submitted application must include:

a. *The appropriate filing fee.*
b. *The original application, typed or printed in ink, signed and notarized.*
c. *Plat(s) showing the information requested in items #4b, #5, #6, #7 and #8 above and as otherwise instructed on this form.*
d. *Deed(s), lease(s), and / or letter(s) of consent, if available.*

When the application is deemed complete, you will receive instructions about publishing notice of the application in a newspaper. If a proper protest to your application is received, a hearing will be scheduled. After the protest period and hearing if required, the application will be presented to the Board for consideration. Application processing time is about 90 days. You may apply for a provisional temporary permit which is effective for up to 90 days if you have an immediate need for water.

If you believe that within the first seven (7) years after issuance of your permit you will not be able to use the full amount of water applied for, please contact Board staff.

Please Note: Oklahoma Administrative Code 785:20-3-9 states:

(a) "Upon filing of an application that is defective as to form or unsatisfactory as to feasibility or safety of the plan or as to the showing of the ability of the applicant to carry the construction to completion, the Board shall advise applicant of the correction, amendments, or changes required, and sixty (60) days from the date the Board so advises shall be allowed for the filing thereof. {82:105.10]"

(c) "Any corrected application filed after the time allowed in (a) of this Section shall be treated in all respects as a new application on the date of its refilling [82:105.10] and the original priority date of filing shall be lost."

(d) "If an application does not correct an application or publish notice as instructed by the Board, and no further proceedings are initiated by the applicant for six months or more after last contact with the Board, the application shall be deemed withdrawn. The Board shall provide notice to the applicant that the application has been deemed withdrawn."

(Instructions provided on back)

Oklahoma Water Resources Board
Application Plat

Applicant Name _____Stream Water Application #_____

Stream System Code _____**(office use only)**

NW NW NW	NE NW NW	NW NE NW	NE NE NW	NW NW NE	NE NW NE	NW NE NE	NE NE NE
SW NW NW	SE NW NW	SW NE NW	SE NE NW	SW NW NE	SE NW NE	SW NE NE	SE NE NE
NW SW NW	NE SW NW	NW SE NW	NE SE NW	NW SW NE	NE SW NE	NW SE NE	NE SE NE
SW SW NW	SE SW NW	SW SE NW	SE SE NW	SW SW NE	SE SW NE	SW SE NE	SE SE NE
NW NW SW	NE NW SW	NW NE SW	NE NE SW	NW NW SE	NE NW SE	NW NE SE	NE NE SE
SW NW SW	SE NW SW	SW NE SW	SE NE SW	SW NW SE	SE NW SE	SW NE SE	SE NE SE
NW SW SW	NE SW SW	NW SE SW	NE SE SW	NW SW SE	NE SW SE	NW SE SE	NE SE SE
SW SW SW	SE SW SW	SW SE SW	SE SE SW	SW SW SE	SE SW SE	SW SE SE	SE SE SE

Legend:

- ● Point of Diversion
- Land Owned or Leased
- Area of Use

☐N ☐EIM

Section_____ Twp._____☐ S Rge._____☐WIM County_____

☐ECM

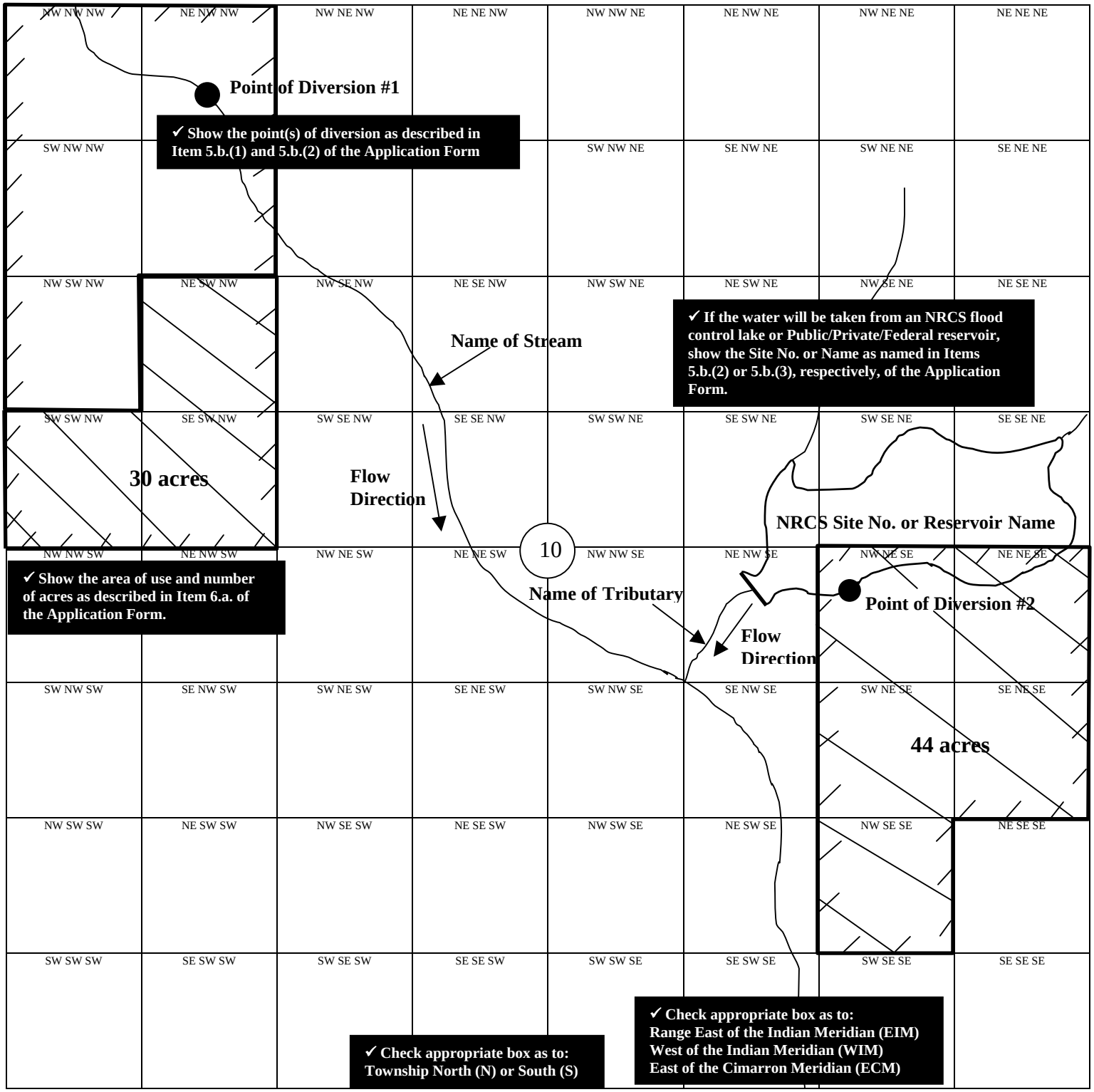
Prepared by: _____ Date:_____

Signature

Title:_____

Oklahoma Water Resources Board
Application Plat Instructions

Applicant Name John Doe Stream Water Application #_____
Stream System Code _____**(office use only)**



Legend:
- Point of Diversion
- Land Owned or Leased
- Area of Use

☒ N ☐ S Section 10 Twp. 7 Rge. 15 ☐ EIM ☒ WIM ☐ ECM County Kiowa

Prepared by: _____ Date:_____
Signature

Title:_____

DATE RECEIVED

SURFACE WATER APPLICATION
FOR 90-DAY PROVISIONAL TEMPORARY PERMIT

Oklahoma Water Resources Board / Permitting Section
3800 N Classen Blvd - Oklahoma City OK 73118
Phone (405) 530-8800 - Fax (405) 530-8900
Web Site www.owrb.state.ok.us

