Oklahoma Comprehensive Water Plan

OCWP

Blue-Boggy Watershed Planning Region Report

Version 1.1

Oklahoma Water Resources Board

The objective of the Oklahoma Comprehensive Water Plan is to ensure a dependable water supply for all Oklahomans through integrated and coordinated water resources planning by providing the information necessary for water providers, policy-makers, and end users to make informed decisions concerning the use and management of Oklahoma's water resources.

This study, managed and executed by the Oklahoma Water Resources Board under its authority to update the Oklahoma Comprehensive Water Plan, was funded jointly through monies generously provided by the Oklahoma State Legislature and the federal government through cooperative agreements with the U.S. Army Corps of Engineers and Bureau of Reclamation.

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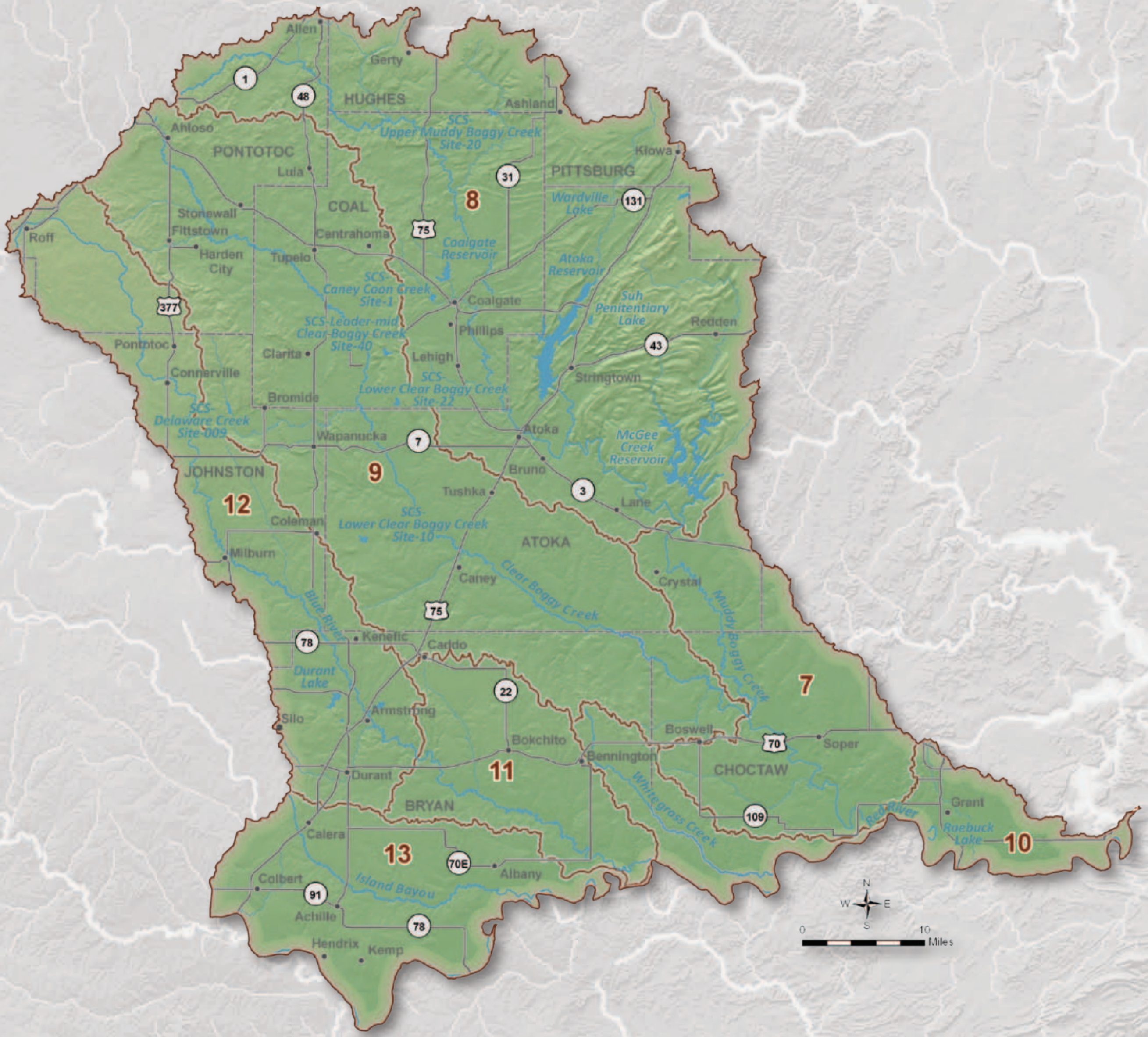
The online version of this 2012 OCWP Watershed Planning Region Report (Version 1.1) includes figures that have been updated since distribution of the original printed version. Revisions herein primarily pertain to the seasonality (i.e., the percent of total annual demand distributed by month) of Crop Irrigation demand. While the annual water demand remains unchanged, the timing and magnitude of projected gaps and depletions have been modified in some basins. The online version may also include other additional or updated data and information since the original version was printed.

Cover photo: Delaware Creek, Chris Neel, OWRB

Oklahoma Comprehensive Water Plan

Blue-Boggy Watershed Planning Region



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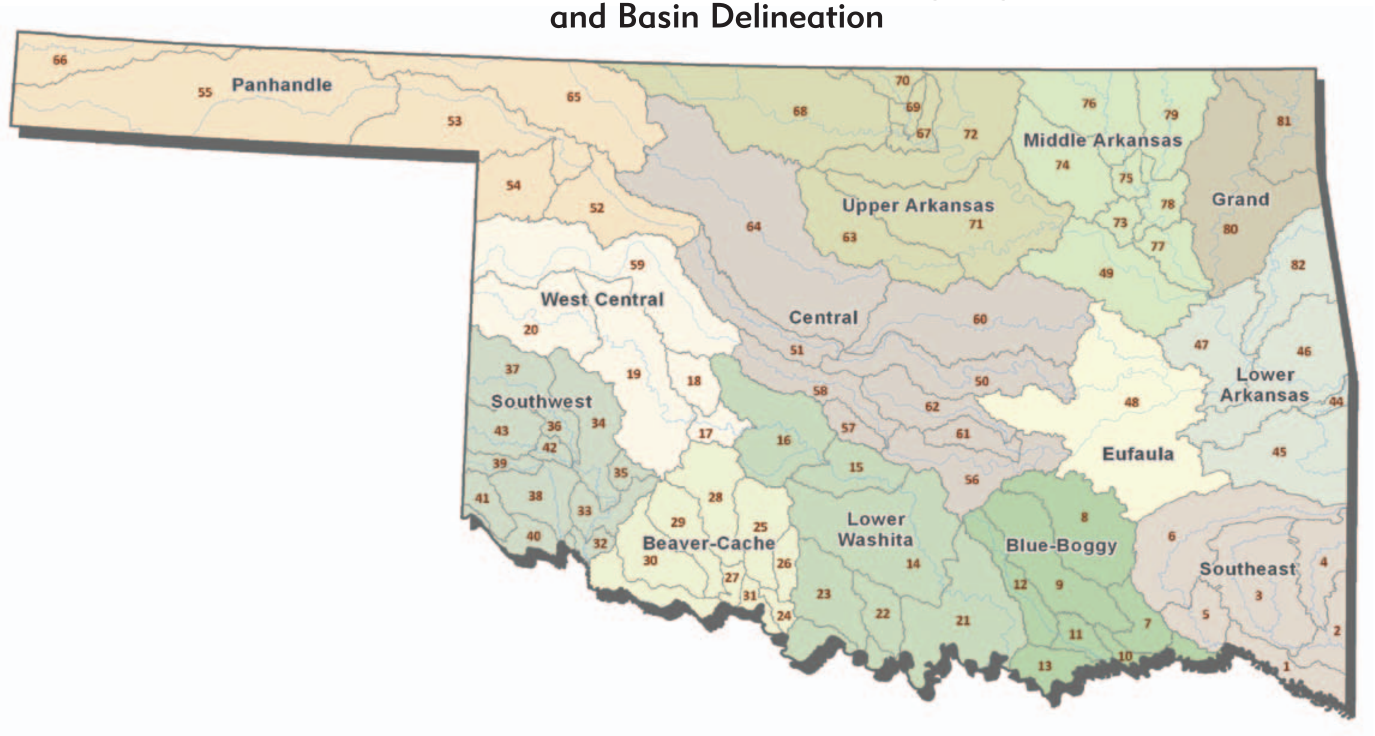


Introduction

The Oklahoma Comprehensive Water Plan (OCWP) was originally developed in 1980 and last updated in 1995. With the specific objective of establishing a reliable supply of water for state users throughout at least the next 50 years, the current update represents the most ambitious and intensive water planning effort ever undertaken by the state. The *2012 OCWP Update* is guided by two ultimate goals:

1. Provide safe and dependable water supply for all Oklahomans while improving the economy and protecting the environment.
2. Provide information so that water providers, policy makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

In accordance with the goals, the *2012 OCWP Update* has been developed under an innovative parallel-path approach: inclusive and dynamic public participation to build sound water policy complemented by detailed technical evaluations.

Also unique to this update are studies conducted according to specific geographic boundaries (watersheds) rather than political boundaries (counties). This new strategy involved dividing the state into 82 surface water basins for water supply availability analysis (see the OCWP *Physical Water Supply Availability Report*). Existing watershed boundaries were revised to include a United States Geological Survey (USGS) stream gage at or near the basin outlet (downstream boundary), where practical. To facilitate consideration of regional supply challenges and potential solutions, basins were aggregated into 13 distinct Watershed Planning Regions.

The primary factors in the determination of reliable future water supplies are physical supplies, water rights, water quality, and infrastructure. Gaps and depletions occur when demand exceeds supply, and can be attributed to physical supply, water rights, infrastructure, or water quality constraints.

This Watershed Planning Region report, one of 13 such documents prepared for the *2012 OCWP Update*, presents elements of technical studies pertinent to the Blue-Boggy Region. Each regional report presents information from both a regional and multiple basin perspective, including water supply/demand analysis results, forecasted water supply shortages, potential supply solutions and alternatives, and supporting technical information.

As a key foundation of OCWP technical work, a computer-based analysis tool, "Oklahoma H2O," was created to compare projected demands with physical supplies for each basin to identify areas of potential water shortages.

Integral to the development of these reports was the Oklahoma H2O tool, a sophisticated database and geographic information system (GIS) based analysis tool created to compare projected water demand to physical supplies in each of the 82 OCWP basins statewide. Recognizing that water planning is not a static process but rather a dynamic one, this versatile tool can be updated over time as new supply and demand data become available, and can be used to evaluate a variety of "what-if" scenarios at the basin level, such as a change in supply sources, demand, new reservoirs, and various other policy management scenarios.

Primary inputs to the model include demand projections for each decade through 2060, founded on widely-accepted methods and peer review of inputs and results by state and federal agency staff, industry representatives, and stakeholder groups for each demand sector. Surface water supply data for each of the 82 basins is based on 58 years of publicly-available daily streamflow gage data collected by the USGS. Groundwater resources were characterized using previously-developed assessments of groundwater aquifer storage and recharge rates.

Additional and supporting information gathered during development of the *2012 OCWP Update* is provided in the *OCWP Executive Report* and various OCWP supplemental reports. Assessments of statewide physical water availability and potential shortages are further documented in the OCWP *Physical Water Supply Availability Report*. Statewide water demand projection methods and results are detailed in the OCWP *Water Demand Forecast Report*. Permitting availability was evaluated based on the OWRB's administrative protocol and documented in the OCWP *Water Supply Permit Availability Report*. All supporting documentation can be found on the OWRB's website.

Regional Overview

The Blue-Boggy Watershed Planning Region includes seven basins (numbered 7-13 for reference). The southern portion of the region lies within the Coastal Plain physiography province and the northern part of the region intersects the Central Lowland and Ouachita provinces. The Blue-Boggy encompasses 3,670 square miles in southern Oklahoma, spanning from Pontotoc County to the Red River on the south and including all or portions of Hughes, Pittsburg, Coal, Johnston, Atoka, Bryan, and Choctaw Counties.

The region's terrain varies from lush pastures in the river bottoms to the rugged foothills of the Arbuckle and Ouachita Mountains. The region's climate is mild with annual mean temperatures varying from 61 °F to 64 °F. Annual average precipitation ranges from 39 inches in the northwest to 51 inches in the southeastern corner. Annual evaporation ranges from 63 inches per year to 55 inches per year.

The largest cities in the region include Durant (2010 population of 15,856), Atoka (3,107), and Coalgate (1,967). The greatest demand is from Crop Irrigation water use.

By 2060, this region is projected to have a total demand of 85,700 acre-feet per year (AFY), an increase of approximately 24,300 AFY (40%) from 2010.

Blue-Boggy Regional Summary

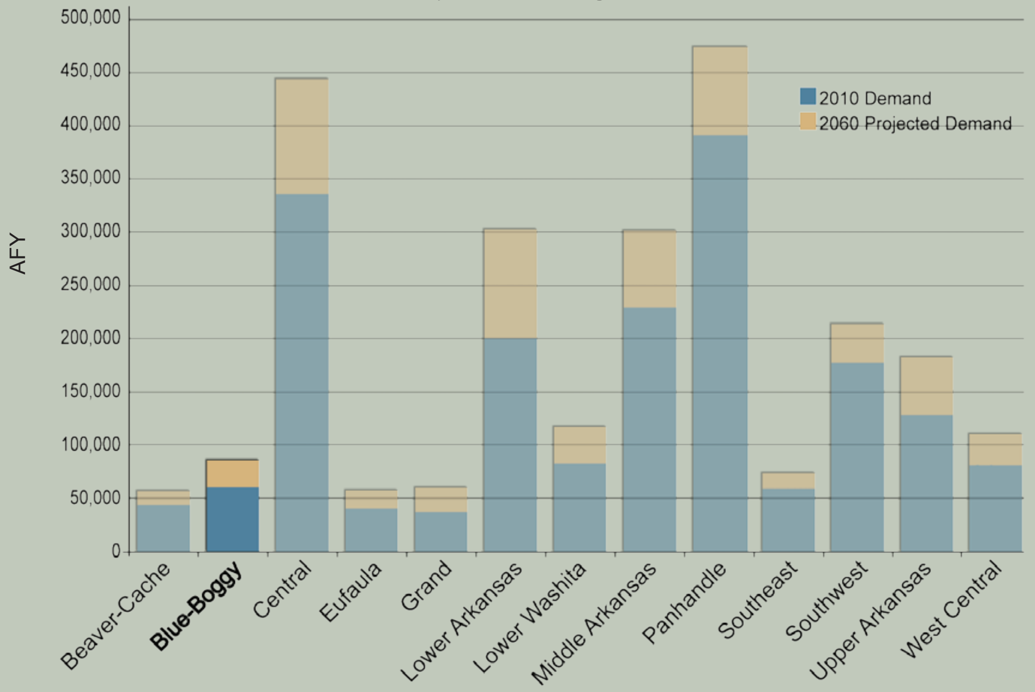
Synopsis

- The Blue-Boggy Watershed Planning Region relies primarily on surface water supplies (including reservoirs) and bedrock groundwater.
- It is anticipated that water users in the region will continue to rely on these sources to meet future demand.
- By 2020, surface water supplies may be insufficient at times to meet demand in Basins 9 and 13.
- By 2020, groundwater storage depletions may occur in Basins 8, 9, and 13 and eventually lead to higher pumping costs, the need for deeper wells, and potential changes to well yields or water quality.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps and alluvial groundwater storage depletions.
- Aquifer storage and recovery in Basins 12 and 13 could be considered to store variable surface water supplies, increase alluvial groundwater storage, and reduce adverse effects of localized storage depletions.
- Surface water alternatives, such as bedrock groundwater supplies and/or developing new reservoirs, could mitigate gaps without major impacts to groundwater storage.
- No basins within the region have been identified as water availability “hot spots,” areas where severe deficits or gaps in supply are anticipated. (See “Water Availability Analysis” in the *2012 OCWP Executive Report*.)

Blue-Boggy Region Demand Summary

Current Water Demand:	61,390 acre-feet/year (3% of state total)		
Largest Demand Sector:	Crop Irrigation (33% of regional total)		
Current Supply Sources:	71% SW	6% Alluvial GW	23% Bedrock GW
Projected Demand (2060):	85,700 acre-feet/year		
Growth (2010-2060):	24,310 acre-feet/year (40%)		

Current and Projected Regional Water Demand



The Blue-Boggy Region accounts for 3% of the state’s total water demand. The largest demand sectors are Crop Irrigation (33% of the region’s overall 2010 demand), Municipal and Industrial (27%), and Thermoelectric Power (22%).

Water Resources & Limitations

Surface Water

Surface water supplies including reservoirs are used to meet 71% of the Blue-Boggy Region’s demand. Surface water supply shortages are expected in Basins 9 and 13 by 2020, in Basin 12 by 2030, and in Basins 10 and 11 by 2040. Shortages are expected to be very infrequent, except in Basin 9 where there will be a 22% probability of gaps occurring in at least one month of the year by 2060. The region is supplied by four major rivers: the Red River, Muddy Boggy Creek, Clear Boggy Creek, and the Blue River. Surface water from Byrds Mill Spring, fed by groundwater from the Arbuckle-Simpson aquifer, supplies a substantial amount of water out-of-region to the City of Ada in the Central Watershed Planning Region. Historically, the rivers and creeks in the region have had substantial flows. However, infrequent periods of low flow can occur, particularly in the summer and fall due to seasonal and long-term trends in precipitation. Large reservoirs have been built on Muddy Boggy Creek and its tributaries to provide public water supply, flood control, and recreation. Major reservoirs in the Blue-Boggy Region include McGee Creek (Bureau of Reclamation), Atoka (Oklahoma City), and Coalgate (City of Coalgate). McGee Creek and Atoka are major out-of-basin supply sources for Oklahoma City and also supply local entities as well. With the exception of the Red River, surface water quality in the region is considered generally good relative to other regions in the state. However, several creeks in the region are impaired for Agricultural use due to high levels of chloride, sulfate and total dissolved solids (TDS). All basins in the region are expected to have available surface water for new permitting to meet local demand through 2060.

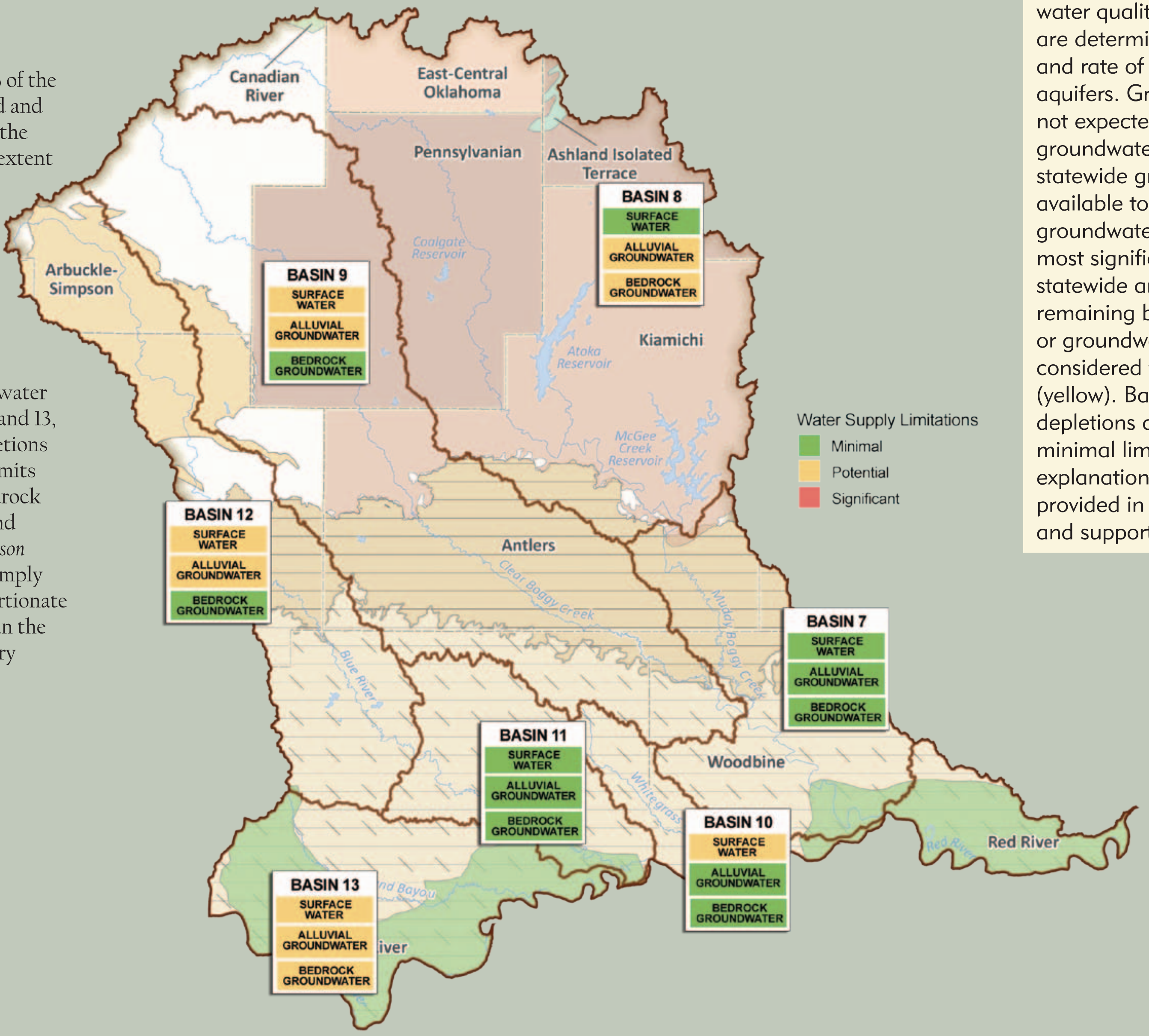
Alluvial Groundwater

Alluvial groundwater is used to meet 6% of the demand in the region. The majority of currently permitted alluvial groundwater withdrawals in the region are from the Red River aquifer. About one quarter of the current alluvial groundwater withdrawals are likely from domestic users who do not require a permit. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions from these aquifers may occur in the winter, summer, and fall. The largest storage depletions are projected to occur in the summer. The availability of permits is not expected to constrain the use of alluvial groundwater supplies to meet local demand through 2060.

Bedrock Groundwater

Bedrock groundwater is used to meet 23% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Arbuckle-Simpson aquifer and to a lesser extent the Antlers aquifer and multiple minor aquifers. The Arbuckle-Simpson aquifer has about 3.7 million acre-feet (AF) of groundwater storage in the region. The Antlers aquifer has about 19.8 million acre-feet (AF) of groundwater storage in the region. The recharge to the major aquifers is expected to be sufficient to meet all of the region's bedrock groundwater demand through 2060, except in Basins 8 and 13, where bedrock groundwater storage depletions may occur by 2020. The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060. Results of the *Arbuckle-Simpson Hydrology Study* indicate that in order to comply with 2003 Senate Bill 288 the equal proportionate share (EPS) will be significantly lower than the current 2 AFY/acre allocation for temporary permits.

Water Supply Limitations
Blue-Boggy Region



Water Supply Limitations

Surface water limitations are determined based on physical availability, water supply availability for new permits, and water quality. Groundwater limitations are determined based on the total size and rate of storage depletions in major aquifers. Groundwater permits are not expected to constrain the use of groundwater through 2060; insufficient statewide groundwater quality data are available to compare basins based on groundwater quality. Basins with the most significant water supply challenges statewide are indicated by a red box. The remaining basins with surface water gaps or groundwater storage depletions were considered to have potential limitations (yellow). Basins without gaps and storage depletions are considered to have minimal limitations (green). Detailed explanations of each basin's supplies are provided in individual basin summaries and supporting data and analysis.

Water Supply Options

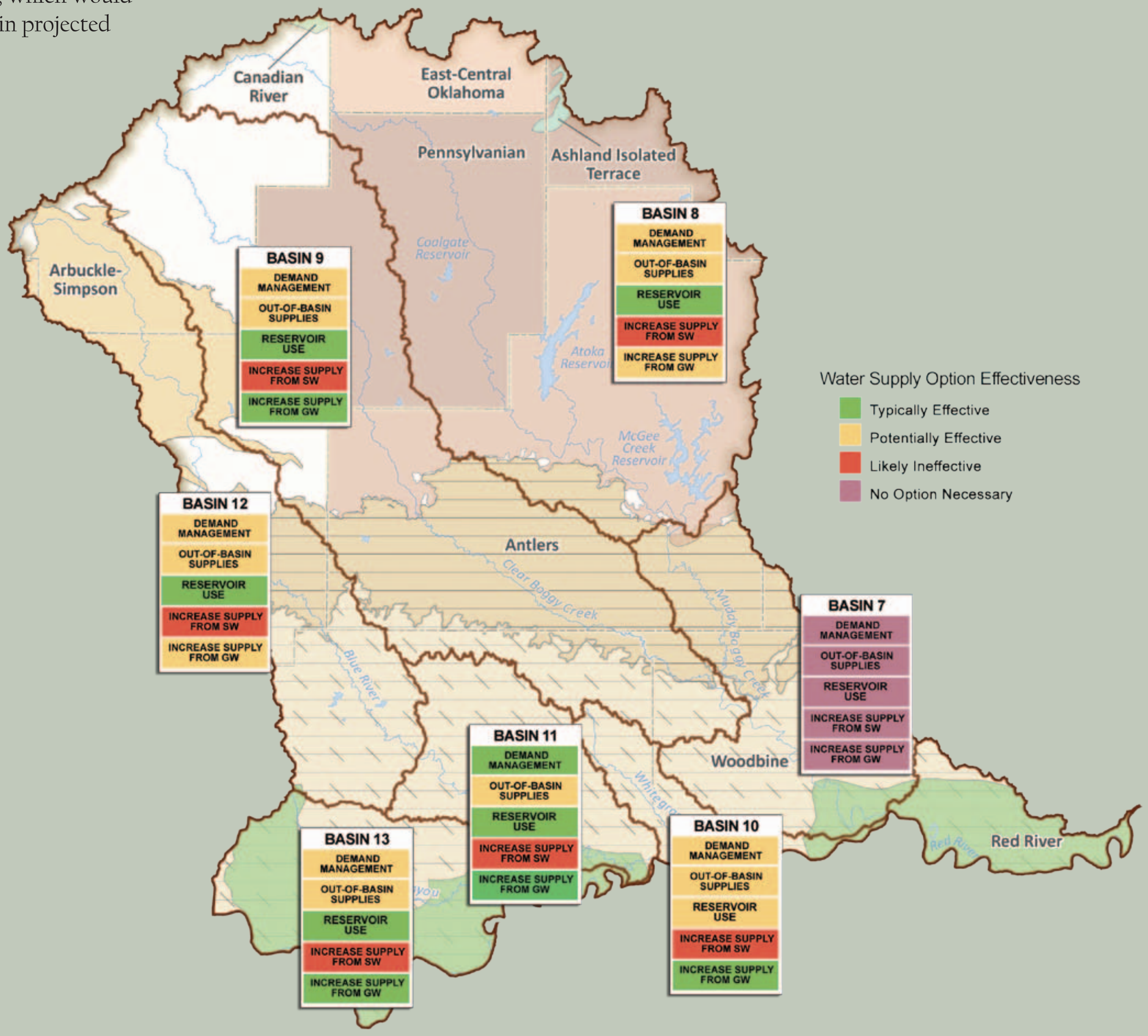
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Surface water supplies, reservoirs, and bedrock groundwater supplies are expected to continue to supply the majority of demand in the Blue-Boggy Region. Surface water users may have physical surface water supply shortages (gaps) in the future, except in Basins 7 and 8. Alluvial and bedrock groundwater storage depletions of major and minor aquifers are also projected in the future.

Water conservation could aid in reducing projected gaps and groundwater storage depletions or delaying the need for additional infrastructure. Moderately expanded permanent conservation activities could reduce gaps and storage depletions throughout the region, and in Basin 11, eliminate surface water gaps. Future reductions could occur from substantially expanded conservation activities. These measures would require a shift from crops with high water demand (e.g., corn for grain and forage crops) to low water demand crops such as sorghum for grain or wheat for grain, along with increased efficiency and increased public water supplier conservation. Due to the generally low frequency of shortages, temporary drought management measures may also be an effective water supply option.

New reservoirs and expanded use of existing reservoirs could enhance the dependability of surface water supplies and eliminate gaps throughout the region. McGee Creek Reservoir in Basin 8 has unpermitted yield that could supply new users. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified seven sites in the Blue-Boggy Region. These water sources could serve as in-basin storage or out-of-basin supplies to provide additional supplies to mitigate the region's surface water gaps and groundwater storage depletions. However, due to the distance from these reservoirs to demand points in each basin, this water supply option may not be cost-effective for many users.

The projected growth in surface water could instead be supplied in part by increased use of the Antlers or Red River aquifers, which would result in minimal or no increases in projected groundwater storage depletions.

Water Supply Options
Blue-Boggy Region



This evaluation was based upon results of physical water supply availability analyses, existing infrastructure, and other basin-specific factors.

Water Supply

Physical Water Availability

Surface Water Resources

Surface water has historically been the primary source of supply used to meet demand in the Blue-Boggy Region. The region's major streams include the Red River, Blue River, Clear Boggy Creek, and Muddy Boggy Creek. Many streams in this region experience a wide range of flows, including both periodic no flow conditions and flooding events. Flows in several basins show significant seasonal variation, with lower flows in late summer and early fall.

Water in the Red River (southern border of the Blue-Boggy region), which maintains substantial flows, may contain high levels of dissolved solids and chlorides in Basin 13 due to natural occurring salt pollution upstream from Denison Dam (Lake Texoma). Water quality improves farther downstream as higher quality flows from tributaries below Denison Dam enter the Red River.

The Blue River (210 miles long) flows southeasterly through Basins 12 and 11 to its confluence with the Red River at the outlet of Basin 11. The Blue River originates from headwater springs in the Arbuckle-Simpson aquifer.

Clear Boggy Creek (190 miles long) runs through Basin 9 in the center of the Blue-Boggy Region. It is a tributary to Muddy Boggy Creek at the outlet of Basin 9. The upper Blue River and some tributaries to Clear Boggy Creek originate from headwater springs in the Arbuckle-Simpson aquifer, the region's major groundwater source.

Muddy Boggy Creek (270 miles long) and its tributaries are located in the eastern portion of the Blue-Boggy Region in Basins 7 and 8. Muddy Boggy Creek is tributary to the Red River at the outlet of Basin 7. Major tributaries include McGee Creek (70 miles) and North Boggy Creek.

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. All three of the large reservoirs in the region are located in Basin 8 in the Muddy Boggy Creek watershed. McGee Creek Reservoir, the only federal reservoir in the region, was built by the Bureau of Reclamation on McGee Creek, a tributary of Muddy Boggy Creek, in 1987. Reservoir purposes include water supply, water quality control, flood control, recreation, and fish and wildlife mitigation. The reservoir provides a dependable water supply yield of about 71,800 AFY, of which 40,000 AFY is allocated to the City of Oklahoma City in the Central Watershed Planning Region and 24,608 AFY is allocated locally to the City of Atoka, Atoka County Commissioners, Southern Oklahoma Development Trust and the City of Coalgate. Atoka Reservoir, one of the state's largest municipal reservoirs, was constructed by Oklahoma City on the North Boggy Creek for the purposes of water supply and recreation. Most of the lake's dependable yield is allocated to Oklahoma City and is accessed via the Atoka pipeline (The city supplements Atoka's water supply by piping water from McGee Creek Reservoir). Additional water supply yield is allocated locally to the City of Atoka for public water supply and to OG&E for power purposes. Atoka Reservoir is currently fully allocated. Coalgate Reservoir supplies water to the City of Coalgate. The water supply yield of this reservoir is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated.

As important sources of surface water in Oklahoma, reservoirs and lakes help provide dependable water supply storage, especially when streams and rivers experience periods of low seasonal flow or drought.

There are other small Natural Resources Conservation Service (NRCS) and privately owned lakes in the region that provide water for agricultural water supply and recreation.

Reservoirs

Blue-Boggy Region

Reservoir Name	Primary Basin Number	Reservoir Owner/Operator	Year Built	Purposes[1]	Normal Pool Storage	Water Supply		Irrigation		Water Quality		Permitted Withdrawals	Remaining Water Supply Yield to be Permitted
						Storage	Yield	Storage	Yield	Storage	Yield		
					AF	AF	AFY	AF	AFY	AF	AFY	AFY	AFY
Atoka	8	City of Oklahoma City	1964	WS, R	105,195	123,500	92,067	0	0	0	0	93,952	0
Coalgate	8	City of Coalgate	1965	WS, FC, R	3,466	---	---	0	0	0	0	3,224	---
McGee Creek	8	Bureau of Reclamation	1987	WS, WQ, FC, R, FW	113,930	109,800	71,800	0	0	0	0	64,608	7,192

No known information is annotated as "---"

[1] *The "Purposes" represent the use(s), as authorized by the funding entity or dam owner(s), for the reservoir storage when constructed.*

WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water

Surface Water Resources

Blue-Boggy Region

Reservoirs in Oklahoma may serve multiple purposes, such as water supply, irrigation, recreation, hydropower generation, and flood control, and typically possess a specific volume of water storage assigned for each purpose.

Water Supply Availability Analysis

For OCWP physical water supply availability analysis, water supplies were divided into three categories: surface water, alluvial aquifers, and bedrock aquifers. Physically available surface water refers to water currently in streams, rivers, lakes, and reservoirs.

The range of historical surface water availability, including droughts, is well-represented in the Oklahoma H2O tool by 58 years of monthly streamflow data (1950 to 2007) recorded by the U.S. Geological Survey (USGS). Therefore, measured streamflow, which reflects current natural and human created conditions (runoff, diversions and use of water, and impoundments and reservoirs), is used to represent the physical water that may be available to meet projected demand.

The estimated average and minimum annual streamflow in 2060 were determined based on historic surface water flow measurements and projected baseline 2060 demand (see Water Demand section). The amount of streamflow in 2060 may vary from basin-level values, due to local variations in demands and local availability of supply sources. The estimated surface water supplies include changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure. Permitting, water quality, infrastructure, non-consumptive demand, and potential climate change implications are considered in separate OCWP analyses. Past reservoir operations are reflected and accounted for in the measured historical streamflow downstream of a reservoir. For this analysis, streamflow was adjusted to reflect interstate compact provisions in accordance with existing administrative protocol.

The amount of water a reservoir can provide from storage is referred to as its yield. The yield is considered the maximum amount of water a reservoir can dependably supply during critical drought periods. The unused yield of existing reservoirs was considered for this analysis. Future potential reservoir storage was considered as a water supply option.

Groundwater supplies are quantified by the amount of water that an aquifer holds ("stored" water) and the rate of aquifer recharge. In Oklahoma, recharge to aquifers is generally from precipitation that falls on the aquifer and percolates to the water table. In some cases, where the altitude of the water table is below the altitude of the stream-water surface, surface water can seep into the aquifer.

For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers, feature shallow water tables, and are exposed at the land surface, where precipitation can readily percolate to the water table. Alluvial aquifers are considered to be more hydrologically connected with streams than are bedrock aquifers and are therefore treated separately.

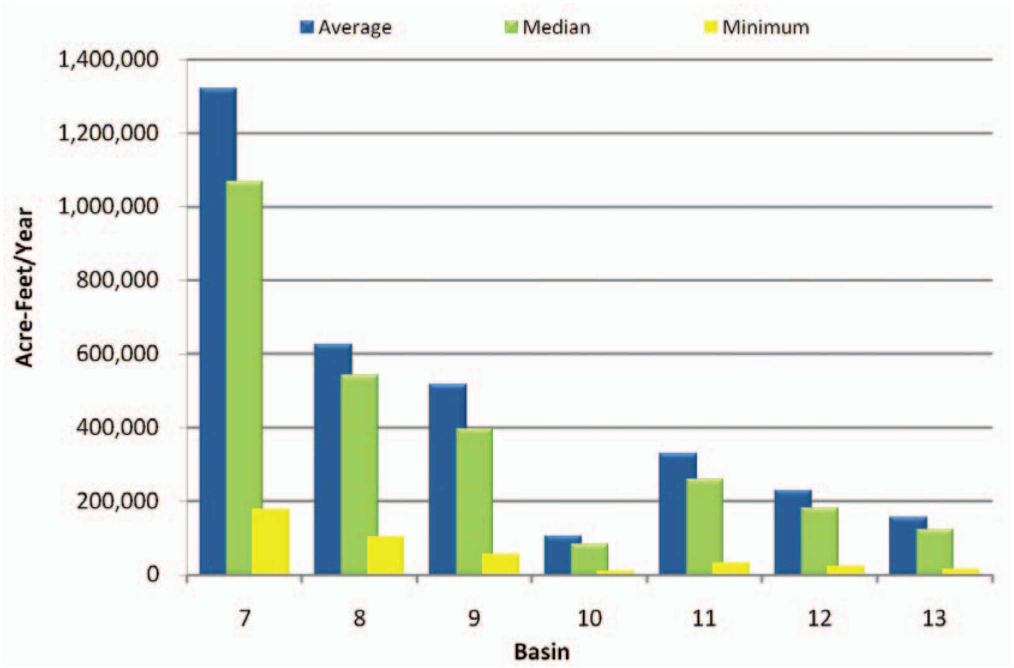
Bedrock aquifers consist of consolidated (solid) or partially consolidated rocks, such as sandstone, limestone, dolomite, and gypsum. Most bedrock aquifers in Oklahoma are exposed at land surface either entirely or in part. Recharge from precipitation is limited in areas where bedrock aquifers are not exposed.

For both alluvial and bedrock aquifers, this analysis was used to predict potential groundwater depletions based on the difference between the groundwater demand and recharge rate. While potential storage depletions do not affect the permit availability of water, it is important to understand the extent of these depletions.

More information is available in the OCWP *Physical Water Supply Availability Report* on the OWRB website.

Surface Water Flows (1950-2007)

Blue-Boggy Region



Surface water is the main source of supply in the Blue-Boggy Region. While the region's average physical surface water supply exceeds projected surface water demand in the region, gaps can occur due to seasonal, long-term hydrologic (drought), or localized variability in surface water flows. Several large reservoirs have been constructed to reduce the impacts of drier periods on surface water users.

Estimated Annual Streamflow in 2060

Blue-Boggy Region

	Basins						
	7	8	9	10	11	12	13
Streamflow Statistic	AFY						
Average Annual Flow	1,299,800	602,100	514,300	104,200	327,000	227,300	155,100
Minimum Annual Flow	164,200	86,200	54,500	10,000	31,000	21,400	14,300

Annual streamflow in 2060 was estimated using historical gaged flow and projections of increased surface water use from 2010 to 2060.

Groundwater Resources

Two major bedrock aquifers, the Antlers and the Arbuckle-Simpson, and two major alluvial aquifers, the Canadian River and Red River, are present in the Blue-Boggy Watershed Planning Region.

Withdrawing groundwater in quantities exceeding the amount of recharge to the aquifer may result in reduced aquifer storage. Therefore, both storage and recharge were considered in determining groundwater availability.

The Antlers aquifer is comprised of poorly cemented sandstone with some layers of sandy shale, silt, and clay. The depth to the top of the sandstone formation from the land surface varies from several feet to 1,000 feet and the saturated thickness ranges from less than 5 feet in the north to about 1,000 feet near the Red River. Large-capacity wells tapping the Antlers aquifer commonly yield 100 to 500 gallons per minute (gpm). Water quality is generally good, with water becoming slightly saline (dissolved solids greater than 1,000 mg/L) in the southern portions of the aquifer. The Antlers bedrock aquifer underlies portions of all basins in the region.

Areas without delineated aquifers may have groundwater present. However, specific quantities, yields, and water quality in these areas are currently unknown.

The Arbuckle-Simpson aquifer consists of several formations; about two-thirds of the aquifer consist of limestone and dolomite, with sandstone and shale present in some areas. The saturated thickness is estimated to be from 2,000 to 3,500 feet. Common well yields vary from 25 to 600 gpm, depending on the well location in the aquifer, with deeper wells yielding more than 1,000 gpm in some areas. The aquifer is the source of Byrds Mill, the largest spring in Oklahoma, and contributes flow to several spring-fed streams, including the Blue River and Delaware Creek. The Arbuckle-Simpson aquifer and surface water from Byrds Mill Spring supply a substantial amount of water out-of-region to the City of Ada in the Central Watershed Planning Region. Water quality is good with dissolved solids generally less than 500 mg/L. The aquifer underlies portions of Basins 9 and 12.

The Red River alluvial aquifer consists of clay, sandy clay, sand, and gravel. The aquifer supplies water for Municipal and Industrial, Crop Irrigation and domestic purposes. The average saturated thickness is estimated to be around 20-30 feet. However, little data are available concerning these deposits and their potential as a major source of groundwater. The aquifer is located in southern portions of Basins 7, 10, 11, and 13.

The Canadian River alluvial aquifer consists of clay and silt downgrading to fine- to coarse-grained sand with lenses of basal gravel. Formation thickness ranges from 20 to 40 feet in the alluvium with a maximum of 50 feet in the terrace deposits. Yields in the alluvium range between 100 and 400 gpm and between 50 and 100 gpm in the terrace. The water is a very hard calcium bicarbonate type with TDS concentrations of approximately 1,000 mg/L. However, the water is generally suitable for most municipal and industrial uses. The Canadian River alluvial and terrace deposits underlie a small portion of Basin 8.

Minor bedrock aquifers in the region include the East-Central Oklahoma, Kiamichi, Pennsylvanian, and Woodbine aquifers. Minor alluvial aquifers include the Ashland Isolated Terrace deposit. Non-delineated minor groundwater sources are also present in the region. Minor aquifers may have a significant amount of water in storage and high recharge rates but generally low yields of less than 50 gpm per well. Groundwater from minor aquifers is an important source of water for domestic and stock water use for individuals in outlying areas not served by rural water systems but may not have sufficient yields for large-volume users.

Permits to withdraw groundwater from aquifers (groundwater basins) where the maximum annual yield has not been set are "temporary" permits that allocate 2 AFY/acre. The temporary permit allocation is not based on storage, discharge or recharge amounts, but on a legislative (statute) estimate of maximum needs of most landowners to ensure sufficient availability of groundwater in advance of completed and approved aquifer studies. As a result, the estimated amount of Groundwater Available for New Permits may exceed the estimated aquifer storage amount. For aquifers (groundwater basins) where the maximum annual yield has been determined (with initial storage volumes estimated), updated estimates of amounts in storage were calculated based on actual reported use of groundwater instead of simulated usage from all lands.

