Oklahoma Comprehensive Water Plan

OCWP

Middle Arkansas
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

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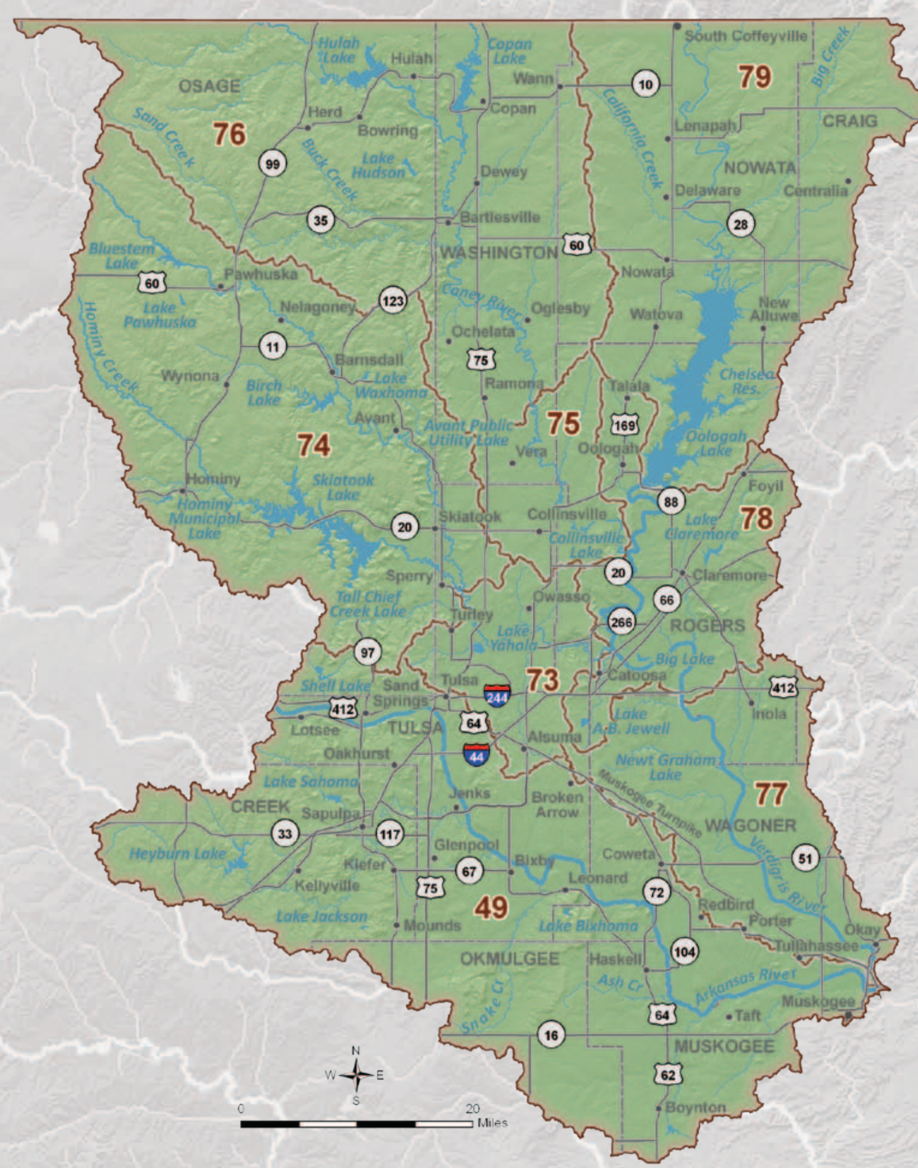
The online version of this 2012 OCWP Watershed Planning Region Report (Version 1.1) includes figures that have been updated since distribution of the original printed version. Revisions herein primarily pertain to the seasonality (i.e., the percent of total annual demand distributed by month) of Crop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

Oklahoma Comprehensive Water Plan

Middle Arkansas Watershed Planning Region



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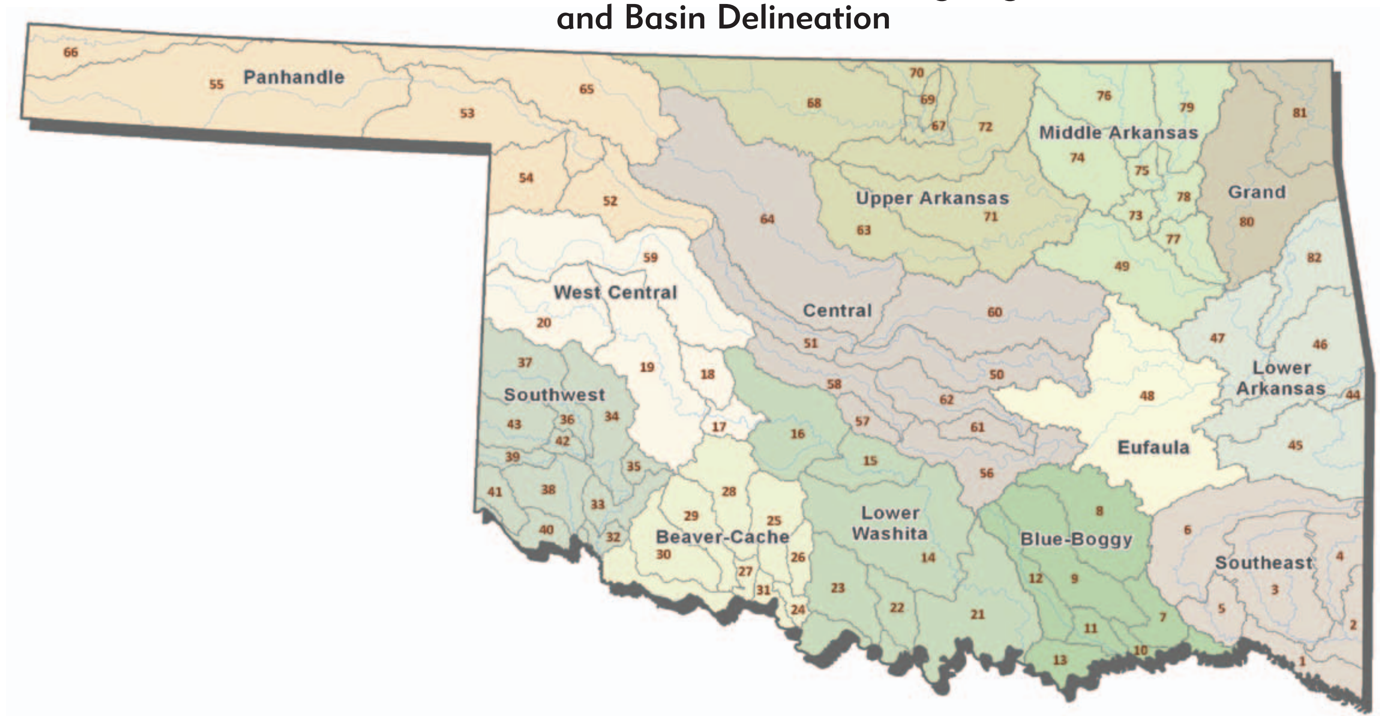


Introduction

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.

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.

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.

This Watershed Planning Region report, one of 13 such documents prepared for the *2012 OCWP Update*, presents elements of technical studies pertinent to the Middle Arkansas 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 Middle Arkansas Watershed Planning Region includes eight basins (numbered 49 and 73-79 for reference). The region is primarily in the Central Lowland physiography province and encompasses 5,173 square miles in northeastern Oklahoma, spanning all of Washington and Nowata Counties and parts of Osage, Craig, Tulsa, Rogers, Mayes, Wagoner, Creek, Okmulgee, and Muskogee Counties.

Encompassing some of the most scenic areas of the state, the region's terrain includes forested mountains, rolling plains, and rich river basins. Much of the region is a mosaic of prairie grassland, and particularly in the eastern portion of the region, woodlands with a mix of rangeland and cropland.

The region's climate is mild with annual mean temperatures varying from 59°F to 61°F. Annual evaporation averages about 56 inches per year. Annual average precipitation ranges from 36 inches in the farthest north to 45 inches in the south and east near Tulsa.

The largest cities in the region include Tulsa (2010 population 391,906), Broken Arrow (98,850), Bartlesville (35,750), Sapulpa (20,544), and Sand Springs (18,906). The greatest demand is from Municipal and Industrial water use.

By 2060, this region is projected to have a total demand of 304,290 acre-feet per year (AFY), an increase of approximately 75,630 AFY (33%) from 2010.

Middle Arkansas Regional Summary

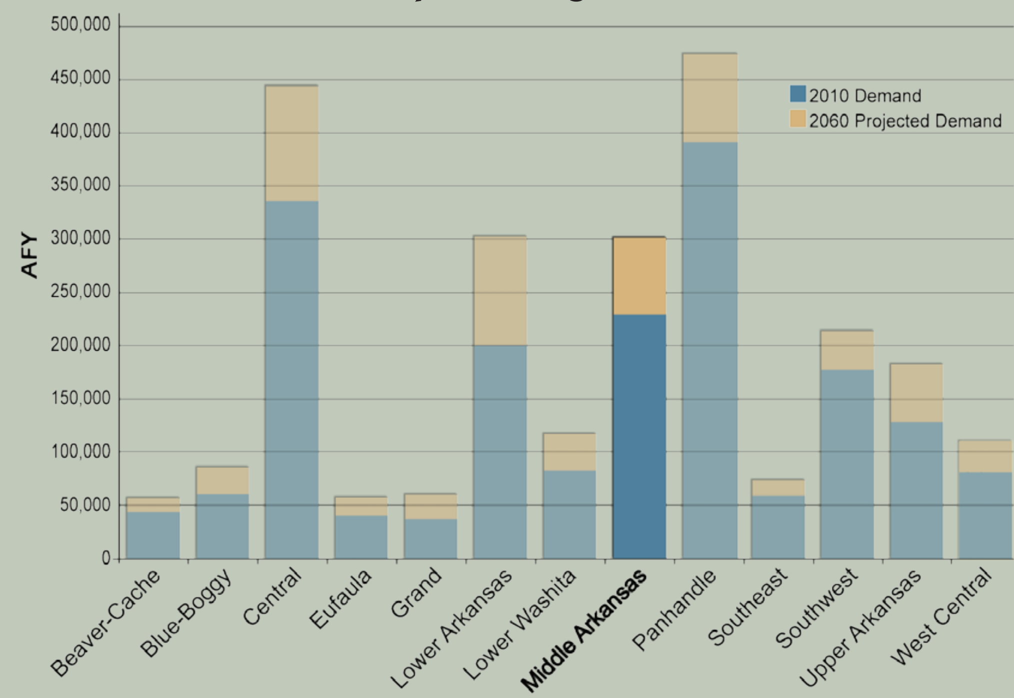
Synopsis

- The Middle Arkansas Watershed Planning Region relies primarily on surface water supplies (including reservoirs) and to a 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, surface water gaps will occur in those basins without existing major reservoirs (Basins 49, 73, 75, 77, and 78).
- By 2020, alluvial groundwater storage depletions in some basins may lead to higher pumping costs, the need for deeper wells, and potential changes to well yields or water quality.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce or eliminate surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.
- Surface water alternatives, such as bedrock groundwater supplies from major aquifers and/or developing new reservoirs, could mitigate surface water gaps without major impacts to groundwater storage.
- No basins within the region have been identified as water availability "hot spots," areas where severe deficits or gaps in supply are anticipated. (See "Water Availability Analysis" in the *2012 OCWP Executive Report*.)

Middle Arkansas Region Demand Summary

Current Water Demand:	228,660 acre-feet/year (12% of state total)
Largest Demand Sector:	Municipal & Industrial (69% of regional total)
Current Supply Sources:	95% SW 4.8% Alluvial GW 0.2% Bedrock GW
Projected Demand (2060):	304,290 acre-feet/year
Growth (2010-2060):	75,630 acre-feet/year (33%)

Current and Projected Regional Water Demand



The Middle Arkansas Region accounts for 12% of the state's total water demand. The largest demand sectors are Municipal and Industrial (69% of the region's overall 2010 demand), Thermoelectric Power (18%), and Crop Irrigation (9%).

Water Resources & Limitations

Surface Water

Surface water is used to meet about 95% of the region's demand. The region is supplied by three major rivers: the Arkansas River, the Verdigris River, and the Caney River. The rivers and creeks in the region can have periods of low to no flow due to seasonal and long-term trends in precipitation, especially on the Verdigris River. Large reservoirs have been built on several rivers and their tributaries to provide water supply, flood control and recreation. Major reservoirs in the Middle Arkansas Region include: Oologah, Skiatook, Copan, Hulah, and Birch. Eleven additional municipal lakes (one for terminal storage) have normal pools ranging from 2,000 AF to 17,000 AF.

Relative to other regions in the state, surface water quality in the region is considered fair to good, except Basin 76 that is rated poor. Multiple rivers, creeks, and lakes, including the major rivers, are impaired for Agricultural use (Crop Irrigation demand sector) and Public and Private Water Supply (Municipal and Industrial demand sector) due to high levels of total dissolved solids (TDS), chloride, sulfate, and chlorophyll-a. These impairments are scheduled to be addressed through the Total Maximum Daily Loads (TMDL) process, but the use of these supplies may be limited in the interim. All basins in the region are expected to have available surface water for new permitting to meet local demand through 2060.

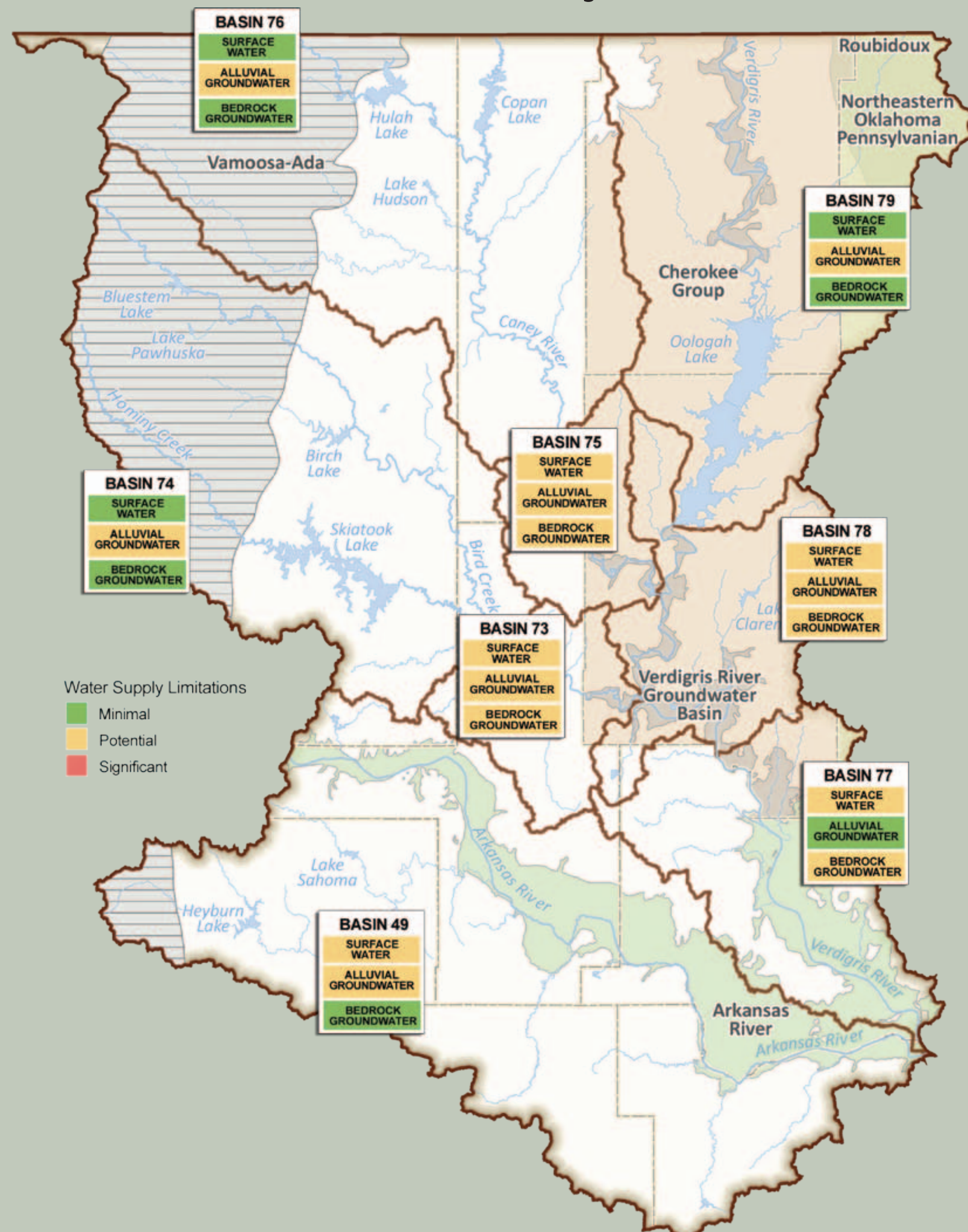
Alluvial Groundwater

Alluvial groundwater is used to meet almost 5% of the demand in the region. The majority of currently permitted alluvial groundwater withdrawals in the region are from the Arkansas River aquifer in Basin 49. The predominant use of alluvial groundwater is for domestic use, which does 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 throughout the year. The largest storage depletions are projected to occur in the summer. In Basin 49, these projected depletions will be small relative to the amount of water in storage in the Arkansas River alluvial aquifer. Site-specific information should be considered for minor aquifers before large-scale use. 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 less than 1% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Vamoosa-Ada aquifer and to a lesser extent multiple minor aquifers. No bedrock aquifer storage depletions are expected to occur in the Middle Arkansas Region. The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060.

Potential 2060 Water Supply Limitations
Middle Arkansas Region



Water Supply Limitations

Surface water limitations were based on physical availability, water supply availability for new permits, and water quality. Groundwater limitations were 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, and 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 were 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

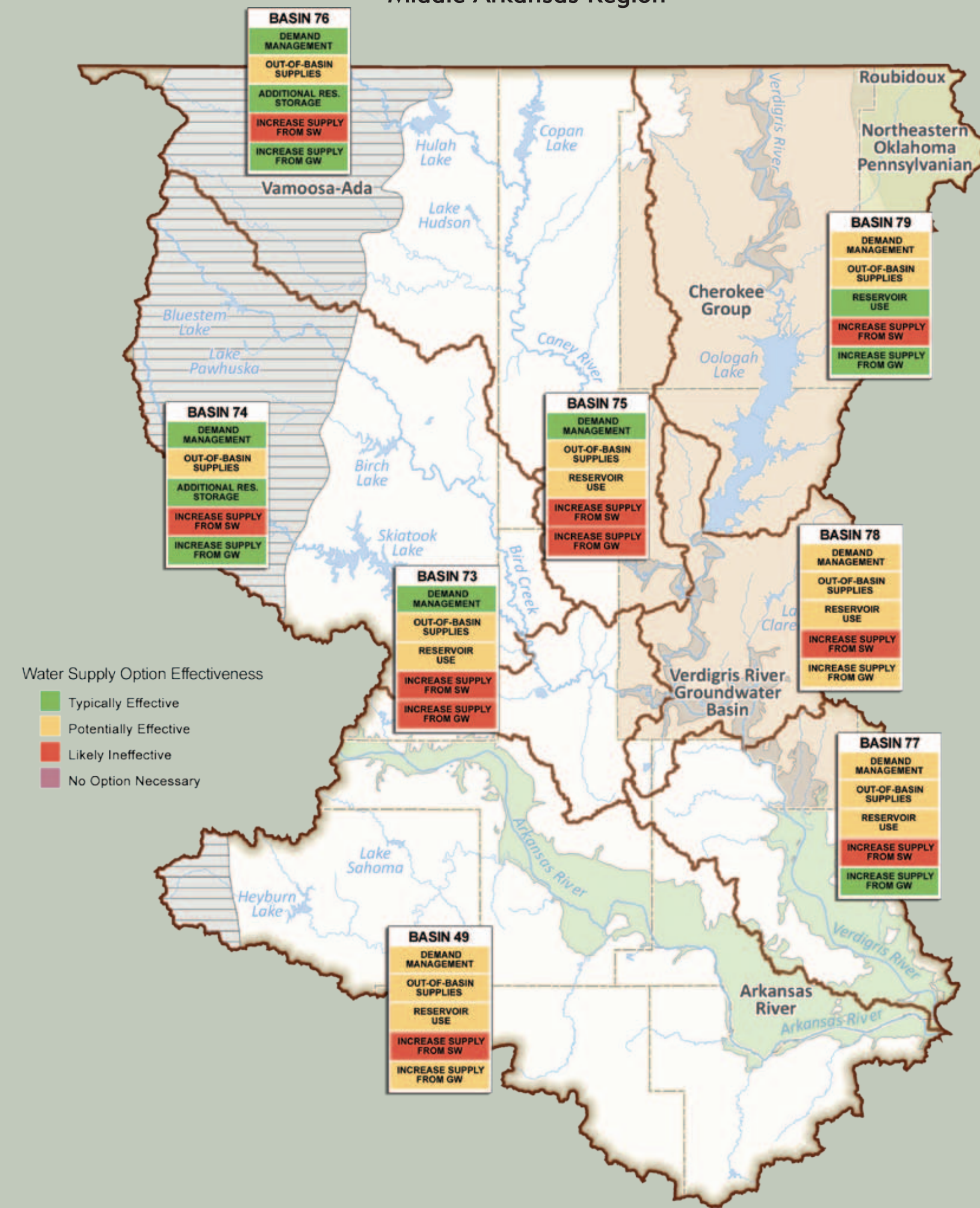
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Surface water supplies and reservoirs are expected to continue to supply the majority of demand in the Middle Arkansas Region. Basins and users that rely on surface water are projected to have physical surface water supply shortages (gaps) in the future, except where major reservoirs can provide adequate supply. Alluvial groundwater storage depletions are also projected in the future. No bedrock aquifer storage depletions are expected to occur in the Middle Arkansas Region.

Water conservation could aid in reducing projected gaps and groundwater storage depletions or in delaying the need for additional infrastructure. Moderately expanded conservation activities, primarily increased conservation by public water suppliers and from increased crop irrigation efficiency, could reduce gaps and storage depletions and, in Basins 73 and 76, could eliminate surface water gaps and alluvial groundwater storage depletions. Further reductions could occur from substantially expanded conservation activities, which could eliminate gaps and storage depletions in Basins 74 and 75. These measures would require a shift from crops with high water demand (e.g., corn) to low water demand crops such as sorghum or wheat, along with increased irrigation efficiency and increased public water supplier conservation. Due to extended dry periods and predominant use of surface water supplies, drought management measures alone will likely be an ineffective water supply option for most basins.

New reservoirs and expanded use of existing reservoirs could enhance the dependability of surface water supplies and eliminate gaps. Major reservoirs in the Middle Arkansas Region have little unpermitted yield, but are expected to meet substantial future demand of existing permit holders. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state. Two reservoirs were identified for future consideration: Candy Lake in Basin 74 and Sand Reservoir in Basin 76. These water sources could serve as interbasin or regional supplies to provide additional water to mitigate the region's surface water gaps and alluvial groundwater storage depletions. However, due to the distance from these reservoirs to demand points in each basin, this water supply option may not be cost-effective for many users.

The projected growth in surface water could instead be supplied in part by increased use of major groundwater aquifers, which would result in minimal increases in projected groundwater storage depletions. However, these aquifers are not widespread in the region, and alluvial users would still be susceptible to the adverse effects of localized storage depletions.

Water Supply Option Effectiveness
Middle Arkansas Region



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

Water Supply

Physical Water Availability

Surface Water Resources

Surface water has historically been the primary source of supply used to meet demand in the Middle Arkansas Region. The region's major streams include the Caney, Verdigris, and Arkansas Rivers. All streams in the region are ultimately tributaries to the Arkansas River. Streams generally have abundant flows, but can experience periods of low flow conditions as well as periodic flooding events. Many basins have significantly lower flows in late summer and fall.

The Arkansas River flows through Basin 49 in the southern portion of the region. In addition to the Verdigris River, major tributaries include Polecat Creek (70 miles long).

The Caney River originates in Kansas and runs for 120 miles through Basins 76 and 75 before joining the Verdigris River in Basin 78 (above the confluence with Bird Creek). The Caney River and its tributaries occupy Basins 75 and 76. Major tributaries include Sand Creek in Basin 76.

The Verdigris River (140 miles long in Oklahoma) originates in Kansas and the mainstem flows into Oklahoma in the northeastern corner of the Middle Arkansas Region. It joins the Arkansas River in Basin 49 in the Middle Arkansas Region. Major tributaries include Bird Creek (approximately 80 miles long in Basins 73 and 74).

In the Middle Arkansas Region, streamflow is variable from year to year and season to season, but is generally abundant with intermittent periods of low flow.

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.

Reservoirs
Middle Arkansas Region

Reservoir Name	Primary Basin Number	Reservoir Owner/ Operator	Year Built	Purpose[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
Birch	74	USACE	1977	FC, WS, WQ, R, FW	19,225	7,600	3,360	---	---	7,600	3,360	2,800	560
Bixhoma	49	City of Bixby	1965	WS, R	3,130	---	---	---	---	---	---	1,120	---
Bluestem	74	City of Pawhuska	1958	WS, R	17,000	---	---	---	---	---	---	2,000	---
Claremore	78	City of Claremore	1930	WS, R	7,900	---	---	---	---	---	---	3,890	---
Copan	76	USACE	1983	FC, WS, WQ, R, FW	43,400	7,500	3,360[2]	---	---	26,100	17,920	3,340	20
Heyburn	49	USACE	1950	FC, WS, R, FW	5,307	2,000	1,904	---	---	0	0	2,085	0
Hominy Municipal	74	City of Hominy	1940	WS, R	5,000	---	---	---	---	---	---	667	---
Hudson	76	City of Bartlesville	1949	WS, R	4,000	---	---	---	---	---	---	---	---
Hulah	76	USACE	1951	FC, WS, LF, R, FW	31,160	19,800	11,088[3]	---	---	7,100	5,040	13,886	2
Oologah	79	USACE	1963	FC, WS, N, R, FW	552,210	342,600	172,480	168,000	91,224	0	0	172,246	234
Pawhuska	74	City of Pawhuska	1936	WS, R	3,600	---	---	---	---	---	---	0	---
Sahoma	49	City of Sapulpa	1947	WS, R	4,850	---	---	---	---	---	---	4,800	---
Shell	49	City of Sand Springs	1922	WS, R	9,500	---	---	---	---	---	---	4,828	---
Skiatook	74	USACE	1984	FC, WS, WQ, R, FW	322,700	62,900	15,680	---	---	233,000	69,440	15,680	0
Waxhoma	74	City of Barnsdall	1955	WS, R	2,000	---	---	---	---	---	---	295	---

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

2 Copan is projected to have 0.97 mgd (approx. 1,086 afy) of dependable water supply yield through 2035, decreasing to 0.88 mgd (approx. 986 AFY) by 2055 (Bartlesville Water Supply and Conveyance Study, PAS Program, USACE, Dec. 2007).

3 Hulah is projected to have 6.4 mgd (approx. 7,168 afy) of dependable water supply yield through 2035, declining to 4.35 mgd (approx. 4,872 AFY) by 2055 (Bartlesville Water Supply and Conveyance Study, PAS Program, USACE, Dec. 2007).

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. The largest are Oologah and Skiatook, constructed in 1963 and 1984, respectively, by the U.S. Army Corps of Engineers.

Oologah Lake, located on the Verdigris River in Basin 79, is authorized for flood control, water supply, navigation, recreation, and fish and wildlife purposes. The majority of the water rights belong to the City of Tulsa for municipal and industrial water supply purposes. The Public Service Company of Oklahoma also holds a substantial water allocation for thermoelectric power generation purposes. Oologah is the only reservoir in Oklahoma that has storage designated specifically for navigation.

Skiatook Lake, located on Hominy Creek in Basin 74, is authorized for flood control, water supply, water quality control, recreation, and fish and wildlife. The majority of the water is currently allocated to the Cities of Sand Springs, Skiatook and Sapulpa.

Other Corps of Engineers multipurpose reservoirs include Hulah and Copan in Basin 76, Birch Lake in Basin 74 and Heyburn Lake in Basin 49.

Some of the major municipal lakes in the region include Hudson in Basin 76; Bluestem, Pawhuska, Waxhoma and Hominy Municipal in Basin 74; Claremore in Basin 78; and Bixhoma, Sahoma, and Shell in Basin 49. There are many other Natural Resources Conservation Service (NRCS) projects, small municipal lakes, and privately owned lakes in the region that provide water for public water supply, agricultural water supply, and recreation.

Surface Water Resources
Middle Arkansas Region

Reservoirs in Oklahoma 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.

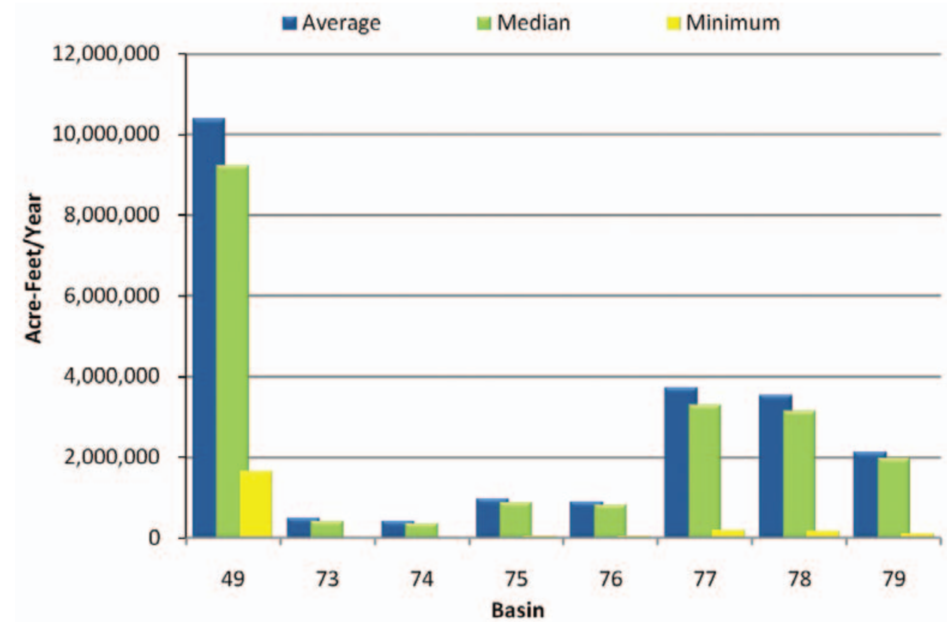
For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers,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



Surface water is the main source of supply in the Middle Arkansas 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
Middle Arkansas Region

Streamflow Statistic	Basins							
	49	73	74	75	76	77	78	79
	AFY							
Average Annual Flow	4,494,400	493,800	413,200	708,400	638,300	2,404,200	2,230,800	1,093,000
Minimum Annual Flow	510,700	13,000	8,100	29,300	28,000	33,700	29,100	49,400

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

Groundwater Resources

Two major bedrock aquifers, the Roubidoux and Vamoosa-Ada, underlie the Middle Arkansas Watershed Planning Region, and the Arkansas River, located in the southern portion of the region, is the only major alluvial aquifer.

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 Roubidoux aquifer consists primarily of dolomite with some interbedded sandstone. The aquifer thickness ranges from zero to greater than 2,000 feet, with average thickness estimated at 1,000 feet. Well yields vary from less than 25 gallons per minute (gpm) to more than 1,000 gpm, with shallower well yields ranging from less than 10 gpm to more than 300 gpm. Water quality in the aquifer is mixed. In some areas concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards, and sodium chloride (salt) water is present along the western and southern edges and at depth; water in other areas is suitable for most purposes. The Roubidoux bedrock aquifer underlies a portion of the northeast corner of Basin 79.

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

The Vamoosa-Ada aquifer consists of 125 to 1,000 feet of interbedded sandstone, shale, and conglomerate. Wells commonly yield 25 to 150 gpm. Water quality is generally good and suitable for use as public supply, although iron infiltration and hardness are problems in some areas and there are local water quality issues resulting from past oil and gas activities. The Vamoosa-Ada bedrock aquifer underlies western portions of Basins 49, 74, and 76.

Wells in the Arkansas River alluvium deposits range from 200 to 500 gpm while wells in the terrace deposits range from 100 to 200 gpm. Formation deposits are commonly 50 to 100 feet in depth with saturated thickness averaging 25 to 75 feet. The formation consists of clays, sand, silt and gravels. Hardness is the major water quality problem and TDS values are usually less than 500 mg/L. The water is generally suitable for most Municipal and Industrial uses, although heavy pumping can cause chloride intrusion into the formation. The aquifer underlies portions of Basins 49 and 77.

Minor bedrock aquifers in the region include the Cherokee Group and the Northeastern Oklahoma Pennsylvanian aquifers in the eastern portion of the region. Minor alluvial aquifers include the Verdigris River Groundwater Basin, also in the eastern areas of the region. There are substantial areas in the central portion of the region where there are no delineated groundwater sources. Minor aquifers may have a significant amount of water in storage and high recharge rates, but generally low yields of less than 50 gpm per well. Groundwater from minor aquifers is an important source of water for domestic and stock water use for individuals in outlying areas not served by rural water systems, but may have insufficient yields for large volume users.

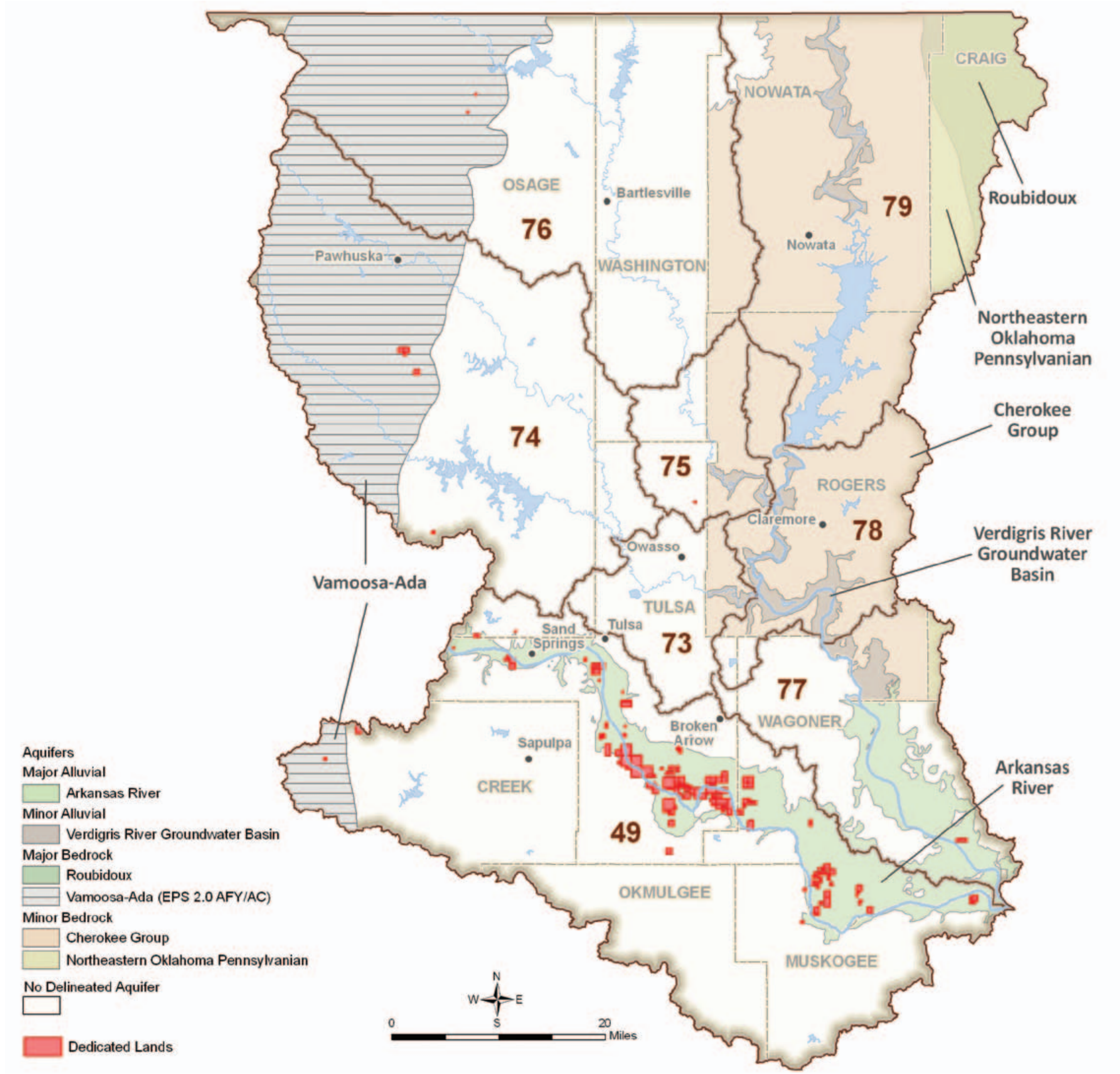
Permits to withdraw groundwater from aquifers (groundwater basins) where the maximum annual yield has not been set are "temporary" permits that allocate 2 AFY/acre. The temporary permit allocation is not based on storage, discharge or recharge amounts, but on a legislative (statute) estimate of maximum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

Groundwater Resources
Middle Arkansas 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
Arkansas River	Alluvial	Major	7%	5.0	15,400	477,000	temporary 2.0	439,700
Roubidoux	Bedrock	Major	3%	2.5	0	816,000	temporary 2.0	166,400
Vamoosa-Ada	Bedrock	Major	16%	1.1-1.4	1,400	1,727,000	2.0	1,034,800
Cherokee Group	Bedrock	Minor	22%	3.0	0	1,358,000	temporary 2.0	1,484,800
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	3%	2.1	0	265,000	temporary 2.0	230,400
Verdigris River Groundwater Basin	Alluvial	Minor	2%	4.2	0	162,000	temporary 2.0	128,000
Non-Delineated Groundwater Source	Alluvial	Minor			300		temporary 2.0	
Non-Delineated Groundwater Source	Bedrock	Minor			700		temporary 2.0	

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
Middle Arkansas Region



Major bedrock aquifers in the Middle Arkansas Region include the Roubidoux and Vamoosa-Ada. Major alluvial aquifers in the region include the Arkansas River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

For the 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 Middle Arkansas Region. For groundwater, equal proportionate shares in the Middle Arkansas Region are 2 acre-feet per year (AFY) per acre for all aquifers. Projections indicate that there will be groundwater available for new permits through 2060 in all basins in the 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.