OFFICE USE ONLY

PT_____

SS_____

Please file in duplicate along with $150.00 filing fee ($200.00 filing fee for expedited)

Applicant's Name _____ City _____ State _____ Zip _____

Contact Person / Title _____ Phone _____ Fax _____

Address / Box No. _____ E-mail / Cellular _____

Amount of surface water requested _____ acre-feet
(1 acre-foot = 325,851 U.S. Gallons)

Purpose: Irrigation of _____ acres
Municipal Oil & Gas Drilling Industrial
Other _____

Water to be diverted from: Stream Creek Pond
SCS Site Lake Federal Reservoir

Name of source of water, if known _____

Rate of withdrawal will not exceed _____ gpm

Method of Diversion _____

Point of Diversion: _____ ¼ of _____ ¼ of _____ ¼
of Section _____ Township _____ Range _____
County _____

Area of Use: _____ ¼ of _____ ¼ of _____ ¼
of Section _____ Township _____ Range _____
County _____

Oil / Gas Lease Name _____

Applicant Owns: Land at the point of diversion? Yes No
Land on which water lines will be located? Yes No

If the answer to either of the above questions is NO, submit written consent from appropriate landowner(s).

Economic Hardship will occur if permit is not granted? Yes No

I verify that the above is true and accurate to the best of my knowledge, and that I will comply with all applicable laws and regulations of the State of Oklahoma.

Authorized Signature _____

Name of Signer _____
Please Print

If different from above:

Address _____

City _____ State _____ Zip _____

Phone _____ Fax _____

NOTARY

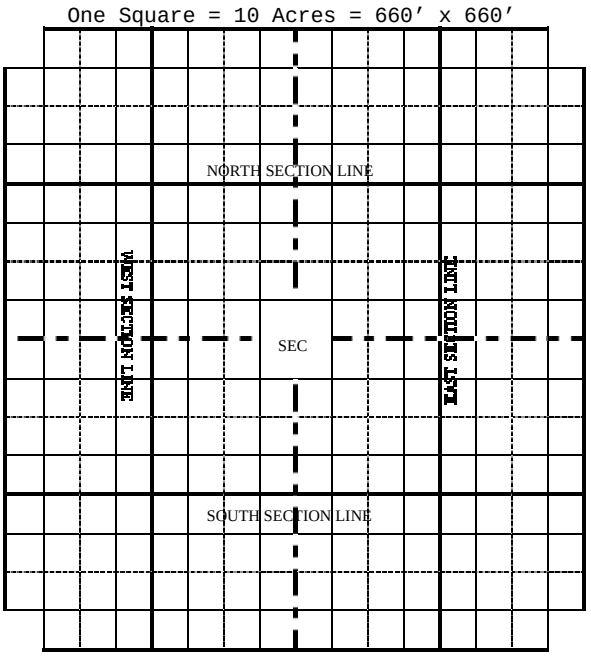
Subscribed and sworn before me
this _____ day of _____ 20 _____

Notary Public _____

My commission expires _____

INSTRUCTIONS FOR PLAT

(●) Spot location of diversion point(s). Sketch in: Ponds, Streams, Lakes, Water lines, etc.



APPROVAL

This application is hereby approved in the amount of _____ acre-feet, subject to the following terms, conditions and limitations:

(1) Provided existing appropriative rights and domestic uses downstream are not affected by this diversion of water.

(2) This permit is valid for 90 days, does not vest the holder with any permanent water rights, and is subject to cancellation by the Board.

(3) _____

Approved on the _____ day of _____ 20 _____

Expires on the _____ day of _____ 20 _____

Duane A. Smith, Executive Director

Form SW T7010 / 07-00

RIGHT OF ACCESS FOR STREAM WATER USE

(LANDOWNER PERMISSION)

I, _____, am the surface owner of land located
(name of surface land owner)

in the _____, _____, County,
(legal description) (county)

and I hereby authorize _____ or a
(name of applicant for permit to water from lake, pond or stream)

duly authorized representative to have access to the diversion point and to cross the land

described above with pipelines or other appurtenances related to use of the water. This right of

access is for: (complete applicable option)

1. a period not to exceed _____ from the date listed below, or
(days, months, or years)

2. _____ an indefinite term.
(√ if applies)

_____ _____
Signature Street address or P.O.Box

_____ _____
Surface Owner Name (print) City, State, Zip

_____ _____
Date Telephone number

State of Oklahoma)
) ss.
County of _____)

Subscribed and sworn to before me this ____day of _____, 20___.

_____
Notary Public

My Commission Expires:_____
(Seal)

Ground Water Use

APPLICATION FOR A PERMIT TO USE GROUNDWATER

OKLAHOMA WATER RESOURCES BOARD
Planning & Management Division
3800 N. Classen Blvd.,Oklahoma City, Oklahoma, 73118
(405) 530-8800 – Fax (405) 530-8900
website: www.owrb.ok.gov

FILING FEE MUST ACCOMPANY APPLICATION

Amount applied for	Fee
0 - 320 acre-feet……	$190.00
321- 640 acre-feet……	$300.00
641 - 1500 acre-feet…….	$375.00
Over 1500 acre-feet…….	$375.00

Plus $150.00 for each 500 acre-feet
(or any increment thereof) over 1500 acre-feet.
(Maximum Fee $3,000.00)

OFFICE USE ONLY

Application No._____Type of Permit_____

Groundwater Basin_____

Equal Proportionate Share _____

1. NAME AND ADDRESS

a. *Print the applicant's full name and mailing address, complete with zip code. If the applicant is a corporation, use the name and business address of the corporation*.

Applicant Name _____ **Phone** (____) _____ - _____
Fax# (_____) _____ -_____

Address _____

City _____ State_____Zip_____

b. *If the contact during the application process is someone other than the applicant listed above, print the name and mailing address of the contact person.*

Contact Name _____ **Phone** (____) ____ - _____
Fax# (_____) _____ - _____

Address _____

City _____ State_____Zip_____

2. AMOUNT OF WATER REQUESTED

State total amount of water applied for in acre-feet per calendar year. One acre-foot of water will cover one acre of land one foot deep and is equal to 325,851 U. S. gallons.

Application is made to take and use_____ acre-feet of water annually.

DATE OF RECEIPT OF APPLICATION
(FOR OFFICE USE ONLY)

Application # _____

3. PURPOSE(S) FOR WHICH WATER WILL BE USED

a. *List the purpose or purposes for which the water would be used if the permit is granted and list the number of acre-feet for each purpose. Be sure that the sum of the amounts listed below equals the total acre-feet in #2 above. If the water is to be used to irrigate crops, list IRRIGATION as the purpose and list the sum total acre-feet for all crops.*

OFFICE USE ONLY SIC Codes	

_____acre-feet of water will be used for _____

_____acre-feet of water will be used for _____

_____acre-feet of water will be used for _____

_____acre-feet of water will be used for _____

Describe fully how the water will be used, and include a description of the system proposed to be used:

_____

_____

_____

b. If the water requested is for irrigation purposes, state the total number of acres that will be irrigated.

