Oklahoma Comprehensive Water Plan

OCWP

Southeast
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.

Oklahoma Comprehensive Water Plan

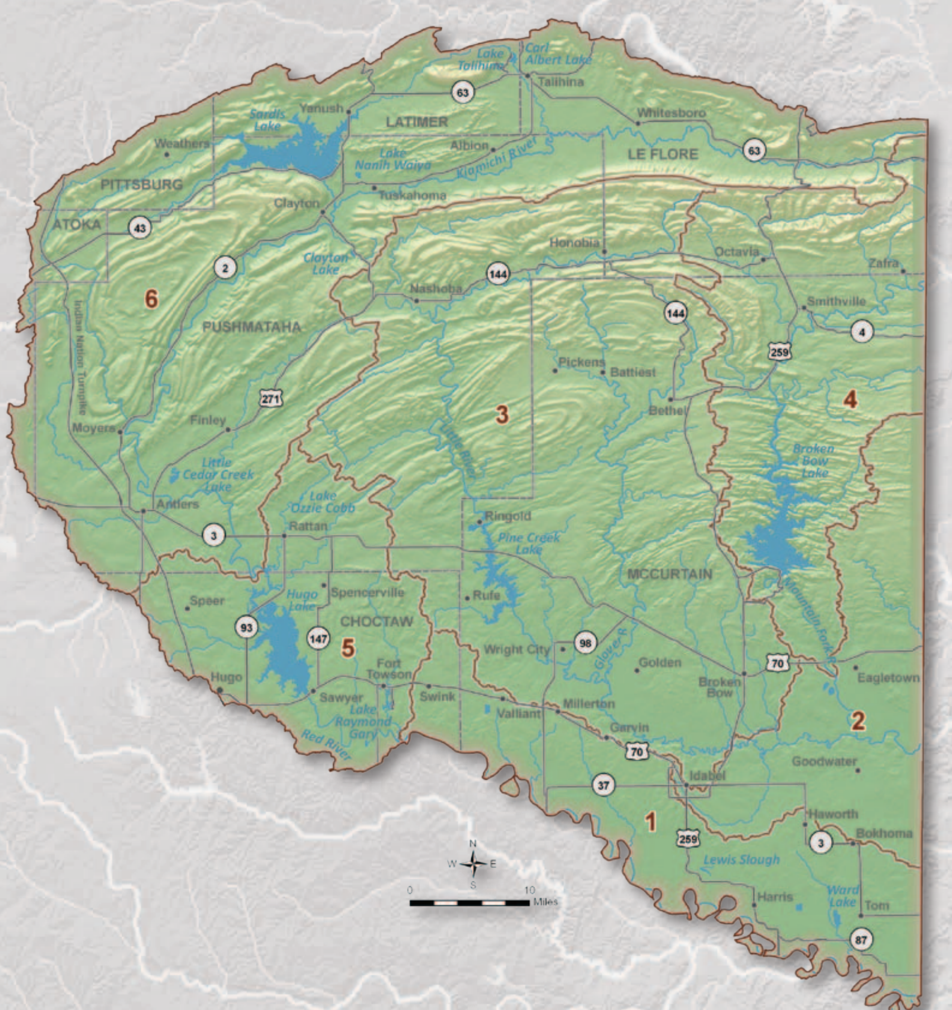
OCWP

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: Beavers Bend State Park, Michael Hardeman Photography

Oklahoma Comprehensive Water Plan

Southeast Watershed Planning Region



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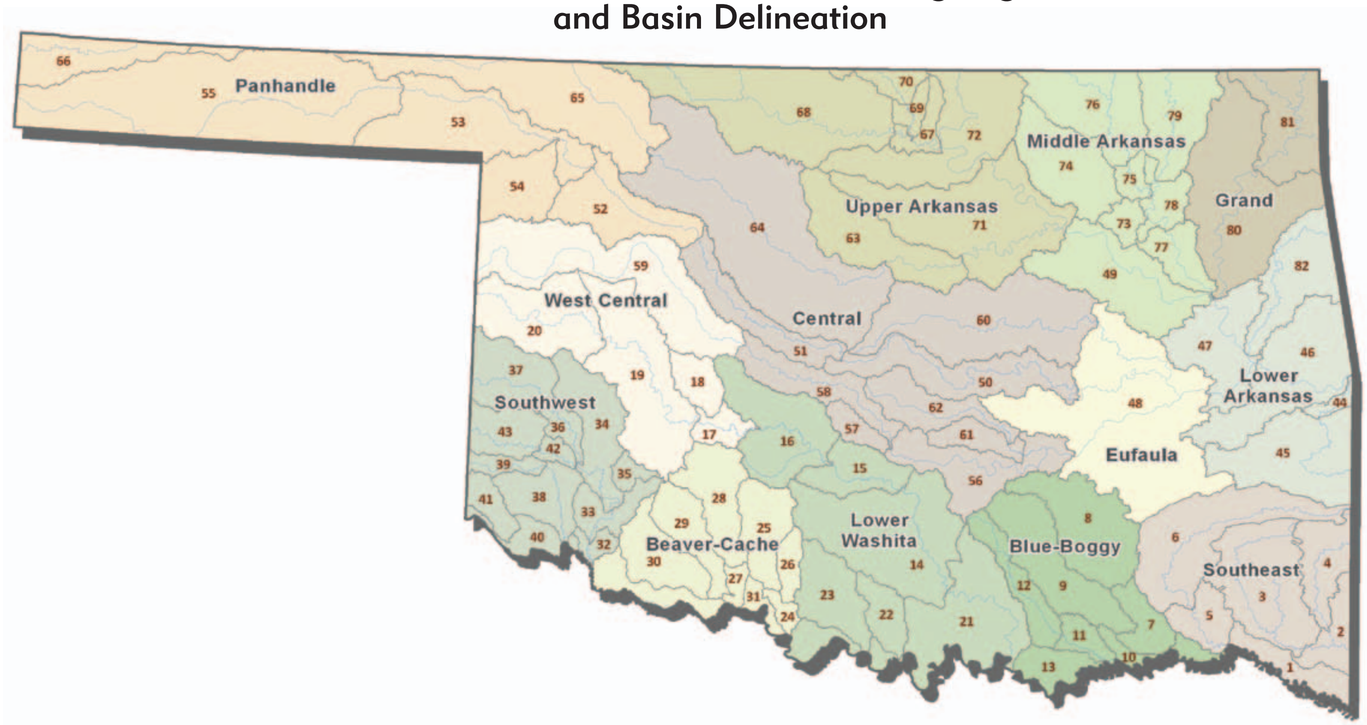


Introduction

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 Beaver-Cache 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 Southeast Watershed Planning Region includes six basins (numbered 1-6 for reference). The region is in the Ouachita and Coastal Plain physiography provinces, encompassing 4,437 square miles in southeastern Oklahoma, spanning from the southeast corner of Pittsburg County to McCurtain County and including portions of Latimer, Leflore, Atoka, Pushmataha, and Choctaw Counties.

The region's terrain varies from the rolling alluvial plains of the Red River to the rugged Kiamichi Mountains, which rise up to 1,600 feet above the surrounding plains.

The region has a generally mild climate with annual mean temperatures varying from 62°F to 64°F. Annual average precipitation ranges from 45 inches in the west to 57 inches in the east. Annual evaporation ranges from 56 inches in the west to 48 inches in the east.

The largest cities in the region include Idabel (2010 population 7,010), Hugo (5,310), Broken Bow (4,120), and Antlers (2,453). The greatest demand is from Self-Supplied Industrial water use.

By 2060, this region is projected to have a total demand of 72,930 acre-feet per year (AFY), an increase of approximately 14,830 AFY (26%) from 2010.

Southeast Regional Summary

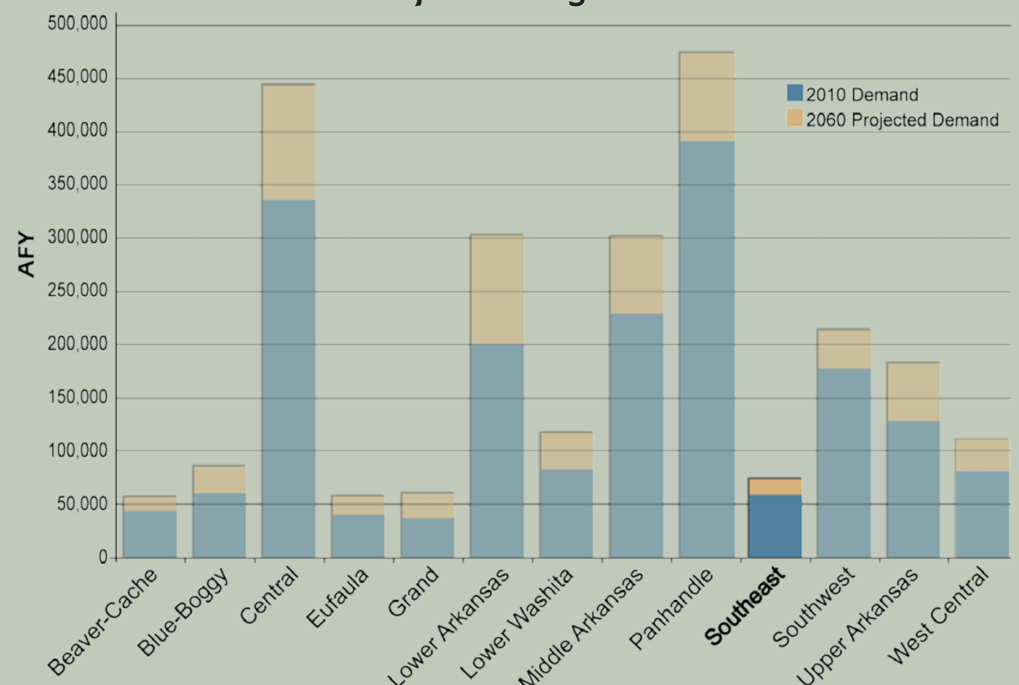
Synopsis

- The Southeast Watershed Planning Region relies primarily on surface water supplies (including reservoirs) and to a much lesser extent on alluvial 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, there is a 2% probability that surface water supplies will at times be insufficient to meet demand in Basin 1.
- By 2020, alluvial groundwater storage depletions may lead to higher pumping costs, the need for deeper wells, and potential changes to well yields or water quality.
- No bedrock groundwater storage depletions are expected in the region through 2060.
- Additional conservation could reduce surface water gaps and alluvial groundwater storage depletions.
- Surface water alternatives, such as bedrock groundwater supplies and/or developing new reservoirs, could mitigate gaps without major impacts to groundwater storage.

Southeast Region Demand Summary

Current Water Demand:	58,100 acre-feet/year (3% of state total)		
Largest Demand Sector:	Self-Supplied Industrial (60% of regional total)		
Current Supply Sources:	96% SW	2% Alluvial GW	2% Bedrock GW
Projected Demand (2060):	72,930 acre-feet/year		
Growth (2010-2060):	14,830 acre-feet/year (26%)		

Current and Projected Regional Water Demand



The Southeast Region accounts for about 3% of the state's total water demand. The largest demand sectors are Self-Supplied Industrial (60% of the region's overall 2010 demand), Thermoelectric Power (14%), and Municipal and Industrial (12%).

Water Resources & Limitations

Surface Water

Surface water is used to meet 96% of the Southeast Region's demand. The region is supplied by four major rivers: the Red, Kiamichi, Little, and Mountain Fork. Historically, the rivers and creeks in the region have had substantial flows. However, infrequent periods of low flow can occur in the summer and fall due to seasonal and long-term trends in precipitation. Large reservoirs have been built on several rivers and their tributaries to provide important benefits such as public water supply, flood control, and recreation. Major reservoirs in the Southeast Region include Broken Bow, Sardis, Pine Creek, and Hugo, all constructed by the U.S. Army Corps of Engineers. Carl Albert is a significant municipal lake and supplies water to the City of Talihina.

With the exception of the Red River, surface water quality in the region is considered good relative to other regions in the state. No surface waters are impaired for Agricultural use (Crop Irrigation demand sector) or Public and Private Water Supply (Municipal and Industrial demand sector). All basins in the region are expected to have available surface water for new permitting to meet local demand through 2060.

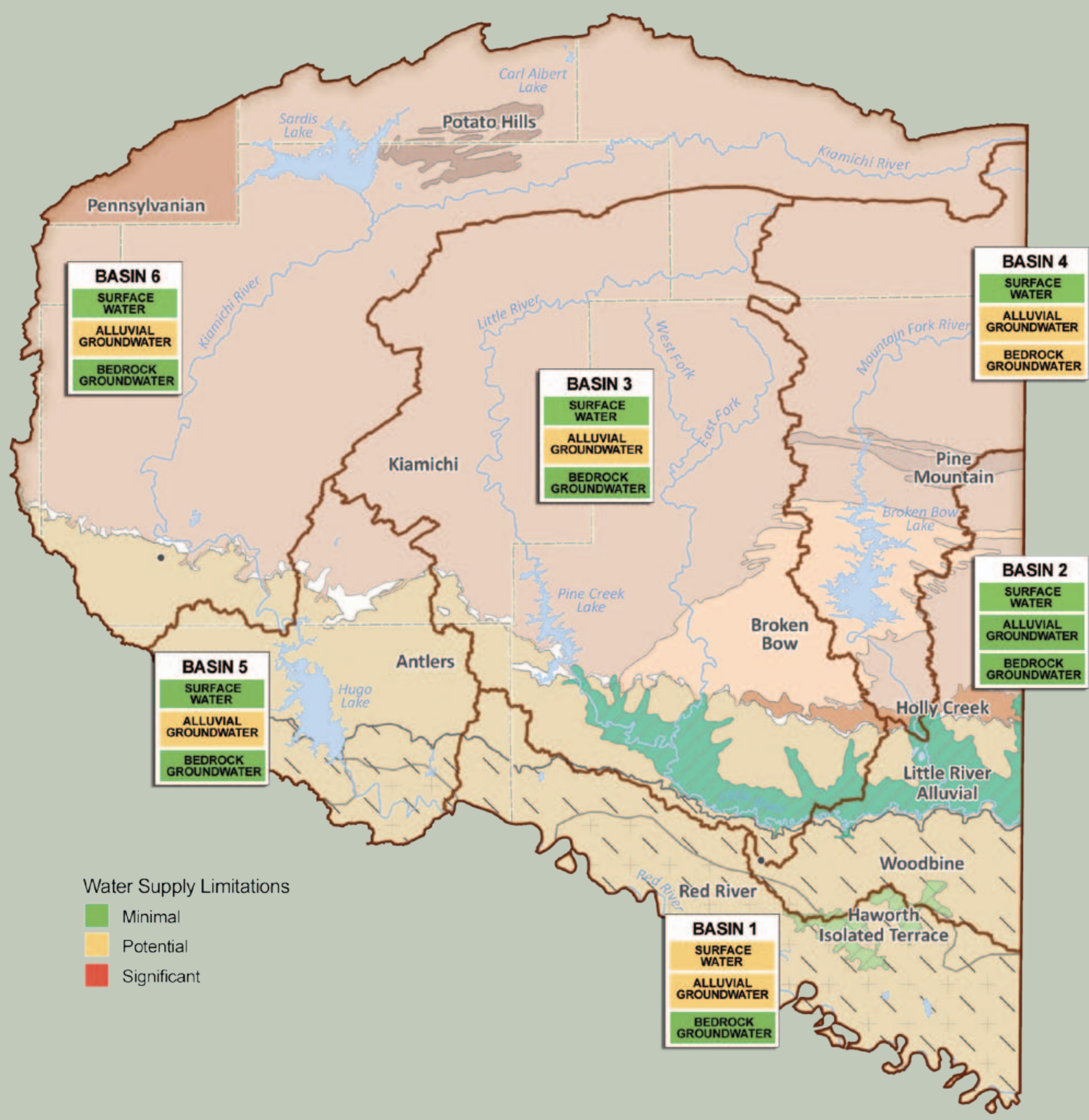
Alluvial Groundwater

Alluvial groundwater is used to meet 2% of the demand in the region. Currently permitted alluvial groundwater withdrawals are from the Red River aquifer and non-delineated minor alluvial aquifers. The majority of alluvial groundwater withdrawals are assumed to be from self-supplied residential 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 are likely to occur in the 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 2% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Antlers aquifer and to a lesser extent the Kiamichi minor aquifer. The Antlers aquifer has about 23 million acre-feet (AF) of groundwater storage in the region and is not expected to experience any bedrock groundwater depletions through 2060. The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet regional demand through 2060.

Water Supply Limitations
Southeast 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 and reservoirs are expected to continue to supply the majority of demand in the Southeast Region. Surface water users in Basin 1 and those that do not have access to major reservoirs may have physical surface water supply shortages (gaps) in the future. Alluvial groundwater storage depletions of minor aquifers are also projected in the future and may occur by 2030 in most basins.

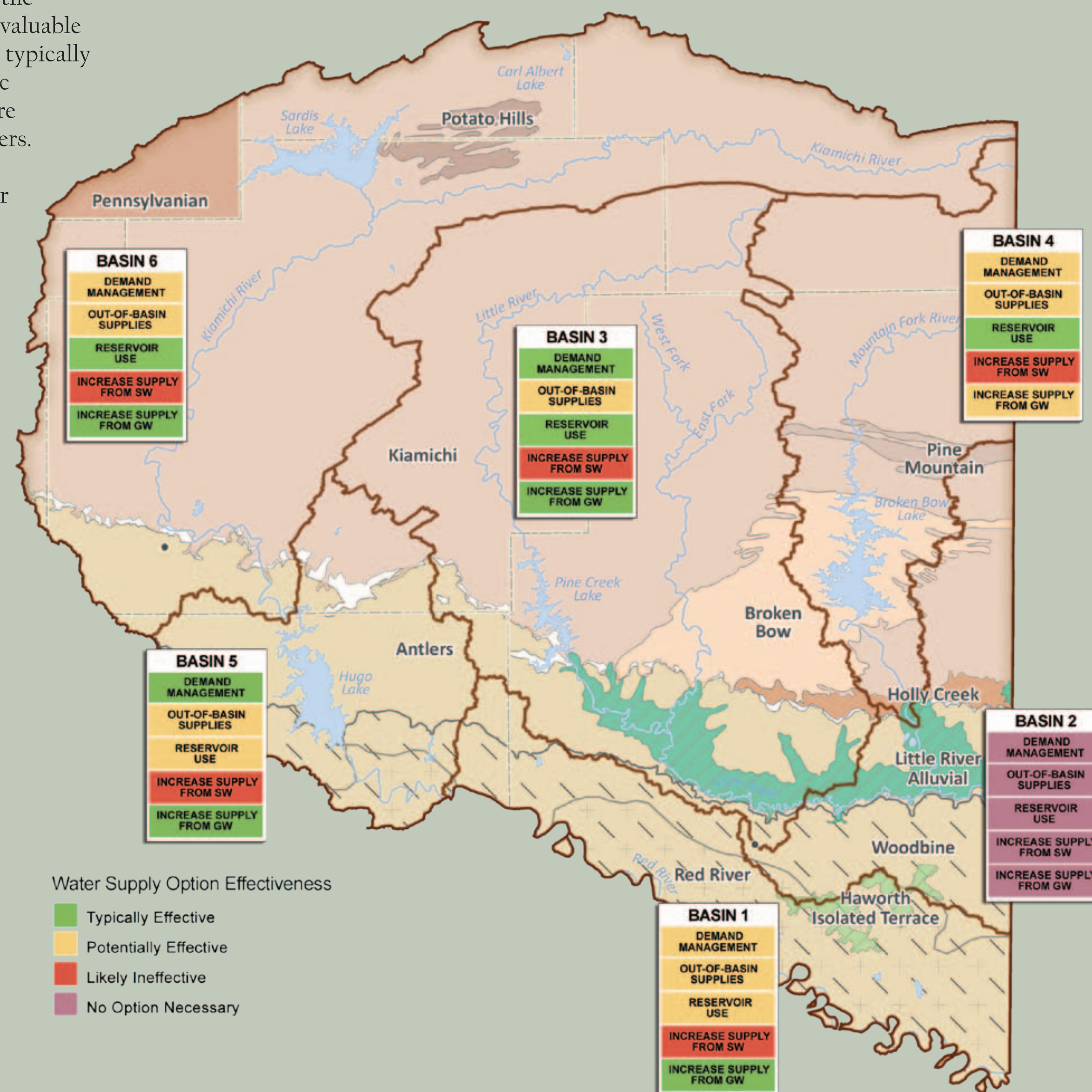
Demand management could aid in reducing projected gaps and groundwater storage depletions or delaying the need for additional infrastructure. Moderately expanded conservation activities, primarily increased conservation by public water suppliers, could reduce gaps and storage depletions throughout the region, and in Basins 3 and 5, eliminate alluvial groundwater storage depletions. 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 low frequency of shortages, temporary drought management measures may be effective.

New reservoirs and expanded use of existing reservoirs could enhance the dependability of surface water supplies and eliminate gaps in Basin 1. Many of the major reservoirs in the region have unpermitted yield that could supply new users. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state. Five potentially viable sites were identified in the region. These water sources could provide additional supplies to mitigate the region's surface water gaps and alluvial groundwater storage depletions. However, due to the availability of water supply yield from existing reservoirs in the region as well as the distance from these potential reservoir sites to demand points in each basin, this water supply option may not be cost-effective for many users.

Minor aquifers, which are prevalent in the northern portion of the region, may be valuable sources of supply for domestic use, but typically have low yields. Therefore, site-specific information should be considered before planning large-scale use of minor aquifers.

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

Water Supply Option Effectiveness
Southeast Region



Effectiveness of water supply options in each basin in the Southeast Region. This evaluation was based upon results of physical water supply availability analysis, 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 Southeast Region. The region's major streams include the Red River, Kiamichi River, Little River, and Mountain Fork of the Little River. Streams in the region generally have abundant flows for much of the year but typically experience lower flows in late summer and early fall.

The Red River, the largest stream in the Southeast Region, is located along the southern border of the region in Basin 1. Historically, water in the Red River mainstem, which maintains substantial flows, has had little use due to water quality concerns. The Red River further upstream, and especially above Denison (Texoma) Dam, contains high levels of dissolved solids and chlorides. However, downstream of its confluence with the Blue River, Boggy Creek(s), and Kiamichi River, quality of the Red River becomes acceptable for most uses, yet is still inferior to that of other streams in the region. Provisions of the Red River Compact would also impact the availability and use of water.

The headwaters of the Kiamichi River are in Basin 6. The river flows 170 miles through Basins 6 and 5 and is a tributary to the Red River at the outlet of Basin 5. Water in the Kiamichi River is of high quality with little mineralization. The Little River (140 miles in Oklahoma) flows southeasterly through Basins 2 and 3 before crossing the state line into Arkansas. Major tributaries include the Glover River and the Mountain Fork.

The headwaters of the Mountain Fork of the Little River are in Arkansas near the Oklahoma state line. The mainstem runs southerly for 60 miles through Basins 2 and 4, where it joins the Little River. Major tributaries include Buffalo Creek (40 miles long in Oklahoma). A section of the upper Mountain Fork River where it flows into Broken Bow Lake is noted for its high quality and has been designated as one of Oklahoma's six scenic rivers. The water quality of the Little River and its tributaries is generally good.

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.

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. There are four major reservoirs in the region, Broken Bow, Pine Creek, Sardis, and Hugo, all constructed by the U.S. Army Corps of Engineers. Broken Bow Lake was completed in 1970 on the Mountain Fork River in Basin 4 for water supply, flood control, recreation, hydropower, water quality, and fish and wildlife benefits. The lake has a dependable water supply yield of 196,000 AFY. Pine Creek Lake, located on the Little River in Basin 3, was completed in 1969 for the purposes of flood control, water supply, water quality, recreation, and fish and wildlife. The lake has a dependable yield of 94,080 AFY for water supply and 40,330 AFY for water quality. Sardis Lake was built in 1983 on Jackfork Creek, a tributary to the Kiamichi River, in Basin 6. The reservoir was authorized for flood control, water supply, recreation, and fish and wildlife and yields 156,800 AFY for water supply purposes. Hugo Lake was completed in 1974 on the Kiamichi River in Basin 5 and provides flood control, water supply, water quality, recreation, and fish and wildlife mitigation. The lake yields 64,960 AFY for water supply and 100,800 AFY for water quality control purposes. One significant municipal lake exists in the region in Basin 5: Carl Albert Lake, which is operated by the City of Talihina for water supply and recreation purposes. There are additional small Natural Resources Conservation Service (NRCS), municipal, and privately owned lakes in the region that provide water for purposes such as public water supply, agricultural water supply, flood control, and recreation.

Reservoirs
Southeast 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
Broken Bow Lake	4	USACE	1970	FC, HP, WS, R, FW	918,070	152,500	196,000	0	0	0	0	10,780	185,220
Carl Albert Lake	5	City of Talihina	1964	WS. FC, R	2,739	---	---	0	0	0	0	1,500	---
Hugo Lake	5	USACE	1974	FC, WS, WQ, R, FW	158,617	47,600	64,960	0	0	73,900	100,800	62,392	2,568
Pine Creek Lake	3	USACE	1969	FC, WS, WQ, FW, R	53,750	49,400	94,080	0	0	21,100	40,330	33,605	60,475
Sardis Lake	6	USACE	1982	FC, WS, R, FW	274,330	274,209	156,800	0	0	0	0	7,030	149,770

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
Southeast Region

Reservoirs may serve multiple purposes, such as water supply, irrigation, recreation, hydropower generation, and flood control. Reservoirs designed for multiple purposes 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.

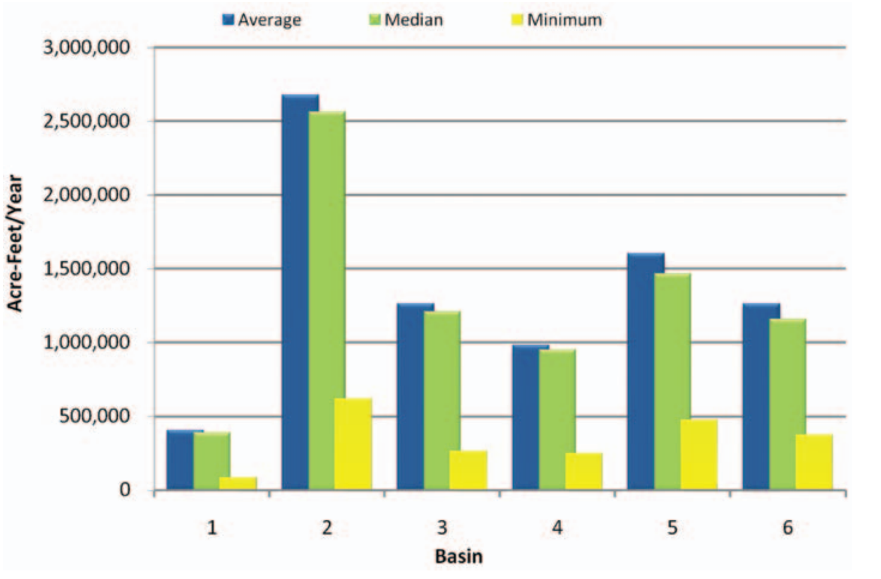
For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers, 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)
Southeast Region



Surface water is the main source of supply in the Southeast 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
Southeast Region

Streamflow Statistic	Basins					
	1	2	3	4	5	6
	AFY					
Average Annual Flow	403,500	2,488,500	1,259,200	798,400	1,596,800	1,263,400
Minimum Annual Flow	83,000	568,800	259,200	201,000	467,700	372,000

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 aquifers, the Antlers and Red River, underlie the southern portion of the Southeast Watershed Planning Region.

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

The Antlers bedrock 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 shallow 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 Oklahoma Department of Environmental Quality (ODEQ) has identified several monitoring wells in this aquifer with elevated nitrate levels and some wells with consistently low pH values. The Antlers bedrock aquifer underlies portions of Basins 1, 2, 3, 5, and 6.

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 the aquifer's potential as a major source of groundwater. The aquifer underlies a significant portion of Basin 1 and southern portions of Basins 2, and 5.