Groundwater Resources
Blue-Boggy Region

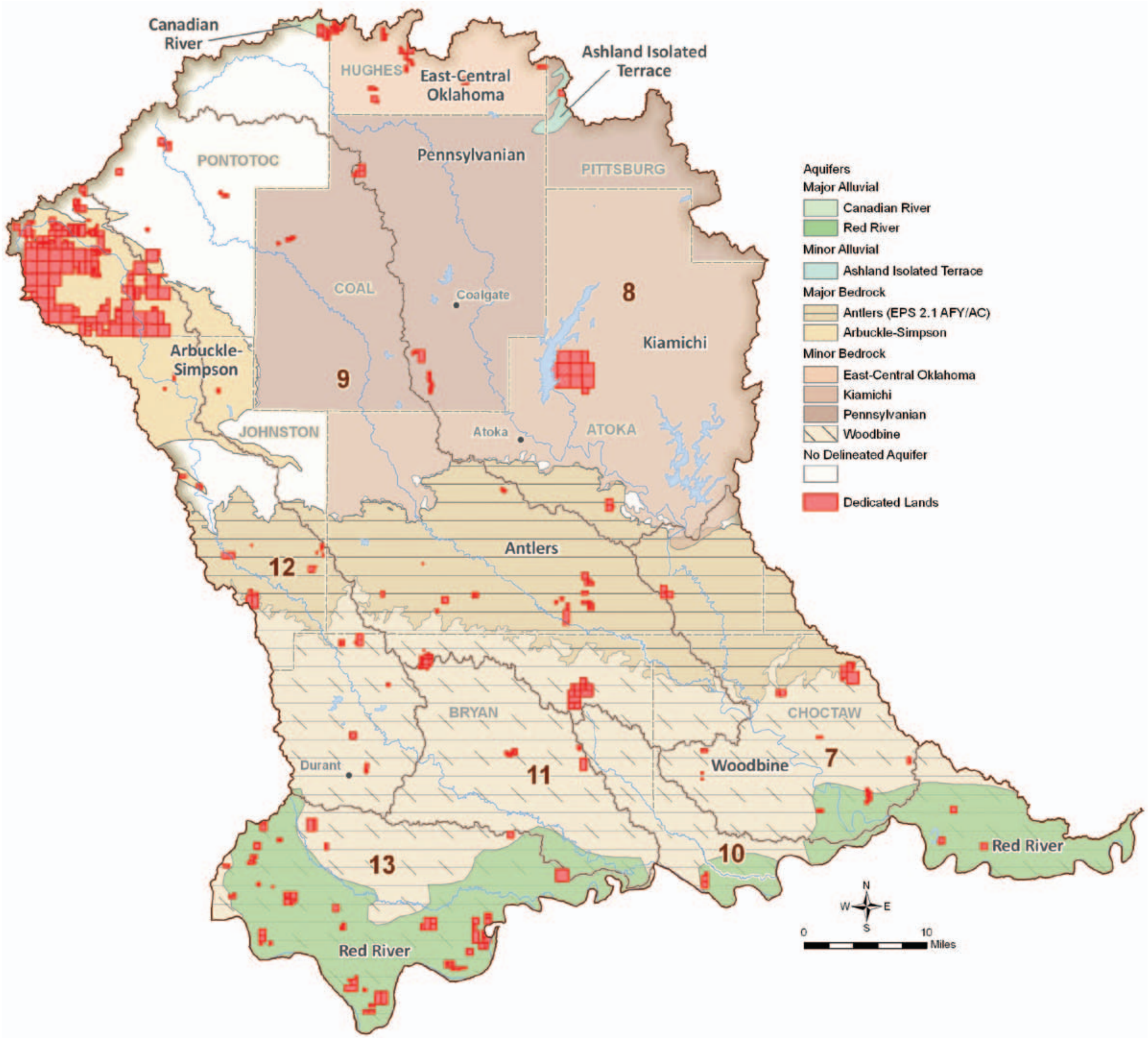
Aquifer			Portion of Region Overlaying Aquifer	Recharge Rate	Current Groundwater Rights	Aquifer Storage in Region	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	Percent	AFY	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	49%	0.3-1.7	15,600	19,872,000	2.1	2,404,100
Arbuckle-Simpson	Bedrock	Major	6%	5.58	106,300	3,714,000	temporary[2]	196,800
Canadian River	Alluvial	Major	<1%	2	700	11,000	temporary 2.0	3,600
Red River	Alluvial	Major	11%	5	3,800	911,000	temporary 2.0	505,500
Ashland Isolated Terrace	Alluvial	Minor	<1%	3.9	0	27,000	temporary 2.0	12,500
East-Central Oklahoma	Bedrock	Minor	3%	2.8	2,300	1,195,000	temporary 2.0	150,600
Kiamichi	Bedrock	Minor	14%	1.1	500	455,000	temporary 2.0	664,700
Pennsylvanian	Bedrock	Minor	17%	1.1	1,600	6,386,000	temporary 2.0	778,400
Woodbine	Bedrock	Minor	35%	2.15	3,400	12,630,000	temporary 2.0	1,621,900
Non-Delineated Groundwater Source	Alluvial	Minor			300			
Non-Delineated Groundwater Source	Bedrock	Minor			300			

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

2 Pursuant to 82 O.S. § 1020.9(A)(2), the temporary allocation for the Arbuckle-Simpson groundwater basin is subject to the OWRB's case-by case determination of what amount will not likely degrade or interfere with springs or streams emanating from the Arbuckle-Simpson.

Groundwater Resources

Blue-Boggy Region



Major bedrock aquifers in the Blue-Boggy Region include the Antlers (which overlies the Woodbine minor bedrock aquifer) and Arbuckle-Simpson. Major alluvial aquifers in the region include the Canadian River and Red River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

For OCWP water availability analysis, "permit availability" pertains to the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law.

If water authorized by a stream water right is not put to beneficial use within the specified time, the OWRB may reduce or cancel the unused amount and return the water to the public domain for appropriation to others.

Projections indicate that there will be surface water available for new permits through 2060 in all basins in the Southeast Region. For groundwater, equal proportionate shares in the Blue-Boggy Region currently range from 2 acre-foot per year (AFY) per acre to 2.1 AFY per acre, but results of the *Arbuckle-Simpson Hydrology Study* indicate that the equal proportionate share may be significantly lower than the current 2 AFY/acre allocation for the aquifer.

Surface Water Permit Availability

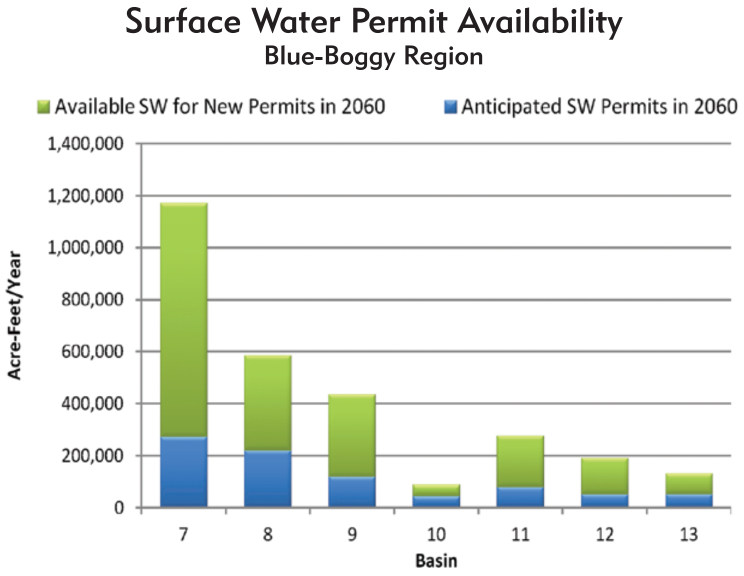
Oklahoma stream water laws are based on riparian and prior appropriation doctrines. Riparian rights to a reasonable use of water, in addition to domestic use, are not subject to permitting or oversight by the OWRB. An appropriative right to stream water is based on the prior appropriation doctrine, which is often described as "first in time, first in right." If a water shortage occurs, the diverter with the older appropriative water right will have first right among other appropriative right holders to divert the available water up to the authorized amount.

To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations, such as those associated with domestic use and interstate compact requirements.

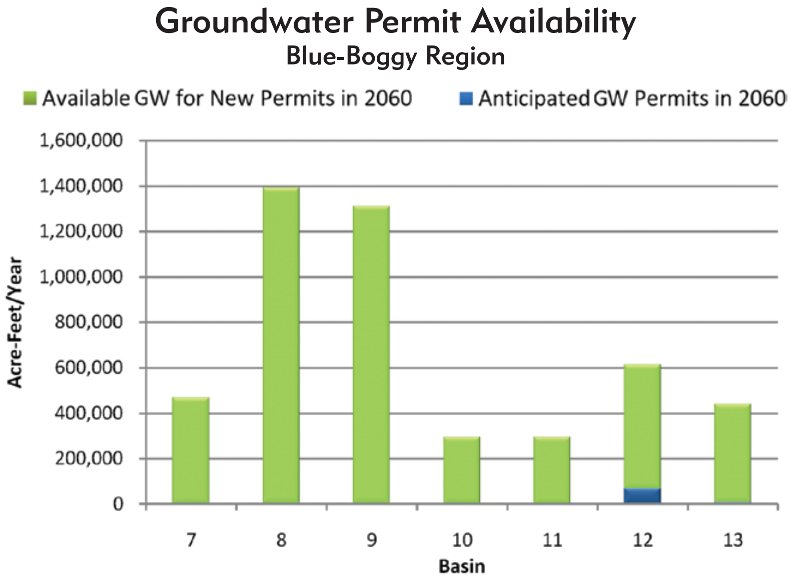
Groundwater Permit Availability

Groundwater available for permits in Oklahoma is generally based on the amount of land owned or leased that overlies a specific aquifer. For unstudied aquifers, temporary permits are granted allocating 2 AFY/acre. For studied aquifers, an "equal proportionate share" (EPS) is established based on the maximum annual yield of water in the aquifer, which is then allocated to each acre of land overlying the groundwater basin. Once an EPS has been established, temporary permits are then converted to regular permits and all new permits are based on the EPS.

For OCWP analysis, the geographical area overlying all aquifers in each basin was determined and the respective EPS or temporary permit allocations were applied. Total current and anticipated future permit needs were then calculated to project remaining groundwater permit availability.



Projections indicate that there will be surface water available for new permits through 2060 in all basins in the Blue-Boggy Region.



Projections indicate that there will be groundwater available for new permits through 2060 in all aquifers in the Blue-Boggy Region.

Water Quality

Water quality of the Blue-Boggy Watershed Planning Region is defined by several minor and major water supply reservoirs and the lower Red River watershed, including Muddy Boggy Creek and the Blue River. The area is a mixture of diverse ecoregions, including the Cross Timbers (CT), Arkansas Valley (AV), Ouachita Mountains (OM), South Central Plains (SCP), and South Central Texas Plains (SCTP).

The eastern edge of the Cross Timbers runs along the western portion of the region and includes the Eastern Cross Timbers to the south and Arbuckle Uplift to the north. Both areas are a mixture of rolling hills with more ridges to the south and inter-mixed plains to the north. Oak savanna and tall grass prairie are underlain by a mixture of sand, shale, clay, sandstone, and limestone in the Eastern Cross Timbers and mostly granite, dolomite, limestone, sandstone, and shale in the Arbuckle Uplift. Dominant land uses are pasture/grazing lands with some cropland to the south. Streams are diverse through the area. In the uplift, most streams run through deep or shallow channels with gravel/cobble/bedrock substrate. To the east, sand becomes more dominant. In the Eastern Cross Timbers, streams become lower gradient, dominated by fine substrates. Ecological diversity, impacted by the poor habitat and sedimentation, is higher in the Arbuckle Uplift, decreasing from west to east and north to south. The Arbuckle Uplift is best typified by the upper Blue River, while the Eastern Cross Timbers is exemplified by the middle/lower Blue River. Stream salinity is moderate with mean conductivity from 400 µS/cm (lower Blue River) to near 520 µS/cm on Delaware Creek. Streams have low nutrient concentrations and are typically oligotrophic with mean total phosphorus (TP) concentrations ranging from 0.08-0.09 ppm and total nitrogen (TN) from 0.65-0.66 ppm. Stream clarity is good with mean turbidities ranging from 20 NTU in the north to near 25 NTU in the south.

Lake Trophic Status

A lake's trophic state, essentially a measure of its biological productivity, is a major determinant of water quality.

Oligotrophic: Low primary productivity and/or low nutrient levels.

Mesotrophic: Moderate primary productivity with moderate nutrient levels.

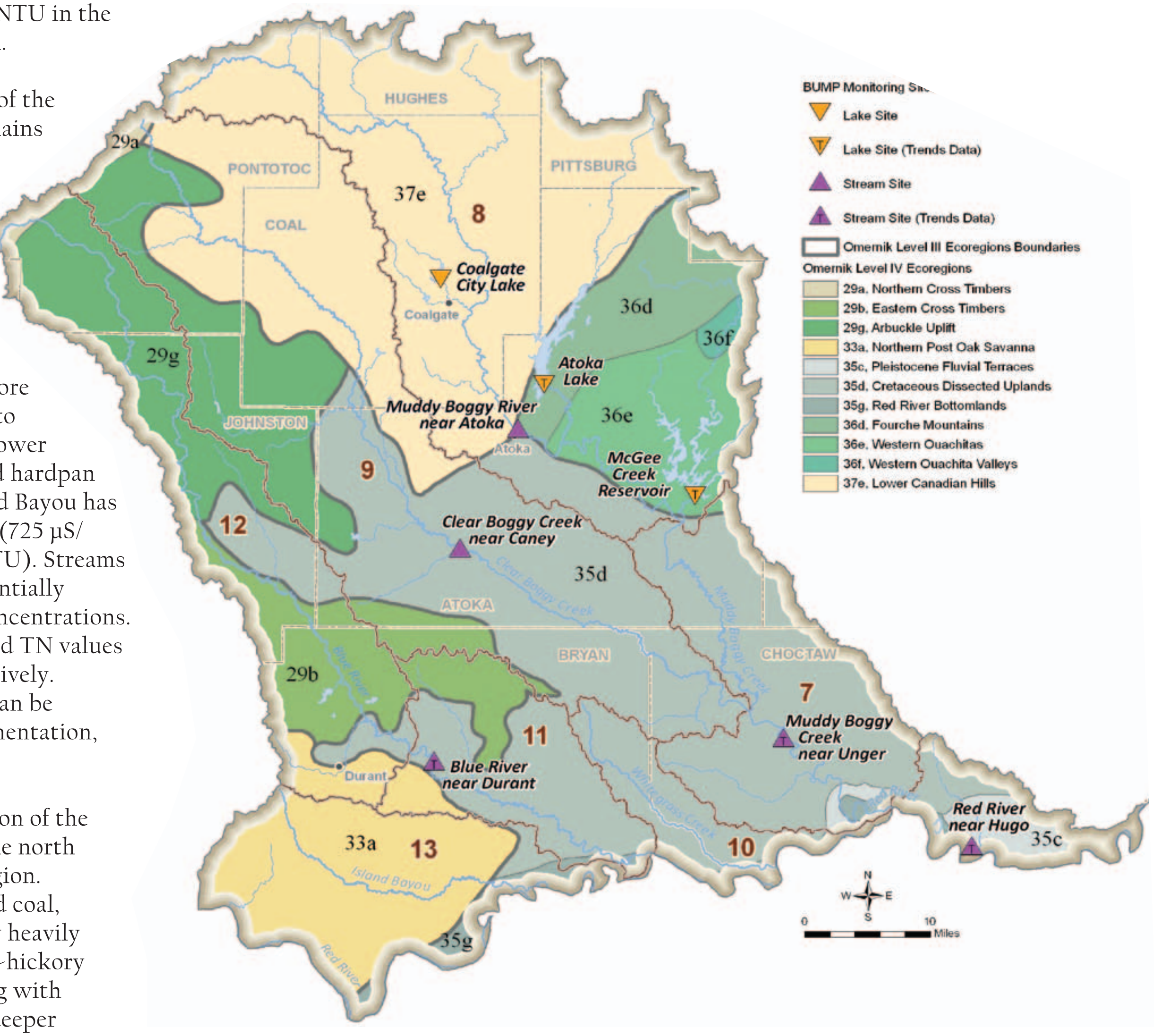
Eutrophic: High primary productivity and nutrient rich.

Hypereutrophic: Excessive primary productivity and excessive nutrients.

Lying in the southwestern corner of the region, the South Central Texas Plains cross into Oklahoma. Although a rolling plain, the Northern Post Oak Savanna is much flatter than areas to the north and east. Underlain mostly by shale, marl, limestone, sand, and gravel, the area is covered by tall grass prairie and oak savanna with cropland and pasture land more dominant than neighboring areas to the north and east. Streams have lower gradients with mud, fine sand, and hardpan clay as dominant substrates. Island Bayou has relatively high mean conductivity (725 µS/cm) and poor water clarity (58 NTU). Streams become less oligotrophic and potentially eutrophic with higher nutrient concentrations. Island Bayou registers mean TP and TN values of 0.26 ppm and 0.93 ppm, respectively. Ecological diversity is lower and can be impacted by channelization, sedimentation, and poor habitat.

The Lower Canadian Hills ecoregion of the Arkansas Valley covers much of the north central portion of the planning region. Underlain by shale, sandstone, and coal, this transitional area is covered by heavily wooded hills and a mixture of oak-hickory and oak-hickory-pine forests along with intervening prairies. Streams are deeper with more diverse habitat than the Northern Cross Timbers, but do not have the ecological diversity of the Arkansas Valley and Ouachita Mountain ecoregions to the east/southeast. Diversity can be impacted by sedimentation and habitat degradation. The area is best represented by the upper Muddy Boggy Creek and its tributaries, including North Boggy and Clear Boggy Creek. Municipal water supply reservoirs include Coalgate City and Atoka Lakes. Salinity is typically low to moderate with lake conductivity values below 100 µS/cm and stream conductivity at the Muddy Boggy less than 275 µS/cm. However, the mean conductivity of Clear Boggy Creek is near 450 µS/cm while North Boggy Creek is 1,220 µS/cm. Water clarity is typically average to poor.

Ecoregions
Blue-Boggy Region



The Blue-Boggy Planning Region is a transitional area with significant contributions from several ecoregions, including the Cross Timbers, Arkansas Valley, Ouachita Mountains, South Central Plains, and South Central Texas Plains. Water quality is highly influenced by both geology and land use practices, and ranges from poor to excellent depending on drainage and location.

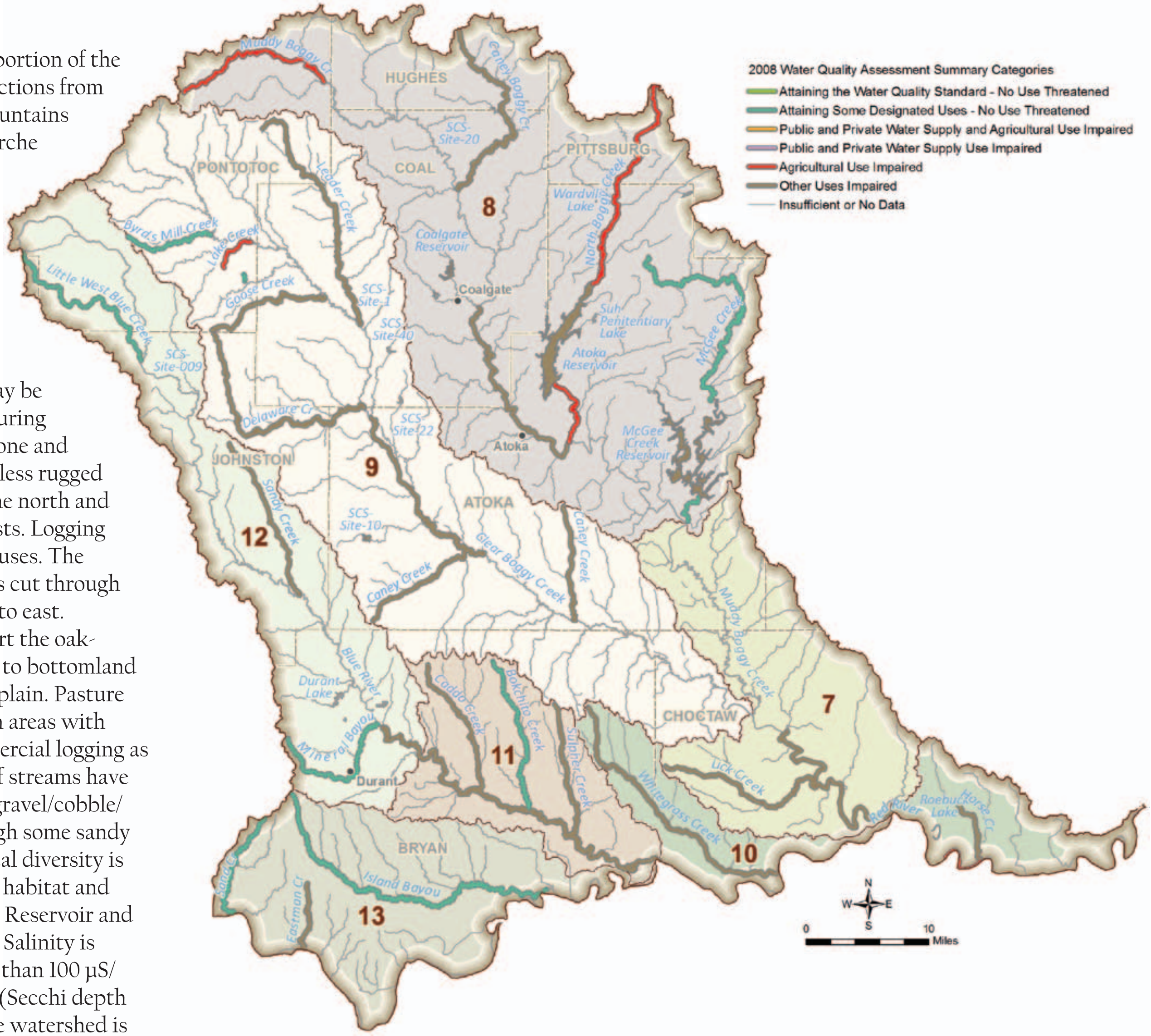
The Clear and Muddy Boggy have turbidity averages of 39 and 51 NTU while lake Secchi depth means range from 25-33 cm. The North Boggy has nearly excellent clarity with mean turbidity of 14 NTU. Streams are oligotrophic to eutrophic. Nutrient values range from low on the North Boggy (TP = 0.06 ppm; TN = 0.48 ppm) to moderate on Muddy Boggy (TP = 0.12 ppm; TN = 1.02 ppm). Lakes are phosphorus limited, ranging from mesotrophic (Coalgate City) to eutrophic (Atoka).

To the east of the AV lies a small portion of the Ouachita Mountains with intersections from the western Ouachita Valleys/Mountains and Fourche Mountains. The Fourche Mountains have long, rugged, steep ridges with narrow to broad shale valleys. Natural vegetation is mostly oak-hickory-pine forests with intervening native grasslands and pasture land/hay fields. Streams have excellent habitat with low to high gradients but may be turbid with disconnected pools during the summer. Underlain by sandstone and shale, the Western Ouachitas are less rugged than the Fourche Mountains to the north and covered by oak-hickory-pine forests. Logging and recreation are the major land uses. The narrow Western Ouachita Valleys cut through the mountains, mostly from west to east. Valley uplands continue to support the oak-hickory-pine forests but give way to bottomland hardwoods in the low-lying floodplain. Pasture land and hay fields dominate open areas with agriculture, recreation, and commercial logging as primary land uses. The majority of streams have moderate to high gradients with gravel/cobble/boulder/bedrock bottoms, although some sandy bottom streams do exist. Ecological diversity is high but can be impacted by poor habitat and sedimentation. The McGee Creek Reservoir and its watershed exemplify this area. Salinity is low with conductivity values less than 100 µS/cm, and water clarity is excellent (Secchi depth = 149 cm). Phosphorus limited, the watershed is mesotrophic and has low nutrient concentrations (TP = 0.03 ppm; TN = 0.35 ppm).

Finally, the Cretaceous Dissected Uplands of the South Central Plains cover most of the southern half to two-thirds of the region with Fluvial Terraces and Red River Bottomlands running along the southern border. Uplands are underlain by a mixture of sand, clay and gravel, characteristic of the Ouachita Mountains. Uplands are covered by oak-hickory-pine forests with pasture land and some remaining natural grasslands. Upland streams may have moderate gradients with lower organic content but typically are more turbid and slightly harder.

Water Quality Impairments

Blue-Boggy Region



Regional water quality impairments based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Some surface waters in this region have elevated levels of turbidity.

Water Quality Impairments

A waterbody is considered to be impaired when its quality does not meet the standards prescribed for its beneficial uses. For example, impairment of the Public and Private Water Supply beneficial use means the use of the waterbody as a drinking water supply is hindered. Impairment of the Agricultural use means the use of the waterbody for livestock watering, irrigation or other agricultural uses is hindered. Impairments can exist for other uses such as Fish and Wildlife Propagation or Recreation.

The Beneficial Use Monitoring Program (BUMP), established in 1998 to document and quantify impairments of assigned beneficial uses of the state's lakes and streams, provides information for supporting and updating the OWQS and prioritizing pollution control programs. A set of rules known as "use support assessment protocols" is also used to determine whether beneficial uses of waterbodies are being supported.

In an individual waterbody, after impairments have been identified, a Total Maximum Daily Load (TMDL) study is conducted to establish the sources of impairments—whether from point sources (discharges) or non-point sources (runoff). The study will then determine the amount of reduction necessary to meet the applicable water quality standards in that waterbody and allocate loads among the various contributors of pollution.

For more detailed review of the state's water quality conditions, see the most recent versions of the OWRB's BUMP Report, and the *Oklahoma Integrated Water Quality Assessment Report*, a comprehensive assessment of water quality in Oklahoma's streams and lakes required by the federal Clean Water Act and developed by the ODEQ.

Water Quality Standards and Implementation

The Oklahoma Water Quality Standards (OWQS) are the cornerstone of the state's water quality management programs. The OWQS are a set of rules promulgated under the federal Clean Water Act and state statutes, designed to maintain and protect the quality of the state's waters. The OWQS designate beneficial uses for streams, lakes, other bodies of surface water, and groundwater that has a mean concentration of Total Dissolved Solids (TDS) of 10,000 milligrams per liter or less. Beneficial uses are the activities for which a waterbody can be used based on physical, chemical, and biological characteristics as well as geographic setting, scenic quality, and economic considerations. Beneficial uses include categories such as Fish and Wildlife Propagation, Public and Private Water Supply, Primary (or Secondary) Body Contact Recreation, Agriculture, and Aesthetics.

The OWQS also contain standards for maintaining and protecting these uses. The purpose of the OWQS is to promote and protect as many beneficial uses as are attainable and to assure that degradation of existing quality of waters of the state does not occur.

The OWQS are applicable to all activities which may affect the water quality of waters of the state, and are to be utilized by all state environmental agencies in implementing their programs to protect water quality. Some examples of these implementation programs are permits for point source (e.g. municipal and industrial) discharges into waters of the state; authorizations for waste disposal from concentrated animal feeding operations; regulation of runoff from nonpoint sources; and corrective actions to clean up polluted waters.

More information about OWQS and the latest revisions can be found on the OWRB website.

Water Quality Standards Implementation
Blue-Boggy Region

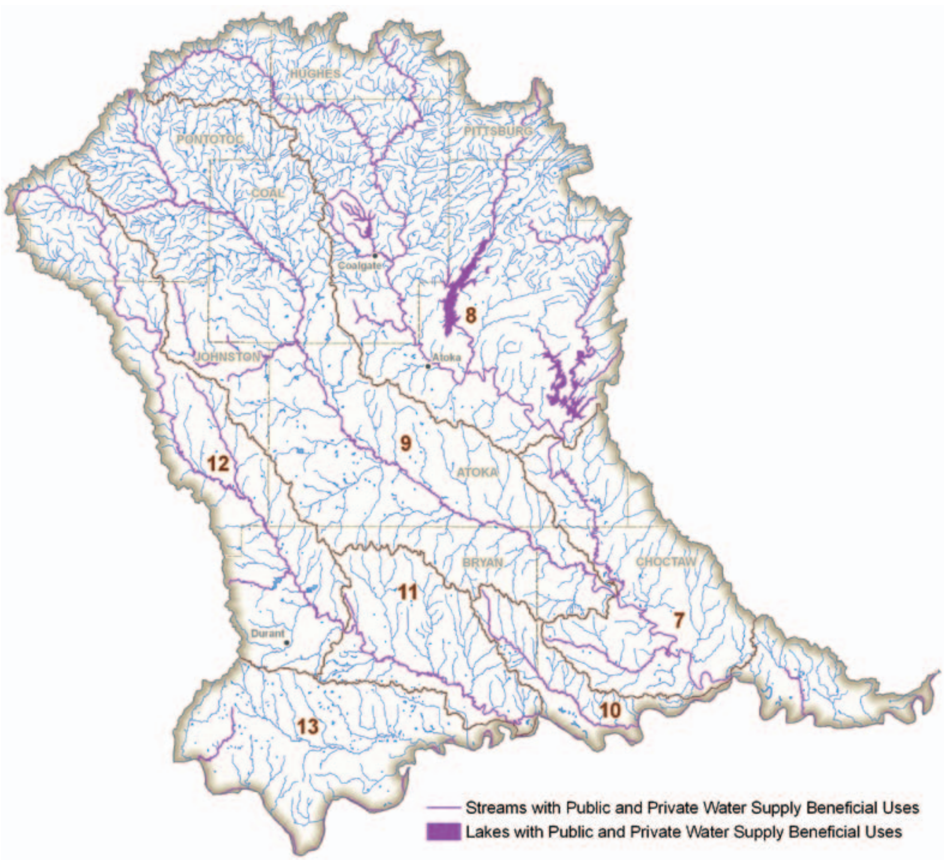
The Oklahoma Department of Environmental Quality has completed TMDL studies on Eastman Creek, Blue River, and Caney Creek. Several other TMDL studies are underway or scheduled.

Example waterbodies include the middle/lower Clear and Muddy Boggy. Salinity is moderate with conductivity values ranging from 280 µS/cm on Clear Boggy to near 340 µS/cm on Muddy Boggy. Clarity is average with turbidity means between 35-50 NTU. Streams are oligotrophic to eutrophic with moderate nutrient concentrations (TP = 0.13-0.15 ppm; TN = 0.76-0.86 ppm). Lowlands contain southern bottomland forests and extensive wetlands. Agriculture, recreation, and commercial logging are the major land uses. Streams have low to moderate gradients with mostly loose sediments but some gravel/cobble bottoms, and while many do not have perennial flow, pools are maintained. Ecological diversity is moderate to high, increasing on a west to east gradient, but can be impacted by poor habitat and sedimentation. The Red River and several tributaries (including Whitegrass Creek) are excellent representative waterbodies. Whitegrass Creek is typical of most tributaries with moderate salinity (conductivity = 260 µS/cm), poor clarity (turbidity = 115 NTU), and moderate nutrient concentrations (TP = 0.11 ppm; TN = 0.68 ppm). With influences from the Lake Texoma watershed, the Red River mainstem has higher salinity (conductivity = 1,220 µS/cm) but is much less turbid (turbidity = 38 NTU). The river is eutrophic with similar nutrient concentrations (TP = 0.12 ppm; TN = 0.90 ppm).

The Blue-Boggy region is underlain by several major and minor bedrock and alluvial aquifers. Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed and data are available from various sources. Water from the Canadian River alluvium and terrace aquifer is predominantly of a calcium magnesium bicarbonate type and variable in dissolved solids content. The Red River alluvium typically has much higher concentrations of dissolved solids. They are generally suitable for most purposes. However, the alluvium and terrace aquifers are highly vulnerable to contamination from surface activities due to their high porosities and permeabilities and shallow water tables. The Antlers Sandstone formation is the most extensive major bedrock aquifer in the region. It runs through the middle portion of the region. Water quality is generally good with dissolved solids between 200 and 1,000 mg/L. Water becomes slightly saline in the southern portions of the aquifer with dissolved solids greater than 1,000 ppm. It is suitable for most uses, but the ODEQ has identified several wells in this aquifer with elevated nitrate levels, and some wells show consistently low pH values.

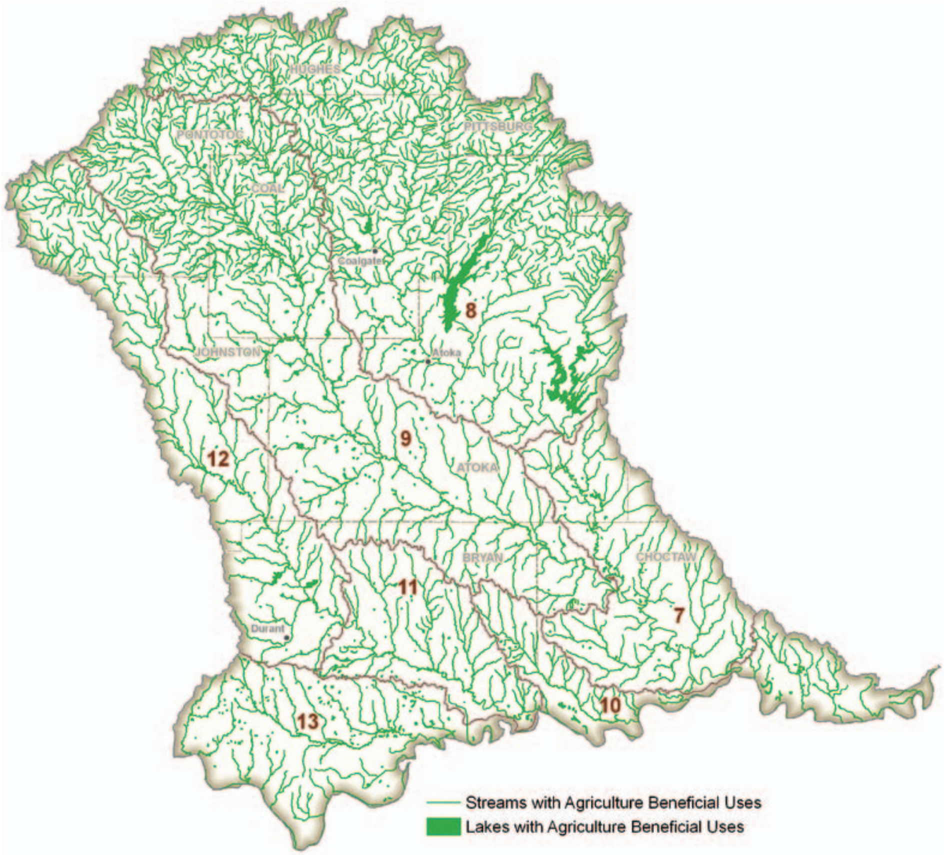
Surface Waters with Designated Beneficial Use for Public/Private Water Supply

Blue-Boggy Region



Surface Waters with Designated Beneficial Use for Agriculture

Blue-Boggy Region



Surface Water Protection

The Oklahoma Water Quality Standards (OWQS) provide protection for surface waters in many ways.

Appendix B Areas are designated in the OWQS as containing waters of recreational and/or ecological significance. Discharges to waterbodies may be limited in these areas.

Source Water Protection Areas are derived from the state's Source Water Protection Program, which analyzes existing and potential threats to the quality of public drinking water in Oklahoma.

The **High Quality Waters** designation in the OWQS refers to waters that exhibit water quality exceeding levels necessary to support the propagation of fishes, shellfishes, wildlife, and recreation in and on the water. This designation prohibits any new point source discharges or additional load or increased concentration of specified pollutants.

The **Sensitive Water Supplies (SWS)** designation applies to public and private water supplies possessing conditions making them more susceptible to pollution events, thus requiring additional protection. This designation restricts point source discharges in the watershed and institutes a 10 μg/L (micrograms per liter) chlorophyll-a criterion to protect against taste and odor problems and reduce water treatment costs.

Outstanding Resource Waters are those constituting outstanding resources or of exceptional recreational and/or ecological significance. This designation prohibits any new point source discharges or additional load or increased concentration of specified pollutants.

Waters designated as **Scenic Rivers** in Appendix A of the OWQS are protected through restrictions on point source discharges in the watershed. A 0.037 mg/L total phosphorus criterion is applied to all Scenic Rivers in Oklahoma.

Nutrient-Limited Watersheds are those containing a waterbody with a designated beneficial use that is adversely affected by excess nutrients.

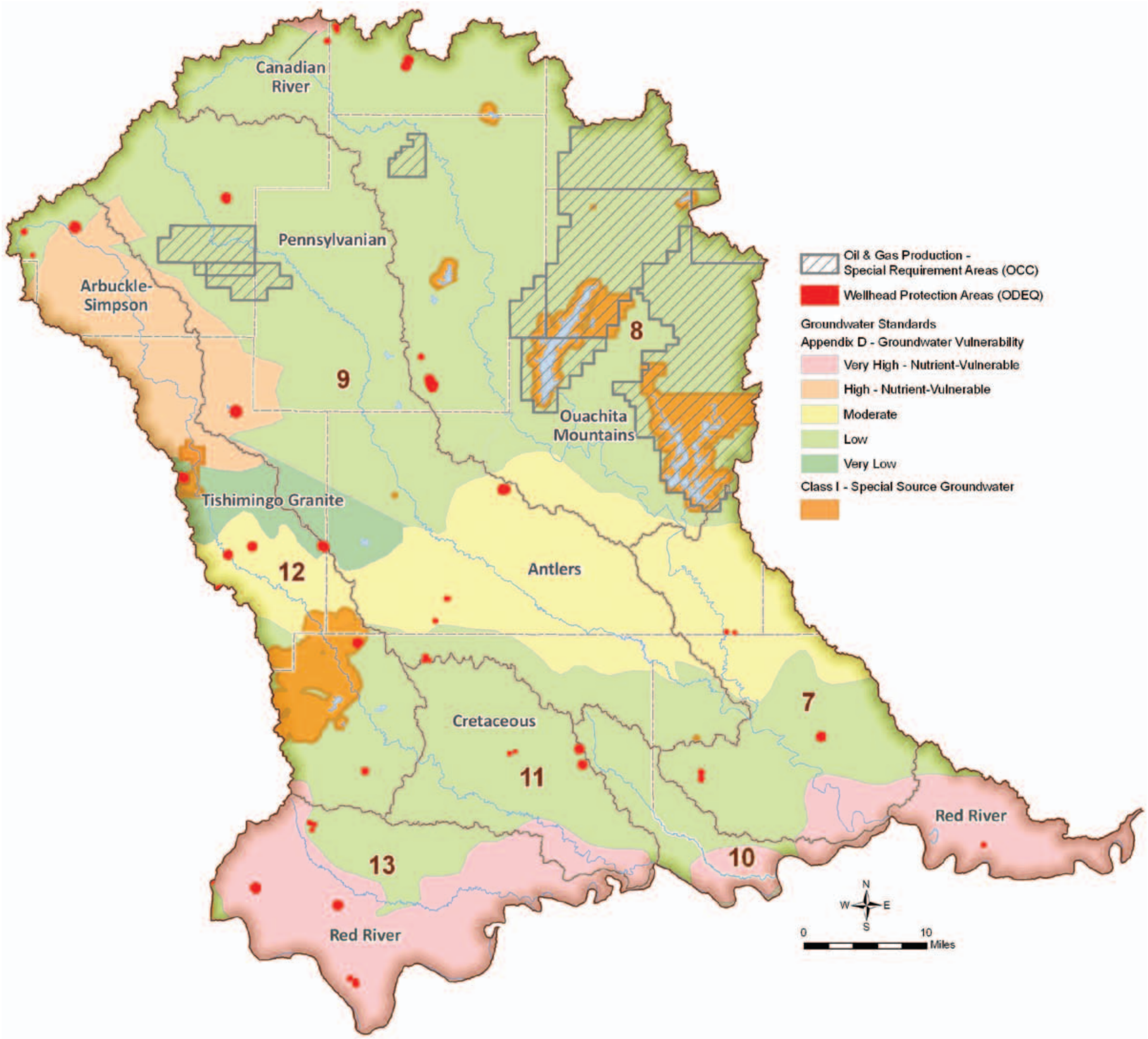
Surface Water Protection Areas

Blue-Boggy Region

Because Durant Lake is a public water supply reservoir and has a relatively small watershed, it could potentially benefit from a SWS designation. This designation could provide protection from new or increased loading from point sources in the watersheds. This additional protection would also provide limits for algae (chlorophyll-a) that can cause taste and odor problems and increased treatment costs.

Groundwater Protection Areas

Blue-Boggy Region



Various types of protection are in place to prevent degradation of groundwater and levels of vulnerability. The Red River alluvial aquifer has been identified by the OWRB as highly vulnerable while the Arbuckle-Simpson aquifer has been identified as very highly vulnerable. These aquifers currently lack protection to prevent degradation.

Groundwater Protection

The Oklahoma Water Quality Standards (OWQS) sets the criteria for protection of groundwater quality as follows: "If the concentration found in the test sample exceeds [detection limit], or if other substances in the groundwater are found in concentrations greater than those found in background conditions, that groundwater shall be deemed to be polluted and corrective action may be required."

Wellhead Protection Areas are established by the Oklahoma Department of Environmental Quality (ODEQ) to improve drinking water quality through the protection of groundwater supplies. The primary goal is to minimize the risk of pollution by limiting potential pollution-related activities on land around public water supplies.

Oil and Gas Production Special Requirement Areas, enacted to protect groundwater and/or surface water, can consist of specially lined drilling mud pits (to prevent leaks and spills) or tanks whose contents are removed upon completion of drilling activities; well set-back distances from streams and lakes; restrictions on fluids and chemicals; or other related protective measures.

Nutrient-Vulnerable Groundwater is a designation given to certain hydrogeologic basins that are designated by the OWRB as having high or very high vulnerability to contamination from surface sources of pollution. This designation can impact land application of manure for regulated agriculture facilities.

Class 1 Special Source Groundwaters are those of exceptional quality and particularly vulnerable to contamination. This classification includes groundwaters located underneath watersheds of Scenic Rivers, within OWQS Appendix B areas, or underneath wellhead or source water protection areas.

Appendix H Limited Areas of Groundwater are localized areas where quality is unsuitable for default beneficial uses due to natural conditions or irreversible human-induced pollution.

NOTE: The State of Oklahoma has conducted a successful surface water quality monitoring program for more than fifteen years. A new comprehensive groundwater quality monitoring program is in the implementation phase and will soon provide a comparable long-term groundwater resource data set.

Water Quality Trends Study

As part of the *2012 OCWP Update*, OWRB monitoring staff compiled more than ten years of Beneficial Use Monitoring Program (BUMP) data and other resources to initiate an ongoing statewide comprehensive analysis of surface water quality trends.

Reservoir Trends: Water quality trends for reservoirs were analyzed for chlorophyll-a, conductivity, total nitrogen, total phosphorus, and turbidity at sixty-five reservoirs across the state. Data sets were of various lengths, depending on the station's period of record. The direction and magnitude of trends varies throughout the state and within regions. However, when considered statewide, the final trend analysis revealed several notable details.

- Chlorophyll-a and nutrient concentrations continue to increase at a number of lakes. The proportions of lakes exhibiting a significant upward trend were 42% for chlorophyll-a, 45% for total nitrogen, and 12% for total phosphorus.
- Likewise, conductivity and turbidity have trended upward over time. Nearly 28% of lakes show a significant upward trend in turbidity, while nearly 45% demonstrate a significant upward trend for conductivity.

Stream Trends: Water quality trends for streams were analyzed for conductivity, total nitrogen, total phosphorus, and turbidity at sixty river stations across the state. Data sets were of various lengths, depending on the station's period of record, but generally, data were divided into historical and recent datasets and analyzed separately and as a whole. The direction and magnitude of trends varies throughout the state and within regions. However, when considered statewide, the final trend analysis revealed several notable details.

- Total nitrogen and phosphorus are very different when comparing period of record to more recent data. When considering the entire period of record, approximately 80% of stations showed a downward trend in nutrients. However, if only the most recent data (approximately 10 years) are considered, the percentage of stations with a downward trend decreases to 13% for nitrogen and 30% for phosphorus. The drop is accounted for in stations with either significant upward trends or no detectable trend.
- Likewise, general turbidity trends have changed over time. Over the entire period of record, approximately 60% of stations demonstrated a significant upward trend. However, more recently, that proportion has dropped to less than 10%.
- Similarly, general conductivity trends have changed over time, albeit less dramatically. Over the entire period of record, approximately 45% of stations demonstrated a significant upward trend. However, more recently, that proportion has dropped to less than 30%.