_____ acres of land are proposed to be irrigated. The proposed crops are_____

_____.

Will you follow applicable requirements, guidelines and best management practices recommended by the Natural Resources Conservation Service or other applicable agencies? ___ Yes _____ No

4. OWNERSHIP AND LEGAL DESCRIPTION OF LAND DEDICATED

a. *No permit of any kind shall be granted without the WRITTEN PERMISSION OF THE SURFACE OWNER OF THE LAND from which the water is to be withdrawn. If the applicant does not own the groundwater underlying the dedicated land, a copy of the lease or agreement giving the applicant the right to withdraw the groundwater must be furnished with the application. Said lease or agreement must specify the number and location of the acres under lease. A municipality may dedicate platted land within its corporate limits under certain conditions.*

_____ acres are owned, _____ acres are leased and / or _____ acres are platted (municipal only), and dedicated to this application. Lands must be shown in attached application plat(s). Attach copy of deed, lease or other written authorization from owner, etc., showing right to use groundwater from the land.

b. *The full legal description of all lands dedicated must be given with the number of acres in each legal description stated. The legal descriptions should be checked against the plats to make sure they agree. Please do not use city lot and block numbers, but show the land on the plat and then convert to the nearest legal description. If more space is needed for legal descriptions, list on a separate sheet of paper and attach it to the application, referencing paragraph 4.b.*

_____ acres in ____ 1/4 of ____1/4 of ____1/4 of Sec_____Twp_____ N ☐ S ☐ Rge_____ ECM ☐ WIM ☐ EIM ☐ in _____ County.

_____ acres in ____ 1/4 of ____1/4 of ____1/4 of Sec_____Twp_____ N ☐ S ☐ Rge_____ ECM ☐ WIM ☐ EIM ☐ in _____ County.

_____ acres in ____ 1/4 of ____1/4 of ____1/4 of Sec_____Twp_____ N ☐ S ☐ Rge_____ ECM ☐ WIM ☐ EIM ☐ in _____ County.

c. The water will be used in _____County, Oklahoma.

Application # _____

5. WELL INFORMATION

a. *Please specify the number of wells requested to be authorized and describe below to the closest quarter section the location of existing and proposed wells. On the attached plat, show the actual location of existing wells and proposed wells by distances in feet from readily fixed points of reference such as section lines, or provide latitude/longitude coordinates of existing wells requested to be authorized. If the applicant does not have specific information as to locations of existing and any proposed wells, the potential well area or areas within the dedicated lands must be indicated on the application plat. Actual well locations and the potential area information for well locations as indicated on the plat will be used to determine the certified mail notice that the applicant must provide. If the requested permit is issued, it will authorize a maximum number of existing wells and proposed wells to be drilled and completed. Absent information to the contrary, a maximum of three wells will be authorized for each 100 acre-feet of groundwater to be withdrawn per year. Proposed wells which are authorized must be drilled and completed within one year of permit issuance.* ***Please note:*** *The well (s) must be drilled according to minimum construction standards established by the Oklahoma Water Resources Board in Chapter 35 of the Board's rules.*

Water is to be withdrawn from _____ well(s) located in : *Legal description must agree with plat.*

Existing
Proposed ____ 1/4 of ____ 1/4 of ____ 1/4 of Sec _____ Twp ____ N ☐ S ☐ Rge_____ ECM ☐ WIM ☐ EIM ☐ in _____ County

Existing
Proposed ____1/4 of _____1/4 of ____ 1/4 of Sec_____ Twp ____ N ☐ S ☐ Rge ____ ECM ☐ WIM ☐ EIM ☐ in _____ County

Existing
Proposed ____1/4 of ____ 1/4 of _____ 1/4 of Sec_____ Twp ____ N ☐ S ☐ Rge ____ ECM ☐ WIM ☐ EIM ☐ in _____ County

b. Has the well(s) to be used already been drilled? ____ Yes _____ No

(1) If yes, please answer the following questions.

(A) Did a licensed water well driller drill and complete the well(s)? ____ Yes _____ No

[Please attach a copy of the well log(s) if available.]

If no, who drilled your well(s)?

_____

Was your well(s) constructed to meet the Oklahoma Water Resources Board's minimum construction standards for water wells? ____ Yes _____ No

(B) List the depth of the well(s) and anticipated pumping rates for each well:

_____

_____

_____

(2) If the well(s) has not been drilled, will a licensed water well driller drill and complete the well(s)?

_____ Yes _____ No

(A)If no, who will drill your well(s)? _____

(B) Will your well(s) be constructed to meet the Oklahoma Water Resources Board's minimum construction standards for water wells? _____ Yes _____ No

(3)Will the well(s) be located at least the following minimum distances away from possible pollution sources:

i. 10 feet from a closed or tight sanitary sewer line; _____Yes ____No ____N/A
ii. 300 feet from the outside perimeter of an existing or proposed waste lagoon for a feedlot or confined animal feeding operation; _____Yes ____No ____N/A
iii. For all other pollution sources (including but are not limited to existing or proposed septic tanks, sewer lines, absorption fields or beds, seepage pits, building foundations, oil & gas wells and landfills):

a) 50 feet if the well is upgradient of the pollution source;
b) 50 to 75 feet if the well is level or downgradient of the pollution source and a 20 foot surface seal is installed;
c) 75 feet if the well is on the same ground level with the pollution source;
d) 100 feet if the well is downgradient of the pollution source

. _____Yes ____No ____N/A

c. ABANDONED WELL PLUGGING. To your knowledge, are there any abandoned or unused water wells, hand dug wells or windmills on the lands dedicated to this application? _____ Yes ____ No

(1) If yes, have all abandoned wells been, or will they be, properly plugged before your use of the water begins? _____Yes _____ No ____ N/A

(2) Have all wells, which are temporarily out of service, been or will they be capped before your use of the water begins? _____ Yes _____ No ____ N/A

6. APPLICATION PLAT

An application plat showing the land and wells and potential well areas dedicated, existing wells within 1/4 mile of the proposed and existing wells and any potential well location area dedicated and other information pertinent to this application must be completed on the Application Plat form and must accompany the application. Municipal and rural water entities may show dedicated lands and wells on other appropriate maps (see #8). (Use additional plat sheets if more than one section is involved in the application.)

7. SURFACE ESTATE OWNERS MAP

A Surface Estate Owners map must be completed on the Surface Owners Map form for each well requested to be authorized and must accompany the application.

8. MUNICIPALITIES AND RURAL WATER ENTITIES

Municipalities and rural water entities must submit a map of the municipality or rural water entity showing the land dedicated, well locations and which land is owned / leased / or platted. The map must show reference points or scale.

If platted lands within the municipal boundaries are dedicated, will the municipality make water available to the platted lands?___Yes ___No Will the wells be located not less than 600 feet within boundaries of the municipal limits?___Yes ___No Will the wells be drilled on the platted lands?___Yes ___No
If platted lands are dedicated, submit a map of the service area and water lines.

9. SYSTEM LOSSES AND LEAKS. How will water system losses or leaks be detected and repaired, and how much time will detection and repair take?

_____
_____
_____

Application # _____

Please note:

Any incomplete or unresponsive answers may cause a delay in the processing of your application.

In addition, Oklahoma Administrative Code (OAC) 785:30-1-4(d) states: "If the application is defective to as to form, the Board shall advise the applicant of the corrections, amendments, or changes required and sixty (60) days shall be allowed for the refilling thereof. If the application is not corrected, amended, or changed within the time required, the Board may inactivate the application. Furthermore, OAC 785:30-3-3(b), states: "If an applicant does not correct an application or publish notice as instructed by the Board, and no further proceedings are initiated by the applicant for six months or more after last contact with the Board, the application shall be deemed withdrawn. The Board Shall provide notice to the applicant that the application has been deemed withdrawn.

APPLICATION SUBMISSION AND PROCESSING

To be deemed complete, the submitted application must include:

a. The appropriate filing fee;
b. The original application, typed or printed in ink, signed and notarized.
c. One copy of the plat(s) showing the information requested in item #6 above and as otherwise instructed on this form.
d. Deed(s), lease(s), and / or letter (s) of consent as required.