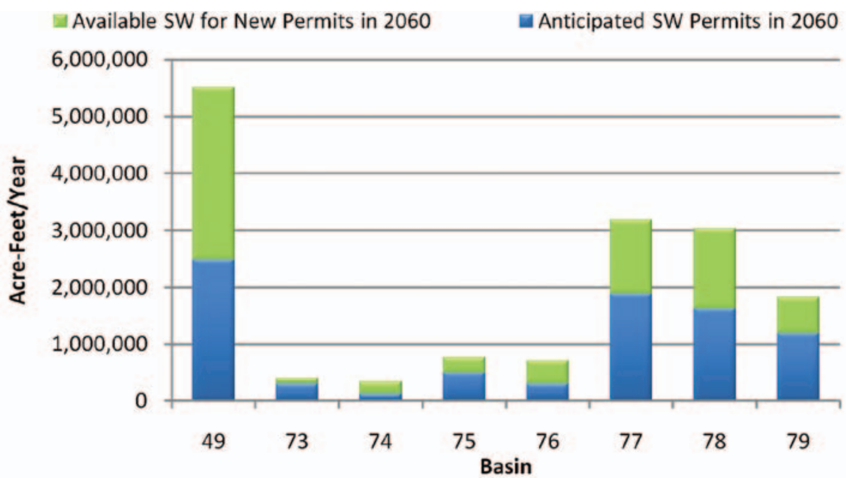
To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations,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

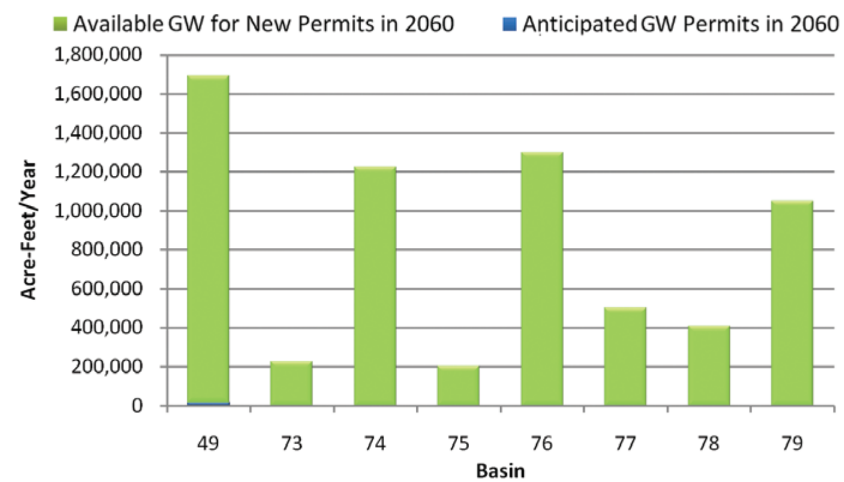
For OCWP analysis, the geographical area overlying all aquifers in each basin was determined and the respective EPS or temporary permit allocations were applied. Total current and anticipated future permit needs were then calculated to project remaining groundwater permit availability.

Surface Water Permit Availability
Middle Arkansas Region



Projections indicate that there will be surface water available for new permits through 2060 in all basins in the Middle Arkansas Region. Water users throughout the region should consider utilizing available water rights in existing reservoirs.

Groundwater Permit Availability
Middle Arkansas Region



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

Water Quality

Water quality of the Middle Arkansas Watershed Planning Region is defined by two major river systems, the Arkansas and Verdigris Rivers, and numerous minor and major water supply/flood control reservoirs. The majority of the region is contained within the Central Irregular Plains (CIP) ecoregion to the east, with considerable Cross Timbers (CT) influence to the west. The Flint Hills (FH) borders along the northwestern edge.

The Osage Cuestas region of the CIP covers greater than one half of the region's eastern geographical area and is drained by the Arkansas and Verdigris Rivers and their tributaries. The area is an irregular plain, underlain by sandstone, shale, and limestone. It is dominated by rangeland and some cropland, interspersed with native tall grass prairies and extensive but disconnected oak-hickory forest. Typically, turbid and deep streams with incised banks meander in broad low gradient valleys. Habitat can be good, but in many areas is choked by mud/silt. The Verdigris runs from north to south through the center, with several major tributaries entering from the west, including Bird and Caney Creeks. The Arkansas drains the lower portion of the ecoregion. Copan, Claremore, and Oologah Lakes are typical water supply lakes in the north. Salinity is low/moderate with mean conductivity in the Verdigris ranging from 300-400 uS, and in lakes, from typically 150-300 uS to over 400 uS (Oologah). In the Arkansas, conductivity remains high, ranging from over 1500 (Bixby) down to 1400 uS (Haskell). Total nitrogen (TN) and phosphorus (TP) values vary in the upper Verdigris drainage, ranging from 0.10-0.37 ppm of TP and 0.90-2.67 ppm of TN, with values low at Keetonville and high on Bird Creek. Along with the phosphorus-limited lakes, all upper areas are eutrophic to hyper-eutrophic. On the lower Verdigris (Caney and Wagoner), nutrient values decrease to 0.16 (TP) and 1.15-1.45 (TN), with Wagoner classified as mesotrophic. The Arkansas is hyper-eutrophic, with TP = 0.23 and TN ranging from 1.34-1.44 ppm. Water clarity is good to fair on the Arkansas (turbidity = 21-40 NTU), and fair (Wagoner and Bird Creek turbidity = 33 NTU) to poor (Caney = 66 NTU) along the Verdigris drainage. Lake clarity is average to good, with average Secchi depths of 32 (Copan) to 68 cm (Oologah). Ecological diversity varies throughout depending on habitat degradation and sedimentation and is typically lower than ecoregions to the east but higher than to the west.

The Northern Cross Timbers covers most of western third of the region. The area is more forested than the neighboring CIP with intervening grasslands and mixed land use. Streams are diverse through the ecoregion. They are narrower, shallower and sand/silt dominated, but still incised. The area is typified by upper Bird Creek in the north and the Arkansas River below Keystone Reservoir to the south. Also, numerous small to large lakes cover the area, including Hulah, Hudson, Waxhoma, Birch, Hominy, Skiatook, Shell, Sahoma, and Heyburn Lakes—going north to south. In streams, salinity is moderate to high with conductivity ranging from 200-300 uS (Bird) to over 1,600 uS (Arkansas). On lakes, salinity is low (Bixhoma = 50-100 uS) to moderate (Skiatook = 200-330 uS). Streams are typically mesotrophic, with TP less than 0.15 and TN less than 1.16 ppm. Lakes are phosphorus limited and range from mesotrophic (e.g.,

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.

Ecoregions
Middle Arkansas Region

The Middle Arkansas Planning Region is dominated by Central Irregular Plains to the east and to a lesser extent, the Cross Timbers to the west. Water quality is highly influenced by both geology and land use practices, and ranges from poor to excellent depending on drainage and location.

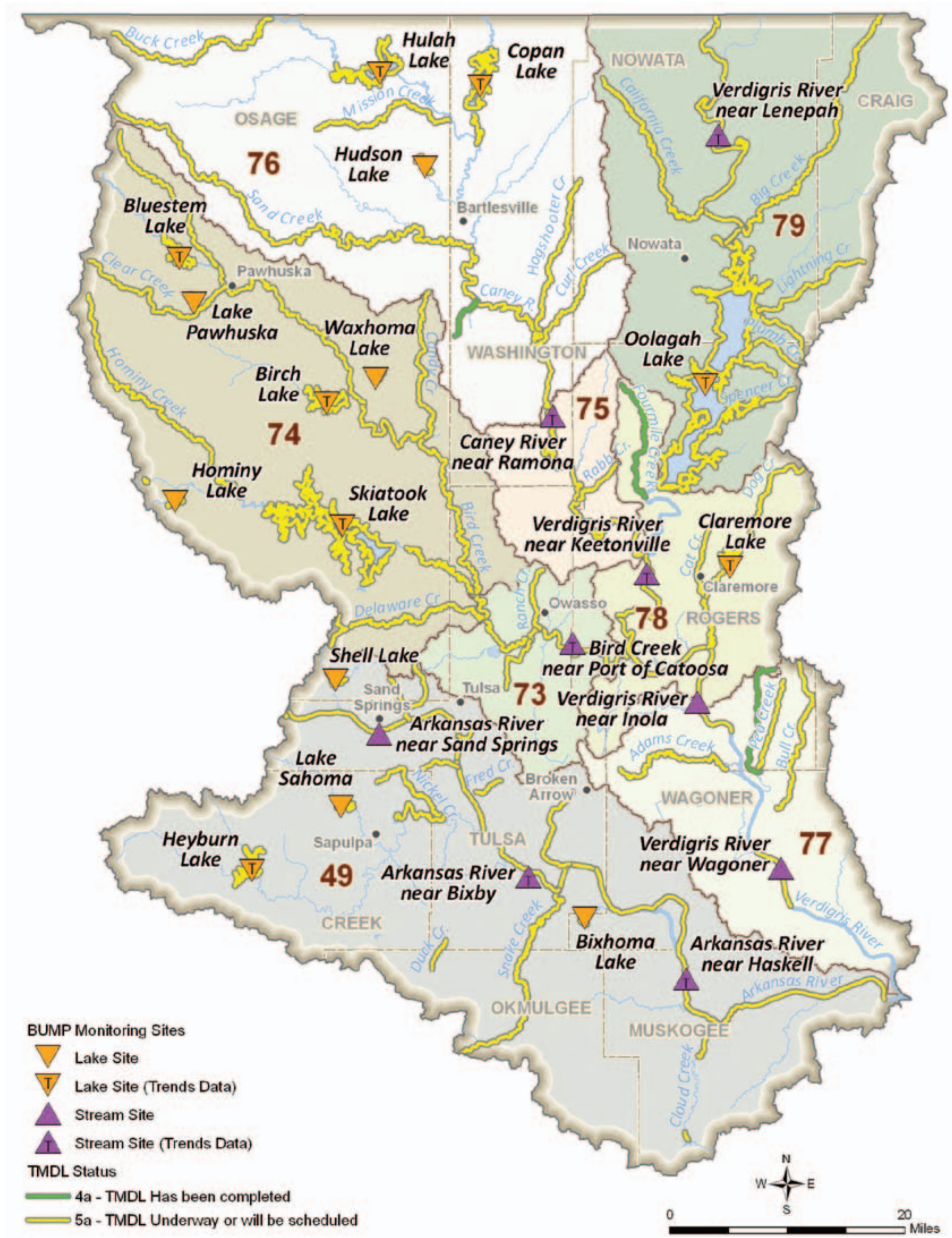
Skiatook, Waxhoma, Bixhoma, and Heyburn) to eutrophic, and nearly hyper-eutrophic (e.g., Hudson). Stream water clarity is excellent (less than 10 NTU on small tributaries) to good on the Arkansas (21 NTU). Lake clarity is variable with many average to excellent (Bixhoma = 146 cm; Waxhoma = 153 cm). However, clarity can be poor (Hulah = 27 cm). Ecological diversity is fair to good, but impacted by poor habitat, salinity (Arkansas), and sedimentation.

Finally, the Flint Hills are underlain by shallow limestone/shale. FH are mostly low hills of rangeland/grassland, including tall grass prairie. Channels are more natural, with low to incised banks and gravel/cobble bottoms. The area is characterized by the headwaters of Bird Creek, and Bluestem and Pawhuska Lakes. Salinity is moderate, with conductivity ranging from 240 (Bluestem) to 500uS (Pawhuska). Lakes are eutrophic and phosphorus limited. Clarity is average (Bluestem = 47 cm) to excellent (Pawhuska = 195 cm). Stream turbidity is typically good. Ecological diversity is higher because of stream morphology and lower salinity/habitat degradation.

Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed, and data are available from municipal authorities and other sources. As was stated earlier in this document, the Middle Arkansas region is underlain by several major and minor bedrock and alluvial aquifers. Water from the Arkansas and Verdigris River alluvial and terrace deposits yield water which is generally hard, typically of a sodium/calcium bicarbonate type, and in some areas, exceeds drinking water standards. The alluvium and terrace aquifers are highly vulnerable to contamination from surface activities due to their high porosities and permeability and shallow water tables. However, alluvial water is generally suitable for most purposes.

Major bedrock aquifers in the region include the Roubidoux and Vamoosa-Ada. Part of the Ozark aquifer, the Roubidoux is in the northeastern

Water Quality Standards Implementation
Middle Arkansas Region



The Middle Arkansas Region could benefit from additional non-point source restoration programs. The ODEQ has completed TMDL studies on Keeler Creek, Inola Creek, and Fourmile 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.

Water Quality Impairments
Middle Arkansas Region

Regional water quality impairments are based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Many surface waters in this region have impacts from urbanization, including increased nutrients and sediment, as well as stream habitat alterations due to increases in impervious surfaces. Other surface water impairments in this region occur from eutrophication of water supplies.

tip of the region (Craig County). Water is hard but generally has low total mineral content. However, in far western portion of the aquifer, concentrations of chloride, sulfate and fluoride exceed drinking water standards. Naturally occurring radioactivity has been detected in some areas. Large concentrations of gross-alpha radioactivity and radium-226 occur near the western edge and appear to be correlated with chloride concentrations. The aquifer is a confined aquifer and is not vulnerable to contamination from surface activities. The Vamoosa-Ada lies along the western edge of the region. Although water quality is generally good, iron infiltration and hardness are problems. Chloride and sulfate concentrations are generally low and, except for areas of local contamination resulting from past oil and gas activities, water is suitable for use as public supply.

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

Middle Arkansas Region

Surface Waters with Designated Beneficial Use for Agriculture

Middle Arkansas Region

Surface Water Protection

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

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

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

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

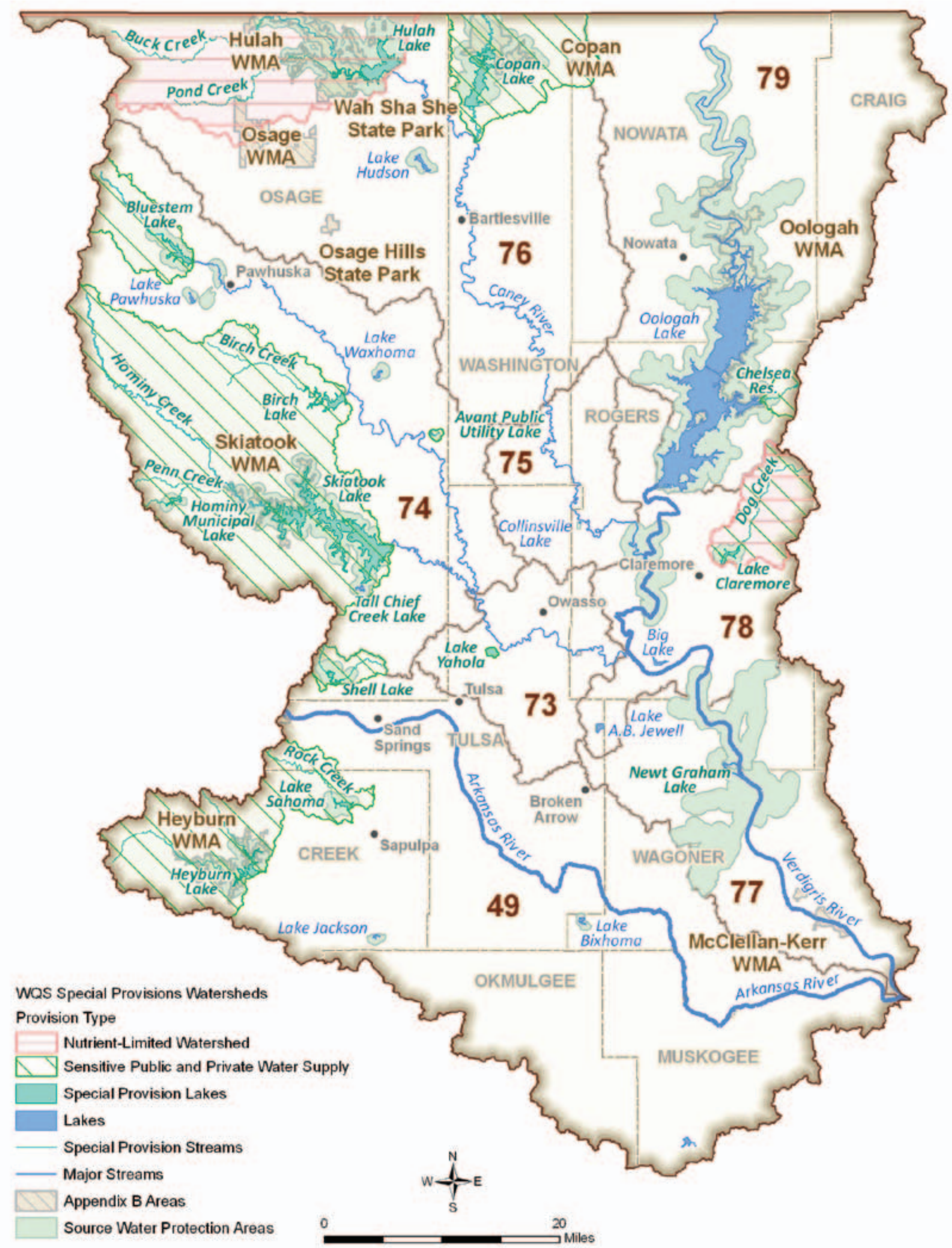
The **Sensitive Water Supplies (SWS)** designation applies to public and private water supplies possessing conditions making them more susceptible to pollution events, thus requiring additional protection. This designation restricts point source discharges in the watershed and institutes a 10 μg/L (micrograms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

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

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

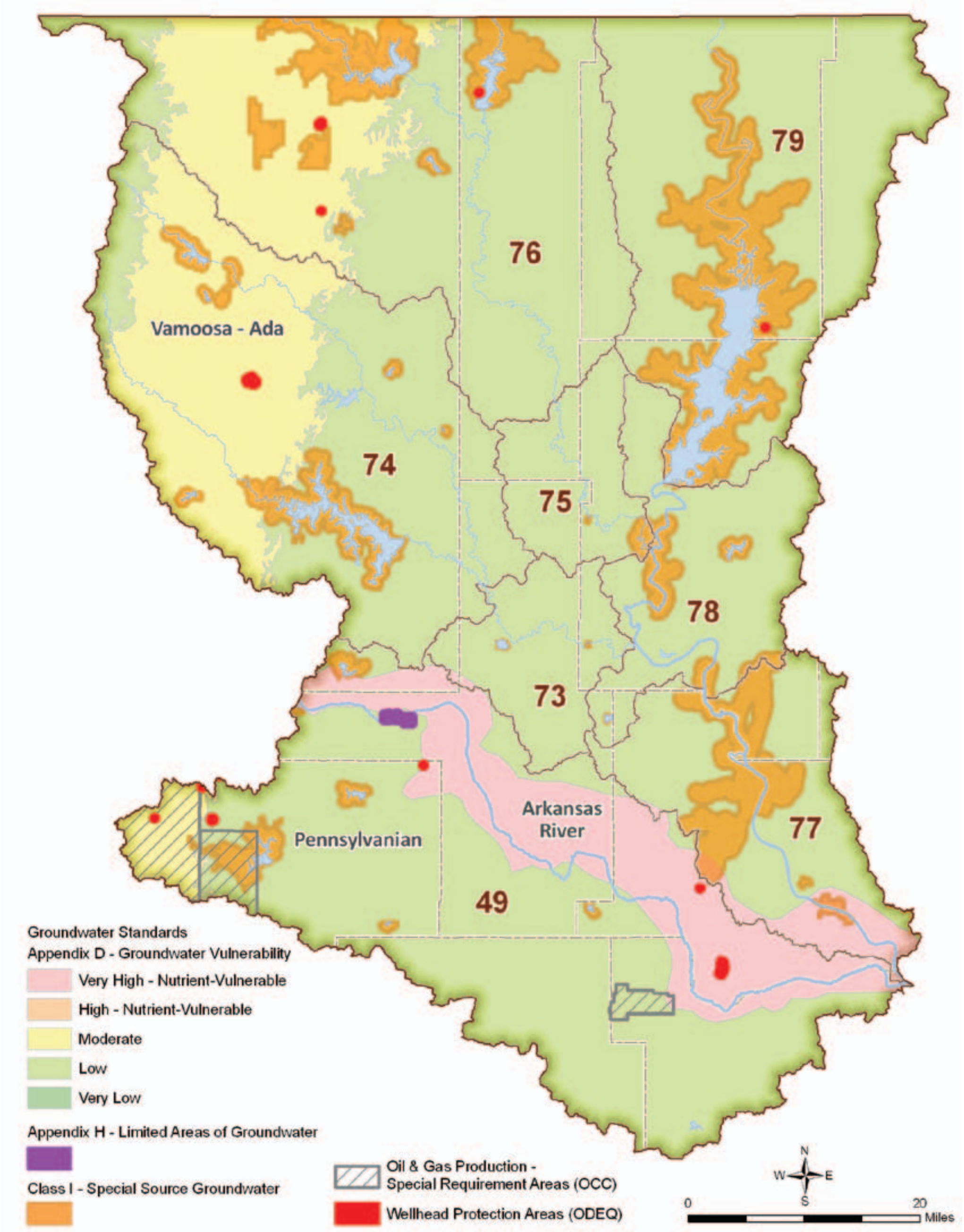
Nutrient-Limited Watersheds are those containing a waterbody with a designated beneficial use that is adversely affected by excess nutrients.

Surface Water Protection Areas
Middle Arkansas Region



Since Lakes Hudson, Pawhuska, Waxhoma, Avant, Jackson, and Bixhoma are public water supply reservoirs and have relatively small watersheds, they could potentially benefit from SWS designations. This designation could provide protection from new or increased loading from point sources in the watershed. This additional protection would also provide limits for algae (chlorophyll-a) that can cause taste and odor problems and increased treatment costs.

Groundwater Protection Areas
Middle Arkansas Region



Various types of protection are in place to prevent degradation of groundwater and address vulnerability. Groundwater quality in this region could benefit from more protection for the Arkansas River alluvial aquifer which has been identified by the OWRB as a "very high" nutrient vulnerable aquifer.

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
Middle Arkansas Region

Parameter	Birch Lake (1980-2009)	Bluestem Lake (1995-2009)	Claremore Lake (1994-2006)	Copan Lake (1994-2008)	Heyburn Lake (1996-2008)	Hulah Lake (1994-2008)	Oologah Lake (1996-2008)	Skiatook Lake (1991-2007)
Chlorophyll-a (mg/m3)	NT	↓	NT	↑	NT	NT	NT	NT
Conductivity (us/cm)	NT	↑	NT	↓	↑	↓	↓	↓
Total Nitrogen (mg/L)	NT	↓	↑	NT	↑	↑	↓	NT
Total Phosphorus (mg/L)	↓	↓	↓	↑	↑	NT	NT	NT
Turbidity (NTU)	↓	↓	↑	↑	↓	↑	↓	NT

Increasing Trend ↑ **Decreasing Trend** ↓ NT = No significant trend detected

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

Notable concerns for reservoir water quality include the following:

- Significant upward trend for total nitrogen on Claremore, Heyburn, and Hulah reservoirs.
- Significant upward trend for turbidity and total phosphorus on various reservoirs.

Stream Water Quality Trends
Middle Arkansas Region

Parameter	Arkansas River near Bixby		Arkansas River near Haskell		Bird Creek at Port of Catoosa		Caney River near Ramona		Verdigris River near Keetonville		Verdigris River near Lenepah	
	All Data Trend (1977-1995, 1998-2009)1	Recent Trend (1998-2009)	All Data Trend (1974-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1974-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1951-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1947-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1944-1993, 1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	NT	NT	↓	↓	NT	NT	↓	NT	↓	NT	↑	NT
Total Nitrogen (mg/L)	↓	↑	↓	↑	↑	↑	↓	NT	↓	NT	↓	NT
Total Phosphorus (mg/L)	NT	NT	↓	↑	NT	NT	↓	↓	↓	↓	↓	NT
Turbidity (NTU)	↑	NT	↑	↑	NT	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.

1 *Date ranges for analyzed data represent the earliest site visit date for at least one parameter yet may not be inclusive of all parameters.*

Notable concerns for stream water quality include the following:

- Significant upward trend for total nitrogen on the Arkansas River and Bird Creek.
- Significant upward trend for turbidity throughout region.

Water Demand

Water demand the Middle Arkansas Region accounts for about 12% of the total statewide demand. Regional demand will increase by 33% (75,630 AFY) from 2010 to 2060. The majority of the demand and growth in demand during this period will be in the Municipal and Industrial sector followed by Thermoelectric Power.

Municipal and Industrial demand is expected to remain the largest demand sector in the region, accounting for approximately 63% of the total regional demand in 2060. Currently, 99% of the demand from this sector is supplied by surface water and 1% by bedrock groundwater.

Thermoelectric Power demand is projected to account for 24% of the 2060 demand. The Green Country OP Services' Green Country Energy plant, Barlow Operators of Tulsa's Walter B. Hall Resource Recovery Facility, and Public Service Company of Oklahoma's Riverside, Tulsa, and Northeastern Plants are the users of water for thermoelectric power generation in the region. Currently, 99% of the demand from this sector is supplied by surface water and 1% by alluvial groundwater.

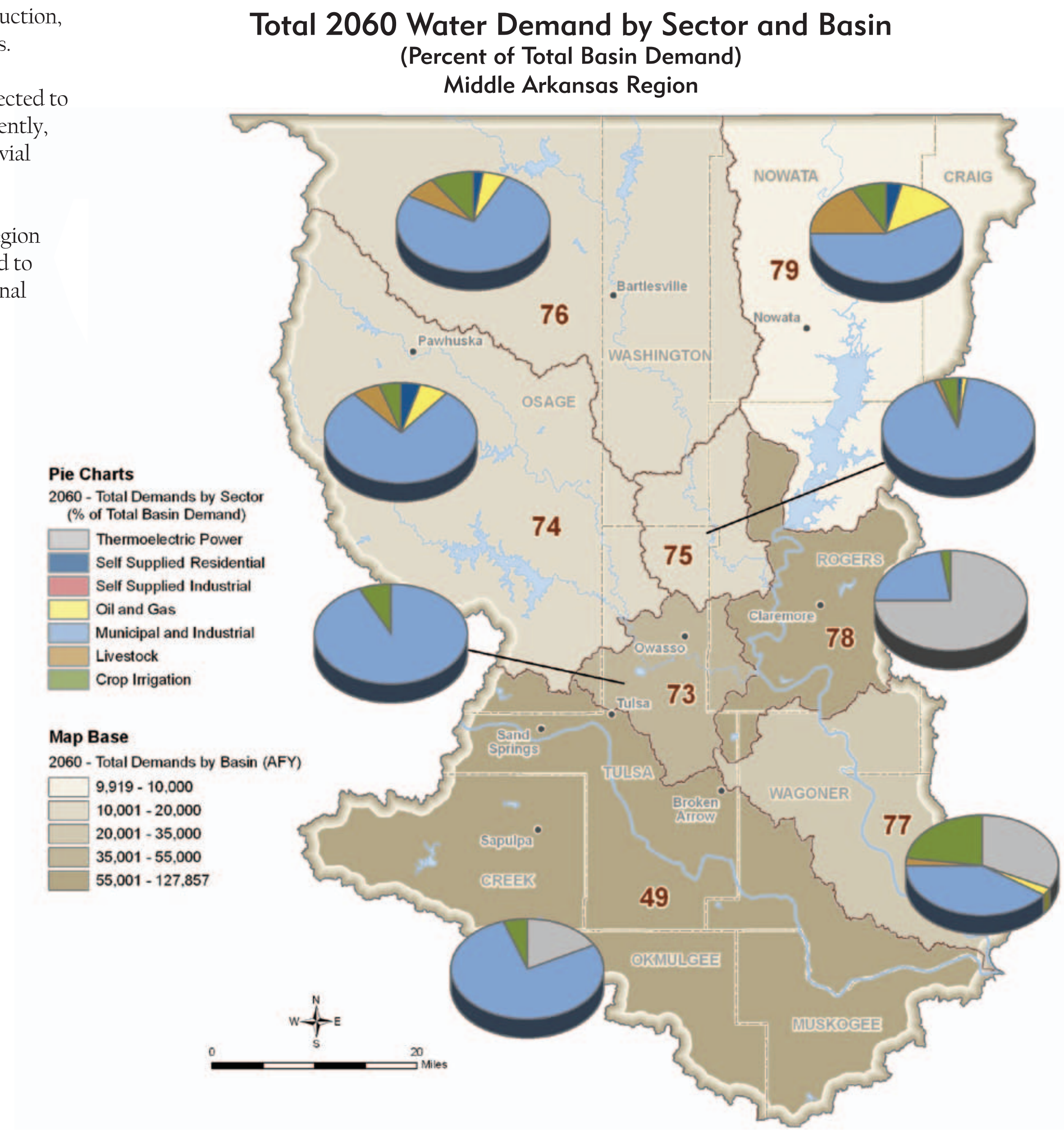
Crop Irrigation demand is expected to account for 8% of the 2060 demand. Currently, 67% of the demand from this sector is supplied by surface water, 32% by alluvial groundwater, and 1% by bedrock groundwater. Predominant irrigated crops in the Middle Arkansas Region include pasture grasses and sod.

Oil and Gas demand is projected to account for approximately 2% of the 2060 demand. Currently, demand for this sector is supplied by surface water.

Livestock demand is projected to account for 2% of the 2060 demand. Currently, 83% of the demand from this sector is supplied by surface water, 16% by alluvial groundwater, and 1% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production, followed distantly by chickens and horses.

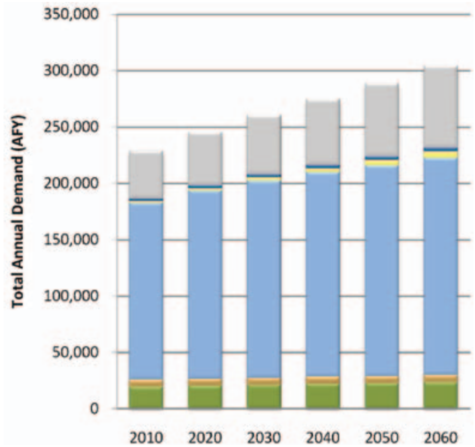
Self-Supplied Residential demand is projected to account for 1% of the 2060 demand. Currently, demand for this sector is supplied by alluvial groundwater.

Self-Supplied Industrial demand in the region is supplied by surface water and projected to account for less than 1% of the total regional demand in 2060.

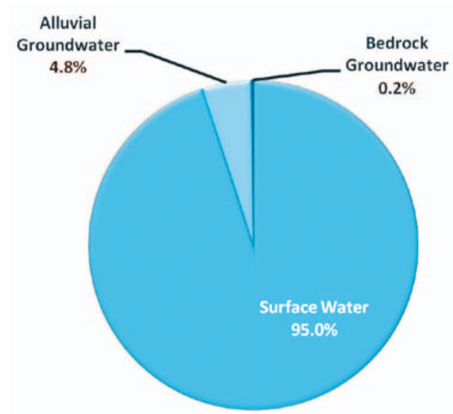


Projected water demand by sector. Municipal and Industrial is expected to remain the largest demand sector in the region, accounting for 63% of the total regional demand in 2060.

Total Water Demand by Sector
Middle Arkansas Region



Supply Sources Used to Meet Current Demand (2010)
Middle Arkansas Region



Water needs in the Middle Arkansas Region account for about 12% of the total statewide demand. Regional demand will increase by 33% (75,630 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial sector followed by Thermoelectric Power.

Total Water Demand by Sector
Middle Arkansas Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	19,500	6,190	157,080	1,350	110	2,520	41,910	228,660
2020	20,310	6,220	167,180	1,950	110	2,720	46,750	245,240
2030	21,130	6,260	175,200	2,660	110	2,880	52,160	260,390
2040	21,940	6,300	181,640	3,500	110	3,020	58,190	274,690
2050	22,560	6,330	187,280	4,450	120	3,150	64,920	288,810
2060	23,560	6,370	193,000	5,520	120	3,290	72,420	304,290

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 Middle Arkansas Region includes 90 of the 785 OCWP public supply systems. 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 Tulsa, Broken Arrow WTP, Bartlesville, Sand Springs, and Owasso. Together, these five systems serve over 65 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.

Public Water Providers
Middle Arkansas Region

Population and Demand Projection Data

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

Public Water Providers/Retail Population Served (1 of 3)

Middle Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
AVANT UTIL AUTH	OK1021305	Osage	71	392	421	441	460	480	499
BAR-DEW WATER ASSOC INC	OK3007406	Washington	200	211	216	218	221	224	227
BARNSDALL	OK1021304	Osage	189	1,354	1,449	1,516	1,582	1,649	1,716
BARTLESVILLE	OK1021401	Washington	119	34,920	35,693	36,040	36,535	37,021	37,585
BIRCH CREEK RWD	OK2005743	Osage	51	40	43	45	47	49	51
BIXBY PWA	OK3007243	Tulsa	103	22,933	24,174	25,203	25,938	26,494	27,033
BOYNTON PWA	OK3005127	Muskogee	115	274	284	294	303	313	313
BROKEN ARROW WTP[3]	OK1021508	Tulsa	125	100,000	122,000	149,000	165,000	182,000	200,800
CATOOSA	OK3006629	Rogers	299	3,187	3,582	3,920	4,237	4,560	4,884
CLAREMORE	OK1021512	Rogers	194	17,116	19,226	21,043	22,726	24,456	26,234
COLLINSVILLE	OK1021505	Tulsa	128	4,766	5,019	5,240	5,394	5,504	5,614
COPAN PWA	OK1021417	Washington	129	1,168	1,196	1,196	1,211	1,225	1,254
COWETA	OK1021509	Wagoner	105	7,397	8,267	8,981	9,640	10,290	10,968
CREEK CO RWD #1	OK1020419	Creek	218	6,051	6,471	6,799	7,110	7,421	7,756
CREEK CO RWD #2	OK3001902	Creek	119	11,162	11,937	12,542	13,116	13,690	14,308
CREEK CO CONSOLIDATED RWD #3	OK3001916	Creek	101	3,064	3,276	3,442	3,600	3,758	3,927
CREEK CO RWD #4	OK3001920	Creek	83	1,021	1,092	1,147	1,200	1,253	1,309
CREEK CO RWD #7	OK1020405	Creek	77	2,316	2,477	2,602	2,722	2,841	2,969
DELAWARE	OK1021502	Nowata	78	473	536	600	664	737	809
DEWEY	OK3007402	Washington	203	3,299	3,381	3,412	3,463	3,504	3,555
ELM BEND RWD INC	OK3005309	Nowata	151	625	714	801	890	984	1,083
GLENPOOL WATER	OK3007223	Tulsa	60	9,719	10,247	10,686	11,001	11,226	11,462
HASKELL PWA	OK2005111	Muskogee	100	60	62	64	66	68	69
HOMINY	OK1021306	Osage	249	2,636	2,827	2,970	3,094	3,228	3,371
INOLA WATER WORKS INC	OK3006612	Rogers	147	1,649	1,851	2,034	2,199	2,364	2,538
JENKS PWA	OK3007201	Tulsa	213	9,724	10,250	10,690	10,996	11,236	11,465
LE ANN WATER	OK3007407	Washington	203	753	770	777	788	799	811
LENAPAH	OK1021501	Nowata	106	309	354	391	436	482	527
MUSKOGEE CO RWD #9	OK3005119	Muskogee	102	302	313	322	330	338	346
MUSKOGEE CO RWD #10	OK3005128	Muskogee	80	276	285	294	301	309	316
MUSKOGEE CO RWD #14	OK3005134	Muskogee	105	60	63	64	66	68	69
NOWATA	OK1021503	Nowata	112	10,416	11,894	13,372	14,850	16,420	18,060
NOWATA CO RW & SD #1	OK3005304	Nowata	95	521	595	668	742	820	902
NOWATA & ROGERS CO CONSOLIDATED RWD #1	OK3005301	Nowata	91	1,713	1,956	2,197	2,441	2,697	2,969
NOWATA CO RWD #2	OK3005303	Nowata	86	364	416	467	519	574	632

Public Water Providers/Retail Population Served (2 of 3)

Middle Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
NOWATA CO RWD #3	OK3005302	Nowata	71	286	327	367	408	451	496
NOWATA CO RWD #5	OK3005307	Nowata	63	103	118	132	147	162	179
NOWATA CO RWD #6	OK3005308	Nowata	72	468	535	601	668	738	812
NOWATA CO RWD #7	OK3005321	Nowata	97	1,457	1,665	1,870	2,077	2,295	2,527
OCHELATA UTIL AUTH	OK3007414	Washington	202	494	504	514	524	524	534
OKAY PWA	OK3007351	Wagoner	65	619	683	746	801	855	910
OKMULGEE CO RWD #6 (HECTORVILLE RWD #6)	OK3005611	Okmulgee	84	7,882	8,458	8,963	9,487	10,030	10,573
OSAGE CO RWD #1	OK3005704	Osage	106	944	1,012	1,061	1,107	1,153	1,205
OSAGE CO RWD #20 (HULAH)	OK1021410	Osage	211	155	166	174	182	189	198
OSAGE CO RWD #5	OK3005721	Osage	101	521	558	585	610	636	664
OSAGE CO RWD #9	OK3005702	Osage	83	291	312	327	341	355	371
OSAGE CO RWD #15	OK3005736	Osage	61	7,454	7,985	8,379	8,740	9,101	9,510
OSAGE CO RWD #18 (EVERGREEN)	OK3005744	Osage	80	308	330	347	361	376	393
OWASSO	OK3007218	Tulsa	94	23,908	25,209	26,291	27,056	27,628	28,199
PAWHUSKA	OK1021301	Osage	178	3,878	4,154	4,359	4,547	4,735	4,948
PORTER PWA	OK3007306	Wagoner	70	2,450	2,752	2,978	3,204	3,431	3,657
RAMONA	OK3007408	Washington	239	1,550	1,577	1,604	1,632	1,659	1,686
RED BIRD	OK3007305	Wagoner	50	159	177	196	215	224	243
ROGERS CO RWD #2	OK3006603	Rogers	76	2,855	3,207	3,511	3,792	4,081	4,377
ROGERS CO RWD #3 COT STA	OK3006650	Rogers	187	4,283	4,812	5,267	5,689	6,123	6,567
ROGERS CO RWD #3 LAKE PLANT	OK1021513	Rogers	128	3,955	4,444	4,864	5,254	5,654	6,064
ROGERS CO RWD #4	OK1021506	Rogers	378	2,595	2,916	3,191	3,447	3,710	3,979
ROGERS CO RWD #5	OK1021507	Rogers	138	10,532	11,833	12,951	13,989	15,054	16,146
ROGERS CO RWD #6	OK3006628	Rogers	159	1,038	1,166	1,277	1,379	1,484	1,592
ROGERS CO RWD #7	OK3006604	Rogers	117	2,907	3,266	3,574	3,861	4,155	4,456
ROGERS CO RWD #8	OK3006606	Rogers	117	3,114	3,499	3,830	4,137	4,452	4,775
ROGERS CO RWD #9	OK3006605	Rogers	78	910	1,023	1,120	1,209	1,301	1,396
ROGERS CO RWD #12	OK3006648	Rogers	273	183	205	225	243	261	280
ROGERS CO RWD #15	OK3006652	Rogers	154	38	43	47	51	55	59
SAND SPRINGS	OK1020420	Tulsa	148	34,718	36,601	38,160	39,264	40,100	40,918
SAND SPRINGS SKYLINE/81ST AREA	OK3007244	Tulsa	144	51	54	56	58	59	60
SAPULPA	OK1020404	Creek	102	19,573	20,940	22,001	23,004	24,017	25,097
SAPULPA RURAL WATER COMPANY	OK3001904	Creek	122	7,000	7,488	7,868	8,227	8,589	8,975
SKIATOOK PWA	OK1021313	Osage	179	2,498	2,673	2,805	2,924	3,050	3,182
SOUTH COFFEYVILLE	OK3005305	Nowata	107	458	524	588	653	722	795