Typical Impact of Trends Study Parameters

Chlorophyll-a is a measure of algae growth. When algae growth increases, there is an increased likelihood of taste and odor problems in drinking water as well as aesthetic issues.

Conductivity is a measure of the ability of water to pass electrical current. In water, conductivity is affected by the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity in streams and rivers is heavily dependent upon regional geology and discharges. High specific conductance indicates high concentrations of dissolved solids, which can affect the suitability of water for domestic, industrial, agricultural, and other uses. At higher conductivity levels, drinking water may have an unpleasant taste or odor or may even cause gastrointestinal distress. High concentration may also cause deterioration of plumbing fixtures and appliances. Relatively expensive water treatment processes, such as reverse osmosis, are required to remove excessive dissolved solids from water. Concerning agriculture, most crops cannot survive if the salinity of the water is too high.

Total Nitrogen is a measure of all dissolved and suspended nitrogen in a water sample. It includes kjeldahl nitrogen (ammonia + organic), nitrate, and nitrite nitrogen. It is naturally abundant in the environment and is a key element necessary for growth of plants and animals. Excess nitrogen from polluting sources can lead to significant water quality problems, including harmful algal blooms, hypoxia, and declines in wildlife and habitat.

Total Phosphorus is one of the key elements necessary for growth of plants and animals. Excess phosphorus leads to significant water quality problems, including harmful algal blooms, hypoxia, and declines in wildlife and habitat. Increases in total phosphorus can lead to excessive growth of algae, which can increase taste and odor problems in drinking water as well as increased costs for treatment.

Turbidity refers to the clarity of water. The greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity. Increases in turbidity can increase treatment costs and have negative effects on aquatic communities by reducing light penetration.

Reservoir Water Quality Trends

Blue-Boggy Region

Parameter	Lake Atoka (1994-2007)	McGee Creek Lake (1996-2009)
Chlorophyll-a (mg/m3)	⬆	NT
Conductivity (us/cm)	⬆	NT
Total Nitrogen (mg/L)	NT	⬆
Total Phosphorus (mg/L)	⇩	⇩
Turbidity (NTU)	NT	NT

Increasing Trend ⬆ **Decreasing Trend** ⇩ NT = No significant trend detected

Trend magnitude and statistical confidence levels vary for each site. Site-specific information can be obtained from the OWRB Water Quality Division.

Notable concerns for reservoir water quality include the following:

- Significant upward trend for chlorophyll-a at Atoka Lake.
- Significant upward trend for total nitrogen at McGee Creek Lake.

Stream Water Quality Trends

Blue-Boggy Region

Parameter	Blue River near Durant		Muddy Boggy near Unger		Red River near Hugo	
	All Data Trend (1975-1992, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1998-2009)[1]	Recent Trend (1999-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	⇩	NT	NT	NT	NT	NT
Total Nitrogen (mg/L)	⇩	⇩	NT	NT	⇩	⬆
Total Phosphorus (mg/L)	⇩	⇩	⇩	⇩	⇩	NT
Turbidity (NTU)	⬆	NT	⇩	⇩	⬆	⇩

Increasing Trend ⬆ **Decreasing Trend** ⇩ NT = No significant trend detected

Trend magnitude and statistical confidence levels vary for each site. Site-specific information can be obtained from the OWRB Water Quality Division.

1 Date ranges for analyzed data represent the earliest site visit date and may not be representative of all parameters.

Notable concerns for stream water quality include the following:

- Significant upward trend for recent total nitrogen on the Red River.
- Significant increase in turbidity over the entire period of record on both the Blue and Red Rivers.

Water Demand

Water needs in the Blue-Boggy Region account for about 3% of the total statewide demand. Regional demand will increase by 40% (24,300 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial, Crop Irrigation, and Thermoelectric Power sectors.

Crop Irrigation demand is expected to account for 31% of the total regional demand in 2060. Currently, 70% of the demand from this sector is satisfied by surface water, 10% by alluvial groundwater, and 20% by bedrock groundwater. Predominant irrigated crops in the Blue-Boggy Region include sod and pasture grasses.

Municipal and Industrial demand is projected to account for approximately 28% of the 2060 demand. Currently, 61% of the demand from this sector is satisfied by surface water, 3% by alluvial groundwater, and 36% by bedrock groundwater.

Thermoelectric Power demands are projected to account for approximately 27% of the 2060 demand. Kiowa Power Partners' Kiamichi Energy Facility, supplied by surface water, is a large user of water for thermoelectric power generation in the region.

Oil and Gas demand is projected to account for approximately 6% of the 2060 demand. Currently, 53% of the demand from this sector is satisfied by surface water and 47% by bedrock groundwater.

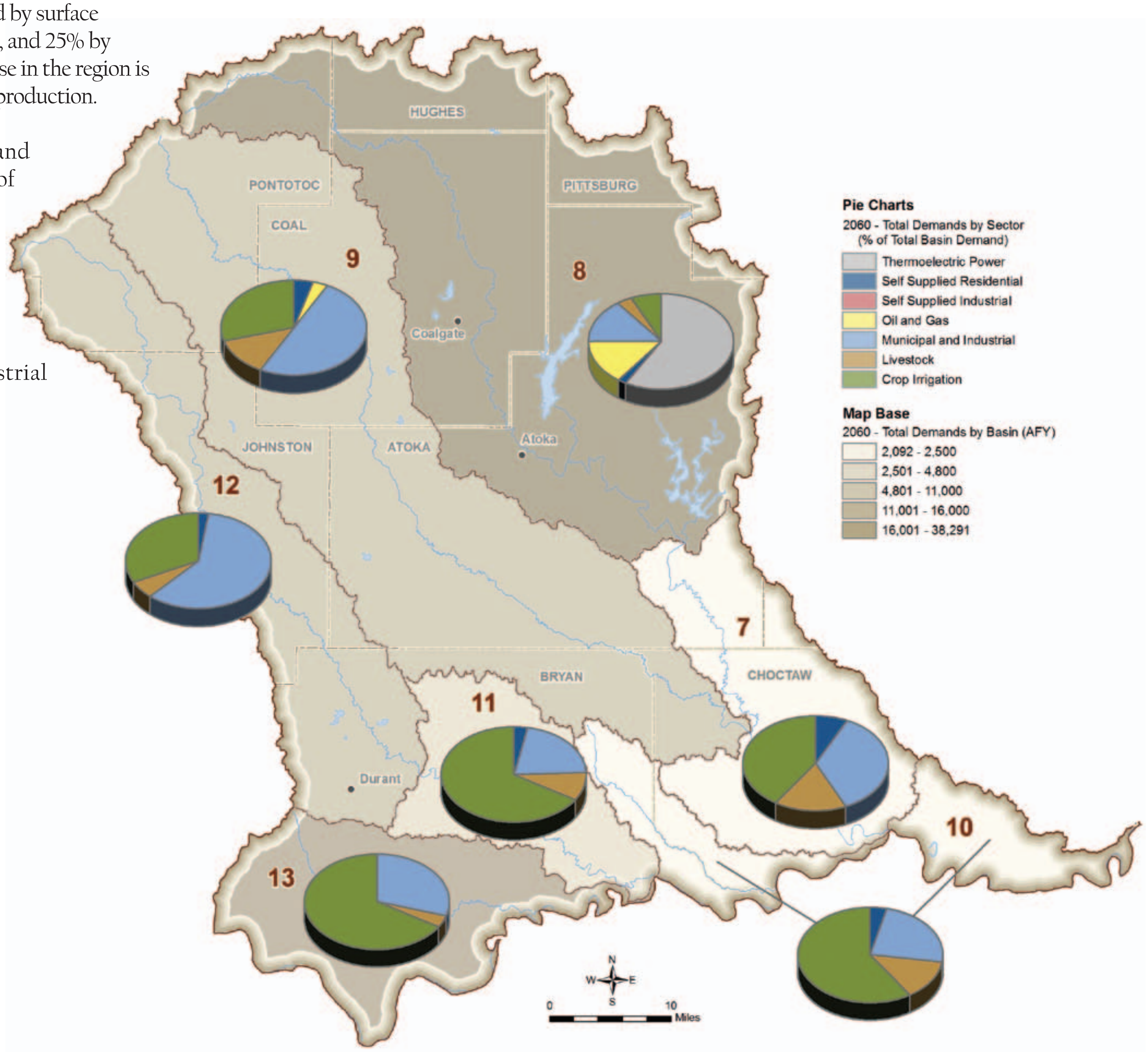
The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Blue-Boggy Region, Basins 8 and 9) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin *Total Demand by Sector* tables.

Livestock demand is projected to account for 6% of the 2060 demand. Currently, 69% of the demand from this sector is satisfied by surface water, 6% by alluvial groundwater, and 25% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production.

Self-Supplied Residential demand is projected to account for 3% of the 2060 demand. Currently, 67% of the demand from this sector is satisfied by alluvial groundwater and 33% by bedrock groundwater.

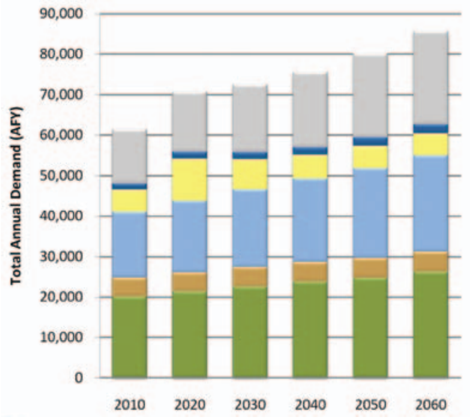
There is no Self-Supplied Industrial demand in the region.

Total 2060 Water Demand by Sector and Basin
(Percent of Total Basin Demand)
Blue-Boggy Region

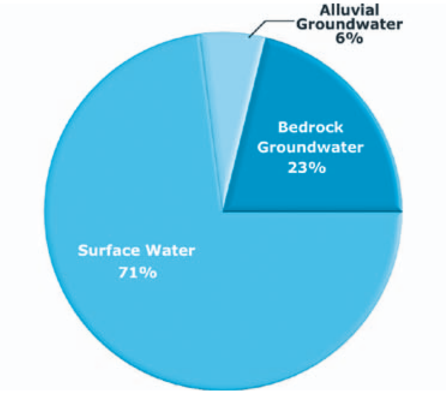


Crop Irrigation is expected to remain the largest demand sector in the region, accounting for 31% of the total regional demand in 2060.

Total Water Demand by Sector
Blue-Boggy Region



Supply Sources Used to Meet Current Demand (2010)
Blue-Boggy Region



Water needs in the Blue-Boggy Region account for about 3% of the total statewide demand. Regional demand will increase by 40% (24,300 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial, Crop Irrigation, and Thermoelectric Power sectors.

Total Water Demand by Sector
Blue-Boggy Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas[1]	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	20,140	4,680	16,340	5,390	0	1,520	13,320	61,390
2020	21,370	4,730	17,780	10,350	0	1,660	14,860	70,750
2030	22,600	4,770	19,250	7,450	0	1,800	16,570	72,450
2040	23,830	4,810	20,740	5,780	0	1,940	18,490	75,590
2050	24,770	4,860	22,280	5,460	0	2,090	20,630	80,090
2060	26,280	4,900	23,840	5,420	0	2,240	23,010	85,700

[1] The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Blue-Boggy Region, Basins 8 and 9) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin Total Demand by Sector tables.

Water Demand

Water demand refers to the amount of water required to meet the needs of people, communities, industry, agriculture, and other users. Growth in water demand frequently corresponds to growth in population, agriculture, industry, or related economic activity. Demands have been projected from 2010 to 2060 in ten-year increments for seven distinct consumptive water demand sectors.

Water Demand Sectors

◼ **Thermoelectric Power:** Thermoelectric power producing plants, using both self-supplied water and municipal-supplied water, are included in the thermoelectric power sector.

🟦 **Self-Supplied Residential:** Households on private wells that are not connected to a public water supply system are included in the SSR sector.

🟥 **Self-Supplied Industrial:** Demands from large industries that do not directly depend upon a public water supply system are included in the SSI sector. Water use data and employment counts were included in this sector, when available.

🟨 **Oil and Gas:** Oil and gas drilling and exploration activities, excluding water used at oil and gas refineries (typically categorized as Self-Supplied Industrial users), are included in the oil and gas sector.

🟦 **Municipal and Industrial:** These demands represent water that is provided by public water systems to homes, businesses, and industries throughout Oklahoma, excluding water supplied to thermoelectric power plants.

🟧 **Livestock:** Livestock demands were evaluated by livestock group (beef, poultry, etc.) based on the 2007 Agriculture Census.

🟩 **Crop Irrigation:** Water demands for crop irrigation were estimated using the 2007 Agriculture Census data for irrigated acres by crop type and county. Crop irrigation requirements were obtained primarily from the Natural Resource Conservation Service Irrigation Guide Reports.

OCWP demands were not projected for non-consumptive or instream water uses, such as hydroelectric power generation, fish and wildlife, recreation and instream flow maintenance. Projections, which were augmented through user/stakeholder input, are based on standard methods using data specific to each sector and OCWP planning basin.

Projections were initially developed for each county in the state, then allocated to each of the 82 basins. To provide regional context, demands were aggregated by Watershed Planning Region. Water shortages were calculated at the basin level to more accurately determine areas where shortages may occur. Therefore, gaps, depletions, and options are presented in detail in the Basin Summaries and subsequent sections. Future demand projections were developed independent of available supply, water quality, or infrastructure considerations. The impacts of climate change, increased water use efficiency, conservation, and non-consumptive uses, such as hydropower, are presented in supplemental OCWP reports.

Present and future demands were applied to supply source categories to facilitate an evaluation of potential surface water gaps and alluvial and bedrock aquifer storage depletions at the basin level. For this baseline analysis, the proportion of each supply source used to meet future demands for each sector was held constant at the proportion established through current, active water use permit allocations. For example, if the crop irrigation sector in a basin currently uses 80% bedrock groundwater, then 80% of the projected future crop irrigation demand is assumed to use bedrock groundwater. Existing out-of-basin supplies are represented as surface water supplies in the receiving basin.

Public Water Providers

There are more than 1,600 Oklahoma water systems permitted or regulated by the Oklahoma Department of Environmental Quality (ODEQ); 785 systems were analyzed in detail for the 2012 OCWP Update. The public systems selected for inclusion, which collectively supply approximately 94 percent of the state's current population, consist of municipal or community water systems and rural water districts that were readily identifiable as non-profit, local governmental entities. This and other information provided in the OCWP will support provider-level planning by providing insight into future supply and infrastructure needs.

The Blue-Boggy Region includes 42 of the 785 public supply systems analyzed for the *2012 OCWP Update*. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems often serve multiple counties and can extend into multiple planning basins and regions.)

In terms of 2010 population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are Durant, Bryan County RW & SD #5, Pontotoc County RWD #7, Atoka County RWS & SWMD #4, and Atoka PWS. Together, these five systems provide service for approximately 53 percent of the population served by public water providers in the region.

Demands upon public water systems, which comprise the majority of the OCWP's Municipal and Industrial (M&I) water demand sector, were analyzed at both the basin and provider level. Retail demand projections detailed in the Public Water Provider Demand Forecast table were developed for each of the OCWP providers in the region. These projections include estimated system losses, defined as water lost either during water production or distribution to residential homes and businesses. Retail demands do not include wholesaled water.

OCWP provider demand forecasts are not intended to supersede water demand forecasts developed by individual providers. OCWP analyses were made using a consistent methodology based on accepted data available on a statewide basis. Where available, provider-generated forecasts were also reviewed as part of this effort.

Public Water Providers
Blue-Boggy Region

Population and Demand Projection Data

Provider level population and demand projection data, developed specifically for OCWP analyses, focus on retail customers for whom the system provides direct service. These estimates were generated from Oklahoma Department of Commerce population projections. In addition, the 2008 OCWP Provider Survey contributed critical information on water production and population served that was used to calculate per capita water use. Population for 2010 was estimated and may not reflect actual 2010 Census values. Exceptions to this methodology are noted.

Public Water Providers/Retail Population Served (1 of 2)

Blue-Boggy Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
ACHILLE	OK2000707	Bryan	99	523	579	635	691	747	803
ALLEN PWA	OK2006202	Pontotoc	101	964	998	1,032	1,065	1,099	1133
ATOKA CO RWD #1 (WARDVILLE)	OK3000305	Atoka	62	129	145	161	177	195	212
ATOKA CO RWD #2	OK3000306	Atoka	160	518	582	645	709	779	849
ATOKA CO RWD #3 (CANEY)	OK2000302	Atoka	212	1,307	1,468	1,628	1,788	1,965	2142
ATOKA CO RWS & SWMD #4	OK1010412	Atoka	171	3,625	4,072	4,516	4,960	5,453	5942
ATOKA PWS	OK1010401	Atoka	251	3,060	3,436	3,811	4,187	4,599	5011
BOKCHITO	OK2000704	Bryan	138	581	636	700	765	820	885
BOSWELL PWA	OK2001205	Choctaw	142	703	723	743	762	782	802
BROMIDE	OK2003517	Johnston	138	170	181	204	226	249	272
BRYAN CO RW & SD #5	OK3000704	Bryan	99	4,542	5,009	5,489	5,968	6,447	6939
BRYAN CO RWD #6	OK3000725	Bryan	58	1,032	1,138	1,247	1,356	1,465	1577
BRYAN CO RWD #7	OK2000705	Bryan	118	237	262	287	312	337	363
BRYAN CO RWD #9	OK2000713	Bryan	77	230	254	278	302	327	352
CADDO	OK2000703	Bryan	159	972	1,074	1,175	1,277	1,379	1490
CALERA, TOWN OF	OK2000702	Bryan	75	1,795	1,980	2,165	2,350	2,544	2738
CENTRAHOMA WATER CO INC	OK3001502	Coal	50	514	593	670	756	849	943
CHOCTAW CO RWD #1	OK2001204	Choctaw	76	2,622	2,688	2,737	2,803	2,872	2938
CHOCTAW RWD #6	OK3001214	Choctaw	77	756	775	789	808	828	847
CLARITA OLNEY WATER CO INC	OK3001501	Coal	151	267	308	348	393	441	490
COAL CO RWD #4 (ROUNDHILL)	OK3001504	Coal	65	225	260	293	331	372	413
COAL CO RWD #5	OK3001505	Coal	100	360	415	469	529	594	660
COALGATE PWA	OK1010402	Coal	241	2,147	2,480	2,804	3,166	3,549	3941
COLBERT PWA	OK2000716	Bryan	118	2,062	2,270	2,478	2,686	2,912	3137
DURANT	OK1010601	Bryan	244	16,036	17,694	19,394	21,094	22,784	24516
HUGHES CO RWD #6 (GERTY)	OK2003224	Hughes	136	1,250	1,364	1,591	1,705	1,932	2045
JOHNSTON CO RWS & SWMD #4	OK2003503	Johnston	80	568	637	710	783	862	945
KENEFIC	OK2000701	Bryan	166	232	265	287	309	342	364
KIOWA	OK1020611	Pittsburg	150	699	738	768	797	837	876
LEHIGH	OK2001501	Coal	100	305	359	404	458	512	566
MILBURN PWA	OK2003520	Johnston	79	318	364	402	439	486	532
PHILLIPS RWD #1	OK3001503	Coal	208	240	285	315	360	405	450

Public Water Providers/Retail Population Served (2 of 2)

Blue-Boggy Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
PITTSBURG CO RWD #11 (KIOWA)	OK3006105	Pittsburg	64	565	597	620	644	676	708
PONTOTOC CO RWD #6 (FITTSTOWN)	OK3006222	Pontotoc	211	787	818	846	874	900	926
PONTOTOC CO RWD #7	OK3006215	Pontotoc	115	4,402	4,572	4,728	4,885	5,030	5176
PONTOTOC CO RWD #9	OK3006218	Pontotoc	77	1,214	1,261	1,304	1,347	1,388	1428
ROFF	OK2006206	Pontotoc	112	746	775	801	828	852	877
SOPER	OK2001201	Choctaw	85	306	306	316	326	336	336
STONEWALL PWA	OK2006203	Pontotoc	137	481	500	517	534	550	566
STRINGTOWN PWA	OK3000303	Atoka	74	1,285	1,460	1,606	1,752	1,928	2103
TUPELO PWA	OK3001506	Coal	99	388	455	512	578	644	720
WAPANUCKA	OK2003518	Johnston	219	1,128	1,266	1,404	1,542	1,703	1864

1 SDWIS - Safe Drinking Water Information System

2 RED ENTRY indicates data was taken from 2007 Water Rights Database. GPD=gallons per day.

Public Water Provider Demand Forecast (1 of 2)

Blue-Boggy Region

			Demand					
			2010	2020	2030	2040	2050	2060
Provider	**SDWIS ID[1]**	**County**	AFY					
ACHILLE	OK2000707	Bryan	58	64	70	76	83	89
ALLEN PWA	OK2006202	Pontotoc	109	113	117	121	124	128
ATOKA CO RWD #1 (WARDVILLE)	OK3000305	Atoka	9	10	11	12	14	15
ATOKA CO RWD #2	OK3000306	Atoka	93	104	116	127	140	152
ATOKA CO RWD #3 (CANEY)	OK2000302	Atoka	310	349	387	425	467	509
ATOKA CO RWS & SWMD #4	OK1010412	Atoka	696	782	867	952	1,047	1,141
ATOKA PWS	OK1010401	Atoka	859	964	1,069	1,175	1,291	1,406
BOKCHITO	OK2000704	Bryan	90	98	108	118	127	137
BOSWELL PWA	OK2001205	Choctaw	112	115	118	121	125	128
BROMIDE	OK2003517	Johnston	26	28	31	35	38	42
BRYAN CO RW & SD #5	OK3000704	Bryan	503	555	608	661	714	768
BRYAN CO RWD #6	OK3000725	Bryan	67	74	81	88	95	102
BRYAN CO RWD #7	OK2000705	Bryan	31	35	38	41	45	48
BRYAN CO RWD #9	OK2000713	Bryan	20	22	24	26	28	30
CADDO	OK2000703	Bryan	173	191	209	227	245	265
CALERA, TOWN OF	OK2000702	Bryan	150	166	181	197	213	229
CENTRAHOMA WATER CO INC	OK3001502	Coal	29	33	38	42	48	53
CHOCTAW CO RWD #1	OK2001204	Choctaw	222	228	232	238	244	249
CHOCTAW RWD #6	OK3001214	Choctaw	66	67	68	70	72	73
CLARITA OLNEY WATER CO INC	OK3001501	Coal	45	52	59	67	75	83
COAL CO RWD #5	OK3001505	Coal	40	46	53	59	67	74
COALGATE PWA	OK1010402	Coal	580	671	758	856	959	1,065
COLBERT PWA	OK2000716	Bryan	271	299	326	354	383	413
DURANT	OK1010601	Bryan	4,391	4,845	5,310	5,776	6,239	6,713
HUGHES CO RWD #6 (GERTY)	OK2003224	Hughes	190	208	242	260	294	312
JOHNSTON CO RWS & SWMD #4	OK2003503	Johnston	51	57	64	70	77	85
KENEFIC	OK2000701	Bryan	43	49	53	57	64	68
KIOWA	OK1020611	Pittsburg	117	124	129	134	141	147
LEHIGH	OK2001501	Coal	34	40	45	51	57	63
MILBURN PWA	OK2003520	Johnston	28	32	36	39	43	47
PHILLIPS RWD #1	OK3001503	Coal	56	66	73	84	94	105
PITTSBURG CO RWD #11 (KIOWA)	OK3006105	Pittsburg	40	43	44	46	48	51
PONTOTOC CO RWD #6 (FITTSTOWN)	OK3006222	Pontotoc	186	193	200	206	212	219
PONTOTOC CO RWD #7	OK3006215	Pontotoc	567	589	609	629	648	666

Projections of Retail Water Demands

Each public water supply system has a "retail" demand, defined as the amount of water used by residential and non-residential customers within that provider's service area. Public-supplied residential demands include water provided to households for domestic uses both inside and outside the home. Non-residential demands include customer uses at office buildings, shopping centers, industrial parks, schools, churches, hotels, and related locations served by a public water supply system. Retail demands do not include wholesale water to other providers.

Municipal and Industrial (M&I) demand is driven by projected population growth and specific customer characteristics. Demand forecasts for each public system are estimated from average water use (in gallons per capita per day) multiplied by projected population. Oklahoma Department of Commerce 2002 population projections (unpublished special tabulation for the OWRB) were calibrated to 2007 Census estimates and used to establish population growth rates for cities, towns, and rural areas through 2060. Population growth rates were applied to 2007 population-served values for each provider to project future years' service area (retail) populations.

The main source of data for per capita water use for each provider was the 2008 OCWP Provider Survey conducted by the OWRB in cooperation with the Oklahoma Rural Water Association and Oklahoma Municipal League. For each responding provider, data from the survey included population served, annual average daily demand, total water produced, wholesale purchases and sales between providers, and estimated system losses.

For missing or incomplete data, the weighted average per capita demand was used for the provider's county. In some cases, provider survey data were supplemented with data from the OWRB water rights database. Per capita supplier demands can vary over time due to precipitation and service area characteristics, such as commercial and industrial activity, tourism, or conservation measures. For the baseline demand projections described here, the per capita demand was held constant through each of the future planning year scenarios. OCWP estimates of potential reductions in demand from conservation measures are analyzed on a basin and regional level, but not for individual provider systems.

Public Water Provider Demand Forecast (2 of 2)

Blue-Boggy Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
PONTOTOC CO RWD #9	OK3006218	Pontotoc	105	109	112	116	120	123
ROFF	OK2006206	Pontotoc	94	97	100	104	107	110
COAL CO RWD #4 (ROUNDHILL)	OK3001504	Coal	16	19	21	24	27	30
SOPER	OK2001201	Choctaw	29	29	30	31	32	32
STONEWALL PWA	OK2006203	Pontotoc	74	77	80	82	85	87
STRINGTOWN PWA	OK3000303	Atoka	107	122	134	146	161	175
TUPELO PWA	OK3001506	Coal	43	50	57	64	71	80
WAPANUCKA	OK2003518	Johnston	277	311	345	378	418	457

[1] SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers

Blue-Boggy Region

Provider	SDWIS ID[1]	Sales			Purchases		
		Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases From	Emergency or Ongoing	Treated or Raw or Both
ATOKA CO RWD #1	OK3000305				Pittsburg Co RWD #11		
ATOKA CO RWD #2	OK3000306				Atoka PWS Atoka Co RWD #4	O E	T T
ATOKA CO RWS & SWMD #4	OK1010412	Stringtown PWA Choctaw Co RWD #6 Atoka Co RWD #2 Atoka PWS	O O E E	T T T T	Atoka PWS	E	T
ATOKA PWS	OK1010401	Atoka Co RWD #2 Atoka Co RWD #4	O E	T T	Atoka Co RWD #4	E	T
BOKCHITO	OK2000704				Bryan Co RWD #5	E	T
BRYAN CO RW & SD #5	OK3000704	Bokchito	E	T	Durant Bryan Co RWS & SWMD #2	O E	T T
BRYAN CO RWD #6	OK3000725				Caddo PWA	O	T
CADDO	OK2000703	Bryan Co RWD #6	O	T			
CENTRAHOMA WATER CO INC	OK3001502				Coalgate PWA	O	T
CHOCTAW CO RWD #1	OK2001204				Hugo	O	T
CHOCTAW RWD #6	OK3001214				Atoka Co RWD #4	O	T
CLARITA OLNEY WATER CO INC	OK3001501				Coalgate PWA	O	T
COAL CO RWD #4 (ROUNDHILL)	OK3001504				Coalgate PWA	O	T
COAL CO RWD #5	OK3001505				Coalgate PWA	O	T
COALGATE PWA	OK1010402	Clarita Olney Water Co Inc Centrahoma Water Co Inc Coal Co RWD #5 Phillips RWD #1	O O O O	T T T T			
DURANT	OK1010601	Bryan Co RWS & SWMD #2 Bryan Co RWD #5	O O	T T			
HUGHES CO RWD #6 (GERTY)	OK2003224	Hughes Co RWD #4	O	T			
MILBURN PWA	OK2003520				Johnston Co RWD #3		T
PHILLIPS RWD #1	OK3001503				Coalgate PWA	O	T
PONTOTOC CO RWD #6 (FITTSTOWN)	OK3006222				Ada	O	R
PONTOTOC CO RWD #7	OK3006215				Ada	O	T
PONTOTOC CO RWD #9	OK3006218				Ada	O	T
STRINGTOWN PWA	OK3000303				Atoka Co RWD #4	O	T
TUPELO PWA	OK3001506				Pontotoc Co RWD #9		

[1] SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers

Some providers sell water on a "wholesale" basis to other providers, effectively increasing the amount of water that the selling provider must deliver and reducing the amount that the purchasing provider diverts from surface and groundwater sources. Wholesale water transfers between public water providers are fairly common and can provide an economical way to meet demands. Wholesale quantities typically vary from year to year depending upon growth, precipitation, emergency conditions, and agreements between systems.

Water transfers between providers can help alleviate costs associated with developing or maintaining infrastructure, such as a reservoir or pipeline; allow access to higher quality or more reliable sources; or provide additional supplies only when required, such as in cases of supply emergencies. Utilizing the 2008 OCWP Provider Survey and OWRB water rights data, the Wholesale Water Transfers table presents a summary of known wholesale arrangements for providers in the region. Transfers can consist of treated or raw water and can occur on a regular basis or only during emergencies. Providers commonly sell to and purchase from multiple water providers.

Provider Water Rights

Public water providers using surface water or groundwater obtain water rights from the OWRB. Water providers purchasing water from other suppliers or sources are not required to obtain water rights as long as the furnishing entity has the appropriate water right or other source of authority. Each public water provider's current water right(s) and source of supply have been summarized in this report. The percentage of each provider's total 2007 water rights from surface water, alluvial groundwater, and bedrock groundwater supplies was also calculated, indicating the relative proportions of sources available to each provider.

A comparison of existing water rights to projected demands can show when additional water rights or other sources and in what amounts might be needed. Forecasts of conditions for the year 2060 indicate where additional water rights may be needed to satisfy demands by that time. However, in most cases, wholesale water transfers to other providers must also be addressed by the selling provider's water rights. Thus, the amount of water rights required will exceed the retail demand for a selling provider and will be less than the retail demand for a purchasing provider.

In preparing to meet long-term needs, public water providers should consider strategic factors appropriate to their sources of water. For example, public water providers who use surface water can seek and obtain a "schedule of use" as part of their stream water right, which addresses projected growth and consequent increases in stream water use. Such schedules of use can be employed to address increases that are anticipated to occur over many years or even decades, as an alternative to the usual requirement to use the full authorized amount of stream water in a seven-year period. On the other hand, public water providers that utilize groundwater should consider the prospect that it may be necessary to purchase or lease additional land in order to increase their groundwater rights.

Public Water Provider Water Rights and Withdrawals - 2010 (1 of 2)

Blue-Boggy Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
ACHILLE	OK2000707	Bryan	403	0%	100%	0%
ALLEN PWA	OK2006202	Pontotoc	283	0%	0%	100%
ATOKA CO RWD #1 (WARDVILLE)	OK3000305	Atoka	---	---	---	---
ATOKA CO RWD #2	OK3000306	Atoka	85	0%	100%	0%
ATOKA CO RWD #3 (CANEY)	OK2000302	Atoka	97	0%	100%	0%
ATOKA CO RWS & SWMD #4	OK1010412	Atoka	---	---	---	---
ATOKA PWS	OK1010401	Atoka	10,000	100%	0%	0%
BOKCHITO	OK2000704	Bryan	200	0%	100%	0%
BOSWELL PWA	OK2001205	Choctaw	126	0%	100%	0%
BROMIDE	OK2003517	Johnston	86	49%	51%	0%
BRYAN CO RW & SD #5	OK3000704	Bryan	---	---	---	---
BRYAN CO RWD #6	OK3000725	Bryan	101	0%	100%	0%
BRYAN CO RWD #7	OK2000705	Bryan	540	0%	100%	0%
BRYAN CO RWD #9	OK2000713	Bryan	80	0%	0%	100%
CADDO	OK2000703	Bryan	1,337	0%	100%	0%
CALERA, TOWN OF	OK2000702	Bryan	960	0%	100%	0%
CENTRAHOMA WATER CO INC	OK3001502	Coal	---	---	---	---
CHOCTAW CO RWD #1	OK2001204	Choctaw	281	0%	87%	13%
CHOCTAW RWD #6	OK3001214	Choctaw	---	---	---	---
CLARITA OLNEY WATER CO INC	OK3001501	Coal	---	---	---	---
COAL CO RWD #4 (ROUNDHILL)	OK3001504	Coal	---	---	---	---
COAL CO RWD #5	OK3001505	Coal	---	---	---	---
COALGATE PWA	OK1010402	Coal	8,168	96%	4%	0%
COLBERT PWA	OK2000716	Bryan	193	0%	0%	100%
DURANT	OK1010601	Bryan	12,342	100%	0%	0%

Public Water Provider Water Rights and Withdrawals - 2010 (2 of 2)

Blue-Boggy Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
HUGHES CO RWD #6 (GERTY)	OK2003224	Hughes	160	0%	0%	100%
JOHNSTON CO RWS& SWMD #4	OK2003503	Johnston	438	0%	100%	0%
KENEFIC	OK2000701	Bryan	63	0%	100%	0%
KIOWA	OK1020611	Pittsburg	302	100%	0%	0%
LEHIGH	OK2001501	Coal	226	0%	100%	0%
MILBURN PWA	OK2003520	Johnston	36	0%	100%	0%
PHILLIPS RWD #1	OK3001503	Coal	---	---	---	---
PITTSBURG CO RWD #11 (KIOWA)	OK3006105	Pittsburg	---	---	---	---
PONTOTOC CO RWD #6 (FITTSTOWN)	OK3006222	Pontotoc	---	---	---	---
PONTOTOC CO RWD #7	OK3006215	Pontotoc	---	---	---	---
PONTOTOC CO RWD #9	OK3006218	Pontotoc	---	---	---	---
ROFF	OK2006206	Pontotoc	1,180	0%	100%	0%
SOPER	OK2001201	Choctaw	15	0%	100%	0%
STONEWALL PWA	OK2006203	Pontotoc	253	0%	100%	0%
STRINGTOWN PWA	OK3000303	Atoka	504	0%	100%	0%
TUPELO PWA	OK3001506	Coal	211	0%	100%	0%
WAPANUCKA	OK2003518	Johnston	320	100%	0%	0%

[1] SDWIS - Safe Drinking Water Information System

Provider Supply Plans

In 2008, a survey was sent to 785 municipal and rural water providers throughout Oklahoma to collect vital background water supply and system information. Additional detail for each of these providers was solicited in 2010 as part of follow-up interviews conducted by the ODEQ. The 2010 interviews sought to confirm key details of the earlier survey and document additional details regarding each provider's water supply infrastructure and plans. This included information on existing sources of supply (including surface water, groundwater, and other providers), short-term supply and infrastructure plans, and long-term supply and infrastructure plans.

In instances where no new source was identified, maintenance of the current source of supply is expected into the future. Providers may or may not have secured the necessary funding to implement their stated plans concerning infrastructure needs, commonly including additional wells or raw water conveyance, storage, and replacement/upgrade of treatment and distribution systems.

Additional support for individual water providers wishing to pursue enhanced planning efforts is documented in the *Public Water Supply Planning Guide*. This guide details how information contained in the OCWP Watershed Planning Region Reports and related planning documents can be used to formulate provider-level plans to meet present and future needs of individual water systems.

OCWP Provider Survey

Blue-Boggy Region

Town of Achille (Bryan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace water lines.
Long-Term Needs
None identified.

Allen PWA (Pontotoc County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace aerator tank and booster pump with dual pump system.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill new wells.

Atoka County RWD 1 (Wardville)
Current Source of Supply
Primary source: Pittsburg RWD 11
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace portion of distribution lines.

Atoka County RWD 2
Current Source of Supply
Primary source: Atoka PWS
Short-Term Needs
Infrastructure improvements: repair or replace infrastructure damaged by 2011 tornado.
Long-Term Needs
None required.

Atoka County RWD 3 (Caney)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: inspect standpipe.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: construct additional groundwater wells.

Atoka County RWS & SWMD 4
Current Source of Supply
Primary source: McGee Creek Lake
Short-Term Needs
New supply source: increase water to McGee Creek Lake.
Infrastructure improvements: clear well needed at the water treatment plant; additional water lines needed to supply water to storage tanks.
Long-Term Needs
New supply source: increase water to McGee Creek Lake.
Infrastructure improvements: additional storage tanks needed.

Atoka PWS (Atoka County)
Current Source of Supply
Primary source: Atoka Lake, McGee Creek Lake
Short-Term Needs
New supply source: add piping to Atoka PWS to take in two sources of surface water.
Infrastructure improvements: additional piping.
Long-Term Needs
New supply source: interconnect to adjacent PWS.
Infrastructure improvements: additional piping.

Town of Bokchito (Bryan County)
Current Source of Supply
Primary source: groundwater
Emergency source: Bryan County RWD 5
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: add a new well.
Long-Term Needs
New supply source: groundwater.

Boswell PWA (Choctaw County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: refurbish wells and pressure filters; repaint water tower.
Long-Term Needs
Infrastructure improvements: replace cast iron pipes.

City of Bromide (Johnston County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill two new wells; install 1-2 miles of new piping to connect wells to existing water tower.
Long-Term Needs
Infrastructure improvements: replace distribution system piping and add fire hydrants and new water meters.

Bryan County RWD 5
Current Source of Supply
Primary source: Durant
Short-Term Needs
Infrastructure improvements: paint water towers.
Long-Term Needs
New supply source: increase storage.
Infrastructure improvements: build additional water towers.

Bryan County RWD 6
Current Source of Supply
Primary source: Caddo PWA
Short-Term Needs
Infrastructure improvements: drill wells.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: add wells.

Bryan County RWD 7
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill another well; add storage tank.
Long-Term Needs
Infrastructure improvements: line replacement; new meters.

Bryan County RWD 9
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill deeper wells.
Long-Term Needs
Infrastructure improvements: water line replacement.

Town of Caddo (Bryan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add new water lines; repair existing storage tank.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill additional wells; add storage tank; new water lines.

Town of Calera (Bryan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill new well.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill additional wells; pipeline repairs and additional storage needed; upgrade existing treatment facility.

Centrahoma Water Co., Inc. (Coal County)
Current Source of Supply
Primary sources: City of Coalgate
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Choctaw County RWD 1
Current Source of Supply
Primary source: groundwater
Emergency source: City of Hugo
Short-Term Needs
Infrastructure improvements: add booster station west of Hugo to blend well water with Hugo water source.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: add additional wells.

OCWP Provider Survey

Blue-Boggy Region

Choctaw County RWD 6
Current Source of Supply
Primary source: McGee Creek Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Clarita Olney Water Co., Inc. (Coal County)
Current Source of Supply
Primary source: City of Coalgate
Short-Term Needs
Infrastructure improvements: add distribution lines and replace some existing line.
Long-Term Needs
Infrastructure improvements: add distribution lines and replace some existing lines; replace pump station pumps.

Coal County RWD 4 Roundhill
Current Source of Supply
Primary source: City of Coalgate
Short-Term Needs
Infrastructure improvement: water tower cleaned and repainted.
Long-Term Needs
Infrastructure improvement: refurbish water tank; replace pumps. Increase size of main water line.

Coal County RWD 5
Current Source of Supply
Primary source: City of Coalgate
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Coalgate PWA (Coal County)
Current Source of Supply
Primary source: Coalgate City Lake
Short-Term Needs
New supply source: McGee Creek Lake.
Infrastructure improvements: build raw water line to City of Oklahoma City aqueduct.
Long-Term Needs
New supply source: city to purchase water from City of Oklahoma City.
Infrastructure improvements: raise level of water of Coalgate Lake 18 inches.

Colbert PWA (Bryan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill addition wells; add pump stations and storage.
Long-Term Needs
New supply source: surface water from Red River.
Infrastructure improvements: drill distribution lines.

City of Durant (Bryan County)
Current Source of Supply
Primary source: Blue River, Lake Durant
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Hughes County RWD 6 (Gerty)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill new replacement wells.
Long-Term Needs
New supply source: groundwater
Infrastructure improvements: drill new replacement wells. Upgrade inadequate main lines.

Johnston County RWS & SWMD 4
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill additional wells. Increase distribution line capacity on south side of system.
Long-Term Needs
New supply source: need additional supply.
Infrastructure improvements: additional storage and increased line capacity in distribution system.

Town of Kenefic (Bryan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Kiowa (Pittsburg County)
Current Source of Supply
Primary source: Katy Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Lehigh (Coal County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Milburn PWA (Johnston County)
Current Source of Supply
Primary source: Johnston County RWD 3
Short-Term Needs
None identified.
Long-Term Needs
New supply source: obtain new sources of water.
Infrastructure improvement: new distribution lines and additional water tower.

Phillips RWD 1 (Coal County)
Current Source of Supply
Primary source: None identified
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Pittsburg County RWD 11 (Kiowa)
Current Source of Supply
Primary source: Kiowa PWS ID 1020611
Short-Term Needs
New supply source: Kiowa PWS.
Infrastructure improvements: add water line to serve customers that are on their own wells or pulling water from the lake.
Long-Term Needs
Infrastructure improvement: add chlorine booster station.

Pontotoc County RWD 6 (Fittstown)
Current Source of Supply
Primary source: City of Ada
Short-Term Needs
New supply source: City of Ada.
Infrastructure improvements: upgrade water tower.
Long-Term Needs
Infrastructure improvement: replace most of distribution system piping; replace water tower.

Pontotoc County RWD 7
Current Source of Supply
Primary source: City of Ada
Short-Term Needs
Infrastructure improvements: replace distribution lines; add storage tank.
Long-Term Needs
Infrastructure improvement: add booster pumps and storage tanks; upsize distribution system lines.

Pontotoc County RWD 9
Current Source of Supply
Primary source: City of Ada
Short-Term Needs
New supply source: City of Ada.
Long-Term Needs
New supply source: identify new water source.

Town of Roff (Pontotoc County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: replace existing water tower.
Long-Term Needs
Infrastructure improvement: drill new wells; replace old distribution lines.

Town of Soper (Choctaw County)
Current Source of Supply
Primary source: groundwater
Emergency source: Antlers Rural Water
Short-Term Needs
New supply source: Antlers Rural Water.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: connect all lines to new service; replace well casing or drill new well.

Stonewall PWA (Pontotoc County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add water storage tower.

Stringtown PWA (Atoka County)
Current Source of Supply
Primary source: Atoka County RWS & SWMD 4
Short-Term Needs
Infrastructure improvements: repair distribution lines near Daisy; add new line on Farmer Rd.
Long-Term Needs
Infrastructure improvements: chlorine booster stations.

Tupelo PWA (Coal County)
Current Source of Supply
Primary source: Pontotoc RWD 9
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: distribution line replacement.

Town of Wapanucka (Johnston County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: inspect standpipe.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: replace distribution system lines.

Drinking Water Infrastructure Cost Summary

As part of the public water provider analysis, regional cost estimates to meet system drinking water infrastructure needs over the next 50 years were prepared. While it is difficult to account for changes that may occur within this extended time frame, it is beneficial to evaluate, at least on the order-of-magnitude level, the long-range costs of providing potable water.

Project cost estimates were developed for a selection of existing water providers, and then weighted to determine total regional costs. The OCWP method is similar to that utilized by the EPA to determine national drinking water infrastructure costs in 2007. However, the OCWP uses a 50-year planning horizon while the EPA uses a 20-year period. Also, the OCWP includes a broader spectrum of project types rather than limiting projects to those eligible for the Drinking Water State Revolving Fund program. While estimated costs for new reservoirs are not included, rehabilitation project costs for existing major reservoirs were applied at the regional level.