After review for accuracy and completeness, you will be contacted about correcting any errors. When the application is deemed complete, you will receive instructions about publishing notice of the application in a newspaper and sending notice of the application to surface estate owners within one-fourth (1/4) mile of the location of existing and proposed wells and any potential well location areas subject of this application. If a proper protest to your application is received, a hearing will be scheduled. After the protest period and hearing if required, the application will be presented to the Board for consideration. Application processing time is about 90 days. You may apply for a provisional temporary permit which is effective for up to 90 days if you have an immediate need for water.

Application # _____

SIGNATURES

The application must be signed as follows:

a. If the applicant is an individual, the application shall be signed by the applicant, or his duly appointed agent who shall present evidence of authority to act as agent with the application.

b. A joint application shall be signed by each applicant or his duly authorized agent, provided that a joint application by husband and wife may be signed by either party. (Joint applicants are required to select one among them to act for and represent the others in dealing with the Board.)

c. If the application is by a partnership, the applicant shall be designated by the firm name followed by the words "a Partnership" and the application shall be signed by each of the general partners or, if signed by one partner or other agent, a written statement of that person's authorization to make the application, signed by the other parties in interest, shall be attached to the application.

d. In the case of an estate or guardianship, the application shall be signed by the duly appointed guardian or representative of the estate, and a certified copy of the letters issued by the court shall be attached to the application.

e. In the case of a water district, county, municipality, etc., the application shall be signed by a duly authorized official, and a certified copy of the resolution or other authorization to make the application shall be attached.

f. In the case of a private corporation, the application shall be signed by a duly authorized person and, if not attested by the secretary or assistant secretary, a copy of the authorization shall be attached to the application.

An attorney duly licensed to practice law in Oklahoma may sign the application for the applicant he or she represents. The Oklahoma Bar Association number must be indicated.

Upon my oath or affirmation, I swear or affirm (1) that all information submitted to the Oklahoma Water Resources Board in connection with this application is true and accurate to the best of my knowledge; and (2) that I or the person or entity I represent will comply with all applicable laws and regulations of the State of Oklahoma or its agencies, and any lawful conditions imposed by the Oklahoma Water Resources Board, which apply or pertain to the use of fresh groundwater.

_____

SIGNATURE OF APPLICANT

_____

PRINT NAME

_____

TITLE (IF APPLICABLE)

STATE OF _____)
) ss.
COUNTY OF _____)

The foregoing instrument was acknowledged before me this _____ day of _____, 20____.

_____

Notary Public

(SEAL)

My commission expires:_____

Application # _____

Oklahoma Water Resources Board
Application Plat

(Instructions provided on back)

Applicant Name_____

NW NW NW	NE NW NW	NW NE NW	NE NE NW	NW NW NE	NE NW NE	NW NE NE	NE NE NE
SW NW NW	SE NW NW	SW NE NW	SE NE NW	SW NW NE	SE NW NE	SW NE NE	SE NE NE
NW SW NW	NE SW NW	NW SE NW	NE SE NW	NW SW NE	NE SW NE	NW SE NE	NE SE NE
SW SW NW	SE SW NW	SW SE NW	SE SE NW	SW SW NE	SE SW NE	SW SE NE	SE SE NE
NW NW SW	NE NW SW	NW NE SW	NE NE SW	NW NW SE	NE NW SE	NW NE SE	NE NE SE
SW NW SW	SE NW SW	SW NE SW	SE NE SW	SW NW SE	SE NW SE	SW NE SE	SE NE SE
NW SW SW	NE SW SW	NW SE SW	NE SE SW	NW SW SE	NE SW SE	NW SE SE	NE SE SE
SW SW SW	SE SW SW	SW SE SW	SE SE SW	SW SW SE	SE SW SE	SW SE SE	SE SE SE

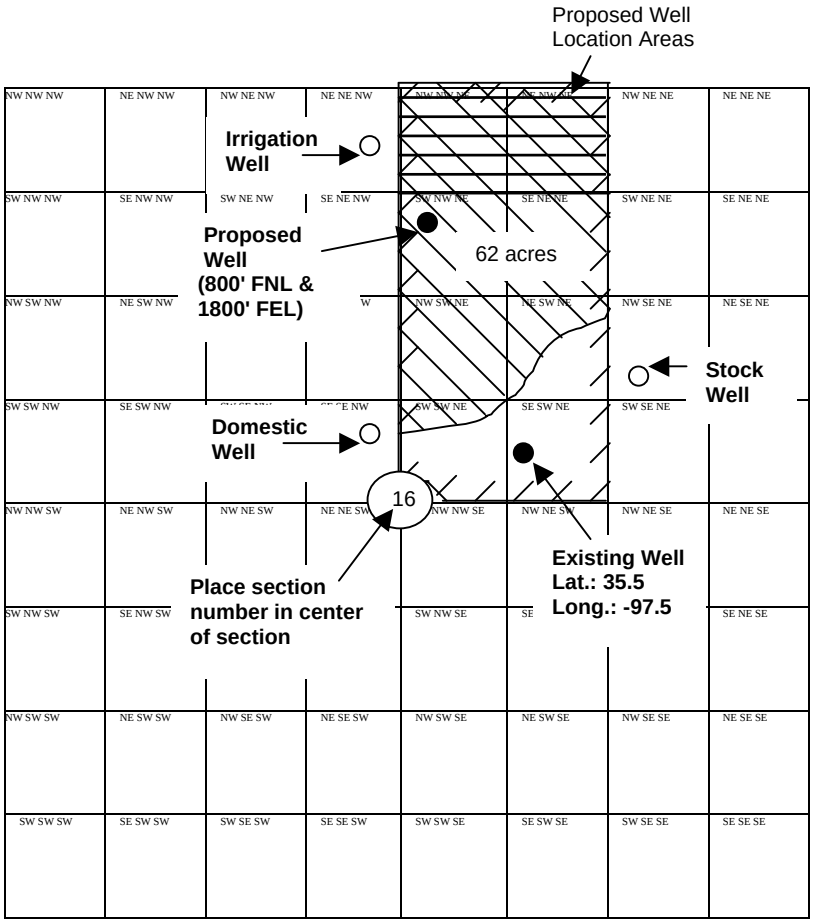
_____ _____

Section – Township – Range County

Application # _____

Oklahoma Water Resources Board
Application Plat Instructions
(Sample)

Applicant Name John Doe



Instructions for Use of Symbols on the Application Plat

● Spot the actual location of each existing well and proposed well with known locations to be authorized and provide distances in feet from section lines or boundaries, or provide lat./long. Coordinates.

○ Show the location of other existing water wells (stock, domestic, irrigation, etc.) within 1/4 mile of dedicated land.

Note: Use additional plats if necessary.

FNL = From the North Line
FEL = From the East Line
Lat. = Latitude
Long. = Longitude

Section 16 – Township 10N – Range 10WIM
Section – Township - Range

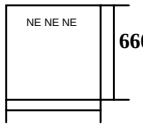
Caddo
County

Land Dedicated

Area of Use
(example: area to be irrigated, locations of poultry houses, swine houses, or fish farms, mining areas, etc.)