Public Water Providers/Retail Population Served (3 of 3)
Middle Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
SPERRY	OK3007202	Tulsa	243	1,038	1,098	1,148	1,178	1,208	1,228
STRIKE AXE (CHIMNEY ROCK)	OK3005739	Osage	73	281	301	316	329	343	358
STRIKE-AXE HWY 60	OK3005701	Osage	163	459	492	516	539	561	586
TAFT	OK3005118	Muskogee	95	355	367	378	387	397	406
TULLAHASSEE WATER	OK3007338	Wagoner	50	112	121	139	149	158	167
TULSA	OK1020418	Tulsa	229	390,771	411,984	429,668	442,134	451,592	460,795
TULSA CO W IMP DIST #14	OK3007213	Tulsa	61	1,337	1,410	1,470	1,513	1,545	1,577
WAGONER	OK1021649	Wagoner	172	8,804	9,839	10,691	11,472	12,243	13,054
WAGONER CO RWD #4	OK1021529	Wagoner	96	22,664	25,311	27,505	29,523	31,510	33,597
WAGONER CO RWD #5	OK1021528	Wagoner	94	7,899	8,822	9,586	10,290	10,982	11,709
WAGONER CO RWD #6	OK3007330	Wagoner	115	1,347	1,504	1,635	1,755	1,873	1,997
WAGONER CO RWD #7 (NEW)	OK1221626	Wagoner	108	1,347	1,504	1,635	1,755	1,873	1,997
WAGONER CO RWD #9	OK1021527	Wagoner	110	3,927	4,386	4,766	5,116	5,460	5,822
WASHINGTON CO RWD #1	OK3007401	Washington	109	1,105	1,129	1,140	1,156	1,171	1,190
WASHINGTON CO RWD #2	OK3007403	Washington	112	2,260	2,310	2,332	2,364	2,396	2,433
WASHINGTON CO RWD #3 (NEW,#1)	OK1021418	Tulsa	106	17,107	18,035	18,810	19,357	19,770	20,174
WASHINGTON CO RWD #5	OK3007409	Washington	75	1,005	1,027	1,036	1,051	1,065	1,081
WASHINGTON CO RWD #7	OK3007415	Washington	235	342	349	352	357	362	368
WATER IMPROVEMENT DISTRICT #3	OK3007221	Tulsa	66	3,053	3,218	3,357	3,454	3,528	3,600
WYNONA	OK2005708	Osage	70	542	580	609	638	666	695

1 SDWIS - Safe Drinking Water Information System

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

3 Population projections taken from Broken Arrow Master Supply Improvements Report, 2008

Projections of Retail Water Demands

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

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

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

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

Public Water Provider Demand Forecast (1 of 3)

Middle Arkansas Region

Provider	SDWIS ID[1]	County	Demand 2010	2020	2030	2040	2050	2060
			AFY					
AVANT UTIL AUTH	OK1021305	Osage	31	34	35	37	38	40
BAR-DEW WATER ASSOC INC	OK3007406	Washington	47	48	49	49	50	51
BARNSDALL	OK1021304	Osage	286	306	320	334	349	363
BARTLESVILLE	OK1021401	Washington	4,658	4,761	4,808	4,874	4,939	5,014
BIRCH CREEK RWD	OK2005743	Osage	2	2	3	3	3	3
BIXBY PWA	OK3007243	Tulsa	2,634	2,776	2,894	2,979	3,043	3,105
BOYNTON PWA	OK3005127	Muskogee	35	37	38	39	40	40
BROKEN ARROW WTP	OK1021508	Tulsa	14,002	17,082	20,863	23,103	25,483	28,116
CATOOSA	OK3006629	Rogers	1,066	1,199	1,312	1,418	1,526	1,634
CLAREMORE	OK1021512	Rogers	3,721	4,180	4,575	4,941	5,317	5,703
COLLINSVILLE	OK1021505	Tulsa	681	717	749	771	787	802
COPAN PWA	OK1021417	Washington	169	173	173	176	178	182
COWETA	OK1021509	Wagoner	870	972	1,056	1,134	1,210	1,290
CREEK CO RWD #1	OK1020419	Creek	1,476	1,578	1,658	1,734	1,810	1,892
CREEK CO RWD #2	OK3001902	Creek	1,487	1,590	1,671	1,747	1,824	1,906
CREEK CO CONSOLIDATED RWD #3	OK3001916	Creek	346	370	388	406	424	443
CREEK CO RWD #4	OK3001920	Creek	95	102	107	112	116	122
CREEK CO RWD #7	OK1020405	Creek	200	214	225	235	246	257
DELAWARE	OK1021502	Nowata	41	47	53	58	65	71
DEWEY	OK3007402	Washington	749	767	774	786	795	807
ELM BEND RWD INC	OK3005309	Nowata	105	120	135	150	166	183
GLENPOOL WATER	OK3007223	Tulsa	654	690	719	741	756	772
HASKELL PWA	OK2005111	Muskogee	7	7	7	7	8	8
HOMINY	OK1021306	Osage	735	788	828	863	900	940
INOLA WATER WORKS INC	OK3006612	Rogers	272	305	335	362	389	418
JENKS PWA	OK3007201	Tulsa	2,321	2,447	2,552	2,625	2,682	2,737
LE ANN WATER	OK3007407	Washington	171	175	176	179	181	184
LENAPAH	OK1021501	Nowata	37	42	46	52	57	62
MUSKOGEE CO RWD #9	OK3005119	Muskogee	35	36	37	38	39	40
MUSKOGEE CO RWD #10	OK3005128	Muskogee	25	26	26	27	28	28
MUSKOGEE CO RWD #14	OK3005134	Muskogee	7	7	8	8	8	8
NOWATA	OK1021503	Nowata	1,311	1,497	1,684	1,870	2,067	2,274
NOWATA CO RW & S DIST #1	OK3005304	Nowata	55	63	71	79	87	96
NOWATA & ROGERS CO CONSOLIDATED RWD #1	OK3005301	Nowata	175	200	224	249	275	303

Public Water Provider Demand Forecast (2 of 3)
Middle Arkansas Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
NOWATA CO RWD #2	OK3005303	Nowata	35	40	45	50	55	61
NOWATA CO RWD #3	OK3005302	Nowata	23	26	29	32	36	39
NOWATA CO RWD #5	OK3005307	Nowata	7	8	9	10	11	13
NOWATA CO RWD #6	OK3005308	Nowata	38	43	48	54	59	65
NOWATA CO RWD #7	OK3005321	Nowata	158	180	202	225	249	274
OCHELATA UTIL AUTH	OK3007414	Washington	112	114	116	119	119	121
OKAY PWA	OK3007351	Wagoner	45	50	54	58	62	66
OKMULGEE CO RWD #6 (HECTORVILLE RWD #6)	OK3005611	Okmulgee	743	798	845	895	946	997
OSAGE CO RWD #1	OK3005704	Osage	112	120	126	131	137	143
OSAGE CO RWD #5	OK3005721	Osage	59	63	66	69	72	75
OSAGE CO RWD #9	OK3005702	Osage	27	29	30	32	33	34
OSAGE CO RWD #15	OK3005736	Osage	508	544	571	595	620	648
OSAGE CO RWD #18 (EVERGREEN)	OK3005744	Osage	27	29	31	32	34	35
OSAGE CO RWD #20 (HULAH)	OK1021410	Osage	37	39	41	43	45	47
OWASSO	OK3007218	Tulsa	2,507	2,644	2,757	2,837	2,897	2,957
PAWHUSKA	OK1021301	Osage	773	828	869	906	944	986
PORTER PWA	OK3007306	Wagoner	192	216	234	251	269	287
RAMONA	OK3007408	Washington	414	422	429	436	444	451
RED BIRD	OK3007305	Wagoner	9	10	11	12	13	14
ROGERS CO RWD #2	OK3006603	Rogers	242	272	298	322	346	371
ROGERS CO RWD #3 COT STA	OK3006650	Rogers	897	1,008	1,103	1,192	1,282	1,375
ROGERS CO RWD #3 LAKE PLANT	OK1021513	Rogers	567	637	697	753	811	869
ROGERS CO RWD #4	OK1021506	Rogers	1,100	1,236	1,353	1,461	1,572	1,686
ROGERS CO RWD #5	OK1021507	Rogers	1,628	1,829	2,002	2,162	2,327	2,496
ROGERS CO RWD #6	OK3006628	Rogers	185	208	227	246	264	283
ROGERS CO RWD #7	OK3006604	Rogers	382	429	470	508	546	586
ROGERS CO RWD #8	OK3006606	Rogers	407	457	500	541	582	624
ROGERS CO RWD #9	OK3006605	Rogers	80	90	98	106	114	123
ROGERS CO RWD #12	OK3006648	Rogers	56	63	69	74	80	86
ROGERS CO RWD #15	OK3006652	Rogers	7	7	8	9	9	10
SAND SPRINGS	OK1020420	Tulsa	5,739	6,050	6,308	6,490	6,629	6,764
SAND SPRINGS SKYLINE/81ST AREA	OK3007244	Tulsa	8	9	9	9	9	10
SAPULPA	OK1020404	Creek	2,228	2,383	2,504	2,618	2,733	2,856
SAPULPA RURAL WATER COMPANY	OK3001904	Creek	956	1,023	1,075	1,124	1,173	1,226

Public Water Provider Demand Forecast (3 of 3)
Middle Arkansas Region

Provider	SDWIS ID[1]	County	Demand 2010	2020	2030	2040	2050	2060
			AFY					
SKIATOOK PWA	OK1021313	Osage	500	535	561	585	610	637
SOUTH COFFEYVILLE	OK3005305	Nowata	55	63	71	78	87	95
SPERRY	OK3007202	Tulsa	283	299	313	321	329	335
STRIKE AXE (CHIMNEY ROCK)	OK3005739	Osage	23	25	26	27	28	29
STRIKE-AXE HWY 60	OK3005701	Osage	84	90	94	98	103	107
TAFT	OK3005118	Muskogee	38	39	40	41	42	43
TULLAHASSEE WATER	OK3007338	Wagoner	6	7	8	8	9	9
TULSA[2]	OK1020418	Tulsa	121,390	135,425	147,108	157,335	168,414	180,272
TULSA CO W IMP DIST #14	OK3007213	Tulsa	91	96	100	103	106	108
WAGONER	OK1021649	Wagoner	1,694	1,893	2,057	2,207	2,356	2,512
WAGONER CO RWD #4	OK1021529	Wagoner	2,450	2,736	2,973	3,191	3,406	3,631
WAGONER CO RWD #5	OK1021528	Wagoner	833	931	1,011	1,086	1,159	1,235
WAGONER CO RWD #6	OK3007330	Wagoner	174	194	211	227	242	258
WAGONER CO RWD #7 (NEW)	OK1221626	Wagoner	162	181	197	212	226	241
WAGONER CO RWD #9	OK1021527	Wagoner	483	539	586	629	671	716
WASHINGTON CO RWD #1	OK3007401	Washington	135	138	139	141	143	145
WASHINGTON CO RWD #2	OK3007403	Washington	285	291	294	298	302	306
WASHINGTON CO RWD #3 (NEW,#1)	OK1021418	Tulsa	2,029	2,139	2,231	2,296	2,345	2,393
WASHINGTON CO RWD #5	OK3007409	Washington	84	86	87	88	89	90
WASHINGTON CO RWD #7	OK3007415	Washington	90	92	93	94	95	97
WATER IMPROVEMENT DISTRICT #3	OK3007221	Tulsa	225	237	247	254	260	265
WYNONA	OK2005708	Osage	42	45	48	50	52	54

1 SDWIS - Safe Drinking Water Information System

2 Tulsa Demands taken from Tulsa Comprehensive Water System Study, 2005 Addendum.

Wholesale Water Transfers (1 of 4)

Middle Arkansas Region

		Sales			Purchases		
Provider	**SDWIS ID[1]**	**Sells To**	**Emergency or Ongoing**	**Treated or Raw or Both**	**Purchases From**	**Emergency or Ongoing**	**Treated or Raw or Both**
BARNSDALL	OK1021304	Osage Co RWD # 5 Osage Co RWD #9	O O	T T			
BARTLESVILLE	OK1021401	Dewey Washington Co RWD #2 Le Ann Water Ochelata Utility Authority Washington Co RWD #1 Osage Co RWD #1 Strike Axe Washington Co RWD #5 Bar-Dew Water Assoc Inc	O O O O O O O O O	T T T T T T T T T			
BAR-DEW WATER ASSOC INC	OK3007406				Bartlesville	O	T
BIXBY PWA	OK3007243				Tulsa	O	T
BOYNTON PWA	OK3005127	Muskogee Co RWD # 14	O	T	Haskell County Water Company		
BROKEN ARROW WTP	OK1021508	Wagoner Co RWD #5	O	T	Oklahoma Ordnance Works Authority	O	T
CATOOSA	OK3006629				Tulsa	O	T
CLAREMORE	OK1021512	Rogers Co RWD #8 Rogers Co RWD #7 Rogers Co RWD #2 Rogers Co RWD #9	O O O	T T T			
COLLINSVILLE	OK1021505				Tulsa	O	
COPAN PWA	OK1021417	Washington Co RWD #7	O	T			
COWETA	OK1021509	Wagoner Co RWD #5	O	T			
CREEK CO RWD #1	OK1020419	Creek Co RWD #2	O	T			
		Creek Co RWD #3	O	T			
CREEK CO RWD #2	OK3001902	Creek Co RWD #7	E	T	Tulsa Sapulpa Creek Co RWD #1	O O O	T T T
CREEK CO RWD #3 CONSOLIDATED	OK3001916				Creek Co RWD # 1	O	T
CREEK CO RWD #4	OK3001920				Sapulpa Rural Water Company	O	T
CREEK CO RWD #7	OK1020405				Creek Co RWD #2	E	T
DEWEY	OK3007402	Washington Co RWD #1	O	T	Bartlesville	O	T
ELM BEND RWD INC	OK3005309				Nowata	O	T
GLENPOOL WATER	OK3007223	Okmulgee Co RWD #6	O	T	Tulsa	O	T
JENKS PWA	OK3007201				Tulsa	O	T
LE ANN WATER	OK3007407	Ramona	O	T	Bartlesville	O	T
MUSKOGEE CO RWD #9	OK3005119				Muskogee		

Wholesale Water Transfers

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

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

Wholesale Water Transfers (2 of 4)
Middle Arkansas Region

Provider	SDWIS ID[1]	Sales			Purchases		
		Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases From	Emergency or Ongoing	Treated or Raw or Both
MUSKOGEE CO RWD #10	OK3005128				Muskogee Haskell County Water Company	O E	T T
MUSKOGEE CO RWD #14	OK3005134				Boynton PWA	O	T
NOWATA	OK1021503	Nowata Co RWD #2 Nowata Co RWD #5 Nowata Co RWD #3 Elm Bend RWD Inc Nowata Co RWD # 6	O O O	T T T T T			
NOWATA & ROGERS CO CONSOLIDATED RWD #1	OK3005301				Chelsea Economic Dev Auth	O	T
NOWATA CO RW & SD #1	OK3005304				Dewey	O	T
NOWATA CO RWD #2	OK3005303				Nowata	O	T
NOWATA CO RWD #3	OK3005302				Nowata	O	T
NOWATA CO RWD #5	OK3005307				Nowata	O	T
NOWATA CO RWD #6	OK3005308				Nowata		T
OCHELATA UTIL AUTH	OK3007414				Bartlesville	O	T
OKAY PWA	OK3007351				Muskogee		
OKMULGEE CO RWD #6 (HECTORVILLE RWD #6)	OK3005611	Okmulgee Co RWD #20 Okmulgee Co RWD #7	O E	T T	Tulsa Okmulgee Glenpool Water	O O O	T T T
OSAGE CO RWD #1	OK3005704				Bartlesville	O	T
OSAGE CO RWD #5	OK3005721				Barnsdall	O	T
OSAGE CO RWD #9	OK3005702				Barnsdall	O	T
OSAGE CO RWD #15	OK3005736				Skiatook PWA Washington Co RWD # 3 Tulsa	O E O	T T T
OSAGE CO RWD #18 (EVERGREEN)	OK3005744				Pawhuska	O	T
OWASSO	OK3007218				Tulsa Washington CoRWD # 3	O E	T T
PAWHUSKA	OK1021301	Osage Co RWD #18	O	T			
PORTER PWA	OK3007306	Tullahassee Water	O	T	Muskogee Wagoner Co RWD #5	O O	T T
RAMONA	OK3007408				Le Ann Water	O	T
RED BIRD	OK3007305				Wagoner Co RWD #5	O	T
ROGERS CO RWD #2	OK3006603				Claremore	O	T
ROGERS CO RWD #3 COT STA	OK3006650				Tulsa		
ROGERS CO RWD #3 LAKE PLANT	OK1021513	Rogers Co RWD #12	O	T			

Wholesale Water Transfers (3 of 4)
Middle Arkansas Region

Provider	SDWIS ID[1]	Sales			Purchases		
		Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases From	Emergency or Ongoing	Treated or Raw or Both
ROGERS CO RWD #5	OK1021507	Rogers Co RWD # 15		T	Tulsa Wagoner Co RWD # 4	E E	B B
ROGERS CO RWD #6	OK3006628				Rogers Co RWD # 8 Mayes Co RWD #2	O	T
ROGERS CO RWD #7	OK3006604	Rogers Co RWD #8 Rogers Co RWD #9	O	T	Rogers Co RWD # 8 Claremore Pryor West RWD # 4	E O O	T T T
ROGERS CO RWD #8	OK3006606	Rogers Co RWD #6 Rogers Co RWD #7	O E	T T	Rogers Co RWD # 7 Claremore	O O	T T
ROGERS CO RWD #9	OK3006605				Claremore Rogers Co RWD #7	O O	T T
ROGERS CO RWD #12	OK3006648				Rogers Co RWD #3 Lake Plant	O	T
ROGERS CO RWD #15	OK3006652				Rogers Co RWD # 5		T
SAND SPRINGS	OK1020420	Tulsa Co W Imp Dist #14 Tulsa	O O	T T			
SAND SPRINGS SKYLINE/81ST AREA	OK3007244				Tulsa	O	T
SAPULPA	OK1020404	Creek Co RWD #2 Sapulpa Rural Water Company	O O	T T			
SAPULPA RURAL WATER COMPANY	OK3001904	Tulsa Creek County RWD #4	O O	T T	Sapulpa Tulsa	O O	T T
SKIATOOK PWA	OK1021313	Osage Co RWD #15	O	T	Tulsa	O	T
SOUTH COFFEYVILLE	OK3005305				South Coffeyville	O	T
SPERRY	OK3007202				Tulsa	O	T
STRIKE AXE (CHIMNEY ROCK)	OK3005739				Bartlesville		
STRIKE AXE HWY 60	OK3005701				Bartlesville		
TAFT	OK3005118				Muskogee		
TULLAHASSEE WATER	OK3007338				Porter PWA	O	T

Wholesale Water Transfers (4 of 4)
Middle Arkansas 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
TULSA	OK1020418	Jay (via Lake Eucha)	O	R	Sapulpa Rural Water Company	O	T
		Jenks PWA	O	T	Sand Springs	O	T
		Owasso	O	T			
		Bixby Public Works Authority	O	T			
		Catoosa	O	T			
		Glenpool	O	T			
		Sand Springs	E	T			
		Sapulpa Rural Water Company	O	T			
		Skiatook PWA	O	T			
		Sperry	O	T			
		Sapulpa	E	T			
		Creek Co RWD #2	O	T			
		Okmulgee Co RWD #6	O	T			
		Osage Co RWD #15	O	T			
		Rogers Co RWD #3 Cot Sta	O	T			
		Rogers Co RWD #5	O	T			
		Wagoner Co RWD #4	O	T			
		Washington Co RWD #3	O	T			
		Water Improvement District #3	O	T			
TULSA CO W IMP DIST #14	OK3007213				Sand Springs	O	T
WAGONER	OK1021649	Wagoner Co RWD #6	O	T			
WAGONER CO RWD #4	OK1021529	Rogers Co RWD #5	E	B	Tulsa	O	T
		Wagoner Co RWD #5	O	T			
WAGONER CO RWD #5	OK1021528	Porter PWA	O	T	Broken Arrow	O	T
		Red Bird	O	T	Wagoner Co RWD #4	O	T
					Coweta	O	T
WAGONER CO RWD #6	OK3007330				Wagoner	O	T
WAGONER CO RWD #7 (NEW)	OK1221626	Wagoner Co RWD #1	E	T			
WASHINGTON CO RWD #1	OK3007401				Bartlesville	O	T
WASHINGTON CO RWD #2	OK3007403				Bartlesville	O	T
WASHINGTON CO RWD #3 (NEW,#1)	OK1021418	Owasso	E	T			
		Osage Co RWD #15	E	T			
		Rogers Co RWD #3	E	T			
WASHINGTON CO RWD #5	OK3007409				Bartlesville	O	T
WASHINGTON CO RWD #7	OK3007415				Copan PWA	O	T
WATER IMPROVEMENT DISTRICT #3	OK3007221				Tulsa	O	T

1 SDWIS - Safe Drinking Water Information System

Public Water Provider Water Rights and Withdrawals - 2010 (1 of 3)

Middle Arkansas Region

Provider	SDWIS ID1	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
AVANT UTIL AUTH	OK1021305	Osage	78	20%	80%	0%
BAR-DEW WATER ASSOC INC	OK3007406	Washington	---	---	---	---
BARNSDALL	OK1021304	Osage	3,095	100%	0%	0%
BARTLESVILLE	OK1021401	Washington	35,669	100%	0%	0%
BIRCH CREEK RWD	OK2005743	Osage	65	0%	0%	100%
BIXBY PWA	OK3007243	Tulsa	2,240	100%	0%	0%
BOYNTON PWA	OK3005127	Muskogee	---	---	---	---
BROKEN ARROW	OK1021508	Tulsa	83,227	100%	0%	0%
CATOOSA	OK3006629	Rogers	---	---	---	---
CLAREMORE	OK1021512	Rogers	7,250	100%	0%	0%
COLLINSVILLE	OK1021505	Tulsa	3,360	100%	0%	0%
COPAN PWA	OK1021417	Washington	2,240	100%	0%	0%
COWETA	OK1021509	Wagoner	2,760	100%	0%	0%
CREEK CO RWD #1	OK1020419	Creek	2,085	100%	0%	0%
CREEK CO RWD #2	OK3001902	Creek	39	100%	---	---
CREEK CO CONSOLIDATED RWD #3	OK3001916	Creek	---	---	---	---
CREEK CO RWD #4	OK3001920	Creek	---	---	---	---
CREEK CO RWD #7	OK1020405	Creek	326	100%	0%	0%
DELAWARE	OK1021502	Nowata	43	100%	0%	0%
DEWEY	OK3007402	Washington	---	---	---	---
ELM BEND RWD INC	OK3005309	Nowata	---	---	---	---
GLENPOOL WATER	OK3007223	Tulsa	---	---	---	---
HASKELL PWA	OK2005111	Muskogee	23	0%	0%	100%
HOMINY	OK1021306	Osage	667	100%	0%	0%
INOLA WATER WORKS INC	OK3006612	Rogers	---	---	---	---
JENKS PWA	OK3007201	Tulsa	---	---	---	---
LE ANN WATER	OK3007407	Washington	---	---	---	---
LENAPAH	OK1021501	Nowata	31	100%	0%	0%
MUSKOGEE CO RWD #8	OK3005117	Muskogee	---	---	---	---
MUSKOGEE CO RWD #9	OK3005119	Muskogee	---	---	---	---
MUSKOGEE CO RWD #10	OK3005128	Muskogee	---	---	---	---
MUSKOGEE CO RWD #14	OK3005134	Muskogee	---	---	---	---
NOWATA	OK1021503	Nowata	546	100%	0%	0%
NOWATA CO RW & SD #1	OK3005304	Nowata	---	---	---	---
NOWATA & ROGERS CO CONSOLIDATED RWD #1	OK3005301	Nowata	---	---	---	---

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 (2 of 3)

Middle Arkansas Region

Provider	SDWIS ID1	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
NOWATA CO RWD #2	OK3005303	Nowata	---	---	---	---
NOWATA CO RWD #3	OK3005302	Nowata	---	---	---	---
NOWATA CO RWD #5	OK3005307	Nowata	---	---	---	---
NOWATA CO RWD #6	OK3005308	Nowata	---	---	---	---
NOWATA CO RWD #7	OK3005321	Nowata	950	100%	0%	0%
OCHELATA UTIL AUTH	OK3007414	Washington	---	---	---	---
OKAY PWA	OK3007351	Wagoner	---	---	---	---
OKMULGEE CO RWD #6 (HECTORVILLE RWD #6)	OK3005611	Okmulgee	---	---	---	---
OSAGE CO RWD #1	OK3005704	Osage	---	---	---	---
OSAGE CO RWD #5	OK3005721	Osage	---	---	---	---
OSAGE CO RWD #9	OK3005702	Osage	---	---	---	---
OSAGE CO RWD #15	OK3005736	Osage	2,109	100%	0%	0%
OSAGE CO RWD #18 (EVERGREEN)	OK3005744	Osage	---	---	---	---
OSAGE CO RWD # 20 (HULAH)	OK1021410	Osage	67	100%	0%	0%
OWASSO	OK3007218	Tulsa	---	---	---	---
PAWHUSKA	OK1021301	Osage	2,955	100%	0%	0%
PORTER PWA	OK3007306	Wagoner	---	---	---	---
RAMONA	OK3007408	Washington	---	---	---	---
RED BIRD	OK3007305	Wagoner	---	---	---	---
ROGERS CO RWD #2	OK3006603	Rogers	---	---	---	---
ROGERS CO RWD #3 COT STA	OK3006650	Rogers	---	---	---	---
ROGERS CO RWD #3 LAKE PLANT	OK1021513	Rogers	5,111	100%	0%	0%
ROGERS CO RWD #4	OK1021506	Rogers	6,310	100%	0%	0%
ROGERS CO RWD #5	OK1021507	Rogers	7,500	100%	0%	0%
ROGERS CO RWD #6	OK3006628	Rogers	---	---	---	---
ROGERS CO RWD #7	OK3006604	Rogers	---	---	---	---
ROGERS CO RWD #8	OK3006606	Rogers	---	---	---	---
ROGERS CO RWD #9	OK3006605	Rogers	---	---	---	---
ROGERS CO RWD #12	OK3006648	Rogers	---	---	---	---
ROGERS CO RWD #15	OK3006652	Rogers	---	---	---	---
SAND SPRINGS	OK1020420	Tulsa	18,268	100%	0%	0%
SAND SPRINGS SKYLINE/81ST AREA	OK3007244	Tulsa	---	---	---	---

Public Water Provider Water Rights and Withdrawals - 2010 (3 of 3)

Middle Arkansas Region

Provider	SDWIS ID1	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
SAPULPA	OK1020404	Creek	8,160	100%	0%	0%
SAPULPA RURAL WATER COMPANY	OK3001904	Creek	---	---	---	---
SKIATOOK PWA	OK1021313	Osage	3,760	100%	0%	0%
SOUTH COFFEYVILLE	OK3005305	Nowata	---	---	---	---
SPERRY	OK3007202	Tulsa	---	---	---	---
STRIKE AXE (CHIMNEY ROCK)	OK3005739	Osage	---	---	---	---
STRIKE-AXE HWY 60	OK3005701	Osage	---	---	---	---
TAFT	OK3005118	Muskogee	---	---	---	---
TULLAHASSEE WATER	OK3007338	Wagoner	---	---	---	---
TULSA	OK1020418	Tulsa	324,707	100%	0%	0%
TULSA CO W IMP DIST #14	OK3007213	Tulsa	---	---	---	---
WAGONER	OK1021649	Wagoner	2,896	100%	0%	0%
WAGONER CO RWD #4	OK1021529	Wagoner	22,485	100%	0%	0%
WAGONER CO RWD #5	OK1021528	Wagoner	3,011	100%	0%	0%
WAGONER CO RWD #6	OK3007330	Wagoner	---	---	---	---
WAGONER CO RWD #7 (NEW)	OK1221626	Wagoner	---	---	---	---
WASHINGTON CO RWD #1	OK3007401	Washington	---	---	---	---
WASHINGTON CO RWD #2	OK3007403	Washington	---	---	---	---
WASHINGTON CO RWD #3 (NEW,#1)	OK1021418	Tulsa	30,377	100%	0%	0%
WASHINGTON CO RWD #5	OK3007409	Washington	---	---	---	---
WASHINGTON CO RWD #7	OK3007415	Washington	---	---	---	---
WATER IMPROVEMENT DISTRICT #3	OK3007221	Tulsa	---	---	---	---
WYNONA	OK2005708	Osage	770	---	---	100%

1 SDWIS - Safe Drinking Water Information System

Provider Supply Plans

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

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

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

OCWP Provider Survey
Middle Arkansas Region

Avant Utilities Authority (Osage County)
Current Source of Supply
Primary source: Avant Lake
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines; add storage.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines; add storage.

Bar-Dew Water Assoc. (Washington County)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace storage tank.

City of Barnsdall (Osage County)
Current Source of Supply
Primary source: Lake Waxhoma
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines; refurbish storage tank.
Long-Term Needs
None identified.

City of Bartlesville (Washington County)
Current Source of Supply
Primary source: Lake Hudson, Hulah Lake, Caney River
Short-Term Needs
New supply source: drill additional wells.
Long-Term Needs
New supply source: reallocation of water in Hulah and Copan lakes.
Infrastructure improvements: new raw water pump station and transmission line from Copan Lake.

Birch Creek RWD (Osage County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add storage; refurbish well and storage tank.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage.

Bixby PWA (Tulsa County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage and booster pump station.

Boynton PWA (Muskogee County)
Current Source of Supply
Primary source: Haskell
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Broken Arrow WTP (Tulsa County)
Current Source of Supply
Primary source: OK Ordnance WA
Short-Term Needs
New supply source: City of Tulsa; OK Ordinance WA for emergency supply.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; construct 20 MGD membrane WTP.

City of Catoosa (Rogers County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Claremore (Rogers County)
Current Source of Supply
Primary source: Claremore Lake, Oologah Lake
Short-Term Needs
Infrastructure improvements: refurbish storage tank; add pump station.
Long-Term Needs
Infrastructure improvements: add pump station; replace distribution system lines; upgrade WTP.

City of Collinsville (Tulsa County)
Current Source of Supply
Primary source: Oologah Lake, Collinsville City Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; new raw water line from Oologah Lake to Collinsville Lake; new WTP.

Consolidated RWD 3 (Creek County)
Current Source of Supply
Primary source: Creek County RWD 1
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; replace storage tank; add storage.

Copan PWA (Washington County)
Current Source of Supply
Primary source: Copan Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Coweta (Wagoner County)
Current Source of Supply
Primary source: oxbow (Verdigris River)
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: upgrades to water treatment plant.

Creek County RWD 1
Current Source of Supply
Primary source: Heyburn Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines; add distribution system lines; refurbish storage tank; add storage tank and pump station.

Creek County RWD 2
Current Source of Supply
Primary source: Cities of Tulsa & Sapulpa, Creek County RWD 1
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Creek County RWD 4
Current Source of Supply
Primary source: Sapulpa Rural Water
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Creek County RWD 7
Current Source of Supply
Primary source: Lake Jackson, Lake Boren
Short-Term Needs
Infrastructure improvements: replace distribution system lines; add distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add distribution system lines.

OCWP Provider Survey
Middle Arkansas Region

Town of Delaware (Nowata County)
Current Source of Supply
Primary sources: Verdigris River
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Dewey (Washington County)
Current Source of Supply
Primary source: Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Elm Bend RWD Inc. (Nowata County)
Current Source of Supply
Primary source: City of Nowata
Short-Term Needs
Infrastructure improvements: replace a portion of distribution system and main lines.
Long-Term Needs
None identified.

Glenpool Water (Tulsa County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
Infrastructure improvements: add storage; add distribution system lines.
Long-Term Needs
New supply source: tie in an additional main trunk line and loop.

Haskell PWA (Muskogee County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

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

Inola Water Works Inc. (Rogers County)
Current Source of Supply
Primary source: Mazie County Water District 2
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Jenks (Tulsa County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
Infrastructure improvements: add distribution system lines.

Le Ann Water (Washington County)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; replace main lines.

Town of Lenapah (Nowata County)
Current Source of Supply
Primary source: Verdigris River
Short-Term Needs
None identified.
Long-Term Needs
None required.

Muskogee County RWD 9
Current Source of Supply
Primary source: City of Muskogee
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Muskogee County RWD 10
Current Source of Supply
Primary source: Ft. Gibson Lake
Short-Term Needs
Infrastructure improvements: add pump station; replace a portion of distribution system lines.
Long-Term Needs
None identified.

Muskogee County RWD 14
Current Source of Supply
Primary source: City of Boynton
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Nowata (Nowata County)
Current Source of Supply
Primary source: Verdigris River
Short-Term Needs
Infrastructure improvements: add water pumps; refurbish golf course standpipe.
Long-Term Needs
Infrastructure improvements: new WTP.

Consolidated RWD 1 Nowata & Rogers County
Current Source of Supply
Primary source: Chelsea Economic Development Authority
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Nowata County RW&S 1
Current Source of Supply
Primary source: City of Dewey
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
None identified.

Nowata County RWD 2
Current Source of Supply
Primary source: City of Nowata
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Nowata County RWD 5
Current Source of Supply
Primary source: City of Nowata, Elm Bend RWD
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
None identified.

Nowata County RWD 6
Current Source of Supply
Primary source: City of Nowata
Short-Term Needs
Infrastructure improvements: replace distribution system lines; add VFDs to pumps.
Long-Term Needs
None identified.

Nowata County RWD 7
Current Source of Supply
Primary source: Coffeyville, KS
Short-Term Needs
Infrastructure improvements: replace distribution system lines;
Long-Term Needs
None identified.

Nowata County RWD 3
Current Source of Supply
Primary source: City of Nowata
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines;
Long-Term Needs
None identified.

Ochelata Utility Authority (Washington County)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines;
Long-Term Needs
New supply source: purchase additional from Bartlesville.

OKAY PWA (Wagoner County)
Current Source of Supply
Primary source: City of Muskogee
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Okmulgee County RWD 6 (Hectorville RWD 6)
Current Source of Supply
Primary source: City of Okmulgee, Tulsa, Glenpool
Short-Term Needs
Infrastructure improvements: replace main lines; refurbish storage towers.
Long-Term Needs
None identified.

Osage County RWD 1
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines; replace pumps.

Osage County RWD 20
Current Source of Supply
Primary source: Hulah Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Osage County RWD 5
Current Source of Supply
Primary source: City of Barnsdall
Short-Term Needs
Infrastructure improvements: add storage; replace a portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: add storage; replace a portion of distribution system lines.

Osage County RWD 15
Current Source of Supply
Primary source: Town of Skiatook, City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Osage County RWD 18 (Evergreen)
Current Source of Supply
Primary source: City of Pawhuska
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add distribution system lines; add pumps.

City of Owasso (Tulsa County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.

City of Pawhuska (Osage County)
Current Source of Supply
Primary source: Bird Creek, Bluestem Lake, Clear Creek
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines; upgrade WTP.

Porter PWA (Wagoner County)
Current Source of Supply
Primary source: City of Muskogee, Wagoner County RWD 5
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Ramona (Washington County)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Town of Redbird (Wagoner County)
Current Source of Supply
Primary source: Wagoner County RWD 5
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Rogers County RWD 2
Current Source of Supply
Primary source: City of Claremore
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines; add storage.

Rogers County RWD 3 (Cot Sta)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Rogers county RWD 3 (Lake Plant)
Current Source of Supply
Primary source: Oologah Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage.

Rogers County RWD 4
Current Source of Supply
Primary source: Oologah Lake
Short-Term Needs
Infrastructure improvements: upgrades to WTP.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage; replace WTP.

Rogers County RWD 5
Current Source of Supply
Primary source: Verdigris River
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
None identified.

Rogers County RWD 6
Current Source of Supply
Primary source: Mayes Cnty RWD 2, Rogers Cnty RWD 8, OK Ordnance Works Authority
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines;

Rogers County RWD 7
Current Source of Supply
Primary source: OK Ordnance Works Authority, City of Claremore
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Rogers County RWD 8
Current Source of Supply
Primary sources: City of Claremore
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage.

Rogers County RWD 9
Current Source of Supply
Primary source: Rogers County RWD 7, City of Claremore
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Rogers County 12
Current Source of Supply
Primary source: Rogers County RWD 3
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Rogers County 15
Current Source of Supply
Primary source: Rogers County 5
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Osage County RWD 9
Current Source of Supply
Primary source: City of Barnsdall
Short-Term Needs
Infrastructure improvements: add storage; add and replace distribution system lines; add booster pump station and chlorine booster station.
Long-Term Needs
Infrastructure improvements: add storage; add and replace distribution system lines; add pump station.

City of Sand Springs (Tulsa County)
Current Source of Supply
Primary source: Skiatook Lake, Shell Creek Lake
Short-Term Needs
Infrastructure improvements: refurbish water storage tanks; replace a portion of distribution system lines.
Long-Term Needs
New supply sources: additional treatment capacity.
Infrastructure improvements: add storage; replace distribution system lines.

Sand Springs Skyline/81st Area (Tulsa County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Sapulpa (Creek County)
Current Source of Supply
Primary source: Skiatook Lake, Sahoma Lake
Short-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.

Sapulpa Rural Water Co. (Creek County)
Current Source of Supply
Primary source: City of Sapulpa, City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Skiatook PWA (Osage County)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.
Long-Term Needs
None identified.

South Coffeyville (Nowata County)
Current Source of Supply
Primary source: City of Coffeyville, KS
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
None identified.

Town of Sperry (Tulsa County)
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Strike-Axe Water Co. (Chimney Rock; Osage Co.)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.

Strike-Axe Water Co. (Hwy 60; Osage Co.)
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.

Town of Taft (Muskogee County)
Current Source of Supply
Primary source: City of Muskogee
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Tullahassee Water (Wagoner County)
Current Source of Supply
Primary source: Town of Porter
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Tulsa (Tulsa County)
Current Source of Supply
Primary source: Lakes Eucha, Spavinaw, Oologah & Hudson (Markham Ferry)
Short-Term Needs
Infrastructure improvements: rehabilitation of Eucha dam; rehabilitation of Lake Yahola and Lynn Lane Reservoir.
Long-Term Needs
Infrastructure improvements: new pipeline, terminal reservoir & pump station; expansion of WTP.