More information on the methodology and cost estimates is available in the OCWP *Drinking Water Infrastructure Needs Assessment by Region* report.

Infrastructure Cost Summary

Blue-Boggy Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$20	$347	$13	$380
Medium	$77	$15	$26	$118
Large	$0	$0	$0	$0
Reservoir[2]	$0	$0	$0	$0
TOTAL	$97	$362	$39	$498

1 Large providers are defined as those serving more than 100,000 people, medium systems as those serving between 3,301 and 100,000 people, and small systems as those serving 3,300 and fewer people.

2 The "reservoir" category is for rehabilitation projects.

- Approximately $0.5 billion is needed to meet the projected drinking water infrastructure needs of the Blue-Boggy region over the next 50 years. The largest infrastructure costs are expected to occur from 2021 to 2040.
- Distribution and transmission projects account for more than 70 percent of the providers' estimated infrastructure costs, followed distantly by water treatment projects.
- Small providers have the largest overall drinking water infrastructure costs.
- There are no projected costs for projects involving rehabilitation of existing reservoirs.

Water Supply Options

Limitations Analysis

For each of the state's 82 OCWP basins, an analysis of water supply and demand was followed by an analysis of limitations for surface water, bedrock groundwater, and alluvial groundwater use. Physical availability limitations for surface water were referred to as gaps. Availability limitations for alluvial and bedrock groundwater were referred to as depletions.

For surface water, the most pertinent limiting characteristics considered were (1) physical availability of water, (2) permit availability, and (3) water quality. For alluvial and bedrock groundwater, permit availability was not a limiting factor through 2060, and existing data were insufficient to conduct meaningful groundwater quality analyses. Therefore, limitations for major alluvial and bedrock aquifers were related to physical availability of water and included an analysis of both the amount of any forecasted depletion relative to the amount of water in storage and rate at which the depletion was predicted to occur.

Methodologies were developed to assess limitations and assign appropriate scores for each supply source in each basin. For surface water, scores were calculated weighting the characteristics as follows: 50% for physical availability, 30% for permit availability, and 20% for water quality. For alluvial and bedrock groundwater scores, the magnitude of depletion relative to amount of water in storage and rate of depletion were each weighted 50%.

The resulting supply limitation scores were used to rank all 82 basins for surface water, major alluvial groundwater, and major bedrock groundwater sources (see Water Supply Limitations map in the regional summary). For each source, basins ranking the highest were considered to be "significantly limited" in the ability of that source to meet forecasted demands reliably. Basins with intermediate rankings were considered to be "potentially limited" for that source. For bedrock and alluvial groundwater rankings, "potentially limited" was also the baseline default given to basins lacking major aquifers due to typically lower yields and insufficient data. Basins with the lowest rankings were considered to be "minimally limited" for that source and not projected to have any gaps or depletions.

Based on an analysis of all three sources of water, the basins with the most significant limitations ranking were identified as "Hot Spots." A discussion of the methodologies used in identifying Hot Spots, results, and recommendations can be found in the *OCWP Executive Report*.

Primary Options

To provide a range of potential solutions for mitigation of water supply shortages in each of the 82 OCWP basins, five primary options were evaluated for potential effectiveness: (1) demand management, (2) use of out-of-basin supplies, (3) reservoir use, (4) increasing reliance on surface water, and (5) increasing reliance on groundwater. For each basin, the potential effectiveness of each primary option was assigned one of three ratings: (1) typically effective, (2) potentially effective, and (3) likely ineffective (see Water Supply Option Effectiveness map in the regional summary). For basins where shortages are not projected, no options are necessary and thus none were evaluated.

Demand Management

"Demand management" refers to the potential to reduce water demands and alleviate gaps or depletions by implementing conservation or drought management measures. Demand management is a vitally important tool that can be implemented either temporarily or permanently to decrease demand and increase available supply. "Conservation measures" refer to long-term activities that result in consistent water savings throughout the year, while "drought management" refers to short-term measures, such as temporary restrictions on outdoor watering. Municipal and industrial conservation techniques can include modifying customer behaviors, using more efficient plumbing fixtures, or eliminating water leaks. Agricultural conservation techniques can include reducing water demand through more efficient irrigation systems and production of crops with decreased water requirements.

Two specific scenarios for conservation were analyzed for the OCWP—moderate and substantial—to assess the relative effectiveness in reducing statewide water demand in the two largest demand sectors, Municipal/Industrial and Crop Irrigation. For the Watershed Planning Region reports, only moderately expanded conservation activities were considered when assessing the overall effectiveness of the demand management option for each basin. A broader analysis of moderate and substantial conservation measures statewide is discussed below and summarized in the "Expanded Options" section of the *OCWP Executive Report*.

Demand management was considered to be "typically effective" in basins where it would likely eliminate both gaps and storage depletions and "potentially effective" in basins where it would likely either reduce gaps and depletions or eliminate either gaps or depletions (but not both). There were no basins where demand management could not reduce gaps and/or storage depletions to at least some extent; therefore this option was not rated "likely ineffective" for any basin.

Out-of-Basin Supplies

Use of "out-of-basin supplies" refers to the option of transferring water through pipelines from a source in one basin to another basin. This option was considered a "potentially effective" solution in all basins due to its general potential in eliminating gaps and depletions. The option was not rated "typically effective" because complexity and cost make it only practical as a long-term solution. The effectiveness of this option for a basin was also assessed with the consideration of potential new reservoir sites within the respective region as identified in the Expanded Options section below and the OCWP *Reservoir Viability Study*.

Reservoir Use

"Reservoir Use" refers to the development of additional in-basin reservoir storage. Reservoir storage can be provided through increased use of existing facilities, such as reallocation of existing purposes at major federal reservoir sites or rehabilitation of smaller NRCS projects to include municipal and/or industrial water supply, or the construction of new reservoirs.

The effectiveness rating of reservoir use for a basin was based on a hypothetical reservoir located at the furthest downstream basin outlet. Water transmission and legal or water quality constraints were not considered; however, potential constraints in permit availability were noted. A site located further upstream could potentially provide adequate yield to meet demand, but would likely require greater storage than a site located at the basin outlet. The effectiveness rating was also largely contingent upon the existence of previously studied reservoir sites (see the Expanded Options section below) and/or the ability of new streamflow diversions with storage to meet basin water demands.

Reservoir use was considered "typically effective" in basins containing one or more potentially viable reservoir sites unless the basin was fully allocated for surface water and had no permit availability. For basins with no permit availability, reservoir use was considered "potentially effective," since diversions would be limited to existing permits. Reservoir use was also considered "potentially effective" in basins that generate sufficient reservoir yield to meet future demand. Statewide, the reservoir use option was considered "likely ineffective" in only three basins (Basins 18, 55, and 66), where it was determined that insufficient streamflow would be available to provide an adequate reservoir yield to meet basin demand.

Increasing Reliance on Surface Water

"Increasing reliance on surface water" refers to changing the surface water-groundwater use ratio to meet future demands by increasing surface water use. For baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions. Increasing the use of surface water through direct diversions without reservoir storage or releases upstream from storage provides a reliable supply option in limited areas of the state and has potential to mitigate bedrock groundwater depletions and/or alluvial groundwater depletions. However, this option largely depends upon local conditions concerning the specific location, amount, and timing of the diversion.

Due to this uncertainty, the pronounced periods of low streamflow in many river systems across the state, and the potential to create or augment surface water gaps, this option was considered "typically ineffective" for all basins. The preferred alternative statewide is reservoir use, which provides the most reliable surface water supply source.

Increasing Reliance on Groundwater

"Increasing reliance on groundwater" refers to changing the surface water-groundwater use ratio to meet future demands by increasing groundwater use. Supplies from major aquifers are particularly reliable because they generally exhibit higher well yields and contain large amounts of water in storage. Minor aquifers can also contain large amounts of water in storage, but well yields are typically lower and may be insufficient to meet the needs of high volume water users. Site-specific information on the suitability of minor aquifers for supply should be considered prior to large-scale use. Additional groundwater supplies may also be developed through artificial recharge (groundwater storage and recovery), which is summarized in the "Expanded Options" section of the *OWRB Executive Report*.

Increased reliance on groundwater supplies was considered "typically effective" in basins where both gaps and depletions could be mitigated in a measured fashion that did not lead to additional groundwater depletions. This option was considered "potentially effective" in basins where surface water gaps could be mitigated by increased groundwater use, but would likely result in increased depletions in either alluvial or bedrock groundwater storage. Increased reliance on groundwater supplies was considered "typically ineffective" in basins where there were no major aquifers.

Expanded Options

In addition to the standard analysis of primary options for each basin, specific OCWP studies were conducted statewide on several more advanced though less conventional options that have potential to reduce basin gaps and depletions. More detailed summaries of these options are available in the *OWRB Executive Report*. Full reports are available on the OWRB website.

Expanded Conservation Measures

Water conservation was considered an essential component of the "demand management" option in basin-level analysis of options for reducing or eliminating gaps and storage depletions. At the basin level, moderately expanded conservation measures were used as the basis for analyzing effectiveness. In a broader OCWP study, summarized in the *OCWP Executive Report* and documented in the OCWP *Water Demand Forecast Report Addendum: Conservation and Climate Change*, both moderately and substantially expanded conservation activities were analyzed at a statewide level for the state's two largest demand sectors: Municipal/Industrial (M&I) and Crop Irrigation. For each sector, two scenarios were analyzed: (1) moderately expanded conservation activities, and (2) substantially expanded conservation activities. Water savings for the municipal and industrial and crop irrigation water use sectors were assessed, and for the M&I sector, a cost-benefit analysis was performed to quantify savings associated with reduced costs in drinking water production and decreased wastewater treatment. The energy savings and associated water savings realized as a result of these decreases were also quantified.

Artificial Aquifer Recharge

In 2008, the Oklahoma Legislature passed Senate Bill 1410 requiring the OWRB to develop and implement criteria to prioritize potential locations throughout the state where artificial recharge demonstration projects are most feasible to meet future water supply challenges. A workgroup of numerous water agencies and user groups was organized to identify suitable locations in both alluvial and bedrock aquifers. Fatal flaw and threshold screening analyses resulted in identification of six alluvial sites and nine bedrock sites. These sites were subjected to further analysis that resulted in five sites deemed by the workgroup as having the best potential for artificial recharge demonstration projects.

Where applicable, potential recharge sites are noted in the "Increasing Reliance on Groundwater" option discussion in basin data and analysis sections of the Watershed Planning Region Reports. The site selection methodology and results for the five selected sites are summarized in the *OCWP Executive Report*; more detailed information on the workgroup and study is presented in the OCWP *Artificial Aquifer Recharge Issues and Recommendations* report.

Marginal Quality Water Sources

In 2008, the Oklahoma Legislature passed Senate Bill 1627 requiring the OWRB to establish a technical workgroup to analyze the expanded use of marginal quality water (MQW) from various sources throughout the state. The group included representatives from state and federal agencies, industry, and other stakeholders. Through facilitated discussions, the group defined MQW as that which has been historically unusable due to technological or economic issues associated with diverting, treating, and/or conveying the water. Five categories of MQW were identified for further characterization and technical analysis: (1) treated wastewater effluent, (2) stormwater runoff, (3) oil and gas flowback/produced water, (4) brackish surface and groundwater, and (5) water with elevated levels of key constituents, such as nitrates, that would require advanced treatment prior to beneficial use.

A phased approach was utilized to meet the study's objectives, which included quantifying and characterizing MQW sources and their locations for use through 2060, assessing constraints to MQW use, and matching identified sources of MQW with projected water shortages across the state. Feasibility of actual use was also reviewed. Of all the general MQW uses evaluated, water reuse—beneficially using treated wastewater to meet certain demand—is perhaps the most commonly applied elsewhere in the U.S. Similarly, wastewater was determined to be one of the most viable sources of marginal quality water for short-term use in Oklahoma. Results of the workgroup's study are summarized in the *OCWP Executive Report*; more detailed information on the workgroup and study is presented in the OCWP *Marginal Quality Water Issues and Recommendations* report.

Potential Reservoir Development

Oklahoma is the location of many reservoirs that provide a dependable, vital water supply source for numerous purposes. While economic, environmental, cultural, and geographical constraints generally limit the construction of new reservoirs, significant interest persists due to their potential in meeting various future needs, particularly those associated with municipalities and regional public supply systems.

As another option to address Oklahoma's long-range water needs, the OCWP *Reservoir Viability Study* was initiated to identify potential reservoir sites throughout the state that have been analyzed to various degrees by the OWRB, Bureau of Reclamation (BOR), U.S. Army Corps of Engineers (USACE), Natural Resources Conservation Service (NRCS), and other public or private agencies. Principal elements of the study included extensive literature search; identification of criteria to determine a reservoir's viability; creation of a database to store essential information for each site; evaluation of sites; Geographic Information System (GIS) mapping of the most viable sites; aerial photograph and map reconnaissance; screening of environmental, cultural, and endangered species issues; estimates of updated construction costs; and categorical assessment of viability. The study revealed more than 100 sites statewide. Each was assigned a ranking, ranging from Category 4 (sites with at least adequate information that are viable candidates for future development) to Category 0 (sites that exist only on a historical map and for which no study data can be verified).

This analysis does not necessarily indicate an actual need or specific recommendation to build any potential project. Rather, these sites are presented to provide local and regional decision-makers with additional tools as they anticipate future water supply needs and opportunities. Study results present only a cursory examination of the many factors associated with project feasibility or implementation. Detailed investigations would be required in all cases to verify feasibility of construction and implementation. A summary of potential reservoir sites statewide is available in the *OCWP Executive Report*; more detailed information on the study is presented in the OCWP *Reservoir Viability Study*. Potential reservoir development sites for this Watershed Planning Region appear on the following table and map.

Reservoir Project Viability Categorization

Category 4: Sites with at least adequate information that are viable candidates for future development.

Category 3: Sites with sufficient data for analysis, but less than desirable for current viability.

Category 2: Sites that may contain fatal flaws or other factors that could severely impede potential development.

Category 1: Sites with limited available data and lacking essential elements of information.

Category 0: Typically sites that exist only on an historical map. Study data cannot be located or verified.

Potential Reservoir Sites (Categories 3 & 4)

Blue-Boggy Region

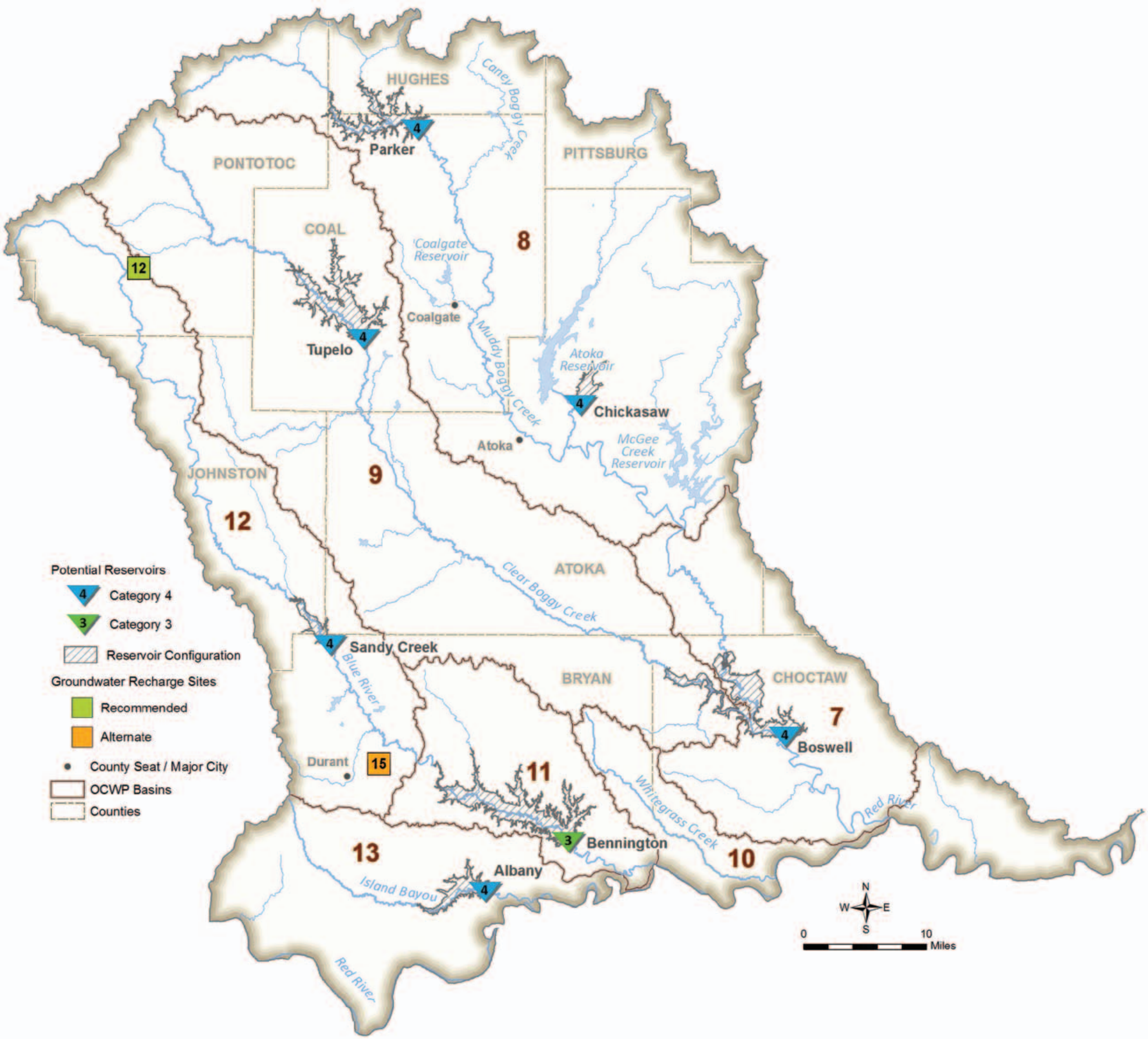
Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool			Primary Study		Updated Cost Estimate[2] (2010 dollars)
						Surface Area	Storage	Dependable Yield	Date	Agency	
					AF	Acres	AF	AFY			
Albany	4	Island Bayou	13	FC, WS, R, FW	147,100	4,960	85,200	35,847	1978	USACE	$81,618,000
Bennington (Durant)	3	Blue River	11	WS, FW, R	---	14,280	287,420	179,000	1975	USACE and Bureau of Reclamation	$180,662,000
Boswell (Alternative D)	4	Boggy Creek	7	FC, WS, FW, R	407,800	26,700	60,870	56,011	1989	Multiple agencies	$254,112,000
Chickasaw	4	Chickasaw Creek	8	WS, FC, R, P, FW	195,260	2,030	36,320	17,900	1995	USACE	$61,661,000
Parker	4	Muddy Boggy Creek	8	FC, WS, FW, R	220,240	6,100	109,940	45,900	1986	USACE	$103,816,000
Sandy Creek	4	Blue River	12	WS, P, FW, R	105,000	1,840	16,920	10,800	1995	USACE	$64,372,000
Tupelo	4	Clear Boggy Creek	9	WS, FW, R	242,000	11,950	227,730	100,820	1975	USACE	$188,599,000

No known information is annotated as "---"

1 WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water

2 Majority of cost estimates were updated using the costs as estimated in previous project reports combined with the USACE Civil Works Construction Cost Index System (CWCCIS) annual escalation figures to scale the original cost estimates to present-day cost estimates. These estimated costs may not accurately reflect current conditions at the proposed project site and are meant to be used for general comparative purposes only.

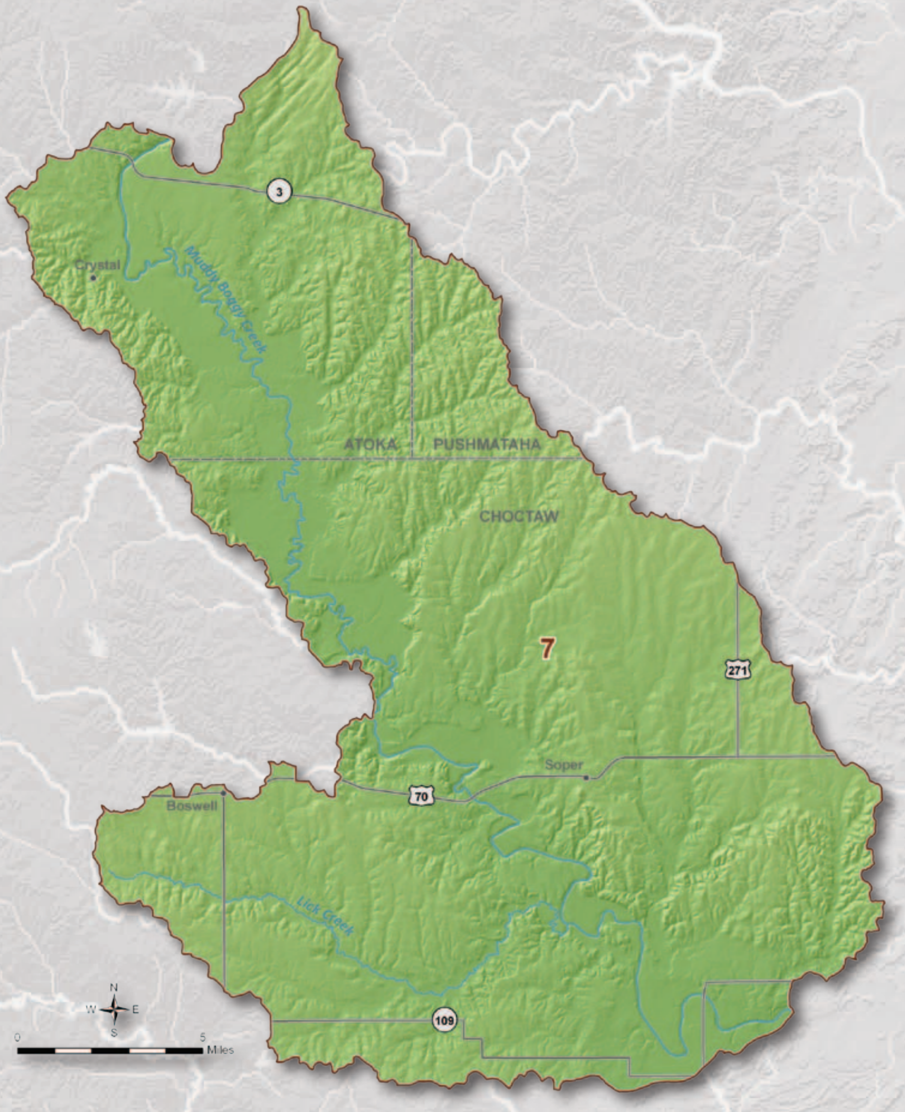
Expanded Water Supply Options
Blue-Boggy Region



Oklahoma Comprehensive Water Plan

Data & Analysis
Blue-Boggy Watershed Planning Region

Basin 7



Basin 7 Summary

Synopsis

- Water users are expected to continue to rely primarily on surface water and bedrock groundwater supplies.
- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not are expected to occur in this basin through 2060; therefore, no supply options are necessary. However, localized gaps and storage depletions may occur.

Basin 7 accounts for about 2% of the current water demand in the Blue-Boggy Watershed Planning Region. About 34% of the basin's demand is from the Municipal and Industrial demand sector. Crop Irrigation and Livestock is about 29% and 27%, respectively, of the basin's 2010 demand. Surface water is used to meet 48% of the current demand in the basin. Groundwater satisfies about 52% of the current demand (6% alluvial and 46% bedrock). The largest growth in demand over the period will be in the Crop Irrigation demand sector.

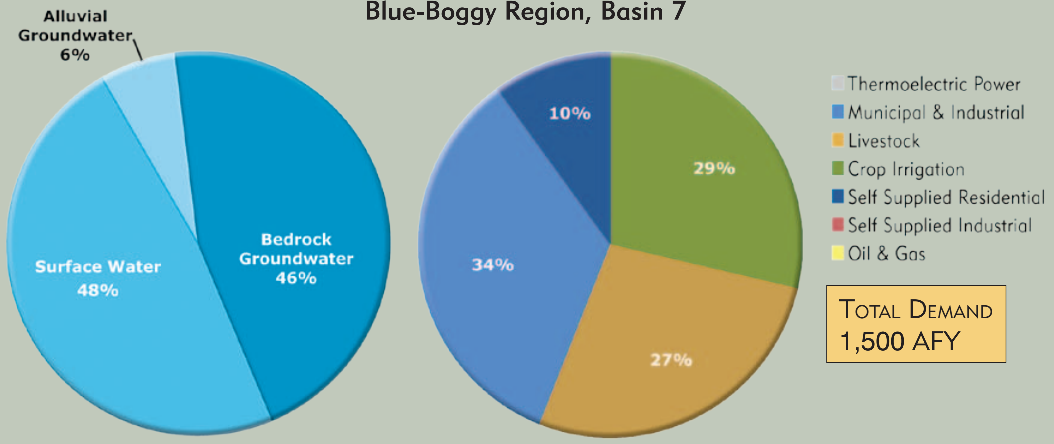
The flow in Muddy Boggy Creek downstream of Bokchito Creek is typically greater than 6,000 AF/month throughout the year and greater than 100,000 AF/month in the spring. However, the river can have periods of low to no flow in any month of the year. The Red River currently has limited use as a water supply source in Basin 7 primarily due to water quality considerations.

The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. With the exception of the Red River, surface water quality in Basin 7 is considered good relative to other basins in the state. There are no water bodies in the basin impaired for Public and Private Water Supply or Agricultural use.

The majority of groundwater rights in Basin 7 are in the Antlers major bedrock aquifer. The Antlers aquifer underlies almost the entire basin, has over 4 million AF of storage in the basin, and receives about 17,000 AFY of recharge from Basin 7. There are currently less than 50 AFY of groundwater

Current Demand by Source and Sector

Blue-Boggy Region, Basin 7

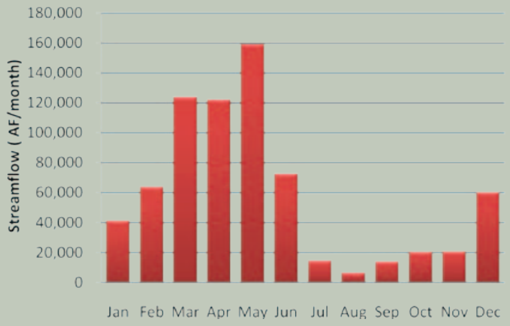


Water Resources

Blue-Boggy Region, Basin 7

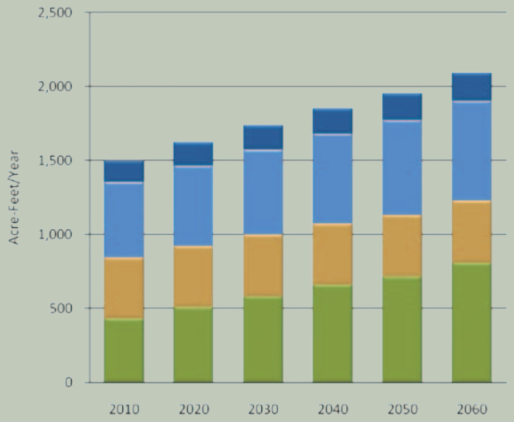
Median Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 7



Projected Water Demand

Blue-Boggy Region, Basin 7



rights in the major Red River alluvial aquifer and there are 500 AFY of permitted withdrawals from the Woodbine minor bedrock aquifer. Domestic users do not require a permit and are assumed to be obtaining supplies from aquifers in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 2,100 AFY in Basin 7 reflects a 600 AFY increase (40%) over the 2010 demand. The majority of the demand is from the Crop Irrigation sector followed by the Municipal and Industrial and Livestock sectors. The peak summer month demand in Basin 7 is about 3 times the winter monthly demand, which is similar to the overall statewide pattern.

Water Supply Limitations

Blue-Boggy Region, Basin 7

- 🟩 Surface Water
- 🟩 Alluvial Groundwater
- 🟩 Bedrock Groundwater

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Blue-Boggy Region, Basin 7

- 🟪 Demand Management
- 🟪 Out-of-Basin Supplies
- 🟪 Reservoir Use
- 🟪 Increasing Supply from Surface Water
- 🟪 Increasing Supply from Groundwater

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not expected to occur in this basin through 2060. However, localized gaps and storage depletions may occur.

Options

Surface water gaps and groundwater storage depletions are not expected through 2060; therefore, no supply options were evaluated.

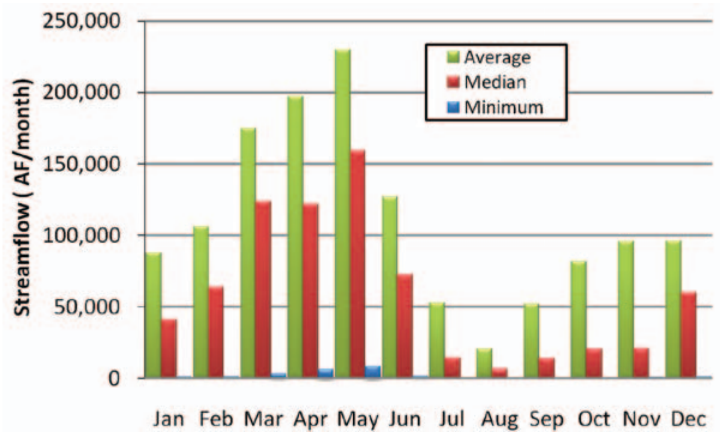
Basin 7 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Muddy Boggy Creek downstream of Bokchito Creek had a period of below-average streamflow from the late 1950s to the mid 1960s. From the early 1990s through the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The Red River currently has limited use as a water supply source in Basin 7 primarily due to water quality considerations. The median flow in Muddy Boggy Creek downstream of Bokchito Creek is greater than 6,000 AF/month throughout the year and greater than 100,000 AF/month in the spring. However, the river can have periods of low to no flow in any month of the year.
- Relative to basins statewide, the surface water quality is in Basin 7 is considered good with the exception of the Red River.
- There are no major existing reservoirs in Basin 7.

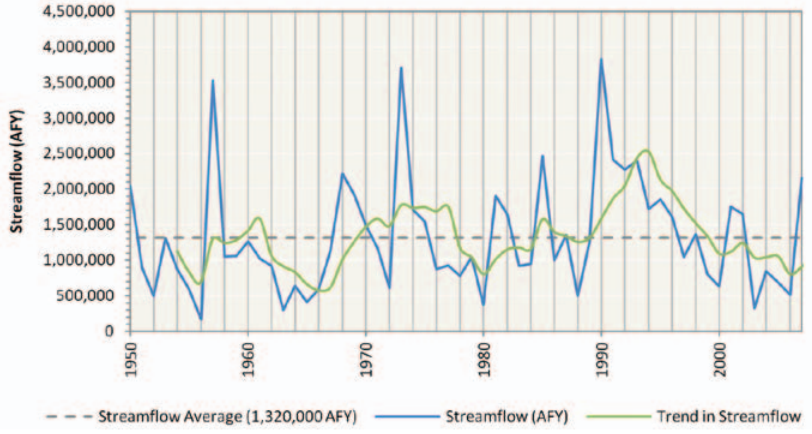
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 7



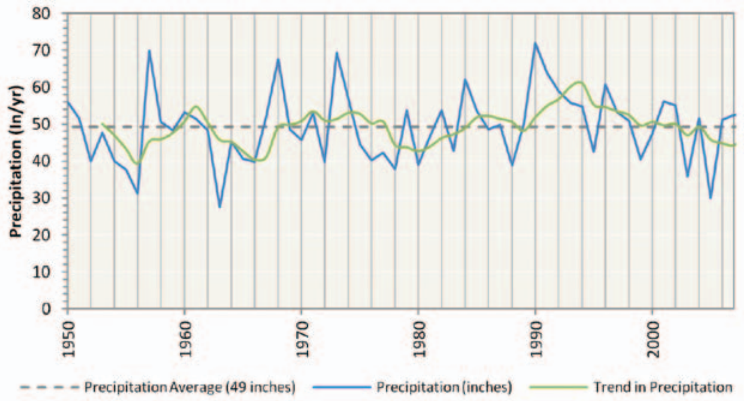
Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 7



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 7

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/acre	AFY
Antlers	Bedrock	Major	98%	3,000	4,214,000	2.1	455,000
Red River	Alluvial	Major	8%	<50	53,000	temporary 2.0	38,100
Kiamichi	Bedrock	Minor	2%	0	9,000	temporary 2.0	12,800
Woodbine	Bedrock	Minor	59%	500	2,088,000	temporary 2.0	268,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

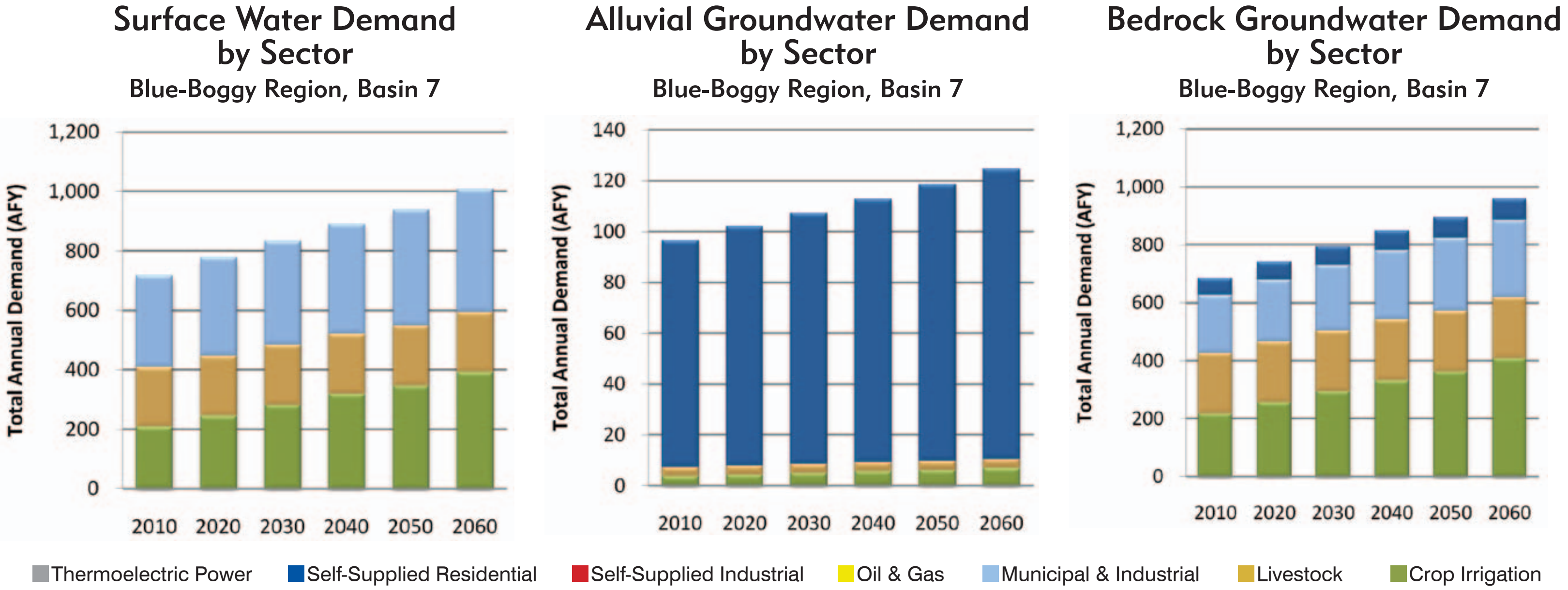
- The majority of groundwater rights in Basin 7 are in the Antlers major bedrock aquifer. The Antlers aquifer underlies almost the entire basin, has more than 4 million AF of storage, and receives about 17,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 7 account for about 2% of the demand in the Blue-Boggy Watershed Planning Region and will increase by 40% (600 AFY) from 2010 to 2060. The largest demand and growth in demand during the period will be in the Crop Irrigation demand sector.
- Surface water is used to meet 48% of total demand in the basin and its use will increase by 65% (5,360 AFY) from 2010 to 2060. The majority of the surface water use and growth in surface water use during the period will be from the Crop Irrigation and Municipal and Industrial demand sectors.
- Alluvial groundwater is used to meet 6% of total demand in the basin and its use will increase by 30% (30 AFY) from 2010 to 2060. The majority of the surface water use and growth in surface water use during the period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 46% of total demand in the basin and its use will increase by 40% (280 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use during the period will be from the Crop Irrigation and Municipal and Industrial demand sectors.



Surface Water Demand by Sector

Blue-Boggy Region, Basin 7

Alluvial Groundwater Demand by Sector

Blue-Boggy Region, Basin 7

Bedrock Groundwater Demand by Sector

Blue-Boggy Region, Basin 7

Total Demand by Sector

Blue-Boggy Region, Basin 7

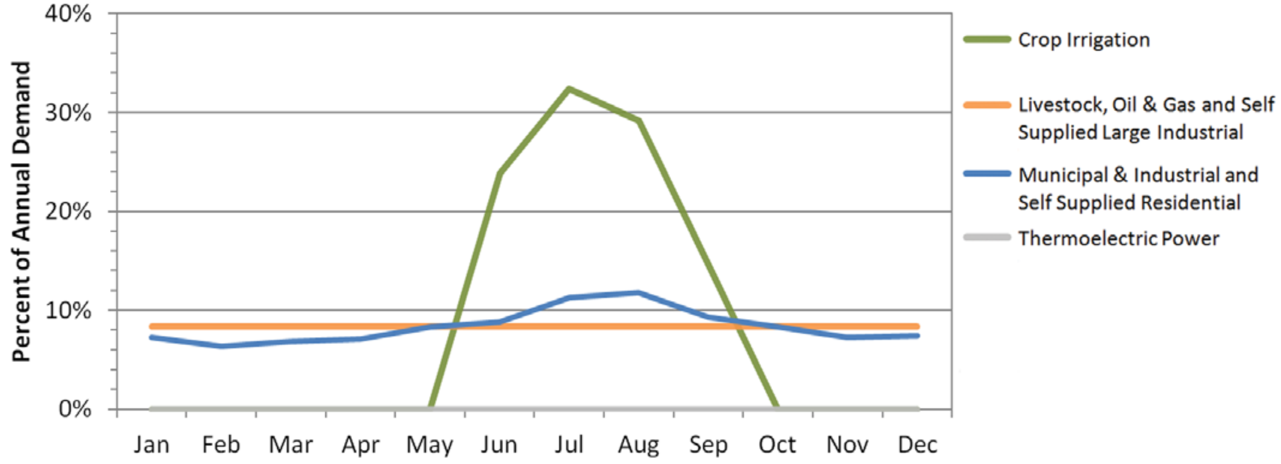
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	430	410	510	0	0	150	0	1,500
2020	510	410	540	0	0	150	0	1,610
2030	580	420	580	0	0	160	0	1,740
2040	660	420	610	0	0	170	0	1,860
2050	720	420	640	0	0	180	0	1,960
2060	810	420	680	0	0	190	0	2,100

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

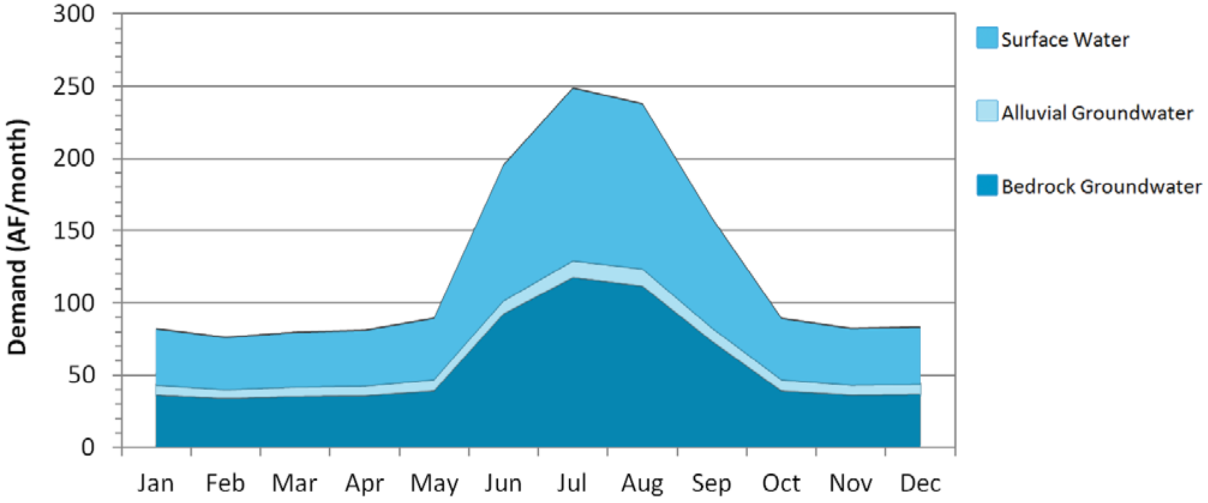
Monthly Demand Distribution by Sector (2010)

Blue-Boggy Region, Basin 7



Monthly Demand Distribution by Source (2010)

Blue-Boggy Region, Basin 7



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors typically use 52% more water in the summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors will have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 7 is about 3 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 3 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at about 1.7 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at about 3.2 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not expected to occur in this basin through 2060. However, localized gaps and storage depletions may occur.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 7

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 7

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 7

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	0	0	0	0%	0%
2050	0	0	0	0%	0%
2060	0	0	0	0%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 7

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

1 Amount shown represents the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 7

	2060 Gap/Storage Depletion			2060 Gap/ Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	0	0	0	0%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in M&I Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

[1] Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Analyses of current and projected water use patterns indicate that no surface water gaps or groundwater storage depletions should occur through 2060.

Demand Management

🟪 No option Necessary.

Out-of-Basin Supplies

🟪 No option Necessary.

Reservoir Use

🟪 No option Necessary.

Increasing Reliance on Surface Water

🟪 No option Necessary.

Increasing Reliance on Groundwater

🟪 No option Necessary.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 7

Reservoir Storage	Diversion
AF	AFY
100	2,200
500	3,100
1,000	3,900
2,500	6,300
5,000	10,300
Required Storage to Meet Growth in Demand (AF)	0
Required Storage to Meet Growth in Surface Water Demand (AF)	0

Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Data & Analysis
Blue-Boggy Watershed Planning Region

Basin 8

Basin 8 Summary

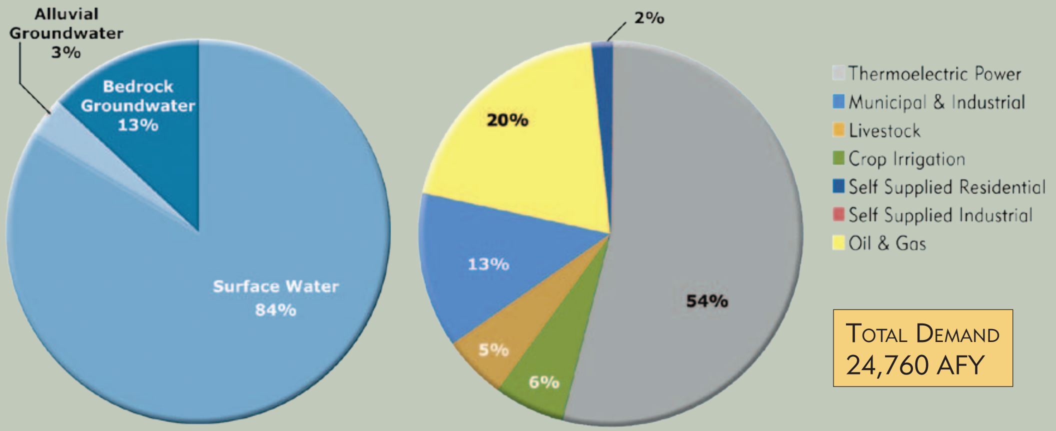
Synopsis

- Water users are expected to continue to rely mainly on major reservoirs and surface water.
- Alluvial and bedrock groundwater storage depletions on minor aquifers may occur by 2020. Localized storage depletions may cause adverse effects for users.
- McGee Creek Lake and other major reservoirs in the basin are capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of the future surface water demand in Basin 8 during periods of low streamflow.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation could mitigate alluvial and bedrock groundwater storage depletions.
- Reservoir storage could be used as an alternative to mitigate alluvial or bedrock groundwater storage depletions.