Potential Well Location Area on Dedicated Lands

(if exact proposed well location within the area is not known)



Each smaller square represents a ten (10) acre tract (or 660 ft x 660 ft)

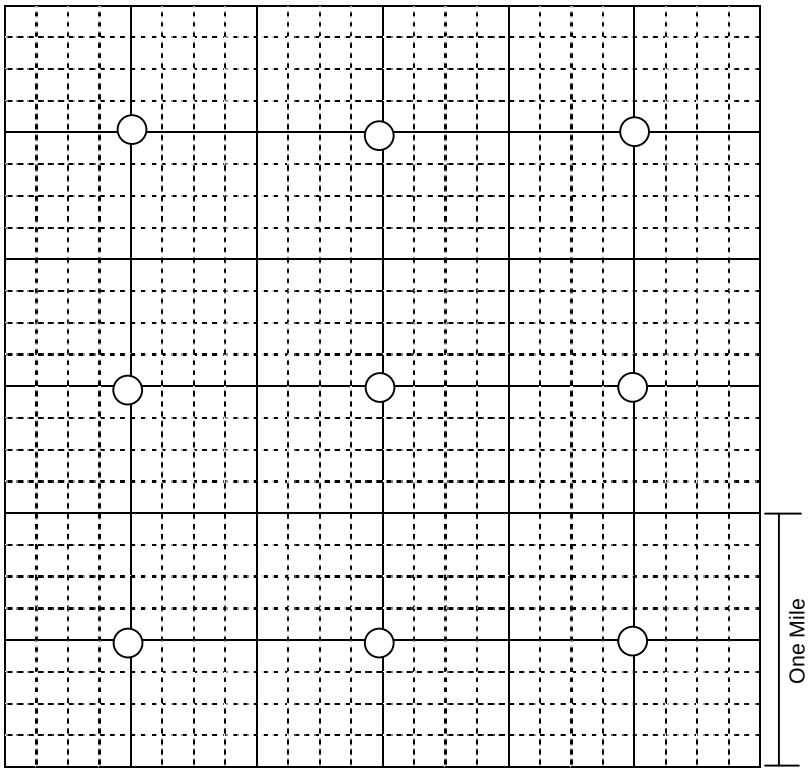
Application # _____

Oklahoma Water Resources Board
Surface Estate Owners Map
(Instructions provided on back)

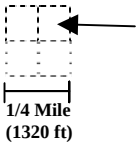
Applicant Name_____

The applicant must furnish names and mailing addresses of all surface estate owners of land located within one-thousand three hundred twenty (1320') from the actual location of existing or proposed wells, and from the outside boundaries of all potential well location areas subject of this application, unless otherwise directed by the Board. Mark the actual location of existing and proposed wells and shade all potential well location areas subject of the application.

One copy of this form must be filed with the Groundwater application.



Plat Scale



Each smaller square represents a ten (10) acre tract. (or 660 ft x 660 ft)

SURFACE ESTATE OWNERS OF LANDS LOCATED WITHIN 1320 FEET OF WELL LOCATIONS OR AREAS

	Name	Address
A.	_____	_____
B.	_____	_____
C.	_____	_____
D.	_____	_____
E.	_____	_____
F.	_____	_____
G.	_____	_____
H.	_____	_____
I.	_____	_____

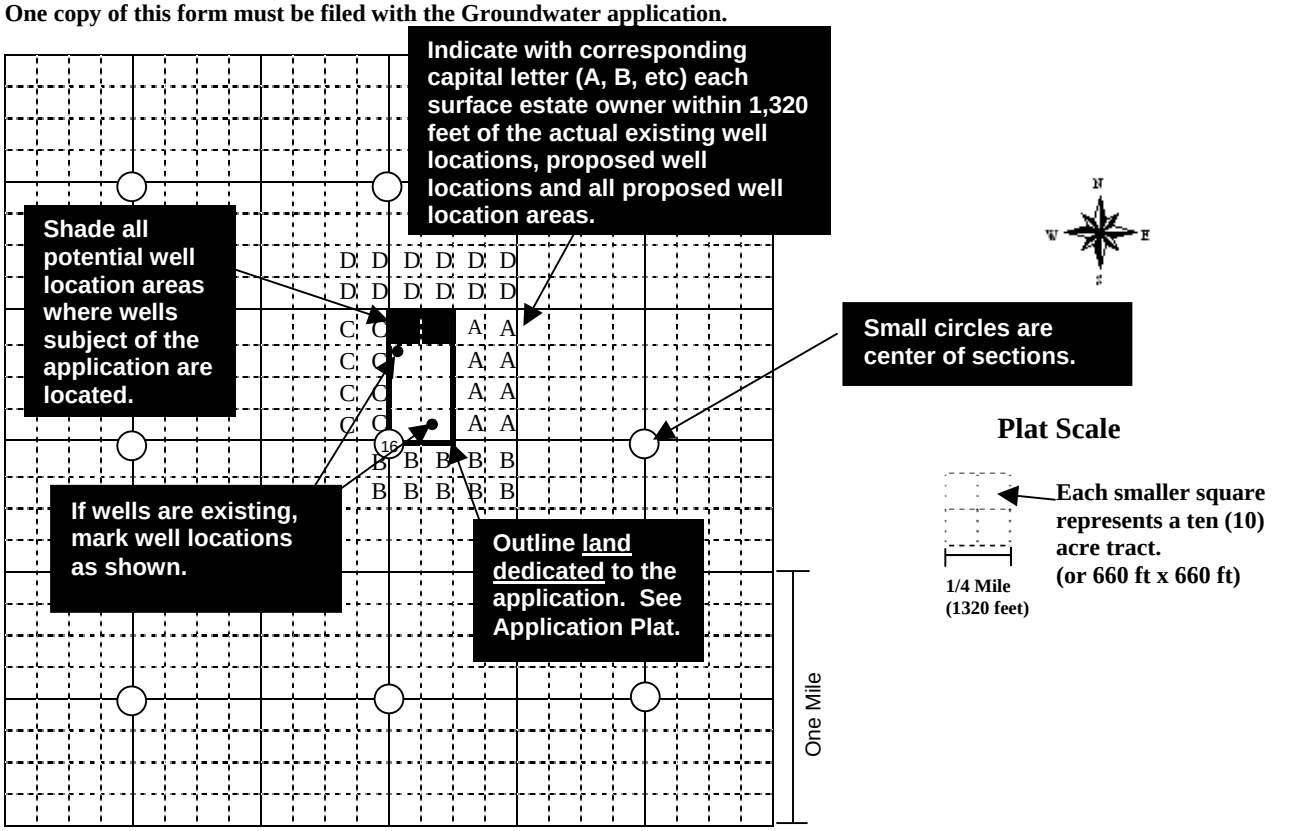
Application # _____

Oklahoma Water Resources Board
Surface Estate Owners Map
(Sample)

Applicant Name_____

The applicant must furnish names and mailing addresses of all surface estate owners of land located within one-thousand three hundred twenty (1320') from the actual location of existing or proposed wells, and from the outside boundaries of all potential well location areas subject of this application, unless otherwise directed by the Board. Mark the actual location of existing and proposed wells and shade all potential well location areas subject of the application.

One copy of this form must be filed with the Groundwater application.



SURFACE ESTATE OWNERS OF LANDS LOCATED WITHIN 1320 FEET OF WELL LOCATIONS OR AREAS

	Name	Address
A.	Jesse Thomas	16200 N. Pennsylvania, Oklahoma City, OK
B.	Jim and April Ferguson	13429 W. Memorial, Oklahoma City, OK
C.	Steve and Mary Burgess	P.O. Box 156, El Reno, OK
D.	Sue Ellen Mayes Estate	P.O. Box 149, El Reno, OK
E.		
F.		
G.		
H.		
I.		

DATE RECEIVED

GROUNDWATER APPLICATION FOR 90-DAY PROVISIONAL TEMPORARY PERMIT

Oklahoma Water Resources Board / Permitting Section
3800 N Classen Blvd - Oklahoma City OK 73118
Phone (405) 530-8800 - Fax (405) 530-8900
Web Site www.owrb.state.ok.us

Please file in duplicate along with $150.00 filing fee ($200.00 filing fee for expedited)

OFFICE USE ONLY

PT _____
WR _____
BASIN _____

Applicant's Name _____ City _____ State _____ Zip _____

Contact Person / Title _____ Phone _____ Fax _____

Address / Box No. _____ E-mail / Cellular _____

Amount of groundwater requested _____ acre-feet
(1 acre-foot = 325,851 U.S. Gallons)

Purpose: Irrigation of _____ acres Municipal

Oil & Gas Drilling Industrial Other _____

Applicant hereby submits with this application:
Proof of ownership (Deed) of land on which water well(s) are located, Or,
Written permission from the surface landowner to take groundwater from well(s).