Tulsa County W Imp. Dist.14
Current Source of Supply
Primary source: City of Sand Springs
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

City of Wagoner (Wagoner County)
Current Source of Supply
Primary source: Ft. Gibson Reservoir
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage.

Wagoner County RWD 4
Current Source of Supply
Primary source: Verdigris River
Short-Term Needs
Infrastructure improvements: add storage; add distribution system lines.
Long-Term Needs
None identified.

Wagoner County RWD 5
Current Source of Supply
Primary source: Verdigris River
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Wagoner County RWD 6
Current Source of Supply
Primary source: City of Wagoner
Short-Term Needs
Infrastructure improvements: refurbish water tower.
Long-Term Needs
None identified.

Wagoner County RWD 7 (new)
Current Source of Supply
Primary source: Ft. Gibson Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Washington County RWD 1
Current Source of Supply
Primary source: City of Dewey
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Washington County RWD 2
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Washington County RWD 3 (New #1)
Current Source of Supply
Primary source: Oologah Lake
Short-Term Needs
New supply source: developing a new water in Caney River.
Infrastructure improvements: new transmission lines and 25 MG storage reservoir.
Long-Term Needs
None identified.

Washington County RWD 5
Current Source of Supply
Primary source: City of Bartlesville
Short-Term Needs
Infrastructure improvements: refurbish 3 standpipes; add distribution system lines to loop; add portable generator in pump station.
Long-Term Needs
Infrastructure improvements: connect to Copan PWA.

Washington County RWD 7
Current Source of Supply
Primary source: Copan PWA
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system pumps; refurbish standpipe.

Water Imp. District 3
Current Source of Supply
Primary source: City of Tulsa
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Wynona (Osage County)
Current Source of Supply
Primary source: Groundwater
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: add storage; replace distribution system lines.

Drinking Water Infrastructure Cost Summary

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

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

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

Infrastructure Cost Summary
Middle Arkansas Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$24	$458	$175	$657
Medium	$829	$252	$2,839	$3,920
Large	$445	$680	$463	$1,588
Reservoir[2]	$0	$26	$54	$80
TOTAL	$1,298	$1,416	$3,531	$6,245

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

2 The "reservoir" category is for rehabilitation projects.

- Approximately $6.2 billion is needed to meet the projected drinking water infrastructure needs of the Middle Arkansas Region over the next 50 years. The largest infrastructure costs are expected to occur after 2040.
- Distribution and transmission projects account for more than 80 percent of the providers' estimated infrastructure costs, followed distantly by water treatment projects.
- Medium providers have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoirs comprise approximately one percent of the total costs.

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)

Middle Arkansas Region

Name	Category	Stream	Basin	Purpose[1]	Total Storage	Conservation Pool			Primary Study		Updated Cost Estimate[2] (2010 dollars)
						Surface Area	Storage	Dependable Yield			
					AF	Acres	AF	AFY	Date	Agency	
Candy	4	Candy Creek	74	FC, WS, WQ, F&W, R	75,420	2,170	43,110	8,625	1971	USACE	$75,217,000
Sand	3	Sand Creek	76	FC, WS, F&W, R	91,000	2,000	35,000	8,740	1985	USACE	$63,010,000

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

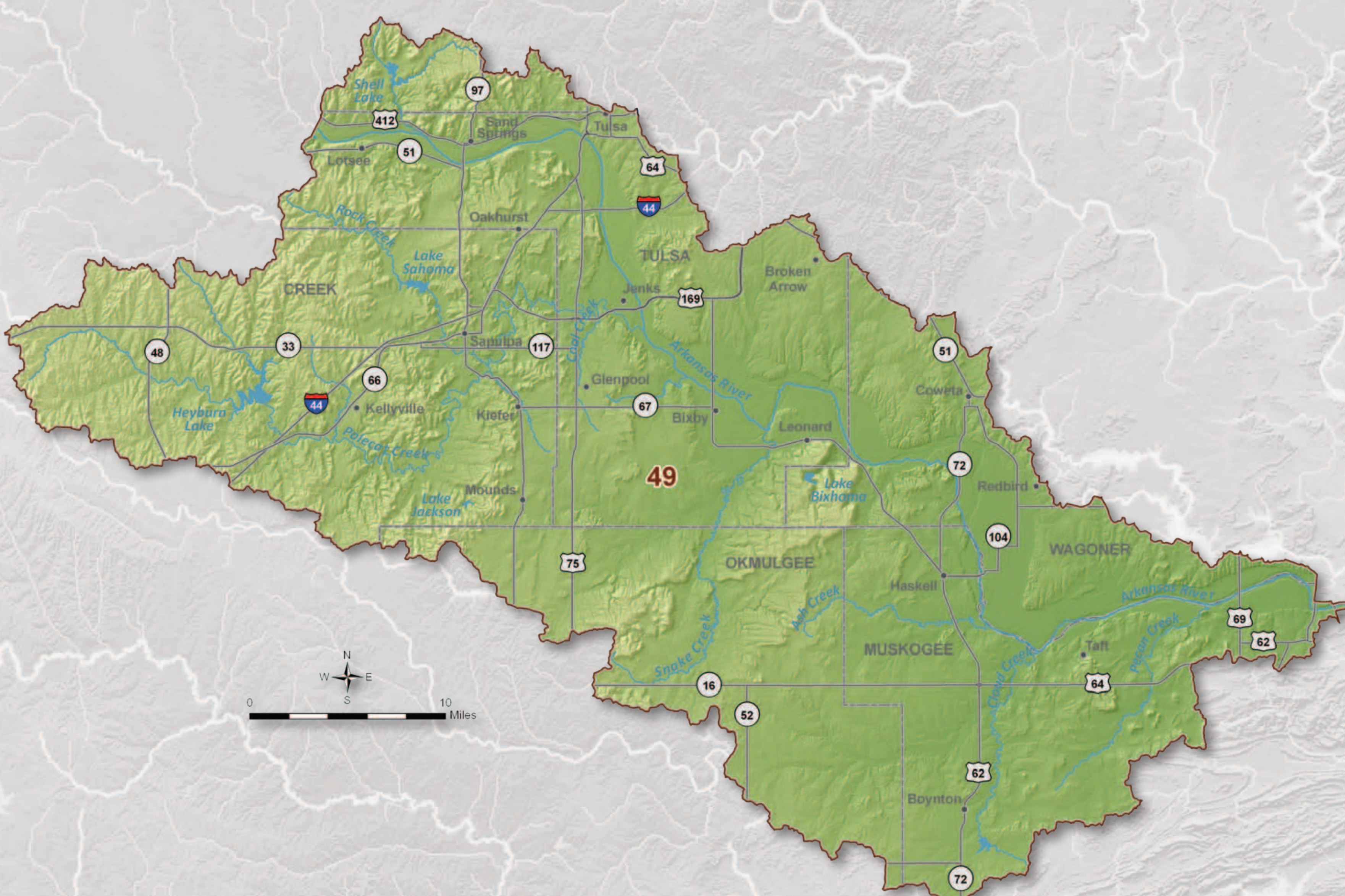
2 The majority of cost estimates were updated using estimated costs from previous project reports combined with the USACE Civil Works Construction Cost Index System (CWCCIS) annual escalation figures to scale the original cost estimates to present-day cost estimates. These estimated costs may not accurately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

Expanded Water Supply Options
Middle Arkansas Region

Data & Analysis

Middle Arkansas Watershed Planning Region

Basin 49

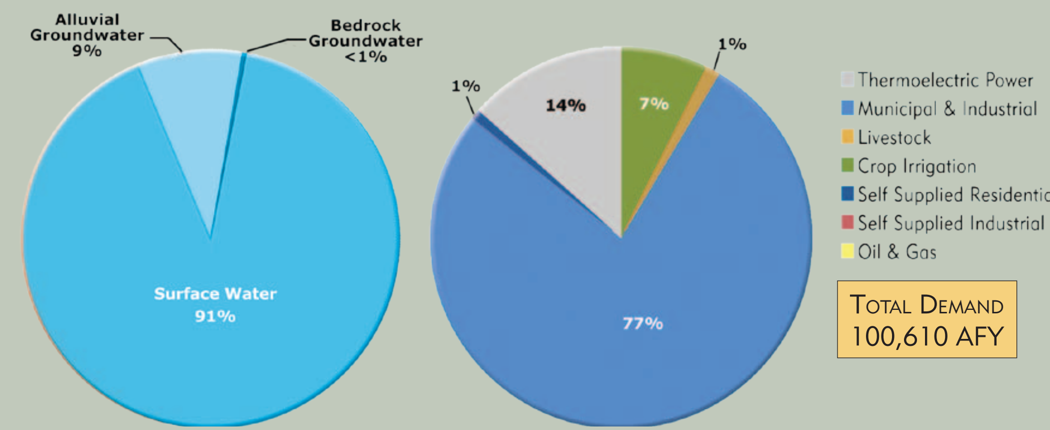


Basin 49 Summary

Synopsis

- Water users are expected to continue to rely primarily on reservoirs and surface water supplies.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater storage depletions may occur by 2020, 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 substantially reduce surface water gaps and adverse effects of localized alluvial groundwater storage depletions.
- Use of additional groundwater supplies and/or developing small reservoirs could mitigate surface water gaps without having major impacts to groundwater storage.

Current Demand by Source and Sector
Middle Arkansas Region, Basin 49



Basin 49 accounts for about 44% of the current water demand in the Middle Arkansas Watershed Planning Region. About 77% of the 2010 demand was from the Municipal and Industrial demand sector. Thermoelectric Power (14%) and Crop Irrigation (7%) are the next largest demand sectors. The basin is supplied primarily by surface water or out-of-basin supplies (about 91%) and, to a lesser extent, alluvial groundwater supplies (9%); a very small amount (less than 1%) of bedrock groundwater is used. The peak summer month demand in Basin 49 is two times the peak winter demand, which is similar to the overall statewide pattern.

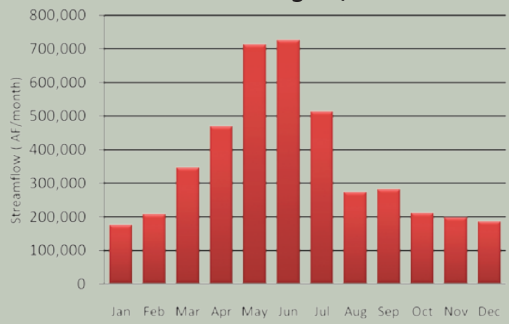
The Arkansas River downstream of Pecan Creek typically has flows greater than 176,000 AF/month in each month of the year. However, the river can have prolonged periods of low flow in any month of the year. The basin has one major federal lake, Heyburn Lake, which was built by the Corps of Engineers for flood control, water supply, recreation, and fish and wildlife. Heyburn contains 2,000 AFY of water supply storage that yields 1,904 AFY and is fully allocated to Creek County Rural Water District #1. The basin has three municipal water supply lakes: the City of Bixhoma's Lake Bixhoma, the City of Sapulpa's Lake Sahoma, and the City of Sand Springs' Shell Lake. The cities of Tulsa, Broken Arrow, Sapulpa and Sand Springs meet much of their demand from out-of-basin supplies. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to basins statewide, the surface water quality in Basin 49 is considered fair. The Arkansas River and several creeks (Duck Creek and Childres Creek) are impaired for Agricultural use due to high levels of chloride and total dissolved solids (TDS).

The majority of current groundwater rights are from the Arkansas River major alluvial aquifer, which underlies about 19% of Basin 49. A small number of water rights are from the Vamoosa-Ada major bedrock aquifer, which underlies 4% of the basin's far western tip, as well as from non-delineated minor bedrock groundwater sources. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

Water Resources
Middle Arkansas Region, Basin 49

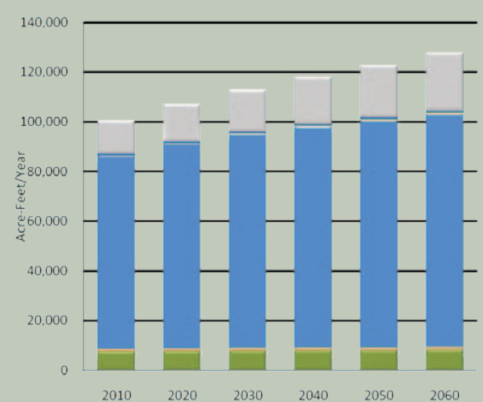
Median Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 49



Projected Water Demand

Middle Arkansas Region, Basin 49



The projected 2060 basin water demand of 127,860 AFY reflects a 27,250 AFY increase (27%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial and Thermoelectric Power demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions may occur by 2020. Surface water gaps will be up to 5,930 AFY and have a 17% probability of occurring in at least one month of the year by 2060. Alluvial groundwater gaps will be up to 620 AFY and have a 17% probability of occurring in at least one month of the year by 2060. Surface water gaps and alluvial groundwater storage depletions in Basin 49 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions are minimal compared to the storage in the Arkansas River aquifer. However, localized storage depletions may cause adverse effects for users. No bedrock groundwater depletions are expected in Basin 49.

Options

Water users are expected to continue to rely primarily on surface water or out-of-basin 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 and Crop Irrigation sectors could reduce surface water gaps and alluvial groundwater depletions. Due to the low probability of gaps and storage depletions, temporary drought management could be an effective means of reducing demand and may mitigate gaps. Temporary drought management activities may not be necessary for alluvial groundwater users, since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-basin supplies could be used to augment supplies and meet demand. The cities of Tulsa, Broken Arrow, Sapulpa and Sand Springs are expected to continue to meet much of their demand in the basin from current out-of-basin supply sources. Increased reliance on existing or new out-of-basin supplies could mitigate surface water gaps and alluvial groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region. However, due to the distance to these sources, out-of-basin supplies may not be cost-effective for some users in the basin.

New in-basin reservoir storage can increase the dependability of available surface water supplies and mitigate gaps and storage depletions in the basin. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and approximately 6,900 AF of new reservoir storage at the basin outlet.

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

Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase the amount of groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 49's portion of the Arkansas River aquifer. However, this aquifer only underlies 20% of the basin and substantial existing urban and agricultural development may limit supplies in the northern portion of the aquifer. The Vamoosa-Ada aquifer may also provide groundwater supplies, but only underlies a very small portion of the basin. Site specific information should be considered before relying on minor aquifers for large-scale use.

Water Supply Limitations

Middle Arkansas Region, Basin 49

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Middle Arkansas Region, Basin 49

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

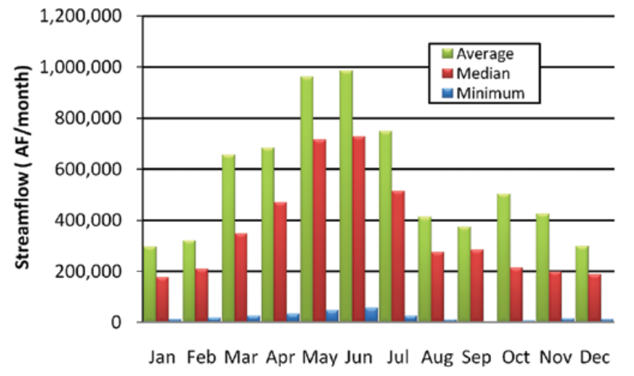
Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Basin 49 Data & Analysis

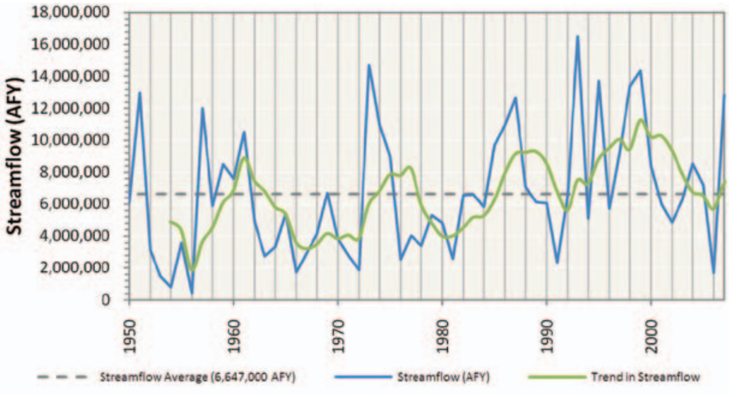
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Arkansas River downstream of Pecan Creek had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median streamflow in the Arkansas River downstream of Pecan Creek is greater than 176,000 AF/month in each month of the year and greater than 700,000 AF/month in May and June. However, the river 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 49 is considered fair.
- Basin 49 has three municipal water supply lakes: the City of Bixhoma's Lake Bixhoma, the City of Sapulpa's Lake Sahoma, and the City of Sand Spring's Shell Lake. The water supply yield of these lakes is unknown; therefore, the ability of the lakes to provide future water supplies could not be evaluated. The Corps of Engineers operates Heyburn Lake for flood control, water supply, recreation, and fish and wildlife. Heyburn can provide up to 1,904 AFY of water supply yield, which is currently allocated to Creek County RWD #1.

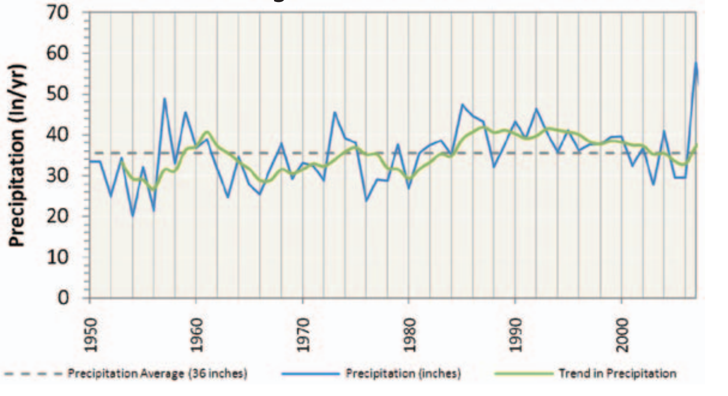
Monthly Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 49



Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 49



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)

Middle Arkansas Region, Basin 49

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
Arkansas River	Alluvial	Major	19%	15,400	344,000	temporary 2.0	286,100
Vamoosa-Ada	Bedrock	Major	4%	200	264,000	2.0	63,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of current groundwater rights are from the Arkansas River alluvial aquifer, which underlies about 19% of Basin 49. There is about 344,000 AF of storage in Basin 49's portion of the Arkansas River aquifer. The Vamoosa-Ada bedrock aquifer underlies a small portion of the far western part of the basin, but receives an estimated 3,000 AFY of recharge from the basin. There are also 300 AFY of groundwater rights in non-delineated minor bedrock aquifers.
- There are no significant groundwater quality issues in Basin 49.

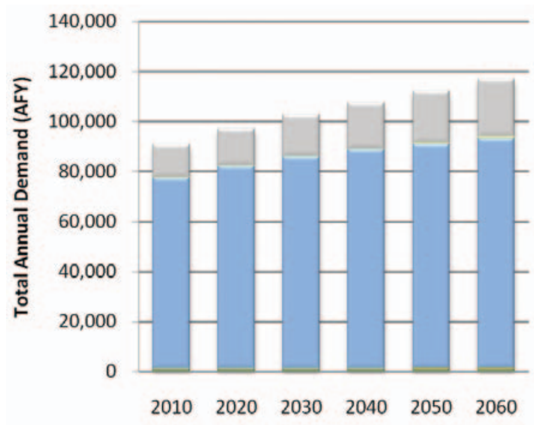
Notes & Assumptions

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

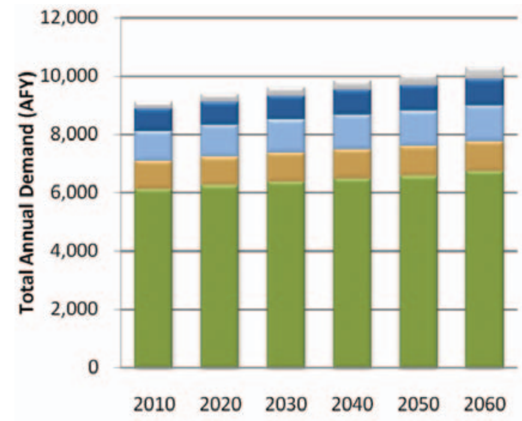
Water Demand

- The water needs of Basin 49 account for about 44% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 27% (27,250 AFY) from 2010 to 2060. The majority of demand and growth in demand will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 91% of the total demand in the basin and its use will increase by 29% (26,040 AFY) from 2010 to 2060. The majority of surface water use and growth in use during this period will be from the Municipal and Industrial demand sector, which will be met in part by existing out-of-basin supplies.
- Alluvial groundwater is used to meet 9% of the total demand in the basin and its use will increase by 13% (1,170 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in use will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet less than 1% of the total demand in the basin and its use will increase by 11% (40 AFY) from 2010 to 2060. The increase in bedrock groundwater use is minimal on a basin scale.

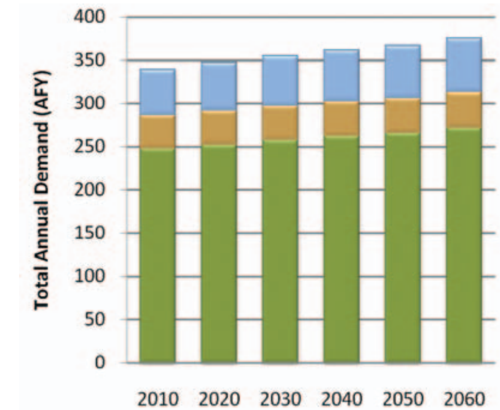
Surface Water Demand by Sector
Middle Arkansas Region, Basin 49



Alluvial Groundwater Demand by Sector
Middle Arkansas Region, Basin 49



Bedrock Groundwater Demand by Sector
Middle Arkansas Region, Basin 49



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

Total Demand by Sector
Middle Arkansas Region, Basin 49

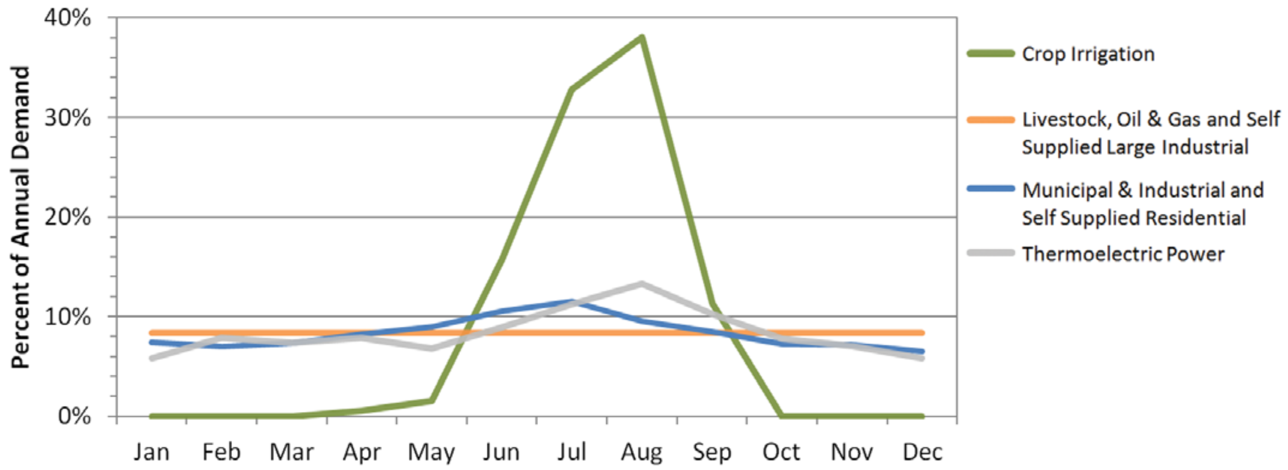
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	7,470	1,180	77,580	110	0	760	13,510	100,610
2020	7,620	1,190	82,300	180	0	800	15,070	107,160
2030	7,760	1,200	86,000	280	0	830	16,810	112,880
2040	7,910	1,210	88,820	390	0	860	18,750	117,940
2050	8,020	1,230	91,160	520	0	880	20,920	122,730
2060	8,200	1,240	93,500	680	0	900	23,340	127,860

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.

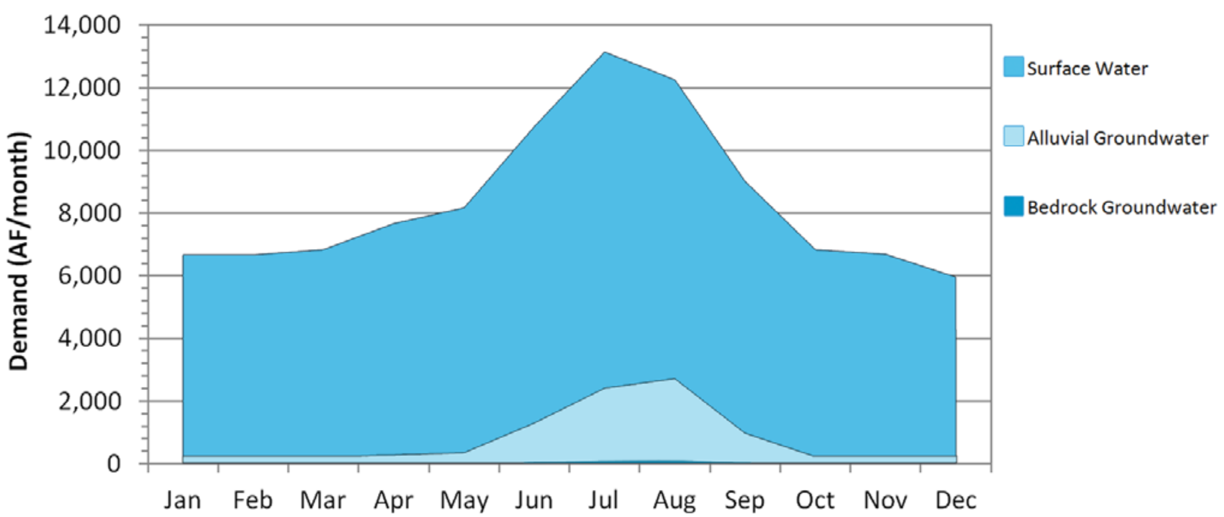
Monthly Demand Distribution by Sector (2010)

Middle Arkansas Region, Basin 49



Monthly Demand Distribution by Source (2010)

Middle Arkansas Region, Basin 49



Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 49 is two times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 1.7 times the monthly winter use. Alluvial and bedrock groundwater use in the peak summer month is more than 12 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions may occur by 2020. No bedrock groundwater depletions are expected in this basin due to the minimal growth in demand from 2010 through 2060.
- Surface water gaps in Basin 49 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 15% (1,820 AF/month) of the surface water demand in the peak summer month, and as much as 12% (990AF/month) of the monthly winter surface water demand. There will be a 17% probability of gaps occurring in at least one month of the year by 2060. Gaps are most likely to occur during fall months.
- Alluvial groundwater storage depletions in Basin 49 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 14% (400 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 11% (30 AF/month) of the monthly winter alluvial groundwater demand. There will be a 17% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during fall months.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water stored in the basin's portion of the Arkansas River alluvial aquifer. However, localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Middle Arkansas Region, Basin 49

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	990	850	3%
Mar-May (Spring)	1,190	830	3%
Jun-Aug (Summer)	1,820	1,820	3%
Sep-Nov (Fall)	1,440	1,020	14%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Middle Arkansas Region, Basin 49

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	30	25	3%
Mar-May (Spring)	40	25	3%
Jun-Aug (Summer)	400	400	3%
Sep-Nov (Fall)	140	30	14%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Middle Arkansas Region, Basin 49

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
2020	400	90	0	16%	9%
2030	1,160	210	0	16%	16%
2040	2,370	340	0	16%	16%
2050	3,980	470	0	16%	16%
2060	5,930	620	0	17%	17%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Middle Arkansas Region, Basin 49

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 49

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	5,930	620	0	17%	17%
Moderately Expanded Conservation in Crop Irrigation Water Use	5,780	570	0	17%	17%
Moderately Expanded Conservation in M&I Water Use	1,160	220	0	16%	7%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	1,010	190	0	16%	7%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	10	0	0	2%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Middle Arkansas Region, Basin 49

Reservoir Storage	Diversion
AF	AFY
100	8,800
500	11,200
1,000	13,300
2,500	17,100
5,000	22,900
Required Storage to Meet Growth in Demand (AF)	6,900
Required Storage to Meet Growth in Surface Water Demand (AF)	6,300

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about 83% and alluvial groundwater depletions by about 70%. Due to the low probability of gaps and storage depletions, temporary drought management could be an effective means of reducing demand, largely from irrigation, and may mitigate gaps. Temporary drought management activities may not be necessary for alluvial groundwater users since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could be used to augment supplies and meet demand. Currently, the Cities of Tulsa, Broken Arrow, Sapulpa and Sand Springs are expected to continue to meet much of their demand from out-of-basin sources. Out-of-basin supplies are primarily from Lake Skiatook in Basin 74, Lake Oolagah in Basin 79, and Lakes Eucha, Spavinaw, and Hudson (Markham Ferry) in Basin 80. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. Increased reliance on existing or new out-of-basin supplies could mitigate surface water gaps and alluvial groundwater storage depletions. However, due to the distance to these reliable sources, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and storage depletions. The entire increase in demand through 2060 could be met by a new river diversion and approximately 6,900 AF of new reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. Reallocation of existing storage at Lake Heyburn for additional water supply is another option currently being pursued through the Corps of Engineers.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on groundwater supplies could mitigate surface water gaps but would increase groundwater depletions. Any increases in groundwater storage depletions would be minimal relative to the volume of water in storage. However, this aquifer underlies only 19% of the basin and existing development may limit supplies in the northern portion of the aquifer. The Vamoosa-Ada aquifer may also provide groundwater supplies, but it underlies only a very small portion of the basin. Site specific information should be considered before increasing use of minor or non-delineated groundwater sources.

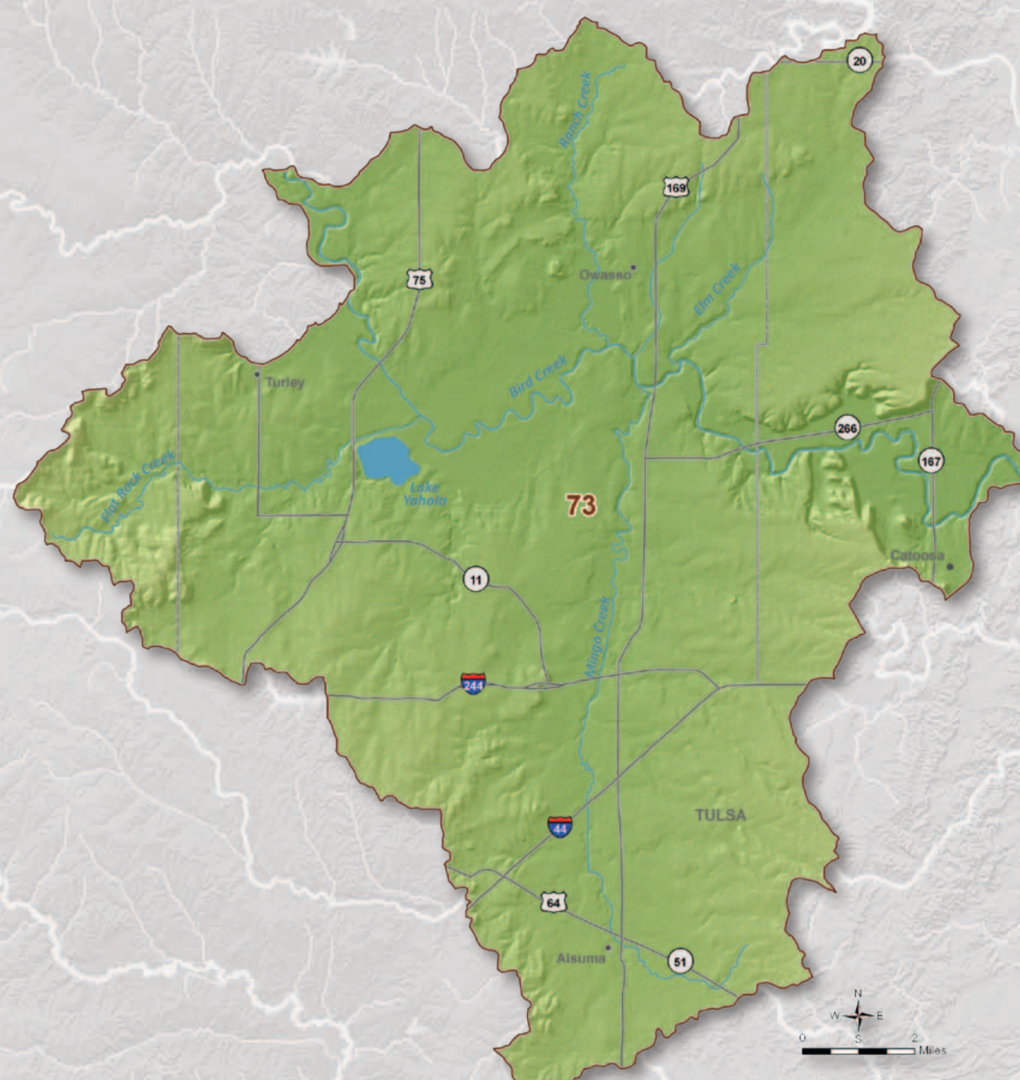
Notes & Assumptions

- 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

Middle Arkansas Watershed Planning Region

Basin 73



Basin 73 Summary

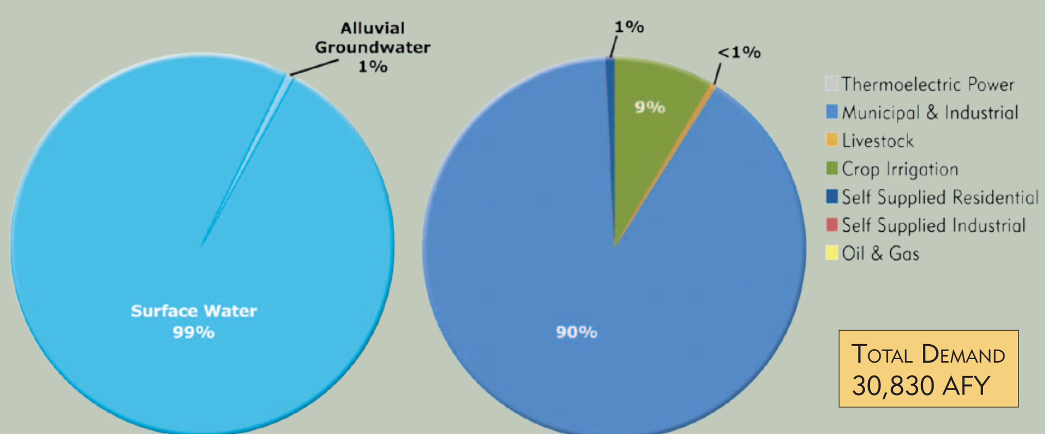
Synopsis

- Water users are expected to continue to rely primarily on surface water supplies and major reservoirs.
- By 2050, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could mitigate surface water gaps.
- New small reservoirs could be utilized to mitigate surface water gaps.

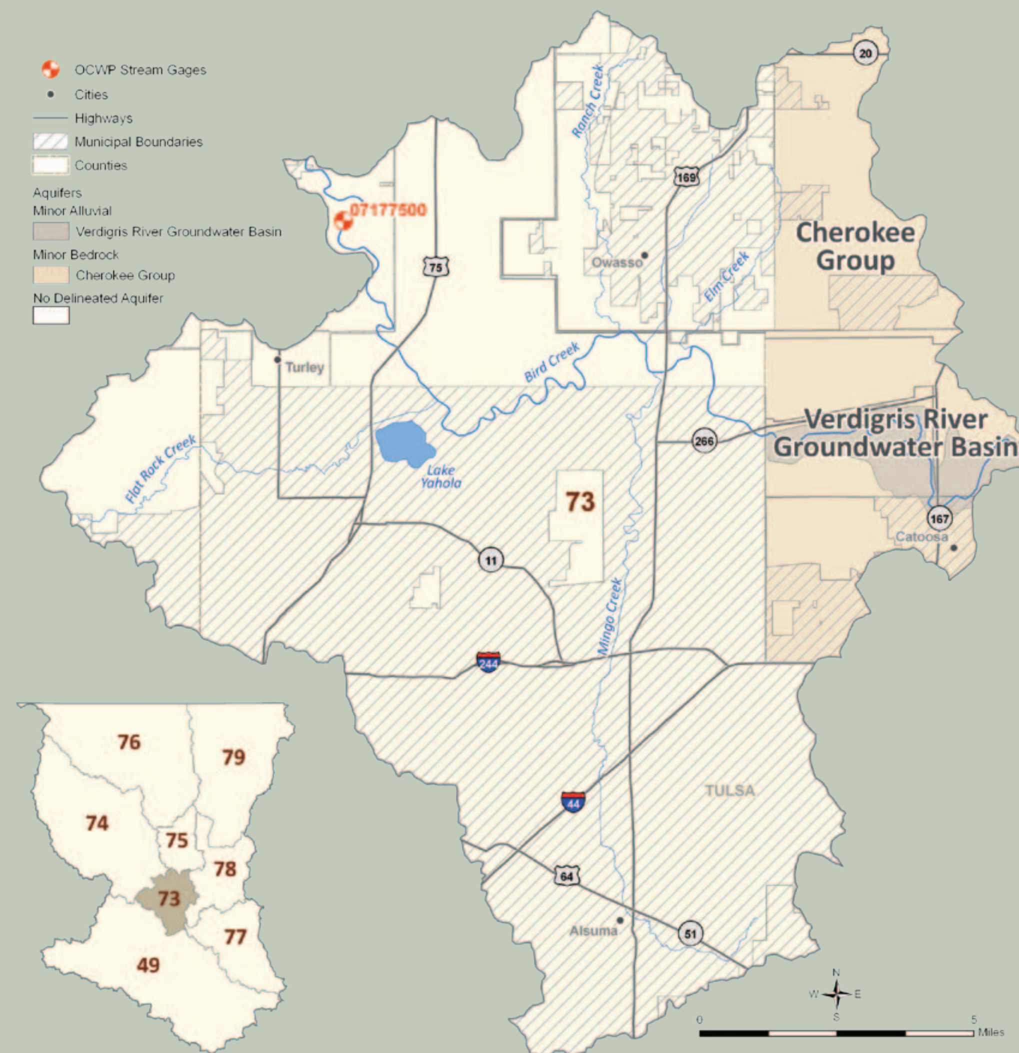
Basin 73 accounts for about 13% of the current water demand in the Middle Arkansas Watershed Planning Region. About 90% of the 2010 demand was in the Municipal and Industrial demand sector. Crop Irrigation (9%) is the second-largest demand sector in 2010. The basin is supplied primarily by surface water or out-of-basin supplies (about 99%). The peak summer month demand is 2 times the winter demand, which is similar to the overall statewide pattern.