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

Minor bedrock aquifers in the region include Broken Bow, Holly Creek, Kiamichi, Pennsylvanian, Pine Mountain, Potato Hills, and Woodbine aquifers. Minor alluvial aquifers include the Little River and Haworth Isolated Terrace. 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 systems but may have insufficient yields to supply 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
Southeast 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	Inch/Yr	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	29%	0.7-1.7	4,600	22,804,000	2.1	1,718,900
Red River	Alluvial	Major	8%	5	200	282,000	temporary 2.0	435,000
Broken Bow	Bedrock	Minor	5%		0	258,000	temporary 2.0	294,400
Haworth Isolated Terrace	Alluvial	Minor	1%	4.8	0	22,000	1.0	19,200
Holly Creek	Bedrock	Minor	<1%		0	70,000	temporary 2.0	25,600
Kiamichi	Bedrock	Minor	61%	1.1	100	2,335,000	temporary 2.0	3,480,500
Little River	Alluvial	Minor	3%	4.8	0	247,000	1.0	89,600
Pennsylvanian	Bedrock	Minor	2%	1.1	0	838,000	temporary 2.0	102,400
Pine Mountain	Bedrock	Minor	1%		0	33,000	temporary 2.0	38,400
Potato Hills	Bedrock	Minor	1%		0	49,000	temporary 2.0	38,400
Woodbine	Bedrock	Minor	15%	21.5	<50	6,414,000	temporary 2.0	831,800
Non-Delineated Groundwater Source	Alluvial	Minor			200			
Non-Delineated Groundwater Source	Bedrock	Minor			0			

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
Southeast Region

The Antlers aquifer is the only major bedrock aquifer in the Southeast Region. The Red River aquifer is the only major alluvial aquifer in the region. 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 region range from 1 acre-foot per year (AFY) per acre to 2.1 AFY per acre. There will be groundwater available for new permits through 2060 in all basins in the Southeast Region.

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.

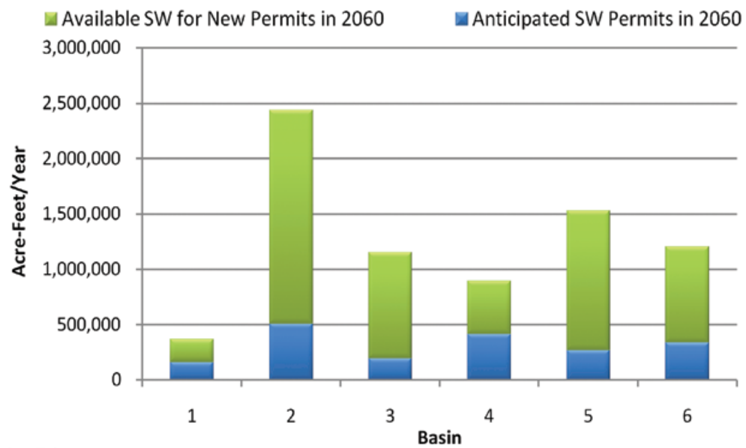
To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations,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

Surface Water Permit Availability
Southeast Region



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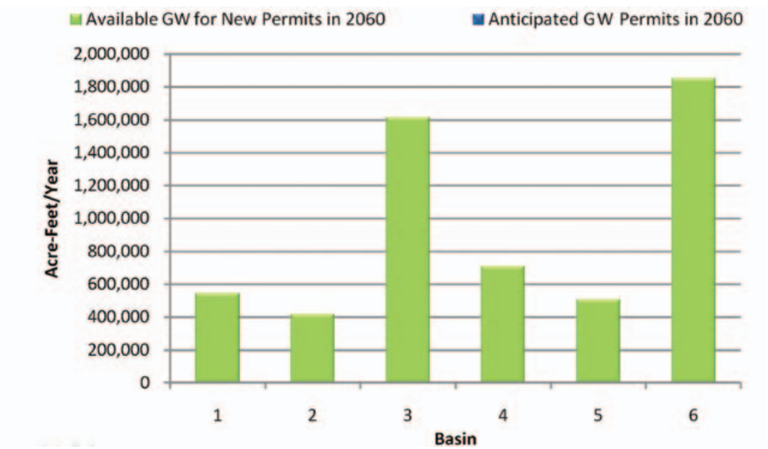
Groundwater Permit Availability
Southeast Region



Projections indicate that there will be groundwater available for new permits through 2060 in all basins in the Southeast Region.

Water Quality

Water quality of the Southeast Watershed Planning Region is defined by the lower Red River watershed and several minor and major water supply reservoirs. The region is primarily located within the Ouachita Mountains (OM) and South Central Plains (SCP) ecoregions.

The OM Ecoregion covers the northern two-thirds to three-quarters of the region. The ecoregion is represented by several sub-ecoregions. Generally, the area is underlain by sedimentary rock, including shale/chert. Uplands are covered by oak-hickory-shortleaf pine forests; many intervening valleys are forested but may have intervening grasslands, hay fields, and pasture. Major land uses are logging and recreation with some agriculture, especially confined feeding operations in the east. 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 Athens Plateau and Central Mountain Ranges (CMR) lie along the eastern edge of the region. While the Athens Plateau is shaped by hills and low ridges underlain by shale, the CMR is more mountainous with sharp ridges and shallow, stony soils underlain mostly by sandstone, chert, and shale. Commercial logging is limited in CMR but widespread along the Plateau. The upper Mountain Fork River is the dominant watershed through both ecoregions while Broken Bow Lake and the lower Mountain Fork represent a large portion of the lower end of the area.

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.

Portions of the Glover River also flow through the CMR but it is more representative of the Western Ouachita Range. Salinity is extremely low throughout both areas. Stream mean conductivity is 30 µS/cm, while lake conductivity is slightly higher. Streams are typically oligotrophic with extremely low means of total phosphorus (TP, 0.01-0.03 ppm) and total nitrogen (TN, 0.45-0.05 ppm). Broken Bow Lake is phosphorus limited and mesotrophic with extremely low nutrient values. Clarity is excellent throughout. Stream mean turbidity values range from 3 to 6 NTU while lake Secchi depth average is 224 cm.

The Western Ouachita Mountains dominate the western 75-80% of the region. Underlain by sandstone and shale, this area has lower elevations than the CMR and is less rugged than both the CMR and Fourche Mountains to the north. Logging and recreation are the major land uses. The upper Little River (including Pine Creek Lake) and Glover River mainstems and watersheds dominate the majority of the area but feeder creeks of the Kiamichi River become more dominant to the west and north. Salinity is extremely low with mean conductivity ranging from 20 µS/cm (Little) to 45 µS/cm (Glover). Pine Creek conductivity is slightly higher but generally remains below 80 µS/cm. Streams are mesotrophic with low nutrient values and excellent clarity. Mean TP, TN, and turbidity values are analogous to the Mountain Fork. Pine Creek Lake is phosphorus limited and eutrophic with slightly higher nutrient concentrations than Broken Bow. Clarity is good with a mean Secchi depth of 83 cm.

The narrow Western Ouachita Valleys cut through the mountains, mostly west to east. Valley uplands continue to support the oak/hickory/pine forests but give way to bottomland

Ecoregions
Southeast Region

The Southeast Planning Region is dominated by the Ouachita Mountains with significant influence from South Central Plains along the southern one-third of the region. Water quality is highly influenced by both geology and to some extent land use practices. It is generally excellent throughout the Ouachitas and is good to excellent through most of the South Central Plains but becomes only average along the Red River Bottomlands.

hardwoods in the low-lying floodplains. Pasture land and hay fields dominate open areas with agriculture, recreation, and commercial logging as primary land uses. The valleys are represented by the upper Kiamichi River and Sardis Lake, as well as numerous smaller lakes, including Ozzie Cobb, Nanih Waiya, and Carl Albert. Salinity is extremely low with mean conductivity ranging from 20 µS/cm (Kiamichi/Big Cedar) to 45 µS/cm (Kiamichi/Antlers). Salinity on Carl Albert and Sardis is analogous to Pine Creek but averages near 150-200 µS/cm on Nanih Waiya and Ozzie Cobb. On the Kiamichi, nutrient values increase and water clarity decreases east to west from Big Cedar to Antlers. While Big Cedar is oligotrophic with very low nutrient concentrations, Antlers is eutrophic (TN = 0.58 ppm and TP = 0.05 ppm). Similarly, turbidity ranges from 6 (Big Cedar) to 14 NTUs (Antlers). Lakes are phosphorus limited and are generally mesotrophic with very low nutrient values. Nutrient concentrations increase considerably on Ozzie Cobb, which is classified as eutrophic. Clarity is average to good with Secchi depth means ranging from 50-100 cm.

The South Central Plains ecoregion covers the southern one-quarter to one-third of the region. The ecoregion is represented by several sub-ecoregions. Underlain mostly by unconsolidated Cretaceous deposits, the area is a series of irregular plains with intervening shallow valleys. Uplands are covered by oak-hickory-pine forests with pasture land and some natural grasslands. 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 and some gravel/cobble bottoms. While many pools lack perennial flow, they are maintained. Ecological diversity is moderate to high, increasing west to east, but can be impacted by poor habitat and sedimentation. Several native fish, including the dollar sunfish and pirate perch, only occur in this ecoregion.

Water Quality Standards Implementation
Southeast Region

The Oklahoma Department of Environmental Quality has completed TMDL studies on Buzzard Creek, Millerton Tributary, Garland Creek, and Yanubbe Creek. Several other TMDL studies are underway or scheduled.

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 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.

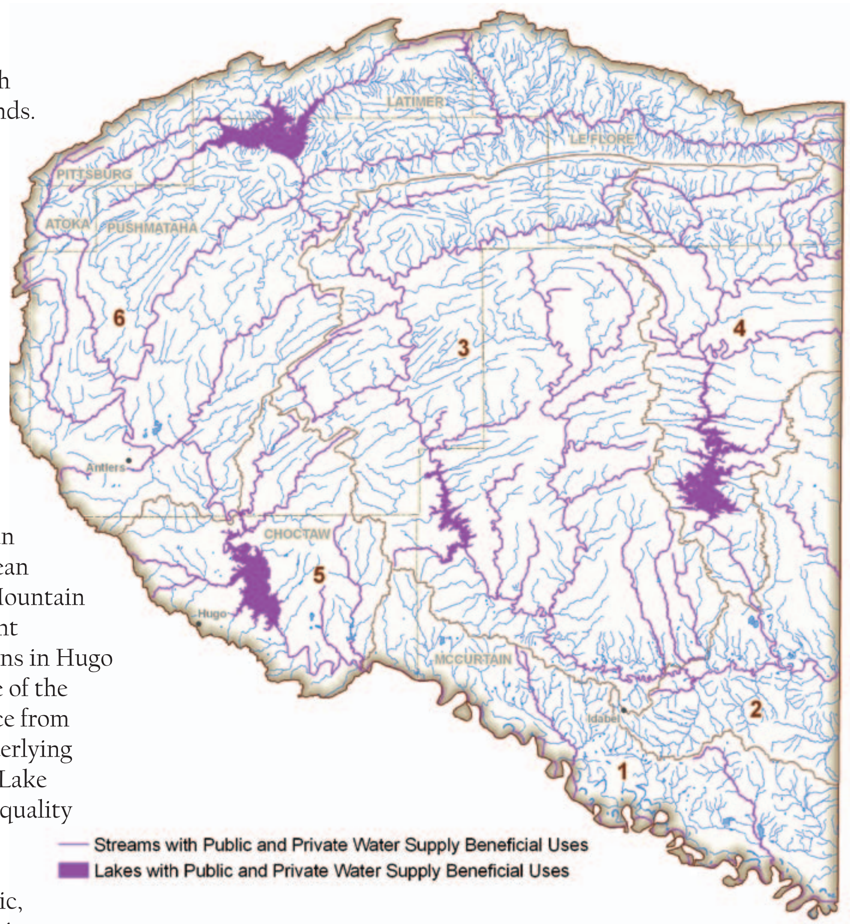
In an individual waterbody, after impairments have been identified, a Total Maximum Daily Load (TMDL) study is conducted to establish the sources of impairments—whether from point sources (discharges) or non-point sources (runoff). The study will then determine the amount of reduction necessary to meet 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.

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

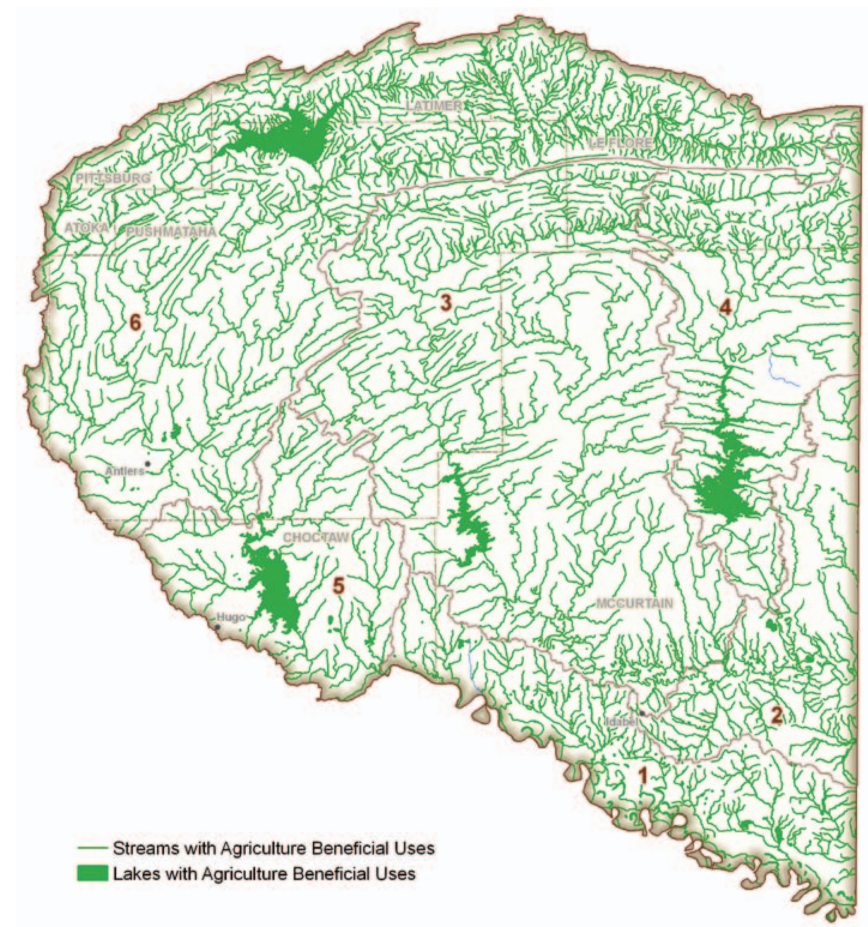
Surface Waters with Designated Beneficial Use for Public/Private Water Supply

Southeast Region



Surface Waters with Designated Beneficial Use for Agriculture

Southeast Region



Water quality throughout the SCP ecoregion is a reflection of the lithological differences between the sub-ecoregions. Streams in the Floodplains and Lowland Terraces (east centrally located) are typically low velocity meandering channels with numerous oxbows and forested wetlands. The Little River is characteristic of the area. Near Holly Creek, it has low conductivity (mean = 75 µS/cm), is oligotrophic with low nutrients (TP = 0.04 ppm and TN = 0.53 ppm), and has near excellent water clarity (12 NTU). Likewise, the surrounding Pleistocene Fluvial Terraces have more clay content and are acidic with low conductivity but are characteristically stained black by high organic content. In the lower portions, dissolved oxygen concentrations are naturally lower than surrounding areas, sometimes with mean values as low as 2-3 ppm. The lower Mountain Fork, below Highway 70, is an excellent waterbody. The Blackland Prairie begins in Hugo Lake and runs along the southern edge of the Lowland Terraces. The major difference from other lowlands in the ecoregion is underlying limestone, marl, and calcareous shale. Lake Raymond Gary is similar but lower in quality than water in the east. Conductivity is slightly higher with values between 100-200 µS/cm. Although it is eutrophic, nutrient values remain low and clarity is average (55 cm). Surrounding all of these areas are the Dissected Uplands, which run the full length of the region, dominating the western half. Underlain by a mixture of sand, clay and gravel, it retains characteristics of the Ouachita Mountains in the Southeast Region. Streams may have moderate gradients with lower organic content but are typically more turbid and slightly harder. Hugo Lake and the lower Kiamichi River are good examples. Conductivity values remain low with approximate means from 80-90 µS/cm. Hugo lake is eutrophic while the river is oligotrophic, but nutrient values remain low. Clarity is lower than surrounding areas with Kiamichi mean turbidity of 29 NTU and Hugo mean Secchi depth of 33 cm. The Red River Bottomlands is located in a large floodplain with low terraces and numerous oxbow lakes. Poorly drained, the river lies in a wide, slow, and meandering valley. Mean conductivity is much higher at 1125 µS/cm while clarity is average at 43 NTU. It is eutrophic with higher nutrient concentrations (TP = 0.14 ppm; TN = 0.90 ppm).

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. The Southeast Region is underlain primarily by minor bedrock and alluvial aquifers although two major aquifers exist in the southern portion of the region. Water from the Red River alluvium and terrace aquifer, the only major alluvial aquifer, has relatively high concentrations of dissolved solids but is 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 only major bedrock aquifer is the Antlers aquifer. Its water quality is generally good though becomes slightly saline in the southern portions of the aquifer. The ODEQ has also identified several monitoring wells in the aquifer with elevated nitrate levels as well as some showing consistently low pH values.

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

Southeast Region

Special OWQS provisions are in place to protect surface waters covering most of this region. These protections should limit new pollutant discharges. When new water supplies are established Sensitive Water Supply protection should be considered.

Groundwater Protection Areas
Southeast Region

Various types of protection are in place to prevent degradation of groundwater and address vulnerability. The Red River alluvial aquifer has been identified as very highly vulnerable.

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

Southeast Region

Parameter	Broken Bow Lake (1987-2009)	Hugo Lake (1993-2008)	Pine Creek Lake (1989-2008)	Sardis Lake (1996-2008)
Chlorophyll-a (mg/m3)	NT	NT	NT	NT
Conductivity (us/cm)	↓	NT	↓	↑
Total Nitrogen (mg/L)	↓	↓	↓	↑
Total Phosphorus (mg/L)	↓	↓	↑	↓
Turbidity (NTU)	↓	NT	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 total phosphorus and chlorophyll-a on Pine Creek Reservoir
- Significant upward trend for total nitrogen on Sardis Reservoir

Stream Water Quality Trends

Southeast Region

Parameter	Glover River near Glover		Kiamichi River near Antlers		Kiamichi River near Big Cedar		Mountain Fork of the Little River near Eagletown		Mountain Fork of the Little River near Smithville		Red River near Hugo	
	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1966-1996, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	↓	NT	↓	↑	↓	↑	↓	↑	↑	↑	NT	NT
Total Nitrogen (mg/L)	↓	↓	↓	NT	↓	↓	↓	↓	NT	NT	↓	↑
Total Phosphorus (mg/L)	↓	↓	↓	NT	↓	↓	↓	↓	↓	↓	↓	NT
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.

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 total nitrogen for recent data on the Red River
- Significant upward trend for period of record turbidity data on the Glover, Mountain Fork, and Red Rivers

Water Demand

Water needs in the Southeast Region account for about 3% of the total statewide demand. Regional demand will increase by 26% (14,830 AFY) from 2010 to 2060. The majority of the demand over this period will be in the Self-Supplied Industrial demand sector followed by the Thermoelectric Power and Municipal and Industrial demand sectors. However, the largest growth in demand will be in the Thermoelectric Power demand sector.

Self-Supplied Industrial demand in the region is projected to account for 51% of the 2060 demand. Currently, demand from this sector is supplied by surface water.

Thermoelectric Power demand is projected to account for 20% of the 2060 demand. The Western Farmers Electric Cooperative's Hugo plant and the Weyerhaeuser Wright City complex are large users of water for thermoelectric power generation in the region. Currently, 94% of the demand from this sector is supplied by surface water and 6% by bedrock groundwater.

The Municipal and Industrial sector is projected to account for approximately 12% of the region's 2060 demand. Currently, 97% of the demand from this sector is supplied by surface water, less than 1% by alluvial groundwater, and 3% by bedrock groundwater.

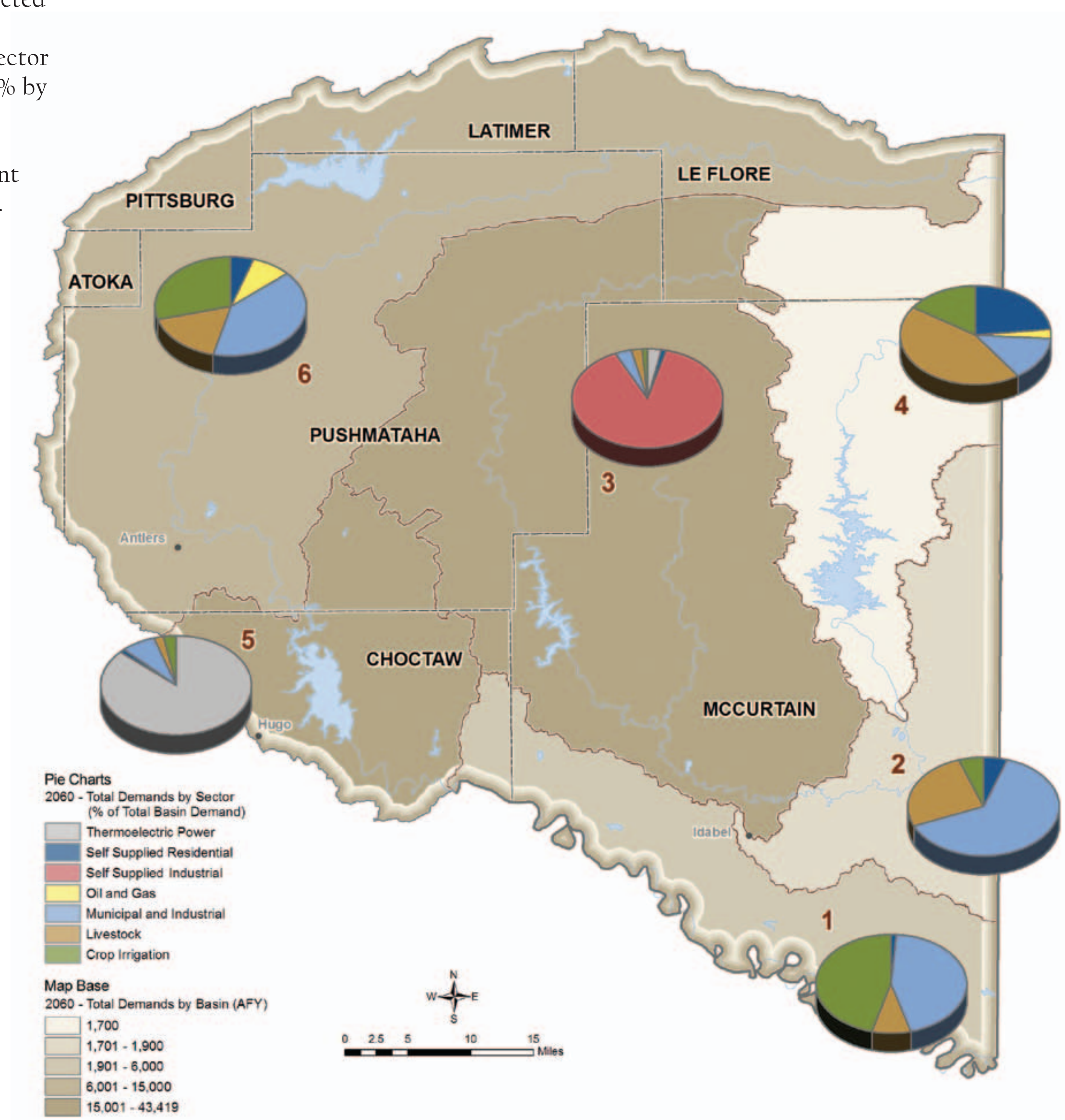
The Crop Irrigation demand sector is expected to account for 8% of the 2060 demand. Currently, 91% of the demand from this sector is supplied by surface water, 3% by alluvial groundwater, and 6% by bedrock groundwater. Irrigated crops in the Southeast Region are predominantly pasture grasses.

Livestock demand is projected to account for 6% of the 2060 demand. Currently, 94% of the demand from this sector is supplied by surface water, 2% by alluvial groundwater, and 4% by bedrock groundwater. Livestock use in the region is predominantly chicken, followed distantly by cattle for cow-calf production.

Self-Supplied Residential demand is projected to account for 2% of the 2060 demand. Currently, 98% of the demand from this sector is supplied by alluvial groundwater and 2% by bedrock groundwater.

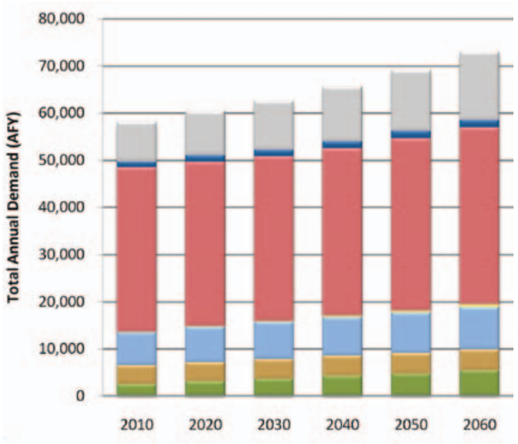
Oil and Gas demand is projected to account for approximately 1% of the 2060 demand. Currently, demand from this sector is supplied by surface water.

Total 2060 Water Demand by Sector and Basin
(Percent of Total Basin Demand)
Southeast Region

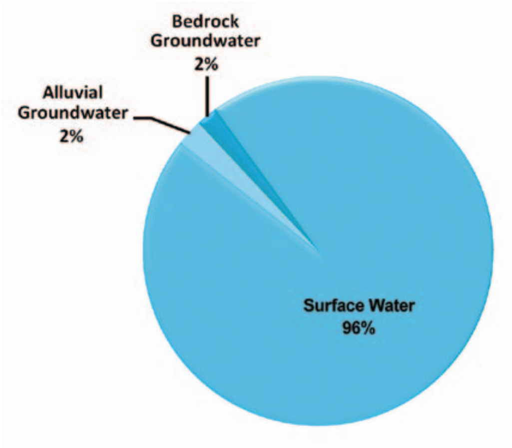


Self-Supplied Industrial is expected to remain the largest demand sector in the region, accounting for 51% of the total regional demand in 2060.

Total Water Demand by Sector
Southeast Region



Supply Sources Used to Meet Current Demand (2010)
Southeast Region



The Southeast Region's water needs account for about 3% of the total statewide demand. Regional demand will increase by 26% (14,830 AFY) from 2010 to 2060. Self-Supplied Industrial demand will continue to be the largest demand sector but significant growth is expected from the Crop Irrigation and Thermoelectric Power sectors.

Total Water Demand by Sector
Southeast Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,530	3,980	7,060	100	34,830	1,300	8,290	58,100
2020	3,120	4,060	7,490	170	34,840	1,380	9,250	60,320
2030	3,710	4,150	7,860	250	34,840	1,450	10,320	62,580
2040	4,300	4,230	8,220	350	35,420	1,510	11,510	65,560
2050	4,760	4,320	8,600	470	36,490	1,580	12,850	69,070
2060	5,490	4,400	8,980	610	37,470	1,650	14,330	72,930

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 Southeast Watershed Planning Region includes 27 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 population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are Broken Bow PWA, Idabel PWA, McCurtain County RWD, Hugo, and Pushmataha County RWD #3. Together, these five systems serve over 60 percent of the combined OCWP public water providers' population 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.