Rate of withdrawal will not exceed _____ gpm

Water will be withdrawn from _____ well(s)

Located in: _____ ¼ of _____ ¼ of _____ ¼
of Section _____ Township _____ Range _____
County _____

Located in: _____ ¼ of _____ ¼ of _____ ¼
of Section _____ Township _____ Range _____
County _____

Area of Use: _____ ¼ of _____ ¼ of _____ ¼
of Section _____ Township _____ Range _____
County _____

Oil / Gas Lease Name _____

Economic Hardship will occur if permit is not granted? Yes No

On behalf of the applicant, I verify that the above is true and accurate to the best of my knowledge, that waste by depletion and waste by pollution will not occur, and that I will comply with all applicable laws and regulations of the State of Oklahoma.

Authorized Signature _____

Name of Signer _____
If different from above: Please Print

Address _____

City _____ State _____ Zip _____

Phone _____ Fax _____

NOTARY

Subscribed and sworn before me

this _____ day of _____ 20 _____

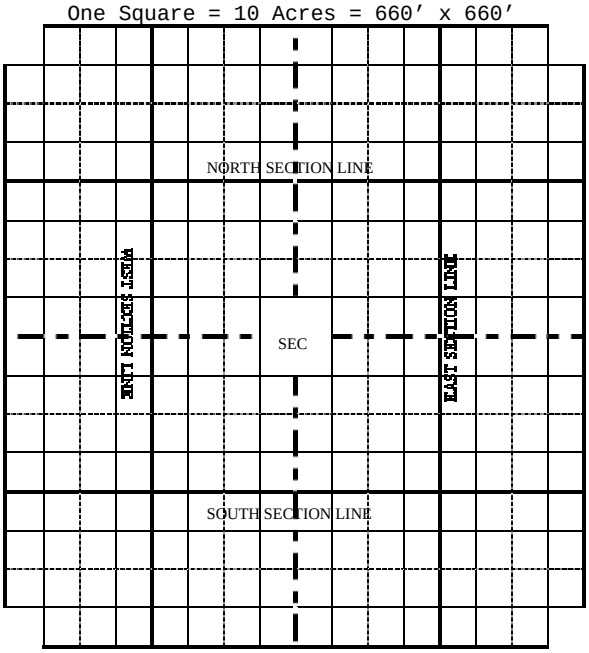
Notary Public _____

My commission expires _____

INSTRUCTIONS FOR PLAT

(●) Spot location of water well(s); (○) Spot location of all existing wells within ¼ mile of the well(s); ////// Outline, with hatch, land the applicant owns or has a valid lease or easement.

One Square = 10 Acres = 660′ x 660′



APPROVAL

This application is hereby approved in the amount of _____ acre-feet, subject to the following terms, conditions and limitations:

(1) This permit is valid for 90 days, does not vest the holder any permanent water rights and is subject to cancellation by the Board.

(2) _____

Approved on the _____ day of _____ 20 _____

Expires on the _____ day of _____ 20 _____

Duane A. Smith, Executive Director

GROUNDWATER LEASE

(LANDOWNER PERMISSION)

I, _____, am the surface owner of _____ acres
(name of surface land owner)

of land located in the _____,_____
(legal description) (county)

County, and I hereby authorize _____ or a
(name of applicant for groundwater permit)

duly authorized representative to apply for a permit, locate wells on the land and withdraw

groundwater from the land described above. This lease is for: (complete applicable option)

1. a period not to exceed _____ from the date listed below, or
(days, months, or years)

2. _____ an indefinite term.
(√ if applies)

_____ _____
Signature Street address or P.O.Box

_____ _____
Surface Owner Name (print) City, State, Zip

_____ _____
Date Telephone number

State of Oklahoma)
) ss.
County of _____)

Subscribed and sworn to before me this ____day of _____, 20___.

_____
Notary Public

My Commission Expires:_____
(Seal)

Disposal

OCC Operator No.

OKLAHOMA CORPORATION COMMISSION
Oil & Gas Conservation Division, UIC Department
Post Office Box 52000
Oklahoma City, Oklahoma 73152-2000

Form 1015
Rev. 2008

Cause P.D. No. _____

☐ **Original**

☐ **Amended**

Application For Administrative Approval
OAC 165:10-5-5

Reason Amended: _____

Applicant				
Address				
City		State		Zip
Well Name/No.				
Well Location				
SHL	1/4	1/4	1/4	1/4
BHL	1/4	1/4	1/4	1/4
Section		Township		Range
County				
API No.				
Unit Name				

☐ COMMERCIAL DISPOSAL WELL

☐ ENHANCED RECOVERY INJECTION WELL

☐ DISPOSAL WELL

☐ LPG

WELL TO BE

☐ DRILLED

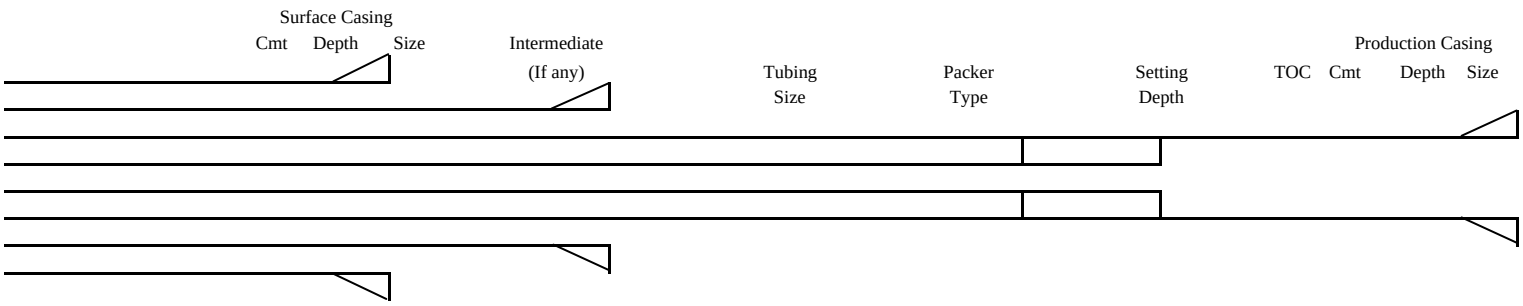
☐ CONVERTED

☐ DIRECTIONAL (GIVE THE BHL)

Well Data

Is well within 1/2 mile of an active or reserve municipal water well? ☐ Yes ☐ No			
Does injection zone contain oil, gas, or fresh water witnin 1/2 mile? ☐ Yes ☐ No	If yes, state which		
Location of injection source(s)			
Geologic name(s) and depth of source(s)			
Geologic name of injection zone		Perforation of injection interval	top bottom
Base of treatable water	☐ Commission maps ☐ Other source (specify	Intervening thickness (top perforation minus base of treatable water	
Average porosity %	Average permeability (Kw)	Present formation pressure **or** Shut-in static fluid level from surface	
Injection rates and pressures	Maximum	BPD	PSI

SKETCH SUBSURFACE FACILITIES



I declare that I have knowledge of the contents of this report and am authorized by my organization to make this report, which was prepared by me or under my supervision and direction with the data and facts stated herein to be true, correct and complete to the best of my knowledge and belief.