Bird Creek upstream of the Verdigris River typically has flows greater than 6,500 AF/month throughout the year and greater than 30,000 AF/month in the spring and summer. However, the river can have prolonged periods of low flow in any month of the year. The basin's largest water body is Yahola, which provides terminal storage for water received out-of-basin from Spavinaw Lake. Spavinaw, located in the Grand Watershed Planning Region, was built as a water supply source for the City of Tulsa. The Cities of Tulsa and Broken Arrow are expected to meet much of their demand in the basin from out-of-basin supplies. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to basins statewide, the surface water quality in Basin 73 is considered fair. Bird

Current Demand by Source and Sector
Middle Arkansas Region, Basin 73

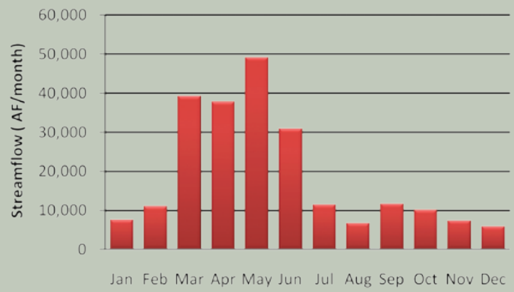


Water Resources
Middle Arkansas Region, Basin 73



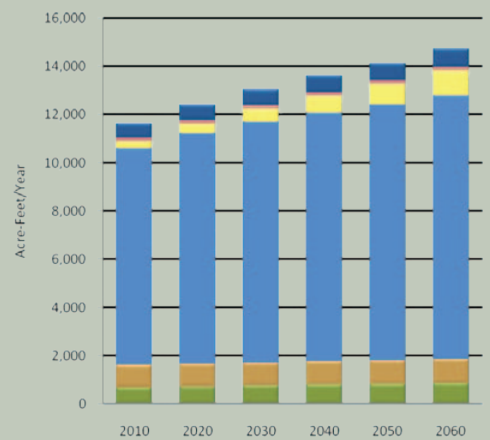
Median Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 73



Projected Water Demand

Middle Arkansas Region, Basin 73



Creek is impaired for Agricultural uses due to high levels of sulfates.

There are currently no groundwater rights in Basin 73. However, it is assumed that non-delineated minor alluvial groundwater sources will supply a small amount of domestic (Self-Supplied Residential) water use, which does not require a permit. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 36,780 AFY reflects a 5,950 AFY increase (19%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2050. Alluvial groundwater storage depletions were not evaluated in detail due to the minimal increase in demand from 2010 to 2060. Surface water gaps will be up to 50 AFY and have a 5% probability of occurring in at least one month of the year by 2060. Surface water gaps in Basin 73 may occur during the summer. Currently, there are no bedrock groundwater rights in Basin 73; therefore, no depletions are expected from this source.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial or Crop Irrigation sectors could mitigate surface water gaps. Due to the low probability of gaps, temporary drought management could be an effective means of reducing demand, largely from outdoor water use, and may mitigate gaps.

New out-of-basin supplies could be used to augment supplies and mitigate gaps. The Cities of Tulsa and Broken Arrow are expected to continue to meet much of their demand from out-of-basin supplies. Increased reliance on existing or new out-of-basin supplies could mitigate surface water gaps and alluvial groundwater storage depletions. The OCWP Reservoir Viability Study, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region. However, due to the distance to these sources, out-of-basin supplies may not be cost-effective for some users in the basin.

Water Supply Limitations

Middle Arkansas Region, Basin 73

Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal | Potential | Significant

Water Supply Option Effectiveness

Middle Arkansas Region, Basin 73

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	Likely Ineffective

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

New in-basin reservoir storage could increase the dependability of available surface water supplies and mitigate gaps in the basin. To supply all of the increase in demand from 2010 to 2060, a new river diversion and approximately 100 AF of new reservoir storage would be needed at the basin outlet.

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

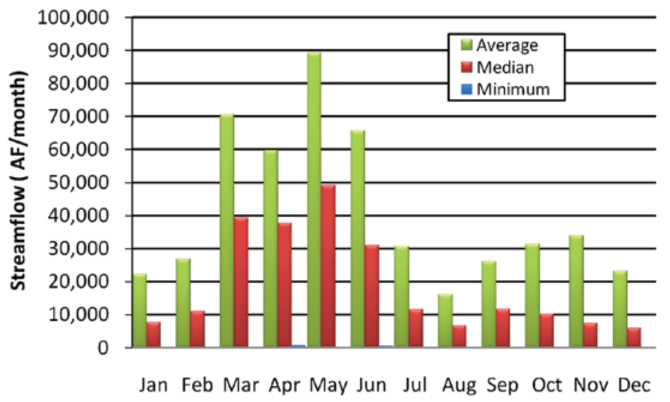
Basin 73 has limited minor groundwater resources; therefore, increased reliance on groundwater supplies without site-specific information may be ineffective, especially for large-scale users.

Basin 73 Data & Analysis

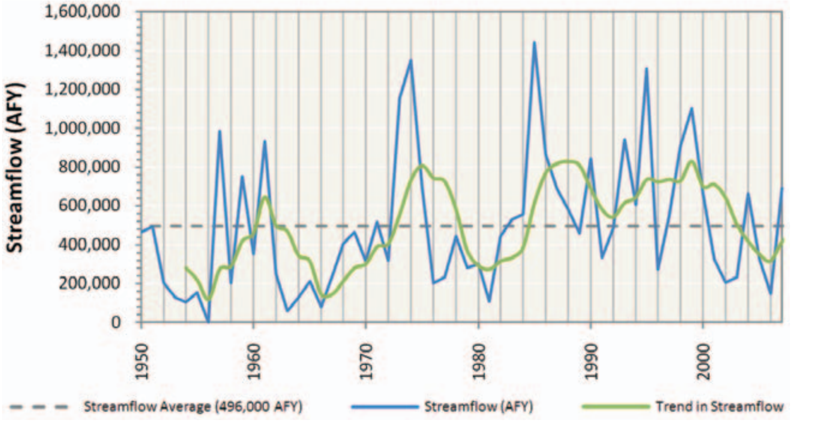
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Bird Creek upstream of the Verdigris River had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to 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 Bird Creek upstream of the Verdigris River has been greater than 6,500 AF/month throughout the year and greater than 30,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 73 is considered fair.
- Yahola provides terminal storage and receives out-of-basin water from Spavinaw Lake, which was built as a water supply source for the City of Tulsa.

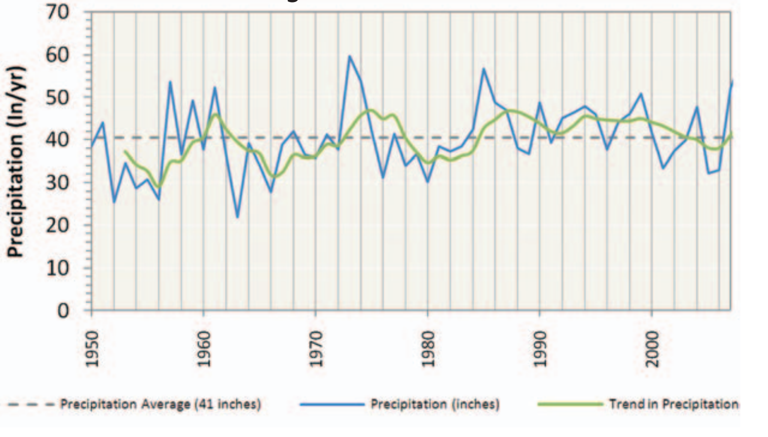
Monthly Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 73



Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 73



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)

Middle Arkansas Region, Basin 73

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
Cherokee Group	Bedrock	Minor	18%	0	35,000	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	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

- There are currently no groundwater rights in Basin 73, it is assumed that non-delineated minor alluvial groundwater sources will supply a small amount of domestic (Self-Supplied Residential) water use, which does not require a permit.
- There are no significant groundwater quality issues in Basin 73.

Notes & Assumptions

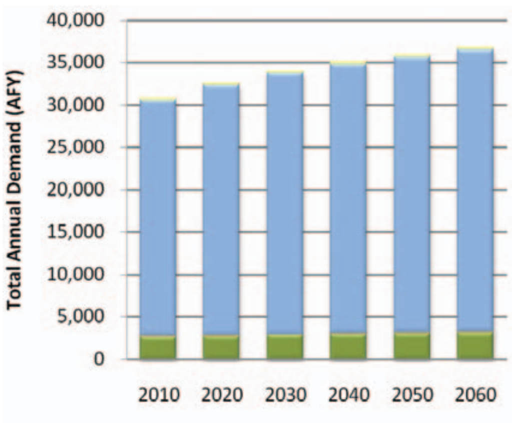
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- The water needs of Basin 73 account for about 13% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 19% (5,950 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be from the Municipal and Industrial demand sector.
- Surface water and out-of-basin supplies are used to meet 99% of the total demand in the basin and their use will increase by 19% (5,910 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 1% of the total demand in the basin and is used exclusively by the Self-Supplied Residential demand sector. The increase in alluvial groundwater use from 2010 to 2060 is minimal on a basin scale.
- Currently, there are no bedrock groundwater rights in Basin 73; therefore, no future demand is assumed from this source.

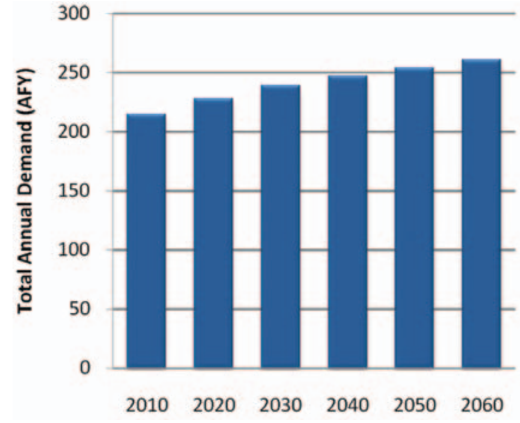
Surface Water Demand by Sector

Middle Arkansas Region, Basin 73



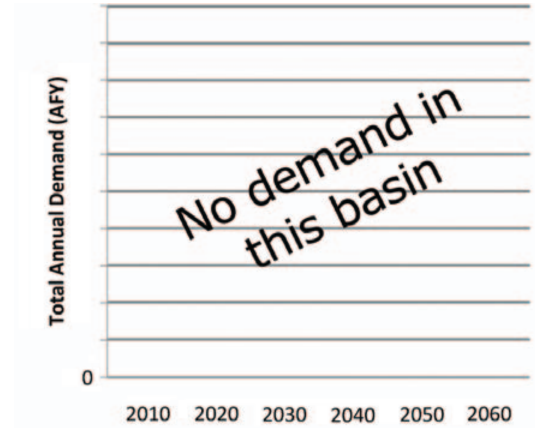
Alluvial Groundwater Demand by Sector

Middle Arkansas Region, Basin 73



Bedrock Groundwater Demand by Sector

Middle Arkansas Region, Basin 73



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

Total Demand by Sector

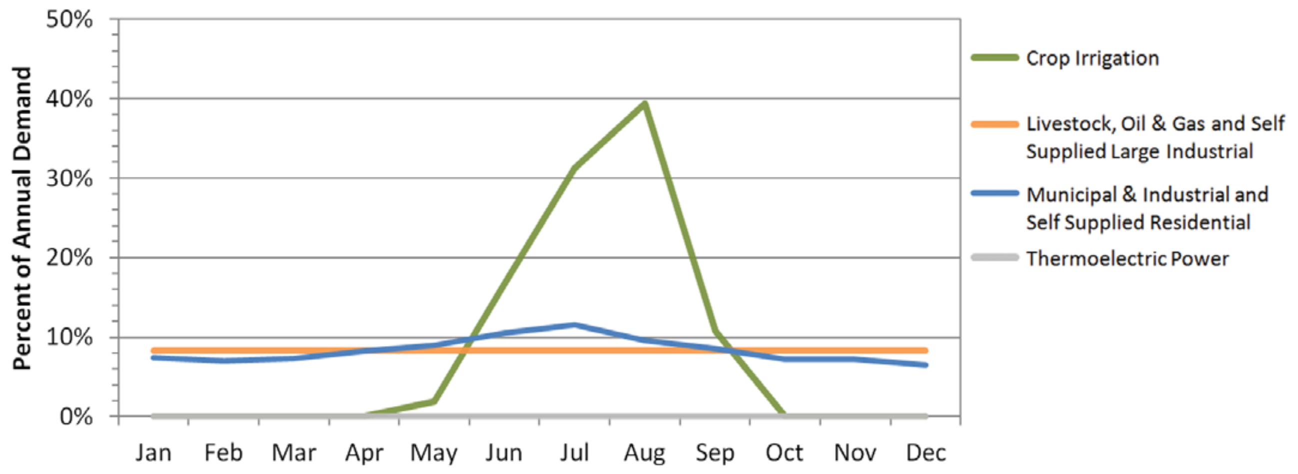
Middle Arkansas Region, Basin 73

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,630	140	27,830	10	0	220	0	30,830
2020	2,730	140	29,510	10	0	230	0	32,620
2030	2,830	140	30,810	20	0	240	0	34,040
2040	2,930	150	31,750	30	0	250	0	35,110
2050	3,000	150	32,480	30	0	250	0	35,910
2060	3,130	150	33,200	40	0	260	0	36,780

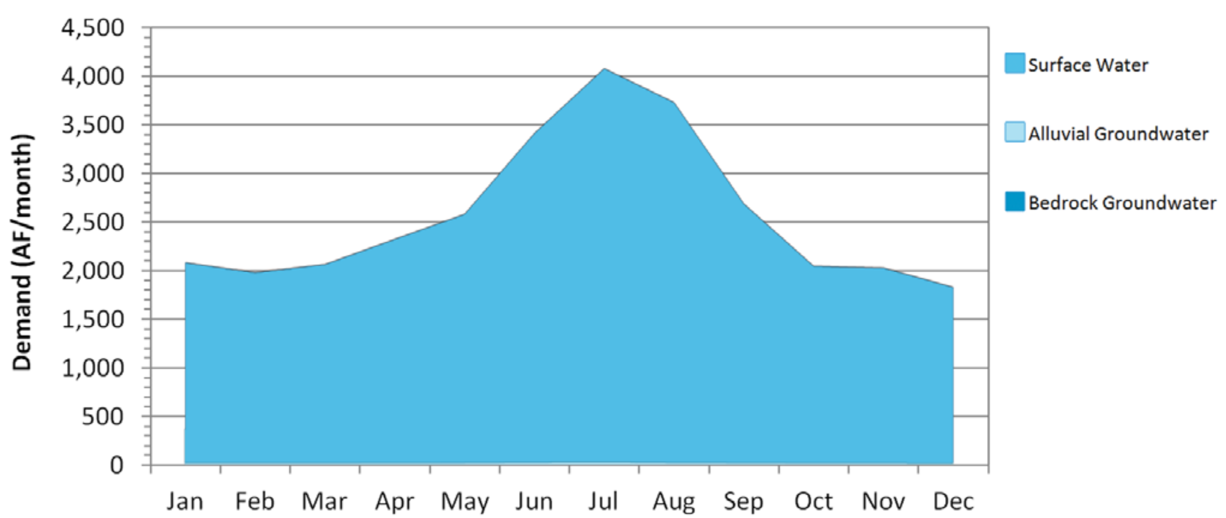
Notes & Assumptions

- 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)
Middle Arkansas Region, Basin 73



Monthly Demand Distribution by Source (2010)
Middle Arkansas Region, Basin 73



Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 73 is 2 times the winter demand, which is similar to the overall statewide pattern. Surface water and alluvial groundwater use in the peak summer month is about 2 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2050. Alluvial groundwater storage depletions were not evaluated in detail due to the minimal increase in demand from 2010 to 2060.
- Surface water gaps in Basin 73 may occur during the summer. By 2060, there will be a 5% probability of gaps occurring during summer months. Surface water gaps in 2060 will be at most 1% (50 AF/month) of the surface water demand in the peak summer month.

Surface Water Gaps by Season (2060 Demand)

Middle Arkansas Region, Basin 73

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)	50	40	5%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 73

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Middle Arkansas Region, Basin 73

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	20	0	0	3%	0%
2060	50	0	0	5%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 73

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 73

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	50	0	0	5%	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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Middle Arkansas Region, Basin 73

Reservoir Storage	Diversion
AF	AFY
100	6,100
500	7,600
1,000	8,900
2,500	11,200
5,000	13,000
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 or Crop Irrigation sectors could mitigate surface water gaps. Due to the low probability and small size of gaps, temporary drought management could be an effective means of reducing demand, largely from outdoor water use, and may mitigate gaps.

Out-of-Basin Supplies

New out-of-basin supplies could be used to augment supplies and mitigate gaps. The Cities of Tulsa and Broken Arrow are expected to continue to meet much of their demand from out-of-basin supplies. Out-of-basin supplies are primarily from Lake Oologah in Basin 79 and Lakes Eucha, Spavinaw and Hudson (Markham Ferry) in Basin 80. Tulsa also has a contract with GRDA for water from Lake W.R. Holway (Basin 80) which may serve as a future out-of-basin water supply for Tulsa. Increased reliance on these supplies or other nearby dependable water supplies could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. However, due to the distance to these reliable water supplies, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps in the basin. To supply all of the increase in demand from 2010 to 2060, a new river diversion and approximately 100 AF of new reservoir storage would be needed at the basin outlet. However, no potentially viable reservoir sites were identified in the basin. Also, the use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Basin 73 has limited minor groundwater resources; therefore, increased reliance on groundwater supplies without site-specific information may be ineffective, especially for large-scale 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.

Oklahoma Comprehensive Water Plan

Data & Analysis
Middle Arkansas Watershed Planning Region

Basin 74

Basin 74 Summary

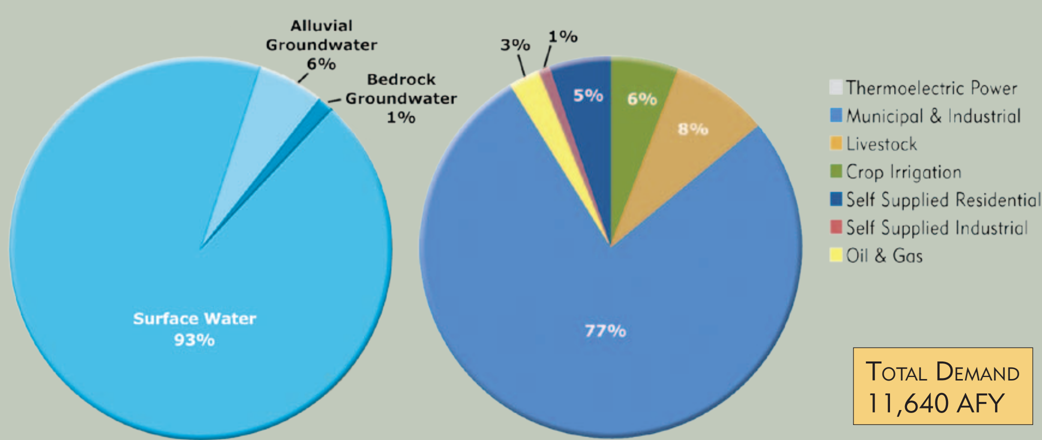
Synopsis

- Water users are expected to continue to rely primarily on surface supplies including major reservoirs.
- Alluvial storage depletions may occur by 2030. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers; therefore, the severity of the storage depletions could not be evaluated due to insufficient information.
- The major reservoirs in Basin 74, including Skiatook Lake and Birch Lake, are capable of providing dependable water supplies to their existing users, and with new infrastructure, could be used to meet all of the Basin 74 future surface water demand during periods of low streamflow.
- To reduce the risk of adverse impacts on water supplies, it is recommended storage depletions be decreased where economically feasible.
- Additional conservation could reduce the adverse effects of localized alluvial groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing small reservoirs could mitigate alluvial groundwater depletions without having major impacts to groundwater storage.

Basin 74 accounts for about 5% of the current water demand in the Middle Arkansas Watershed Planning Region. More than three-quarters of the 2010 demand was in the Municipal and Industrial demand sector while the other sectors each account for 1% to 8% of the 2010 demand. Surface water satisfies about 93% of the total demand in the basin. Groundwater satisfies about 7% of the demand (1% bedrock and 6% alluvial). The peak summer month

Current Demand by Source and Sector

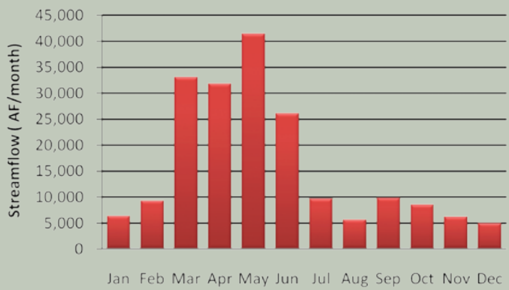
Middle Arkansas Region, Basin 74



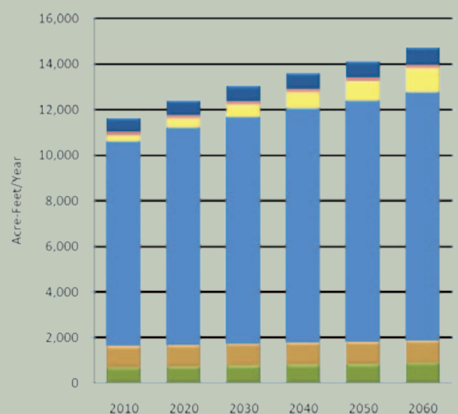
Water Resources

Middle Arkansas Region, Basin 74

Median Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 74



Projected Water Demand
Middle Arkansas Region, Basin 74



demand in Basin 74 is about 1.7 times the monthly winter demand, which is less pronounced than the overall statewide pattern.

Bird Creek near Sperry typically has flows greater than 5,000 AF/month throughout the year and greater than 30,000 AFY in spring and early summer. However, the river can have periods of low flow in any month of the year. Basin 74 has two major reservoirs. Skiatook Lake was constructed by the U.S. Army Corps of Engineers and provides 15,680 AFY of dependable water supply yield which is fully allocated. The lake also contains enough water quality storage to yield an additional 69,440 AFY. The lake currently provides water in-basin to Skiatook and out-of-basin to Sand Springs and Sapulpa. Birch Lake, also constructed by the U.S. Army Corps of Engineers, provides 3,360 AFY of dependable water supply yield, which is used in part by the City of Barnsdall. Birch Lake is expected to provide additional supplies in the future and has unpermitted water supply yield. The lake also has water quality storage yielding 3,360 AFY. There are many other public and privately owned lakes in the basin, such as Bluestem, Waxhoma, Hominy and Avant, that supply water for multiple purposes; however, the ability of these lakes to provide future water supply could not be evaluated because their yields are unknown. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

Relative to basins statewide, the surface water quality is in Basin 74 is considered good. However, Delaware Creek and Hominy Creek are impaired for Agricultural use due to high levels of chloride, sulfates, and total dissolved solids.

The majority of groundwater rights in Basin 74 are from the Vamoosa-Ada major bedrock aquifer. The Vamoosa-Ada aquifer underlies the eastern half of the basin (about 45% of the basin area). There are also permits in non-delineated minor alluvial and bedrock aquifers. However, the largest demand for groundwater is from minor alluvial and bedrock aquifers for domestic use, which does not require a permit. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 14,710 AFY reflects a 3,070 AFY increase (26%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2030. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin. Alluvial groundwater depletions are expected to be up to 130 AFY and have a 22% probability of occurring in at least one month of the year by 2060. Alluvial depletions

Water Supply Limitations
Middle Arkansas Region, Basin 74

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal   Potential   Significant

Water Supply Option Effectiveness
Middle Arkansas Region, Basin 74

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

in Basin 74 may occur throughout the year. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the severity of the storage depletions could not be evaluated. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

The major reservoirs in Basin 74, including Skiatook Lake and Birch Lake, are capable of providing dependable water supplies to their existing users, and with new infrastructure, could be used to meet all of the Basin 74 future surface water demand during periods of low streamflow.

Options

Water users are expected to continue to rely primarily on major reservoirs and 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.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could substantially reduce 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.

New out-of-basin supplies could be used to augment supplies and mitigate 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, due to the distance to dependable out-of-basin supplies and the presence of in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Reservoir storage within the basin could provide dependable supplies to mitigate storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 2,100 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Candy Lake as a potentially viable site in Basin 74.

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

Increased reliance on bedrock groundwater could mitigate alluvial groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 74's portion of the Vamoosa-Ada aquifer. However, the aquifer underlies only about half of the basin.

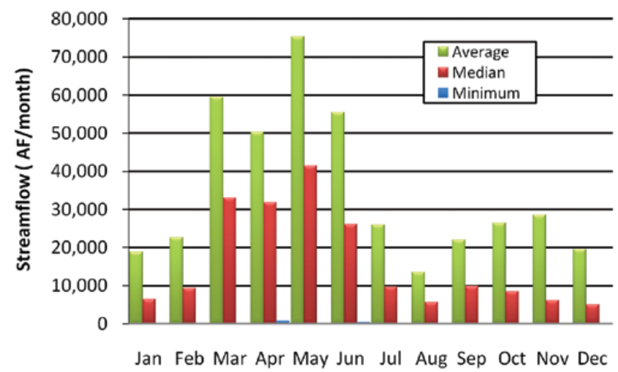
Basin 74 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The basin had a prolonged period of below-average streamflow from the early 1960s through early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to the early 2000s the basin went through a prolonged period of above-average streamflow and precipitation demonstrating local hydrologic variability.
- The median flow in Bird Creek near Sperry is greater than 5,000 AF/month throughout the year and greater than 30,000 AFY in spring and early summer. However, the river can have periods of low flow in any month of the year. The surface water quality in Basin 74 is considered good.
- Basin 74 has six major reservoirs. Skiatook Lake is operated by the Corps of Engineers and provides 15,680 AFY of dependable water supply yield. The lake provides water supplies to the cities of Sand Springs, Sapulpa, and Skiatook, and is expected to provide these users additional supplies in the future. Birch Lake is operated by the Corps of Engineers and provides 3,360 AFY of water supply yield, which is used in part by the City of Barnsdall. Birch Lake is expected to provide additional supplies in the future and has unpermitted yield. The water supply yields of other reservoirs in the basin are unknown; therefore, the ability of these reservoirs to provide future water supplies could not be evaluated.

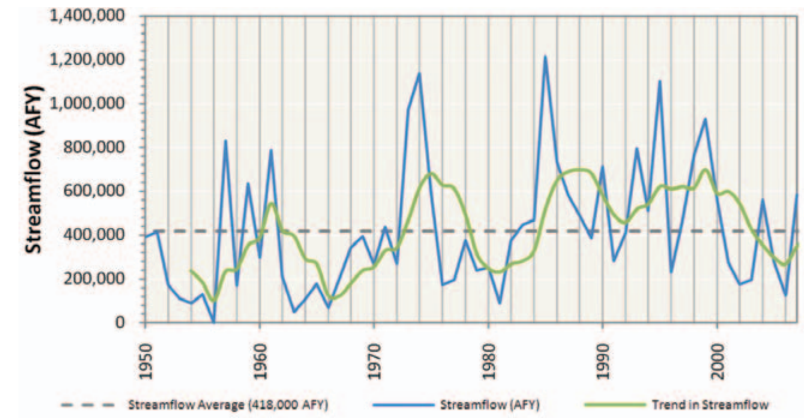
Monthly Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 74



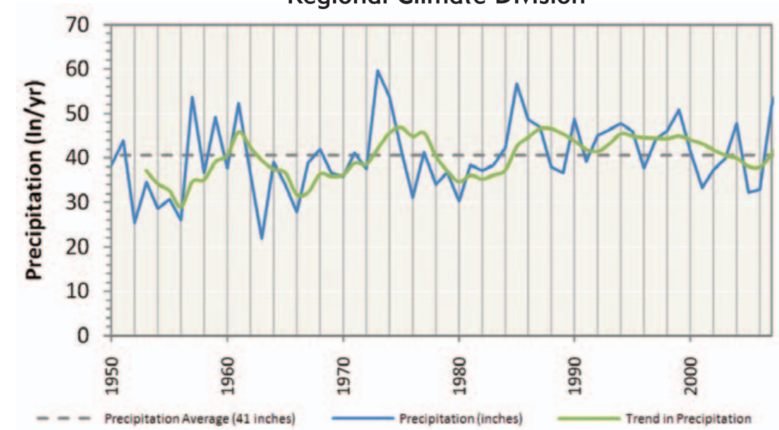
Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 74



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)

Middle Arkansas Region, Basin 74

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
Vamoosa-Ada	Bedrock	Major	45%	1,100	826,000	2.0	549,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	400	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	300	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of water rights in Basin 74 are from the Vamoosa-Ada major bedrock aquifer. The Vamoosa-Ada aquifer underlies the western portion of the basin (about 45% of the basin area) and is estimated to have about 826,000 AF of groundwater storage in Basin 74. The aquifer receives an estimated 25,000 AFY of recharge from the basin. There are also permits in non-delineated minor alluvial and bedrock aquifers.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

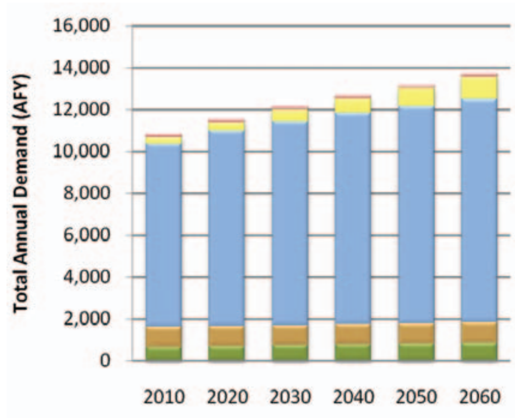
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- The water needs of Basin 74 account for about 5% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 26% (3,070 AFY) from 2010 to 2060. The majority of demand and growth in demand from 2010 to 2060 will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 93% of the total demand in the basin and its use will increase by 27% (2,880 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 6% of the total demand in the basin and its use will increase by 24% (160 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet about 1% of the total demand in the basin. The growth in bedrock groundwater from 2010 to 2060 (30 AFY) is minimal on a basin scale.

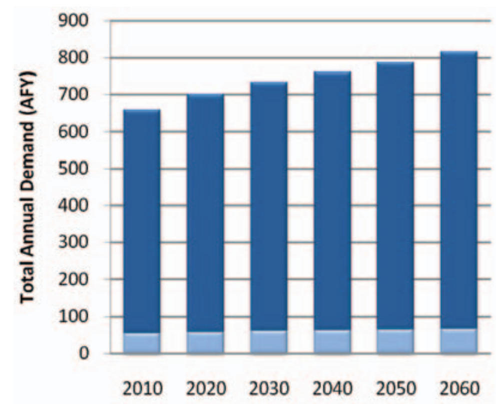
Surface Water Demand by Sector

Middle Arkansas Region, Basin 74



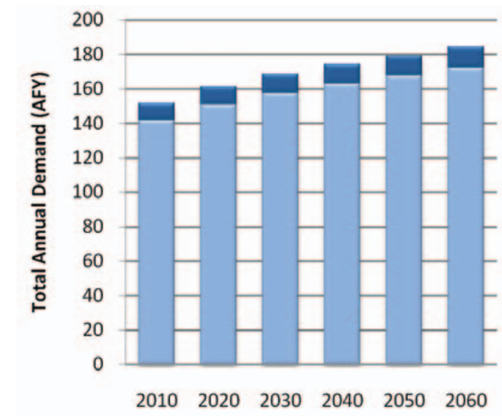
Alluvial Groundwater Demand by Sector

Middle Arkansas Region, Basin 74



Bedrock Groundwater Demand by Sector

Middle Arkansas Region, Basin 74



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

Total Demand by Sector

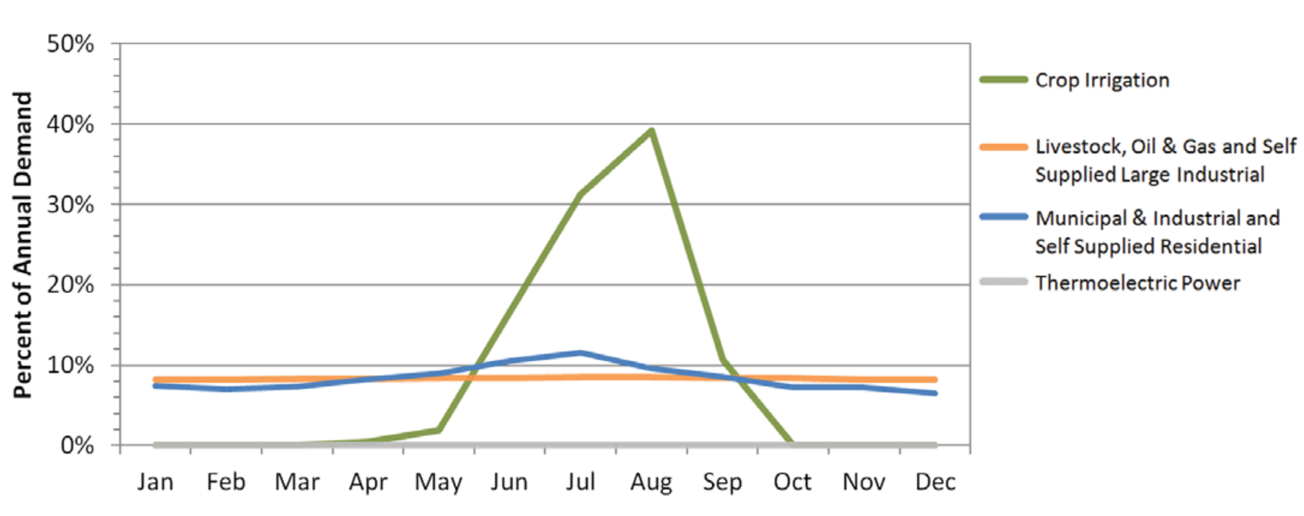
Middle Arkansas Region, Basin 74

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	680	950	8,980	310	110	610	0	11,640
2020	720	960	9,550	420	110	650	0	12,410
2030	760	960	9,970	550	110	680	0	13,030
2040	800	970	10,310	700	110	710	0	13,600
2050	830	980	10,600	870	120	740	0	14,140
2060	880	990	10,910	1,050	120	760	0	14,710

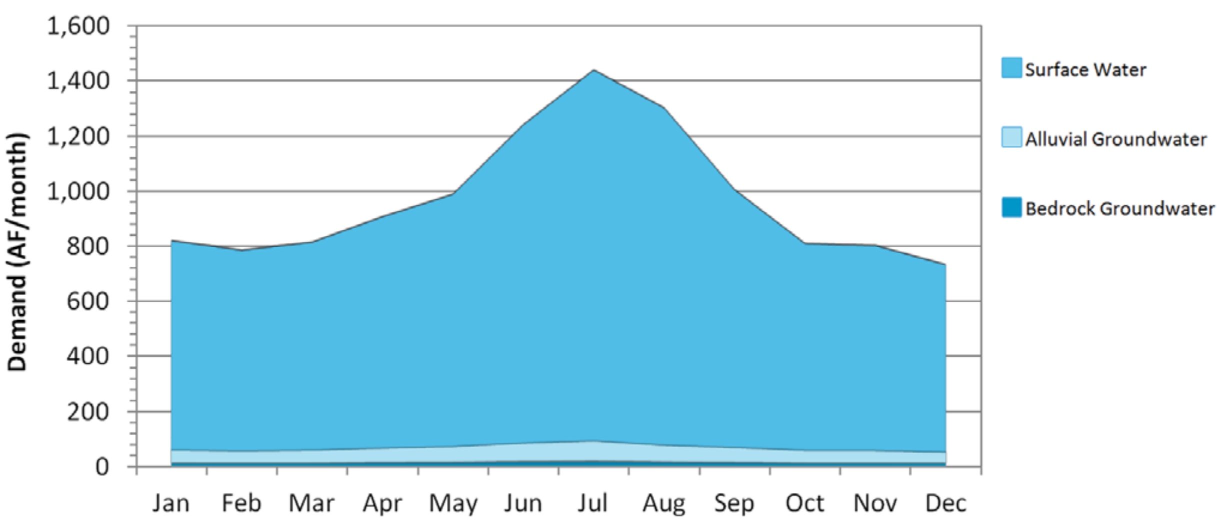
Notes & Assumptions

- 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)
Middle Arkansas Region, Basin 74



Monthly Demand Distribution by Source (2010)
Middle Arkansas Region, Basin 74



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months, but it accounts for only a small portion of the demand in this basin. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 74 is about 1.7 times the monthly winter demand, which is less pronounced than to the overall statewide pattern. Both surface water and alluvial groundwater used in the peak summer month is about 1.6 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2030. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin.
- Alluvial groundwater storage depletions in Basin 74 may occur throughout the year. Alluvial groundwater storage depletions in 2060 will be up to 22% (20 AF/month) of the alluvial groundwater demand in the peak summer month, and up to 17% (10 AF/month) of the peak winter month alluvial groundwater demand. 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 well yields, water quality, and/or pumping costs.
- There is a 22% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during fall months.

Surface Water Gaps by Season (2060 Demand)
Middle Arkansas Region, Basin 74

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Middle Arkansas Region, Basin 74

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	7%
Mar-May (Spring)	10	10	2%
Jun-Aug (Summer)	20	20	9%
Sep-Nov (Fall)	20	10	12%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Middle Arkansas Region, Basin 74

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	70	0	0%	5%
2040	0	70	0	0%	12%
2050	0	90	0	0%	19%
2060	0	130	0	0%	22%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Middle Arkansas Region, Basin 74

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 74

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	130	0	0%	22%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	130	0	0%	22%
Moderately Expanded Conservation in M&I Water Use	0	40	0	0%	5%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	40	0	0%	5%
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

Middle Arkansas Region, Basin 74

Reservoir Storage	Diversion
AF	AFY
100	200
500	800
1,000	1,500
2,500	3,500
5,000	5,200
Required Storage to Meet Growth in Demand (AF)	2,100
Required Storage to Meet Growth in Surface Water Demand (AF)	2,000

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 Crop Irrigation sectors could reduce alluvial groundwater depletions by about 70%. 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) New out-of-basin supplies could be used to augment supplies and 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 Middle Arkansas Watershed Planning Region: Sand Reservoir in Basin 76. However, due to the distance to dependable sources and presence of existing in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

(Typically Effective) The major reservoirs in Basin 74, including Skiatook Lake and Birch Lake, are capable of providing dependable water supplies to their existing users, and with new infrastructure, could be used to meet all of the Basin 74 future surface water demand during periods of low streamflow. Reservoir storage could provide dependable supplies to mitigate groundwater storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 2,100 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future storage depletions. Reallocation of existing storage at Skiatook Lake to provide additional water supply is another option that is being pursued through the Corps of Engineers. The OWRB Reservoir Viability Study also identified Candy Lake as a potential reservoir site in Basin 74.