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

Southeast Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
ANTLERS	OK1010302	Pushmataha	154	2,685	3,044	3,375	3,725	4,122	4,510
BROKEN BOW PWA	OK1010214	McCurtain	307	15,187	15,846	16,401	16,886	17,372	17,857
CHOCTAW COUNTY RWD #2	OK3001203	Choctaw	58	456	467	476	487	499	511
CHOCTAW COUNTY RWSG & SWMD #3	OK3001209	Choctaw	70	252	258	263	269	276	282
CLAYTON PWA	OK3006408	Pushmataha	368	741	843	927	1,019	1,130	1,242
FORT TOWSON	OK2001207	Choctaw	72	617	637	647	667	677	697
GARVIN	OK3004809	McCurtain	60	235	235	251	251	266	266
HAWORTH	OK3004810	McCurtain	62	376	386	407	417	427	447
HUGO	OK1010314	Choctaw	83	5,578	5,716	5,825	5,964	6,113	6,251
IDABEL PWA	OK1010203	McCurtain	158	7,034	7,357	7,611	7,827	8,061	8,286
LATIMER CO RWD #2	OK3003903	Latimer	54	1,253	1,311	1,380	1,460	1,538	1,631
LEFLORE CO RWD #3	OK3004006	LeFlore	125	1,404	1,514	1,612	1,710	1,808	1,912
LEFLORE CO RWD #17	OK3004048	LeFlore	50	439	473	504	535	565	598
MCCURTAIN CO RWD #1	OK3004806	McCurtain	133	3,795	3,966	4,104	4,222	4,350	4,467
MCCURTAIN CO RWD #2	OK3004814	McCurtain	60	764	798	826	850	876	899
MCCURTAIN CO RWD #5 (HOCHATOWN)	OK3004804	McCurtain	51	1,246	1,302	1,347	1,386	1,428	1,466
MCCURTAIN CO RWD #7	OK3004801	McCurtain	132	1,847	1,930	1,997	2,055	2,117	2,174
MCCURTAIN CO RWD #8 (MT. FORK WATER)	OK1010207	McCurtain	133	5,778	6,038	6,249	6,428	6,623	6,802
MCCURTAIN CO RWD #9	OK3004820	McCurtain	171	1,011	1,056	1,093	1,125	1,159	1,190
PUSHMATAHA CO RWD #1	OK3006403	Pushmataha	65	1,240	1,401	1,554	1,716	1,897	2,079
PUSHMATAHA CO RWD #2 (ALBION)	OK3006402	Pushmataha	75	1,039	1,169	1,299	1,429	1,558	1,753
PUSHMATAHA CO RWD #3	OK1010318	Pushmataha	106	4,753	5,371	5,956	6,579	7,271	7,968
PUSHMATAHA CO RWD #5 (NASHOBA)	OK3006410	Pushmataha	72	738	834	925	1,021	1,129	1,237
SARDIS LAKE WATER AUTHORITY	OK1010319	Pushmataha	281	600	678	752	830	918	1,006
TALIHINA	OK1010304	LeFlore	225	1,328	1,430	1,522	1,614	1,706	1,808
VALLIANT PWA	OK3004812	McCurtain	155	966	1,010	1,045	1,075	1,108	1,138
WRIGHT CITY PWA	OK3004811	McCurtain	116	963	1,006	1,042	1,071	1,104	1,134

1 SDWIS - Safe Drinking Water Information System
2 GPD=gallons per day.

Projections of Retail Water Demand

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 demand includes water provided to households for domestic uses both inside and outside the home. Non-residential demand includes customer uses at office buildings, shopping centers, industrial parks, schools, churches, hotels, and related locations served by a public water supply system. Retail demand doesn't 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, 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 systems.

Public Water Provider Demand Forecast

Southeast Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
ANTLERS	OK1010302	Pushmataha	463	525	582	643	711	778
BROKEN BOW PWA	OK1010214	McCurtain	5,223	5,449	5,640	5,807	5,974	6,141
CHOCTAW COUNTY RWD #2	OK3001203	Choctaw	29	30	31	31	32	33
CHOCTAW COUNTY RWSG & SWMD #3	OK3001209	Choctaw	20	20	21	21	22	22
CLAYTON PWA	OK3006408	Pushmataha	306	348	382	420	466	512
FORT TOWSON	OK2001207	Choctaw	50	51	52	54	55	56
GARVIN	OK3004809	McCurtain	16	16	17	17	18	18
HAWORTH	OK3004810	McCurtain	26	27	28	29	30	31
HUGO	OK1010314	Choctaw	519	531	542	554	568	581
IDABEL PWA	OK1010203	McCurtain	1,241	1,298	1,343	1,381	1,422	1,462
LATIMER CO RWD #2	OK3003903	Latimer	76	79	83	88	93	99
LEFLORE CO RWD #3	OK3004006	LeFlore	197	212	226	239	253	268
LEFLORE CO RWD #17	OK3004048	LeFlore	25	27	28	30	32	33
MCCURTAIN CO RWD #1	OK3004806	McCurtain	567	592	613	631	650	667
MCCURTAIN CO RWD #2	OK3004814	McCurtain	51	54	56	57	59	60
MCCURTAIN CO RWD #5 (HOCHATOWN)	OK3004804	McCurtain	71	75	77	79	82	84
MCCURTAIN CO RWD #7	OK3004801	McCurtain	273	285	295	304	313	321
MCCURTAIN CO RWD #8 (MT. FORK WATER)	OK1010207	McCurtain	858	897	928	955	984	1,010
MCCURTAIN CO RWD #9	OK3004820	McCurtain	194	203	210	216	222	228
PUSHMATAHA CO RWD #1	OK3006403	Pushmataha	90	102	113	125	138	151
PUSHMATAHA CO RWD #2 (ALBION)	OK3006402	Pushmataha	87	98	109	120	131	147
PUSHMATAHA CO RWD #3	OK1010318	Pushmataha	564	637	707	781	863	946
PUSHMATAHA CO RWD #5 (NASHOBA)	OK3006410	Pushmataha	60	67	75	83	91	100
SARDIS LAKE WATER AUTHORITY	OK1010319	Pushmataha	189	214	237	262	289	317
TALIHINA	OK1010304	LeFlore	334	360	383	406	429	455
VALLIANT PWA	OK3004812	McCurtain	168	175	181	187	192	198
WRIGHT CITY PWA	OK3004811	McCurtain	125	131	135	139	143	147

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers

Southeast Region

Provider	SDWIS ID[1]	Sales: Sells To	Sales: Emergency or Ongoing	Sales: Treated or Raw or Both	Purchases: Purchases from	Purchases: Emergency or Ongoing	Purchases: Treated or Raw or Both
BROKEN BOW PWA	OK1010214	Garvin Idabel PWA McCurtain Co RWD #1 McCurtain Co RWD #5 Valliant PWA Wright City PWA Haworth	O E O O O O	T T T T T T			
CHOCTAW COUNTY RWD #2	OK3001203				Valliant PWA	O	T
CHOCTAW COUNTY RWSG & SWMD #3	OK3001209				Hugo	O	T
CLAYTON PWA	OK3006408				Sardis Lake Water Authority	O	T
GARVIN	OK3004809				Broken Bow PWA	O	T
HAWORTH	OK3004810				McCurtain Co RWD #1 Broken Bow PWA	E	T
HUGO	OK1010314	Choctaw Co RWD #1 Choctaw Co RWSG & SWMD #3	O O	T T			
IDABEL PWA	OK1010203	McCurtain Co RWD #2 McCurtain Co RWD #7 McCurtain Co RWD #1	O O E	T B T	Broken Bow PWA	E	T
LATIMER CO RWD #2	OK3003903				Sardis Lake Water Authority Talihina	O E	T
LEFLORE CO RWD #3	OK3004006				Talihina Water District	O	
LEFLORE CO RWD #17	OK3004048				Mena Water Department	O	
MCCURTAIN CO RWD #1	OK3004806	Haworth	O	T	Broken Bow PWA Idabel PWA	O E	T T
MCCURTAIN CO RWD #2	OK3004814				Idabel PWA	O	T
MCCURTAIN CO RWD # 5 (HOCHATOWN)	OK3004804				Broken Bow PWA	O	T
MCCURTAIN CO RWD #7	OK3004801				Idabel PWA	O	B
PUSHMATAHA CO RWD #1	OK3006403				Sardis Lake Water Authority	O	T
PUSHMATAHA CO RWD #2 (ALBION)	OK3006402				Talihina	O	T
PUSHMATAHA CO RWD #5 (NASHOBA)	OK3006410				Sardis Lake Water Authority	O	T
SARDIS LAKE WATER AUTHORITY	OK1010319	Pushmataha Co RWD #1 Latimer Co RWD #2 Clayton PWA Pushmataha Co RWD #5	O O O O	T T T T			
TALIHINA	OK1010304	Leflore Co RWD # 3 Pushmataha Co RWD # 2 Latimer Co RWD # 3 Latimer Co RWD #2	O O O E	T T T			
VALLIANT PWA	OK3004812	Choctaw Co RWD # 2	O	T	Broken Bow PWA	O	T
WRIGHT CITY PWA	OK3004811				Broken Bow PWA	O	T

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 demand. 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)

Southeast Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source: Permitted Surface Water	Source: Permitted Alluvial Groundwater	Source: Permitted Bedrock Groundwater
			AFY	Percent		
ANTLERS	OK1010302	Pushmataha	758	100%	0%	0%
BROKEN BOW PWA	OK1010214	McCurtain	10,660	100%	0%	0%
CHOCTAW COUNTY RWD #2	OK3001203	Choctaw	---	---	---	---
CHOCTAW COUNTY RWSG & SWMD #3	OK3001209	Choctaw	---	---	---	---
CLAYTON PWA	OK3006408	Pushmataha	0	0%	0%	0%
FORT TOWSON	OK2001207	Choctaw	40	0%	100%	0%
GARVIN	OK3004809	McCurtain	---	---	---	---
HAWORTH	OK3004810	McCurtain	---	---	---	---
HUGO	OK1010314	Choctaw	30,500	100%	0%	0%
IDABEL PWA	OK1010203	McCurtain	4,929	100%	0%	0%
LATIMER CO RWD #2	OK3003903	Latimer	1,000	100%	0%	0%
MCCURTAIN CO RWD #1	OK3004806	McCurtain	2,000	100%	0%	0%
LEFLORE CO RWD #3	OK3004006	LeFlore	---	---	---	---
LEFLORE CO RWD #17	OK3004048	LeFlore	---	---	---	---
MCCURTAIN CO RWD #2	OK3004814	McCurtain	55	0%	100%	0%
MCCURTAIN CO RWD #5 (HOCHATOWN)	OK3004804	McCurtain	---	---	---	---
MCCURTAIN CO RWD #7	OK3004801	McCurtain	---	---	---	---
MCCURTAIN CO RWD #8 (MT. FORK WATER)	OK1010207	McCurtain	1,711	100%	0%	0%
MCCURTAIN CO RWD #9	OK3004820	McCurtain	---	---	---	---
PUSHMATAHA CO RWD #1	OK3006403	Pushmataha	---	---	---	---
PUSHMATAHA CO RWD #2 (ALBION)	OK3006402	Pushmataha	---	---	---	---
PUSHMATAHA CO RWD #3	OK1010318	Pushmataha	700	100%	0%	0%
PUSHMATAHA CO RWD #5 (NASHOBA)	OK3006410	Pushmataha	80	---	---	100%
SARDIS LAKE WATER AUTHORITY	OK1010319	Pushmataha	6,000	100%	0%	0%
TALIHINA	OK1010304	LeFlore	1,800	100%	0%	0%
VALLIANT PWA	OK3004812	McCurtain	614	100%	0%	0%
WRIGHT CITY PWA	OK3004811	McCurtain	---	---	---	---

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey
Southeast Region

City of Antlers (Pushmataha County)
Current Source of Supply
Primary source: Kiamichi River, Hugo Lake
Short-Term Needs
Infrastructure improvements: add storage.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Broken Bow PWA (McCurtain County)
Current Source of Supply
Primary source: Broken Bow Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add new clearwell.

Choctaw County RWD 2
Current Source of Supply
Primary source: Valiant PWA
Short-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.

Choctaw County RWSG & SWMD 3
Current Source of Supply
Primary sources: Kiamichi or Hugo Reservoir
Short-Term Needs
None identified.
Long-Term Needs
New supply source: Connection from City of Hugo.

Clayton PWA (Pushmataha County)
Current Source of Supply
Primary source: Sardis Lake WA
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Fort Towson (Choctaw County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add water meters; refurbish water tower.
Long-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.

Town of Garvin (McCurtain County)
Current Source of Supply
Primary source: Broken Bow PWA
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.

Town of Haworth (McCurtain County)
Current Source of Supply
Primary source: Broken Bow PWA.
Short-Term Needs
Infrastructure improvements: add storage.
Long-Term Needs
None identified.

City of Hugo (Choctaw County)
Current Source of Supply
Primary source: Hugo Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Idabel PWA (McCurtain County)
Current Source of Supply
Primary source: Little River
Emergency source: Caddo County RWD 3
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Latimer County RWD 2
Current Source of Supply
Primary sources: Sardis Lake WA, Talihina PWA
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add pump station & storage.

LeFlore County RWD 3
Current Source of Supply
Primary source: City of Talihina
Short-Term Needs
Infrastructure improvement: refurbish storage tanks; replace meters.
Long-Term Needs
Infrastructure improvement: replace distribution system lines.

LeFlore County RWD 17
Current Source of Supply
Primary source: Freedom Rural Water Association
Short-Term Needs
Infrastructure improvement: replace distribution system lines; add meters.
Long-Term Needs
Infrastructure improvement: replace distribution system lines.

McCurtain County RWD 1
Current Source of Supply
Primary sources: Broken Bow PWA
Short-Term Needs
None identified.
Long-Term Needs
None identified.

McCurtain County RWD 2
Current Source of Supply
Primary source: Idabel
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
Infrastructure improvements: add standpipe & pump station.

McCurtain County RWD 5 (Hochatown)
Current Source of Supply
Primary sources: Broken Bow Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.

McCurtain County RWD 7
Current Source of Supply
Primary source: Broken Bow PWA.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

McCurtain County RWD 8 (Mt. Fork Water)
Current Source of Supply
Primary source: Mountain Fork River
Short-Term Needs
Infrastructure improvements: add storage; new microfilter plant with pre-sed basin; new million gal. storage tank.
Long-Term Needs
Infrastructure improvements: add storage; plant expansion.

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.

McCurtain County RWD 9

Current Source of Supply

Primary source: Broken Bow PWA

Short-Term Needs

Infrastructure improvements: add standpipes.

Long-Term Needs

New supply source: Pushmataha County RWD 3 and/or Idabel. Infrastructure improvements: add pump stations; interconnect with Pushmataha County RWD 3 and/or Idabel.

Pushmataha County RWD 1

Current Source of Supply

Primary source: Sardis Lake WA

Short-Term Needs

Infrastructure improvements: add standpipe; replace distribution system lines.

Long-Term Needs

Infrastructure improvements: replace distribution system lines.

Pushmataha County RWD 2 (Albion)

Current Source of Supply

Primary sources: Talihina

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: replace water line from Talihina.

Pushmataha County RWD 3

Current Source of Supply

Primary source: Kiamichi River

Short-Term Needs

Infrastructure improvements: replace raw water intake at river; add distribution system lines.

Long-Term Needs

Infrastructure improvements: replace distribution system lines; convert to separate inlet and outlet pipes for 6 standpipes

Pushmataha County RWD 5 (Nashoba)

Current Source of Supply

Primary source: Sardis Lake WA

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Sardis Lake WA (Pushmataha County)

Current Source of Supply

Primary source: Sardis Lake

Short-Term Needs

New supply source: additional water rights to Sardis Lake. Infrastructure improvements: add pressure reducing valve in distribution system lines.

Long-Term Needs

Infrastructure improvements: refurbish water tank; move lake intake.

Town of Talihina (LeFlore County)

Current Source of Supply

Primary source: Lake Carl Albert

Short-Term Needs

Infrastructure improvements: add storage.

Long-Term Needs

None identified.

Town of Valliant (McCurtain County)

Current Source of Supply

Primary source: Broken Bow PWA

Short-Term Needs

Infrastructure improvements: replace distribution system lines.

Long-Term Needs

None identified.

Wright City PWA (McCurtain County)

Current Source of Supply

Primary source: Broken Bow PWA

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Infrastructure Cost Summary
Southeast Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$18	$751	$440	$1,209
Medium	$266	$347	$203	$816
Large	$0	$0	$0	$0
Reservoir[2]	$0	$0	$0	$0
Total	$284	$1,098	$643	$2,025

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 or fewer people.

2 The "reservoir" category refers specifically to rehabilitation projects.

- Approximately $2 billion is needed to meet the projected drinking water infrastructure needs of the Southeast Region over the next 50 years. The largest infrastructure costs are expected to occur between 2021 and 2040.
- Distribution and transmission projects account for more than 95 percent of the providers' estimated infrastructure costs.
- Small providers have the largest overall drinking water infrastructure costs.
- There are no expected costs for rehabilitation of existing reservoirs.

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.

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)

Southeast Region

Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool: Surface Area	Conservation Pool: Storage	Conservation Pool: Dependable Yield	Primary Study: Date	Primary Study: Agency	Updated Cost Estimate[2] (2010 dollars)
					AF	Acres	AF	AFY			
Buck Creek	3	Buck Creek	6	WS, FC, FW, R	95,000	785	48,250	56,011	1975	USACE	$155,959,000
Caney Mountain	4	Little River	3	WS, FW, R	389,600	10,440	384,720	280,055	1975	USACE	$131,312,000
Finley	4	Cedar Creek	6	WS, FC, FW, R	204,910	5,100	85,870	95,219	1975	USACE	$128,617,000
Kellond	3	Ten Mile Creek	6	WS, FC, FW, R	92,320	3,410	49,010	56,011	1975	USACE	$135,986,000
Tuskahoma	3	Kiamichi River	6	HP, WS, R, FW	49,100	4,500	49,100	63,852	1989	Multiple agencies	$95,781,000

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

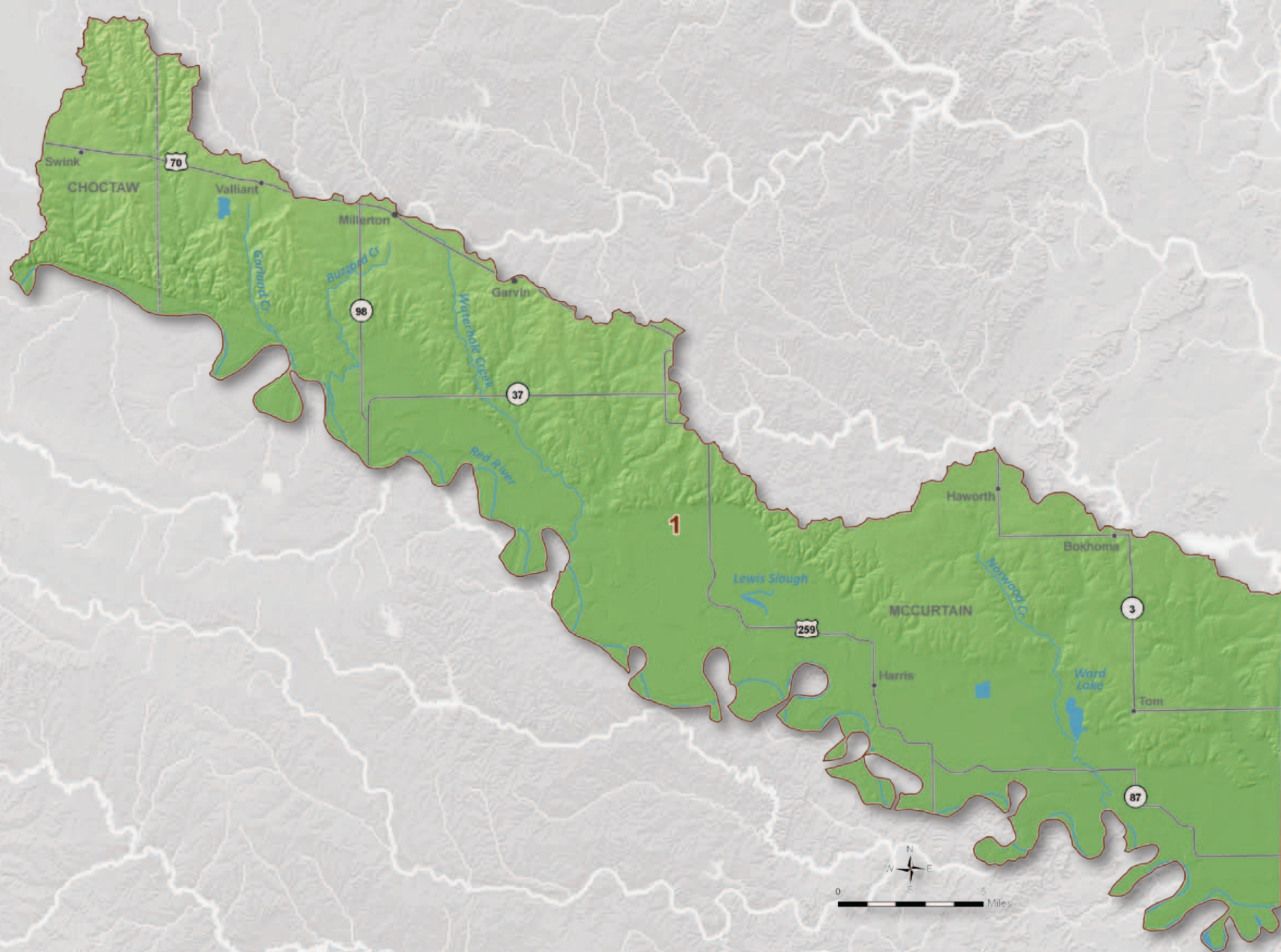
2 The majority of cost estimates were updated using estimated costs from previous project reports combined with the U.S. Army Corps of Engineers Civil Works Construction Cost Index System (CWCCIS) annual escalation figures to scale the original cost estimates to present-day cost estimates. These estimated 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
Southeast Region

Oklahoma Comprehensive Water Plan

Data & Analysis
Southeast Watershed Planning Region

Basin 1

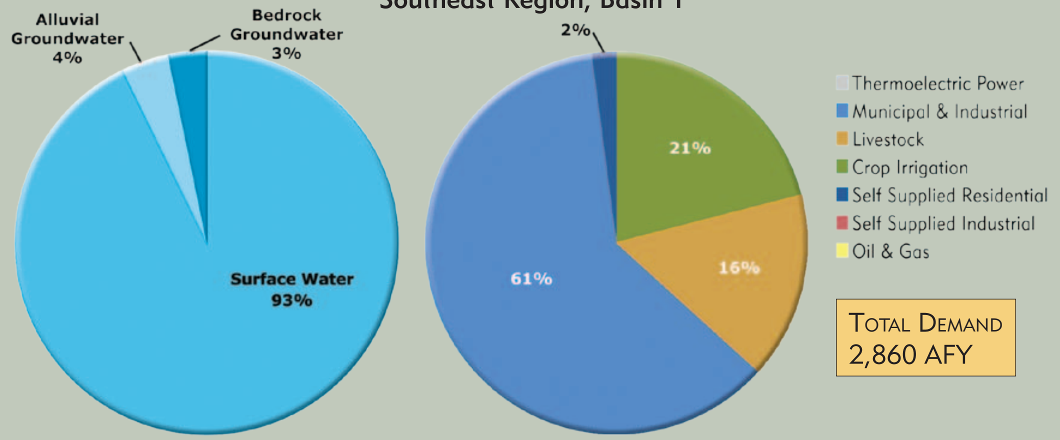


Basin 1 Summary

Synopsis

- Water users are expected to continue to rely on surface water and to a lesser extent groundwater supplies.
- Starting in 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, but 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 gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps.
- Use of additional groundwater supplies and/or developing new small reservoirs could mitigate gaps without having major impacts to groundwater storage.

Current Demand by Source and Sector
Southeast Region, Basin 1



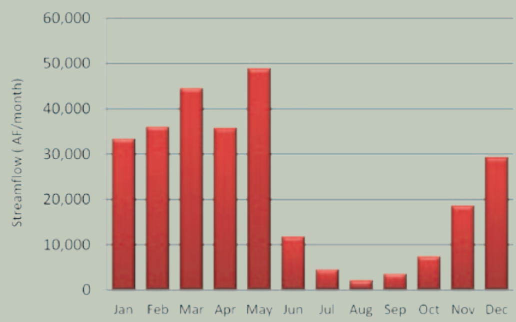
Basin 1 accounts for about 5% of the current water demand in the Southeast Watershed Planning Region. About 61% of the 2010 basin demand was from the Municipal and Industrial demand sector. Crop Irrigation (21%) is the second largest demand sector. Surface water satisfies about 93% of the current demand in the basin. Groundwater satisfies about 7% of the current demand (4% alluvial and 3% bedrock). The peak summer month total water demand in Basin 1 is 2.5 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in tributaries to the Red River downstream of Norwood Creek is typically greater than 2,000 AF/month throughout the year and greater than about 30,000 AF/month in the winter and spring. However, the tributaries can have periods of low flow in the summer, fall, and winter. The Red River is not currently used as a public water supply source in Basin 1 primarily due to water quality concerns. There are no major reservoirs in the 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 1 is considered good relative to other basins in the state.

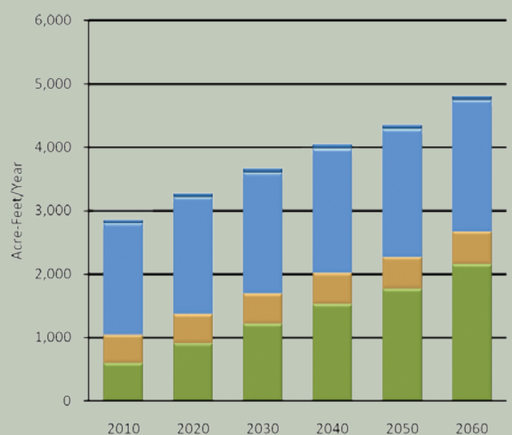
There are currently less than 350 AFY of groundwater rights in Basin 1. There are 100 AFY of groundwater rights in the Antlers major bedrock aquifer, 200 AFY in the Red River major alluvial aquifer, and less than 50 AFY of water rights in the Woodbine minor bedrock aquifer. The Antlers aquifer has over 8 million AF of storage in the basin and receives about 15,000 AFY of recharge from Basin 1. Residential (domestic) use does not require a permit and is assumed to be supplied by groundwater sources. Site-specific information on the suitability of 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 basin-wide groundwater quality issues.

Water Resources
Southeast Region, Basin 1

Median Historical Streamflow at the Basin Outlet
Southeast Region, Basin 1



Projected Water Demand
Southeast Region, Basin 1



The projected 2060 water demand of 4,810 AFY in Basin 1 reflects a 1,950 AFY increase (68%) over the 2010 demand. The majority of demand from 2010 to 2050 will be in the Municipal and Industrial demand sector. The largest growth in demand will be in the Crop Irrigation demand sector. In 2060, Crop Irrigation will become the largest demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2020 and alluvial groundwater depletions may occur by 2030. Bedrock groundwater storage depletions are not expected to occur in the Antlers aquifer. Surface water gaps will be up to 780 AFY in 2060 and have a 16% probability of occurring in at least one month of the year. Surface water gaps in Basin 1 may occur during the summer and fall, but are most likely to occur during summer months. Alluvial groundwater depletions will have a 5% probability of occurring in at least one month of the year and will be up to 40 AFY in 2060. Alluvial groundwater storage depletions in Basin 1 may occur during the summer and fall. Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the aquifer. 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, gaps and storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could reduce surface water gaps. Additional conservation activities are not expected to significantly reduce alluvial groundwater storage depletions. Temporary drought management activities could reduce demand, largely from irrigation, and may reduce gaps. Temporary drought management activities may not be needed for the alluvial groundwater users, since aquifer storage could continue to provide supplies during droughts.

Existing or new out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. In addition, the Southeast Region has multiple large lakes (e.g., Broken Bow, Pine Creek, and Hugo) with unpermitted yield that could be used to meet future demands. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified five potential out-of-basin sites in the Southeast Region. However, due to the very low probability of gaps and distance to these supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Water Supply Limitations
Southeast Region, Basin 1

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal   Potential   Significant

Water Supply Option Effectiveness
Southeast Region, Basin 1

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 in-basin reservoir storage can increase the dependability of available surface water supplies and mitigate gaps and adverse effects of localized storage depletions in the basin. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,000 AF of reservoir 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.

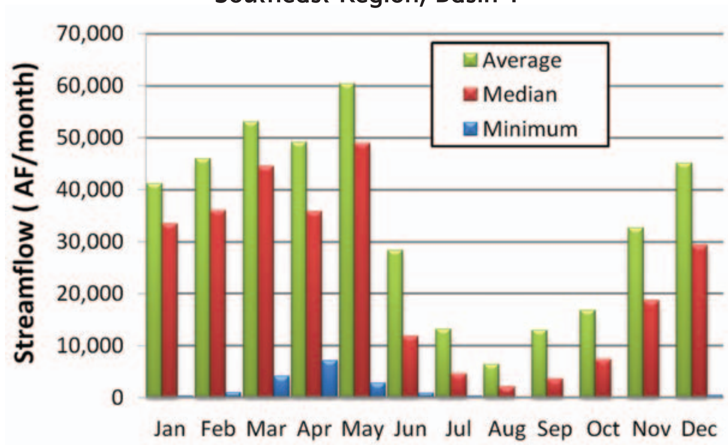
Increased reliance on bedrock or alluvial groundwater could mitigate surface water gaps, but may increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 1's portion of the Antlers or Red River aquifers.