Signature _____ Date _____

Name & Title **(Typed or Printed)** _____ Phone (AC/Number) _____

Form 1015 (Continued)

1. Attach $35.00 filing fee for injection and noncommercial disposal; or $1,000.00 for commercial disposal well application.

2. Notice that an application has been filed shall be published by the applicant in a newspaper of general circulation in the county in which the well is located and in a newspaper of general circulation published in Oklahoma City, Oklahoma. The applicant shall file proof of publication before the application is approved. The notice shall include PD number, name and address of applicant, surface and bottom hole (if directional hole) location of proposed injection or disposal well to the nearest 10 acre tract, geologic name and depth of injection zone, injection pressure, and volume. If no written objection is received within 15 days from the date of publication, the application will be approved administratively.

3. In addition to filing Form 1015, an affidavit of mailing or delivery with names and addresses of those notified shall be filed not later than five days after the application is filed.

4. The applicant must have appropriate surety prior to approval of the application.

5. Attach signed analysis of fresh water from two or more producing wells within one mile of injection well, fill out OCC water well inventory form or notarized statement as to why samples were not submitted.

6. Attach signed analysis of representative sample of water to be injected. The analysis should include the exact legal location where the sample was taken.

7. Attach plat showing subject well and total depths of all known oil and gas wells, abandoned, drilling and dry holes within 1/4 mile for noncommercial wells and within 1/2 mile for commercial wells.

8. Attach Completion Report Form 1002A.

9. Attach electric or radioactivity log of the subject well.

10. Attach schematic drawing of subsurface facilities including: casing size, setting depth, amount of cement used, measured or calculated, tops of cement to surface, intermediate (if any) and production casings; size and setting depth of tubing; type and setting depth of packer; geologic name of injection zone, showing top and bottom of injection interval.

11. The original and six copies of the application and one complete set of attachments shall be mailed to the Corporation Commission Underground Injection Control Department.

12. Deliver one copy of the application to the landowner on whose land the injection well is to be located and to each operator of a producing leasehold within 1/2 mile of the proposed well.

13. A well shall not be used for injection or disposal unless annual fluid injection report Form 1012A is filed by April 1st each year.

The names and addresses of those to whom copies of this application and attachments have been sent.

OCC Log in No.

OKLAHOMA CORPORATION COMMISSION
Oil & Gas Conservation Division
Post Office Box 52000
Oklahoma City, Oklahoma 73152-2000

Form 1014S
Rev. 2008

Application for Land Application
OAC 165:10-7-19f2, 10-7-25f2, 10-7-26g2

Operator			OCC No.
Address			Phone No.
City	State	Zip	FAX No.

Well Name/No.				API No.
Location within Sec.	Sec.	Twp.	Rge.	County

Land Application Area

Location within Sec.	Sec.	Twp.	Rge.	County

The following facts are submitted: ***NOTE: If the answer to A or B is yes, please attach written explanation.***

A. Has land application area ever been used for this type of practice? ☐ Yes ☐ No

B. Has pit received any materials except natural precipitation since sampling? ☐ Yes ☐ No

C. Is this application for a closed system? If yes skip to H. ☐ Yes ☐ No

D. Was Field Inspector contacted to witness sampling? ☐ Yes ☐ No

E. Dimensions of pit: Length _____ Width _____ Depth _____

F. Total volume of liquids to be land applied: _____ bbls.

G. Total volume of solids to be land applied: _____ bbls. or _____ cu.ft.

H. Method of application:
☐ Spray irrigation gun ☐ Injection ☐ Tank truck with spreader bar or diffuser ☐ Other _____

I. Number of acres in proposed application area: _____ potential application area: _____

Attachments:

☐ Copy of written permission form surface owner
☐ Map or diagram, drawn to scale, showing proposed and potential and application areas
☐ Site suitability report
☐ Analysis of materials to be land applied (exempt for closed systems)
☐ Analysis of soil
☐ Investigation report and diagram (for contaminated soils only)
☐ Loading calculations (exempt for closed system)
☐ Manufacturer, model number and specifications of testing equipment (for closed systems only)
☐ Other _____

Executed this _____ day of _____, _____.

_____
Signature of Operator, Contractor, or Agent

STATE OF _____)
) SS
COUNTY OF _____)

Before me, the undersigned authority, on this day personally appeared _____ known to me to be the person whose name is subscribed to the above instrument, who being by me duly sworn on oath, states that he is duly authorized to make the above report and that he has knowledge of the facts stated therein, and that said report is true and correct.

Subscribed and sworn to before me this _____ day of _____, _____.

My Commission Expires: _____

_____
Notary Public

Please be reminded that certain conditions or stipulations in OAC 165:10-7-19f2, 10-7-25f2, and 10-7-26g2 must be adhered to. Below are only some of them. Please refer to the respective rules for others.

A. The applicant shall notify the appropriate Field Inspector at lease 24 hours prior to the commencement of land application to allow a Commission representative an opportunity to be present.
B. A representative of the applicant shall be on the land application site at all times during which materials are being applied.
C. Weather Restrictions:
   Land applications, including incorporation, shall not be done:
   1. During precipitation events or when precipitation is imminent;
   2. When the soil moisture content is at a level such that the soil cannot readily take the addition of materials;
   3. When the ground is frozen; or
   4. By spray irrigation when the wind velocity is such that even distribution of materials cannot be accomplished or the buffer zones below cannot be maintained. (Drilling fluids only.)
D. Buffer Zones:
   Land application shall not be done within the following buffer zones:
   1. 50 feet of a property line boundary;
   2. 300 feet of any actively-producing water well used for domestic or irrigation purposes; and
   3. One-quarter mile of any actively-producing water well used for municipal purposes.
E. Runoff or Ponding Prohibited:
   No runoff or ponding of land applied materials shall be allowed during application.
F. Time Period:
   Land application shall be completed within 90 days from the date of the permit. At the end of the 90-day period, the permit shall expire by its own terms. To renew the permit, the applicant shall resample the fluids and/or cuttings to be land applied, submit a new analysis, and receive a notification of renewal from a Field Operations office.

DISTRICT I	DISTRICT II	DISTRICT III	DISTRICT IV
115 West 6th Street	101 South 6th Street	1020 Willow Street	1400 Hoppe Blvd.
Post Office Box 779	Post Office Box 1107	Post Office Box 1525	Suite D
Bristow, OK 74010-0779	Kingfisher, OK 73750-1107	Duncan, OK 73533	Ada, OK 74820
(918) 367-3396	(405) 375-5570	(580) 255-0103	(580) 332-3441
OGBristowOffice@occemail.com	OGKingfisherOffice@occemail.com	OGDuncanOffice@occemail.com	OGAdaOffice@occemail.com

Permit No.

LA

FOR OCC USE ONLY

Maximum application rate	bbls/ac	Minimum acreage required	
Additional requirements			

This application for land application has been ☐ **APPROVED** ☐ **DISAPPROVED**

Expiration Date _____

_____
OCC Representative

_____
Date

The reason for disapproval is:

☐ Application incomplete _____

☐ Laboratory analysis incomplete _____

☐ Size of potential land application area too small _____

☐ Other _____

OCC Log-In Number

OKLAHOMA CORPORATION COMMISSION
Oil & Gas Conservation Division
Post Office Box 52000
Oklahoma City, Oklahoma 73152-2000

Form 1014D
Rev. 2003

Application For Surface Discharge
OAC 165:10-7-17and 165:10-7-32

Operator			OCC No.
Address			Phone No.
City	State	Zip	FAX No.

Well Name/No.				API No.
Location within Sec.	Sec.	Twp.	Rge.	County

The following is for Irrigation of Produced Water (165:10-7-17)

Was District Office contacted to witness sampling? ☐ Yes ☐ No Maximum volume to be discharged at one time _____ Bbls.