Basin 8 accounts for about 40% of the current water demand in the Blue-Boggy Watershed Planning Region. About 54% of the basin demand, excluding out of basin transfers, is from the Thermoelectric Power demand sector. Oil and Gas (20%) is the second largest demand sector. Surface water satisfies about 84% of the current demand in the basin. Groundwater satisfies about 16% of the current demand (3% alluvial and 13% bedrock). The peak summer month total water demand in Basin 8 is about 1.4 times the winter monthly demand, which is less pronounced than the overall statewide pattern.

The flow in Muddy Boggy Creek near Farris is typically greater than 2,300 AF/month throughout the year and greater than 18,000 AF/month in the winter and spring. However, the creek can have periods of low to no flow in any month of the year. The one major federal reservoir in the basin, McGee Creek Reservoir, is a Bureau of Reclamation project on McGee Creek, a tributary of Muddy Boggy Creek. McGee Creek was completed in 1987 for the purposes of water supply, water quality control, flood control, recreation, and fish and wildlife mitigation. The reservoir provides a dependable water supply yield of 71,800 AFY, of which 40,000 AFY is allocated to the Oklahoma City and 24,608 AFY is allocated locally to the City of Atoka, Atoka County Commissioners, Southern Oklahoma Development Trust, and the City of Coalgate. McGee Creek Reservoir currently has 7,192 AFY of unpermitted yield that could meet the demand of new users. Atoka Reservoir, one of the state's major municipal reservoirs, was constructed on the North Boggy Creek by Oklahoma City in 1964 for the purposes of water supply and recreation. Most of the lake's 92,067 AFY of dependable yield is allocated to Oklahoma City in the Central Watershed Planning Region and is accessed via the Atoka pipeline. Additional water supply yield is allocated locally to the City

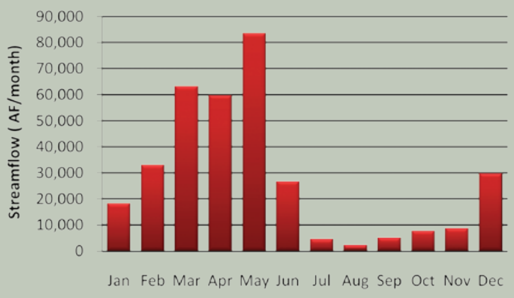
Current Demand by Source and Sector
Blue-Boggy Region, Basin 8



Water Resources
Blue-Boggy Region, Basin 8

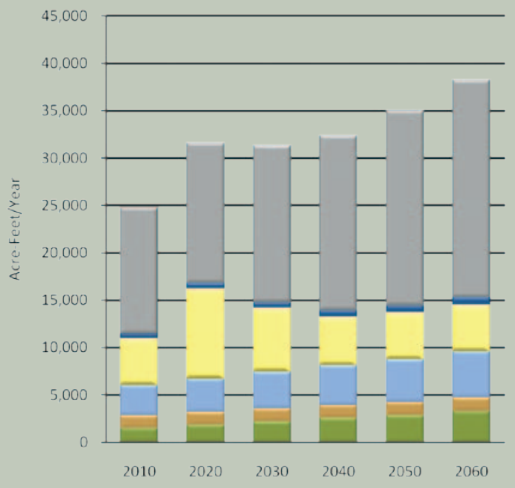
Median Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 8



Projected Water Demand

Blue-Boggy Region, Basin 8



of Atoka for public water supply and to OG&E for power purposes. Atoka Reservoir is fully allocated and is expected to continue to supply existing users in the future. Coalgate Reservoir supplies water to the City of Coalgate. The water supply yield of this reservoir is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Parker Lake, the only remaining major federal reservoir currently authorized for construction, is located on the Muddy Boggy Creek in Basin 8 and authorized for flood control, water supply, recreation, and fish and wildlife mitigation with an estimated dependable water supply yield of 45,900 AFY. Pre-construction engineering and design have been completed for the project but a local cost-sharing partner would need to be identified and engineering and economic data would need to be updated before the project could be reactivated. Relative to other basins in the state, the surface water quality in Basin 8 is considered good. However, North Boggy Creek and the headwaters of Muddy Boggy Creek are impaired for Agricultural use due to high levels of chloride, sulfate and total dissolved solids (TDS).

The majority of groundwater rights in Basin 8 are in the East-Central Oklahoma minor bedrock aquifer with 2,300 AFY. There are 700 AFY of groundwater rights in the Canadian River major alluvial aquifer, which underlies less than 1% of the basin. There are 300 AFY of groundwater rights in the Antlers major bedrock aquifer, which underlies only 4% of the basin. However, the basin provides about 4,000 AFY of recharge to the Antlers aquifer. There are also permits in multiple minor bedrock aquifers and non-delineated minor alluvial aquifers. Additionally, domestic users do not require a permit and are assumed to be obtaining supplies from minor aquifers in the basin. Site-specific information on the suitability of minor aquifers for supply should be considered before large scale use. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 38,300 AFY in Basin 8 reflects a 13,540 AFY increase (55%) over the 2010 demand. The majority of the demand and growth in demand over the period will be in the Thermoelectric Power demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial and bedrock groundwater storage depletions are projected to occur by 2020. Surface water gaps are not expected through 2060. McGee Creek Lake is capable of providing reliable water supplies to its existing users and with new infrastructure could supply sufficient water to meet all of Basin 8's future surface water demand during periods of low streamflow. Alluvial groundwater depletions have a moderately high probability (59%) of occurring in at least one month of the year by 2060 and will be up to 260 AFY on a basin-scale. Alluvial groundwater storage depletions in Basin 8 may occur in the winter, summer, and fall, peaking in size during the summer. Bedrock groundwater depletions will be up to 1,910 AFY by 2020, but fall to 370 AFY by 2060. This is due to variability in Oil and Gas demand associated with the anticipated timing of Woodford Shale drilling activities. Bedrock groundwater storage depletions in Basin 8 may occur in the summer and fall, peaking in size during the summer. Future alluvial and bedrock groundwater withdrawals are expected to occur primarily from minor aquifers, which cannot be fully evaluated due to insufficient information. Although groundwater depletions will be minimal compared to the total amount of water in storage in the basin, localized storage depletions are expected to occur and may adversely affect well yields, water quality, and/or pumping costs.

Water Supply Limitations

Blue-Boggy Region, Basin 8

🟩	Surface Water
🟨	Alluvial Groundwater
🟨	Bedrock Groundwater

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Blue-Boggy Region, Basin 8

🟨	Demand Management
🟨	Out-of-Basin Supplies
🟩	Reservoir Use
🟥	Increasing Supply from Surface Water
🟨	Increasing Supply from Groundwater

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

Options

Water users are expected to continue to rely primarily on surface water supplies, including reservoirs. To reduce the risk of adverse impacts to the basin's water users, groundwater storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce alluvial and bedrock groundwater storage depletions. Temporary drought management activities may not be necessary for groundwater demand, since the groundwater storage could continue to provide supplies during droughts and may not be effective given the moderately high probability of depletions each year.

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified five potentially viable out-of-basin sites in the Blue-Boggy Region. However, in light of the unpermitted yield of McGee Creek Lake and distances to potential reservoir sites, out-of-basin supplies may not be cost-effective for some users.

Use of unpermitted yield in McGee Creek Lake or new reservoir storage could be used to meet all of the basin's future demand during periods of low streamflow. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 5,700 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified two potential sites in the basin.

Increased reliance on surface water through direct diversions, without reservoir storage, may create surface water gaps and is not recommended.

Basin 8 is underlain primarily by minor groundwater aquifers, which may not have sufficient yield for large-scale users. Therefore, site-specific information should be considered before increasing reliance on groundwater supplies.

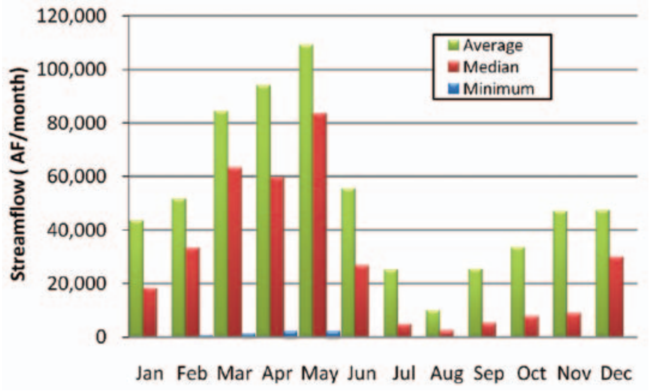
Basin 8 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Muddy Boggy Creek near Farris had a period of below-average streamflow in the mid-1960s and mid-1980s. From the early 1990s through the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in Muddy Boggy Creek near Farris is greater than 2,300 AF/month throughout the year and greater than 18,000 AF/month in the winter and spring. However, the creek can have periods of low to no flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 8 is considered good.
- McGee Creek Reservoir was built by the Bureau of Reclamation and provides about 71,800 AFY of dependable water supply yield. McGee Creek Reservoir has about 7,190 AFY of unpermitted yield that could meet the demand of new users. Atoka Reservoir was built by Oklahoma City, which holds water rights to the majority of the 92,067 AFY of dependable yield, while a lesser amount is allocated locally. Atoka Reservoir is fully allocated and expected to continue to supply its existing users in the future. Coalgate Reservoir supplies water to the City of Coalgate. The water supply yield is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated.

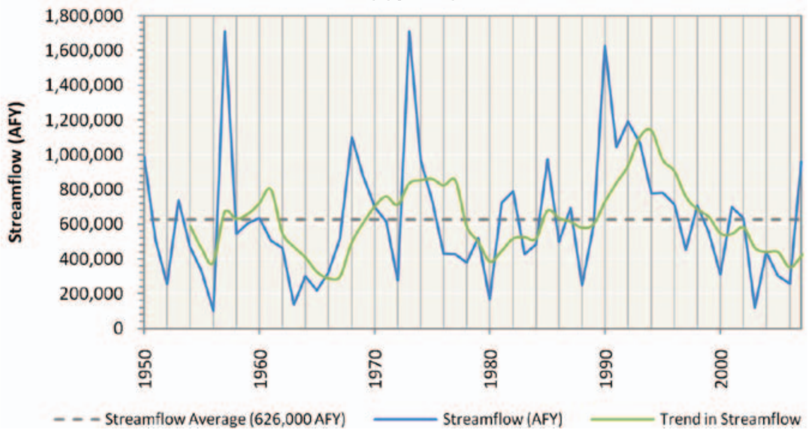
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 8



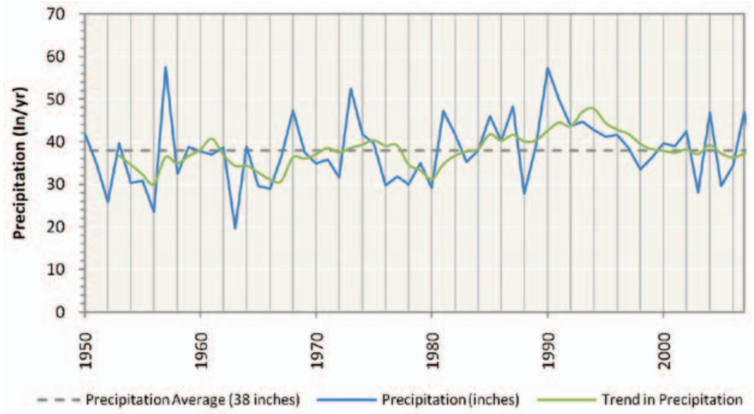
Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 8



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 8

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	Percent	AFY	AF	AFY/acre	AFY
Antlers	Bedrock	Major	4%	300	270,000	2.1	53,100
Canadian	Alluvial	Major	<1%	700	11,000	temporary 2.0	3,600
Ashland Isolated Terrace	Alluvial	Minor	1%	0	27,000	temporary 2.0	12,500
East-Central Oklahoma	Bedrock	Minor	11%	2,300	1,195,000	temporary 2.0	150,600
Kiamichi	Bedrock	Minor	41%	500	386,000	temporary 2.0	562,300
Pennsylvanian	Bedrock	Minor	36%	700	4,083,000	temporary 2.0	497,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	300	N/A	temporary 2.0	N/A

[1] *Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.*

Groundwater Resources

- The majority of groundwater rights in Basin 8 are in the East-Central Oklahoma minor bedrock aquifer. The basin provides about 4,000 AFY of recharge to the Antlers aquifer. There are additional permits in multiple minor bedrock aquifers and non-delineated minor alluvial aquifers.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

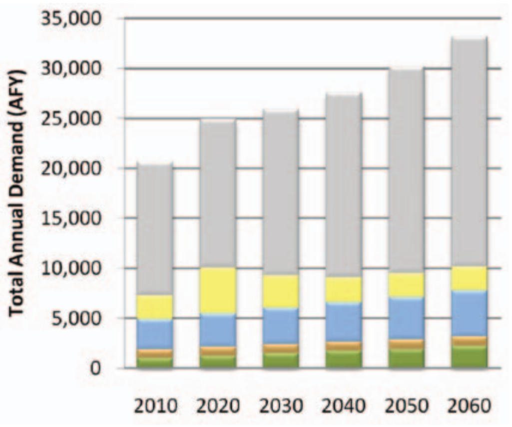
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs for Basin 8 account for about 40% of the demand in the Blue-Boggy Watershed Planning Region and will increase by 55% (13,540 AFY) from 2010 to 2060. The majority of the demand and growth in demand during the period will be from the Thermoelectric Power demand sector.
- Surface water is used to meet 84% of total demand in the basin and its use will increase by 61% (12,530 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Thermoelectric Power demand sector.
- Alluvial groundwater is used to meet 3% of total demand in the basin and its use will increase by 65% (540 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 13% of total demand in the basin and its use will increase by 14% (460 AFY) from 2010 to 2060. The majority of bedrock groundwater use will be in the Oil and Gas demand sector, which will peak around 2020 because of anticipated Woodford Shale drilling activities. The largest sustained growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

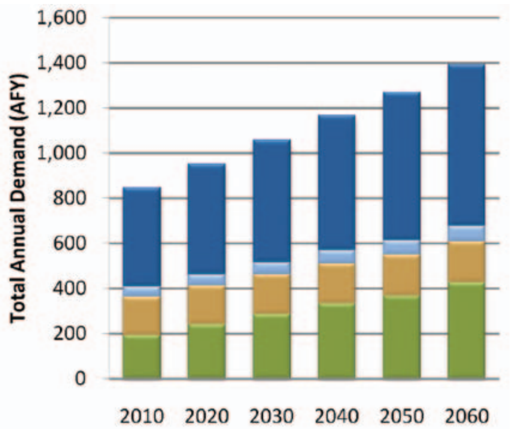
Surface Water Demand by Sector

Blue-Boggy Region, Basin 8



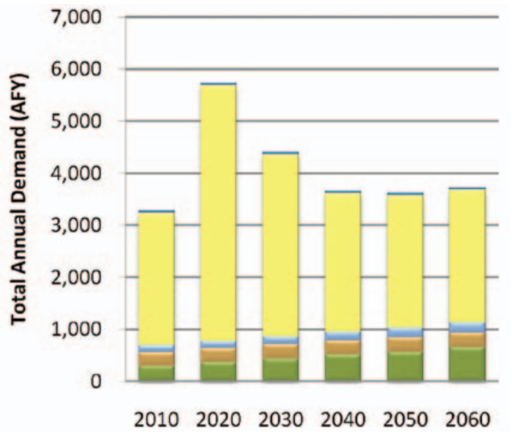
Alluvial Groundwater Demand by Sector

Blue-Boggy Region, Basin 8



Bedrock Groundwater Demand by Sector

Blue-Boggy Region, Basin 8



■ Thermoelectric Power ■ Self-Supplied Residential ■ Self-Supplied Industrial ■ Oil & Gas ■ Municipal & Industrial ■ Livestock ■ Crop Irrigation

Total Demand by Sector

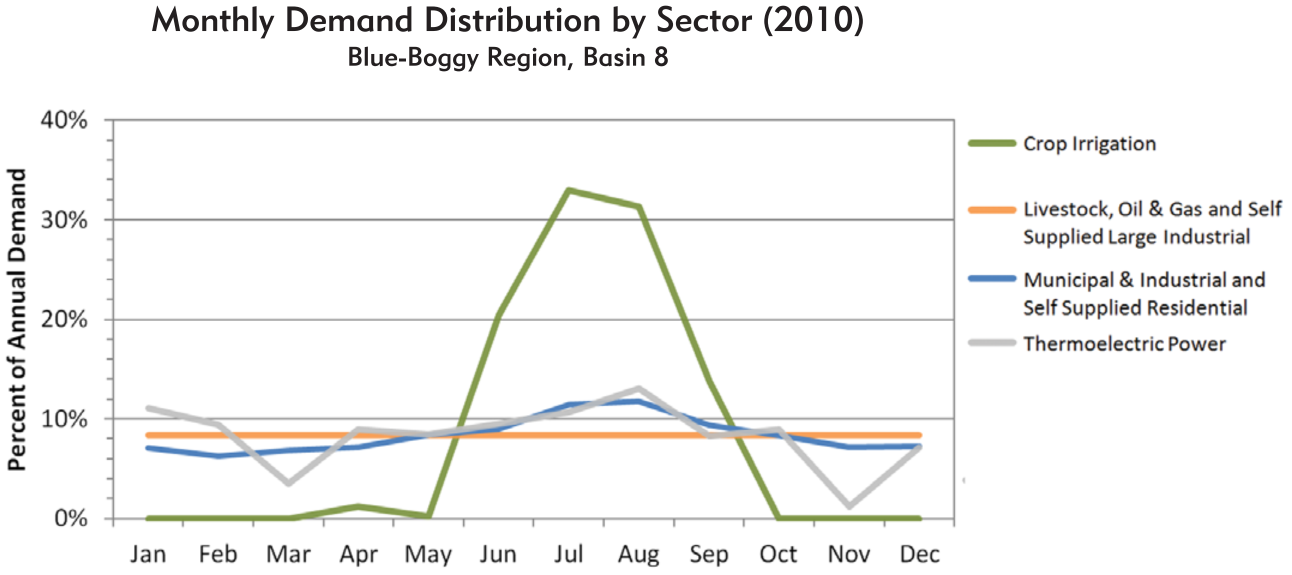
Blue-Boggy Region, Basin 8

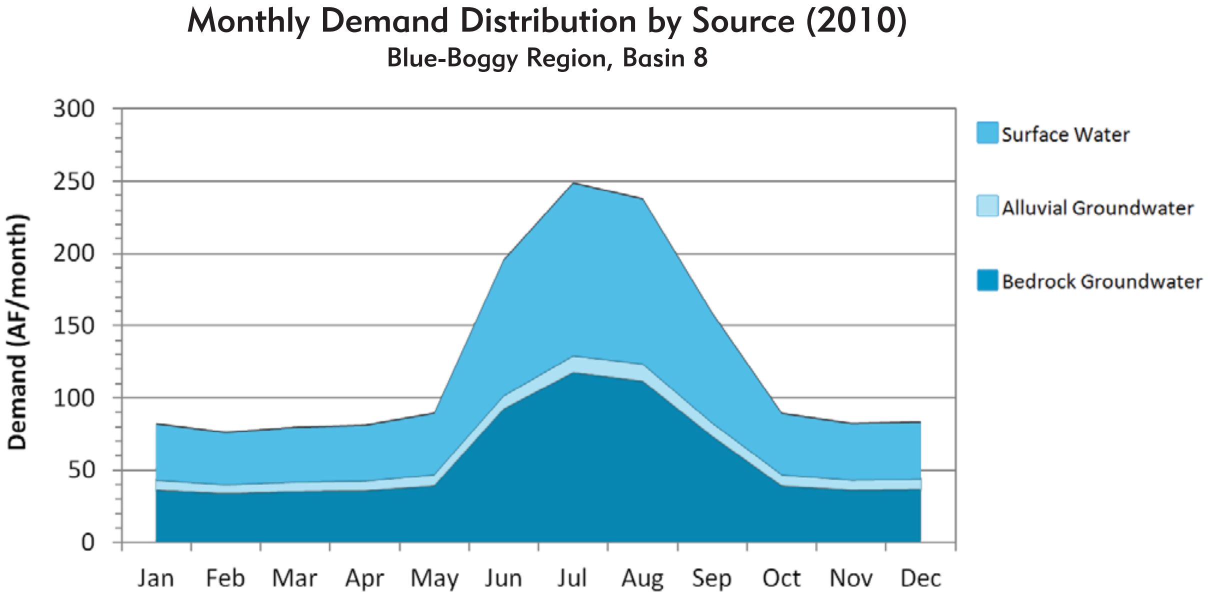
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas[1]	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,490	1,310	3,240	4,940	0	460	13,320	24,760
2020	1,840	1,330	3,550	9,520	0	510	14,860	31,610
2030	2,200	1,350	3,870	6,770	0	570	16,570	31,330
2040	2,560	1,370	4,200	5,160	0	620	18,490	32,400
2050	2,840	1,390	4,550	4,940	0	680	20,630	35,030
2060	3,280	1,410	4,910	4,940	0	750	23,010	38,300

[1] *The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Blue-Boggy Region, Basins 8 and 9) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin Total Demand by Sector tables.*

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 57% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Thermoelectric Power demand is highest in August and lowest in November. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 3 is about 1.4 times the peak monthly winter demand, which is less pronounced than the overall statewide pattern. Monthly surface groundwater use peaks in the summer at about 1.4 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at about 2.7 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at about 1.4 times the peak monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial and bedrock groundwater storage depletions are projected to occur by 2020. Surface water gaps are not expected through 2060.
- Alluvial groundwater storage depletions in Basin 8 may occur in the winter, summer, and fall, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 32% (80 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 29% (20 AF/month) of the winter monthly alluvial groundwater demand. There will be a 59% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 8 may occur in the summer and fall, peaking in size during the summer. Bedrock groundwater depletions will be up to 1,910 AFY by 2020, but fall to 370 AFY by 2060. This is due to variability in Oil and Gas demand associated with the anticipated timing of Woodford Shale drilling activities. Bedrock groundwater storage depletions in 2060 will be 27% (130 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 11% (40 AF/month) on average of the fall months' peak bedrock groundwater demand.
- Future groundwater withdrawals are expected to occur primarily from minor aquifers, which cannot be fully evaluated due to insufficient information. Although groundwater depletions will be minimal compared to the total amount of water in storage in the basin, localized storage depletions are expected to occur and may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 8

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

[1] Amount shown represents the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 8

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	10	12%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	80	50	50%
Sep-Nov (Fall)	50	20	28%

[1] Amount shown represents the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 8

	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
Planning Horizon	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	50	1,910	0%	24%
2030	0	70	600	0%	28%
2040	0	120	250	0%	40%
2050	0	180	270	0%	48%
2060	0	260	370	0%	59%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 8

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	130
Sep-Nov (Fall)	40

[1] Amount shown represents the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 8

	2060 Gap/Storage Depletion			2060 Gap/ Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	0	260	370	0%	59%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	250	330	0%	59%
Moderately Expanded Conservation in M&I Water Use	0	240	350	0%	59%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	220	320	0%	57%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	190	160	0%	52%

1 Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 8

Reservoir Storage	Diversion
AF	AFY
100	1,600
500	2,700
1,000	3,900
2,500	7,000
5,000	12,200
Required Storage to Meet Growth in Demand (AF)	5,700
Required Storage to Meet Growth in Surface Water Demand (AF)	5,000

Water Supply Options & Effectiveness

🟩 Typically Effective 🟨 Potentially Effective

🟥 Likely Ineffective 🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce alluvial and bedrock groundwater storage depletions by about 15%. Temporary drought management activities may not be necessary for groundwater demand, since the groundwater storage could continue to provide supplies during droughts, and may not be effective given the moderately high probability of depletions each year.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified five potentially viable out-of-basin sites in the Blue-Boggy Region: Boswell in Basin 7; Tupelo in Basin 9; Bennington in Basin 11; Sandy Creek in Basin 12; and Albany in Basin 13. However, in light of the unpermitted yield of McGee Creek Lake and distance to potential reservoirs, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

🟩 Use of unpermitted yield in McGee Creek Lake or new reservoir storage could be used to meet all of the basin's future demand during periods of low streamflow. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 5,700 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future groundwater depletions. The OCWP *Reservoir Viability Study* also identified Parker Lake (the only remaining federal reservoir in Oklahoma currently authorized for construction) and Chickasaw Lake as potentially viable sites in the basin.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water through direct diversions, without reservoir storage, may create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟨 Increasing reliance on groundwater resources may increase groundwater depletions, which would be relatively small compared to the total amount of water in storage in the basin. However, Basin 8 is underlain primarily by minor ground water aquifers, which may not have sufficient yield for large-scale users. Therefore, site-specific information on the suitability of minor aquifers for use should be considered before increasing reliance on these supplies.

Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Blue-Boggy Watershed Planning Region

Basin 9

Basin 9 Summary

Synopsis

- Water users are expected to continue to rely mainly on surface water and bedrock groundwater.
- By 2020, there is a low to moderate probability of surface water gaps from increased demand on existing supplies during low flow periods.
- Alluvial groundwater storage depletions from minor aquifers may occur by 2020. Localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that surface water gaps and groundwater storage depletions be decreased where economically feasible.
- Additional conservation or temporary drought management measures could reduce surface water gaps and alluvial groundwater storage depletions.
- To mitigate surface water gaps, dependable groundwater supplies and/or developing new reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

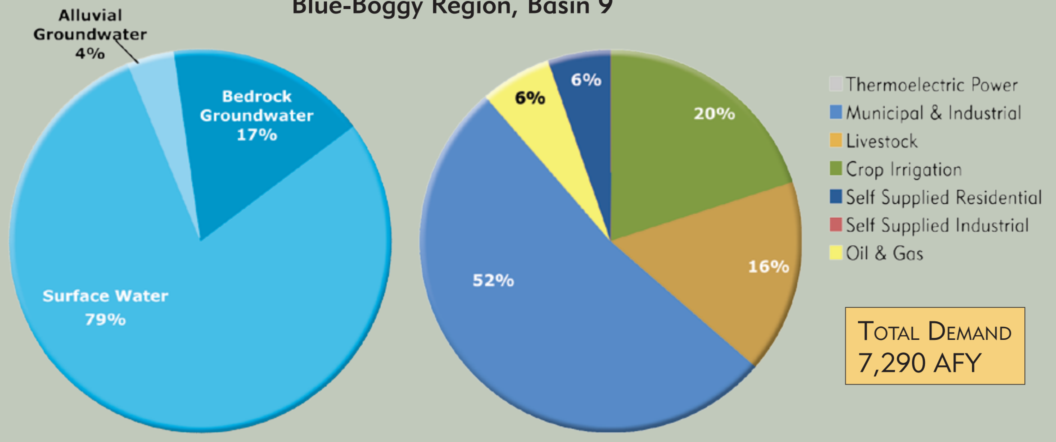
Basin 9 accounts for about 12% of the current water demand in the Blue-Boggy Watershed Planning Region. About 52% of the basin demand is from the Municipal and Industrial demand sector. Crop Irrigation is the second largest demand sector at 20%. Surface water satisfies about 79% of the current demand in the basin. Groundwater satisfies about 21% of the current demand (4% alluvial and 17% bedrock). The peak summer month demand in Basin 9 is about 2.5 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in Clear Boggy Creek upstream of Muddy Boggy Creek is typically greater than 2,800 AF/month throughout the year and greater than 30,000 AF/month in spring and early summer. However, the creek can have periods of low to no flow in any month of the year. There are no major reservoirs in this basin. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. The surface water quality in Basin 9 is considered fair relative to other basins in the state. Lake Creek, a small tributary, is impaired for Agricultural use due to high levels of chloride and total dissolved solids (TDS).

The majority of water rights in Basin 9 are from the Antlers major bedrock aquifer. The Antlers aquifer underlies much of the southern portion of the basin and is estimated to have over 3.6 million AF of groundwater storage in Basin 9. There are substantial groundwater rights in the Arbuckle-Simpson major bedrock aquifer, but the aquifer only underlies 5% of the basin area. The OWRB is currently studying the aquifer in compliance with the 2003 Senate Bill 288 legislation to set a maximum annual yield and equal proportionate share. Permits for use

Current Demand by Source and Sector

Blue-Boggy Region, Basin 9

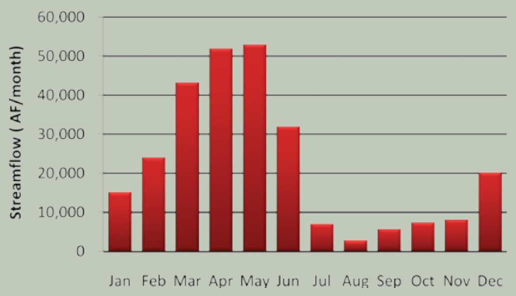


Total Demand
7,290 AFY

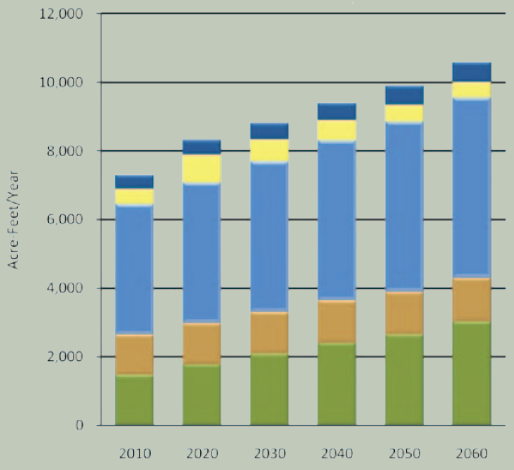
Water Resources

Blue-Boggy Region, Basin 9

Median Historical Streamflow at the Basin Outlet
Blue-Boggy Region, Basin 9



Projected Water Demand
Blue-Boggy Region, Basin 9



from the aquifer are currently temporary and permitted amounts are expected to decrease upon being made permanent. There are 900 AFY of water rights in the Pennsylvanian minor bedrock aquifer and 300 AFY from non-delineated minor bedrock groundwater sources. Domestic users do not require a permit and are assumed to be obtaining supplies from basin-wide groundwater sources. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 10,580 AFY in Basin 9 reflects a 3,290 AFY increase (45%) over the 2010 demand. The largest demand from 2010 to 2060 will be in the Municipal and Industrial demand sector, but the largest growth in demand will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2020. Surface water gaps and alluvial groundwater storage depletions in Basin 9 may occur during summer and fall. No bedrock groundwater storage depletions are expected through 2060 in this basin. Surface water gaps will be up to 1,370 AFY and have a 22% probability of occurring in at least one month of the year by 2060. Alluvial groundwater depletions will be up to 60 AFY and have a 22% probability of occurring in at least one month of the year by 2060. The entire alluvial groundwater use and growth in use over this period are assumed to be in the Self-Supplied Residential (domestic) demand sector. Future alluvial groundwater withdrawals are expected to occur from non- delineated minor aquifers; therefore, due to insufficient information, the extent of the storage depletions could not be fully evaluated. While withdrawals and depletions will be small relative to the total amount of water in storage, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Options

Water users are expected to continue to rely primarily on surface water supplies and bedrock groundwater. To reduce the risk of adverse impacts to the basin's water users, gaps and storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation sectors could reduce surface water gaps and alluvial groundwater depletions. While temporary drought management activities may alleviate surface water gaps, permanent conservation activities may be more effective since there is a moderate probability of gaps. Temporary drought management activities may not be necessary for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Water Supply Limitations
Blue-Boggy Region, Basin 9

Surface Water	🟨
Alluvial Groundwater	🟨
Bedrock Groundwater	🟩

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness
Blue-Boggy Region, Basin 9

Demand Management	🟨
Out-of-Basin Supplies	🟨
Reservoir Use	🟩
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟩

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

New out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region. This includes Parker Lake, in Basin 8, which is the only remaining federal reservoir in Oklahoma currently authorized for construction. However, due to the distance to out-of-basin supplies and presence of in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for many users.

Additional reservoir storage could provide dependable supplies to mitigate gaps and storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 2,000 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Tupelo Lake as a potentially viable site in Basin 9.

Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on major bedrock aquifers could mitigate alluvial groundwater storage depletions or surface water gaps, but may cause bedrock groundwater storage depletions. Any storage depletions would be small relative to the volume of water stored in Basin 9's portion of the Antlers and Arbuckle-Simpson aquifers. However, the Antlers aquifer only underlies the southern half of the basin and the Arbuckle-Simpson only underlies a small portion (5%) of the northern half of the basin. Increased reliance on minor bedrock aquifers for domestic use could mitigate alluvial groundwater depletions, but site specific studies should be conducted before consideration of large-scale use.

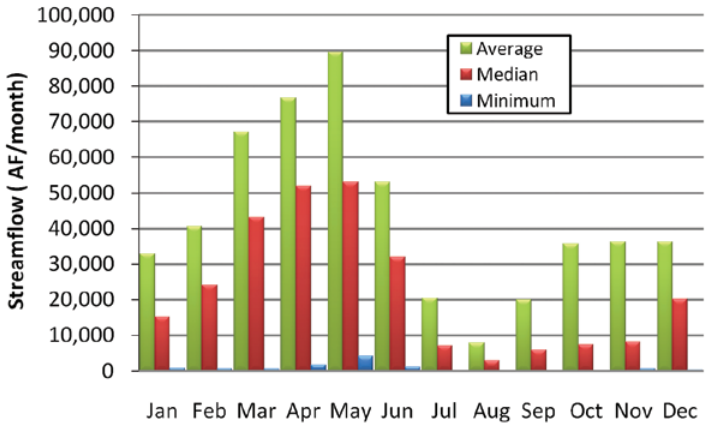
Basin 9 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The basin had a prolonged period of below-average streamflow in the 1960s, corresponding to a period of below-average precipitation. In the 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in Clear Boggy Creek upstream of Muddy Boggy Creek is greater than 2,800 AF/month throughout the year and is greater than 30,000 AF/month in spring and early summer. However, the creek can have periods of low to no flow in any month of the year.
- Relative to basins statewide, the surface water quality is in Basin 9 is considered fair.
- There are no major reservoirs in this basin.

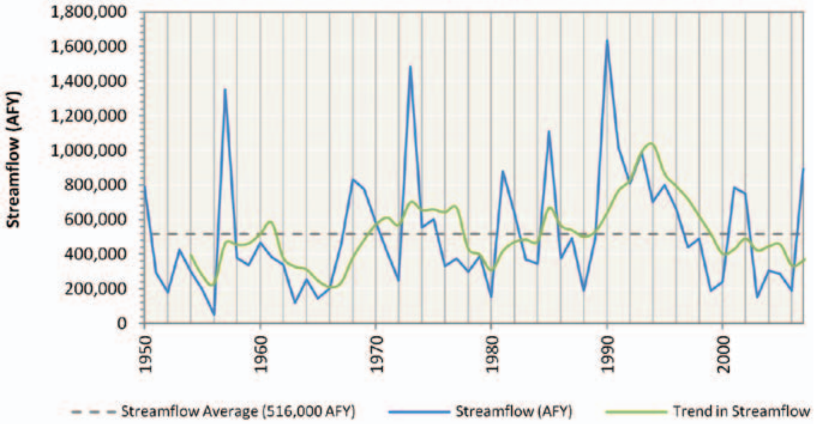
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 9



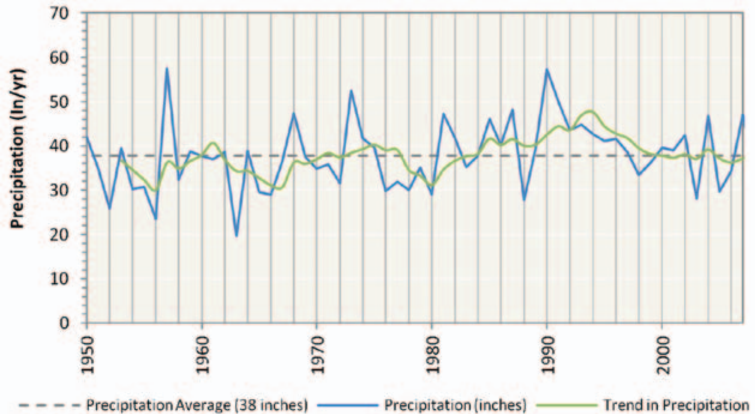
Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 9



Historical Precipitation

Regional Climate Division



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- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 9

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	Percent	AFY	AF	AFY/acre	AFY
Antlers	Bedrock	Major	42%	3,500	3,623,000	2.1	560,800
Arbuckle-Simpson	Bedrock	Major	5%	1,000	892,000	temporary[2]	63,900
Kiamichi	Bedrock	Minor	7%	0	60,000	temporary 2.0	89,600
Pennsylvanian	Bedrock	Minor	22%	900	2,303,000	temporary 2.0	281,400
Woodbine	Bedrock	Minor	13%	0	1,293,000	temporary 2.0	166,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

2 Pursuant to 82 O.S. § 1020.9(A)(2), the temporary allocation for the Arbuckle-Simpson groundwater basin is subject to the OWRB's case-by case determination of what amount will not likely degrade or interfere with springs or streams emanating from the Arbuckle-Simpson.

Groundwater Resources

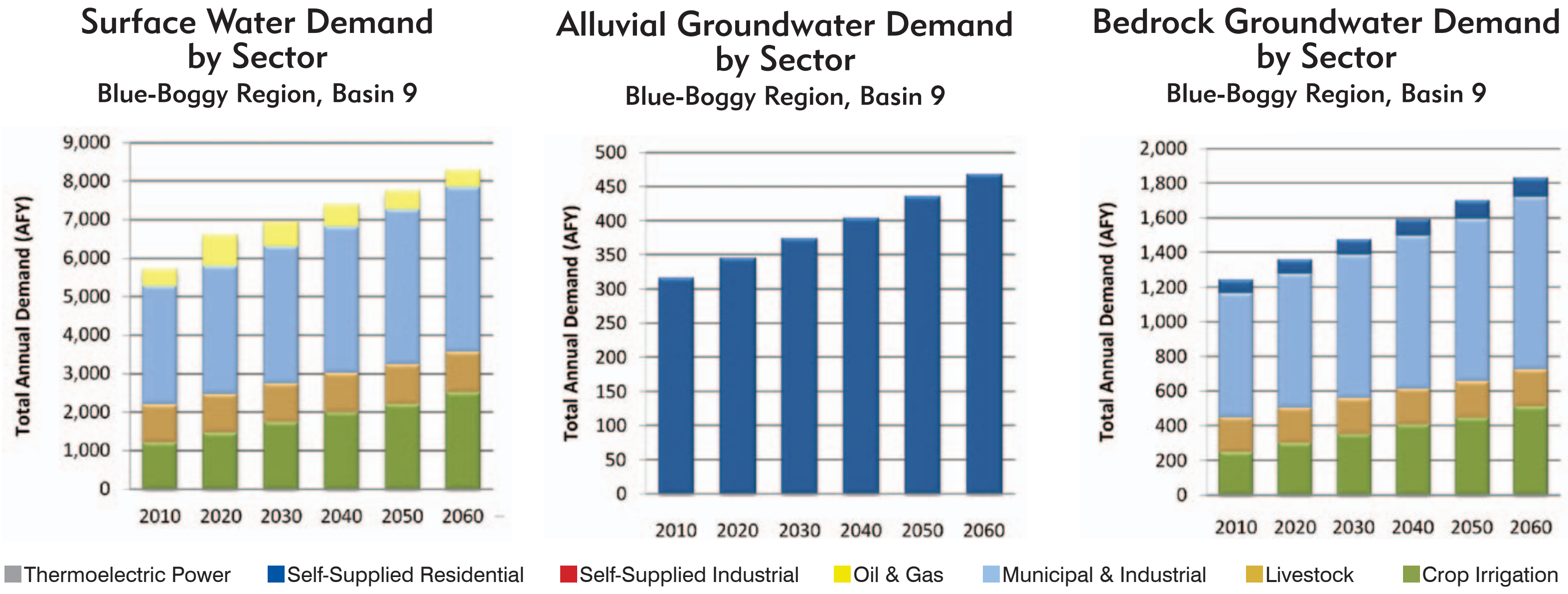
- The majority of water rights in Basin 9 are from the Antlers major bedrock aquifer. The Antlers aquifer underlies about 40% of the southern portion of the basin and is estimated to have more than 3.6 million AF of groundwater storage in Basin 9. There are substantial groundwater rights in the Arbuckle-Simpson major bedrock aquifer but the aquifer only underlies 5% of the basin area. The OWRB is currently studying the aquifer in compliance with the 2003 Senate Bill 288 legislation to set a maximum annual yield and equal proportionate share. With the exception of prior rights permits to the aquifer are currently temporary and permitted amounts are expected to decrease upon being made permanent. The need to dedicate more land to access existing or future supplies may make the Arbuckle-Simpson aquifer less cost-effective for some users. Basin 9 contributes about 40,000 AFY of recharge to major bedrock aquifers, largely to the Antlers aquifer.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 9 account for about 12% of the total demand in the Blue-Boggy Watershed Planning Region and will increase by 45% (3,290 AFY) from 2010 to 2060. The largest demand will be from the Municipal and Industrial demand sector, but the largest growth in demand will be from the Crop Irrigation demand sector.
- Surface water is used to meet 79% of the total demand in the basin and its use will increase by 45% (2,550 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Municipal and Industrial and Crop Irrigation demand sectors.
- Alluvial groundwater is used to meet 4% of the total demand in the basin and its use will increase by 48% (150 AFY) from 2010 to 2060. All alluvial groundwater use will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet about 17% of the total demand in the basin and its use will increase by 48% (590 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Municipal and Industrial demand sector.