Basin 1 Data & Analysis

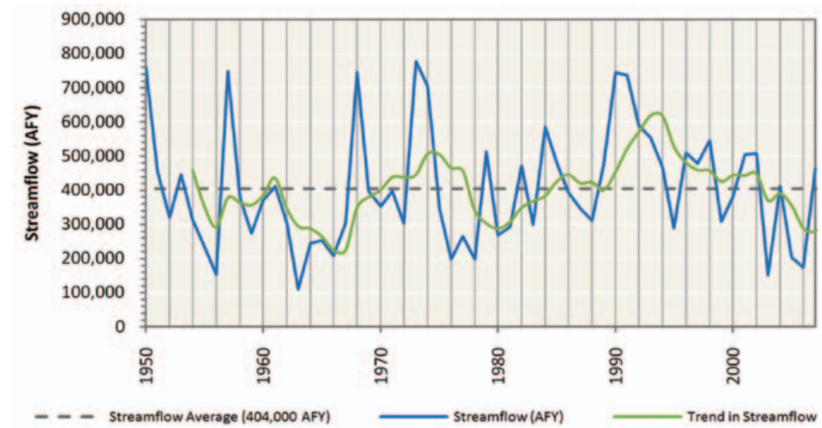
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The tributaries to the Red River downstream of Norwood Creek had a period of below-average streamflow in the 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 median flow in tributaries to the Red River downstream of Norwood Creek is greater than 2,000 AF/month throughout the year and greater than about 30,000 AF/month in the winter and spring. However, the tributaries can have periods of low flow in the summer, fall, and winter.
- Relative to other basins in the state, the surface water quality in Basin 1, with the exception of the Red River, is considered good.
- There are no major reservoirs in the basin.

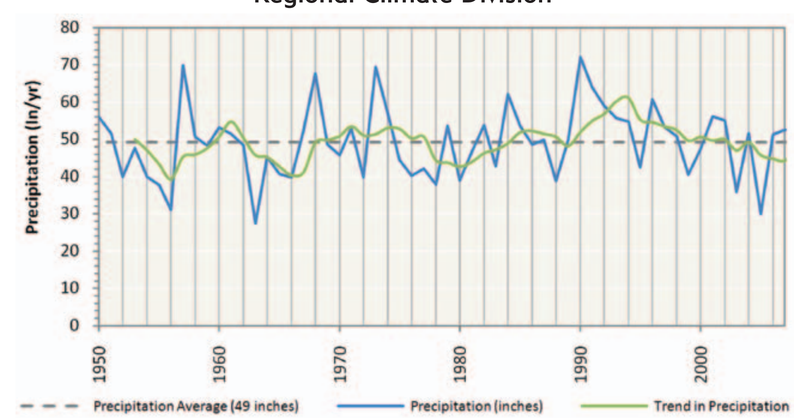
Monthly Historical Streamflow at the Basin Outlet
Southeast Region, Basin 1



Historical Streamflow at the Basin Outlet
Southeast Region, Basin 1



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

Southeast Region, Basin 1

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%	100	8,213,000	2.1	547,500
Red River	Alluvial	Major	70%	200	196,000	temporary 2.0	371,000
Haworth Isolated Terrace	Alluvial	Minor	5%	0	15,000	1.0	12,800
Woodbine	Bedrock	Minor	93%	<50	3,878,000	temporary 2.0	499,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	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 current groundwater rights in the basin are from the Antlers and Red River aquifers. The Antlers aquifer has more than 8.2 million AF of storage in the basin and receives about 15,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

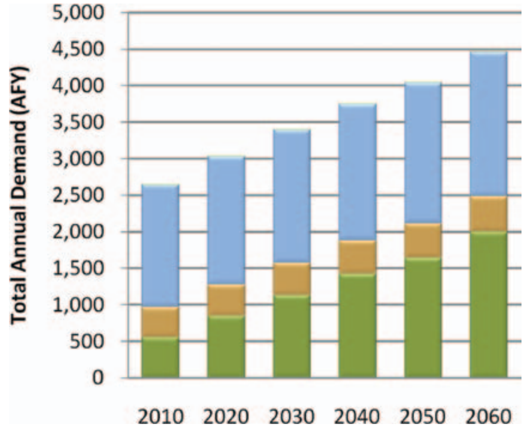
Notes & Assumptions

- 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.

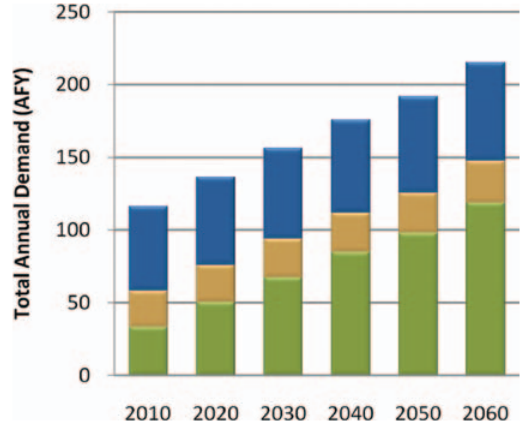
Water Demand

- Basin 1's water needs account for about 5% of the demand in the Southeast Watershed Planning Region and will increase by 68% (1,950 AFY) from 2010 to 2060. The largest demand over this period will be in the Municipal and Industrial demand sector until 2060, when Crop Irrigation will become the largest demand sector. The majority of growth in demand will be from the Crop Irrigation demand sector.
- Surface water is used to meet 93% of total demands in the basin and its use will increase by 68% (1,810 AFY) from 2010 to 2060. The majority of surface water use during this period will be from the Municipal and Industrial demand sector. However, the majority of the growth in surface water use from 2010 to 2060 will be in the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet 4% of total demands in the basin and its use will increase by 85% (100 AFY) from 2010 to 2060. Significant alluvial groundwater use and the majority of growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 3% of total demands in the basin and its use will increase by 39% (40 AFY) from 2010 to 2060. The majority of bedrock groundwater use is in the Municipal and Industrial demand sector. However, the majority of the growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

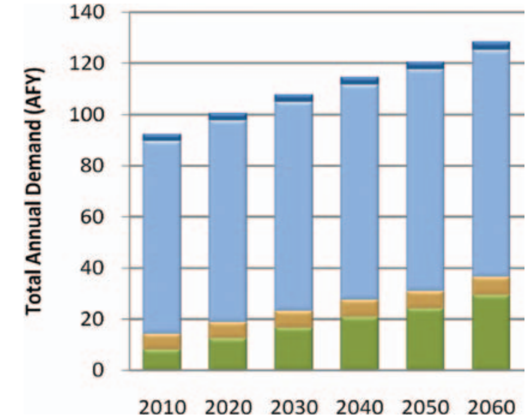
Surface Water Demand by Sector
Southeast Region, Basin 1



Alluvial Groundwater Demand by Sector
Southeast Region, Basin 1



Bedrock Groundwater Demand by Sector
Southeast Region, Basin 1



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

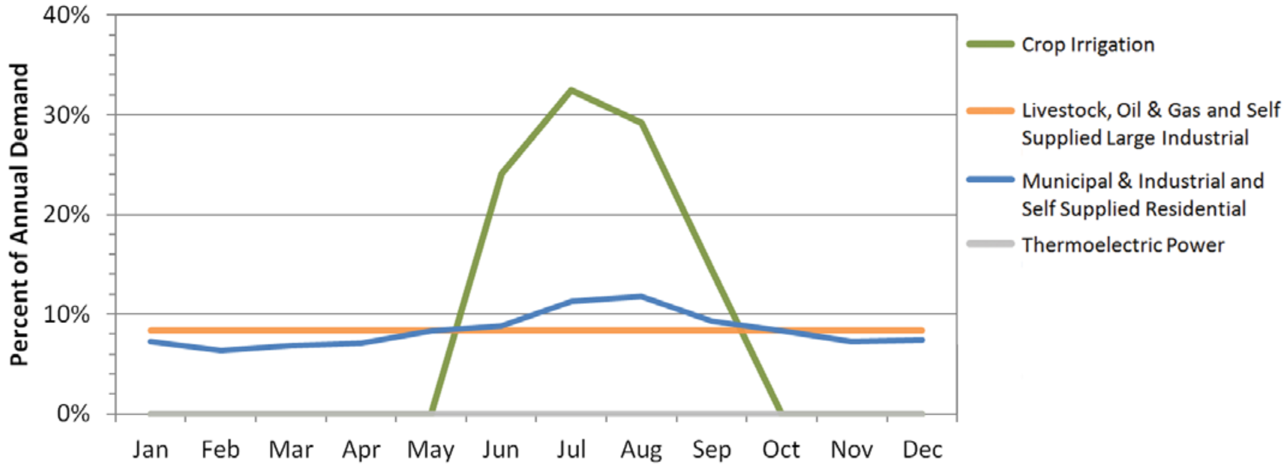
Total Demand by Sector
Southeast Region, Basin 1

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	600	450	1,750	0	0	60	0	2,860
2020	910	460	1,840	0	0	60	0	3,270
2030	1,220	480	1,900	0	0	70	0	3,670
2040	1,530	490	1,960	0	0	70	0	4,050
2050	1,770	500	2,020	0	0	70	0	4,360
2060	2,150	520	2,070	0	0	70	0	4,810

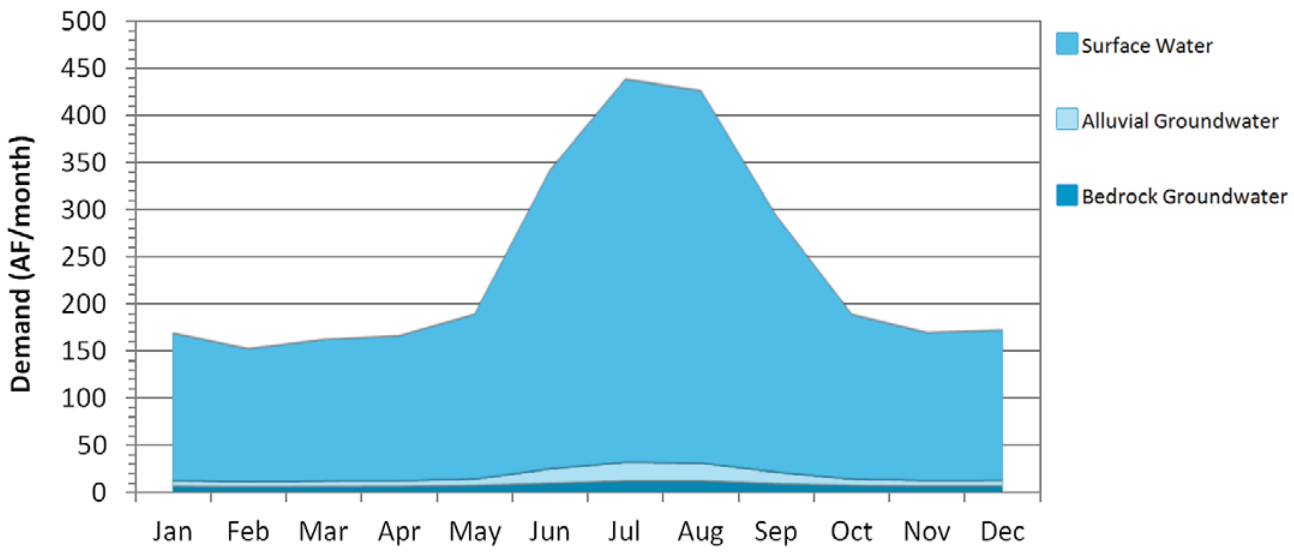
Notes & Assumptions

- 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)
Southeast Region, Basin 1



Monthly Demand Distribution by Source (2010)
Southeast Region, Basin 1



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 1 is 2.5 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 2.6 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at 3 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 1.9 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2020, while alluvial groundwater storage depletions may occur by 2030. Bedrock groundwater storage depletions are not expected to occur from the Antlers aquifer.
- Surface water gaps in Basin 1 may occur during the summer and fall. Surface water gaps in 2060 will be up to 45% (390 AF/month) of the peak summer month surface water demand and will be up to 41% (210 AF/month) of the peak fall month demand.
- There will be a 16% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during summer months.
- Alluvial groundwater storage depletions in Basin 1 may occur during the 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 33% (10 AF/month) of the largest fall month's alluvial groundwater demand.
- There will be a 5% probability of alluvial 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.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the aquifer. However, localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Southeast Region, Basin 1

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)	390	110	14%
Sep-Nov (Fall)	210	90	3%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 1

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	10	5%
Sep-Nov (Fall)	10	10	2%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Southeast Region, Basin 1

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	80	0	0	2%	0%
2030	210	10	0	3%	2%
2040	340	20	0	3%	3%
2050	500	20	0	7%	3%
2060	780	40	0	16%	5%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 1

Months (Season)	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 largest amount for any one month in 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

Southeast Region, Basin 1

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	780	40	0	16%	5%
Moderately Expanded Conservation in Crop Irrigation Water Use	780	40	0	16%	5%
Moderately Expanded Conservation in M&I Water Use	590	40	0	9%	5%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	590	40	0	9%	5%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	420	30	0	7%	5%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southeast Region, Basin 1

Reservoir Storage	Diversion
AF	AFY
100	400
500	1,300
1,000	2,000
2,500	4,100
5,000	7,600
Required Storage to Meet Growth in Demand (AF)	1,000
Required Storage to Meet Growth in Surface Water Demand (AF)	900

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 demand sector could reduce surface water gaps by 24%. Additional conservation activities are not expected to significantly reduce alluvial groundwater storage depletions. Temporary drought management activities could reduce demand, largely from outdoor water use and irrigation, and may reduce gaps. Temporary drought management activities may not be needed for the alluvial groundwater users, since aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Existing and new out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The Southeast Region has multiple large lakes (e.g., Broken Bow, Pine Creek and Hugo) with unpermitted yield that could be used to meet future demands. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified five potentially viable out-of-basin sites in the region: Caney Mountain in Basin 3 and Buck Creek, Finley, Kellond and Tuskahoma in Basin 6. However, due to the very low probability of gaps and distance to these supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and adverse effects of localized storage depletions in the basin. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,000 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 size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on bedrock or alluvial groundwater could mitigate surface water gaps, but may increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 1's portion of the Antlers or Red River aquifers. However, an increase in localized storage depletions may cause increased adverse impacts to some users.

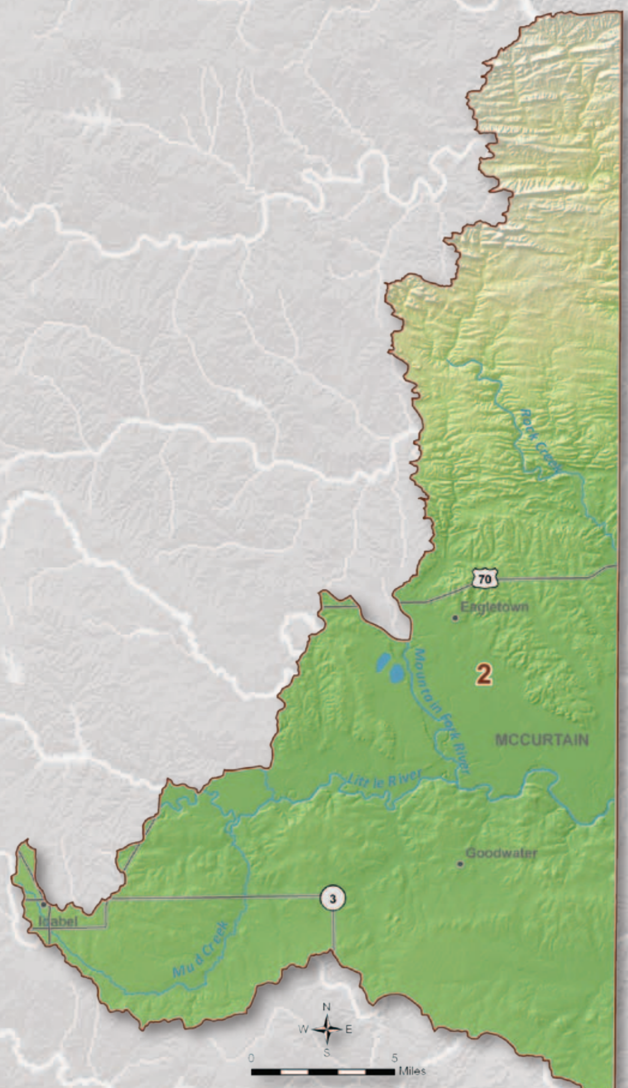
Notes & Assumptions

- 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

Southeast Watershed Planning Region

Basin 2



Basin 2 Summary

Synopsis

- Water users are expected to continue to rely on surface water and to a lesser extent groundwater supplies.
- 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 and groundwater storage depletions are not expected through 2060; therefore, no supply options were evaluated.

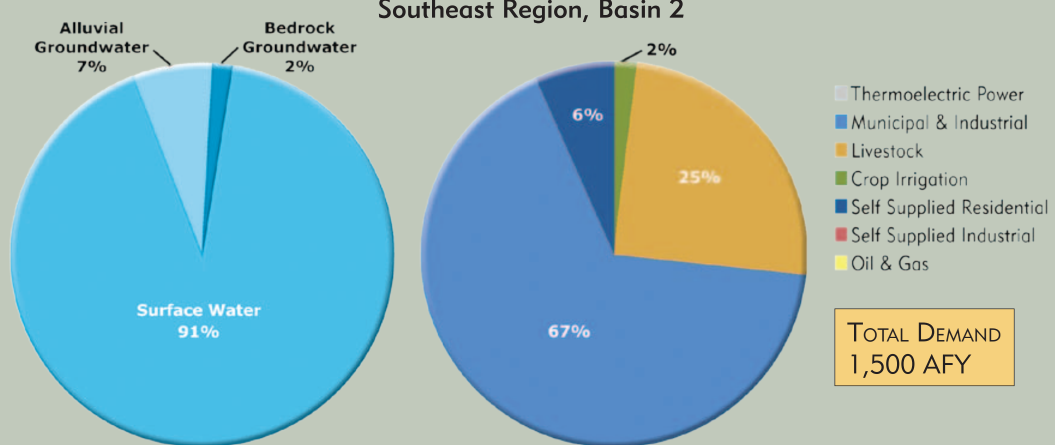
Basin 2 accounts for about 3% of the current water demand in the Southeast Watershed Planning Region. About 67% of the basin's 2010 demand is in the Municipal and Industrial sector. Livestock is the second largest water use sector at 25%. Surface water satisfies about 91% of the current demand in the basin. Groundwater satisfies about 9% of the demand (7% alluvial and 2% bedrock). The peak summer month total water demand in Basin 2 is 1.5 times the winter monthly demand, which is less pronounced than the overall statewide pattern.

The flow in the Little River downstream of Crooked Creek is typically greater than 50,000 AF/month throughout the year and greater than about 200,000 AF/month in the winter and spring. However, the river can experience periods of low flow in the summer and fall. There are no major reservoirs in the 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 2 is considered good.

There are 100 AFY of groundwater rights in the Antlers major bedrock aquifer in Basin 2. This aquifer underlies about 60% of the basin and has over 4.5 million AF of water in storage. Domestic users do not require a permit and may be using major and minor 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

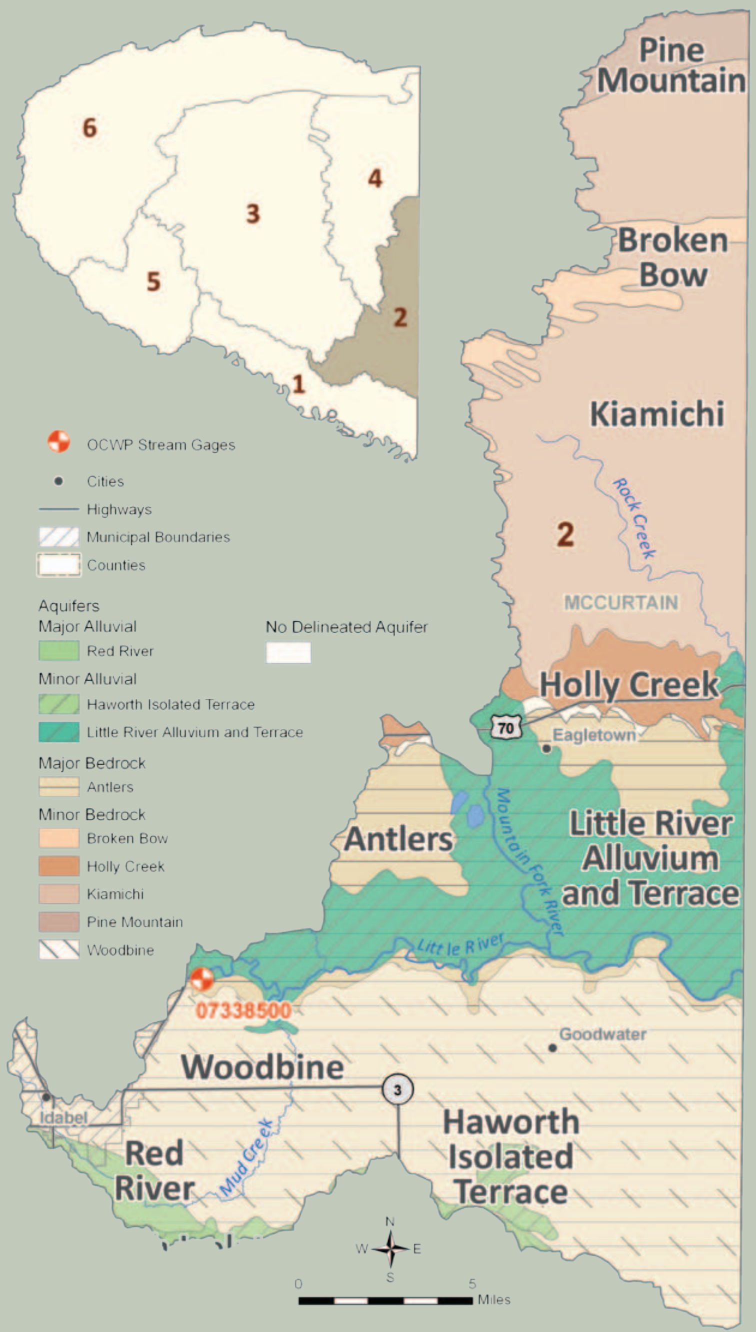
Current Demand by Source and Sector

Southeast Region, Basin 2

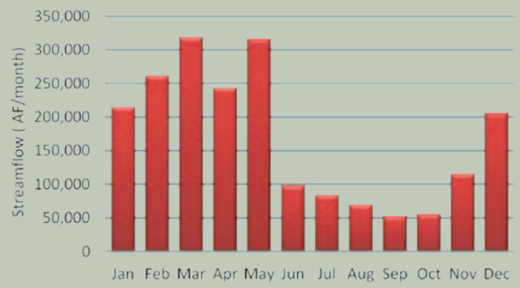


Water Resources

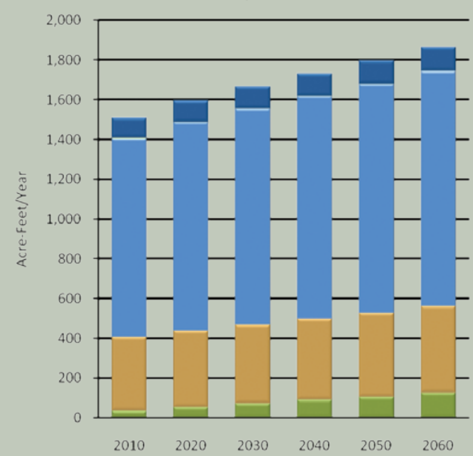
Southeast Region, Basin 2



Median Historical Streamflow at the Basin Outlet
Southeast Region, Basin 2



Projected Water Demand
Southeast Region, Basin 2



are no significant basin-wide groundwater quality issues.

The projected 2060 water demand of 1,860 AFY in Basin 2 reflects a 360 AFY increase (24%) over the 2010 demand. The majority of the demand and 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 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.

Water Supply Limitations
Southeast Region, Basin 2

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Southeast Region, Basin 2

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

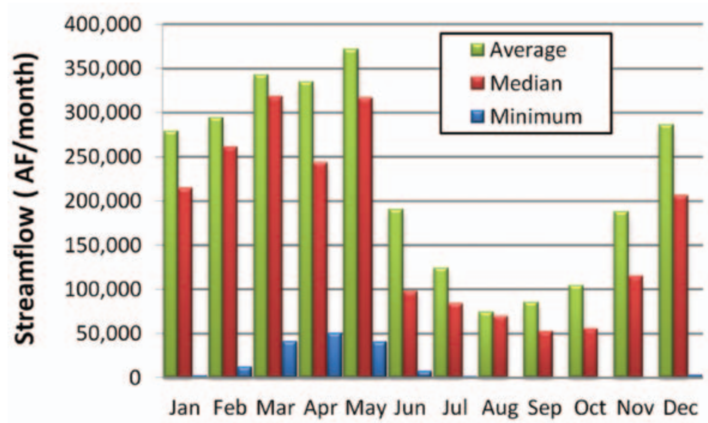
Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Basin 2 Data & Analysis

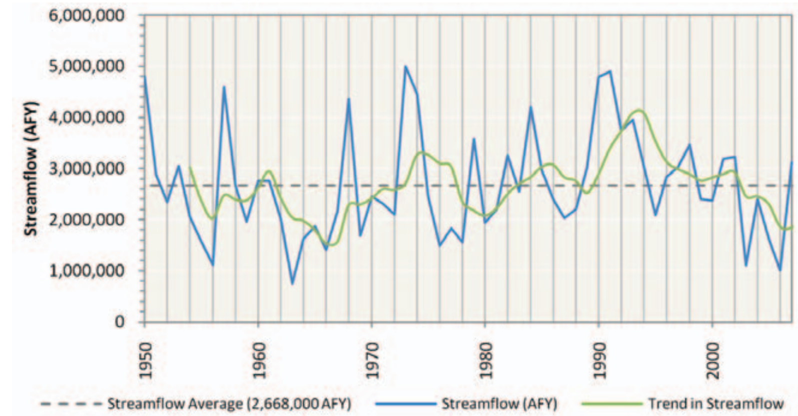
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Little River downstream of Crooked Creek had a period of below-average streamflow in the 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 median flow in the Little River downstream of Crooked Creek is greater than 50,000 AF/month throughout the year and greater than 200,000 AF/month in the winter and spring. However, the river can have periods of low flow in the summer and fall.
- Relative to other basins in the state, the surface water quality in Basin 2 is considered good.
- There are no major reservoirs in the basin.

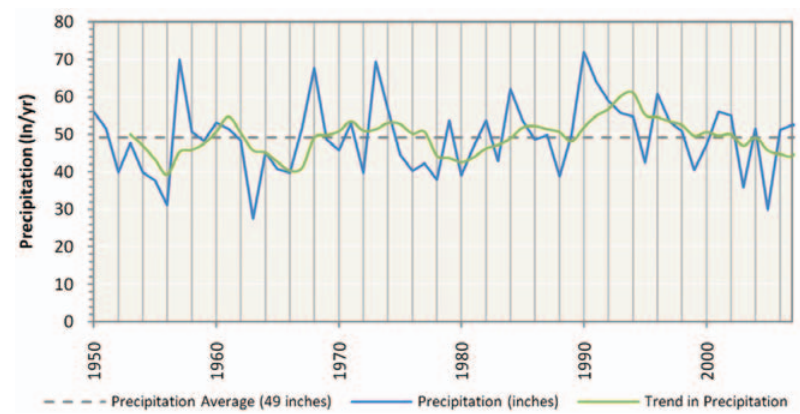
Monthly Historical Streamflow at the Basin Outlet
Southeast Region, Basin 2



Historical Streamflow at the Basin Outlet
Southeast Region, Basin 2



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)

Southeast Region, Basin 2

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	63%	100	4,561,000	2.1	295,600
Red River	Alluvial	Major	2%	0	4,000	temporary 2.0	12,800
Broken Bow	Bedrock	Minor	3%	0	11,000	temporary 2.0	12,800
Haworth Isolated Terrace	Alluvial	Minor	2%	0	7,000	1.0	6,400
Holly Creek	Bedrock	Minor	4%	0	35,000	temporary 2.0	12,800
Kiamichi	Bedrock	Minor	30%	0	86,000	temporary 2.0	128,000
Little River Alluvium and Terrace	Alluvial	Minor	17%	0	106,000	1.0	38,400
Pine Mountain	Bedrock	Minor	2%	0	11,000	temporary 2.0	12,800
Woodbine	Bedrock	Minor	38%	0	1,293,000	temporary 2.0	166,400
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

- All groundwater rights in the basin are from the Antlers aquifer. The Antlers aquifer underlies about 63% of the basin, has more than 4.5 million AF of water stored in the basin, and receives about 8,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

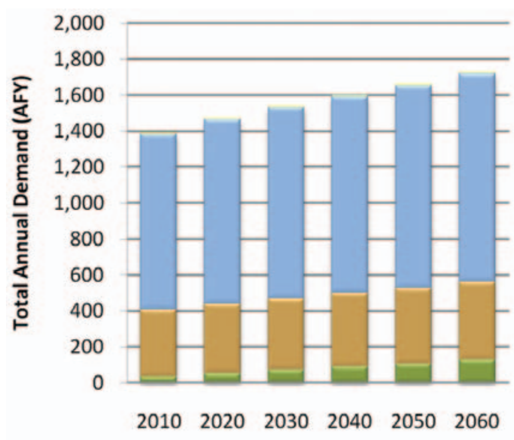
Notes & Assumptions

- 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.