Increasing Reliance on Surface Water

(Likely Ineffective) Increased reliance on surface water supplies, without reservoir storage, may create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

(Typically Effective) Increased reliance on bedrock groundwater could mitigate alluvial groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 74's portion of the Vamoosa-Ada aquifer. However, the aquifer underlies only about half of the basin.

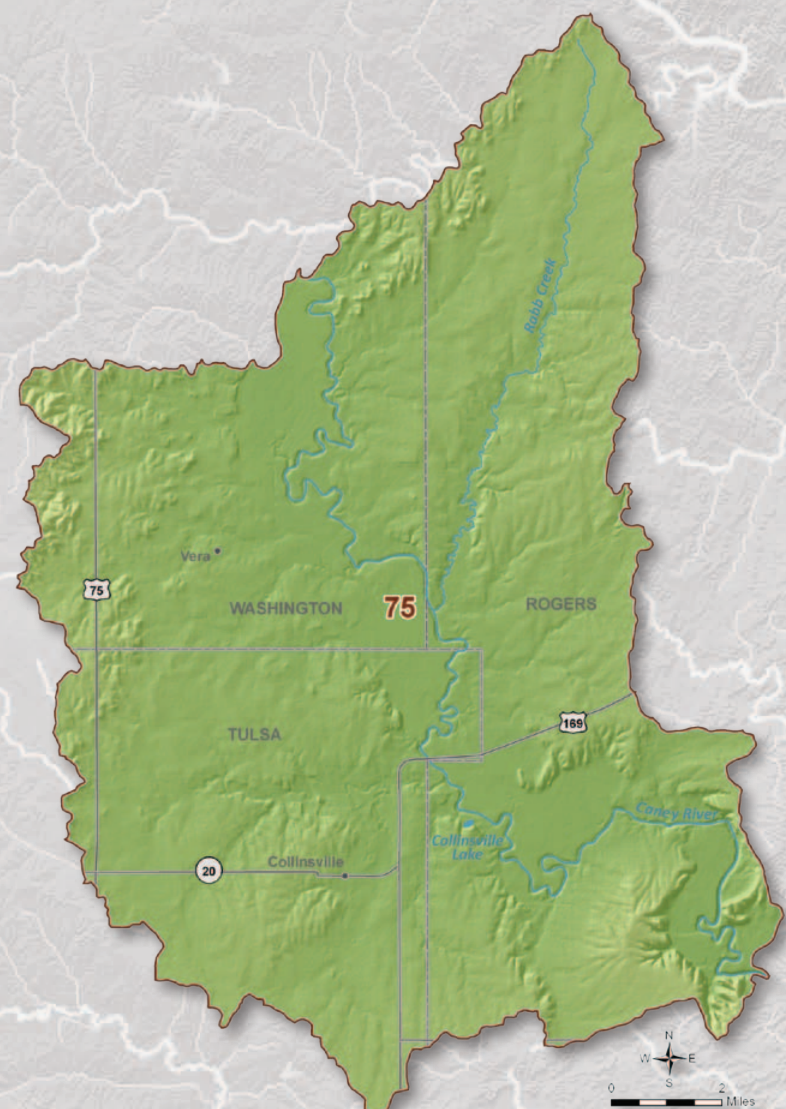
Notes & Assumptions

- 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
Middle Arkansas Watershed Planning Region

Basin 75



Basin 75 Summary

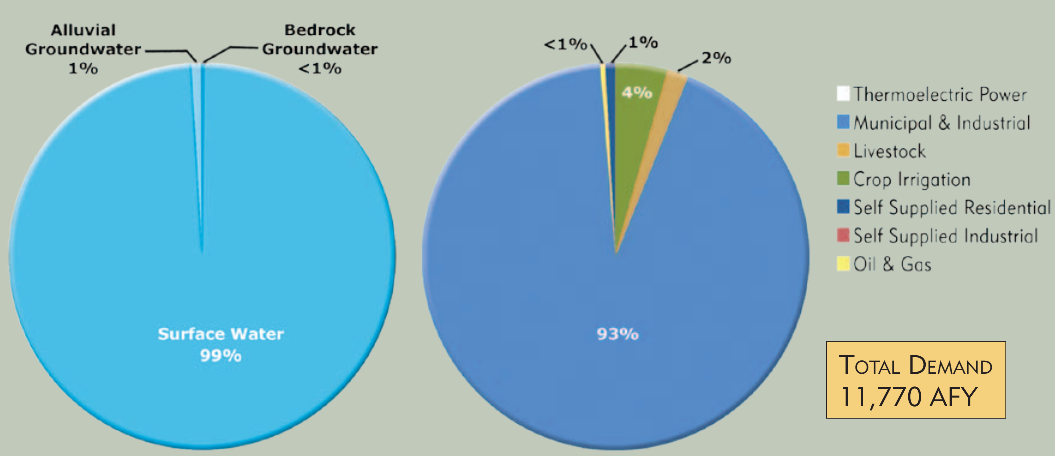
Synopsis

- Water users are expected to continue to rely mainly on surface water and out-of-basin supplies.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods. Groundwater storage depletions are not expected on a basin level by 2060. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on basin water supplies, it is recommended that surface water gaps be decreased where economically feasible.
- Additional conservation could reduce surface water gaps. Due to the low probability of gaps, temporary drought management could be an effective means of reducing demand, largely from outdoor water use, and may mitigate gaps.
- Additional conservation could reduce surface water gaps.
- Increased use of out-of-basin supplies from Oologah Lake could mitigate surface water gaps, but the lake is currently fully allocated. New reservoirs could be developed to mitigate gaps.
- Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended. Basin 75 has limited groundwater resources; therefore, increased reliance on groundwater supplies without site-specific information is not recommended.

Basin 75 accounts for about 5% of the current water demand in the Middle Arkansas Watershed Planning Region. About 93% of the 2010 demand was in the Municipal and Industrial demand sector. Crop Irrigation (4%) is the second-largest demand sector in 2010. Basin water demands are met almost entirely by surface water and out-of-basin supplies (about 99%). The peak summer month demand in Basin 75 is about 1.8 times

Current Demand by Source and Sector

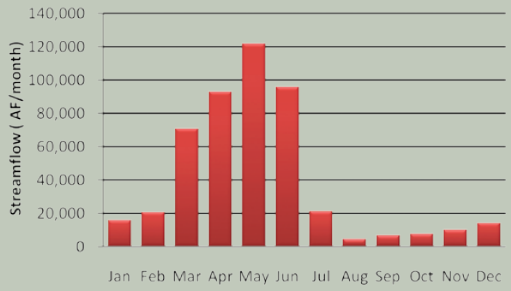
Middle Arkansas Region, Basin 75



Water Resources

Middle Arkansas Region, Basin 75

Median Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 75



Projected Water Demand
Middle Arkansas Region, Basin 75

the winter demand, which is less pronounced than the overall statewide pattern.

The Caney River upstream of the Verdigris River typically has flows greater than 4,500 AF/month throughout the year and greater than 70,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year. There are no major reservoirs within this basin. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to basins statewide, the surface water quality in Basin 75 is considered fair.

Basin 75 has less than 50 AFY of groundwater rights in non-delineated minor bedrock aquifers. Domestic users may also obtain supplies from minor alluvial aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 14,600 AFY reflects a 2,830 AFY increase (24%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps are expected to occur by 2020. Surface water gaps will be up to 1,040 AFY and have a 10% probability of occurring in at least one month of the year by 2060. Alluvial groundwater depletions were not evaluated, due to the minimal increase in demand from 2010 to 2060. Bedrock groundwater demand is minimal in Basin 75.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about 76%. Due to the low probability of surface water gaps temporary drought management, largely from outdoor water use, could be an effective means of reducing demand and may mitigate gaps.

Several public water providers, including the City of Collinsville, Washington County RWD #3, and Rogers County RWD #4, currently obtain supplies from Oologah Lake in Basin 79. Increased use of this supply in the future could be used to meet surface water gaps. However, Oologah Lake is currently fully allocated; therefore, any future use of this source would need to take into consideration existing water rights.

Water Supply Limitations
Middle Arkansas Region, Basin 75

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal · Potential · Significant

Water Supply Option Effectiveness
Middle Arkansas Region, Basin 75

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

The OCWP Reservoir Viability Study, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region. However, due to the distance to these and other reliable sources, out-of-basin supplies may not be cost-effective for some users in the basin.

New in-basin reservoir storage could increase the dependability of available surface water supplies and mitigate gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and approximately 1,100 AF of new reservoir storage at the basin outlet.

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

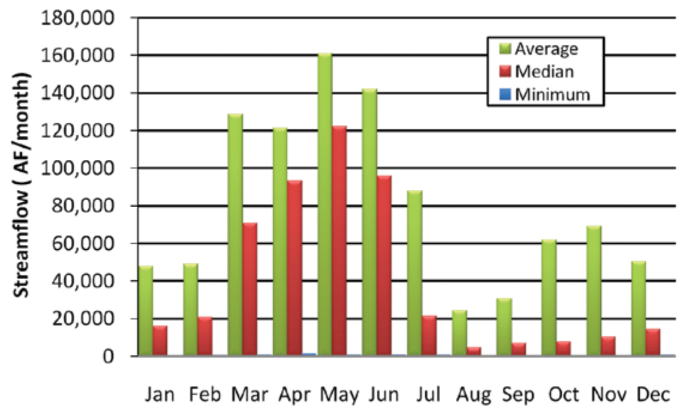
Basin 75 has limited minor groundwater resources; therefore, increased reliance on groundwater supplies without site-specific information may be ineffective, especially for large-scale users.

Basin 75 Data & Analysis

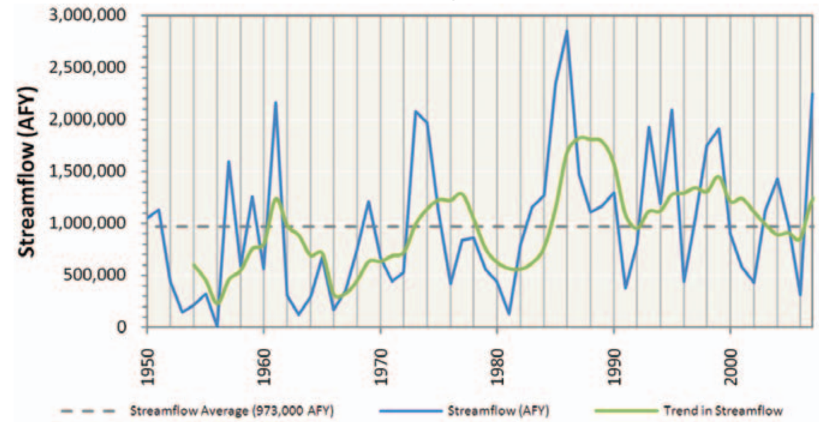
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Caney River upstream of the Verdigris River had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to the mid 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in Caney River upstream of the Verdigris River is greater than 4,500 AF/month throughout the year and greater than 70,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 75 is considered fair.
- There are no major reservoirs within this basin

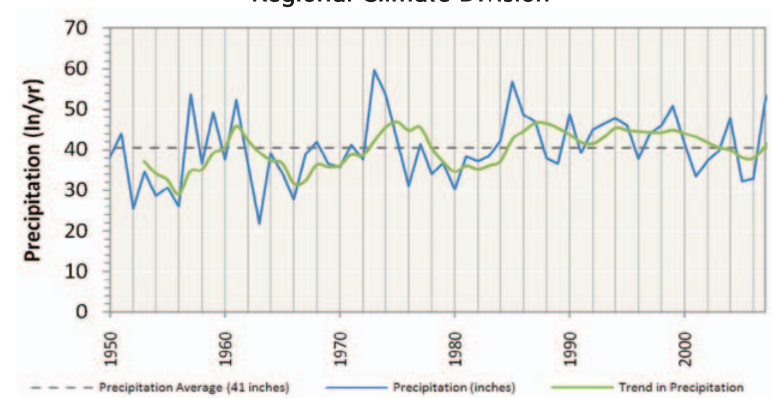
Monthly Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 75



Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 75



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)

Middle Arkansas Region, Basin 75

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
Cherokee Group	Bedrock	Minor	46%	0	82,000	temporary 2.0	89,600
Verdigris River Groundwater Basin	Alluvial	Minor	5%	0	16,000	temporary 2.0	12,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	<50	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

- Basin 75 has less than 50 AFY of groundwater rights in non-delineated minor bedrock aquifers. However, it is assumed that non-delineated minor alluvial groundwater sources will also supply a small amount of domestic (Self-Supplied Residential) water use, which does not require a permit.
- There are no significant groundwater quality issues in Basin 75.

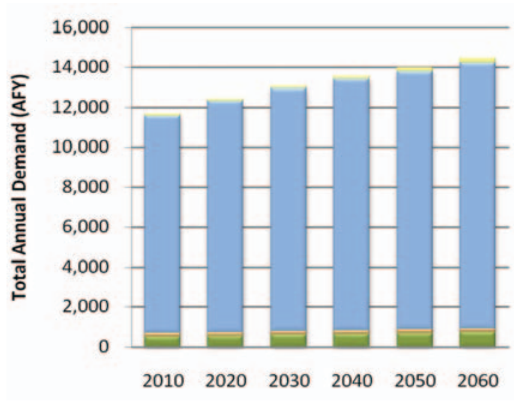
Notes & Assumptions

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

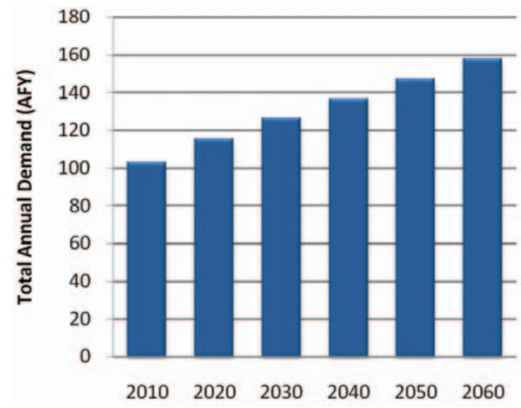
Water Demand

- The water needs of Basin 75 account for about 5% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 24% (2,830 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be from the Municipal and Industrial demand sector.
- Surface water and out-of-basin supplies are used to meet 99% of the total demand in the basin and its use will increase by 24% (2,780 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 1% of the total demand in the basin and its use will increase by 53% (60 AFY) from 2010 to 2060. The alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet less than 1% of the total demand in the basin. The increase in bedrock groundwater demand from 2010 to 2060 is minimal on a basin scale.

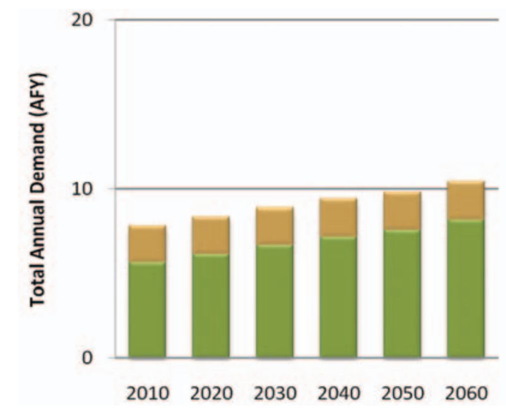
Surface Water Demand by Sector
Middle Arkansas Region, Basin 75



Alluvial Groundwater Demand by Sector
Middle Arkansas Region, Basin 75



Bedrock Groundwater Demand by Sector
Middle Arkansas Region, Basin 75



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

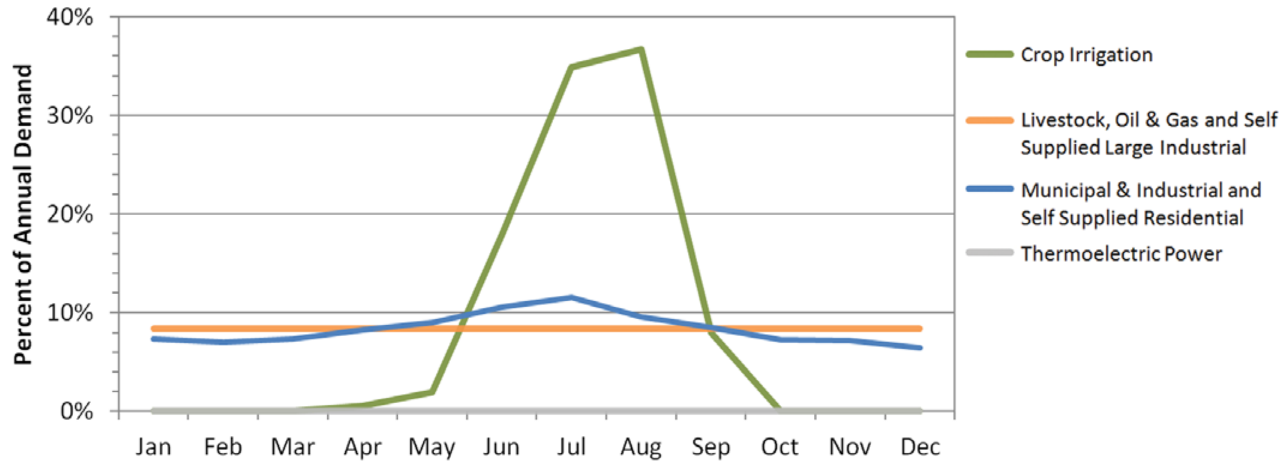
Total Demand by Sector
Middle Arkansas Region, Basin 75

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	520	200	10,900	50	0	100	0	11,770
2020	560	200	11,590	70	0	120	0	12,540
2030	610	200	12,150	100	0	130	0	13,190
2040	660	200	12,570	140	0	140	0	13,710
2050	690	200	12,920	170	0	150	0	14,130
2060	750	200	13,270	220	0	160	0	14,600

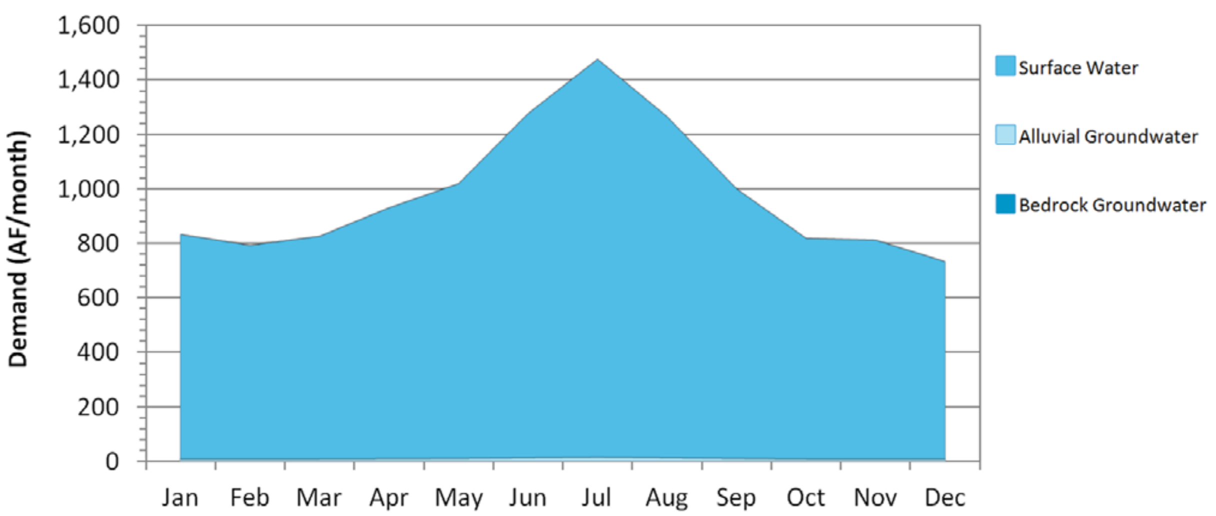
Notes & Assumptions

- 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)
Middle Arkansas Region, Basin 75



Monthly Demand Distribution by Source (2010)
Middle Arkansas Region, Basin 75



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months, but it accounts for only a small portion of the demand in this basin. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 75 is about 1.8 times the winter demand, which is less pronounced than the overall statewide pattern. Surface water and alluvial groundwater use in the peak summer month is about 1.7 times the winter use. Monthly bedrock groundwater use peaks in the summer at about 15 times the winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2020. No alluvial aquifer storage depletions are expected to occur by 2060. Bedrock groundwater depletions were not evaluated, due to the minimal increase in demand from 2010 to 2060.
- Surface water gaps in Basin 75 may occur during the summer, fall, and winter, peaking in size during the summer. Surface water gaps in 2060 will be up to 16% (300 AF/month) of the surface water demand in the peak summer month, and up to 11% (110 AF/month) of the peak winter month surface water demand.
- There will be a 10% 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.

Surface Water Gaps by Season (2060 Demand)

Middle Arkansas Region, Basin 75

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	110	90	3%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	300	130	9%
Sep-Nov (Fall)	230	140	5%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 75

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Middle Arkansas Region, Basin 75

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	130	0	0	3%	0%
2030	360	0	0	3%	0%
2040	580	0	0	5%	0%
2050	750	0	0	7%	0%
2060	1,040	0	0	10%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 75

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 75

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	1,040	0	0	10%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	980	0	0	10%	0%
Moderately Expanded Conservation in M&I Water Use	260	0	0	5%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	250	0	0	3%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	20	0	0	2%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Middle Arkansas Region, Basin 75

Reservoir Storage	Diversion
AF	AFY
100	500
500	1,600
1,000	2,600
2,500	4,500
5,000	6,700
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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about 76%. Due to the low probability of gaps, temporary drought management, largely from outdoor water use, could be an effective means of reducing demand and may mitigate gaps.

Out-of-Basin Supplies

Several public water providers, including the City of Collinsville, Washington County RWD #3, and Rogers County RWD #4, currently obtain supplies from Oologah Lake in Basin 79. Increased use of these supplies in the future could reduce surface water gaps. However, Oologah Lake is currently fully allocated; therefore, any future use of this source would need to take into consideration existing water rights. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. However, due to the distance to these and other reliable sources, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps. The entire increase in demand from 2010 to 2060 could be met by a new reservoir diversion and approximately 1,100 AF of new reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps.

Increasing Reliance on Surface Water

Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps and may be ineffective, especially for large-scale users.

Increasing Reliance on Groundwater

Basin 75 has limited minor groundwater resources; therefore, increased reliance on groundwater supplies without site-specific information is not recommended.

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
Middle Arkansas Watershed Planning Region

Basin 76

Basin 76 Summary

Synopsis

- Water users are expected to continue to rely mainly on surface water supplies and reservoirs.
- Alluvial groundwater storage depletions have a very low (3%) probability of occurring by 2060 and will be small in size on a basin scale. However, localized storage depletions may cause adverse effects for users.
- Hulah Lake and Copan Lake, with reallocation of storage, are capable of providing dependable water supplies to their existing users.
- 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 the adverse effects of localized alluvial groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing small reservoirs could mitigate alluvial groundwater storage depletions without having major impacts to groundwater storage.

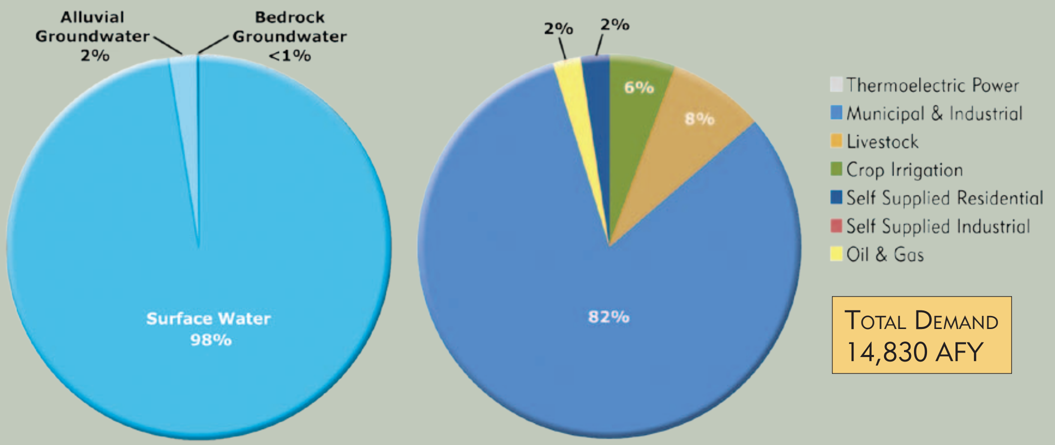
Basin 76 accounts for about 6% of the current water demand in the Middle Arkansas Watershed Planning Region. About 82% of the 2010 demand was in the Municipal and Industrial demand sector. Agricultural uses (Crop Irrigation and Livestock combined) account for about 14% of the 2010 demand. Surface water satisfies about 98% of the total demand in the basin. Groundwater satisfies about 2% of the demand, almost entirely from alluvial aquifers. The peak summer month total water demand in Basin 76 is about 1.8 times the peak winter month demand, which is less pronounced than the overall statewide pattern.

The Caney River near Ramona typically has flows greater than 4,300 AF/month throughout the year and greater than 65,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year. There are two major reservoirs in the basin: Hulah Lake and Copan Lake. Copan Lake was built by the Corps of Engineers for the purposes of flood control, water supply, water quality control and fish and wildlife. The Lake contains 7,500 AF of water supply storage with a dependable yield of 3,360 AFY, and 26,100 AF of water quality storage with a dependable yield of 17,920 AFY. Hulah Lake, also built by the Corps of Engineers, provides storage for flood control, water supply, low flow regulation (including water quality) and conservation. The Lake contains 19,800 AF of water supply storage with a yield of 11,088 AFY, and 7,100 AF of water quality storage with a dependable yield of 5,040 AFY. There are many other public and privately owned lakes in the region that provide water for multiple purposes; however, the ability of these lakes to provide future water supply could not be evaluated because their yields are unknown. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to basins statewide, the surface water quality in Basin 76 is considered poor. Copan Lake is impaired for Public and Private Water Supply use due to high levels of chlorophyll-a. However, individual lakes and streams may have acceptable water quality.

There are less than 150 AFY of groundwater rights permitted in the basin, primarily from the Vamoosa-Ada major bedrock aquifer

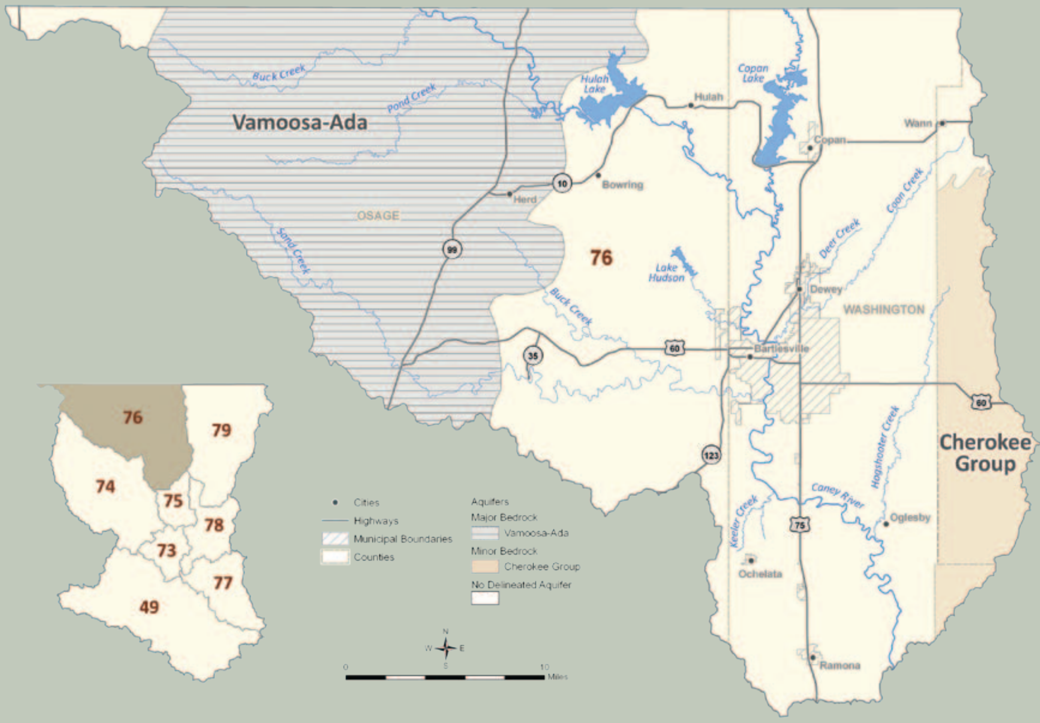
Current Demand by Source and Sector

Middle Arkansas Region, Basin 76

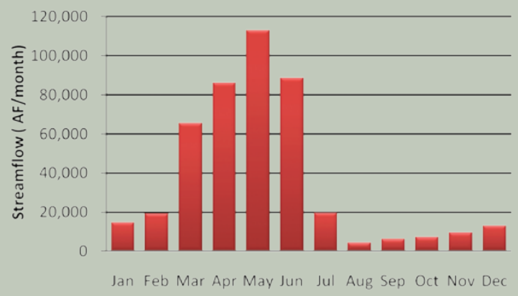


Water Resources

Middle Arkansas Region, Basin 76



Median Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 76



Projected Water Demand
Middle Arkansas Region, Basin 76

underlying the western one-third of the basin and, to a lesser extent, from non-delineated minor bedrock aquifers. However, the largest demand for groundwater is from minor alluvial and major bedrock aquifers for domestic use, which does not require a permit. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 18,280 AFY reflects a 3,450 AFY increase (23%) over the 2010 demand. The majority of demand and growth in demand will occur in the Municipal and Industrial sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2050. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin. Alluvial groundwater storage depletions will be up to 30 AFY and have a 3% probability of occurring in at least one month of the year by 2060. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the severity of the storage depletions could not be evaluated due to insufficient information. However, 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 and existing reservoirs. 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 Crop Irrigation 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.

New out-of-basin supplies could be used to mitigate groundwater storage depletions. There are several large water supply reservoirs in the region that provide dependable supplies; however, any future use of these sources would need to take into consideration existing water rights. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potential out-of-basin site in the Middle Arkansas Region. However, due to the distance to out-of-basin supplies and the existing in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Water Supply Limitations
Middle Arkansas Region, Basin 76

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal · Potential · Significant

Water Supply Option Effectiveness
Middle Arkansas Region, Basin 76

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

Reallocated reservoir storage from existing lakes or new reservoirs could increase the dependability of available surface water supplies and mitigate the adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and approximately 900 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Sand Reservoir as a potential site in Basin 76.

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

Increased reliance on the Vamoosa-Ada aquifer could mitigate alluvial groundwater storage depletions without creating bedrock storage depletions. However, the aquifer only underlies the western one-third of the basin.

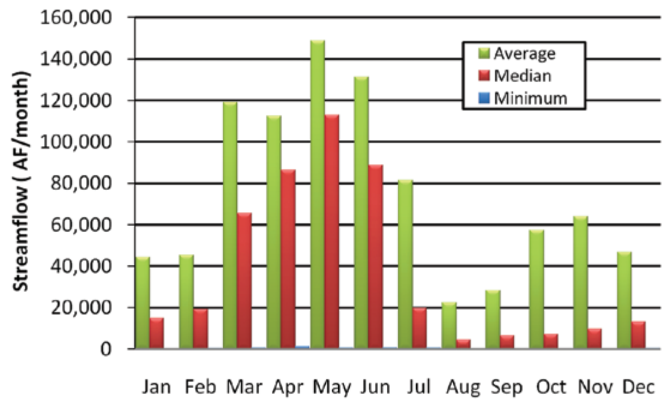
Basin 76 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Caney River near Ramona had a prolonged period of below-average streamflow and precipitation from the early 1960s through the early 1970s. From the mid 1980s to the mid 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 Caney River near Ramona is greater than 4,300 AF/month throughout the year and greater than 65,000 AF/month in spring and early summer; it can have prolonged periods of low flow in any month. The surface water quality in Basin 76 is generally considered poor relative to other basins in the state.
- Hulah Lake provides 11,088 AFY of water supply yield and supplies the City of Bartlesville and Osage County RWD# 20. Copan Lake provides 3,360 AFY of water supply yield and supplies the City of Copan; Bartlesville also has permitted use. Both lakes also contain unpermitted water quality yield. Lake Hudson also provides supply for Bartlesville; however, the water supply yield is unknown.

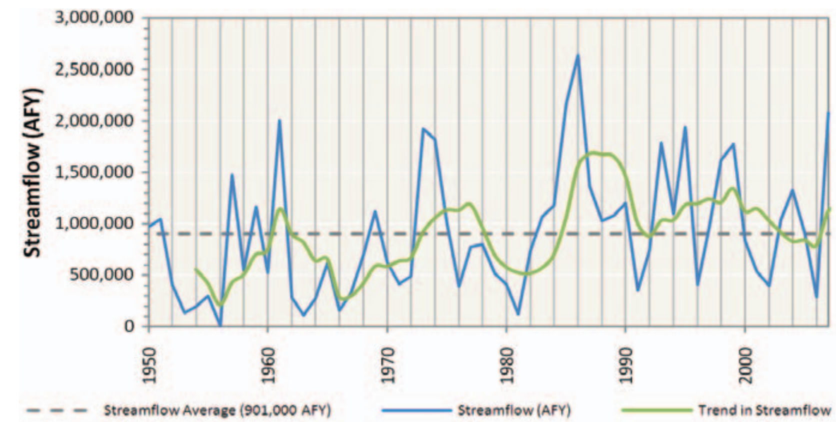
Monthly Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 76



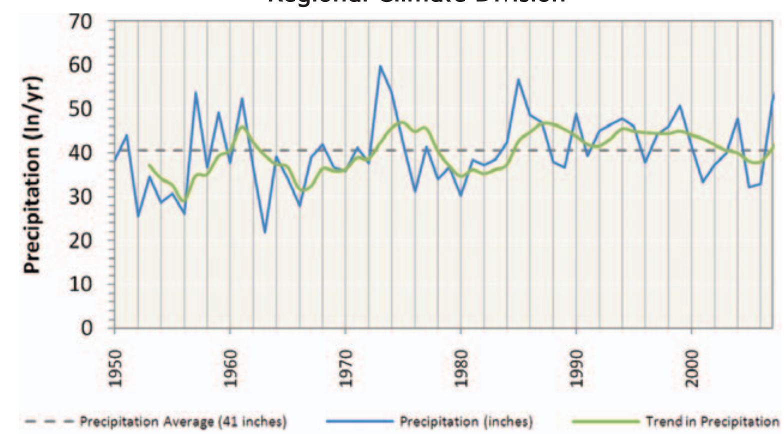
Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 76



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)

Middle Arkansas Region, Basin 76

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
Vamoosa-Ada	Bedrock	Major	33%	100	637,000	2.0	422,400
Cherokee Group	Bedrock	Minor	7%	0	82,000	temporary 2.0	89,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	<50	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

- Basin 76 has less than 150 AFY of groundwater rights, which are in the Vamoosa-Ada major bedrock aquifer and non-delineated minor bedrock aquifers. However, the largest demand for groundwater is assumed to be primarily from minor alluvial aquifers for domestic use (Self-Supplied Residential) which does not require a permit. The estimated recharge to the Vamoosa-Ada aquifer, which underlies about a third of the basin, is 19,000 AFY.
- There are no significant groundwater quality issues in Basin 76.

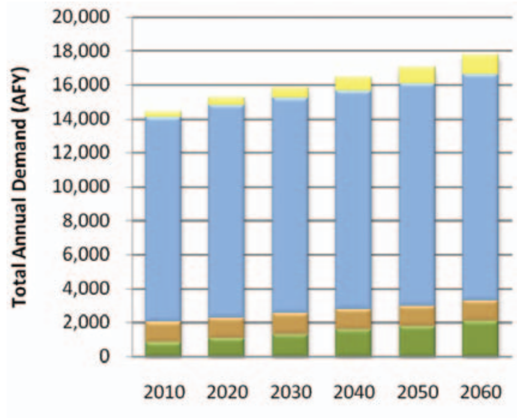
Notes & Assumptions

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

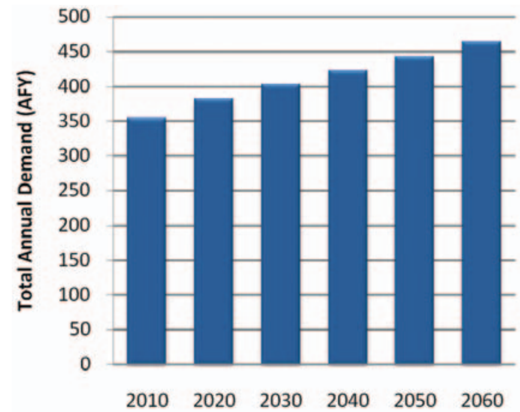
Water Demand

- The water needs of Basin 76 account for about 6% of the total demand in the Middle Arkansas Region and will increase by 23% (3,450 AFY) from 2010 to 2060. The majority of demand and largest growth in demand during this period will be from the Municipal and Industrial sector. However, the Crop Irrigation demand sector, while much smaller, will have a similar amount of growth in demand from 2010 to 2060.
- Surface water and out-of-basin supplies are used to meet 98% of the total demand in the basin and their use will increase by 23% (3,340 AFY) from 2010 to 2060. The majority of surface water use will be in the Municipal and Industrial demand sector. The largest growth in surface water use over this period will be from the Municipal and Industrial demand sector followed closely by the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet almost 2% of the total demand in the basin and its use will increase by 31% (110 AFY) from 2010 to 2060. The alluvial groundwater use and growth in alluvial groundwater use over this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet less than 1% of the total demand in the basin. The increase in bedrock groundwater demand is minimal on a basin scale.