Surface Water Demand by Sector
Blue-Boggy Region, Basin 9

Alluvial Groundwater Demand by Sector
Blue-Boggy Region, Basin 9

Bedrock Groundwater Demand by Sector
Blue-Boggy Region, Basin 9

Total Demand by Sector

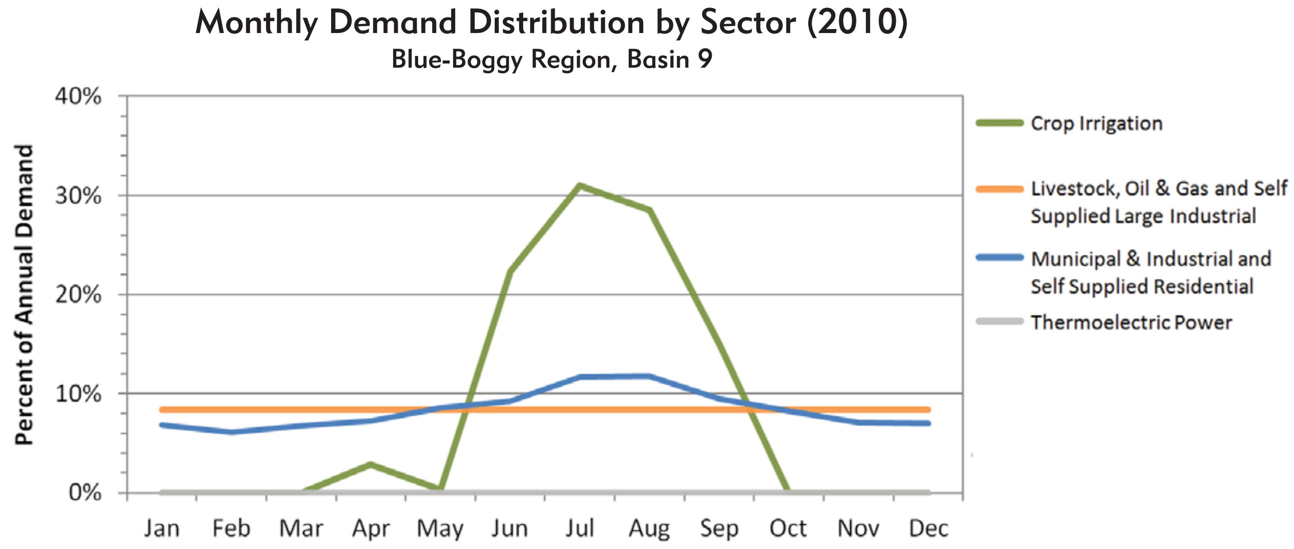
Blue-Boggy Region, Basin 9

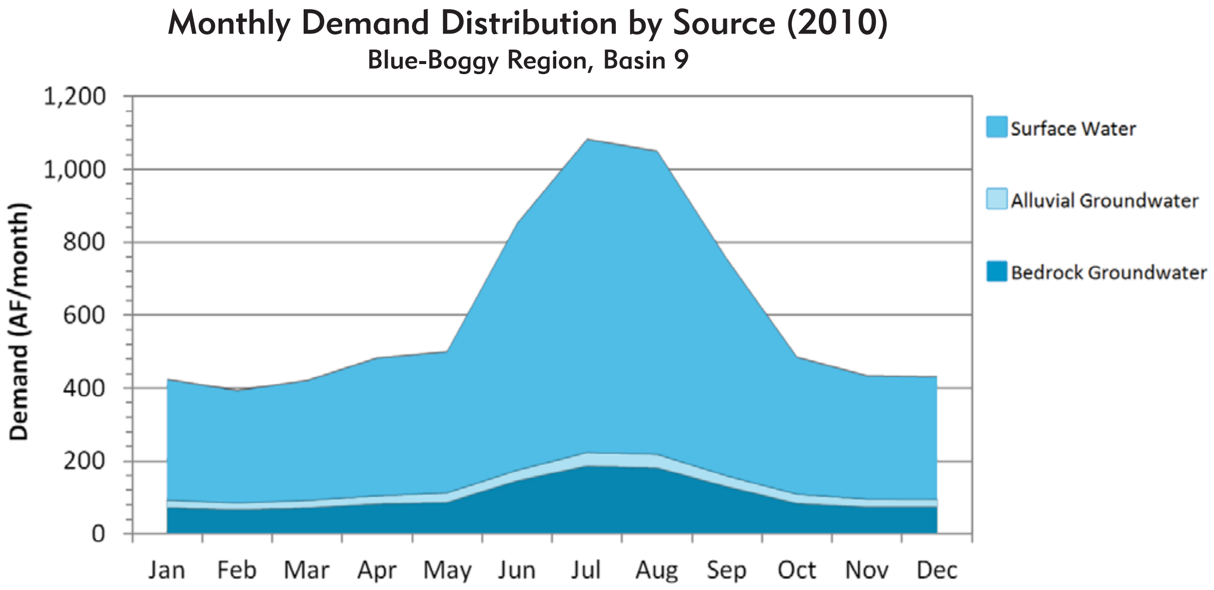
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas[1]	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,460	1,190	3,810	440	0	390	0	7,290
2020	1,770	1,200	4,110	810	0	430	0	8,320
2030	2,090	1,220	4,390	660	0	460	0	8,820
2040	2,400	1,230	4,680	590	0	500	0	9,400
2050	2,640	1,250	4,970	490	0	540	0	9,890
2060	3,020	1,270	5,270	440	0	580	0	10,580

1 The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Blue-Boggy Region, Basins 8 and 9) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin Total Demand by Sector tables.

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 64% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 9 is about 2.5 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.6 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at about 1.7 times the monthly winter use. Bedrock groundwater use in the peak summer month is about 2.6 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2020. No bedrock groundwater depletions are expected through 2060 in this basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.
- Surface water gaps in Basin 9 may occur during summer and fall. Surface water gaps in 2060 will be up to 36% (500 AF/month) of the surface water demand in the peak summer month, and as much as 32% (290 AF/month) of the fall monthly surface water demand. Surface water gaps are expected to be up to 1,370 AFY and have a 22% probability of occurring in at least one month of the year by 2060.
- Alluvial groundwater storage depletions in Basin 9 may occur during summer and fall. Alluvial groundwater storage depletions in 2060 will be up to 40% (20 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 25% (10 AF/month) of the fall monthly alluvial groundwater demand. There will be a 22% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions have similar probabilities of occurring in both summer and fall months.
- Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the extent of the storage depletions cannot be fully evaluated due to insufficient information.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 9

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	500	470	19%
Sep-Nov (Fall)	290	290	14%

1 Amount shown represents the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 9

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	20	20	17%
Sep-Nov (Fall)	10	10	14%

1 Amount shown represents the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 9

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	400	20	0	16%	12%
2030	610	30	0	19%	14%
2040	870	40	0	22%	17%
2050	1,070	60	0	22%	21%
2060	1,370	60	0	22%	22%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 9

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

1 Amount shown represents the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 9

	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	1,370	60	0	22%	22%
Moderately Expanded Conservation in Crop Irrigation Water Use	1,280	60	0	22%	22%
Moderately Expanded Conservation in M&I Water Use	1,090	50	0	22%	19%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	1,000	30	0	22%	19%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	550	20	0	19%	12%

[1] Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 9

Reservoir Storage	Diversion
AF	AFY
100	200
500	800
1,000	1,700
2,500	4,200
5,000	8,400
Required Storage to Meet Growth in Demand (AF)	2,000
Required Storage to Meet Growth in Surface Water Demand (AF)	1,500

Water Supply Options & Effectiveness

🟩 Typically Effective	🟨 Potentially Effective
🟥 Likely Ineffective	🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation sectors could reduce surface water gaps by 27% and alluvial groundwater depletions by about 50%. Permanent conservation activities may be more effective than temporary drought management activities, since there is a moderate probability of surface water gaps. Temporary drought management activities may not be necessary for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

🟨 New out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region: Boswell in Basin 7; Chickasaw and Parker in Basin 8; Bennington in Basin 11; Sandy Creek in Basin 12; and Albany in Basin 13. (Parker Lake is the only remaining federal reservoir in Oklahoma currently authorized for construction.) However, due to the distance to out-of-basin supplies and presence of in-basin groundwater sources, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

🟩 Reservoir storage could provide dependable supplies to mitigate gaps and storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 2,000 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Tupelo Lake as a potentially viable site in Basin 9.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water supplies, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟩 Increased reliance on major bedrock aquifer could mitigate alluvial groundwater storage depletions or surface water gaps, but may cause bedrock storage depletions. Any storage depletions would be small relative to the volume of water stored in Basin 9's portion of the Antlers and Arbuckle-Simpson aquifers. However, the Antlers only underlies the southern half of the basin and the Arbuckle-Simpson only underlies a small portion (5%) of the northern half of the basin. Increased reliance on minor bedrock aquifers for domestic use could mitigate alluvial groundwater depletions, but site specific studies should be conducted before consideration of large-scale use

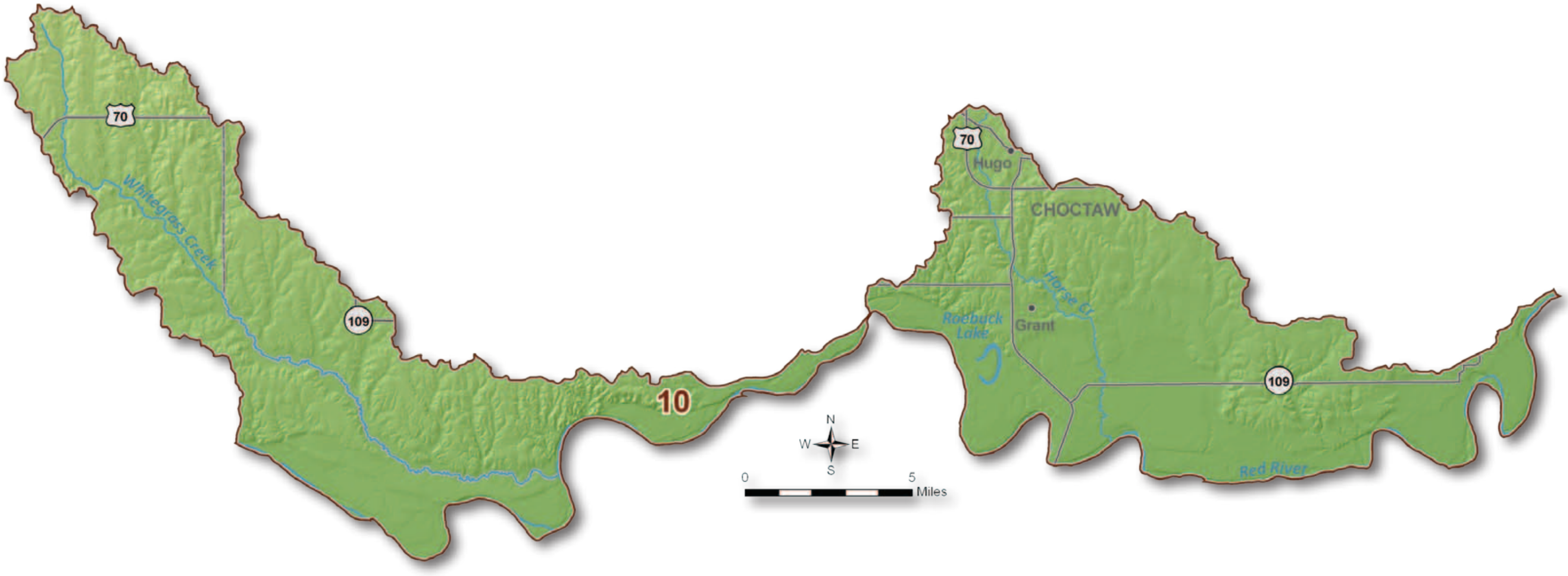
Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Blue-Boggy Watershed Planning Region

Basin 10



Basin 10 Summary

Synopsis

- Water users are expected to continue to rely mainly on surface water.
- By 2040, there is a very low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation or temporary drought management measures could reduce surface water gaps.
- To mitigate surface water gaps, dependable groundwater supplies and/or developing new small reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

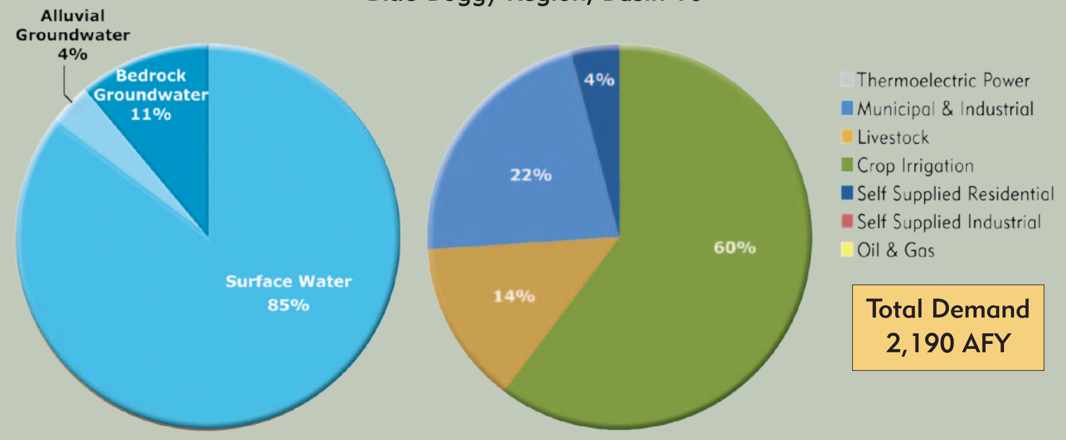
Basin 10 accounts for about 4% of the current water demand in the Blue-Boggy Watershed Planning Region. About 60% of the basin demand is from the Crop Irrigation demand sector. Municipal and Industrial is the second largest demand sector at 22%. Surface water satisfies about 85% of the current demand in the basin. Groundwater satisfies about 15% of the current demand (4% alluvial and 11% bedrock). The peak summer month demand in Basin 10 is about 9.4 times the winter monthly demand, which is more pronounced than the overall statewide pattern.

The flow in tributaries to the Red River is typically greater than 1,300 AF/month throughout the year and greater than 6,000 AF/month in spring and early summer. However, the tributaries can have periods of low flow in any month of the year. There are no major reservoirs in this basin. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. With the exception of the Red River, the surface water quality in Basin 10 is considered good relative to other basins in the state. No water bodies in this basin are impaired for Public and Private Water Supply or Agricultural use.

The majority of water rights in Basin 10 are from the Antlers major bedrock aquifer. The Antlers aquifer underlies almost the entire basin and is estimated to have over 2.9 million AF of groundwater in storage in Basin 10. The aquifer receives an estimated 7,000 AFY of recharge in Basin 10. There are 100 AFY of permits in the Red River major alluvial aquifer. Domestic use does not require a permit and is assumed to be

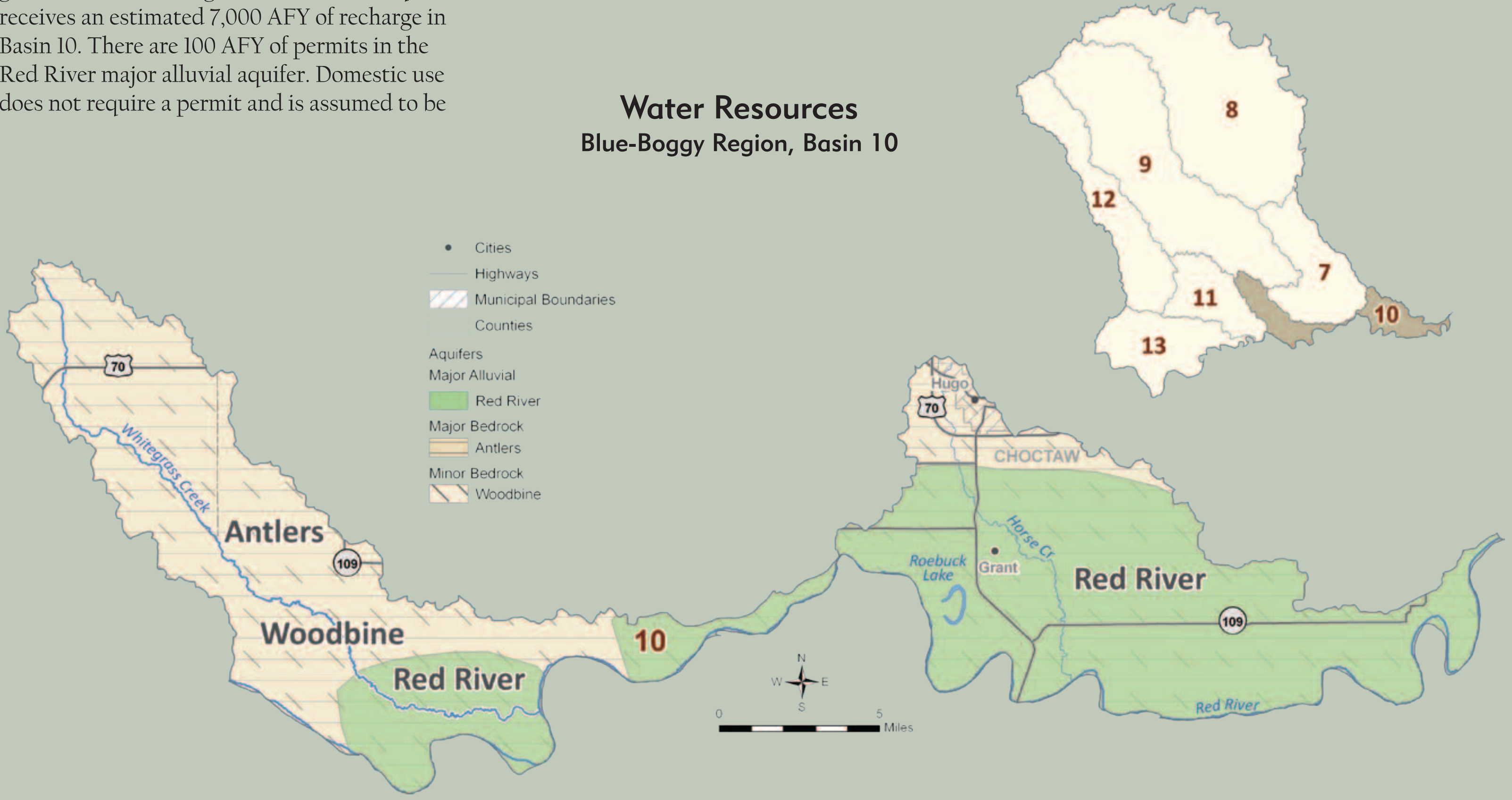
Current Demand by Source and Sector

Blue-Boggy Region, Basin 10



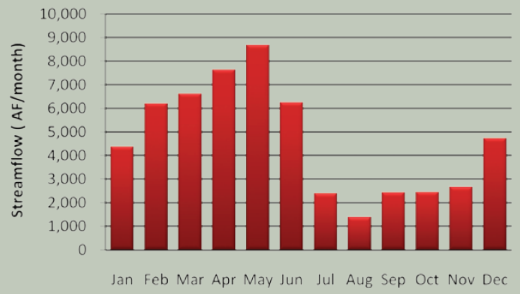
Water Resources

Blue-Boggy Region, Basin 10



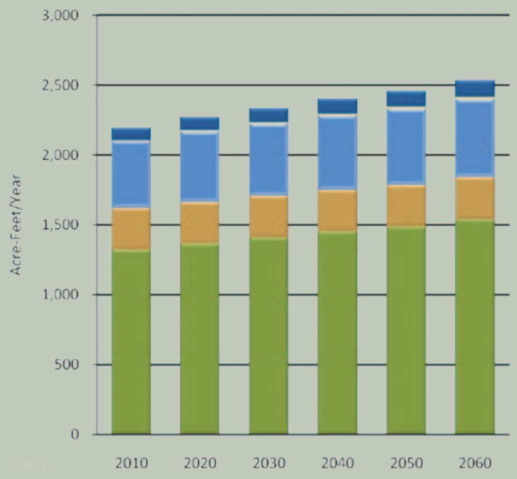
Median Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 10



Projected Water Demand

Blue-Boggy Region, Basin 10



supplied primarily by alluvial aquifers in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 2,540 AFY in Basin 10 reflects a 350 AFY increase (16%) over the 2010 demand. The majority of the demand and growth in demand from 2010 to 2060 will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2040. Surface water gaps are expected to be up to 40 AFY and have a 3% probability of occurring in at least one month of the year by 2060. Surface water gaps in Basin 10 may occur during the summer and fall. No alluvial or bedrock groundwater depletions are expected through 2060. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Options

Water users are expected to continue to rely primarily on surface water supplies. To reduce the risk of adverse impacts to the basin's water users, surface water gaps should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps. In light of the very low probability of gaps each year, temporary drought management activities could also potentially mitigate surface water gaps.

Out-of-basin supplies could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified seven potential out-of-basin sites in the Blue-Boggy Region. This includes Parker Lake, in Basin 8, which is the only federal reservoir in Oklahoma currently authorized for construction. However, in light of the low probability of gaps, out-of-basin supplies may not be cost-effective.

Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 100 AF of storage at the basin outlet.

Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on groundwater could mitigate surface water gaps. Any storage depletions would be minimal relative to the volume of water in storage.

Water Supply Limitations

Blue-Boggy Region, Basin 10

Surface Water	🟨
Alluvial Groundwater	🟩
Bedrock Groundwater	🟩

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Blue-Boggy Region, Basin 10

Demand Management	🟨
Out-of-Basin Supplies	🟨
Reservoir Use	🟨
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟩

🟩 Typically Effective 🟨 Potentially Effective

🟥 Likely Ineffective 🟪 No Option Necessary

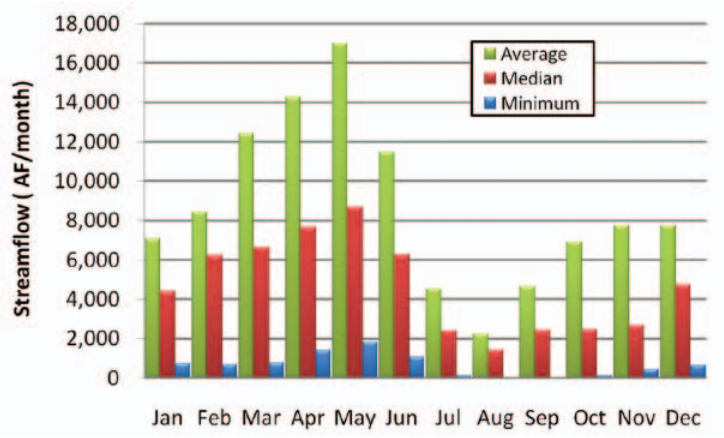
Basin 10 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The basin had a prolonged period of below-average streamflow in the 1960s, corresponding to a period of below-average precipitation. In the 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The Red River is not currently used as a water supply source due to water quality constraints. The median flow in tributaries to the Red River is greater than 1,300 AF/month throughout the year and is greater than 6,000 AF/month in spring and early summer. However, the tributaries can have periods of low flow in any month of the year.
- Relative to basins statewide, the surface water quality is in Basin 10 is considered fair with the exception of the Red River.
- There are no major reservoirs in the basin.

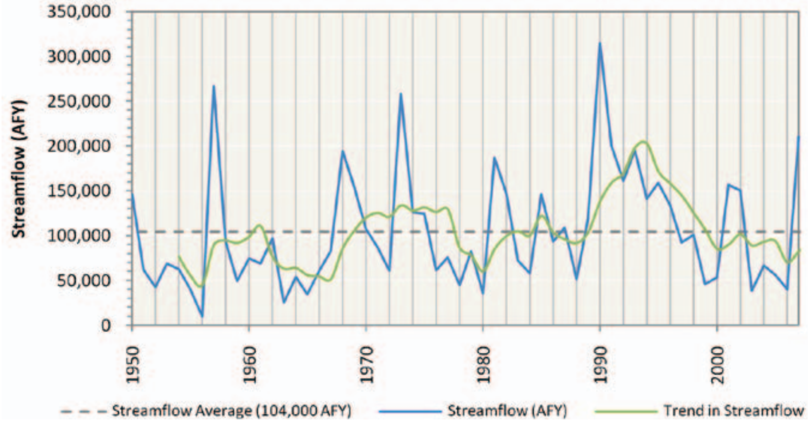
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 10



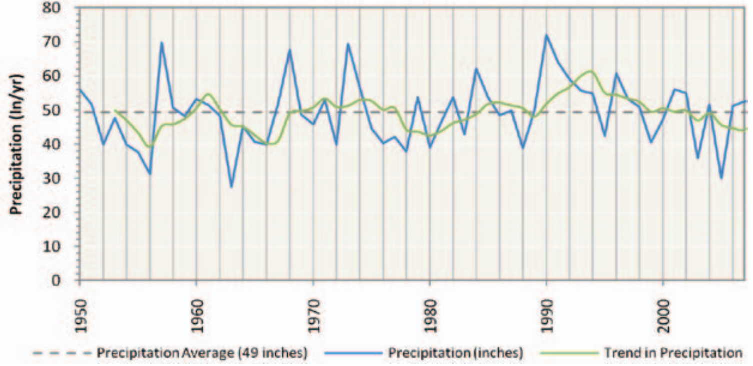
Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 10



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 10

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	Percent	AFY	AF	AFY/acre	AFY
Red River	Alluvial	Major	55%	100	248,000	temporary 2.0	152,600
Antlers	Bedrock	Major	99%	3,600	2,960,000	2.1	286,900
Woodbine	Bedrock	Minor	99%	0	2,188,000	temporary 2.0	281,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

- The majority of water rights in Basin 10 are from the Antlers major bedrock aquifer. The Antlers aquifer underlies almost the entire basin and is estimated to have more than 2.9 million AF of groundwater storage in Basin 10 and receives an estimated 7,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

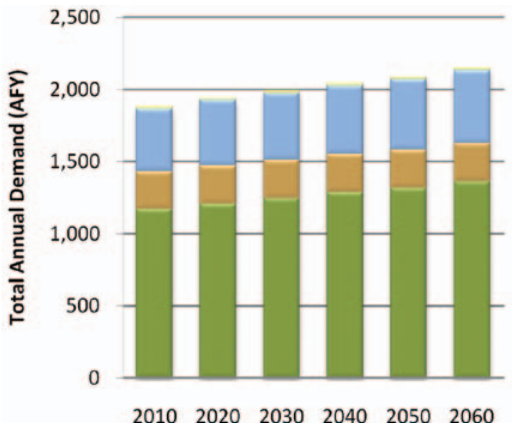
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 10 account for about 4% of the total demand in the Blue-Boggy Watershed Planning Region and will increase by 16% (350 AFY) from 2010 to 2060. The majority of the demand and growth in demand will be from the Crop Irrigation demand sector.
- Surface water is used to meet 85% of the total demand in the basin and its use will increase by 15% (280 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet 4% of the total demand in the basin and its use will increase by 32% (30 AFY) from 2010 to 2060. Alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 11% of the total demand in the basin and its use will increase by 15% (40 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from Crop Irrigation demand sector.

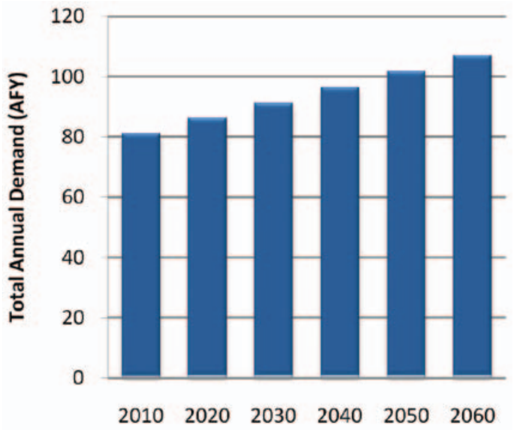
Surface Water Demand by Sector

Blue-Boggy Region, Basin 10



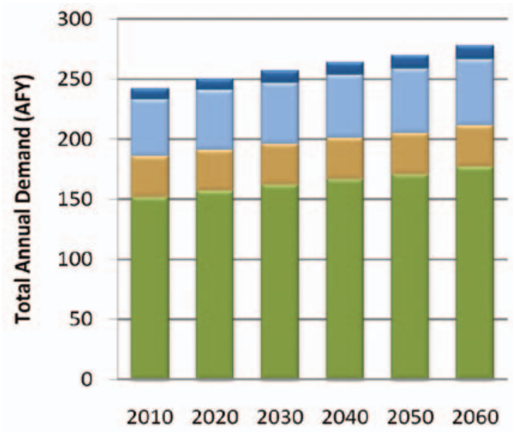
Alluvial Groundwater Demand by Sector

Blue-Boggy Region, Basin 10



Bedrock Groundwater Demand by Sector

Blue-Boggy Region, Basin 10



▨ Thermoelectric Power ▨ Self-Supplied Residential ▨ Self-Supplied Industrial ▨ Oil & Gas ▨ Municipal & Industrial ▨ Livestock ▨ Crop Irrigation

Total Demand by Sector

Blue-Boggy Region, Basin 10

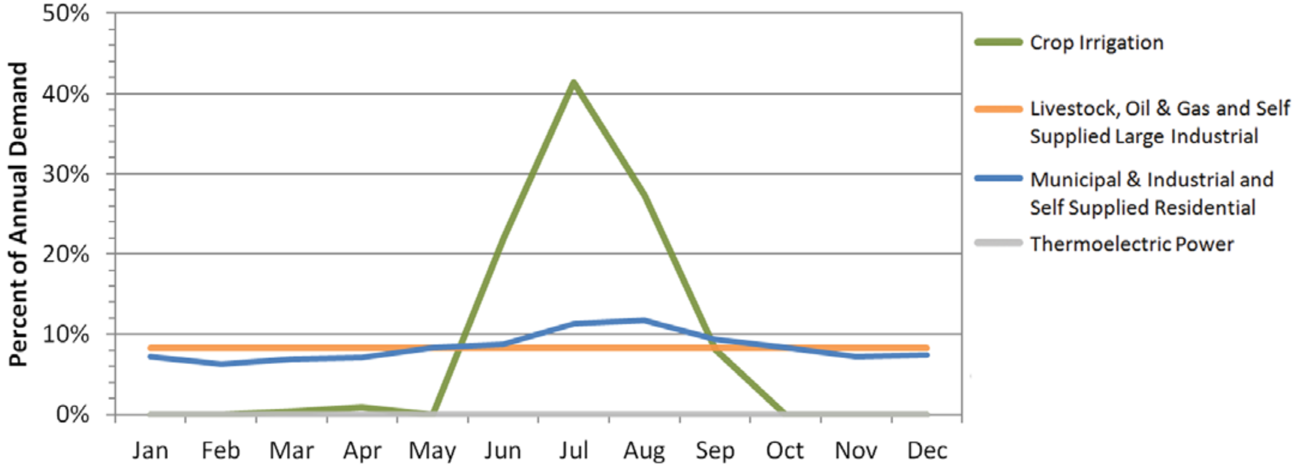
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,320	300	480	0	0	90	0	2,190
2020	1,360	300	510	10	0	90	0	2,270
2030	1,410	300	520	10	0	100	0	2,340
2040	1,450	300	530	10	0	110	0	2,400
2050	1,490	300	550	10	0	110	0	2,460
2060	1,540	300	560	20	0	120	0	2,540

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

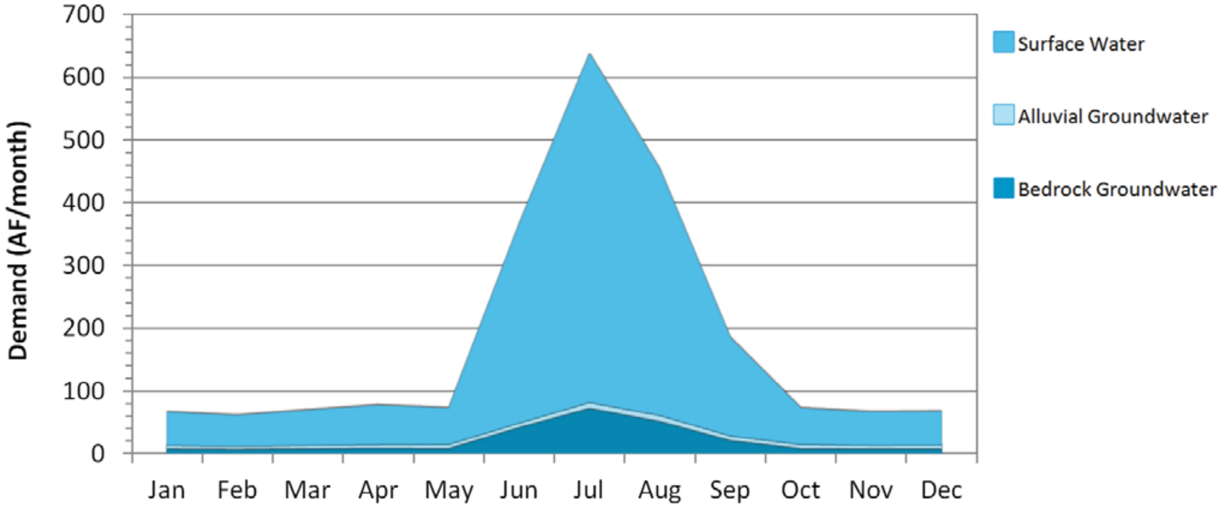
Monthly Demand Distribution by Sector (2010)

Blue-Boggy Region, Basin 10



Monthly Demand Distribution by Source (2010)

Blue-Boggy Region, Basin 10



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 10 is about 9.4 times the winter monthly demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 10.2 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at about 1.6 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at about 10.3 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2040. No alluvial or bedrock groundwater storage depletions are expected through 2060. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.
- Surface water gaps in Basin 10 may occur during the summer and fall. Surface water gaps are expected to be up to 40 AFY and have a 3% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps in 2060 will be up to 7% (30 AF/month) of the surface water demand in the peak summer month, and as much as 6% (10 AF/month) of the fall monthly surface water demand. Surface water gaps have a similar low probability of occurring in both summer and fall.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 10

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	30	25	3%
Sep-Nov (Fall)	10	10	2%

[1] Amount shown represents the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 10

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

[1] Amount shown represents the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 10

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	10	0	0	2%	0%
2050	30	0	0	2%	0%
2060	40	0	0	3%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 10

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

[1] Amount shown represents the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 10

	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	40	0	0	3%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	20	0	0	2%	0%
Moderately Expanded Conservation in M&I Water Use	20	0	0	2%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

[1] Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 10

Reservoir Storage	Diversion
AF	AFY
100	500
500	1,100
1,000	1,800
2,500	4,300
5,000	7,500
Required Storage to Meet Growth in Demand (AF)	100
Required Storage to Meet Growth in Surface Water Demand (AF)	<100

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors may mitigate surface water gaps in 2060. In light of the very low probability of gaps each year, temporary drought management activities could also potentially mitigate surface water gaps.

Out-of-Basin Supplies

🟨 The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified seven potential out-of-basin sites in the Blue-Boggy Region: Boswell in Basin 7; Chickasaw and Parker in Basin 8; Tupelo in Basin 9; Bennington in Basin 11; Sandy Creek in Basin 12; and Albany in Basin 13 (Parker Lake is the only federal reservoir in Oklahoma currently authorized for construction); however, due to the distance to these supplies and presence of in-basin groundwater sources, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

🟨 Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 100 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future surface water gaps. The OCWP *Reservoir Viability Study* did not identify a feasible reservoir site in Basin 10.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟩 Increased reliance on bedrock groundwater could mitigate surface water gaps. Any increases in storage depletions would be minimal relative to the volume of groundwater in storage in Basin 10.

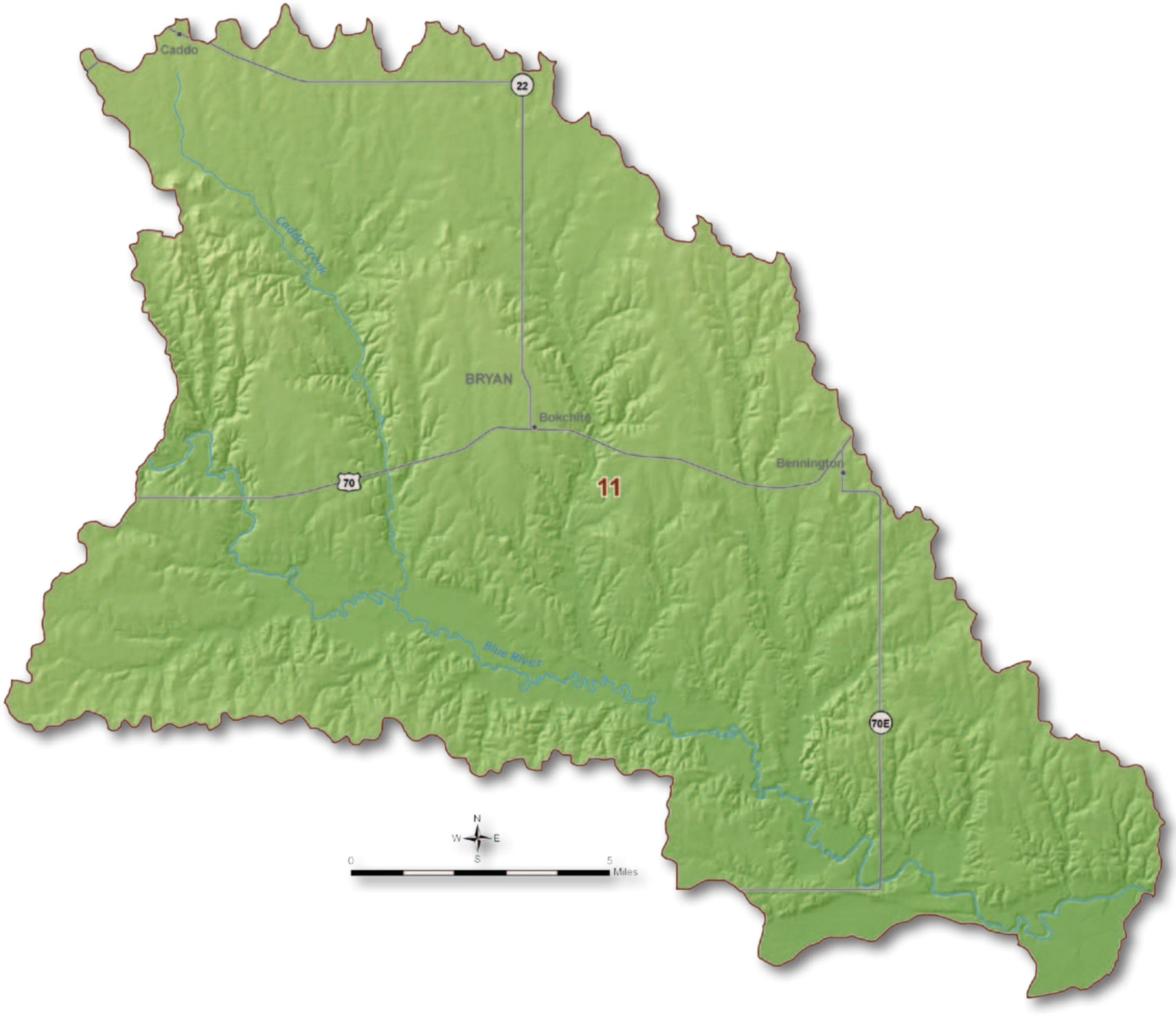
Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Blue-Boggy Watershed Planning Region

Basin 11



Basin 11 Summary

Synopsis

- Water users are expected to continue to rely mainly on surface water and bedrock groundwater.
- By 2040, there is a very low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation or temporary drought management measures could mitigate surface water gaps.
- Developing additional dependable groundwater supplies and/or new small reservoirs could mitigate surface water gaps without major impacts to groundwater storage.

Basin 11 accounts for about 7% of the current water demand in the Blue-Boggy Watershed Planning Region. About 73% of the basin's demand is from the Crop Irrigation demand sector. Municipal and Industrial is the second largest demand sector at 15%. Surface water satisfies about 83% of the current demand in the basin. Groundwater satisfies about 17% of the current demand (1% alluvial and 16% bedrock). The peak summer month demand in Basin 11 is about 16.3 times the winter monthly demand, which is more pronounced than the overall statewide pattern.

The flow in the Blue River upstream of the Red River is typically greater than 4,300 AF/month throughout the year and greater than 19,500 AF/month in the spring and early summer. However, the river can have periods of low flow in any month of the year. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. There are no major reservoirs in this basin. Relative to other basins in the state, the surface water quality in Basin 11 is considered good. There are no water bodies in the basin impaired for Public and Private Water Supply or Agricultural use.

All current water rights in Basin 11 are from the Antlers major bedrock aquifer. The Antlers aquifer underlies the entire basin and is estimated to have over 2.6 million AF of groundwater storage in Basin 11. The aquifer receives an estimated 4,000 AFY of recharge in Basin 11. Domestic users do not require a permit and are assumed to be obtaining supplies from groundwater sources. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

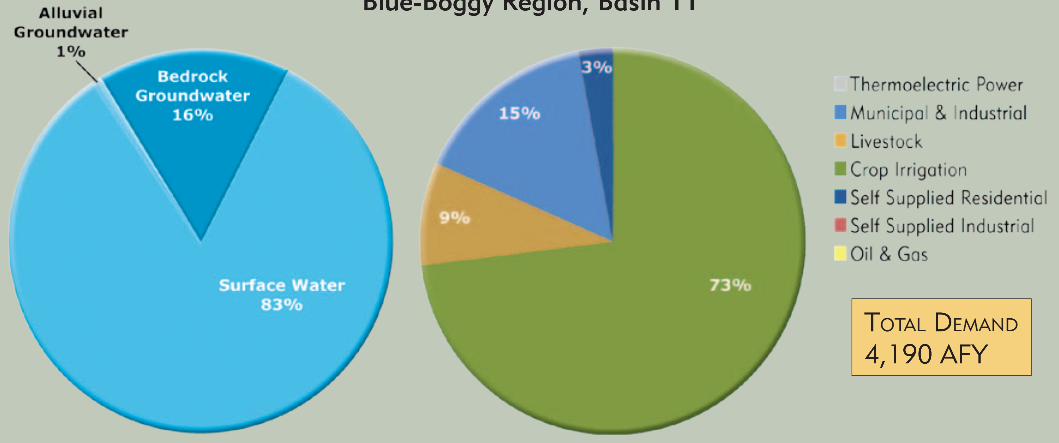
The projected 2060 water demand of 4,810 AFY in Basin 11 reflects a 620 AFY increase (14%) over the 2010 demand. The majority of the demand over this period will be in the Crop Irrigation demand sector. However, the majority of growth in demand will be in the Municipal and Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps are projected to occur by 2040. Surface water gaps are expected to be up to 40 AFY and have a 3% probability of occurring in at least one month of the year by 2060. Surface water gaps in Basin 11 may occur during summer and fall, peaking in size during the summer. Alluvial and bedrock groundwater storage depletions are not expected through 2060. However, localized storage depletions may occur and

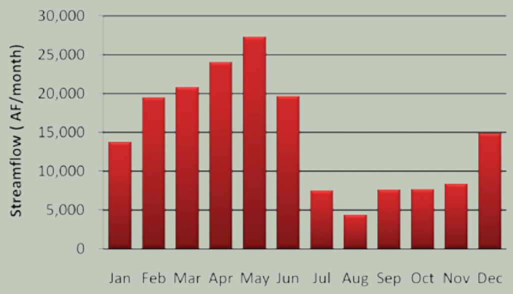
Current Demand by Source and Sector

Blue-Boggy Region, Basin 11



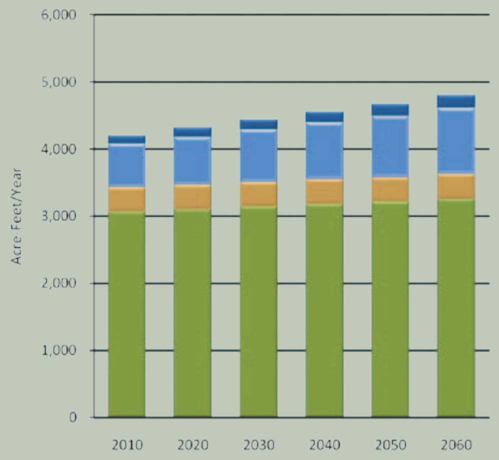
Median Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 11



Projected Water Demand

Blue-Boggy Region, Basin 11



adversely affect well yields, water quality, and/or pumping costs.

Options

Water users are expected to continue to rely primarily on surface water supplies and to a lesser extent, bedrock groundwater. To reduce the risk of adverse impacts to the basin's water users, surface water gaps should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Crop Irrigation demand sector could mitigate surface water gaps. Due to the small size and low probability of gaps, temporary drought management may be effective in reducing surface water use and eliminating gaps.

Out-of-basin supplies could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region. This includes Parker Lake, in Basin 8, which is the only federal reservoir in Oklahoma currently authorized for construction. However, in light of the distance to these supplies and low probability of gaps, out-of-basin supplies may not be cost-effective.

Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 100 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Bennington Reservoir as a potentially viable reservoir site in Basin 11.

Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on bedrock groundwater could mitigate surface water gaps. Any storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Antlers aquifer.

Water Supply Limitations

Blue-Boggy Region, Basin 11

Surface Water	🟩
Alluvial Groundwater	🟩
Bedrock Groundwater	🟩

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Blue-Boggy Region, Basin 11

Demand Management	🟩
Out-of-Basin Supplies	🟨
Reservoir Use	🟩
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟩

🟩 Typically Effective 🟨 Potentially Effective

🟥 Likely Ineffective 🟪 No Option Necessary

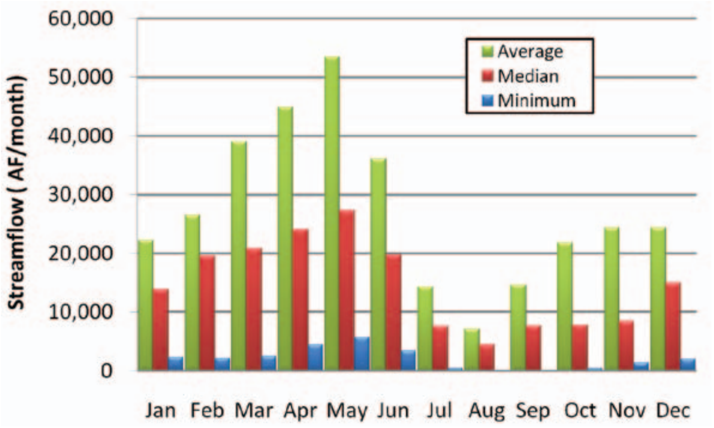
Basin 11 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Blue River upstream of the Red River had a prolonged period of below-average streamflow in the 1960s, corresponding to a period of below-average precipitation. From the late 1980s to the late1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Blue River upstream of Red River is greater than 4,300 AF/month throughout the year and greater than 19,500 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 11 is considered good.
- There are no major reservoirs in the basin.

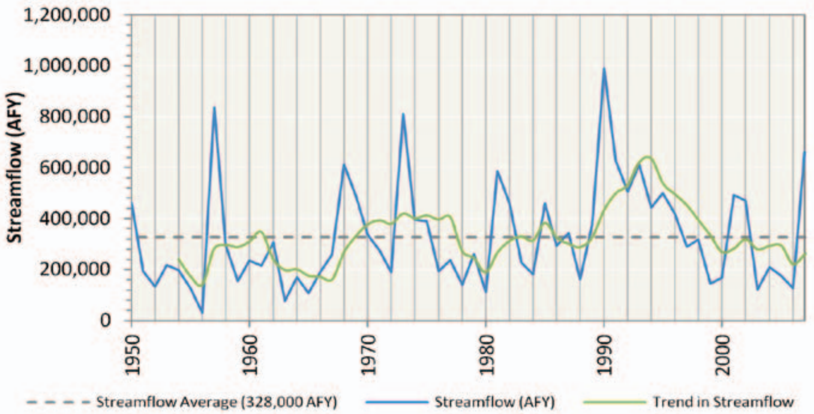
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 11



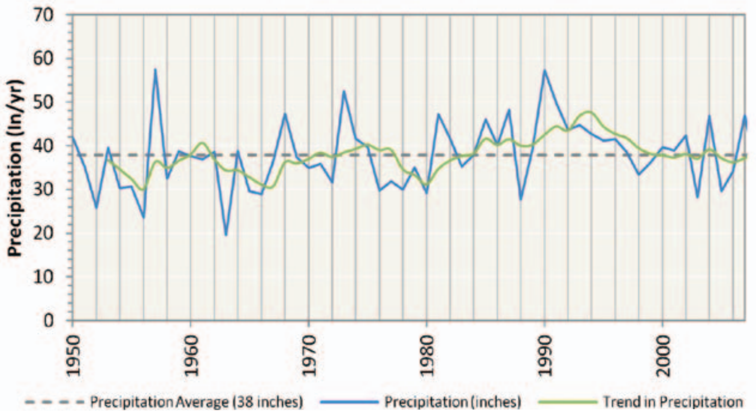
Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 11



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 11

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Red River	Alluvial	Major	8%	0	45,000	temporary 2.0	25,600
Antlers	Bedrock	Major	100%	1,900	2,622,000	2.1	292,600
Woodbine	Bedrock	Minor	100%	0	2,188,000	temporary 2.0	281,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

- All current groundwater rights in Basin 11 are in the Antlers major bedrock aquifer. The Antlers aquifer has more than 2.6 million AF of storage in Basin 11 and underlies all of the basin. The estimated recharge to the Antlers aquifer from Basin 11 is 4,000 AFY.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

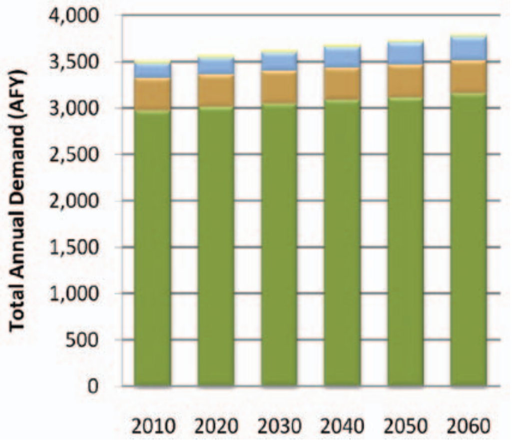
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 11 account for about 7% of the total demand in the Blue-Boggy Watershed Planning Region and will increase by 14% (620 AFY) from 2010 to 2060. The majority of the demand during this period will be from the Crop Irrigation demand sector. The majority of growth in demand will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 83% of the total demand in the basin and its use will increase by 8% (280 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet 1% of the total demand in the basin and its use will increase by 51% from 2010 to 2060. All of the alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Self-Supplied Residential demand sector, which is minimal on a basin scale
- Bedrock groundwater is used to meet 16% of the total demand in the basin and its use will increase by 45% (320 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be in the Municipal and Industrial demand sector.

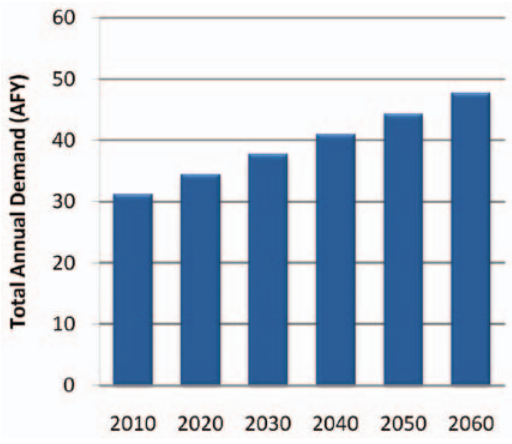
Surface Water Demand by Sector

Blue-Boggy Region, Basin 11



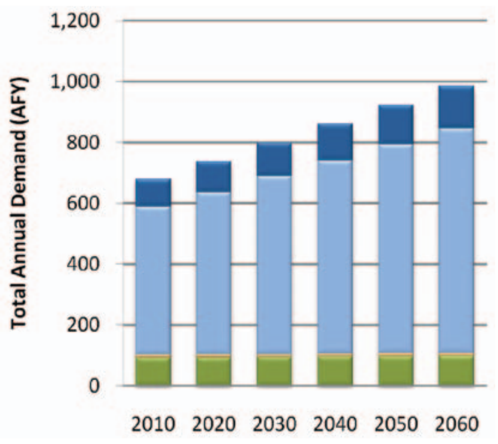
Alluvial Groundwater Demand by Sector

Blue-Boggy Region, Basin 11



Bedrock Groundwater Demand by Sector

Blue-Boggy Region, Basin 11



■ Thermoelectric Power ■ Self-Supplied Residential ■ Self-Supplied Industrial ■ Oil & Gas ■ Municipal & Industrial ■ Livestock ■ Crop Irrigation

Total Demand by Sector

Blue-Boggy Region, Basin 11

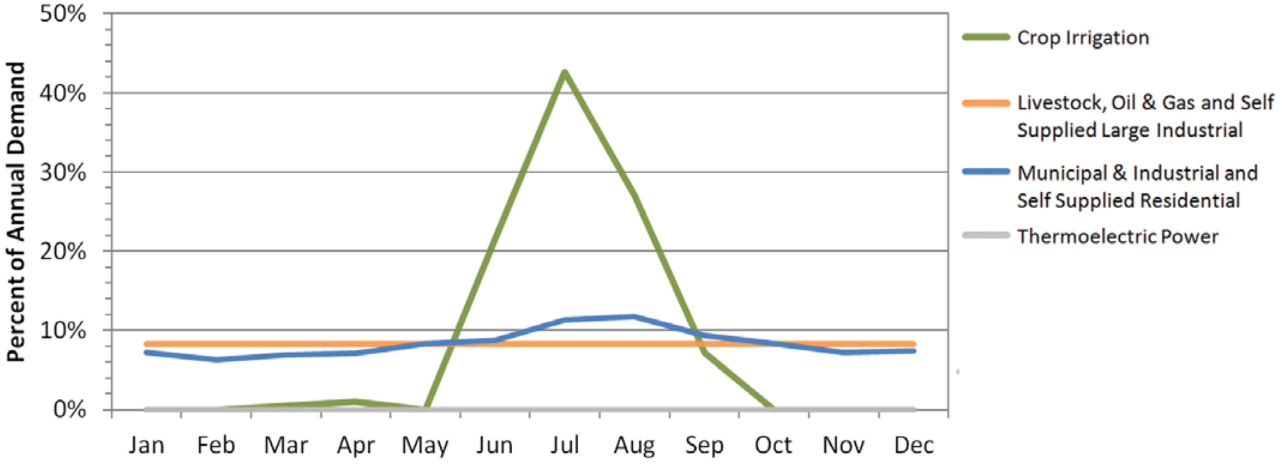
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	3,060	360	650	0	0	120	0	4,190
2020	3,100	360	710	0	0	140	0	4,310
2030	3,140	360	780	0	0	150	0	4,430
2040	3,180	360	850	0	0	160	0	4,550
2050	3,210	370	920	0	0	170	0	4,670
2060	3,260	370	990	0	0	190	0	4,810

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

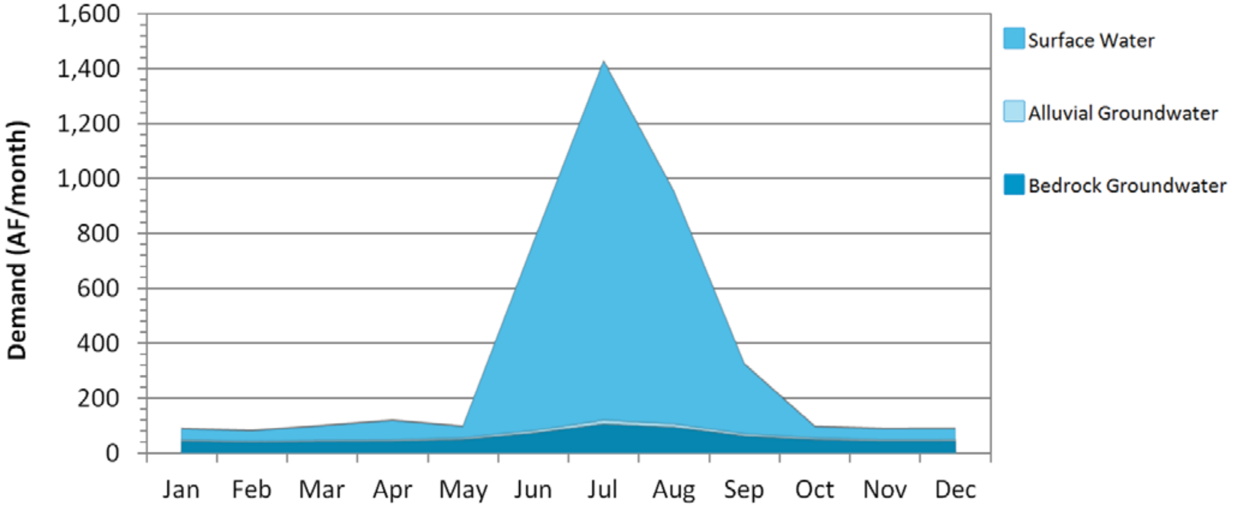
Monthly Demand Distribution by Sector (2010)

Blue-Boggy Region, Basin 11



Monthly Demand Distribution by Source (2010)

Blue-Boggy Region, Basin 11



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 11 is about 16.3 times the winter demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 31.7 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at about 1.6 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at about 2.4 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps are projected to occur by 2040. Alluvial and bedrock groundwater storage depletions are not expected through 2060. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.
- Surface water gaps in Basin 11 may occur during summer and fall, peaking in size during the summer. Surface water gaps are expected to be up to 40 AFY and have a 3% probability of occurring in at least one month of the year by 2060. Surface water gaps in 2060 will be up to 3% (40 AF/month) of the surface water demand in the peak summer month, and as much as 4% (10 AF/month) of the fall monthly surface water demand. Surface water gaps have a similar low probability in both summer and fall.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 11

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	30	20	3%
Sep-Nov (Fall)	10	10	2%

1 Amount shown represent the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 11

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represent the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 11

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AF			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	10	0	0	2%	0%
2050	30	0	0	3%	0%
2060	40	0	0	3%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 11

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

1 Amount shown represent the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 11

	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	40	0	0	3%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in M&I Water Use	40	0	0	3%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

[1] Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 11

Reservoir Storage	Diversion
AF	AFY
100	500
500	1,600
1,000	2,700
2,500	5,800
5,000	10,400
Required Storage to Meet Growth in Demand (AF)	100
Required Storage to Meet Growth in Surface Water Demand (AF)	<100

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟩 Moderately expanded permanent conservation activities in the Crop Irrigation demand sector could mitigate surface water gaps. Due to the small size and low probability of gaps, temporary drought management may be effective in reducing surface water use and eliminating gaps.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could be developed to mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region: Boswell in Basin 7; Chickasaw and Parker in Basin 8; Tupelo in Basin 9; Sandy Creek in Basin 12; and Albany in Basin 13. (Parker Lake is the only remaining federal reservoir in Oklahoma currently authorized for construction.) However, in light of the distance to these supplies and low probability of gaps, out-of-basin supplies may not be cost-effective.

Reservoir Use

🟩 Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 100 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future surface water gaps. The OCWP *Reservoir Viability Study* also identified Bennington Reservoir as a potentially viable reservoir site in Basin 11.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟩 Increased reliance on bedrock groundwater could mitigate surface water gaps. Any storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Antlers aquifer.

Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Blue-Boggy Watershed Planning Region

Basin 12

Basin 12 Summary

Synopsis

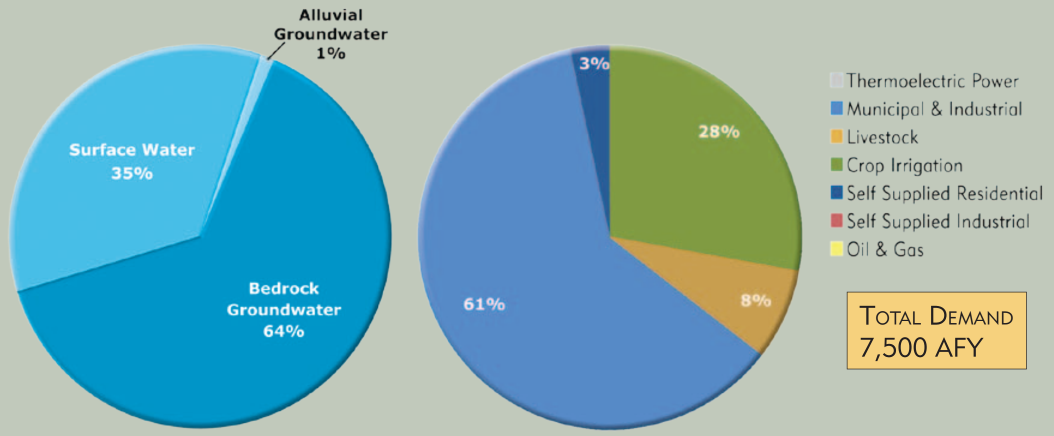
- Water users are expected to continue to rely mainly on surface water and bedrock groundwater.
- By 2030, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce the risk of adverse impacts on water supplies, it is recommended that surface water gaps be decreased where economically feasible.
- Additional conservation or temporary drought management measures could reduce surface water gaps.
- Aquifer storage and recovery could be considered to store variable surface water supplies, increase alluvial groundwater storage, and reduce adverse effects of localized storage depletions.
- To mitigate surface water gaps, dependable groundwater supplies and/or developing new reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

Basin 12 accounts for about 12% of the current water demand in the Blue-Boggy Watershed Planning Region. About 61% of the basin's demand is from the Municipal and Industrial demand sector. Crop Irrigation is the second largest demand sector at 28%. Surface water satisfies about 35% of the current demand in the basin. Groundwater satisfies about 65% of the current demand (1% alluvial and 64% bedrock). The peak summer month demand in Basin 12 is about 3.6 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in the Blue River near Blue is typically greater than 3,000 AF/month throughout the year and greater than 13,500 AF/month in spring and early summer.

Current Demand by Source and Sector

Blue-Boggy Region, Basin 12



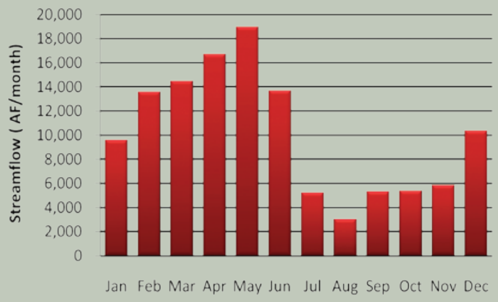
TOTAL DEMAND
7,500 AFY

Water Resources

Blue-Boggy Region, Basin 12

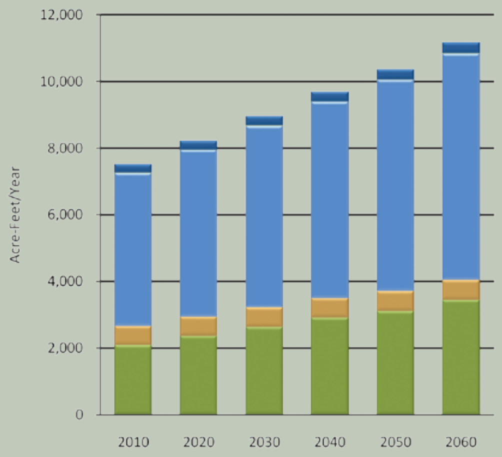
Median Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 12



Projected Water Demand

Blue-Boggy Region, Basin 12



However, the river can have periods of low flow in any month of the year. The Blue River originates from headwater springs in the Arbuckle-Simpson aquifer. There are no major reservoirs in this basin. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 12 is considered good. There are no water bodies in the basin impaired for Public and Private Water Supply or Agricultural use.

The majority of water rights in Basin 12 are from the Arbuckle-Simpson major bedrock aquifer and, to a much lesser extent, the Antlers major bedrock aquifer. The Arbuckle-Simpson aquifer underlies the northern portion of the basin and is estimated to have over 2.8 million AF of water storage in the basin. The Antlers aquifer underlies the southern portion of the basin and is estimated to have over 2.3 million AF of groundwater storage in Basin 12. These major bedrock aquifers, particularly the Arbuckle-Simpson aquifer, receive an estimated 52,000 AFY of recharge in Basin 12. Domestic use does not require a permit and is assumed to be withdrawn from groundwater sources. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 11,170 AFY in Basin 12 reflects a 3,670 AFY increase (49%) over the 2010 demand. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps are projected to occur by 2030. Surface water gaps are expected to be up to 210 AFY and have a 5% probability of occurring in at least one month of the year by 2060. Surface water gaps in Basin 12 may occur during summer and fall, peaking in size during the summer. Alluvial and bedrock groundwater storage depletions are not expected through 2060. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Options

Water users are expected to continue to rely primarily on bedrock groundwater supplies and to a lesser extent, surface water. To reduce the risk of adverse impacts to the basin's water users, surface water gaps should be decreased where economically feasible.

Water Supply Limitations

Blue-Boggy Region, Basin 12

Surface Water	🟨
Alluvial Groundwater	🟨
Bedrock Groundwater	🟩

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Blue-Boggy Region, Basin 12

Demand Management	🟨
Out-of-Basin Supplies	🟨
Reservoir Use	🟩
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟨

🟩 Typically Effective 🟨 Potentially Effective

🟥 Likely Ineffective 🟪 No Option Necessary

Moderately expanded permanent conservation activities in the Crop Irrigation, Self-Supplied Residential, and Municipal and Industrial demand sectors could reduce surface water gaps. Due to the small size and low probability of gaps, temporary drought management may be effective in reducing surface water use and eliminating gaps.

Out-of-basin supplies could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region. This includes Parker Lake in Basin 8 which is the only federal reservoir in Oklahoma currently authorized for construction. However, in light of the distance to these supplies and low probability of gaps, out-of-basin supplies may not be cost-effective.

Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 1,400 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Sandy Creek Lake as a potential reservoir site in Basin 12.

Increased reliance on surface water supplies, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on major bedrock groundwater sources could mitigate surface water gaps. Any storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Arbuckle-Simpson or Antlers aquifer. However, results of the *Arbuckle-Simpson Hydrology Study* indicate that in order to comply with Senate Bill 288, the equal proportionate share will be significantly lower than the current 2 AFY/acre allocation for temporary permits. The Aquifer Recharge Workgroup also identified Site #12 near Ada (Byrds Mill Spring) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the Blue River to recharge the Arbuckle-Simpson aquifer.

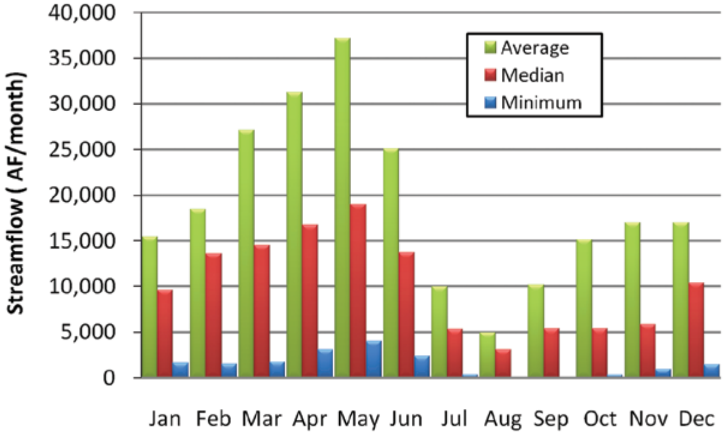
Basin 12 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The basin had a prolonged period of below-average streamflow in the 1960s, corresponding to a period of below-average precipitation. In the 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Blue River near Blue is greater than 3,000 AF/month throughout the year and is greater than 13,500 AF/month in spring and early summer. However, the river can have periods of low flow in any month of the year.
- Relative to basins statewide, the surface water quality is in Basin 12 is considered good.
- There are no major reservoirs in the basin.

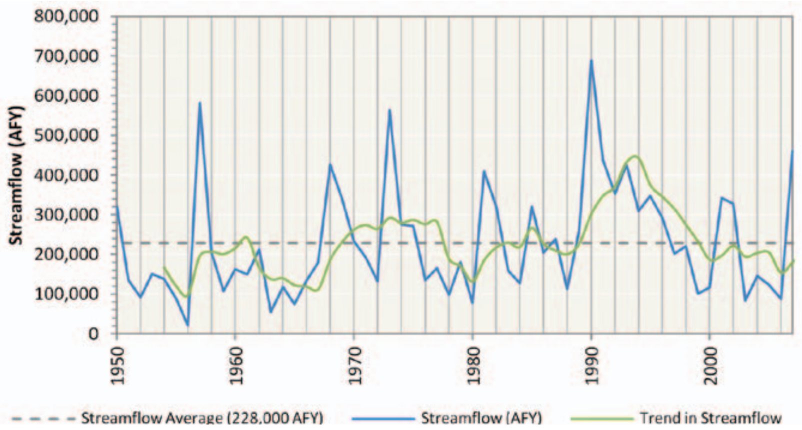
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 12



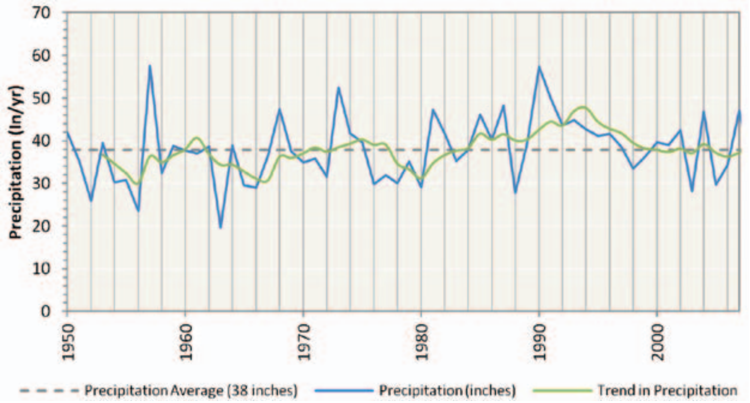
Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 12



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 12

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/acre	AFY
Antlers	Bedrock	Major	55%	2,300	2,309,000	2.1	331,600
Arbuckle-Simpson	Bedrock	Major	34%	105,300	2,822,000	temporary 2.0	132,900
Woodbine	Bedrock	Minor	36%	0	1,691,000	temporary 2.0	217,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

2 Pursuant to 82 O.S. § 1020.9(A)(2), the temporary allocation for the Arbuckle-Simpson groundwater basin is subject to the OWRB's case-by case determination of what amount will not likely degrade or interfere with springs or streams emanating from the Arbuckle-Simpson.

Groundwater Resources

- The majority of water rights in Basin 12 are from the Arbuckle-Simpson major bedrock aquifer, and to a much lesser extent, the Antlers major bedrock aquifer. The Arbuckle-Simpson aquifer underlies the northern portion of the basin and is estimated to have more than 2.8 million AF of groundwater storage in Basin 12. The OWRB is currently studying the Arbuckle-Simpson aquifer in compliance with 2003 Senate Bill 288 legislation to set a Maximum Annual Yield and Equal Proportionate Share. Permits to the aquifer are currently temporary and permitted amounts are expected to decrease upon being made permanent. The Antlers aquifer underlies the southern portion of the basin and is estimated to have more than 2.3 million AF of groundwater storage in Basin 12. These major bedrock aquifers, particularly the Arbuckle-Simpson aquifer, receive an estimated 52,000 AFY of recharge in Basin 12.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

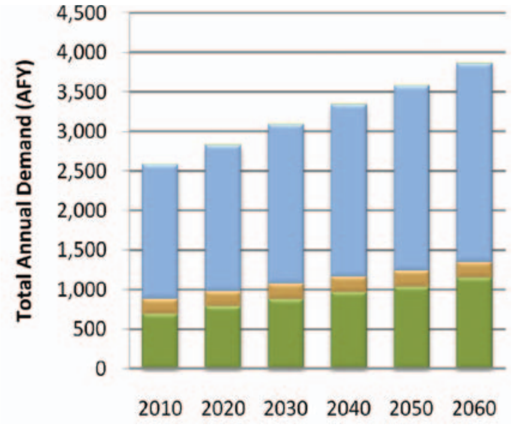
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 12 account for about 12% of the total demand in the Blue-Boggy Watershed Planning Region and will increase by 49% (3,670 AFY) from 2010 to 2060. The majority of the demand and growth in demand from during this period will be in the Municipal and Industrial demand sector.
- Surface water is used to meet 35% of the total demand in the basin and its use will increase by 50% (1,280 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be in the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 1% of the total demand in the basin and its use will increase by 28% (30 AFY) from 2010 to 2060. All of the alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Self-Supplied Residential demand sector, which is minimal on a basin scale.
- Bedrock groundwater is used to meet 64% of the total demand in the basin and its use will increase by 45% (2,360 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Municipal and Industrial demand sector.

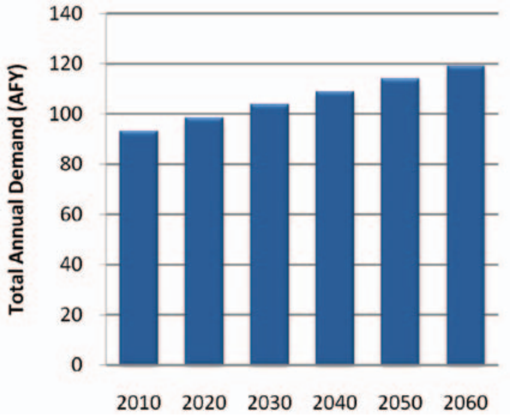
Surface Water Demand by Sector

Blue-Boggy Region, Basin 12



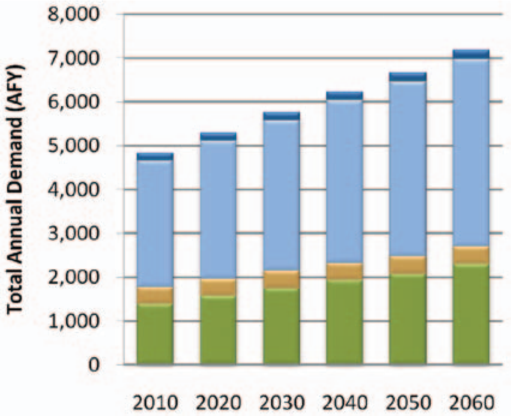
Alluvial Groundwater Demand by Sector

Blue-Boggy Region, Basin 12



Bedrock Groundwater Demand by Sector

Blue-Boggy Region, Basin 12



■ Thermoelectric Power ■ Self-Supplied Residential ■ Self-Supplied Industrial ■ Oil & Gas ■ Municipal & Industrial ■ Livestock ■ Crop Irrigation

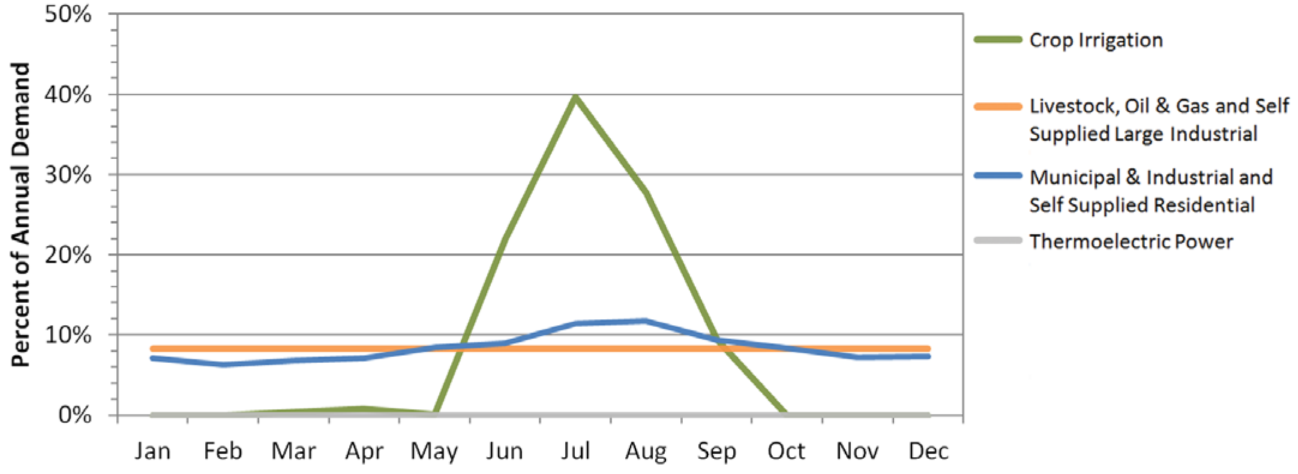
Total Demand by Sector

Blue-Boggy Region, Basin 12

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,090	570	4,590	0	0	250	0	7,500
2020	2,360	580	5,010	0	0	270	0	8,220
2030	2,630	590	5,450	0	0	280	0	8,950
2040	2,900	590	5,890	10	0	290	0	9,680
2050	3,110	600	6,340	10	0	310	0	10,370
2060	3,450	600	6,790	10	0	320	0	11,170

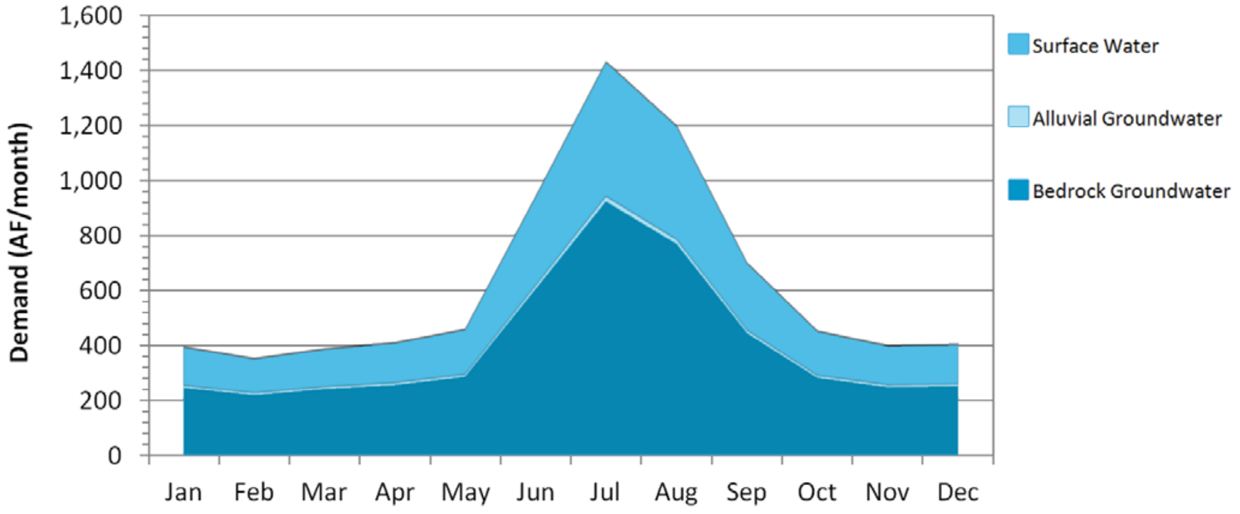
Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.



Monthly Demand Distribution by Sector (2010)

Blue-Boggy Region, Basin 12



Monthly Demand Distribution by Source (2010)

Blue-Boggy Region, Basin 12

Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 55% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 12 is nearly 3.6 times the winter monthly demand, which is similar to the overall statewide pattern. Surface water in the peak summer month is about 3.5 times greater than the monthly winter demand. Alluvial groundwater use in the peak summer month is about 1.6 times greater than the monthly winter demand. Monthly bedrock groundwater use peaks in the summer at about 3.7 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps are projected to occur by 2030. Alluvial and bedrock groundwater storage depletions are not expected through 2060. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.
- Surface water gaps in Basin 12 may occur during summer and fall, peaking in size during the summer. There will be a 5% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps in 2060 will be up to 21% (130 AF/month) of the surface water demand in the peak summer month, and as much as 22% (80 AF/month) of the fall months' surface water demand. Surface water gaps have a low probability of occurring in both summer and fall.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 12

	Maximum Gap[1]	Median Gap	Probability
Months (Season)	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	130	90	5%
Sep-Nov (Fall)	80	80	2%

[1] Amount shown represent the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 12

	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
Months (Season)	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

[1] Amount shown represent the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 12

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	40	0	0	2%	0%
2040	90	0	0	3%	0%
2050	150	0	0	3%	0%
2060	210	0	0	5%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 12

	Maximum Storage Depletion[1]
Months (Season)	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

[1] Amount shown represent the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 12

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	210	0	0	5%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	200	0	0	5%	0%
Moderately Expanded Conservation in M&I Water Use	140	0	0	3%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	130	0	0	3%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	50	0	0	2%	0%

1 Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 12

Reservoir Storage	Diversion
AF	AFY
100	700
500	1,800
1,000	2,800
2,500	5,700
5,000	10,100
Required Storage to Meet Growth in Demand (AF)	1,400
Required Storage to Meet Growth in Surface Water Demand (AF)	300

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Crop Irrigation, Self-Supplied Residential, and Municipal and Industrial demand sectors could reduce surface water gaps by about 38%. Due to the small size and low probability of gaps, temporary drought management may be effective in reducing surface water use and eliminating gaps.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could be developed to mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region: Boswell in Basin 7; Chickasaw and Parker in Basin 8; Tupelo in Basin 9; Bennington in Basin 11; and Albany in Basin 13. (Parker Lake is the only remaining federal reservoir in Oklahoma currently authorized for construction.) However, in light of the distance to these supplies and low probability of gaps, out-of-basin supplies may not be cost-effective.

Reservoir Use

🟩 Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 1,400 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future surface water gaps. The OCWP *Reservoir Viability Study* also identified Sandy Creek Lake as a potentially viable site in Basin 12.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟨 Increased reliance on bedrock groundwater could mitigate surface water gaps. Any storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Arbuckle-Simpson or Antlers aquifer. However, a forthcoming change to the equal proportionate share for the Arbuckle-Simpson aquifer may decrease the amount of available water. The Aquifer Recharge Workgroup also identified Site #12 near Ada (Byrds Mill Spring) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the Blue River to recharge the Arbuckle-Simpson aquifer.

Notes & Assumptions

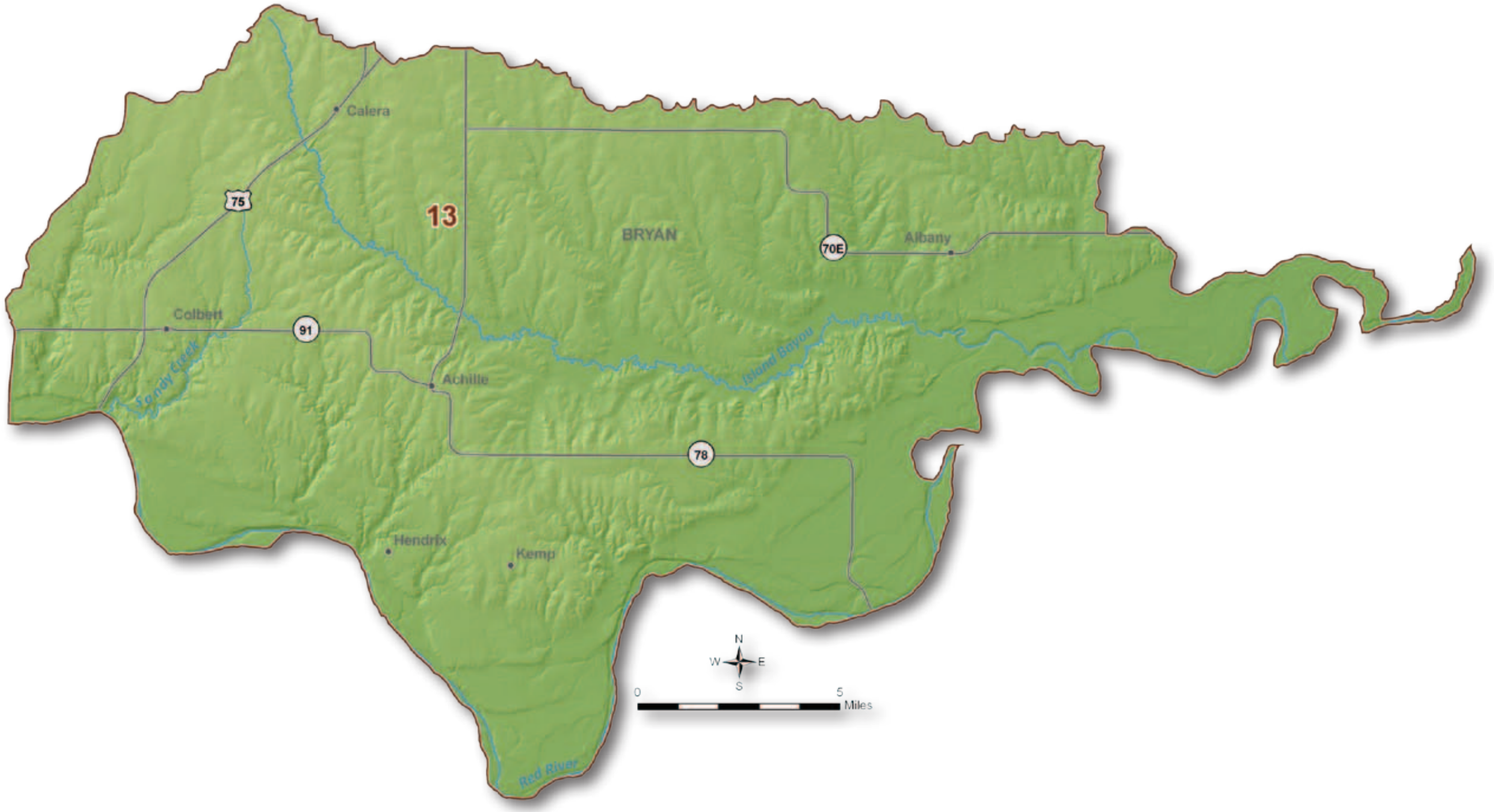
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis

Blue-Boggy Watershed Planning Region

Basin 13



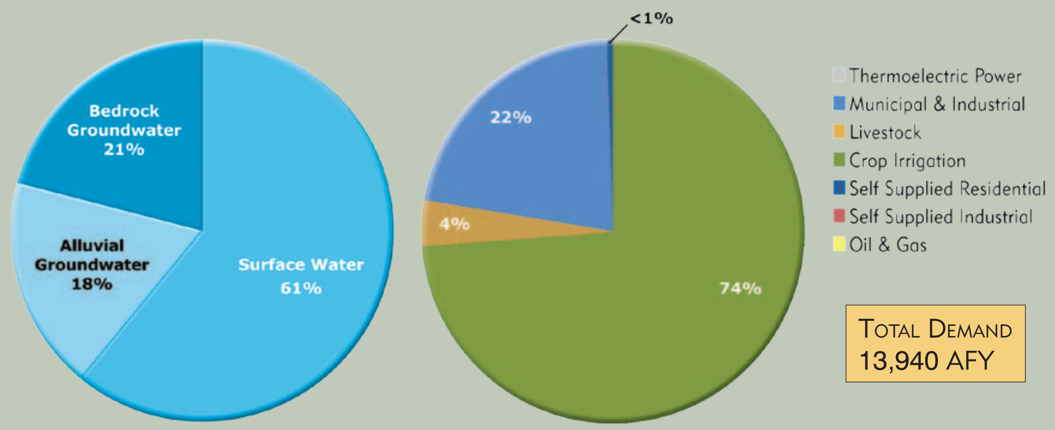
Basin 13 Summary

Synopsis

- Water users are expected to continue to rely mainly on surface water and, to a lesser extent, alluvial and bedrock groundwater.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater storage depletions may occur by 2030 and bedrock groundwater storage depletions may occur by 2020. These storage depletions will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation or temporary drought management measures could reduce surface water gaps and groundwater storage depletions.
- To mitigate surface water gaps, dependable groundwater supplies and/or developing new reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

Current Demand by Source and Sector

Blue-Boggy Region, Basin 13



Total Demand
13,940 AFY

Basin 13 accounts for about 23% of the current water demand in the Blue-Boggy Watershed Planning Region. About 74% of the basin's demand is from the Crop Irrigation demand sector. Municipal and Industrial is the second largest demand sector at 22%. Surface water satisfies about 61% of the current demand in the basin. Groundwater satisfies about 39% of the current demand (18% alluvial and 21% bedrock). The peak summer month demand in Basin 13 is about 17.3 times the winter monthly demand, which is more pronounced than the overall statewide pattern.