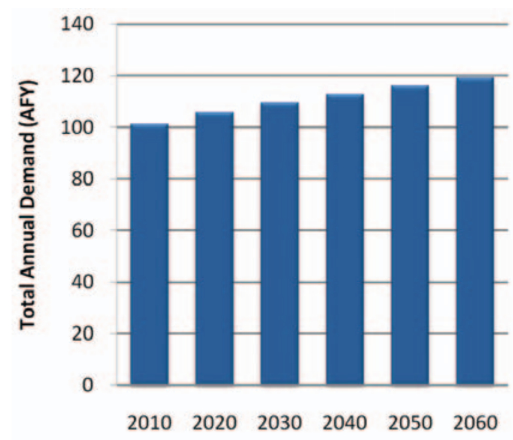
Water Demand

- Basin 2's water needs account for about 3% of the demand in the Southeast Watershed Planning Region and will increase by 24% (360 AFY) from 2010 to 2060. The majority of the demand and growth in demand during this period will be in the Municipal and Industrial demand sector.
- Surface water is used to meet 91% of total demands in the basin and its use will increase by 24% (330 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 demand sector.
- Alluvial groundwater is used to meet 7% of total demands in the basin and represents demands from Self-Supplied Residential water use. Alluvial groundwater use will increase by 18% (20 AFY) from 2010 to 2060.
- Bedrock groundwater is used to meet 2% of total demands in the basin and its use will increase by 10 AFY from 2010 to 2060. This increase in demand is minimal on a basin-scale.

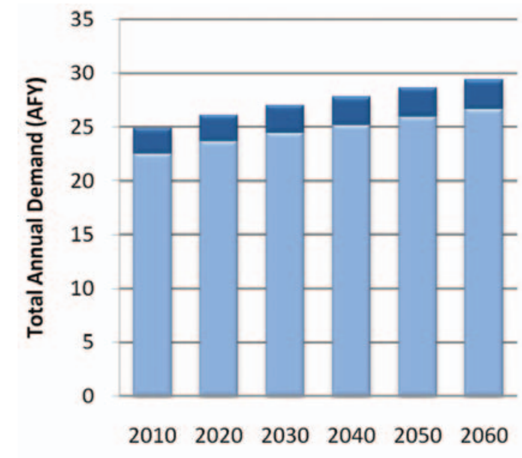
Surface Water Demand by Sector
Southeast Region, Basin 2



Alluvial Groundwater Demand by Sector
Southeast Region, Basin 2



Bedrock Groundwater Demand by Sector
Southeast Region, Basin 2



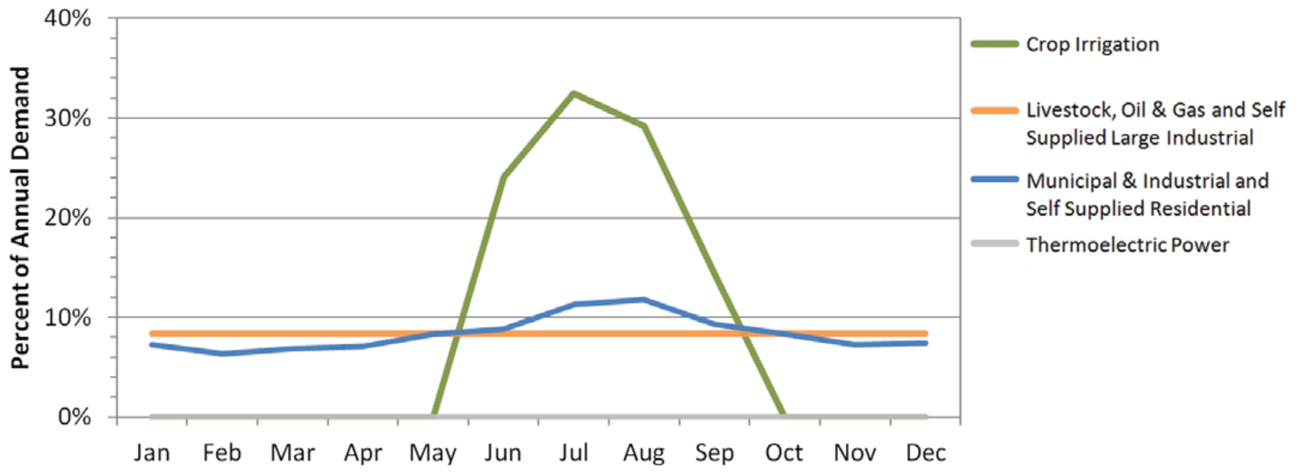
Total Demand by Sector
Southeast Region, Basin 2

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	30	370	1,000	0	0	100	0	1,500
2020	50	380	1,050	0	0	110	0	1,590
2030	70	400	1,090	0	0	110	0	1,670
2040	90	410	1,120	0	0	120	0	1,740
2050	100	420	1,150	0	0	120	0	1,790
2060	130	430	1,180	0	0	120	0	1,860

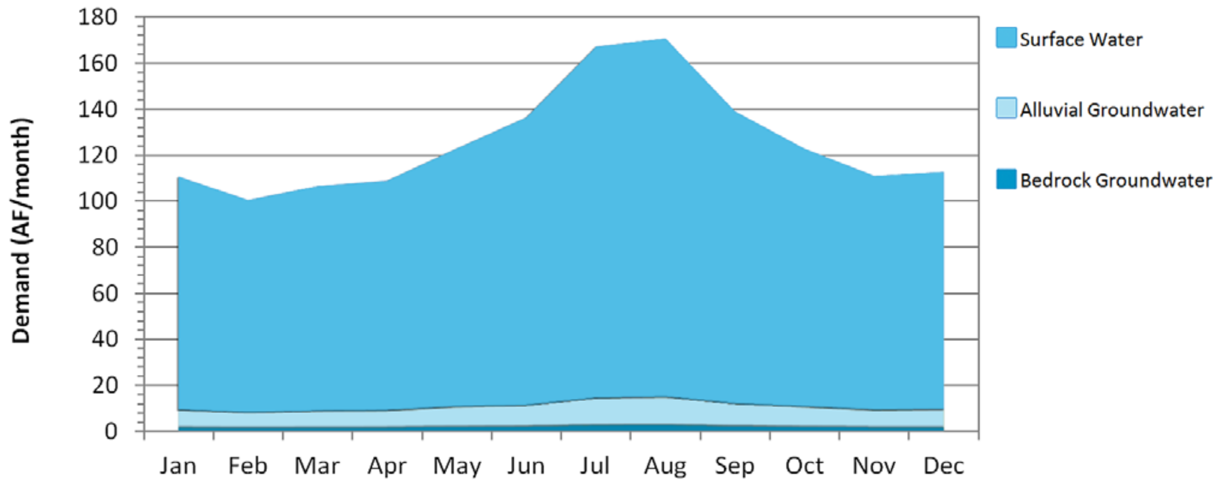
Notes & Assumptions

- 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)
Southeast Region, Basin 2



Monthly Demand Distribution by Source (2010)
Southeast Region, Basin 2



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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 2 is 1.5 times the monthly winter demand, which is less pronounced than the overall statewide pattern. Water use from all sources in the peak summer month is between 1.5 and 1.6 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 are expected to occur in this basin through 2060.

Surface Water Gaps by Season (2060 Demand)
Southeast Region, Basin 2

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 largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 2

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 largest amount for any one month in season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions
Southeast Region, Basin 2

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)
Southeast Region, Basin 2

Months (Season)	Average 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 largest amount for any one month in 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

Southeast Region, Basin 2

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	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 in Basin 2 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

Southeast Region, Basin 2

Reservoir Storage	Diversion
AF	AFY
100	1,000
500	3,300
1,000	4,800
2,500	8,400
5,000	13,300
Required Storage to Meet Growth in Demand (AF)	0
Required Storage to Meet Growth in Surface Water Demand (AF)	0

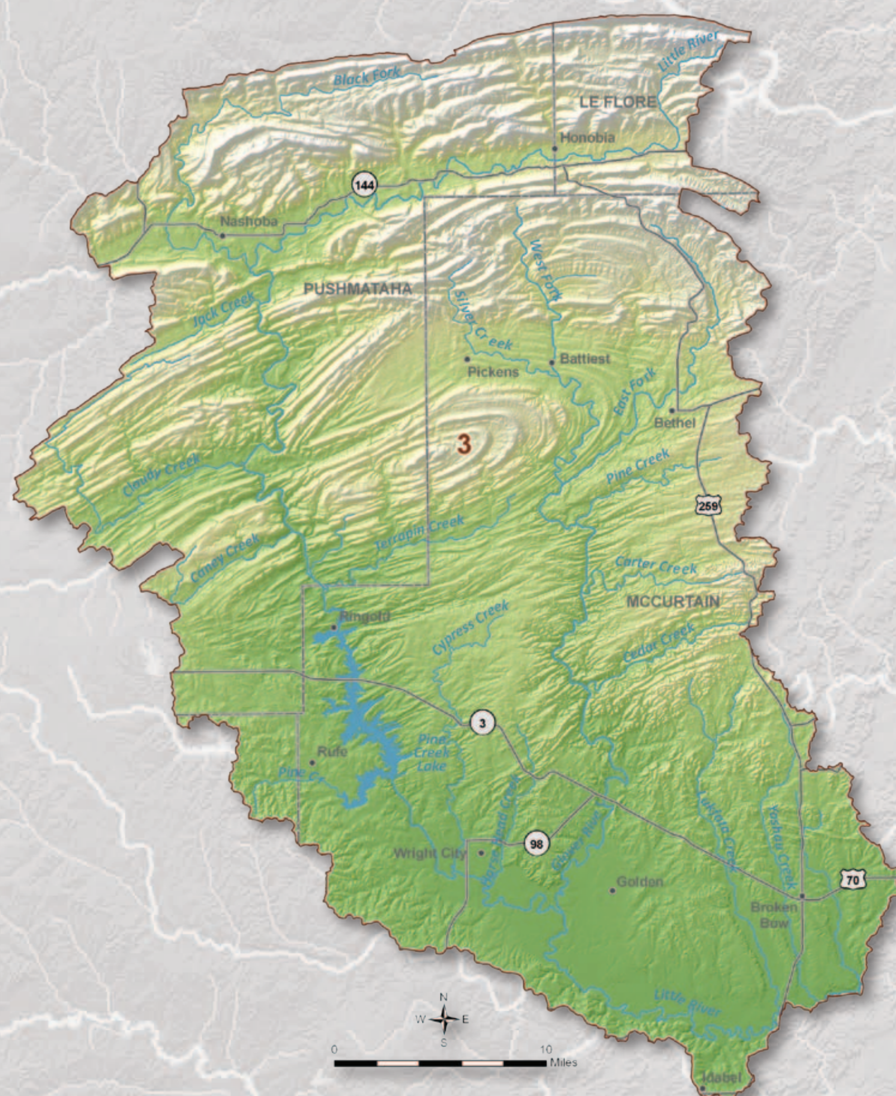
Notes & Assumptions

- 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.

Oklahoma Comprehensive Water Plan

Data & Analysis
Southeast Watershed Planning Region

Basin 3



Basin 3 Summary

Synopsis

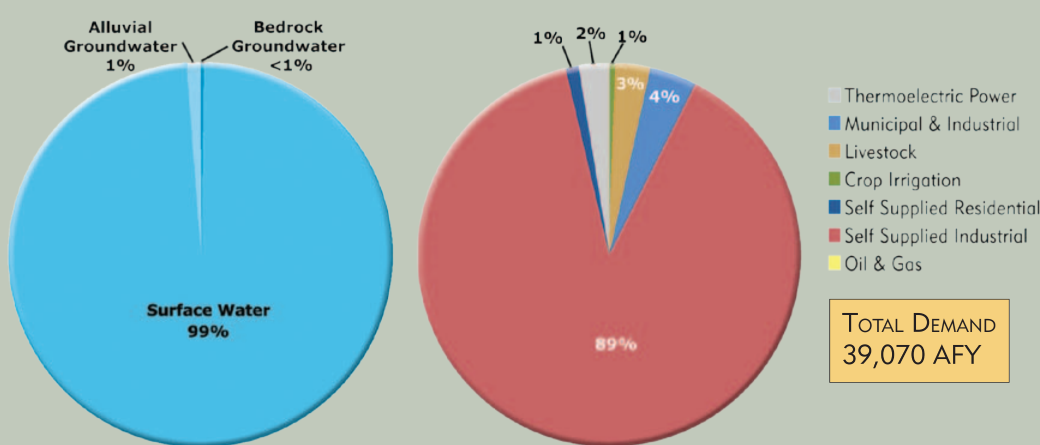
- Water users are expected to continue to rely mainly on Pine Creek Lake and surface water.
- Alluvial groundwater storage depletions may occur by 2060, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- Pine Creek Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 3's future demand.
- 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 groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing new small reservoirs could mitigate alluvial groundwater storage depletions without having major impacts to groundwater storage.

Basin 3 accounts for about 67% of the current water demand in the Southeast Watershed Planning Region. About 89% of the 2010 demand is from the Self-Supplied Industrial sector. Surface water is used to meet almost 99% of the current demand in the basin. Groundwater satisfies about 1% of the demand. The peak summer month total water demand in Basin 3 is 1.1 times the winter monthly demand, which is much less pronounced than the overall statewide pattern.

The flow in the Little River downstream of the Glover River is typically greater than 6,000 AF/month throughout the year and greater than 90,000 AF/month in the winter and spring. However, the river can have periods of low flow in the summer and fall. Pine Creek Lake, the only major lake in the basin, was constructed on the Little River by the Corps of Engineers in 1969 for the purposes of flood control, water supply, water quality,

Current Demand by Source and Sector

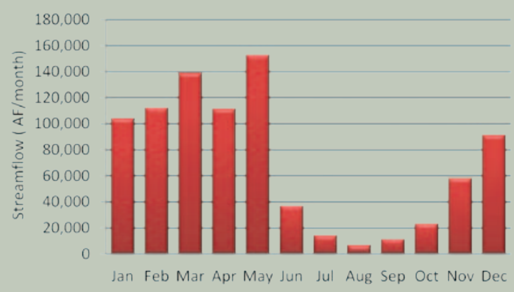
Southeast Region, Basin 3



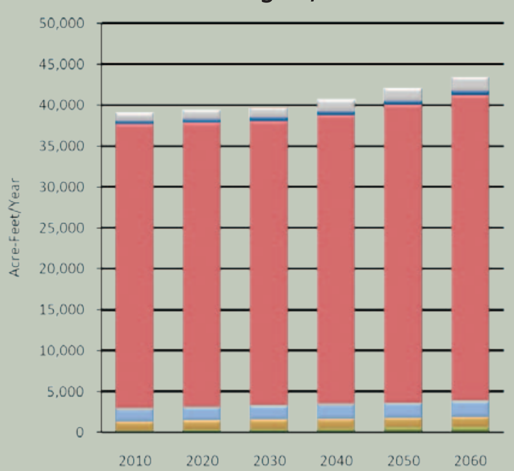
Water Resources

Southeast Region, Basin 3

Median Historical Streamflow at the Basin Outlet
Southeast Region, Basin 3



Projected Water Demand
Southeast Region, Basin 3



recreation, and fish and wildlife. The reservoir includes 49,400 AF of water supply storage and 21,100 acre-feet of water quality storage for dependable yields of 94,080 AFY and 40,330 AFY, respectively. The International Paper Company is currently the only water rights holder. The lake has substantial unpermitted yield that could be used to meet future demand. 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 3 is considered good.

There are 400 AFY of groundwater rights in Basin 3, including 300 AFY of groundwater rights in the Antlers major bedrock aquifer and 100 AFY in non-delineated minor alluvial aquifers. The Antlers aquifer has over 4.7 million AF of storage in the basin and receives about 9,000 AFY of recharge from Basin 3. 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. 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 basin-wide groundwater quality issues.

The projected 2060 water demand of 43,430 AFY in Basin 3 reflects a 4,360 AFY increase (11%) over the 2010 demand. The majority of the demand and growth in demand from 2010 to 2060 will be in the Self-Supplied Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2060. Bedrock groundwater storage depletions were not evaluated in detail due to the minimal increase in demand from 2010 to 2060. Pine Creek Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 3's future water demand. Alluvial groundwater depletions have a very low probability (2%) of occurring in the summer and will be minimal (10 AFY) on a basin-scale. Future alluvial groundwater withdrawals are expected to occur from minor aquifers; therefore, 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. To reduce the risk of adverse impacts to the basin's water users, storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and

Water Supply Limitations
Southeast Region, Basin 3

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal Potential Significant

Water Supply Option Effectiveness
Southeast Region, Basin 3

Demand Management	Typically Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Typically Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Typically Effective

Typically Effective Potentially Effective Likely Ineffective No Option Necessary

Self-Supplied Residential demand sectors could mitigate alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potentially viable out-of-basin sites in the region. However, in light of the minimal size and very low probability of groundwater storage depletions, as well as the substantial amount of unpermitted yield in Pine Creek Lake, out-of-basin supplies may not be cost-effective.

Pine Creek Lake or new in-basin reservoir storage could be used to meet all of the basin's future demand. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,100 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified one potentially viable site in Basin 3.

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

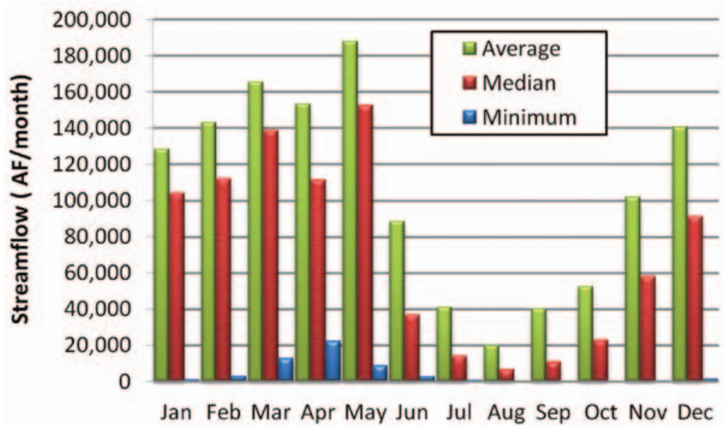
Increased reliance on the Antlers aquifer could mitigate alluvial groundwater storage depletions or localized surface water gaps from users without access to Pine Creek Lake; however, the aquifer only underlies about a quarter of the basin. Increased reliance on minor bedrock aquifers to meet future Self-Supplied Residential (domestic) demand may also mitigate alluvial groundwater depletions. However, site specific information on the suitability of minor aquifers for supply should be considered before large-scale use.

Basin 3 Data & Analysis

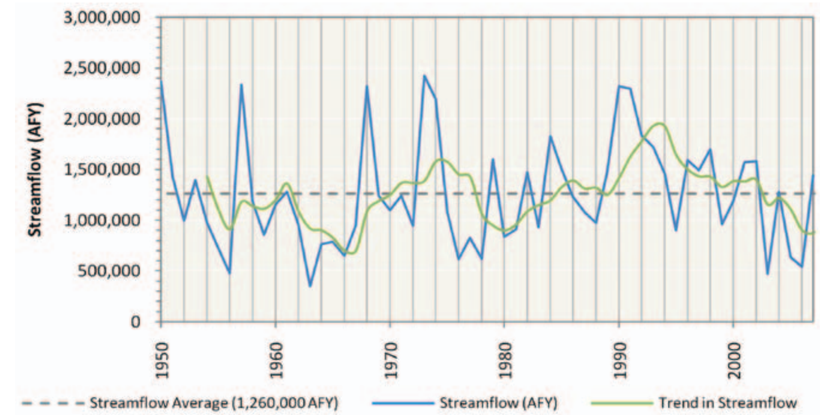
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Little River downstream of the Glover River had a period of below-average streamflow in the 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 median flow in Little River downstream of Glover River is greater than 6,000 AF/month throughout the year and greater than 90,000 AF/month in the winter and spring. However, the river can have periods of low flow in the summer and fall.
- Relative to other basins in the state, the surface water quality in Basin 3 is considered good.
- Pine Creek Lake was constructed by the U.S. Army Corps of Engineers and provides 94,080 AFY of dependable water supply yield. The lake has substantial unpermitted yield that could be used to meet future demand.

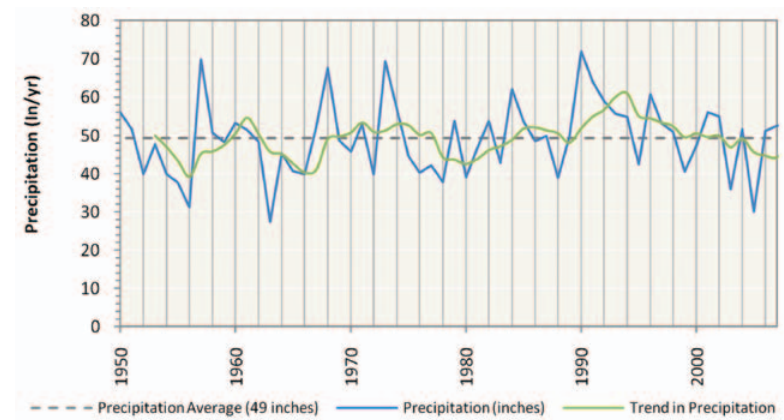
Monthly Historical Streamflow at the Basin Outlet
Southeast Region, Basin 3



Historical Streamflow at the Basin Outlet
Southeast Region, Basin 3



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)

Southeast Region, Basin 3

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	19%	300	4,753,000	2.1	320,700
Broken Bow	Bedrock	Minor	10%	0	135,000	temporary 2.0	153,600
Holly Creek	Bedrock	Minor	1%	0	35,000	temporary 2.0	12,800
Kiamichi	Bedrock	Minor	71%	0	790,000	temporary 2.0	1,177,400
Little River Alluvium and Terrace	Alluvial	Minor	6%	0	141,000	1.0	51,200
Woodbine	Bedrock	Minor	1%	0	199,000	temporary 2.0	25,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	100	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 the basin are from the Antlers aquifer. The Antlers aquifer has more than 4.7 million AF of storage in the basin and receives about 9,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

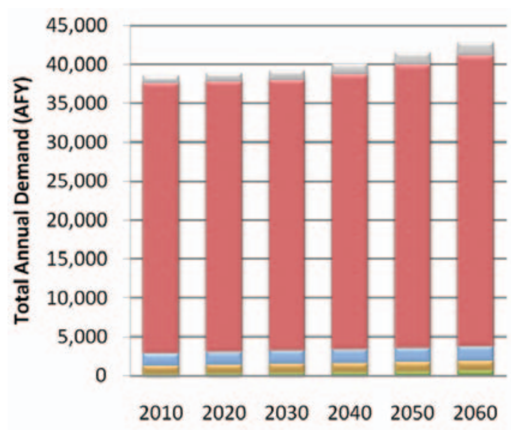
Notes & Assumptions

- 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.

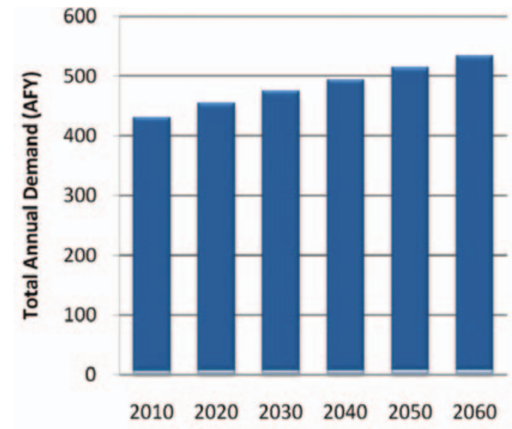
Water Demand

- Basin 3's water needs account for about 67% of the demand in the Southeast Watershed Planning Region and will increase by 11% (4,360 AFY) from 2010 to 2060. The majority of demand and growth in demand during the period will be from the Self-Supplied Industrial demand sector.
- Surface water is used to meet about 99% of total demand in the basin and its use will increase by 11% (4,250 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Self-Supplied Industrial demand sector.
- Alluvial groundwater is used to meet 1% of total demands in the basin and represents almost entirely the demands from Self-Supplied Residential water use. Alluvial groundwater use will increase by 24% (100 AFY) from 2010 to 2060.
- Bedrock groundwater is used to meet less than 1% of total demands in the basin and its use will increase by 10 AFY from 2010 to 2060. This increase in demand is minimal on a basin-scale.