Method of Application: Spray irrigation gun _____ Number of acres in proposed discharge area? _____

Other _____

The following is for Reclaim and/or Recycle Produced Water (165:10-7-32)

Location of site where produced water is to be obtained

Location within section (1/4 1/4 1/4)	Sec.	Twp.	Rge.	County

NOTE **:** If more than one location is to be used, please submit a list of leases the produced water will be obtained

Describe intented beneficial use.

☐ Air Drilling ☐ Well pad and lease road construction

☐ Other _____

☐ Copy of water analysis demonstrating TDS of produced water is below 5,000 mg/l, and oil and grese is less than 1000 mg/l.

Executed this _____ day of _____, _____.

_____
Signature of Affiant

STATE OF _____)
) SS:
COUNTY OF _____)

Before me, the undersigned authority, on this day personally appeared _____
known to me to be the person whose name is subscribed to the above instrument, who being by me duly sworn on oath states that he is duly authorized to make the above report and that he has knowledge of the facts stated therein, and that said report is true and correct.

Subscribed and sworn to before me this _____ day of _____, _____.

_____
Notary Public

My Commission Expires: _____

Commission No. _____

Instructions

Please be reminded that certain conditions or stipulations in **165:10-7-17** must be adhered to. Below are some of them. Please refer to subsection (i) of the rule for others.

A. A representative of the operator shall be on the discharge site at all times during which water is being applied.

1 ☐ Copy of notice to surface owner attached.

2 ☐ Copy of contract or affidavit attached (required only if operator has a contractor or agent).

3 ☐ Map or diagram, drawn to scale, showing proposed and potential discharge areas attached.

4 ☐ Site suitability report attached.

5 ☐ Produced water analysis attached or exemption.

6 ☐ Soil analysis attached or exemption.

7 ☐ Other attachments _____

B. Weather Restrictions:

Surface discharge shall not be done:

1. During precipitation events or when precipitation is imminent;
2. When the soil moisture content is at a level such that the soil would not readily take the additional water;
3. When the ground is frozen; or
4. By spray irrigation when the wind velocity is such that even distribution of water be accomplished or the buffer zones below cannot be maintained.

For the Reclaim/Recycle of produced water (165:10-7-32):

1. No person shall use produced water for any other purpose except as provided by this permit. Any operator failing to obtain a permit may be fined up to $500.00.
2. This permit shall cover the reclamation of produced water from oil and gas wells for a single well location for the prupose of water supply for surface activities used *for a specific permitted use. This does not include the use of produced water for down-hole operations referred to as weighted water under OCC 165:10-7-24(2).*
3. Quality of produced water for the purposes of this permit shall be limited to Total Dissolved Solids (TDS) content not to exceed 5,000 mg/l and oil and grease content not to exceed 1,000 mg/l.
4. Notification to OCC District Office. The Operator shall orally notify the district Office when produced water is initially to be hauled to the permitted well site.
5. A copy of written notice to the surface owner that the applicant intends to use produced water as per 165:10-7-32 to a specific portion of real property as designated by legal description. For purposes of notice, a written waiver from the surface owner may also be submitted.
6. No runoff or ponding of discharged water shall be allowed during application.
7. If the intended use is for lease road construction, provide a map of the lease road.

FOR OCC USE ONLY

Permit No.
SD

This application has been: ☐ **APPROVED** Maximum discharge rate _____ bbls/acre. (165:10-7-17 only)

OCC Representative	Date

Form 1014CS
Rev. 2001

OKLAHOMA CORPORATION COMMISSION
Oil & Gas Conservation Division
Pollution Abatement Department
Post Office Box 52000
Oklahoma City, Oklahoma 73152-2000

Application For Commercial Soil Farming
OAC 165:10-9-2(i)1

Applicant		Phone No.
Address		FAX No.
City	State	Zip

Soil Farming Order No.	Soil Farming Location 1/4 1/4 1/4 1/4		
Sec.	Twp.	Rge.	County

The following facts are submitted:

Well Location (if applicable) 1/4 1/4 1/4	Sec.	Twp.	Rge.	County

Dimensions of pit contents: (attach additional page if more than one pit will be involved)	Length ft.	Width ft.	Depth ft.

Number of frac tanks (if applicable)	Total volume to be soil farmed bbls.	Number of acres to be soil farmed (include plot number if applicable)

Materials to be soil farmed are ☐ Liquids ☐ Solids ☐ Both

Proposed method of application: (and incorporation, if applicable)

Proposed loading rate: (complete for the most limiting parameter only)
(attach calculations for all parameters and copy of analysis of pit contents)

Dry Weight bbls/ac	TSS bbls/ac	Arsenic bbls/ac	Oil l& Grease bbls/ac	Chromium bbls/ac

Proposed date of commencement: _____ **completion:** _____

Executed this _____ day of _____, _____.

_____
Signature of Affiant

State of _____)
) SS
County of _____)

Before me, the undersigned authority, on this day personally appeared _____ known to me to be the person whose name is subscribed to the above instrument, who being by me duly sworn on oath, states that he is duly authorized to make the above report and that he has knowledge of the facts stated therein, and that said report is true and correct.

Subscribed and sworn to before me this _____ day of _____, _____.

_____
Notary Public

My commission expires: _____

The following minimum conditions or stipulations must be adhered to:

Maximum application rate _____ Minimum acreage required _____

A. The applicant shall notify the appropriate district office of the Commission at least 24 hours in advance of soil farming to allow a representative to be present to witness the work. The district office shall also be notified within 24 hours of the completion of each soil farming application.

B. A representative of the applicant shall be on the soil farming site at all times during application of the pit materials to the land.

C. Soil farming shall **not** be done:
   1. During precipitation events or when precipitation is imminent;
   2. When the soil moisture is at a level such that the soil would not readily take the addition of drilling fluids;
   3. When the ground is frozen; or
   4. When the wind velocity is such that even distribution of materials cannot be accomplished or the buffer zones cannot be maintained.

D. No soil farming shall be done within:
   1. 100 feet of a property line boundary;
   2. 50 feet of any stream not designated by Oklahoma Water Quality Standards;
   3. 300 feet of any actively-producing water well used for domestic, irrigation, or industrial purposes; or
   4. 1300 feet of any actively-producing water well used for municipal purposes.

E. No runoff or ponding of soil-farmed materials shall be allowed during application.

F. When the spray irrigation method is used and solids eventually accumulate on the soil surface to a one-eighth-inch depth, then the materials shall be incorporated prior to subsequent soil farming.

G. If the vegetative cover is destroyed or significantly damaged by disking, injection, or other practice associated with soil farming, the vegetative cover shall be reestablished within one year after the last soil farming application.

H. Soil farming shall be carried out within 2 months from the date of approval of the permit. At the end of the 2-month period, the permit shall expire by its own terms. The Manager of Pollution Abatement may, upon written request, separately grant up to two extensions of the permit for periods of 2 months each.

I. If the applicant violates the order, permit, or Rule 165:10-9-2(i)1, soil farming shall be discontinued and the Pollution Abatement Department shall be contacted immediately. The Pollution Abatement Department may revoke the permit and/or required the operator to do remedial work. If the permit is not revoked, soil farming may resume with the approval of the Pollution Abatement Department

J. Other _____

_____

_____

Permit No. CSF

☐ **APPROVED** ☐ **DISAPPROVED**

_____ _____

Pollution Abatement Department Date

The reason for disapproval is:

☐ Application incomplete ☐ Analysis incomplete ☐ Loading calculations incorrect ☐ Size of soil farming area too small

☐ Maximum cumulative loading would be exceeded ☐ Other _____

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