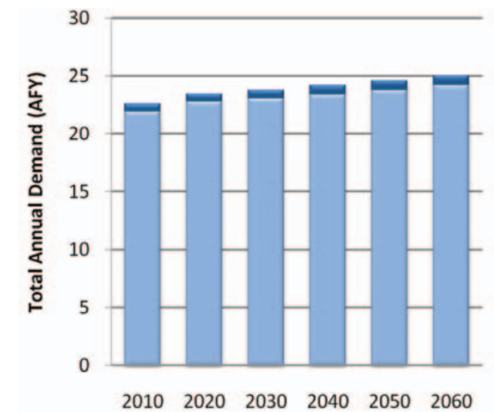
Surface Water Demand by Sector
Middle Arkansas Region, Basin 76



Alluvial Groundwater Demand by Sector
Middle Arkansas Region, Basin 76



Bedrock Groundwater Demand by Sector
Middle Arkansas Region, Basin 76



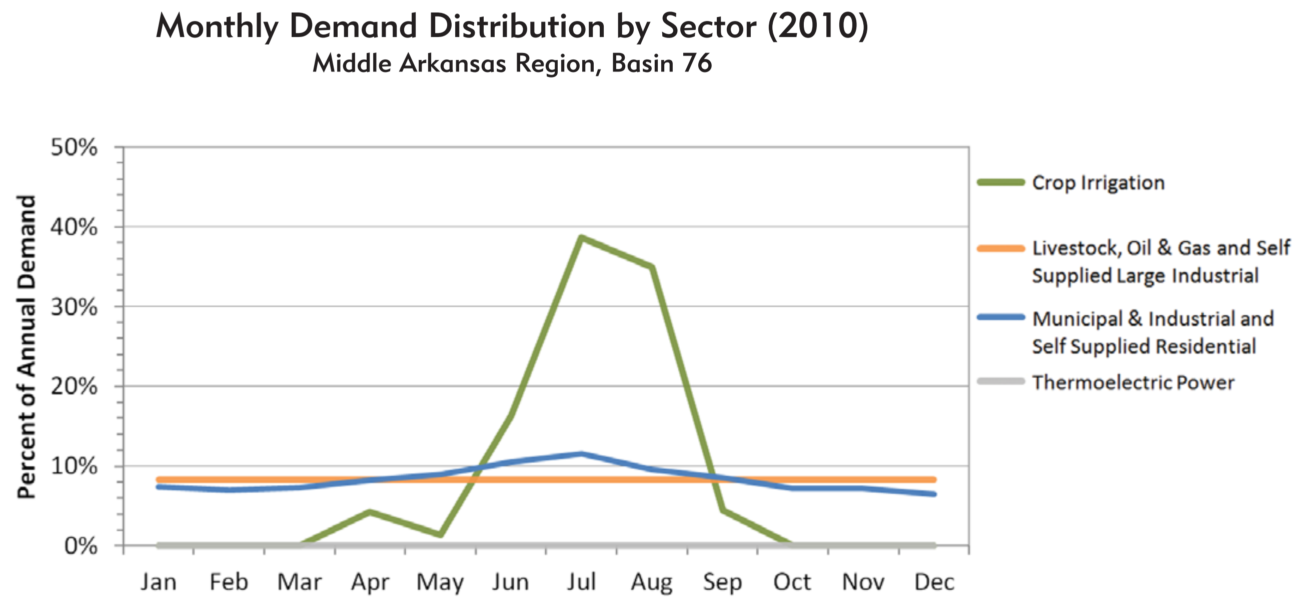
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

Total Demand by Sector
Middle Arkansas Region, Basin 76

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	840	1,190	12,090	350	0	360	0	14,830
2020	1,090	1,200	12,540	470	0	380	0	15,680
2030	1,340	1,210	12,700	620	0	400	0	16,270
2040	1,580	1,210	12,900	790	0	420	0	16,900
2050	1,770	1,220	13,100	980	0	440	0	17,510
2060	2,070	1,230	13,330	1,180	0	470	0	18,280

Notes & Assumptions

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

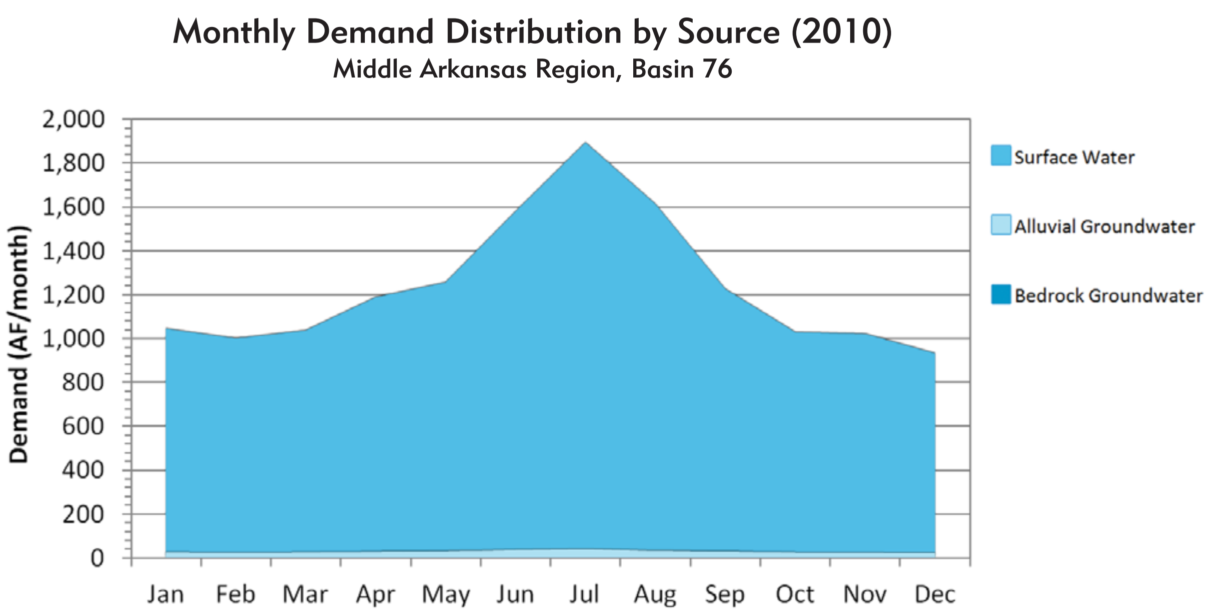


Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 76 is about 1.8 times the peak winter month demand, which is similar to the overall statewide pattern. All sources have similar ratios of peak summer month use to winter use.



Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2050. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin.
- There will be a 3% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in 2060 will be up to 25% (10 AF/month) of the peak summer and fall monthly alluvial groundwater demand. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the severity of the storage depletions could not be evaluated due to insufficient information. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Middle Arkansas Region, Basin 76

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 Amounts shown represent the largest amounts for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 76

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)	10	10	2%

1 Amounts shown represent the largest amounts for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Middle Arkansas Region, Basin 76

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AF			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	0	0	0	0%	0%
2050	0	20	0	0%	2%
2060	0	30	0	0%	3%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 76

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

1 Amounts shown represent the largest amounts for any one month in the season indicated.

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 76

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	30	0	0%	3%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	30	0	0%	3%
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

Middle Arkansas Region, Basin 76

Reservoir Storage	Diversion
AF	AFY
100	900
500	2,300
1,000	3,900
2,500	6,500
5,000	9,700
Required Storage to Meet Growth in Demand (AF)	900
Required Storage to Meet Growth in Surface Water Demand (AF)	800

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

Out-of-Basin Supplies

New out-of-basin supplies could be used to augment supplies and mitigate storage depletions. There are multiple large water supply reservoirs in the Middle Arkansas Watershed Planning Region that provide dependable supplies; however, any future use of these sources would need to take into consideration existing water rights. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the Middle Arkansas Watershed Planning Region: Candy Lake in Basin 74. However, due to the distance to out-of-basin supplies and the existing in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

Reallocated reservoir storage from existing lakes or new in-basin reservoirs could increase the dependability of available surface water supplies and mitigate the adverse affects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and approximately 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 amount of storage necessary to mitigate future gaps and storage depletions. The OWRB *Reservoir Viability Study* also identified Sand Reservoir as a potential reservoir site in Basin 76.

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 Vamoosa-Ada aquifer could mitigate alluvial groundwater storage depletions without creating bedrock storage depletions. However, the aquifer only underlies the western one-third of the basin.

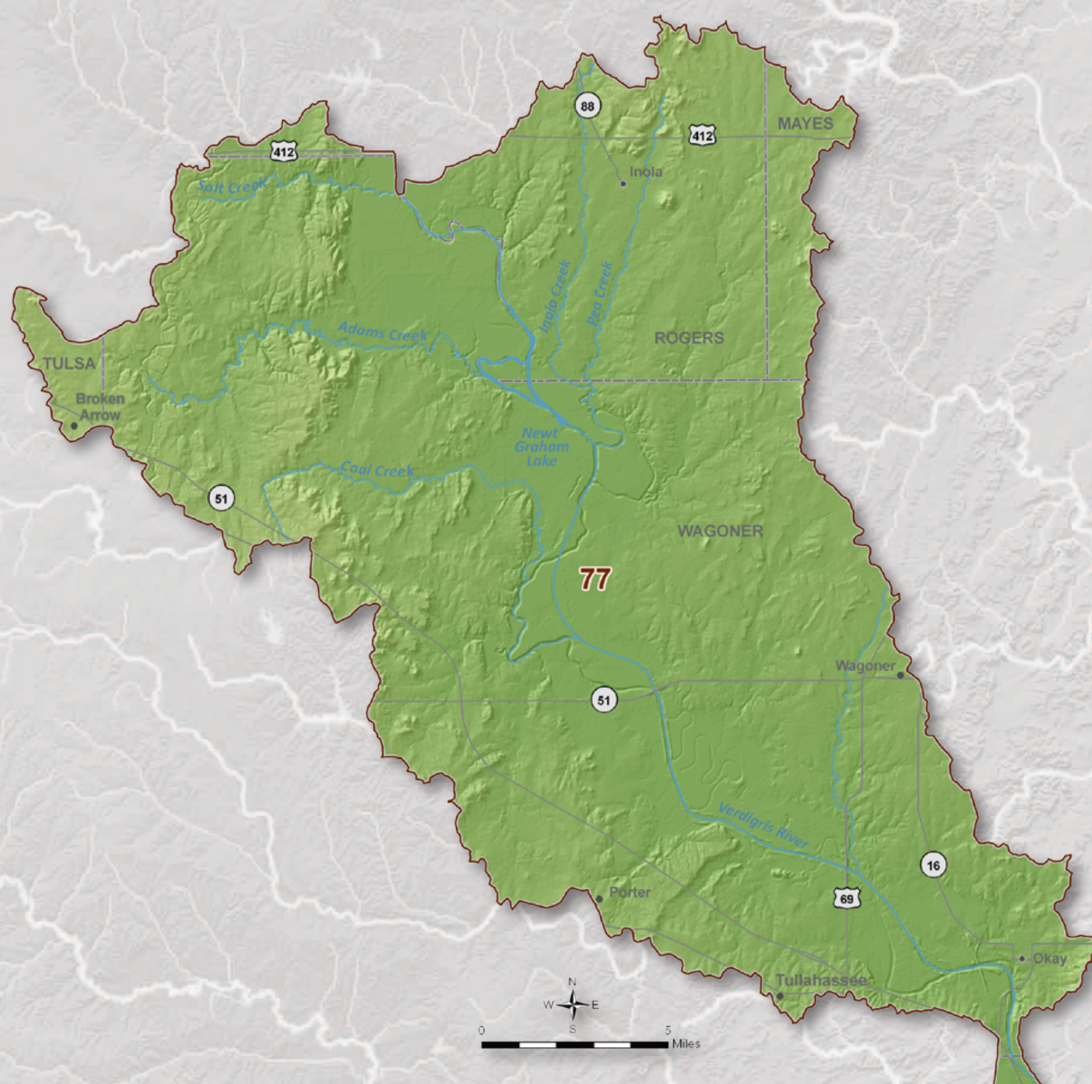
Notes & Assumptions

- 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
Middle Arkansas Watershed Planning Region

Basin 77



Basin 77 Summary

Synopsis

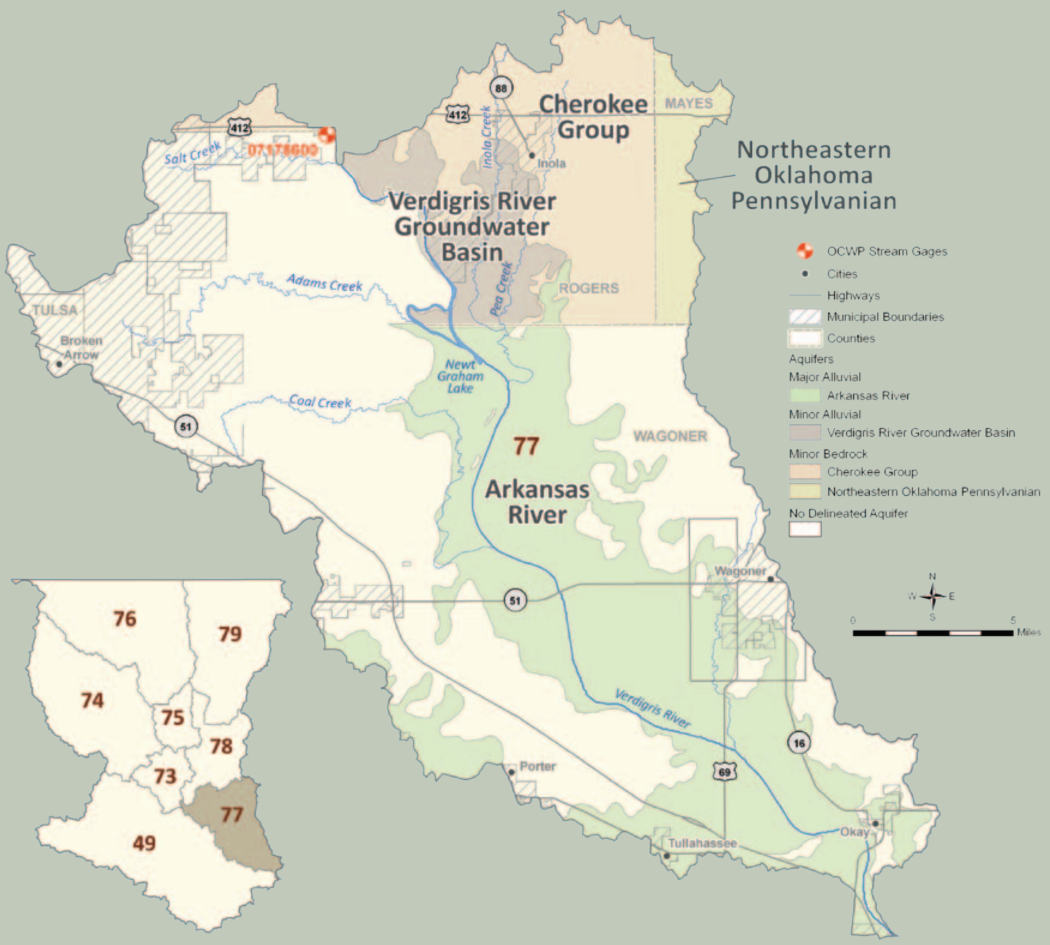
- Water users are expected to continue to rely mainly on surface water supplies.
- By 2020, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce the risk of adverse impacts on water supplies, it is recommended that surface water gaps be decreased where economically feasible.
- Additional conservation could reduce surface water gaps.
- Use of additional groundwater supplies and/or developing small reservoirs could mitigate surface water gaps without having major impacts to groundwater storage.

Basin 77 accounts for about 8% of the current water demand in the Middle Arkansas Watershed Planning Region. About 40% of the 2010 demand was in the Municipal and Industrial demand sector. Crop Irrigation (32%) and Thermoelectric Power (25%) are the next-largest demand sectors. Surface water and out-of-basin supplies satisfy over 99% of the total demand in Basin 77. Alluvial groundwater satisfies less than 1% of the total demand in the basin. The peak summer month demand in Basin 77 is about 6 times the peak winter month demand, which is similar to the overall statewide pattern.

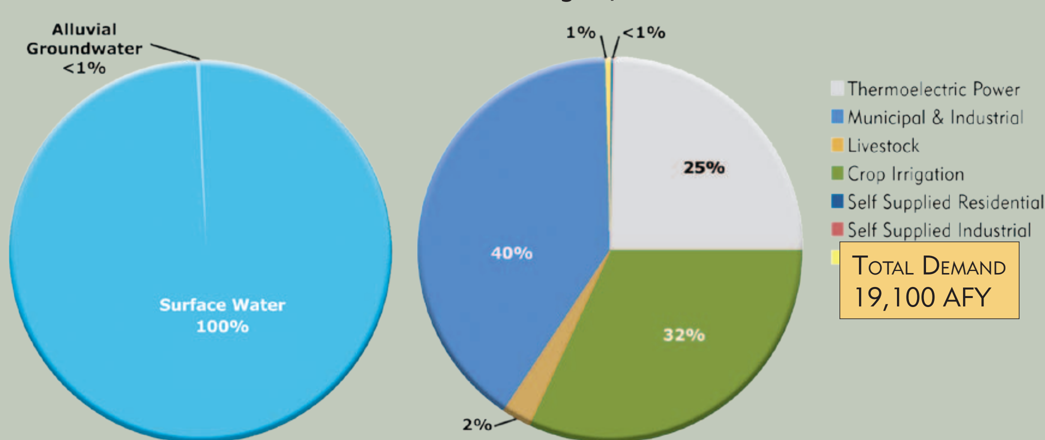
The Verdigris River upstream of the Arkansas River typically has flows greater than 25,000 AF/month in each month of the year and greater than 300,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year. There are no major reservoirs 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 basins statewide, the surface water quality is in Basin 77 is considered fair.

Although the Arkansas River major alluvial aquifer has substantial storage and underlies about 30% of the basin, there are no groundwater rights in Basin 77. The only demand for groundwater is for domestic use, which does not require permits and assumed to be supplied

Water Resources
Middle Arkansas Region, Basin 77

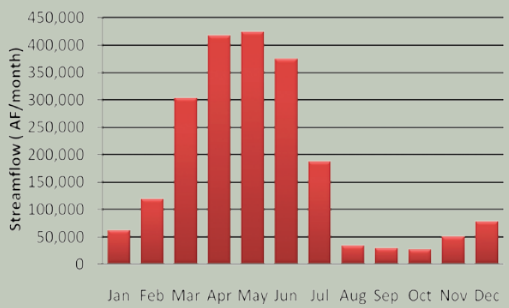


Current Demand by Source and Sector
Middle Arkansas Region, Basin 77



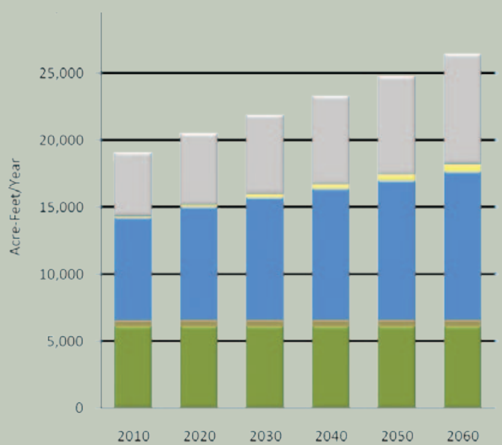
Median Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 77



Projected Water Demand

Middle Arkansas Region, Basin 77



from the Arkansas River aquifer and other minor alluvial aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 26,420 AFY reflects a 7,320 AFY increase (38%) over the 2010 demand. The largest growth in demand will occur in the Municipal and Industrial and Thermoelectric Power sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2020. No alluvial groundwater depletions are expected in this basin due to the minimal growth in its use from 2010 through 2060. Surface water gaps will be up to 4,440 AFY and have a 67% probability of occurring in at least one month of the year by 2060. No bedrock groundwater demand is assumed in Basin 77.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about a third. Due to the high probability of gaps, temporary drought management activities will likely be ineffective.

Out-of-basin supplies could be used to augment supplies and meet demand. Currently, most public water suppliers in the basin, including the cities of Broken Arrow and Wagoner, are expected to meet much of their demand from out-of-basin supply sources. Major out-of-basin supply sources include Fort Gibson Lake and the Oklahoma Ordnance Works Authority in the Grand Watershed Planning Region. Increased reliance on these supplies or other nearby dependable water supplies with new infrastructure could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region. However, due to the distance to these reliable sources, out-of-basin supplies may not be cost-effective for some users in the basin.

New in-basin reservoir storage could increase the dependability of available surface water supplies and mitigate gaps. The entire increase in water demand from 2010 to 2060 could be met by a new

Water Supply Limitations

Middle Arkansas Region, Basin 77

Surface Water	Potential
Alluvial Groundwater	Minimal
Bedrock Groundwater	Potential

Minimal Potential Significant

Water Supply Option Effectiveness

Middle Arkansas Region, Basin 77

Demand Management	Potentially 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

river diversion and approximately 3,700 AF of new reservoir storage at the basin outlet.

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

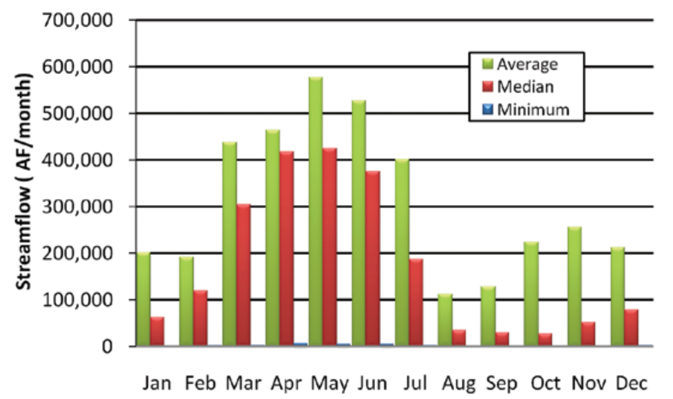
Increased reliance on groundwater supplies could mitigate surface water gaps, but may cause groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 77's portion of the Arkansas River aquifer. However, this aquifer only underlies a third of the basin.

Basin 77 Data & Analysis

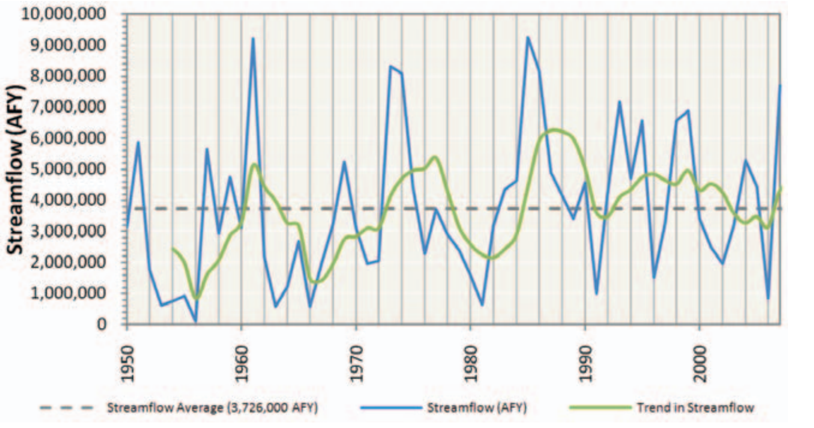
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Verdigris River upstream of the Arkansas River had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median streamflow in the Verdigris River upstream of the Arkansas River is greater than 25,000 AF/month throughout the year and greater than 300,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 77 is considered fair.
- There are no major reservoirs in the basin.

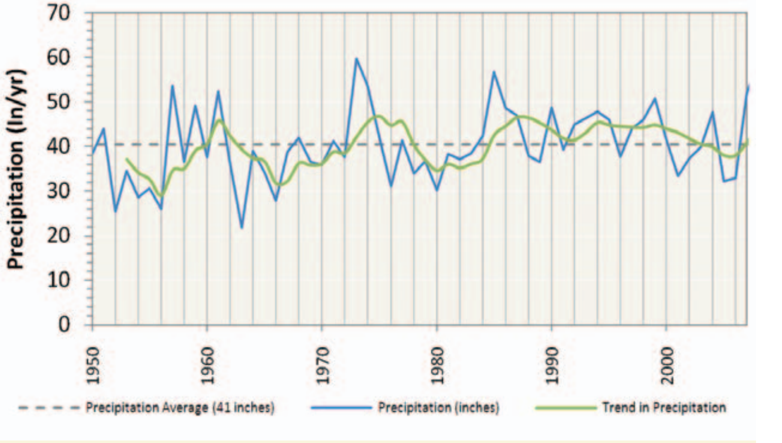
Monthly Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 77



Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 77



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)

Middle Arkansas Region, Basin 77

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AF/acre	AFY
Arkansas River	Alluvial	Major	30%	0	133,000	temporary 2.0	153,600
Verdigris River Groundwater Basin	Alluvial	Minor	5%	0	32,000	temporary 2.0	25,600
Cherokee Group	Bedrock	Minor	17%	0	82,000	temporary 2.0	89,600
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	3%	0	15,000	temporary 2.0	12,800
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

- There are no groundwater rights in basin 77, although it is assumed that non-delineated minor alluvial groundwater sources will supply a small amount of domestic (Self-Supplied Residential) water use, which does not require a permit.. The Arkansas River alluvial aquifer has substantial storage and underlies about 30% of the basin.
- There are no significant groundwater quality issues in Basin 77.

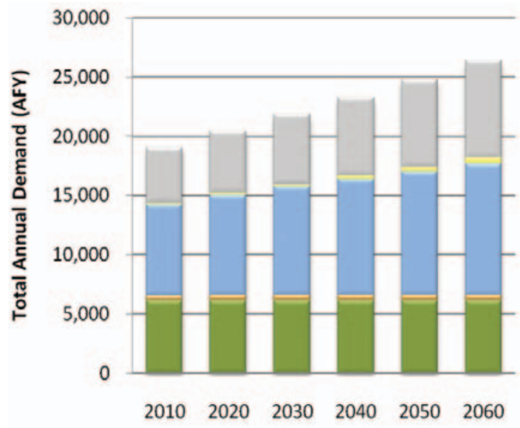
Notes & Assumptions

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

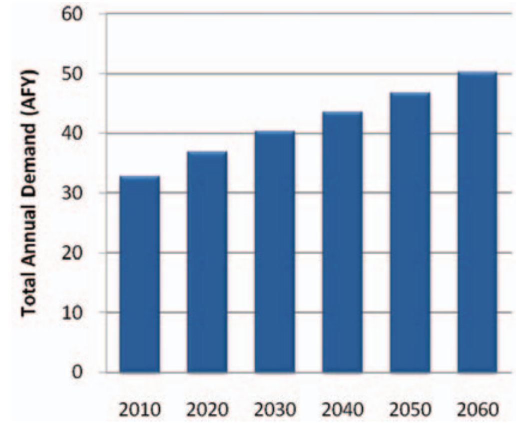
Water Demand

- The water needs of Basin 77 account for about 8% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 38% (7,320 AFY) from 2010 to 2060. The majority of demand during this period will be from the Municipal and Industrial demand sector. The majority of growth in demand from 2010 to 2060 will be from the Municipal and Industrial and Thermoelectric Power demand sectors.
- Surface water is used to meet over 99% of the total demand in the basin and its use will increase by 38% (7,300 AFY) from 2010 to 2060. The majority of surface water use will be from the Municipal and Industrial demand sector, which will be met in part by existing out-of-basin supplies. The largest growth in surface water use from 2010 to 2060 will be from the Municipal and Industrial and Thermoelectric Power demand sectors.
- Alluvial groundwater is used to meet less than 1% of the total demand in the basin and its use will increase by 53% (20 AFY) from 2010 to 2060. The entire alluvial groundwater use and growth in use over this period is assumed to be in the Self-Supplied Residential demand sector, which is minimal on a basin scale.
- There is no current bedrock groundwater use in Basin 77; therefore, no future demand is assumed from this source.

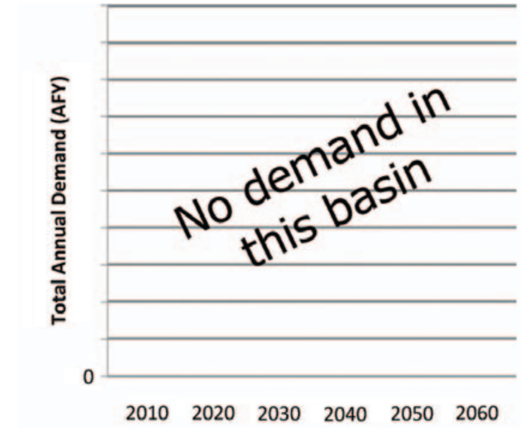
Surface Water Demand by Sector
Middle Arkansas Region, Basin 77



Alluvial Groundwater Demand by Sector
Middle Arkansas Region, Basin 77



Bedrock Groundwater Demand by Sector
Middle Arkansas Region, Basin 77



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

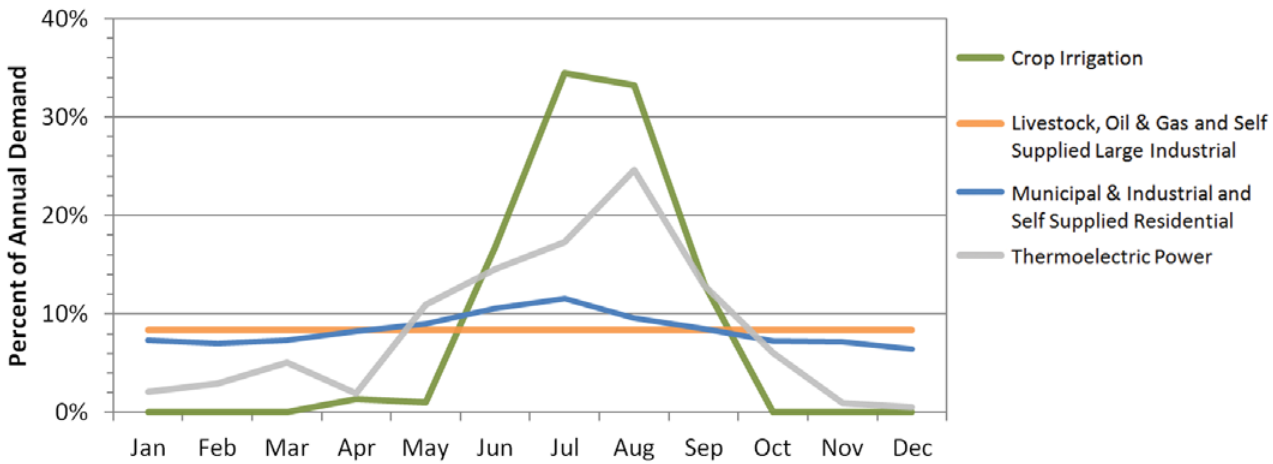
Total Demand by Sector
Middle Arkansas Region, Basin 77

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	6,100	460	7,690	90	0	30	4,730	19,100
2020	6,100	460	8,470	150	0	40	5,280	20,500
2030	6,110	470	9,160	230	0	40	5,890	21,900
2040	6,110	470	9,790	320	0	40	6,570	23,300
2050	6,120	470	10,400	430	0	50	7,330	24,800
2060	6,120	470	11,040	560	0	50	8,180	26,420

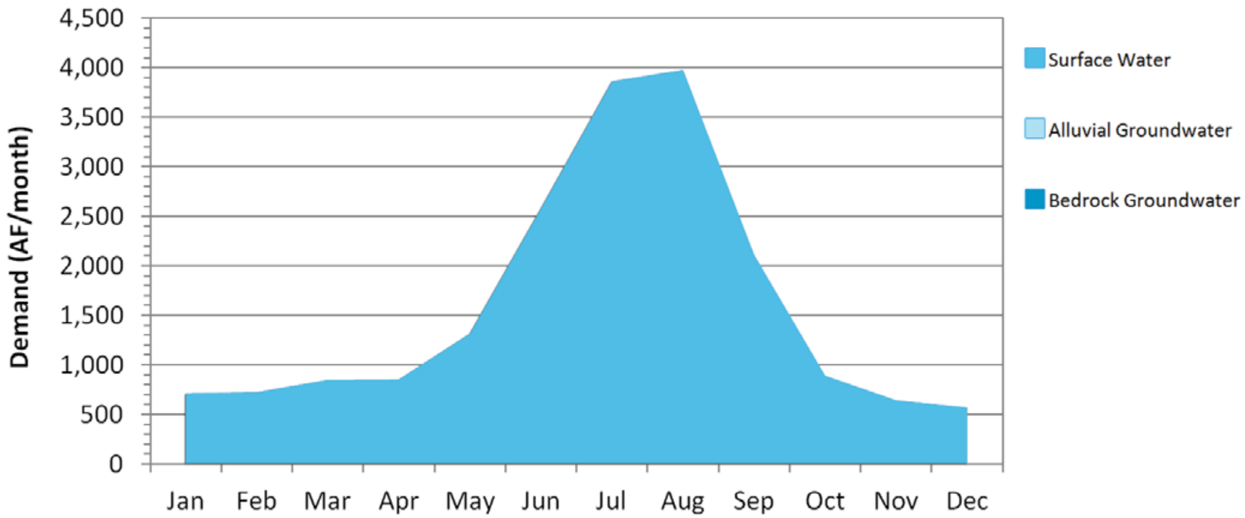
Notes & Assumptions

- 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)
Middle Arkansas Region, Basin 77



Monthly Demand Distribution by Source (2010)
Middle Arkansas Region, Basin 77



Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 77 is about 6 times the peak winter month demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 6 times the peak winter use. Alluvial groundwater use in the peak summer month is about 1.6 times the peak winter month demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2020. No alluvial groundwater depletions are expected in this basin due to the minimal growth in its use from 2010 through 2060.
- Basin 77 has historically had substantial streamflow in the Verdigris River. Upstream demand from both in-state basins and Kansas will reduce streamflow and recharge to alluvial groundwater aquifers.
- Surface water gaps in Basin 77 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 24% (1,220 AF/month) of the surface water demand in the peak summer month and as much as 35% (380 AF/month) of the peak winter month surface water demand.
- There will be a 67% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are least likely to occur during spring months.

Surface Water Gaps by Season (2060 Demand)
Middle Arkansas Region, Basin 77

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	380	320	36%
Mar-May (Spring)	720	460	10%
Jun-Aug (Summer)	1,220	1,030	43%
Sep-Nov (Fall)	770	490	38%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Middle Arkansas Region, Basin 77

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Middle Arkansas Region, Basin 77

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	550	0	0	36%	0%
2030	1,260	0	0	50%	0%
2040	2,180	0	0	57%	0%
2050	3,360	0	0	64%	0%
2060	4,440	0	0	67%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Middle Arkansas Region, Basin 77

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 77

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	4,440	0	0	67%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	4,240	0	0	67%	0%
Moderately Expanded Conservation in M&I Water Use	3,150	0	0	66%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	2,960	0	0	64%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	1,990	0	0	59%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Middle Arkansas Region, Basin 77

Reservoir Storage	Diversion
AF	AFY
100	200
500	1,000
1,000	2,000
2,500	5,100
5,000	9,600
Required Storage to Meet Growth in Demand (AF)	3,700
Required Storage to Meet Growth in Surface Water Demand (AF)	3,700

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 Crop Irrigation demand sectors could reduce surface water gaps by about a third. Due to the high probability of gaps, temporary drought management activities will likely be ineffective.

Out-of-Basin Supplies

Out-of-basin supplies could be used to augment supplies and meet demand. Currently, most public water suppliers in the basin, including the cities of Broken Arrow and Wagoner, are expected to meet much of their demand from out-of-basin supply sources. Major out-of-basin supply sources include the Grand River basin, Fort Gibson Lake, and the Oklahoma Ordnance Works Authority in the Grand Watershed Planning Region. Increased reliance on these supplies or other nearby dependable water supplies, with new infrastructure, could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. However, due to the distance to these reliable sources, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps. The entire increase in surface water demand from 2010 to 2060 could be met by a new river diversion and approximately 3,700 AF of new reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

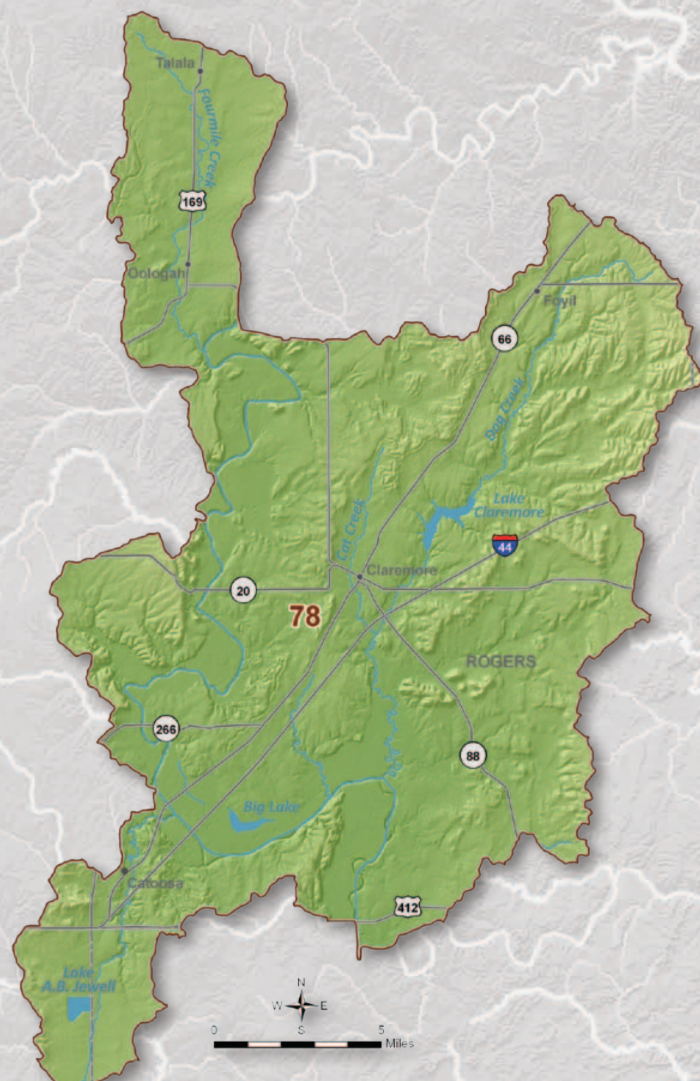
Increased reliance on groundwater supplies could mitigate surface water gaps, but may cause groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 77's portion of the Arkansas River aquifer. However, this aquifer only underlies a third of the basin.

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
Middle Arkansas Watershed Planning Region

Basin 78



Basin 78 Summary

Synopsis

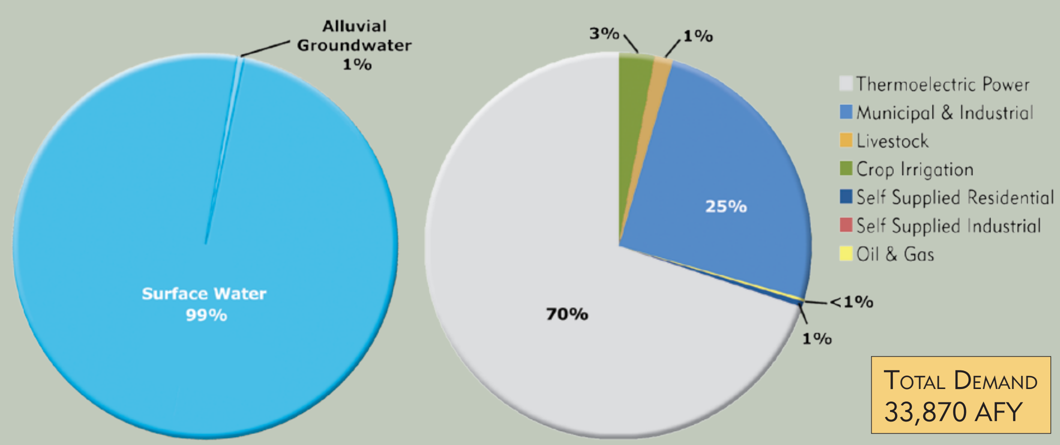
- Water users are expected to continue to rely primarily on surface water and out-of-basin supplies.
- By 2020, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater storage depletions may occur by 2040. Localized 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 and reduce the adverse effects of localized alluvial groundwater storage depletions.
- New reservoirs could be developed to mitigate surface water gaps.