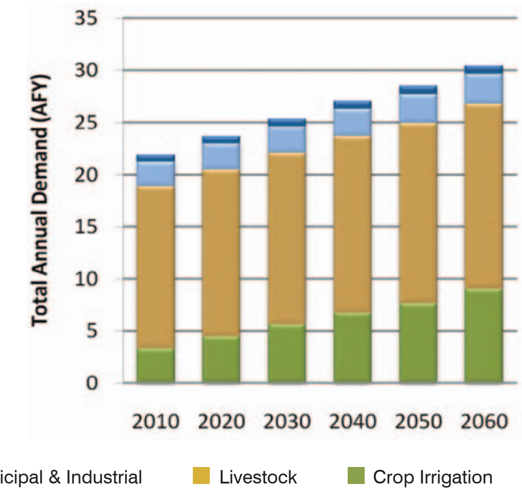
Surface Water Demand by Sector
Southeast Region, Basin 3



Alluvial Groundwater Demand by Sector
Southeast Region, Basin 3



Bedrock Groundwater Demand by Sector
Southeast Region, Basin 3



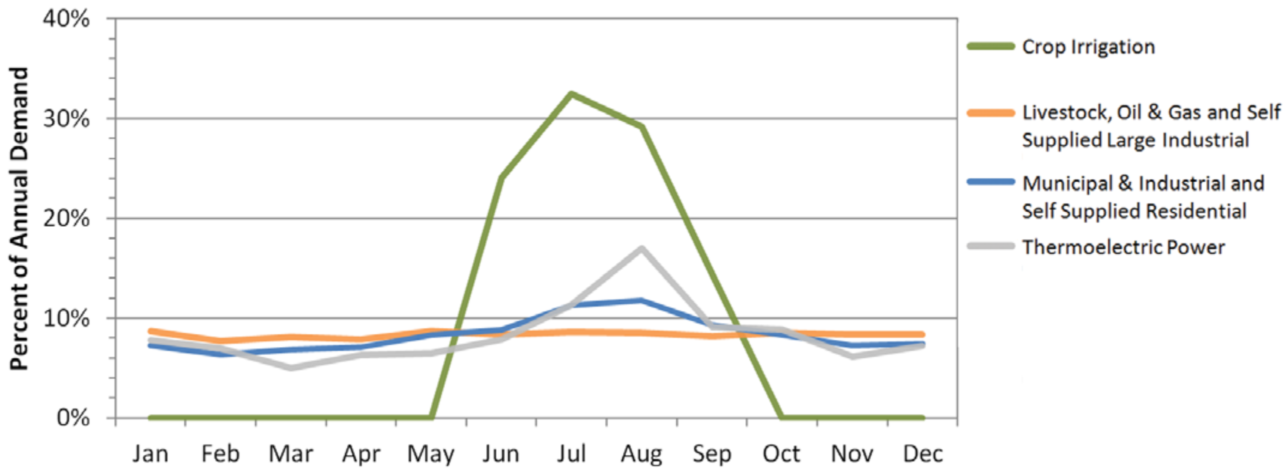
Total Demand by Sector
Southeast Region, Basin 3

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	240	1,110	1,560	0	34,740	430	990	39,070
2020	320	1,140	1,650	0	34,740	450	1,100	39,400
2030	400	1,170	1,710	0	34,740	470	1,230	39,720
2040	480	1,200	1,770	0	35,320	490	1,370	40,630
2050	550	1,230	1,840	0	36,390	510	1,530	42,050
2060	650	1,270	1,900	0	37,370	530	1,710	43,430

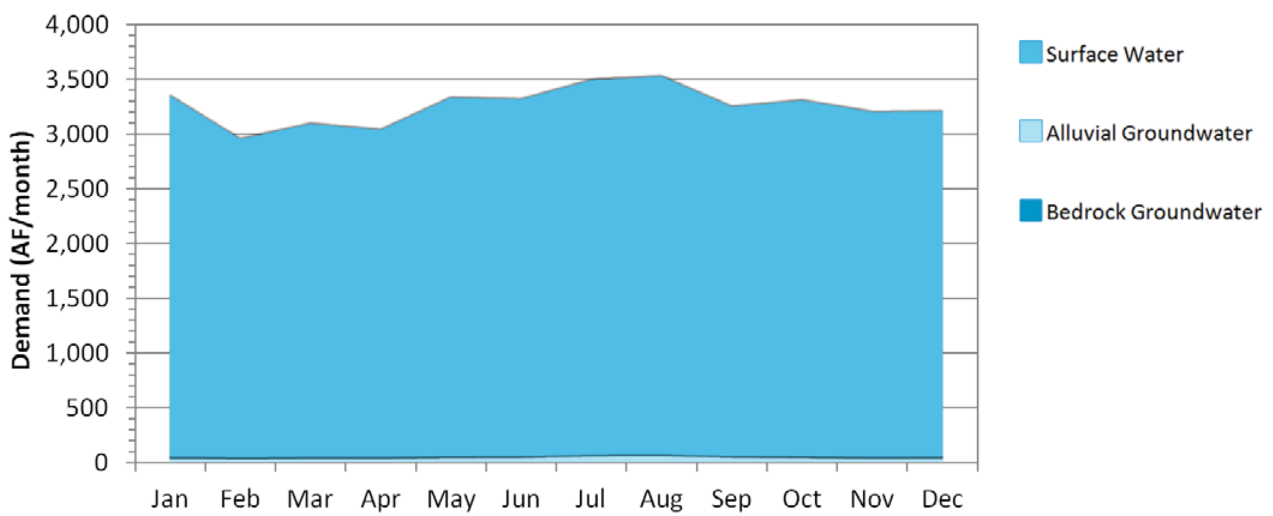
Notes & Assumptions

- 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)
Southeast Region, Basin 3



Monthly Demand Distribution by Source (2010)
Southeast Region, Basin 3



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. Thermoelectric Power peaks in summer and has the least demand in March and November. The Self-Supplied Industrial demand sector and 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 3 is about 1.1 times the monthly winter demand, which is less pronounced than the overall statewide pattern. Surface water use in the peak summer month is about the same as monthly winter 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 1.8 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, small alluvial groundwater storage depletions may occur by 2060. Surface water gaps are not expected. Bedrock groundwater storage depletions were not evaluated in detail due to the minimal increase in its use from 2010 to 2060.
- Alluvial groundwater storage depletions in Basin 3 have a very low probability (2%) of occurring in the summer and will be minimal (10 AFY) on a basin-scale. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the severity of the storage depletions could not be evaluated.
- Localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Southeast Region, Basin 3

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 largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 3

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)	10	10	2%
Sep-Nov (Fall)	0	0	0%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Southeast Region, Basin 3

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	10	0	0%	2%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 3

Months (Season)	Average 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 largest amount for any one month in 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

Southeast Region, Basin 3

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	0	10	0	0%	2%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	10	0	0%	2%
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.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southeast Region, Basin 3

Reservoir Storage	Diversion
AF	AFY
100	1,100
500	2,400
1,000	4,100
2,500	8,800
5,000	14,600
Required Storage to Meet Growth in Demand (AF)	1,100
Required Storage to Meet Growth in Surface Water Demand (AF)	1,100

Water Supply Options & Effectiveness

Typically Effective | Potentially Effective | Likely Ineffective | No Option Necessary

Demand Management

[Typically Effective] Moderately expanded permanent conservation activities in the Municipal and Industrial and Self-Supplied Residential demand sectors could mitigate alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

Out-of-Basin Supplies

[Potentially Effective] Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potentially viable out-of-basin sites in the region: Buck Creek, Finley, Kellond and Tuskahoma are in Basin 6. However, in light of the small size and very low probability of groundwater storage depletions, as well as the substantial amount of unpermitted yield in Pine Creek Lake, out-of-basin supplies may not be cost-effective.

Reservoir Use

[Typically Effective] Pine Creek Lake or new in-basin reservoir storage could be used to meet all of Basin 3's future demand. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,100 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 size of storage necessary to mitigate storage depletions. The OCWP *Reservoir Viability Study* also identified one potentially viable site in Basin 3 (Caney Mountain Reservoir).

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

[Typically Effective] Increased reliance on the Antlers aquifer could mitigate alluvial groundwater storage depletions or localized surface water gaps from users without access to Pine Creek Lake; however, the aquifer only underlies about a quarter of the basin. Increased reliance on minor bedrock aquifers to meet future Self Supplied Residential (domestic) demand may also mitigate alluvial groundwater depletions. However, site specific information on the suitability of minor aquifers for supply should be considered before 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
Southeast Watershed Planning Region

Basin 4

Basin 4 Summary

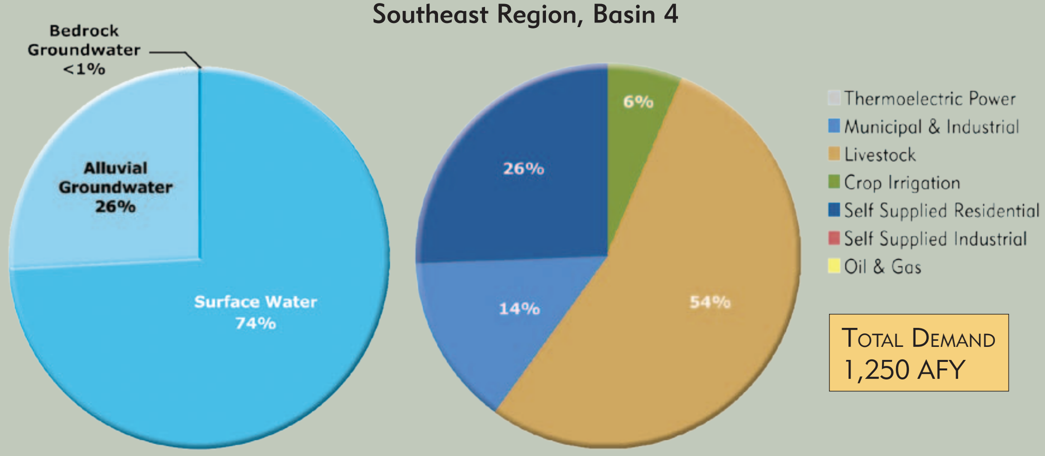
Synopsis

- Water users are expected to continue to rely mainly on Broken Bow Lake and surface water.
- Alluvial groundwater storage depletions may occur by 2030, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- Broken Bow Lake is capable of providing dependable water supplies to its existing users and with new infrastructure could be used to meet all of Basin 4's future demand. However, the majority of demand in the basin is from geographically dispersed demand sectors (Livestock and Crop Irrigation), which may not have access to Broken Bow Lake.
- 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 alluvial groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing new small reservoirs could mitigate alluvial groundwater depletions without having major impacts to groundwater storage. Site-specific information on the suitability of minor aquifers for supply should be considered before large-scale use.

Basin 4 accounts for about 2% of the current water demand in the Southeast Watershed Planning Region. About 54% of the basin's 2010 demand is from the Livestock demand sector. Self-Supplied Residential is the second largest demand sector at 26%. Surface water satisfies about 74% of the current demand in the basin. Groundwater satisfies about 26% of the demand. The peak summer month total water demand in Basin 4 is 1.5 times the winter monthly demand, which is less pronounced than the overall statewide pattern.

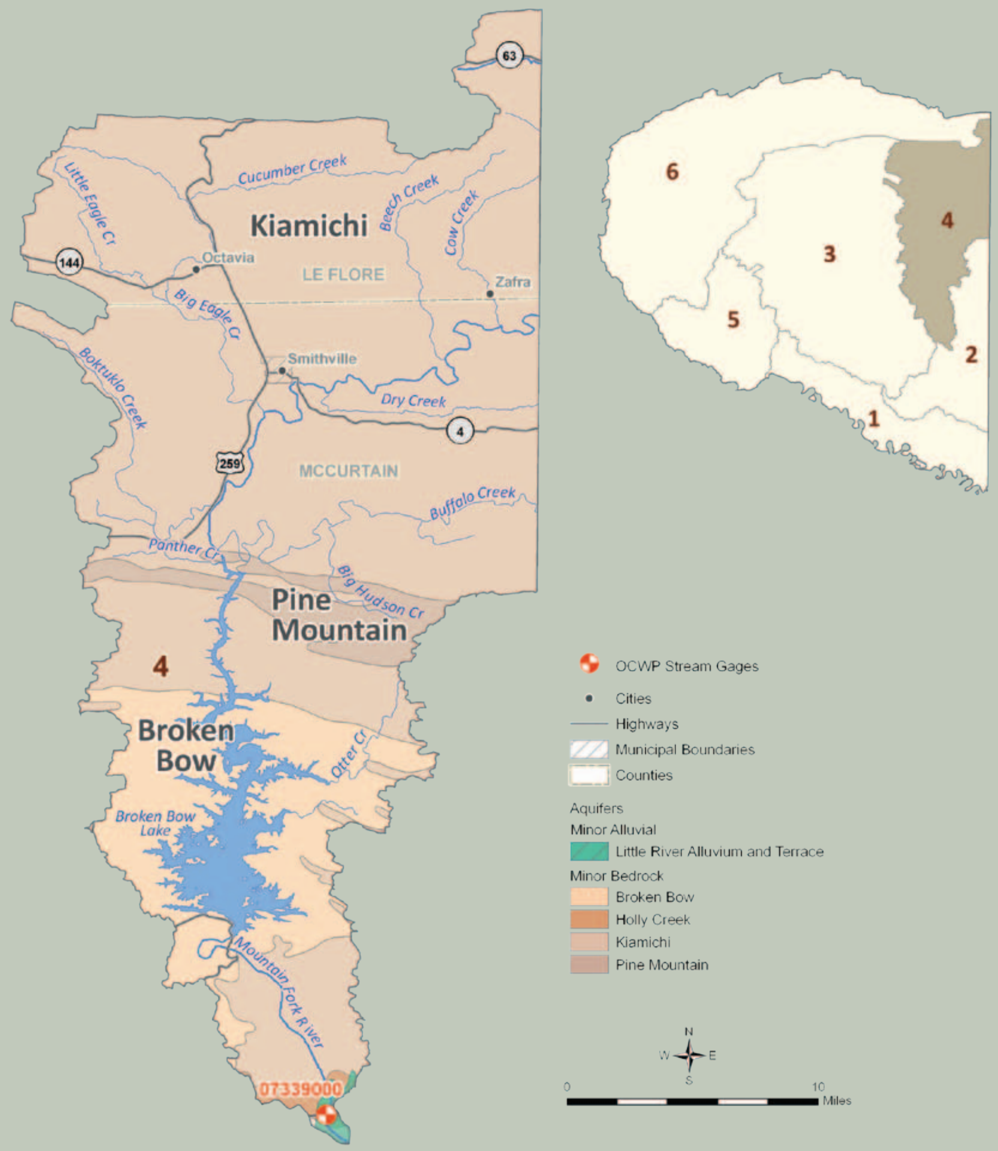
Current Demand by Source and Sector

Southeast Region, Basin 4

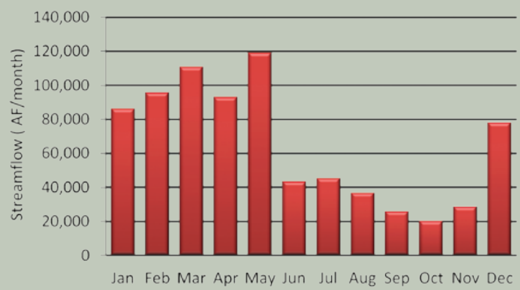


Water Resources

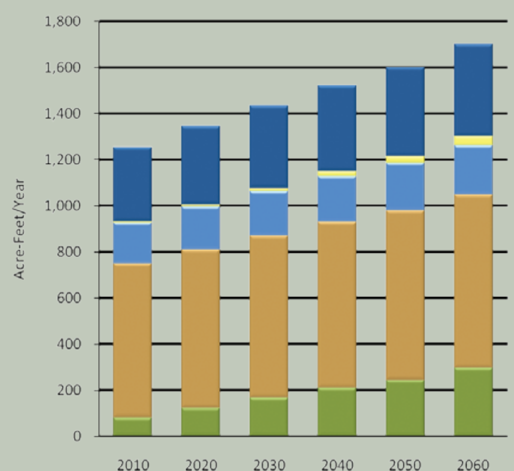
Southeast Region, Basin 4



Median Historical Streamflow at the Basin Outlet
Southeast Region, Basin 4



Projected Water Demand
Southeast Region, Basin 4



The flow in the Mountain Fork River below Buffalo Creek is typically greater than 20,000 AF/month throughout the year and greater than 78,000 AF/month in the winter and spring. However, the river can have periods of low to no flow in the summer, fall, and winter. Broken Bow Lake was constructed on the Mountain Fork River in 1970 by the Corps of Engineers for the purposes of water supply, flood control, recreation, hydropower, water quality, and fish and wildlife mitigation. The reservoir has 152,500 AF of water supply storage with a dependable yield of 196,000 AFY. The lake has substantial unpermitted yield that could be used to meet future demands. 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 4 is considered good.

There are less than 50 AFY of groundwater rights in Basin 4, which are in the Kiamichi minor bedrock aquifer. Domestic users do not require a permit and are assumed to be obtaining supplies from minor 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 basin-wide groundwater quality issues in the basin.

The projected 2060 water demand of 1,700 AFY in Basin 4 reflects a 450 AFY increase (36%) over the 2010 demand. The majority of the demand from 2010 to 2060 will be in the Livestock demand sector. However, the largest growth in demand from over this period will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2030. Surface water gaps are not expected through 2060. Bedrock groundwater storage depletions were not evaluated in detail due to the minimal demand in the basin. Broken Bow Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 4's future water demand. However, the majority of demand in the basin is from geographically dispersed demand sectors (Livestock and Crop Irrigation) that may not have access to Broken Bow Lake. Therefore, localized surface water gaps may occur but could not be quantified. Alluvial groundwater depletions have a low probability of occurring in the summer and fall and will be small (20 AFY) on a basin-scale. Future alluvial groundwater withdrawals are expected to occur from minor aquifers. The severity of the storage depletions could not be evaluated due to insufficient information. Localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Water Supply Limitations
Southeast Region, Basin 4

Water Supply Limitations
Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Southeast Region, Basin 4

Water Supply Option Effectiveness
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 and, to a lesser extent, on alluvial groundwater. To reduce the risk of adverse impacts to the basin's water users, storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Self-Supplied Residential demand sectors could reduce alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide reliable supplies during drought periods.

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 region. However, in light of the minimal size and low probability of storage depletions and the unpermitted yield of Broken Bow Lake, out-of-basin supplies may not be cost-effective for many users in the basin.

Broken Bow Lake or new in-basin reservoir storage could be used to meet all of Basin 4'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 100 AF of reservoir storage at the basin outlet.

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

Increased reliance on minor bedrock aquifers could alleviate alluvial groundwater depletions. However, site-specific information on the suitability of minor aquifers for supply should be considered before increased reliance on these supplies or large-scale use.

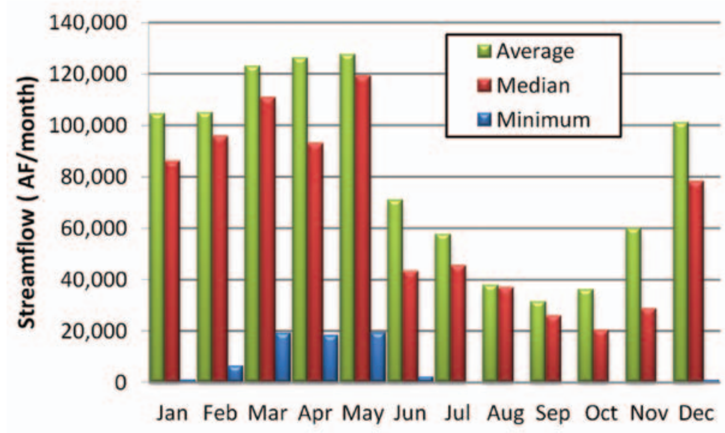
Basin 4 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Mountain Fork River below Buffalo Creek had a period of below-average streamflow from the early 1960s to the mid 1970s. 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 the Mountain Fork River below Buffalo Creek is greater than 20,000 AF/month throughout the year and greater than 78,000 AF/month in the winter and spring. However, the river can have periods of low to no flow in the summer, fall, and winter.
- Relative to other basins in the state, the surface water quality in Basin 4 is considered good.
- Broken Bow Lake is operated by the U.S. Army Corps of Engineers and provides 196,000 AFY of dependable water supply yield. The lake has substantial unpermitted yield that could be used to meet future demand.

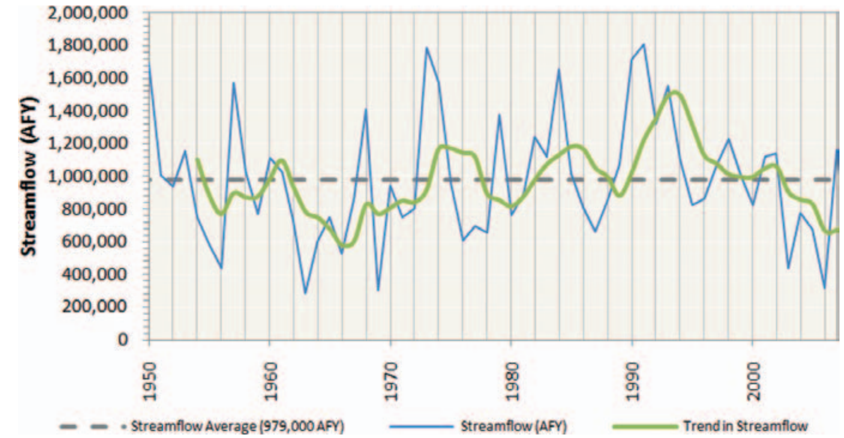
Monthly Historical Streamflow at the Basin Outlet

Southeast Region, Basin 4



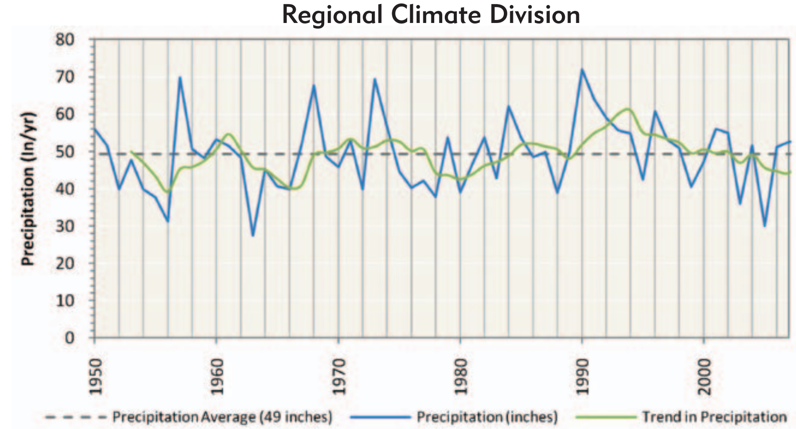
Historical Streamflow at the Basin Outlet

Southeast Region, Basin 4



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)

Southeast Region, Basin 4

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
Broken Bow	Bedrock	Minor	18%	0	112,000	temporary 2.0	128,000
Kiamichi	Bedrock	Minor	77%	<50	369,000	temporary 2.0	550,400
Pine Mountain	Bedrock	Minor	4%	0	22,000	temporary 2.0	25,600
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

- For Basin 4, groundwater rights total less than 50 AFY in the Kiamichi minor bedrock aquifer.
- There are no significant groundwater quality issues in the basin.

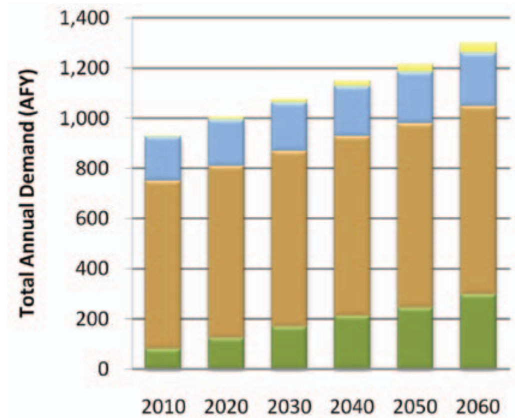
Notes & Assumptions

- 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.

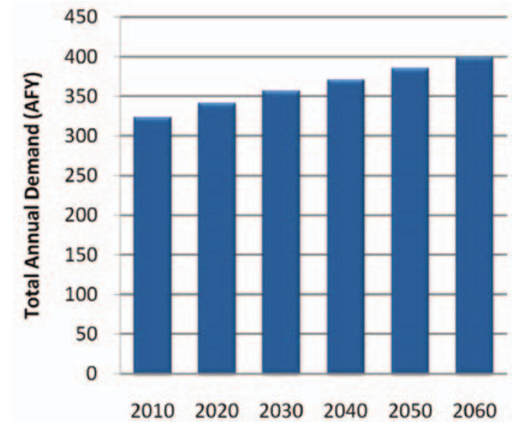
Water Demand

- Basin 4's water needs account for about 2% of the demand in the Southeast Watershed Planning Region and will increase by 36% (450 AFY) from 2010 to 2060. The majority of demand during this period will be from the Livestock demand sector. However, the largest growth in demand from 2010 to 2060 will be from the Crop Irrigation demand sector.
- Surface water is used to meet 74% of total demands in the basin and its use will increase by 40% (370 AFY) from 2010 to 2060. The majority of the surface water use over this period will be in the Livestock surface water use sector. However, the largest growth in surface water use from 2010 to 2060 will be from the Crop Irrigation surface water use sector.
- Alluvial groundwater is used to meet 26% of total demands in the basin and represents demands from Self-Supplied Residential water use. Alluvial groundwater use will increase by 24% (80 AFY) from 2010 to 2060.
- Bedrock groundwater is used to meet less than1% of total demands in the basin.

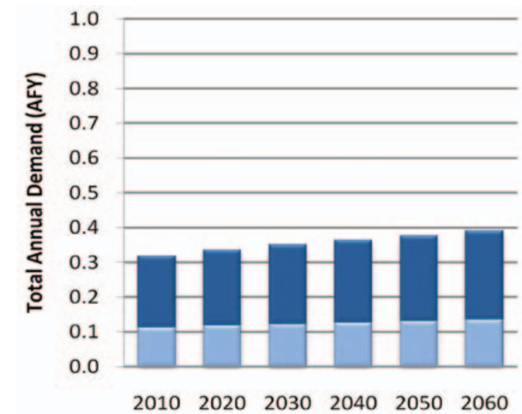
Surface Water Demand by Sector
Southeast Region, Basin 4



Alluvial Groundwater Demand by Sector
Southeast Region, Basin 4



Bedrock Groundwater Demand by Sector
Southeast Region, Basin 4

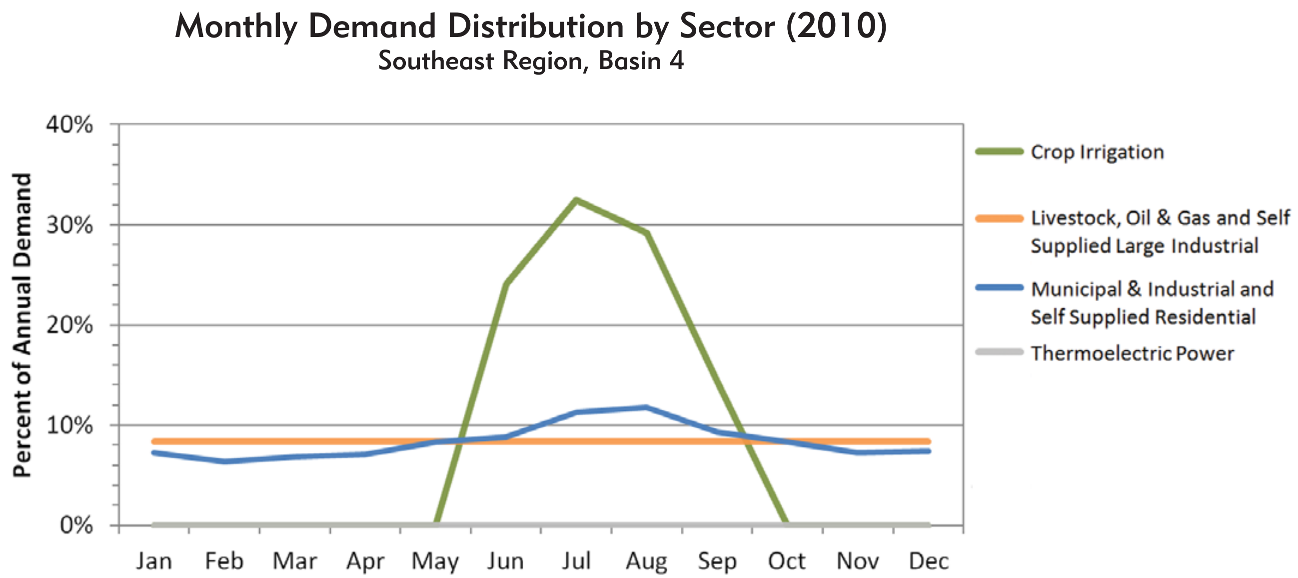


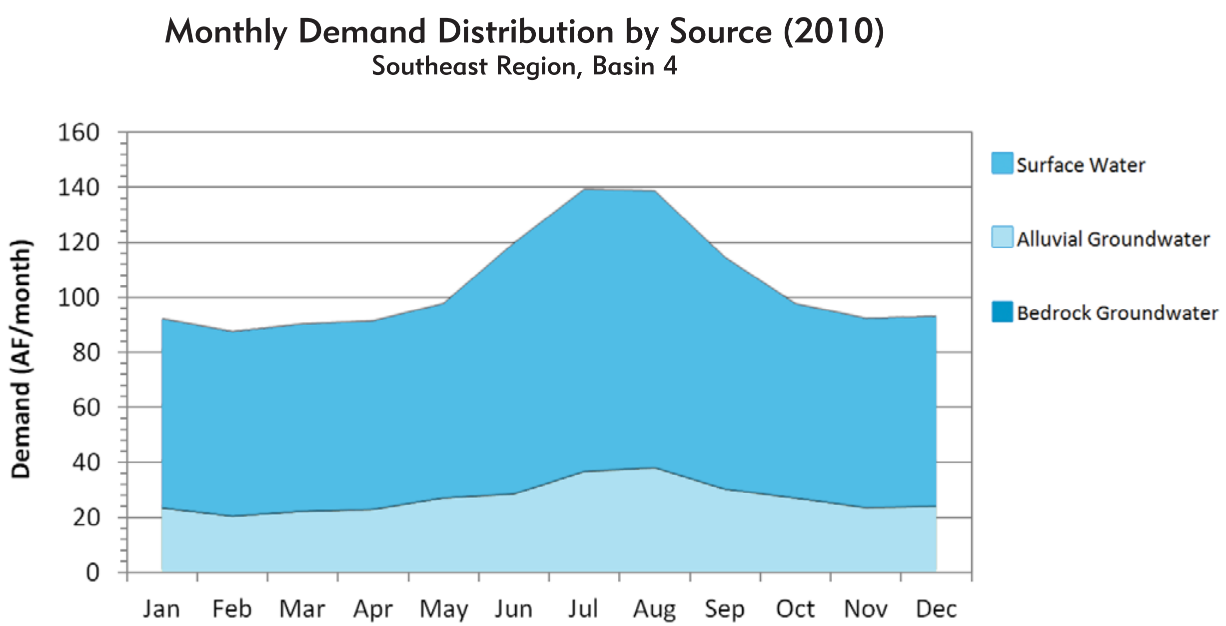
Total Demand by Sector
Southeast Region, Basin 4

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	80	670	180	0	0	320	0	1,250
2020	120	690	190	10	0	340	0	1,350
2030	170	700	190	10	0	360	0	1,430
2040	210	720	200	20	0	370	0	1,520
2050	240	730	210	30	0	390	0	1,600
2060	300	750	210	40	0	400	0	1,700

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 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. Livestock and 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 4 is about 1.5 times the monthly winter demand, which is less pronounced than the overall statewide pattern. All water sources' peak summer month use are between 1.5 and 1.6 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2030. Surface water gaps are not expected through 2060. Bedrock groundwater storage depletions were not evaluated in detail due to the minimal bedrock groundwater demand in the basin.
- Broken Bow Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 4's future surface water demand during periods of low streamflow. However, the majority of demand in the basin is from geographically dispersed demand sectors (Livestock and Crop Irrigation), which may not have access to Broken Bow Lake. Therefore, localized surface water gaps may occur, but could not be quantified.
- Alluvial groundwater storage depletions in Basin 4 have a low probability of occurring in the 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 peak fall months' alluvial groundwater demand. Future alluvial groundwater withdrawals are expected to occur from minor aquifers. The severity of the storage depletions could not be evaluated due to insufficient information. Localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demands)

Southeast Region, Basin 4

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 largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Southeast Region, Basin 4

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	2%
Sep-Nov (Fall)	10	10	2%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southeast Region, Basin 4

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	10	0	0%	2%
2040	0	10	0	0%	3%
2050	0	10	0	0%	3%
2060	0	20	0	0%	5%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Southeast Region, Basin 4

Months (Season)	Average 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 largest amount for any one month in 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

Southeast Region, Basin 4

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	0	20	0	0%	5%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	20	0	0%	5%
Moderately Expanded Conservation in M&I Water Use	0	10	0	0%	3%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	10	0	0%	3%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	10	0	0%	3%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southeast Region, Basin 4

Reservoir Storage	Diversion
AF	AFY
100	500
500	1,700
1,000	3,000
2,500	5,600
5,000	9,900
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 Self-Supplied Residential demand sectors could reduce alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

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 region: Caney Mountain in Basin 3 and Buck Creek, Finley, Kellond and Tuskahoma in Basin 6. However, in light of the small size and low probability of storage depletions and the unpermitted yield of Broken Bow Lake, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Broken Bow Lake or new in-basin reservoir storage could be used to meet all of Basin 4's future demand. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 100 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 size of storage necessary to mitigate storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Basin 4 only has minor aquifers, thus limited groundwater resources. Increased reliance on minor bedrock aquifers to meet Self Supplied Residential (domestic) demand may mitigate alluvial groundwater depletions. However, site specific information on the suitability of minor aquifers for supply should be considered before large-scale use.