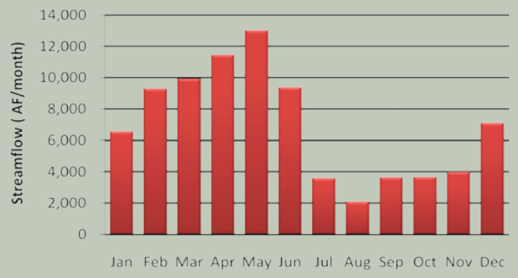
The flow in tributaries to the Red River downstream of the Blue River is typically greater than 2,000 AF/month throughout the year and greater than 9,000 AF/month in spring and early summer. However, the tributaries can have periods of low flow in any month of the year. The Red River has limited use as a municipal water supply source primarily due to water quality concerns. There are no major reservoirs in this basin. The availability of permits is not expected to limit the development of surface

Water Resources

Blue-Boggy Region, Basin 13

Median Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 13



Projected Water Demand

Blue-Boggy Region, Basin 13

water supplies for in-basin use through 2060. With the exception of the Red River, the surface water quality in Basin 13 is considered good relative to basins statewide. There are no water bodies in this basin impaired for Public and Private Water Supply or Agricultural use.

The majority of groundwater rights in Basin 13 are from the Red River aquifer. The Red River aquifer underlies the southern and western portions of the basin and has over 550,000 AF of groundwater storage in Basin 13. There are also a substantial number of permits in the Woodbine minor aquifer and Antlers aquifer. The Antlers aquifer underlies almost the entire basin and is estimated to have over 3.8 million AF of groundwater storage in Basin 13. The aquifer receives an estimated 5,000 AFY of recharge in Basin 13. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 16,230 AFY in Basin 13 reflects a 2,290 AFY increase (16%) over the 2010 demand. The majority of the demand over this period will be in the Crop Irrigation demand sector. However, the majority of growth in demand from 2010 to 2060 will be in the Municipal and Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions may occur by 2020, while alluvial groundwater storage depletions may occur by 2030. Surface water gaps will be up to 320 AFY and have a 7% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions will be up to 100 AFY and have a 5% probability of occurring in at least one month of the year by 2060. Bedrock groundwater storage depletions will be up to 300 AFY by 2060. Surface water gaps and alluvial groundwater storage depletions in Basin 13 may occur during the summer and fall. Bedrock groundwater storage depletions will occur in the summer. Projected annual alluvial and bedrock groundwater storage depletions are minimal relative to the amount of water in storage in major aquifers in the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Options

Water users are expected to continue to rely primarily on surface water supplies and to a lesser extent, alluvial and bedrock groundwater. To reduce the risk of adverse impacts to the basin's water users, gaps and storage depletions should be decreased where economically feasible.

Water Supply Limitations

Blue-Boggy Region, Basin 13

Surface Water	🟨
Alluvial Groundwater	🟨
Bedrock Groundwater	🟨

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Blue-Boggy Region, Basin 13

Demand Management	🟨
Out-of-Basin Supplies	🟨
Reservoir Use	🟩
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟩

🟩 Typically Effective 🟨 Potentially Effective

🟥 Likely Ineffective 🟪 No Option Necessary

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps and groundwater storage depletions. Temporary drought management activities could also potentially reduce gaps, due to the small size and low probability of gaps. Temporary drought management activities may not be necessary for groundwater demand, since groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region. This includes Parker Lake, in Basin 8, which is the only federal reservoir in Oklahoma currently authorized for construction. However, in light of the distance to these supplies and substantial groundwater supplies, out-of-basin supplies may not be cost-effective for some users.

Reservoir storage could provide dependable supplies to mitigate surface water gaps and groundwater storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 800 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Albany Lake as a potentially viable reservoir site in Basin 13.

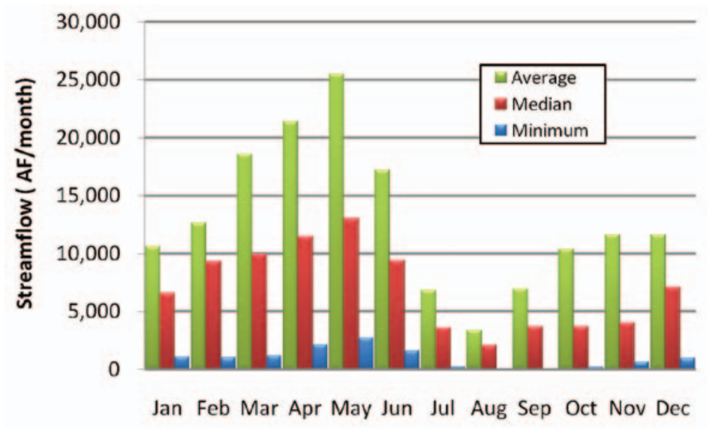
Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on major alluvial or bedrock groundwater could mitigate surface water gaps. Any increases in storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Red River or Antlers aquifers. The Aquifer Recharge Workgroup also identified a site near Durant and Calera (site # 15) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the Red River to recharge the Antlers aquifer.

Basin 13 Data & Analysis

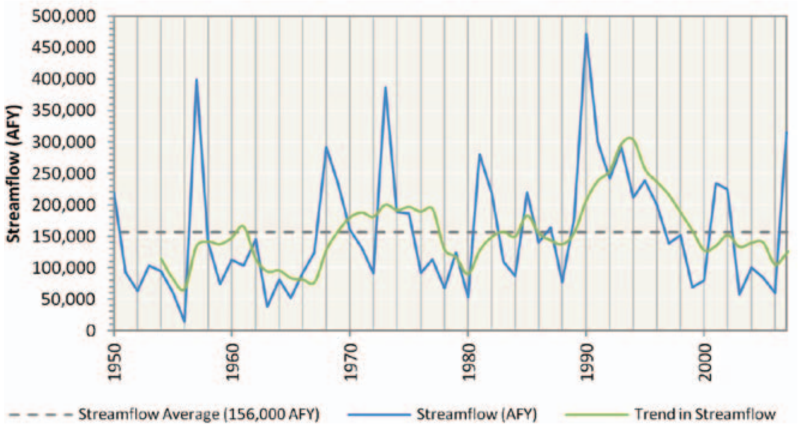
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The basin had a prolonged period of below-average streamflow in the 1960s, corresponding to a period of below-average precipitation. In the 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The Red River has limited use as a municipal water supply source primarily due to water quality constraints. The median flow in tributaries to the Red River downstream of the Blue River is greater than 2,000 AF/month throughout the year and is greater than 9,000 AF/month in spring and early summer. However, the tributaries can have periods of low flow in any month of the year.
- Relative to basins statewide, the surface water quality in Basin 13 is considered good.
- There are no major reservoirs in the basin.



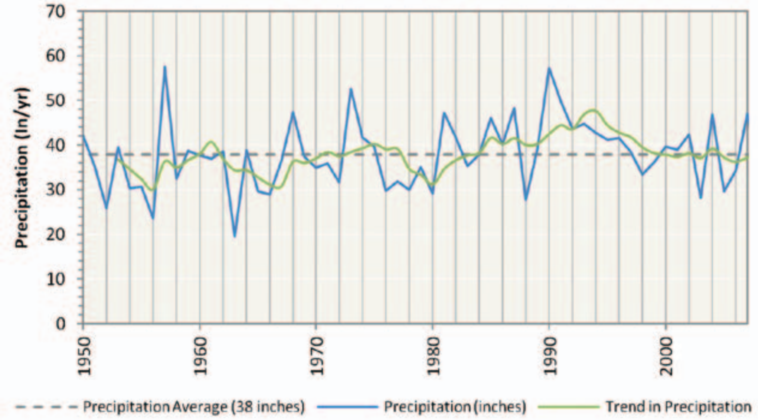
Monthly Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 13



Historical Streamflow at the Basin Outlet

Blue-Boggy Region, Basin 13



Historical Precipitation

Regional Climate Division

Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Blue-Boggy Region, Basin 13

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AF/acre/year	AFY
Red River	Alluvial	Major	69%	3,700	565,000	temporary 2.0	289,200
Antlers	Bedrock	Major	99%	1,000	3,874,000	2.1	424,100
Woodbine	Bedrock	Minor	99%	2,900	3,182,000	temporary 2.0	406,300
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

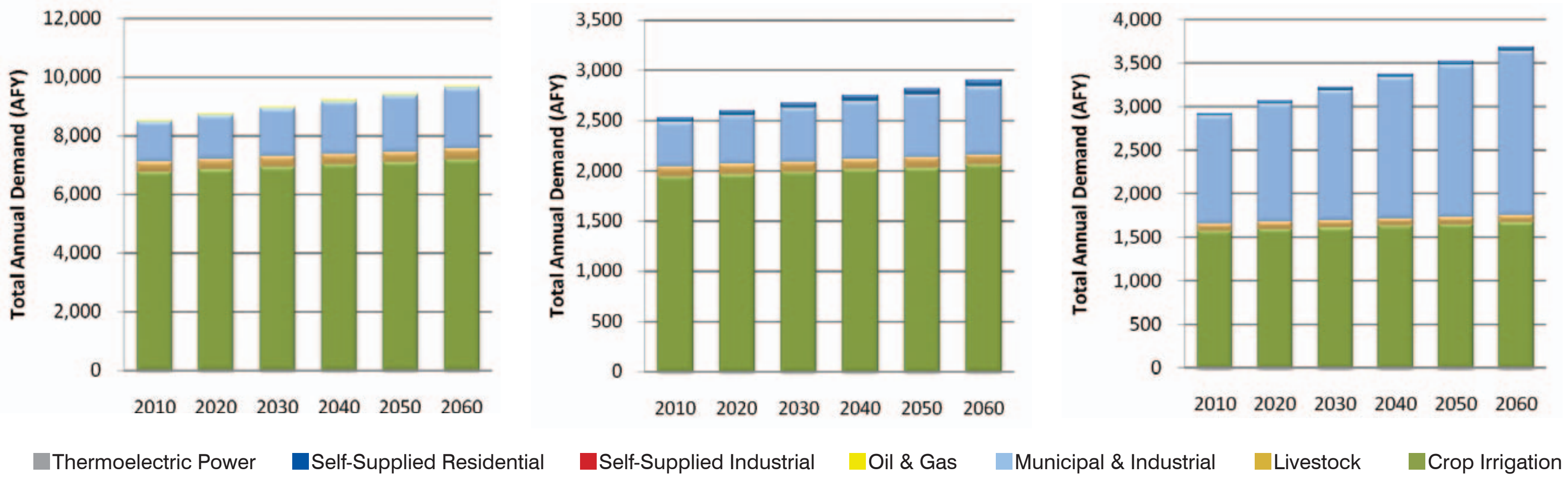
- The majority of water rights in Basin 13 are from the Red River major alluvial aquifer. The Red River alluvial aquifer underlies the southern and western portions of the basin and has more than 550,000 AF of groundwater storage in Basin 13. There are also water rights in the Antlers major bedrock aquifer. The Antlers aquifer underlies almost the entire basin and is estimated to have more than 3.8 million AF of groundwater storage in Basin 13.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 13 account for about 23% of the total demand in the Blue-Boggy Watershed Planning Region and will increase by 16% (2,290 AFY) from 2010 to 2060. The majority of the demand during this period will be from the Crop Irrigation demand sector. The majority of growth in demand will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 61% of the total demand in the basin and its use will increase by 14% (1,150 AFY) from 2010 to 2060. The majority of surface water use during this period will be in the Crop Irrigation sector. The majority of growth in surface water use will be from the Municipal and Industrial sector.
- Alluvial groundwater is used to meet 18% of the total demand in the basin and its use will increase by 15% (380 AFY) from 2010 to 2060. The majority of alluvial groundwater use during this period will be in the Crop Irrigation demand sector. The majority of growth in alluvial groundwater use will be from the Municipal and Industrial demand sector.
- Bedrock groundwater is used to meet 21% of the total demand in the basin and its use will increase by 26% (760 AFY) from 2010 to 2060. The majority of bedrock groundwater use during this period will initially be from the Crop Irrigation demand sector. The majority of growth in bedrock groundwater use and largest 2060 bedrock groundwater use will be from the Municipal and Industrial demand sector.



Surface Water Demand by Sector

Blue-Boggy Region, Basin 13

Alluvial Groundwater Demand by Sector

Blue-Boggy Region, Basin 13

Bedrock Groundwater Demand by Sector

Blue-Boggy Region, Basin 13

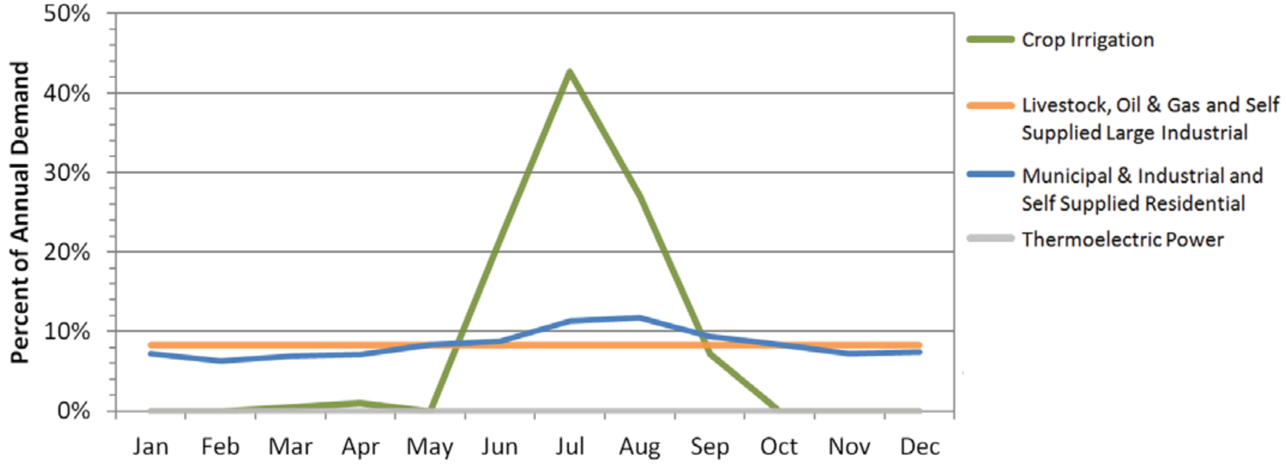
Total Demand by Sector

Blue-Boggy Region, Basin 13

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	10,290	530	3,050	0	0	70	0	13,940
2020	10,420	540	3,350	10	0	80	0	14,400
2030	10,550	540	3,670	10	0	80	0	14,850
2040	10,680	540	3,990	10	0	90	0	15,310
2050	10,780	540	4,310	10	0	100	0	15,740
2060	10,930	540	4,640	10	0	110	0	16,230

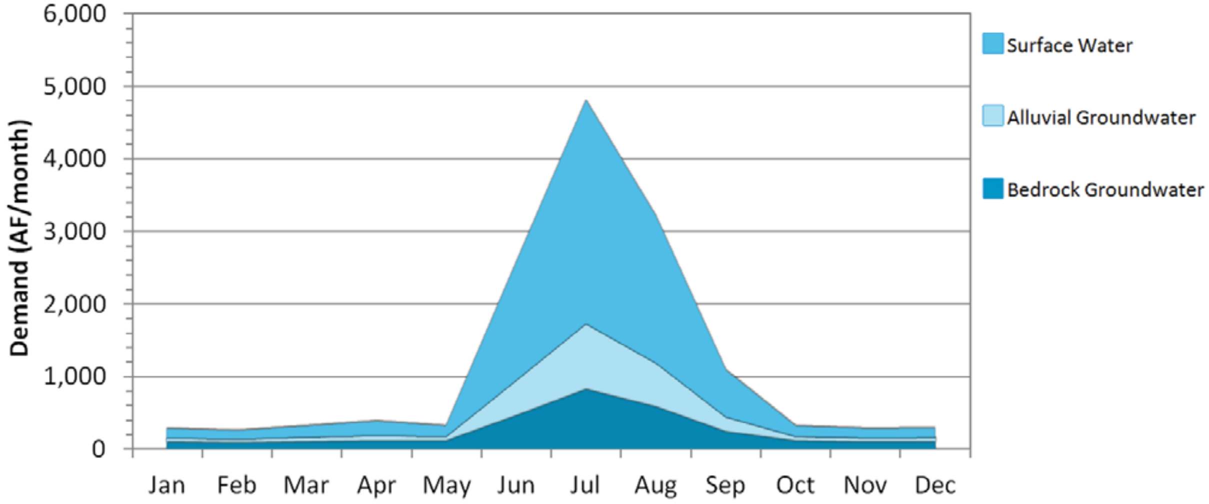
Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.



Monthly Demand Distribution by Sector (2010)

Blue-Boggy Region, Basin 13



Monthly Demand Distribution by Source (2010)

Blue-Boggy Region, Basin 13

Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 13 is about 17.3 times the monthly winter demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 23.5 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at about 20.1 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at about 8.2 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions may occur by 2020 while alluvial groundwater storage depletions may occur by 2030.
- Surface water gaps in Basin 13 may occur during the summer and fall, peaking in size during the summer. There will be a 7% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps in 2060 will be up to 7% (160 AF/month) of the surface water demand in the peak summer month, and 12% (80 AF/month) of the peak fall month surface water demand. Surface water gaps will have a low probability of occurring in both summer and fall.
- Alluvial groundwater storage depletions in Basin 13 may occur during the summer and fall, peaking in size during the summer. There will be a 5% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in 2060 will be up to 8% (50 AF/month) of the alluvial groundwater demand in the peak summer month, and 13% (30 AF/month) of the peak fall month alluvial groundwater demand. Alluvial groundwater storage depletions will have a low probability of occurring in both summer and fall months.
- Bedrock groundwater storage depletions in Basin 13 may occur during the summer. Bedrock groundwater storage depletions in 2060 will be 13% (120 AF/month) of the bedrock groundwater demand in the peak summer month.
- Projected annual alluvial and bedrock groundwater storage depletions are minimal relative to the amount of water in storage in major aquifers in the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Blue-Boggy Region, Basin 13

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	160	95	5%
Sep-Nov (Fall)	80	80	2%

[1] Amount shown represent the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 13

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	50	35	5%
Sep-Nov (Fall)	30	30	2%

[1] Amount shown represent the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Blue-Boggy Region, Basin 13

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	10	0	40	2%	0%
2030	70	20	120	3%	3%
2040	120	30	180	5%	5%
2050	200	60	230	5%	5%
2060	320	100	300	7%	5%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Blue-Boggy Region, Basin 13

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	120
Sep-Nov (Fall)	0

[1] Amount shown represent the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Blue-Boggy Region, Basin 13

	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	320	100	300	7%	5%
Moderately Expanded Conservation in Crop Irrigation Water Use	120	40	220	5%	3%
Moderately Expanded Conservation in M&I Water Use	240	70	230	5%	5%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	60	20	140	3%	2%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	10	0	10	2%	0%

1 Conservation Activities are documented in the OCWP Water Demand Forecast Report.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Blue-Boggy Region, Basin 13

Reservoir Storage	Diversion
AF	AFY
100	600
500	1,700
1,000	2,800
2,500	5,600
5,000	10,300
Required Storage to Meet Growth in Demand (AF)	800
Required Storage to Meet Growth in Surface Water Demand (AF)	300

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps and alluvial groundwater storage depletions by about 81% and bedrock groundwater storage depletions by about 53%. Temporary drought management activities could also potentially reduce gaps due to the small size and low probability of gaps. Temporary drought management activities may not be necessary for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could mitigate surface water gaps and alluvial groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Blue-Boggy Region: Boswell in Basin 7; Chickasaw and Parker in Basin 8; Tupelo in Basin 9; Bennington in Basin 11; and Sandy Creek in Basin 12. (Parker Lake is the only federal reservoir in Oklahoma currently authorized for construction.) However, in light of the distance to these supplies and substantial in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

🟩 Reservoir storage could provide dependable supplies to mitigate surface water gaps and groundwater storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 800 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Albany Lake as a potentially viable reservoir site in Basin 13.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟩 Increased reliance on alluvial or bedrock groundwater could mitigate surface water gaps. Any increases in storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Red River or Antlers aquifers. The Aquifer Recharge Workgroup also identified a site near Durant and Calera (site # 15) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the Red River to recharge the Antlers aquifer.

Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Glossary

Acre-foot: volume of water that would cover one acre of land to a depth of one foot; equivalent to 43,560 cubic feet or 325,851 gallons.

Alkalinity: measurement of the water's ability to neutralize acids. High alkalinity usually indicates the presence of carbonate, bicarbonates, or hydroxides. Waters that have high alkalinity values are often considered undesirable because of excessive hardness and high concentrations of sodium salts. Waters with low alkalinity have little capacity to buffer acidic inputs and are susceptible to acidification (low pH).

Alluvial aquifer: aquifer with porous media consisting of loose, unconsolidated sediments deposited by fluvial (river) or aeolian (wind) processes, typical of river beds, floodplains, dunes, and terraces.

Alluvial groundwater: water found in an alluvial aquifer.

Alluvium: sediments of clay, silt, gravel, or other unconsolidated material deposited over time by a flowing stream on its floodplain or delta; frequently associated with higher-lying terrace deposits of groundwater.

Appendix B areas: waters of the state into which discharges may be limited and that are located within the boundaries of areas listed in Appendix B of OWRB rules Chapter 45 on Oklahoma's Water Quality Standards (OWQS); including but not limited to National and State parks, forests, wilderness areas, wildlife management areas, and wildlife refuges. Appendix B may include areas inhabited by federally listed threatened or endangered species and other appropriate areas.

Appropriative right: right acquired under the procedure provided by law to take a specific quantity of water by direct diversion from a stream, an impoundment thereon, or a playa lake, and to apply such water to a specific beneficial use or uses.

Aquifer: geologic unit or formation that contains sufficient saturated, permeable material to yield economically significant quantities of water to wells and springs.

Artificial recharge: any man-made process specifically designed for the primary purpose of increasing the amount of water entering into an aquifer.

Attainable uses: best uses achievable for a particular waterbody given water of adequate quality.

Background: ambient condition upstream or upgradient from a facility, practice, or activity that has not been affected by that facility, practice or activity.

Basin: see Surface water basin.

Basin outlet: the furthest downstream geographic point in an OCWP planning basin.

Bedrock aquifer: aquifer with porous media consisting of lithified (semi-consolidated or consolidated) sediments, such as limestone, sandstone, siltstone, or fractured crystalline rock.

Bedrock groundwater: water found in a bedrock aquifer.

Beneficial use: (1) The use of stream or groundwater when reasonable intelligence and diligence are exercised in its application for a lawful purpose and as is economically necessary for that purpose. Beneficial uses include but are not limited to municipal, industrial, agricultural, irrigation, recreation, fish and wildlife, etc., as defined in OWRB rules Chapter 20 on stream water use and Chapter 30 on groundwater use. (2) A classification in OWQS of the waters of the State, according to their best uses in the interest of the public set forth in OWRB rules Chapter 45 on OWQS.

Board: Oklahoma Water Resources Board.

Chlorophyll-a: primary photosynthetic plant pigment used in water quality analysis as a measure of algae growth.

Conductivity: a measure of the ability of water to pass electrical current. High specific conductance indicates high concentrations of dissolved solids.

Conjunctive management: water management approach that takes into account the interactions between groundwaters and surface waters and how those interactions may affect water availability.

Conservation: protection from loss and waste. Conservation of water may mean to save or store water for later use or to use water more efficiently.

Conservation pool: reservoir storage of water for the project's authorized purpose other than flood control.

Consumptive use: a use of water that diverts it from a water supply.

Cultural eutrophication: condition occurring in lakes and streams whereby normal processes of eutrophication are accelerated by human activities.

CWSRF: see State Revolving Fund (SRF).

Dam: any artificial barrier, together with appurtenant works, which does or may impound or divert water.

Degradation: any condition caused by the activities of humans resulting in the prolonged impairment of any constituent of an aquatic environment.

Demand: amount of water required to meet the needs of people, communities, industry, agriculture, and other users.

Demand forecast: estimate of expected water demands for a given planning horizon.

Demand management: adjusting use of water through temporary or permanent conservation measures to meet the water needs of a basin or region.

Demand sectors: distinct consumptive users of the state's waters. For OCWP analysis, seven demand sectors were identified: thermoelectric power, self-supplied residential, self-supplied industrial, oil and gas, municipal and industrial, livestock, and crop irrigation.

Dependable yield: the maximum amount of water a reservoir can dependably supply from storage during a drought of record.

Depletion: a condition that occurs when the amount of existing and future demand for groundwater exceeds available recharge.

Dissolved oxygen: amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water. Low levels of dissolved oxygen facilitate the release of nutrients from sediments.

Diversion: to take water from a stream or waterbody into a pipe, canal, or other conduit, either by pumping or gravity flow.

Domestic use: in relation to OWRB permitting, the use of water by a natural individual or by a family or household for household purposes, for farm and domestic animals up to the normal grazing capacity of the land whether or not the animals are actually owned by such natural individual or family, and for the irrigation of land not exceeding a total of three acres in area for the growing of gardens, orchards, and lawns. Domestic use also includes: (1) the use of water for agriculture purposes by natural individuals, (2) use of water for fire protection, and (3) use of water by non-household entities for drinking water purposes, restroom use, and the watering of lawns, provided that the amount of water used for any such purposes does not exceed five acre-feet per year.

Drainage area: total area above the discharge point drained by a receiving stream.

DWSRF: see State Revolving Fund (SRF).

Drought management: short-term measures to conserve water to sustain a basin's or region's needs during times of below normal rainfall.

Ecoregion (ecological region): an ecologically and geographically defined area; sometimes referred to as a bioregion.

Effluent: any fluid emitted by a source to a stream, reservoir, or basin, including a partially or completely treated waste fluid that is produced by and flows out of an industrial or wastewater treatment plant or sewer.

Elevation: elevation in feet in relation to mean sea level (MSL).

Equal proportionate share (EPS): portion of the maximum annual yield of water from a groundwater basin that is allocated to each acre of land overlying the basin or subbasin.

Eutrophic: a water quality characterization, or "trophic status," that indicates abundant nutrients and high rates of productivity in a lake, frequently resulting in oxygen depletion below the surface.

Eutrophication: the process whereby the condition of a waterbody changes from one of low biologic productivity and clear water to one of high productivity and water made turbid by the accelerated growth of algae.

Flood control pool: reservoir storage of excess runoff above the conservation pool storage capacity that is discharged at a regulated rate to reduce potential downstream flood damage.

Floodplain: the land adjacent to a body of water which has been or may be covered by flooding, including, but not limited to, the one-hundred year flood (the flood expected to be equaled or exceeded every 100 years on average).

Fresh water: water that has less than five thousand (5,000) parts per million total dissolved solids.

Gap: an anticipated shortage in supply of surface water due to a deficiency of physical water supply or the inability or failure to obtain necessary water rights.

Groundwater: 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 a definite stream.

Groundwater basin: a distinct underground body of water overlain by contiguous land having substantially the same geological and hydrological characteristics and yield capabilities. The area boundaries of a major or minor basin can be determined by political boundaries, geological, hydrological, or other reasonable physical boundaries.

Groundwater recharge: see Recharge.

Hardness: a measure of the mineral content of water. Water containing high concentrations (usually greater than 60 ppm) of iron, calcium, magnesium, and hydrogen ions is usually considered "hard water."

High Quality Waters (HQW): a designation in the OWQS referring to waters that exhibit water quality exceeding levels necessary to support the propagation of fishes, shellfishes, wildlife, and recreation in and on the water. This designation prohibits any new point source discharge or additional load or increased concentration of specified pollutants.

Hydraulic conductivity: the capacity of rock to transmit groundwater under pressure.

Hydrologic unit code: a numerical designation utilized by the United States Geologic Survey and other federal and state agencies as a way of identifying all drainage basins in the U.S. in a nested arrangement from largest to smallest, consisting of a multi-digit code that identifies each of the levels of classification within two-digit fields.

Hypereutrophic: a surface water quality characterization, or "trophic status," that indicates excessive primary productivity and excessive nutrient levels in a lake.

Impaired water: waterbody in which the quality fails to meet the standards prescribed for its beneficial uses.

Impoundment: body of water, such as a pond or lake, confined by a dam, dike, floodgate, or other barrier established to collect and store water.

Infiltration: the gradual downward flow of water from the surface of the earth into the subsurface.

Instream flow: a quantity of water to be set aside in a stream or river to ensure downstream environmental, social, and economic benefits are met (further defined in the OCWP *Instream Flow Issues & Recommendations* report).

Interbasin transfer: the physical conveyance of water from one basin to another.

Levee: a man-made structure, usually an earthen embankment, designed and constructed to contain, control, or divert the flow of water so as to provide protection from temporary flooding.

Major groundwater basin: a distinct underground body of water overlain by contiguous land and having essentially the same geological and hydrological characteristics and from which groundwater wells yield at least fifty (50) gallons per minute on the average basin-wide if from a bedrock aquifer, and at least one hundred fifty (150) gallons per minute on the average basin-wide if from an alluvium and terrace aquifer, or as otherwise designated by the OWRB.

Marginal quality water: waters that have been historically unusable due to technological or economic issues associated with diversion, treatment, or conveyance.

Maximum annual yield (MAY): determination by the OWRB of the total amount of fresh groundwater that can be produced from each basin or subbasin allowing a minimum twenty-year life of such basin or subbasin.

Mesotrophic: a surface water quality characterization, or "trophic status," describing those lakes with moderate primary productivity and moderate nutrient levels.

Million gallons per day (mgd): a rate of flow equal to 1.54723 cubic feet per second or 3.0689 acre-feet per day.

Minor groundwater basin: a distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and which is not a major groundwater basin.

Nitrogen limited: in reference to water chemistry, where growth or amount of primary producers (e.g., algae) is restricted in a waterbody due in large part to available nitrogen.

Non-consumptive use: use of water in a manner that does not reduce the amount of supply, such as navigation, hydropower production, protection of habitat for hunting, maintaining water levels for boating recreation, or maintaining flow, level and/or temperature for fishing, swimming, habitat, etc.

Nonpoint source (NPS): a source of pollution without a well-defined point of origin. Nonpoint source pollution is commonly caused by sediment, nutrients, and organic or toxic substances originating from land use activities. It occurs when the rate of material entering a waterbody exceeds its natural level.

Normal pool elevation: the target lake elevation at which a reservoir was designed to impound water to create a dependable water supply; sometimes referred to as the top of the conservation pool.

Normal pool storage: volume of water held in a reservoir when it is at normal pool elevation.

Numerical criteria: concentrations or other quantitative measures of chemical, physical or biological parameters that are assigned to protect the beneficial use of a waterbody.

Numerical standard: the most stringent of the OWQS numerical criteria assigned to the beneficial uses for a given stream.

Nutrient-impaired reservoir: reservoir with a beneficial use or uses impaired by human-induced eutrophication as determined by a Nutrient-Limited Watershed Impairment Study.

Nutrient-Limited Watershed (NLW): watershed of a waterbody with a designated beneficial use that is adversely affected by excess nutrients as determined by a Carlson's Trophic State Index (using chlorophyll-a) of 62 or greater, or is otherwise listed as "NLW" in Appendix A of the OWQS.

Nutrients: elements or compounds essential as raw materials for an organism's growth and development; these include carbon, oxygen, nitrogen, and phosphorus.

Oklahoma Water Quality Standards (OWQS): rules promulgated by the OWRB in Oklahoma Administrative Code Title 785, Chapter 45, which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.

Oligotrophic: a surface water quality characterization, or "trophic status," describing those lakes with low primary productivity and/or low nutrient levels.

Outfall: a point source that contains the effluent being discharged to the receiving water.

Percolation: the movement of water through unsaturated subsurface soil layers, usually continuing downward to the groundwater or water table (distinguished from Seepage).

Permit availability: the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law.

pH: the measurement of the hydrogen-ion concentration in water. A pH below 7 is acidic (the lower the number, the more acidic the water, with a decrease of one full unit representing an increase in acidity of ten times) and a pH above 7 (to a maximum of 14) is basic (the higher the number, the more basic the water). In Oklahoma, fresh waters typically exhibit a pH range from 5.5 in the southeast to almost 9.0 in central areas.

Phosphorus limited: in reference to water chemistry, where growth or amount of primary producers (e.g., algae) is restricted in a waterbody due in large part to the amount of available phosphorus.

Physical water availability: amount of water currently in streams, rivers, lakes, reservoirs, and aquifers; sometimes referred to as "wet water."

Point source: any discernible, confined and discrete conveyance, including any pipe, ditch, channel, tunnel, well, discrete fissure, container, rolling stock or concentrated animal feeding operation from which pollutants are or may be discharged. This term does not include return flows from irrigation agriculture.

Potable: describing water suitable for drinking.

Primary Body Contact Recreation (PBCR): a classification in OWQS of a waterbody's use; involves direct body contact with the water where a possibility of ingestion exists. In these cases, the water shall not contain chemical, physical or biological substances in concentrations that irritate the skin or sense organs or are toxic or cause illness upon ingestion by human beings.

Primary productivity: the production of chemical energy in organic compounds by living organisms. In lakes and streams, this is essentially the lowest denominator of the food chain (phytoplankton) bringing energy into the system via photosynthesis.

Prior groundwater right: comparable to a permit, a right to use groundwater recognized by the OWRB as having been established by compliance with state groundwater laws in effect prior to 1973.

Provider: private or public entity that supplies water to end users or other providers. For OCWP analyses, "public water providers" included approximately 785 non-profit, local governmental municipal or community water systems and rural water districts.

Recharge: the inflow of water to an alluvial or bedrock aquifer.

Reservoir: a surface depression containing water impounded by a dam.

Return water or return flow: the portion of water diverted from a water supply that returns to a watercourse.

Reverse osmosis: a process that removes salts and other substances from water. Pressure is placed on the stronger of two unequal concentrations separated by a semi-permeable membrane; a common method of desalination.

Riparian water right (riparian right): the right of an owner of land adjoining a stream or watercourse to use water from that stream for reasonable purposes.

Riverine: relating to, formed by, or resembling a river (including tributaries), stream, etc.

Salinity: the concentration of salt in water measured in milligrams per liter (mg/L) or parts per million (ppm).

Salt water: any water containing more than five thousand (5,000) parts per million total dissolved solids.

Saturated thickness: thickness below the zone of the water table in which the interstices are filled with groundwater.

Scenic Rivers: streams in "Scenic River" areas designated by the Oklahoma Legislature that possess unique natural scenic beauty, water conservation, fish, wildlife and outdoor recreational values. These areas are listed and described in Title 82 of Oklahoma Statutes, Section 1451.

Sediment: particles transported and deposited by water deriving from rocks, soil, or biological material.

Seepage: the movement of water through saturated material often indicated by the appearance or disappearance of water at the ground surface, as in the loss of water from a reservoir through an earthen dam (distinguished from Percolation).

Sensitive sole source groundwater basin or subbasin: a major groundwater basin or subbasin all or a portion of which has been designated by the U.S. Environmental Protection Agency (EPA) as a "Sole Source Aquifer" and serves as a mechanism to protect drinking water supplies in areas with limited water supply alternatives. It includes any portion of a contiguous aquifer located within five miles of the known areal extent of the surface outcrop of the designated groundwater basin or subbasin.

Sensitive Water Supplies (SWS): designation that applies to public and private water supplies possessing conditions that make them more susceptible to pollution events. This designation restricts point source discharges in the watershed and institutes a 10 μg/L (micrograms per liter) chlorophyll-a criterion to protect against taste and odor problems and reduce water treatment costs.

Soft water: water that contains little to no magnesium or calcium salts.

State Revolving Fund (SRF): fund or program used to provide loans to eligible entities for qualified projects in accordance with Federal law, rules and guidelines administered by the EPA and state. Two separate SRF programs are administered in Oklahoma: the Clean Water SRF is intended to control water pollution and is administered by OWRB; the Drinking Water SRF was created to provide safe drinking water and is administered jointly by the OWRB and ODEQ.

Storm sewer: a sewer specifically designed to control and convey stormwater, surface runoff, and related drainage.

Stream system: drainage area of a watercourse or series of watercourses that converges in a large watercourse with defined boundaries.

Stream water: water in a definite stream that includes water in ponds, lakes, reservoirs, and playa lakes.

Streamflow: the rate of water discharged from a source indicated in volume with respect to time.

Surface water: water in streams and waterbodies as well as diffused over the land surface.

Surface water basin: geographic area drained by a single stream system. For OCWP analysis, Oklahoma has been divided into 82 surface water basins (also referenced as "planning basins").

Temporary permit: for groundwater basins or subbasins for which a maximum annual yield has not been determined, temporary permits are granted to users allocating two acre-feet of water per acre of land per year. Temporary permits are for one-year terms that can be revalidated annually by the permittee. When the maximum annual yield and equal proportionate share are approved by the OWRB, all temporary permits overlying the studied basin are converted to regular permits at the new approved allocation amount.

Terrace deposits: fluvial or wind-blown deposits occurring along the margin and above the level of a body of water and representing the former floodplain of a stream or river.

Total dissolved solids (TDS): a measure of the amount of dissolved material in the water column, reported in mg/L, with values in fresh water naturally ranging from 0-1000 mg/L. High concentrations of TDS limit the suitability of water as a drinking and livestock watering source as well as irrigation supply.

Total maximum daily load (TMDL): sum of individual wasteload allocations for point sources, safety reserves, and loads from nonpoint source and natural backgrounds.

Total nitrogen: for water quality analysis, a measure of all forms of nitrogen (organic and inorganic). Excess nitrogen can lead to harmful algae blooms, hypoxia, and declines in wildlife and habitat.

Total phosphorus: for water quality analysis, a measure of all forms of phosphorus, often used as an indicator of eutrophication and excessive productivity.

Transmissivity: measure of how much water can be transmitted horizontally through an aquifer. Transmissivity is the product of hydraulic conductivity of the rock and saturated thickness of the aquifer.

Tributary: stream or other body of water, surface or underground, that contributes to another larger stream or body of water.

Trophic State Index (TSI): one of the most commonly used measurements to compare lake trophic status, based on algal biomass. Carlson's TSI uses chlorophyll-a concentrations to define the level of eutrophication on a scale of 1 to 100, thus indicating the general biological condition of the waterbody.

Trophic status: a lake's trophic state, essentially a measure of its biological productivity. The various trophic status levels (Oligotrophic, Mesotrophic, Eutrophic, and Hypereutrophic) provide a relative measure of overall water quality conditions in a lake.

Turbidity: a combination of suspended and colloidal materials (e.g., silt, clay, or plankton) that reduce the transmission of light through scattering or absorption. Turbidity values are generally reported in Nephelometric Turbidity Units (NTUs).

Vested stream water right (vested right): comparable to a permit, a right to use stream water recognized by the OWRB as having been established by compliance with state stream water laws in effect prior to 1963.

Waste by depletion: unauthorized use of wells or groundwater; drilling a well, taking, or using fresh groundwater without a permit, except for domestic use; taking more fresh groundwater than is authorized by permit; taking or using fresh groundwater so that the water is lost for beneficial use; transporting fresh groundwater from a well to the place of use in such a manner that there is an excessive loss in transit; allowing fresh groundwater to reach a pervious stratum and be lost into cavernous or otherwise pervious materials encountered in a well; drilling wells and producing fresh groundwater there from except in accordance with well spacing requirements; or using fresh groundwater for air conditioning or cooling purposes without providing facilities to aerate and reuse such water.

Waste by pollution: permitting or causing the pollution of a fresh water strata or basin through any act that will permit fresh groundwater polluted by minerals or other waste to filter or intrude into a basin or subbasin, or failure to properly plug abandoned fresh water wells.

Water quality: physical, chemical, and biological characteristics of water that determine diversity, stability, and productivity of the climax biotic community or affect human health.

Water right: right to the use of stream or groundwater for beneficial use reflected by permits or vested rights for stream water or permits or prior rights for groundwater.

Wastewater reuse: treated municipal and industrial wastewater captured and reused commonly for non-potable irrigation and industrial applications to reduce demand upon potable water systems.

Water supply: a body of water, whether static or moving on or under the surface of the ground, or in a man-made reservoir, available for beneficial use on a dependable basis.

Water supply availability: for OCWP analysis, the consideration of whether or not water is available that meets three necessary requirements: physical water is present, the water is of a usable quality, and a water right or permit to use the water has been or can be obtained.

Water supply options: alternatives that a basin or region may implement to meet changing water demands. For OCWP analysis, "primary options" include demand management, use of out-of-basin supplies, reservoir use, increasing reliance on surface water, and increasing reliance on groundwater; "expanded options" include expanding conservation measures, artificial aquifer recharge, use of marginal quality water sources, and potential reservoir development.

Water table: The upper surface of a zone of saturation; the upper surface of the groundwater.

Waterbody: any specified segment or body of waters of the state, including but not limited to an entire stream or lake or a portion thereof.

Watercourse: the channel or area that conveys a flow of water.

Waters of the state: all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state.

Watershed: the boundaries of a drainage area of a watercourse or series of watercourses that diverge above a designated location or diversion point determined by the OWRB.

Well: any type of excavation for the purpose of obtaining groundwater or to monitor or observe conditions under the surface of the earth; does not include oil and gas wells.

Well yield: amount of water that a water supply well can produce (usually in gpm), which generally depends on the geologic formation and well construction.

Wholesale: for purposes of OCWP Public Water Provider analyses, water sold from one public water provider to another.

Withdrawal: water removed from a supply source.

AF: acre-foot or acre-feet

AFD: acre-feet per day

AFY: acre-feet per year

BMPs: best management practices

BOD: biochemical oxygen demand

cfs: cubic feet per second

CWAC: Cool Water Aquatic Community

CWSRF: Clean Water State Revolving Fund

DO: dissolved oxygen

DWSRF: Drinking Water State Revolving Fund

EPS: equal proportionate share

FACT: Funding Agency Coordinating Team

gpm: gallons per minute

HLAC: Habitat Limited Aquatic Community

HQW: High Quality Waters

HUC: hydrologic unit code

M&I: municipal and industrial

MAY: maximum annual yield

mgd: million gallons per day

µS/cm: microsiemens per centimeter (see specific conductivity)

mg/L: milligrams per liter

NLW: nutrient-limited watershed

NPS: nonpoint source

NPDES: National Pollutant Discharge Elimination System

NRCS: Natural Resources Conservation Service

NTU: Nephelometric Turbidity Unit (see "Turbidity")

OCWP: Oklahoma Comprehensive Water Plan

ODEQ: Oklahoma Department of Environmental Quality

O&G: Oil and Gas

ORW: Outstanding Resource Water

OWQS: Oklahoma Water Quality Standards

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

pH: hydrogen ion activity

ppm: parts per million

RD: Rural Development

REAP: Rural Economic Action Plan

SBCR: Secondary Body Contact Recreation

SDWIS: Safe Drinking Water Information System

SRF: State Revolving Fund

SSI: Self-Supplied Industrial

SSR: Self-Supplied Residential

SWS: Sensitive Water Supply

TDS: total dissolved solids

TMDL: total maximum daily load

TSI: Trophic State Index

TSS: total suspended solids

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WLA: wasteload allocation

WWAC: Warm Water Aquatic Community

Water Quantity Conversion Factors

Desired Unit

		CFS	GPM	MGD	AFY	AFD
Initial Unit	CFS	—	450	.646	724	1.98
	GPM	.00222	—	.00144	1.61	.00442
	MGD	1.55	695	—	1120	3.07
	AFY	.0014	.62	.00089	—	.00274
	AFD	.504	226	.326	365	—

EXAMPLE: Converting from MGD to CFS. To convert from an initial value of 140 MGD to CFS, multiply 140 times 1.55 to come up with the desired conversion, which would be 217 CFS (140 X 1.55 = 217).

CFS: cubic feet per second
GPM: gallons per minute
MGD: millions gallons per day
AFY: acre-feet per year
AFD: acre-feet per day
1 acre-foot: 325,851 gallons

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