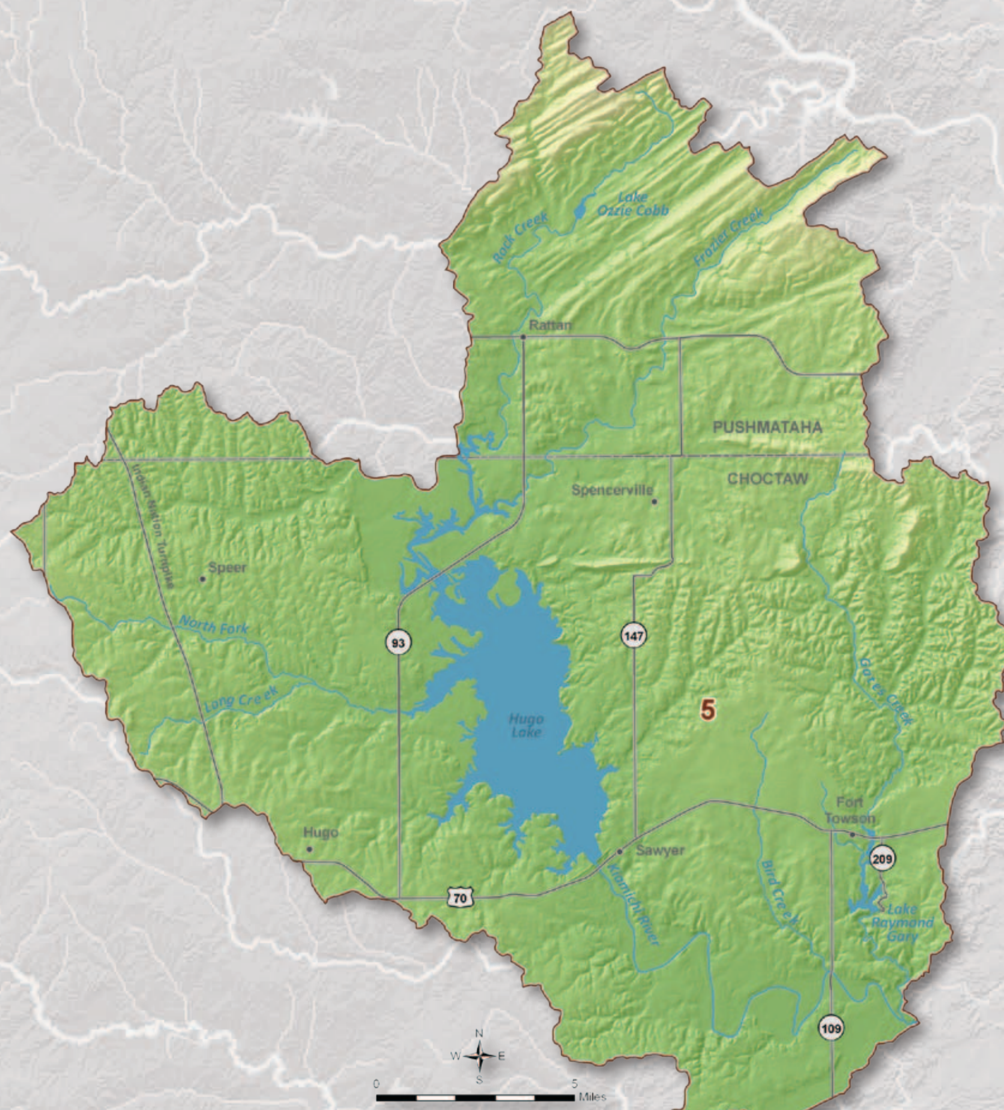
Notes & Assumptions

- 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
Southeast Watershed Planning Region

Basin 5



Basin 5 Summary

Synopsis

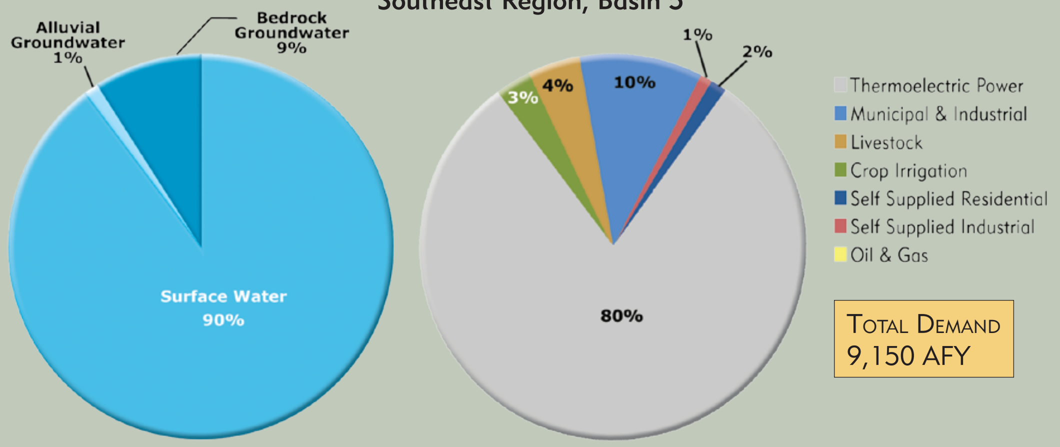
- Water users are expected to continue to rely mainly on Hugo Lake and surface water.
- Alluvial groundwater storage depletions may occur by 2060, but will be minimal in size relative to aquifer storage in the basin. However, localized groundwater storage depletions may cause adverse effects for users.
- Hugo Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 5's future water demand.
- 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 groundwater storage depletions.
- Increased reliance on bedrock aquifers could mitigate alluvial groundwater storage depletions from users without access to Hugo Lake.

Basin 5 accounts for about 16% of the current water demand in the Southeast Watershed Planning Region. About 80% of the basin's 2010 demand is from the Thermoelectric Power demand sector. Municipal and Industrial is the second largest demand sector at 10%. Surface water satisfies about 90% of the current demand in the basin. Groundwater satisfies about 10% of the current demand (1% alluvial and 9% bedrock). The peak summer month total water demand in Basin 5 is 1.2 times the winter monthly demand, which is less pronounced than the overall statewide pattern.

The flow in the Kiamichi River downstream of Gates Creek is typically greater than 22,000 AF/month throughout the year and greater than about 77,000 AF/month in the winter and spring. However, the river can have periods of low flow in the summer and fall. Hugo Lake was constructed on the Kiamichi River by the Corps of Engineers in 1974 and contains 47,600 AF of water supply storage for a dependable yield of 64,960 AFY and an additional 73,900 AF of water quality storage with a dependable yield of 100,800 AFY. The majority of the water rights are currently held

Current Demand by Source and Sector

Southeast Region, Basin 5

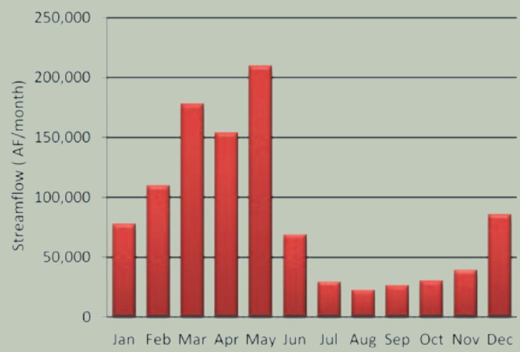


Total Demand 9,150 AFY

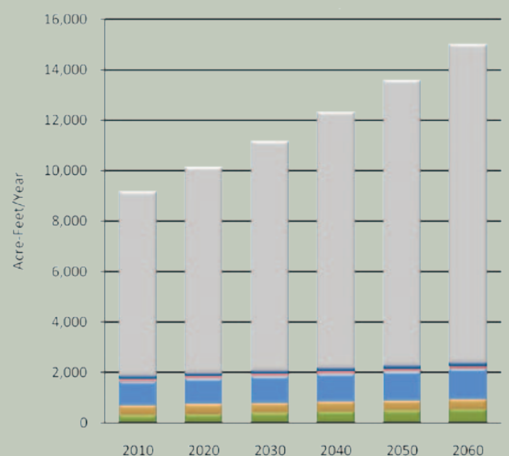
Water Resources

Southeast Region, Basin 5

Median Historical Streamflow at the Basin Outlet
Southeast Region, Basin 5



Projected Water Demand
Southeast Region, Basin 5



by Hugo Municipal Authority for public water supply and Western Farmers Electric Coop for power generation. The lake has about 2,568 AFY of unpermitted water supply yield that could be used to meet future demands. 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 5 is considered good.

Current groundwater rights in the basin are from the Antlers major bedrock aquifer, which underlies about 84% of the basin, contains over 4 million AF of storage, and receives about 13,000 AFY of recharge from Basin 5. Domestic users do not require a permit and are assumed to be obtaining supplies from minor 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 basin-wide groundwater quality issues.

The projected 2060 water demand of 15,010 AFY in Basin 5 reflects a 5,860 AFY increase (64%) 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 groundwater storage depletions may occur by 2060. Surface water gaps and bedrock groundwater storage depletions are not expected through 2060. Hugo Lake is capable of providing dependable water supplies to its existing users and, with new infrastructure, could be used to meet all of the basin's future water demand during periods of low streamflow. Alluvial groundwater storage depletions in Basin 5 have a low probability (7%) of occurring in the summer and will be small (20 AFY) on a basin-scale. Future alluvial groundwater withdrawals are expected to occur from minor aquifers to meet Self-Supplied Residential (domestic) water demand. Although depletions will be minimal compared to the 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. To reduce the risk of adverse impacts to the basin's water users, storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Self-Supplied Residential demand sectors

Water Supply Limitations
Southeast Region, Basin 5

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal · Potential · Significant

Water Supply Option Effectiveness
Southeast Region, Basin 5

Demand Management	Typically Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Potentially Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Typically Effective

Typically Effective · Potentially Effective · Likely Ineffective · No Option Necessary

could mitigate alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

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 region. However, in light of the small size and very low probability of storage depletions and the unpermitted yield of Hugo Lake, out-of-basin supplies may not be cost-effective

Reallocation of water quality storage to water supply at Hugo Lake or new in-basin reservoir storage could also be used to meet all of Basin 5'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 1,900 AF of reservoir storage at the basin outlet.

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

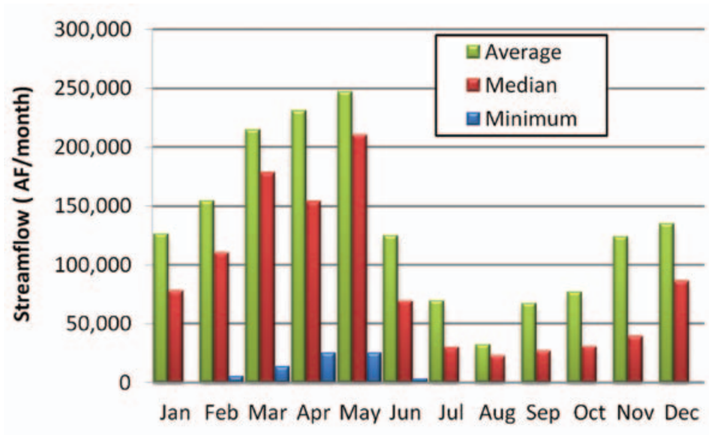
Increased reliance on the Antlers aquifer could mitigate alluvial groundwater storage depletions or localized surface water gaps from users who do not have access to Hugo Lake. Increased reliance on minor bedrock aquifers to meet future Self Supplied Residential (domestic) demand may also mitigate alluvial groundwater depletions. However, site specific information on the suitability of minor aquifers for supply should be considered before large-scale use.

Basin 5 Data & Analysis

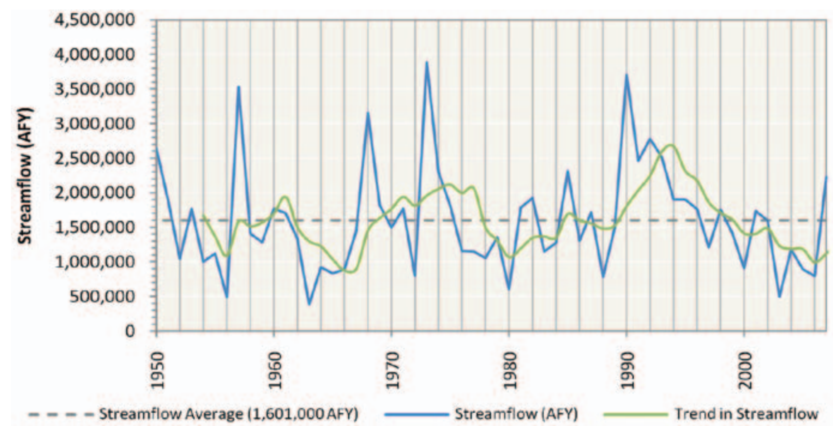
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Kiamichi River downstream of Gates Creek had a period of below-average streamflow in the 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 median flow in the Kiamichi River downstream of Gates Creek is greater than 22,000 AF/month throughout the year and greater than about 77,000 AF/month in the winter and spring. However, the river can have periods of low flow in the summer and fall.
- Relative to other basins in the state, the surface water quality in Basin 5 is considered good.
- Hugo Lake is operated by the U.S. Army Corps of Engineers and provides about 64,900 AFY of dependable water supply yield. The lake has 2,568 AFY of unpermitted water supply yield that could be used to meet future demands.

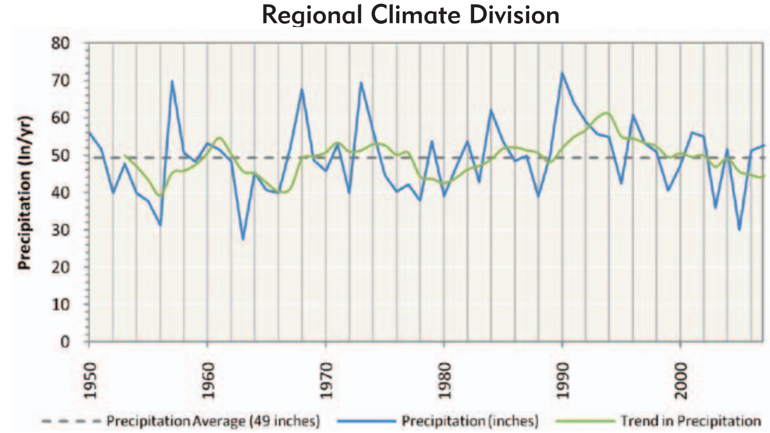
Monthly Historical Streamflow at the Basin Outlet
Southeast Region, Basin 5



Historical Streamflow at the Basin Outlet
Southeast Region, Basin 5



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)

Southeast Region, Basin 5

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	84%	3,800	4,386,000	2.1	421,200
Red River	Alluvial	Major	11%	0	82,000	temporary 2.0	51,200
Kiamichi	Bedrock	Minor	14%	0	43,000	temporary 2.0	64,000
Woodbine	Bedrock	Minor	30%	0	1,094,000	temporary 2.0	140,800
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 groundwater rights in the basin are from the Antlers aquifer. The Antlers aquifer underlies about 84% of the basin, has more than 4.3 million AF of storage, and receives about 13,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

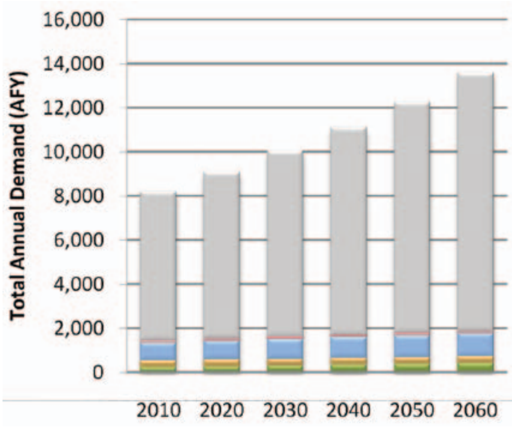
Notes & Assumptions

- 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.

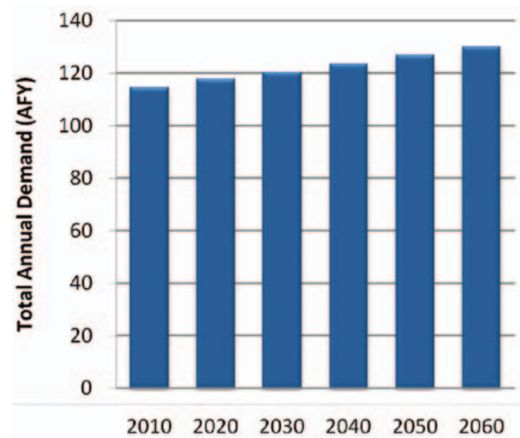
Water Demand

- Basin 5's water needs account for about 16% of the demand in the Southeast Watershed Planning Region and will increase by 64% (5,860 AFY) from 2010 to 2060. The majority of demand and growth in demand during the period will be from the Thermoelectric Power demand sector.
- Surface water is used to meet 90% of total demands 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 Thermoelectric Power demand sector.
- Alluvial groundwater is used to meet 1% of total demands in the basin and represents demands from Self-Supplied Residential water use. Alluvial groundwater use will increase by 14% (20 AFY) from 2010 to 2060.
- Bedrock groundwater is used to meet 9% of total demands in the basin and its use will increase by 58% (480 AFY) from 2010 to 2060. The majority of the bedrock groundwater use and growth in bedrock groundwater use during the period will be in the Thermoelectric Power demand sector.

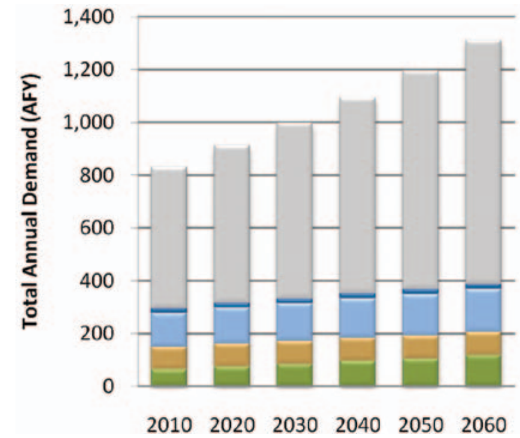
Surface Water Demand by Sector
Southeast Region, Basin 5



Alluvial Groundwater Demand by Sector
Southeast Region, Basin 5



Bedrock Groundwater Demand by Sector
Southeast Region, Basin 5



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

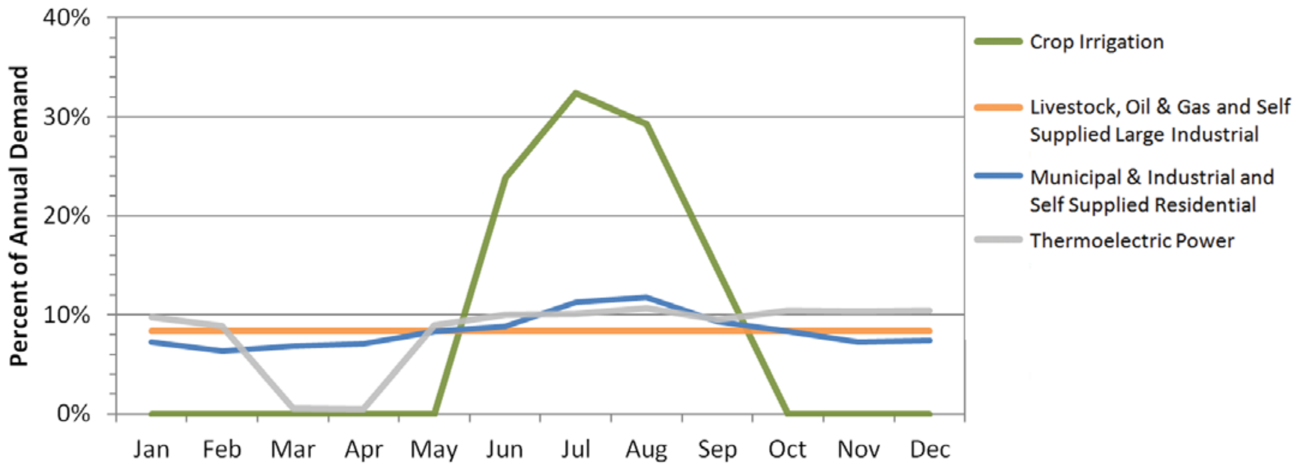
Total Demand by Sector
Southeast Region, Basin 5

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	290	390	950	0	90	130	7,300	9,150
2020	340	400	1,010	0	100	140	8,150	10,140
2030	390	400	1,050	0	100	140	9,090	11,170
2040	430	400	1,100	0	100	140	10,140	12,310
2050	470	400	1,160	0	100	150	11,310	13,590
2060	530	400	1,210	0	100	150	12,620	15,010

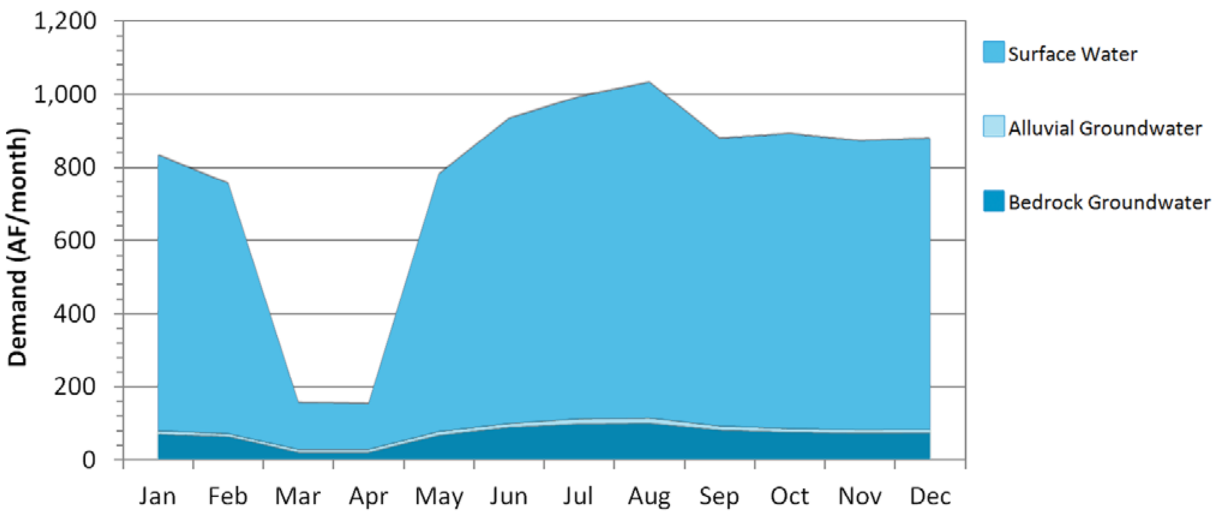
Notes & Assumptions

- 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)
Southeast Region, Basin 5



Monthly Demand Distribution by Source (2010)
Southeast Region, Basin 5



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. Thermoelectric Power has relatively consistent demand throughout the year, except March and April when there is substantially less demand. 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 5 is 1.2 times the winter monthly demand, which is less pronounced than the overall statewide pattern. Surface water use in the peak summer month is 1.2 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at 1.6 times the winter use. Monthly bedrock groundwater use peaks in the summer at 1.4 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2060. Surface water gaps and bedrock groundwater storage depletions are not expected.
- Alluvial groundwater storage depletions in Basin 5 have a low probability (7%) of occurring in the summer. Alluvial groundwater storage depletions in 2060 will be small in size (20 AF/month); however, storage depletions may represent the entire alluvial groundwater demand. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. The severity of the storage depletions cannot be evaluated due to insufficient data. Localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Southeast Region, Basin 5

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 largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 5

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)	10	10	7%
Sep-Nov (Fall)	0	0	0%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Southeast Region, Basin 5

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	20	0	0%	7%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 5

Months (Season)	Average 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 largest amount for any one month in 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
Southeast Region, Basin 5

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	0	20	0	0%	5%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	20	0	0%	5%
Moderately Expanded Conservation in M&I Water Use	0	10	0	0%	3%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	10	0	0%	3%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	10	0	0%	2%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage
Southeast Region, Basin 5

Reservoir Storage	Diversion
AF	AFY
100	300
500	1,600
1,000	3,100
2,500	7,000
5,000	12,000
Required Storage to Meet Growth in Demand (AF)	1,900
Required Storage to Meet Growth in Surface Water Demand (AF)	1,700

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 Self-Supplied Residential demand sectors could decrease the magnitude and probability of alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

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 region: Caney Mountain in Basin 3 and Buck Creek, Finley, Kellond and Tuskahoma in Basin 6. However, in light of the small size and very low probability of storage depletions and the unpermitted yield of Hugo Lake, out-of-basin supplies may not be cost-effective.

Reservoir Use

The entire increase in demand from 2010 to 2060 could also be supplied by a river diversion and 1,900 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 size of storage necessary to mitigate storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on the Antlers or Red River aquifers could mitigate alluvial groundwater storage depletions or localized surface water gaps from users without access to Hugo Lake. Increased reliance on minor bedrock aquifers to meet future Self Supplied Residential (domestic) demand may also mitigate alluvial groundwater depletions. However, site specific information on the suitability of minor aquifers for supply should be considered before large-scale use.

Notes & Assumptions

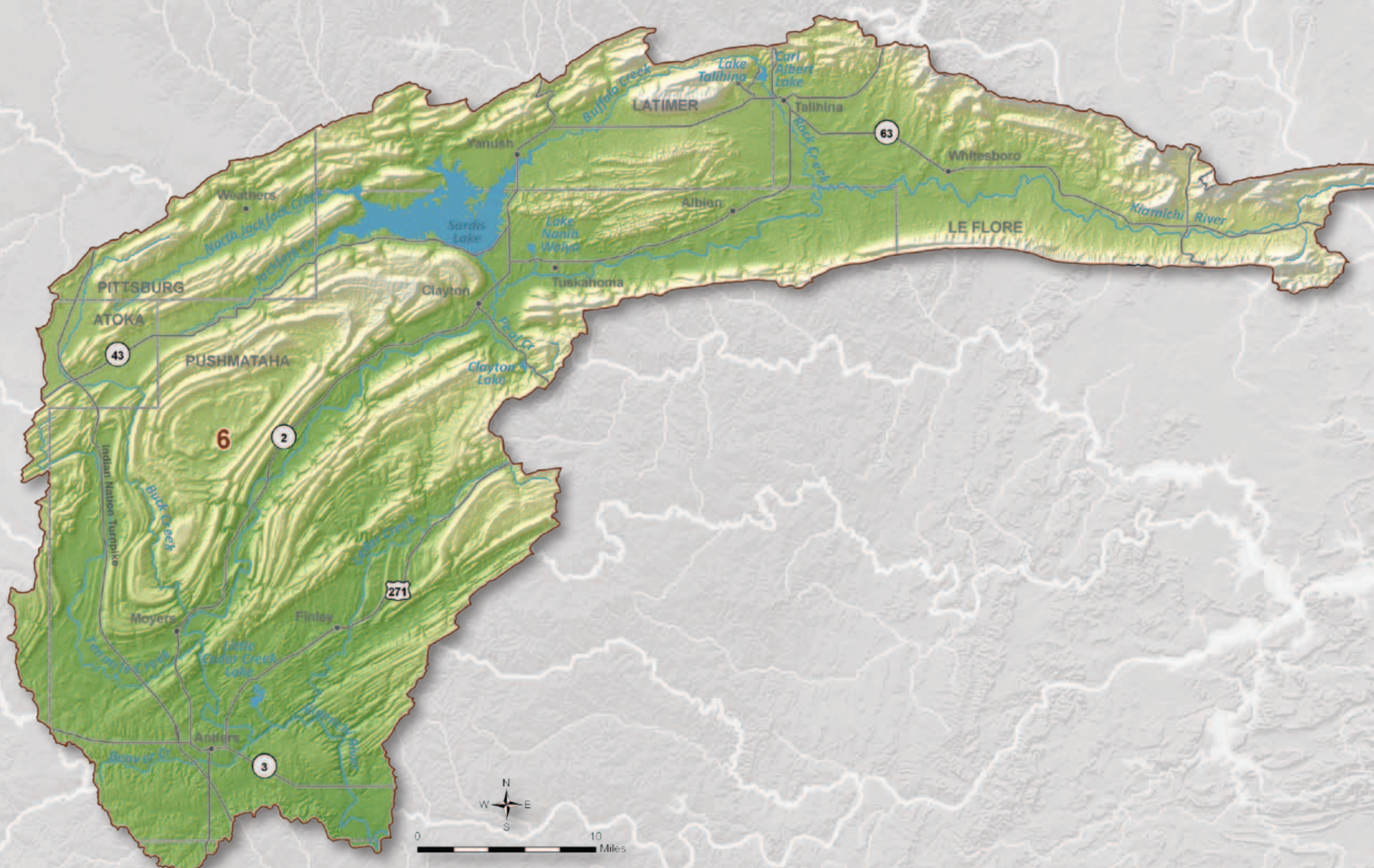
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands 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

Southeast Watershed Planning Region

Basin 6



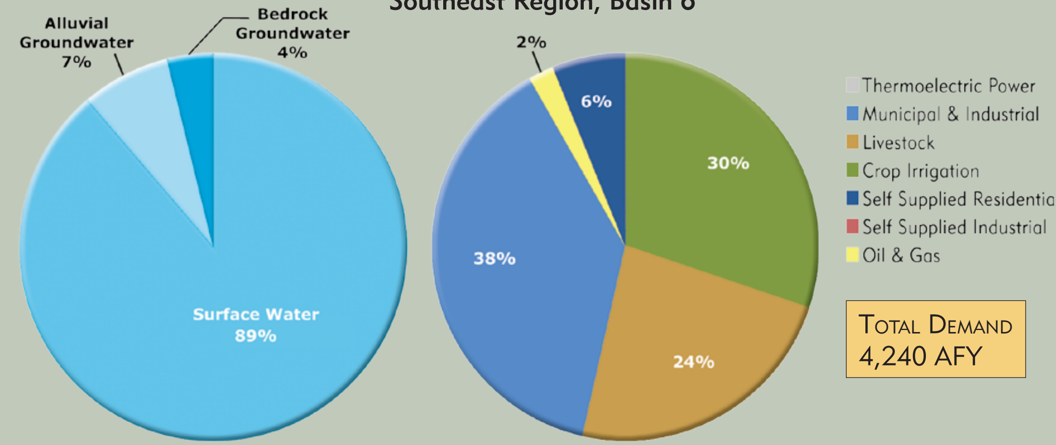
Basin 6 Summary

Synopsis

- Water users are expected to continue to rely mainly on Sardis Lake and surface water.
- Alluvial groundwater storage depletions may occur by 2030, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- Sardis Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 6's future water demand.
- To reduce the risk of adverse impacts on water supplies, it is recommended that groundwater storage depletions be decreased where economically feasible.
- Additional conservation could reduce alluvial groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing new small reservoirs could mitigate alluvial groundwater depletions for users without access to major reservoirs; impacts to groundwater storage could be minimal.

Current Demand by Source and Sector

Southeast Region, Basin 6

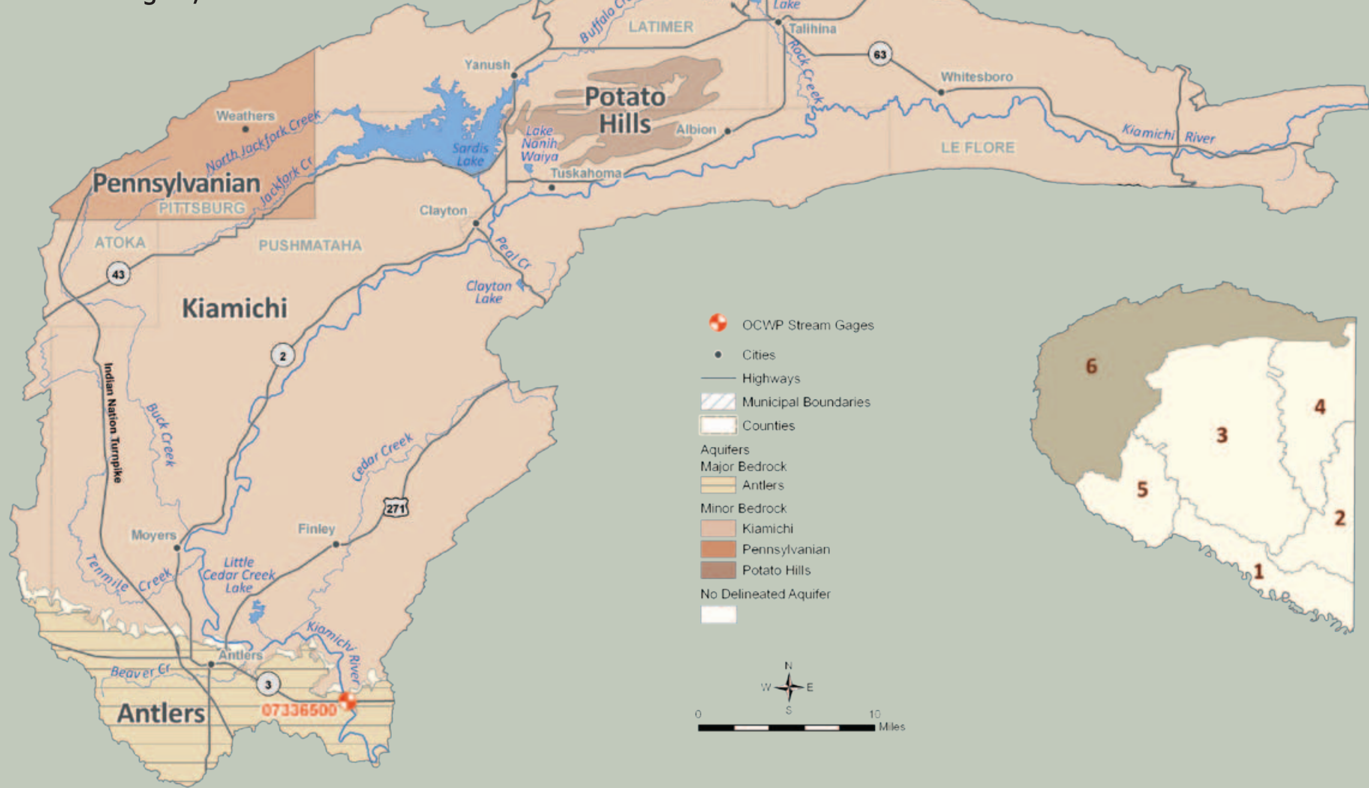


Basin 6 accounts for about 7% of the current water demand in the Southeast Watershed Planning Region. About 38% of the basin's demand is from the Municipal and Industrial demand sector. Crop Irrigation is the second largest demand sector at 30% and is followed closely by the Livestock sector at 24% of the total demand. Surface water satisfies about 89% of the current demand in the basin. Groundwater satisfies about 11% of the demand (7% alluvial and 4% bedrock). The peak summer month total water demand in Basin 6 is 3.2 times the winter monthly demand, which is similar to the overall statewide pattern.

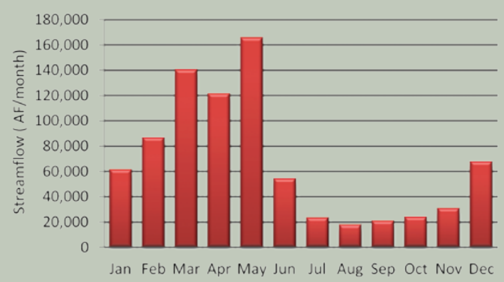
The flow in the Kiamichi River near Belzoni is typically greater than 17,900 AF/month throughout the year and greater than about 60,000 AF/month in the winter and spring. However, the river can have periods of low flow in the summer and fall. Sardis Lake was constructed in 1983 on Jackfork Creek by the Corps of Engineers for water supply, flood control, recreation, and fish and wildlife purposes. The reservoir contains 274,209 AF of water supply storage with a dependable yield of 156,800 AFY. Carl Albert Lake provides water supplies to the City of Talihina. The water

Water Resources

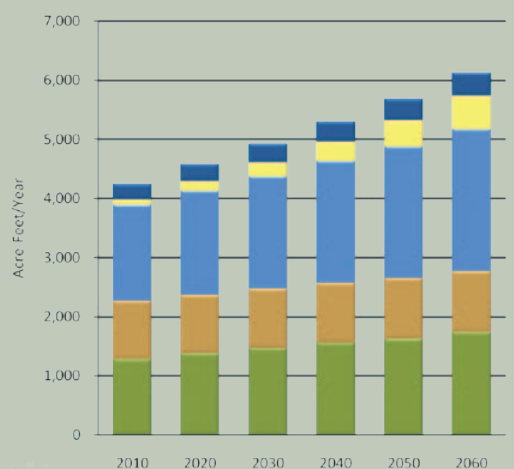
Southeast Region, Basin 6



Median Historical Streamflow at the Basin Outlet
Southeast Region, Basin 6



Projected Water Demand
Southeast Region, Basin 6



supply yield of this lake 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. Relative to other basins in the state, the surface water quality in Basin 6 is considered good.

There are 500 AFY of groundwater rights in Basin 6, including 300 AFY of rights in the Antlers major bedrock aquifer, 100 AFY in the Kiamichi minor bedrock aquifer, and 100 AF of water rights in non-delineated minor alluvial aquifers. The Antlers aquifer has almost 900,000 AF of storage in the basin and receives about 9,000 AFY of recharge from Basin 6. 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. 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 basin-wide groundwater quality issues.

The projected 2060 water demand of 6,130 AFY reflects a 1,890 AFY increase (44%) over the 2010 demand. The majority of the demand and the largest growth in demand over the period will be in the Municipal and Industrial demand sector. There will also be significant growth in demand from 2010 to 2060 in the Crop Irrigation and Oil and Gas demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2030. Surface water gaps and bedrock groundwater storage depletions are not expected through 2060. Sardis Lake is capable of providing dependable water supplies to its existing users and, with new infrastructure, could be used to meet all of the basin's future water demand. However, the availability of supplies from Sardis Lake may be restricted in the future by pending permit applications. Alluvial groundwater storage depletions in Basin 6 have a low probability (10%) of occurring in the summer and fall and will be small (40 AFY in 2060) on a basin-scale. Future alluvial groundwater withdrawals are expected to occur from minor aquifers. Although groundwater depletions will be minimal compared to the 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. To reduce the risk of adverse impacts to the basin's water users, groundwater storage depletions should be decreased where economically feasible.

Water Supply Limitations
Southeast Region, Basin 6

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal   Potential   Significant

Water Supply Option Effectiveness
Southeast Region, Basin 6

Demand Management	Potentially Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Typically Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Typically Effective

Typically Effective   Potentially Effective
Likely Ineffective   No Option Necessary

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors could reduce alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the region. However, in light of the small size and very low probability of storage depletions, out-of-basin supplies may not be cost-effective for many users in the basin.

New reservoir storage could be used to meet all of the Basin 6 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 600 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified four potentially viable sites in Basin 6.

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

Increased reliance on the Antlers aquifer could mitigate alluvial groundwater storage depletions or localized surface water gaps from users without access to reservoirs, but the aquifer only underlies a small portion of the basin. Increased reliance on minor bedrock aquifers to meet future Self-Supplied Residential (domestic) demand may also mitigate alluvial groundwater depletions. However, site-specific information on the suitability of minor aquifers for supply should be considered before large-scale use.

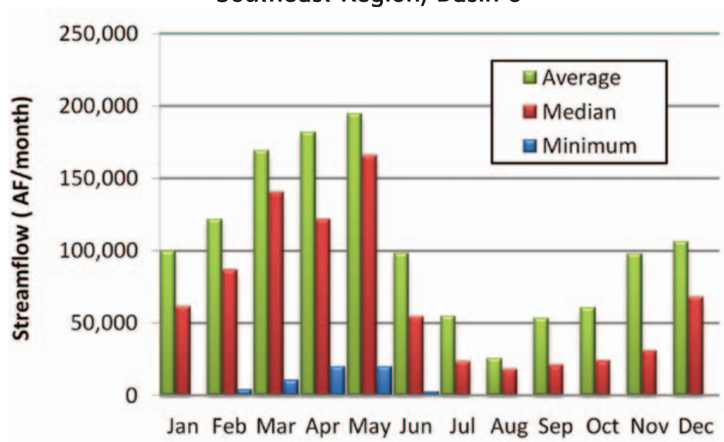
Basin 6 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Kiamichi River near Belzoni had a period of below-average streamflow in the 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 median flow in the Kiamichi River near Belzoni is greater than 17,900 AF/month throughout the year and greater than about 60,000 AF/month in the winter and spring. However, the river can have periods of low to no flow in the summer and fall.
- Relative to other basins in the state, the surface water quality in Basin 6 is considered good.
- Sardis Lake is operated by the U.S. Army Corps of Engineers and has approximately 156,800 AFY of dependable water supply yield. Carl Albert Lake provides water supplies to the City of Talihina. The water supply yield of this lake is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated.

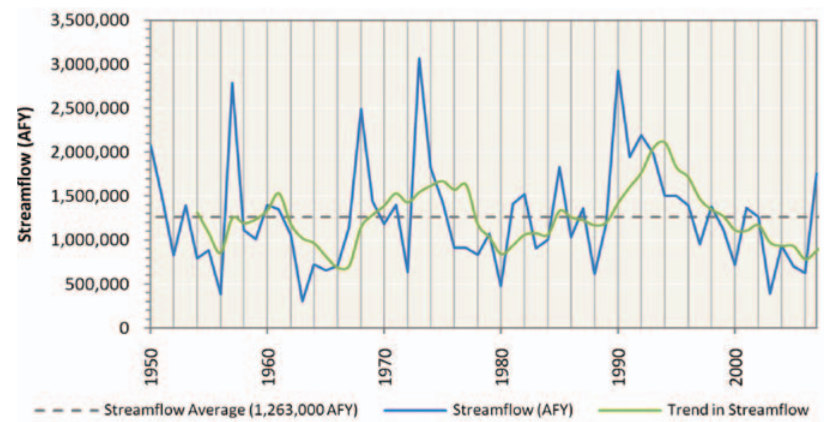
Monthly Historical Streamflow at the Basin Outlet

Southeast Region, Basin 6



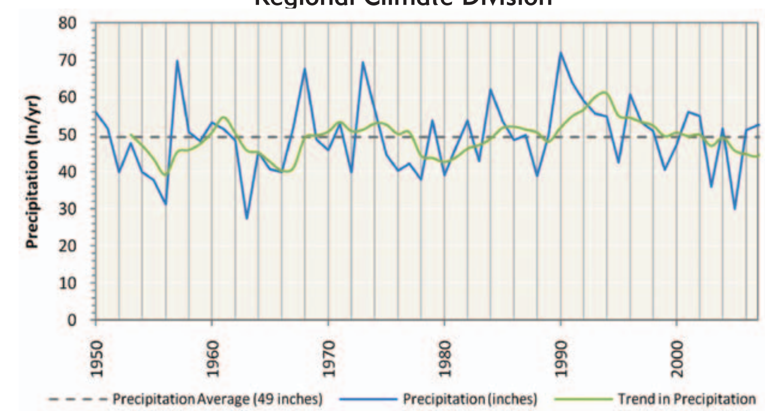
Historical Streamflow at the Basin Outlet

Southeast Region, Basin 6



Historical Precipitation

Regional Climate Division



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Groundwater Resources - Aquifer Summary (2010)
Southeast Region, Basin 6

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Kiamichi	Bedrock	Minor	84%	100	1,047,000	temporary 2.0	1,560,700
Pennsylvanian	Bedrock	Minor	6%	0	838,000	temporary 2.0	102,400
Potato Hills	Bedrock	Minor	2%	0	49,000	temporary 2.0	38,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	100	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 the rights are from the Antlers aquifer. The Antlers aquifer has 891,000 AF of storage in the basin and receives about 9,000 AFY of recharge.
- There are no significant groundwater quality issues in the basin.

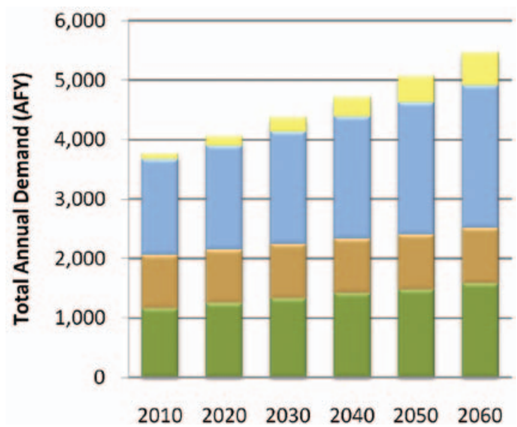
Notes & Assumptions

- 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.

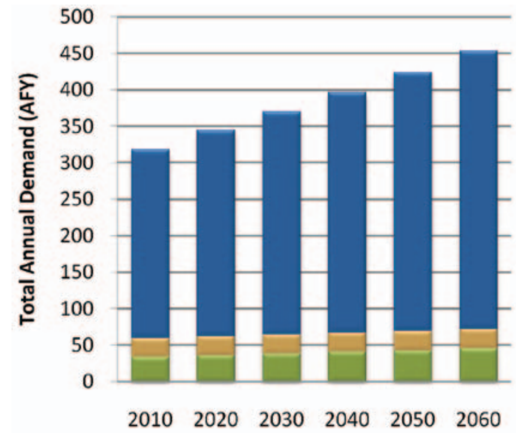
Water Demand

- Basin 6's water needs account for about 7% of the demand in the Southeast Watershed Planning Region and will increase by 44% (1,890 AFY) from 2010 to 2060. The majority of demand and the largest growth in demand during the period will be from the Municipal and Industrial demand sector. There will also be significant growth in demand from the Crop Irrigation and Oil and Gas demand sectors.
- Surface water is used to meet 89% of total demand in the basin and its use will increase by 45% (1,710 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water user during the period will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 7% of total demand in the basin and largely represents demand from Self-Supplied Residential water use. Alluvial groundwater use will increase by 43% (140 AFY) from 2010 to 2060.
- Bedrock groundwater is used to meet 4% of total demand in the basin and its use will increase by 24% (40 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during the period will be from the Crop Irrigation demand sector.

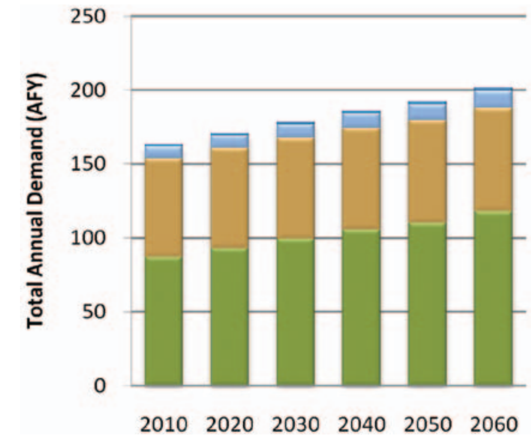
Surface Water Demand by Sector
Southeast Region, Basin 6



Alluvial Groundwater Demand by Sector
Southeast Region, Basin 6



Bedrock Groundwater Demand by Sector
Southeast Region, Basin 6



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

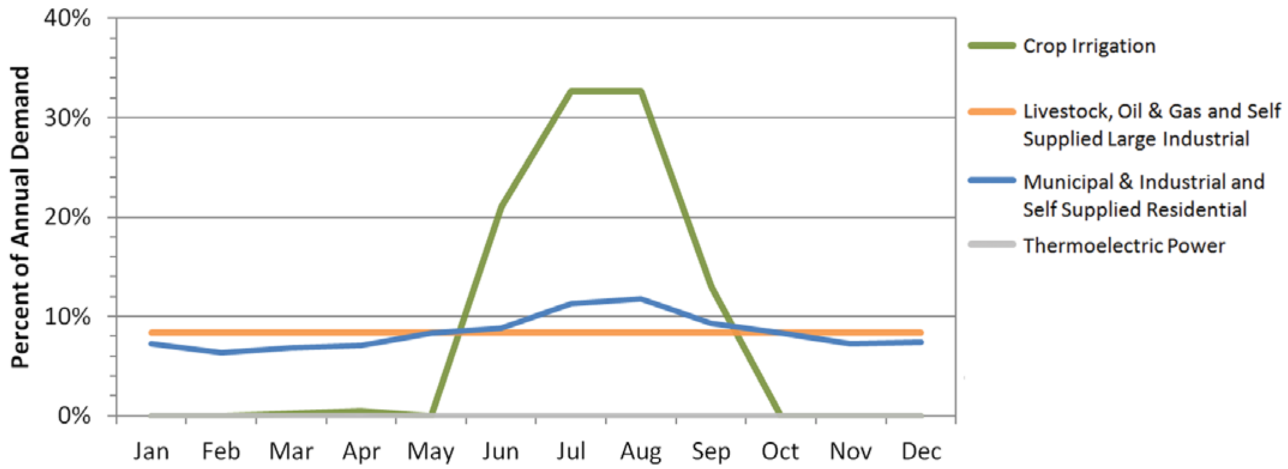
Total Demand by Sector
Southeast Region, Basin 6

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,280	990	1,620	90	0	260	0	4,240
2020	1,370	1,000	1,760	160	0	280	0	4,570
2030	1,470	1,010	1,910	240	0	310	0	4,940
2040	1,560	1,010	2,070	330	0	330	0	5,300
2050	1,630	1,020	2,240	440	0	360	0	5,690
2060	1,740	1,030	2,410	570	0	380	0	6,130

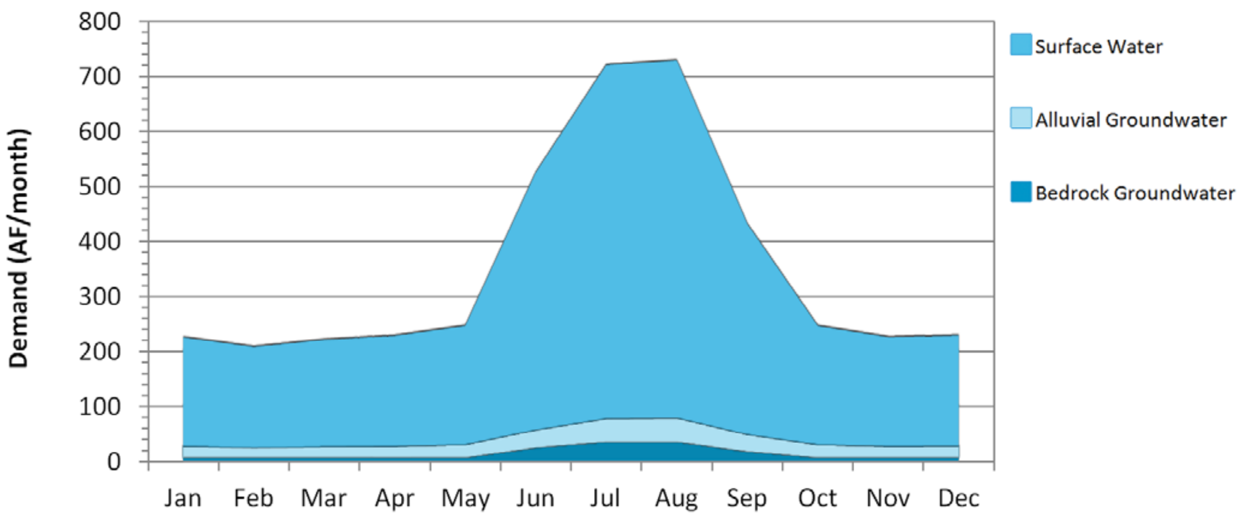
Notes & Assumptions

- 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)
Southeast Region, Basin 6



Monthly Demand Distribution by Source (2010)
Southeast Region, Basin 6



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 6 is 3.2 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 3.2 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at 2 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 5.6 times the winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2030. Surface water gaps and bedrock groundwater storage depletions are not expected through 2060.
- Alluvial groundwater storage depletions in Basin 6 may occur in the summer and fall. Alluvial groundwater storage depletions in 2060 will be up to 33% (20 AF/month) of the alluvial groundwater demand in the peak summer month and as much as 25% (10 AF/month) of the peak fall months' alluvial groundwater demand.
- Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Southeast Region, Basin 6

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 largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southeast Region, Basin 6

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	7%
Sep-Nov (Fall)	10	10	5%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Southeast Region, Basin 6

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	10	0	0%	5%
2040	0	30	0	0%	9%
2050	0	30	0	0%	9%
2060	0	40	0	0%	10%

Bedrock Groundwater Storage Depletions by Season(2060 Demand)
Southeast Region, Basin 6

Months (Season)	Average 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 largest amount for any one month in 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

Southeast Region, Basin 6

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	0	40	0	0%	10%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	40	0	0%	9%
Moderately Expanded Conservation in M&I Water Use	0	30	0	0%	9%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	30	0	0%	9%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	20	0	0%	7%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southeast Region, Basin 6

Reservoir Storage	Diversion
AF	AFY
100	300
500	1,500
1,000	3,000
2,500	6,700
5,000	11,700
Required Storage to Meet Growth in Demand (AF)	600
Required Storage to Meet Growth in Surface Water Demand (AF)	600

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 demand sectors could reduce the size of alluvial groundwater storage depletions. Temporary drought management activities could also mitigate storage depletions, but may not be needed if minor aquifer storage continues to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate alluvial groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the region: Caney Mountain in Basin 3. However, in light of the small size and very low probability of storage depletions, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

With new infrastructure, Sardis Lake could be used to meet all of Basin 6's future water demand. New reservoir storage could also be used to meet all of the Basin 6 future demand during periods of low streamflow. The entire increase in demand from 2010 to 2060 could be supplied by 600 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 size of storage necessary to mitigate storage depletions. In addition, the OCWP Reservoir Viability Study identified four potentially viable sites in Basin 6 (Tuskahoma Lake, Finley Lake, Kellond Lake, and Buck Creek Lake).

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

Increased reliance on the Antlers aquifer could mitigate alluvial groundwater storage depletions or localized surface water gaps for users without access to reservoirs, but it only underlies a small portion of the basin. Site-specific information on the suitability of minor aquifers for supply should be considered before increased reliance on these supplies or large-scale use. Increased reliance on minor bedrock aquifers to meet future Self Supplied Residential (domestic) demand may also mitigate alluvial groundwater depletions. However, site specific information on the suitability of minor aquifers for supply should be considered before 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.

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 basinwide if from a bedrock aquifer, and at least one hundred fifty (150) gallons per minute on the average basinwide 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

Initial Unit	CFS	GPM	MGD	AFY	AFD
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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