Basin 78 accounts for about 15% of the current water demand in the Middle Arkansas Watershed Planning Region. About 70% of the 2010 demand was in the Thermoelectric Power demand sector. Municipal and Industrial (25%) is the second-largest demand sector in 2010. Surface water and out-of-basin supplies satisfy about 99% of the total demand in Basin 78. Alluvial groundwater satisfies about 1% of the total demand in the basin. The peak summer month total water demand in Basin 78 is about 1.3 times the peak winter month demand, which is less pronounced than the overall statewide pattern.

Flow in the Verdigris River near Inola is typically greater than 25,500 AF/month throughout the year and greater than 170,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year. Lake Claremore is the major reservoir in the area, providing water supply and recreation for the City of Claremore. The water supply yield is unknown; therefore,

Current Demand by Source and Sector

Middle Arkansas Region, Basin 78



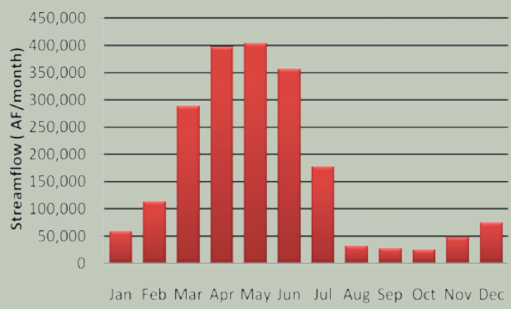
TOTAL DEMAND
33,870 AFY

Water Resources

Middle Arkansas Region, Basin 78

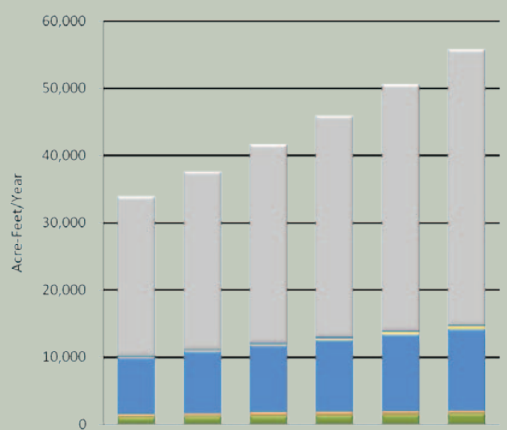
Median Historical Streamflow at the Basin Outlet

Middle Arkansas Region, Basin 78



Projected Water Demand

Middle Arkansas Region, Basin 78



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 basins statewide, the surface water quality in Basin 78 is considered fair. Cat Creek is impaired for Agricultural use due to high levels of sulfates. Claremore Lake is impaired for Public and Private Water Supply use due to high levels of chlorophyll-a.

There are currently less than 50 AF of water rights from the Verdigris River minor alluvial aquifer in Basin 78. However, the largest demand for groundwater is from minor alluvial aquifers for domestic use, which does not require a permit. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 55,710 AFY reflects a 21,840 AFY increase (64%) over the 2010 demand. The majority of growth in demand will occur in the Thermoelectric Power sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2020, while alluvial groundwater storage depletions may occur by 2040. Surface water gaps will be up to 11,780 AFY and have a 67% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions will be up to 70 AFY and have a 62% probability of occurring in at least one month of the year by 2060. Surface water gaps and alluvial groundwater storage depletions may occur throughout the year. Currently, there are no bedrock groundwater rights in Basin 78; therefore, no future demand is assumed from this source.

Options

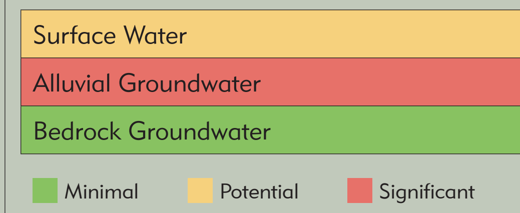
Water users are expected to continue to rely primarily on surface water and out-of-basin supplies. To reduce the risk of adverse impacts to the basin's water users, surface water gaps and alluvial groundwater storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors could reduce surface water gaps by about 15% and alluvial groundwater depletions by about 30%. Temporary drought management activities may be ineffective for this basin, since there is a high probability of gaps and the storage in alluvial aquifers could continue to provide supplies during droughts.

Public water providers in the basin are currently supplied by out-of-basin supplies

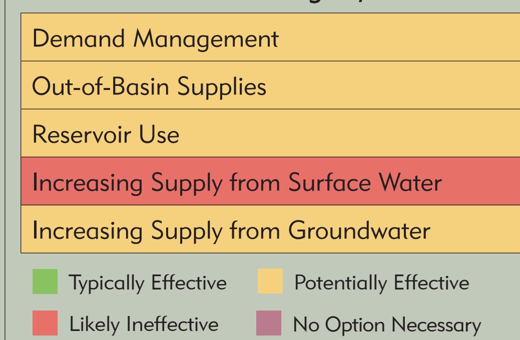
Water Supply Limitations

Middle Arkansas Region, Basin 78



Water Supply Option Effectiveness

Middle Arkansas Region, Basin 78



from Lake Oologah, the City of Tulsa, and the Oklahoma Ordnance Works Authority. Increased use of these supplies in the future could be used to meet surface water gaps. However, future use of these sources would need to take into consideration existing water rights. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region. Due to the distance to these and other reliable supplies, out-of-basin supplies may not be cost-effective for some users.

New in-basin reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and adverse effects of alluvial groundwater storage depletions in the basin. To supply all of the increase in demand from 2010 to 2060, a new river diversion and approximately 12,100 AF of new reservoir storage would be needed at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

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

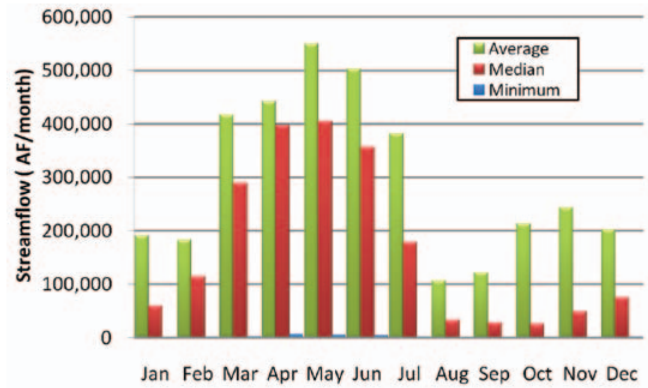
Basin 78 only has minor groundwater aquifers, which may not have sufficient yield for large-scale users. Therefore, site-specific information should be considered before increasing reliance on groundwater supplies.

Basin 78 Data & Analysis

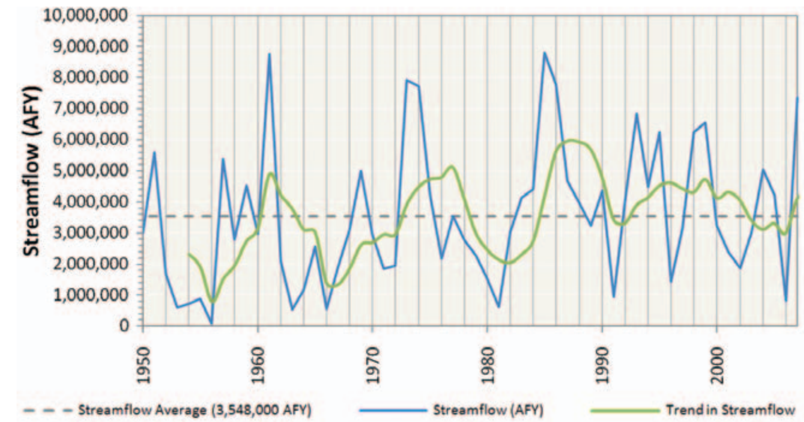
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Verdigris River near Inola had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to 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 Verdigris River near Inola has been greater than 25,500 AF/month throughout the year and greater than 170,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 78 is considered fair.
- Lake Claremore provides water supply and recreation for the city of Claremore. The water supply yield is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated.

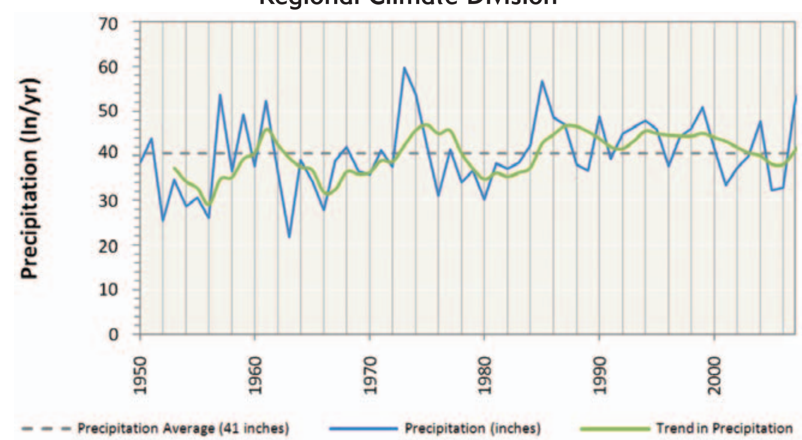
Monthly Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 78



Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 78



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)

Middle Arkansas Region, Basin 78

Aquifer			Portion of Basin Overlying 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	AFY2
Cherokee Group	Bedrock	Minor	95%	0	351,000	temporary 2.0	384,000
Verdigris River Groundwater Basin	Alluvial	Minor	13%	<50	65,000	temporary 2.0	51,200
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

- There are currently less than 50 AF of water rights in the Verdigris River minor alluvial aquifer in Basin 78. However, it is assumed that non-delineated minor alluvial groundwater sources will also supply a small amount of domestic (Self-Supplied Residential) water use, which does not require a permit. Site-specific information on the suitability of minor aquifers for supply should be considered before large scale use.
- There are no significant groundwater quality issues in Basin 78.

Notes & Assumptions

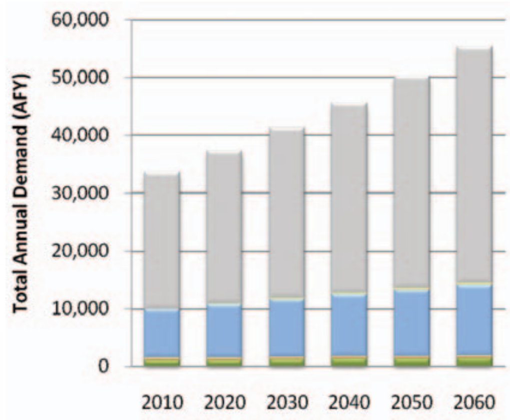
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- The water needs of Basin 78 account for about 15% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 64% (21,840 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be in the Thermoelectric Power demand sector.
- Surface water and out-of-basin supplies are used to meet 99% of the total demand in the basin and their use will increase by 65% (21,740 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Thermoelectric Power demand sector.
- Alluvial groundwater is used to meet 1% of the total demand in the basin and is used almost exclusively by the Self-Supplied Residential demand sector. Alluvial groundwater use will increase by 53% (90 AFY) from 2010 to 2060.
- Currently, there are no bedrock groundwater rights in Basin 78; therefore, no future demand is assumed from this source.

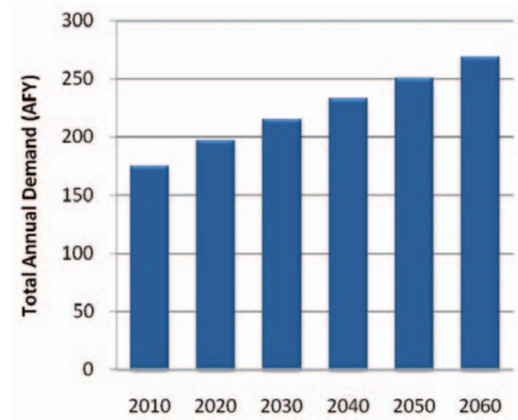
Surface Water Demand by Sector

Middle Arkansas Region, Basin 78



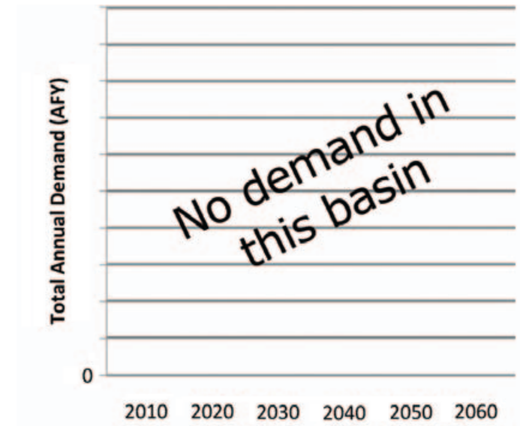
Alluvial Groundwater Demand by Sector

Middle Arkansas Region, Basin 78



Bedrock Groundwater Demand by Sector

Middle Arkansas Region, Basin 78



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

Total Demand by Sector

Middle Arkansas Region, Basin 78

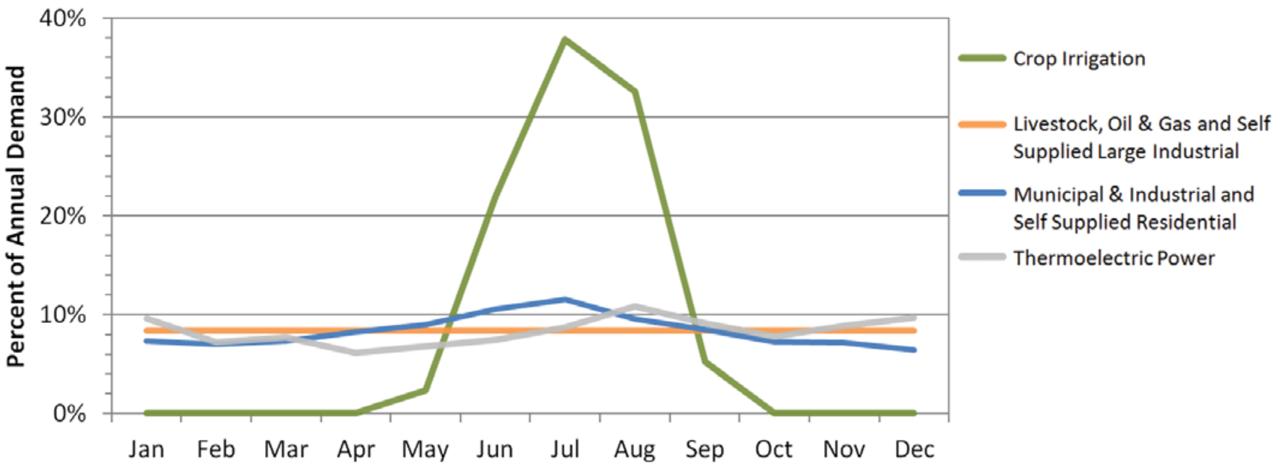
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,050	490	8,420	70	0	170	23,670	33,870
2020	1,140	500	9,240	110	0	200	26,400	37,590
2030	1,230	500	10,010	170	0	210	29,460	41,580
2040	1,320	500	10,710	240	0	230	32,860	45,860
2050	1,390	510	11,400	320	0	250	36,660	50,530
2060	1,500	510	12,120	410	0	270	40,900	55,710

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.

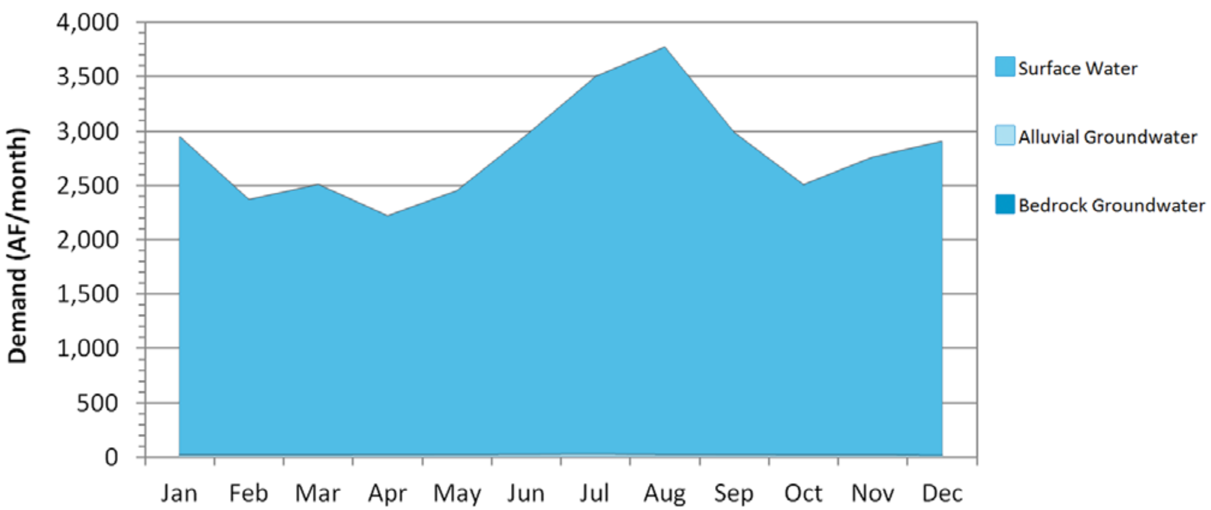
Monthly Demand Distribution by Sector (2010)

Middle Arkansas Region, Basin 78



Monthly Demand Distribution by Source (2010)

Middle Arkansas Region, Basin 78



Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 78 is about 1.3 times the peak winter month demand, which is less pronounced than the overall statewide pattern. Surface water demand in the peak summer month is about 1.6 times the peak winter month demand. Alluvial groundwater demand in the peak summer month is about 1.6 times the peak winter month demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2020, while alluvial groundwater storage depletions are expected by 2040.
- Surface water gaps in Basin 78 may occur throughout the year. There will be a 67% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps in 2060 will be about 39% (2,380 AF/month) of the surface water demand in the peak summer month, and as much as 39% (1,630 AF/month) of the surface water demand in the peak spring month. Surface water gaps are least likely to occur during spring months.
- Alluvial groundwater storage depletions in basin 78 may occur throughout the year. There will be a 62% probability of storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in 2060 will be up to 33% (10 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 50% (10 AF/month) of the peak winter month alluvial groundwater demand.
- 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 impact well yields, water quality and/or pumping costs

Surface Water Gaps by Season (2060 Demand)

Middle Arkansas Region, Basin 78

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	1,950	1,540	38%
Mar-May (Spring)	1,630	1,400	12%
Jun-Aug (Summer)	2,380	2,080	43%
Sep-Nov (Fall)	1,930	1,630	38%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 78

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	29%
Mar-May (Spring)	10	10	10%
Jun-Aug (Summer)	10	10	40%
Sep-Nov (Fall)	10	10	31%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Middle Arkansas Region, Basin 78

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	1,620	0	0	36%	0%
2030	3,840	0	0	47%	0%
2040	6,150	20	0	60%	38%
2050	8,580	60	0	64%	57%
2060	11,780	70	0	67%	62%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 78

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 78

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	11,780	70	0	67%	62%
Moderately Expanded Conservation in Crop Irrigation Water Use	11,740	70	0	67%	62%
Moderately Expanded Conservation in M&I Water Use	10,090	50	0	62%	47%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	10,070	50	0	62%	43%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	9,030	50	0	60%	38%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Middle Arkansas Region, Basin 78

Reservoir Storage	Diversion
AF	AFY
100	200
500	1,200
1,000	2,400
2,500	6,000
5,000	11,100
Required Storage to Meet Growth in Demand (AF)	12,100
Required Storage to Meet Growth in Surface Water Demand (AF)	12,100

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors could reduce surface water gaps by about 15% and alluvial groundwater depletions by about 30%. Temporary drought management activities may not be effective for this basin, since there is a high probability of gaps. and the storage in alluvial aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

Public water providers in the basin are currently supplied by out-of-basin supplies from Lake Oologah, the city of Tulsa, and the Oklahoma Ordinance Works Authority. Increased use of these supplies in the future could be used to meet surface water gaps. However, future use of these sources would need to take into consideration existing water rights. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. Due to the distance to these and other reliable supplies, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

New reservoir storage can increase the dependability of available surface water supplies and mitigate gaps and adverse effects of alluvial groundwater storage depletions in the basin. To supply all of the increase in demand from 2010 to 2060, a new river diversion and approximately 12,100 AF of new reservoir storage would be needed at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

Increased reliance on surface water beyond the current proportion, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Basin 78 only has minor groundwater aquifers, which may not have sufficient yield for large-scale users. Therefore, site-specific information should be considered before increasing reliance on groundwater supplies.

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

Middle Arkansas Watershed Planning Region

Basin 79

Basin 79 Summary

Synopsis

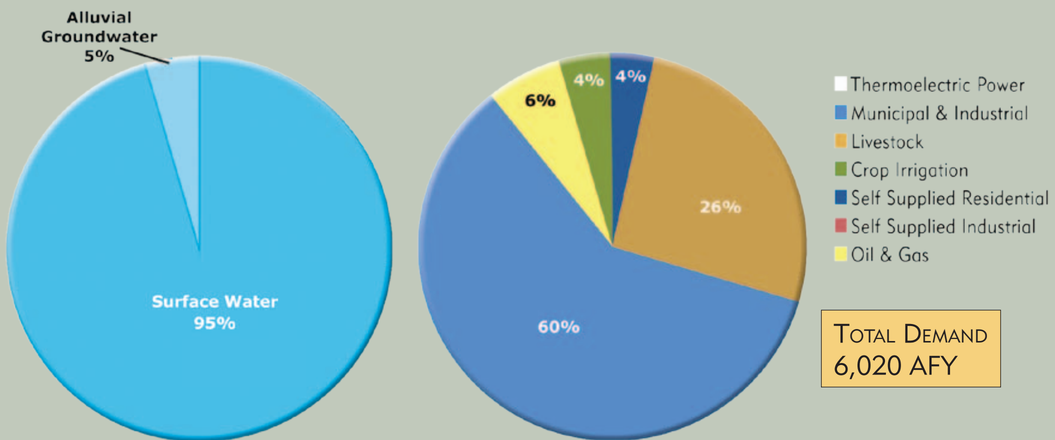
- Water users are expected to continue to rely mainly on surface water supplies and Oologah Lake.
- Alluvial groundwater storage depletions have a very low probability of occurring by 2030 and will be small in size on a basin scale. However, localized storage depletions may cause adverse effects for users.
- 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 the adverse effects of localized alluvial groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing small reservoirs could mitigate alluvial groundwater storage depletions without having major impacts to groundwater storage.

Basin 79 accounts for about 3% of the current water demand in the Middle Arkansas Watershed Planning Region. About 60% of the 2010 demand was in the Municipal and Industrial demand sector. Livestock (26%) is the second-largest demand sector. Surface water satisfies about 95% of the total demand in the basin. Alluvial groundwater supplies about 5% of the basin's demand. The peak summer month demand in Basin 79 is about 1.5 times the peak winter month demand, which is less pronounced than the overall statewide pattern.

The Verdigris River below Oologah Dam typically has flow greater than 16,500 AF/month throughout the year and greater than 140,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year. The major lake in the basin is Oologah Lake, which was constructed by the U.S. Army Corps of Engineers and has a dependable yield of 172,480 AFY. Oologah Lake is almost fully allocated, but is expected to provide increased supplies in the future to its existing users. There are numerous other

Current Demand by Source and Sector

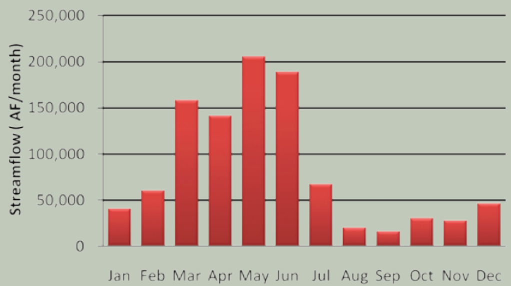
Middle Arkansas Region, Basin 79



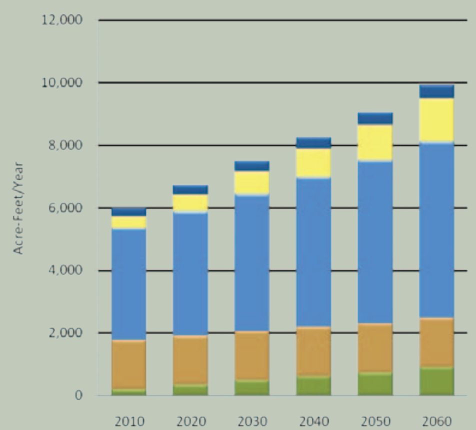
Water Resources

Middle Arkansas Region, Basin 79

Median Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 79



Projected Water Demand
Middle Arkansas Region, Basin 79



small lakes in the region that could not be evaluated without water yield information. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

There are currently no groundwater rights in Basin 79. The only demand for groundwater is for domestic use, which does not require permits and is assumed to be supplied from minor alluvial aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

Relative to basins statewide, the surface water quality is in Basin 79 is considered fair. Big Creek, California Creek, and multiple smaller tributaries to Oologah Lake are impaired for Agricultural use due to high levels of sulfates and total dissolved solids (TDS). There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 9,910 AFY reflects a 3,890 AFY increase (65%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial and Oil and Gas sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions are projected to occur by 2030. There are no surface water gaps expected for 2060 demand conditions in this basin. Alluvial groundwater depletions are expected to be up to 50 AFY and have a 7% probability of occurring in at least one month of the year by 2060.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce alluvial groundwater storage depletions. Due to the low probability and size of depletions, temporary drought management—largely from outdoor water use restrictions—could be an effective means of reducing demand and mitigating alluvial groundwater storage depletions.

New out-of-basin sources could be used to augment supplies and mitigate storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region. However, due to the substantial in-basin reservoir storage and distance to new sources of supply, out-of-basin supplies may not be cost-effective for many users.

Water Supply Limitations
Middle Arkansas Region, Basin 79

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Middle Arkansas Region, Basin 79

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 alluvial groundwater storage depletions in the basin. To supply all of the increase in demand from 2010 to 2060, a new river diversion and approximately 900 AF of new reservoir storage would be needed at the basin outlet.

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

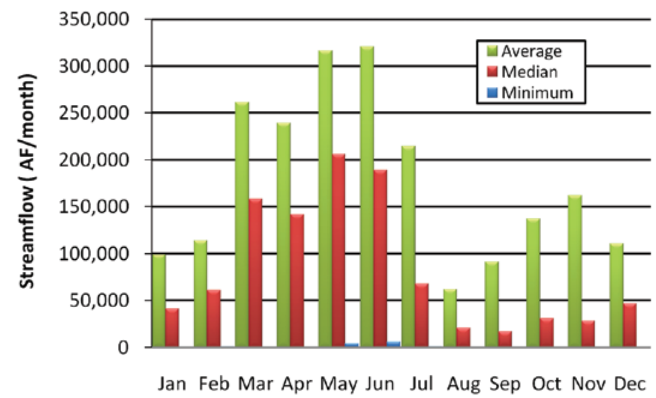
Increased reliance on the Cherokee Group and/or Northwestern Oklahoma Pennsylvanian minor bedrock aquifers for domestic use may mitigate alluvial groundwater depletions. Increased reliance on the Roubidoux major bedrock groundwater aquifer may also mitigate alluvial storage depletions. However, this aquifer only underlies the northeastern portion of the basin.

Basin 79 Data & Analysis

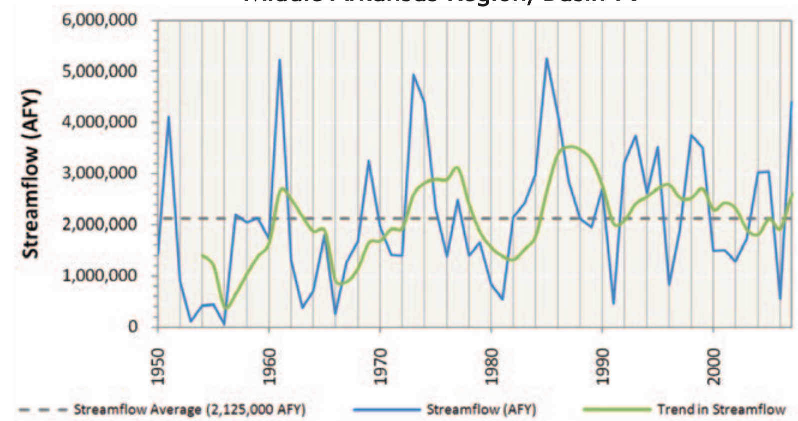
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Verdigris River below Oologah Dam had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The median flow in the Verdigris River below Oologah Dam has been greater than 16,500 AF/month throughout the year and greater than 140,000 AF/month in the spring and early summer. However, the river can have prolonged periods of low flow in any month of the year. Relative to other basins in the state, the surface water quality in Basin 79 is considered fair.
- Oologah Lake is located at the outlet of Basin 79 and provides water supplies to Tulsa, Public Service Company of Oklahoma, and six additional public water providers in the region. The lake is operated by the Corps of Engineers and has a dependable yield of 172,480 AFY. Oologah Lake is expected to provide increased supplies in the future to its existing users.

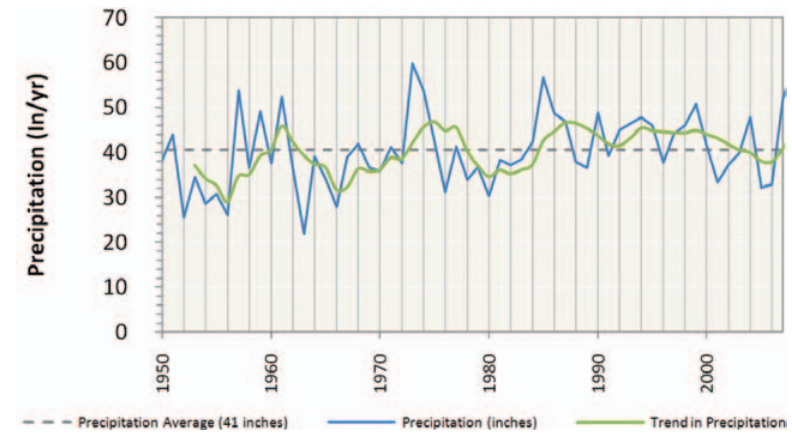
Monthly Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 79



Historical Streamflow at the Basin Outlet
Middle Arkansas Region, Basin 79



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)

Middle Arkansas Region, Basin 79

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
Roubidoux	Bedrock	Major	15%	0	816,000	temporary 2.0	166,400
Cherokee Group	Bedrock	Minor	76%	0	726,000	temporary 2.0	793,600
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	21%	0	250,000	temporary 2.0	217,600
Verdigris River Groundwater Basin	Alluvial	Minor	4%	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	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

- There are currently no groundwater rights in Basin 79. However, it is assumed that non-delineated minor alluvial groundwater sources will also supply a small amount of domestic (Self-Supplied Residential) water use, which does not require a permit.
- There are no significant groundwater quality issues in Basin 79.

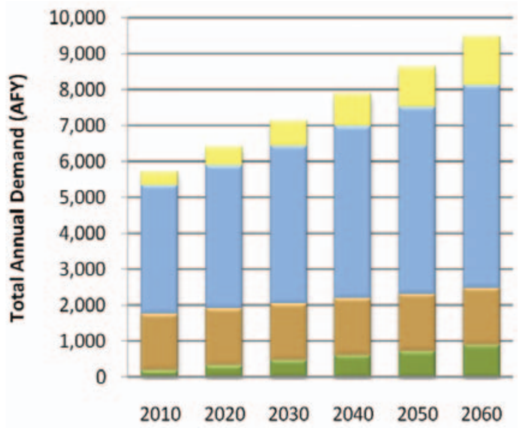
Notes & Assumptions

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

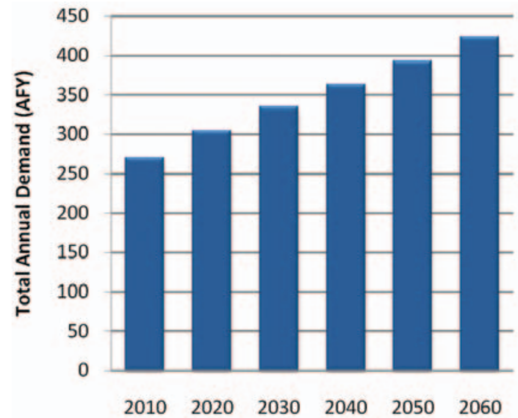
Water Demand

- The water needs of Basin 79 account for about 3% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 65% (3,890 AFY) from 2010 to 2060. The majority of demand and growth in demand over this period will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 95% of the total demand in the basin and its use will increase by 65% (3,740 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 5% of the total demand in the basin and is used exclusively by the Self-Supplied Residential demand sector. Alluvial groundwater use will increase by 56% (150 AFY) from 2010 to 2060.
- Currently, there are no bedrock groundwater rights in Basin 79; therefore, no future demand is assumed from this source for analysis.

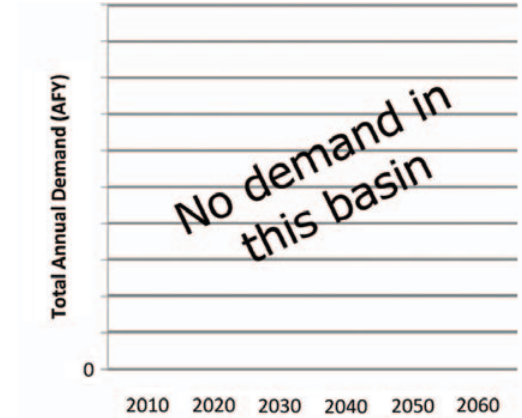
Surface Water Demand by Sector
Middle Arkansas Region, Basin 79



Alluvial Groundwater Demand by Sector
Middle Arkansas Region, Basin 79



Bedrock Groundwater Demand by Sector
Middle Arkansas Region, Basin 79



Total Demand by Sector
Middle Arkansas Region, Basin 79

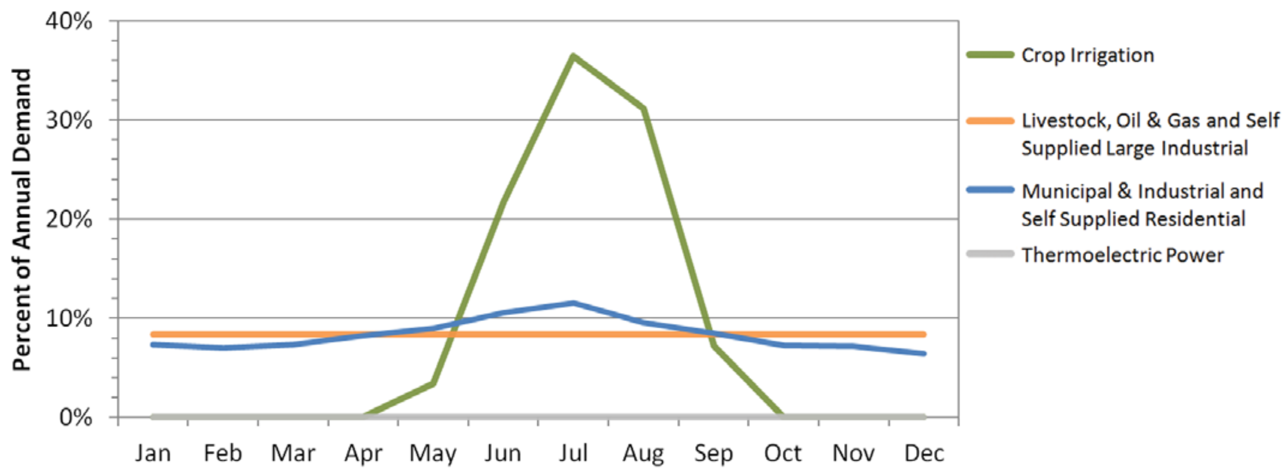
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	210	1,570	3,590	380	0	270	0	6,020
2020	350	1,570	3,990	520	0	300	0	6,730
2030	490	1,580	4,400	700	0	340	0	7,510
2040	630	1,580	4,790	900	0	360	0	8,260
2050	740	1,580	5,200	1,120	0	390	0	9,030
2060	910	1,580	5,630	1,370	0	420	0	9,910

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.

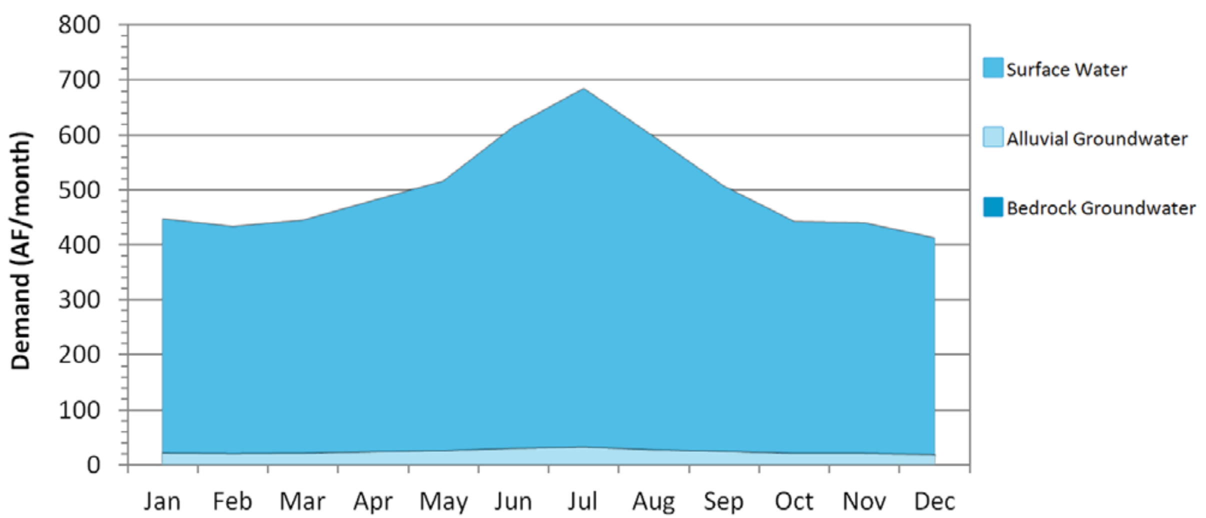
Monthly Demand Distribution by Sector (2010)

Middle Arkansas Region, Basin 79



Monthly Demand Distribution by Source (2010)

Middle Arkansas Region, Basin 79



Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 79 is about 1.5 times the peak winter month demand, which is less pronounced than the overall statewide pattern. Surface water and alluvial groundwater use in the peak summer month is about 1.5 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2030. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin.
- Alluvial groundwater storage depletions in Basin 79 may occur during the summer and fall. By 2060, there will be a 7% probability of alluvial groundwater storage depletions occurring in at least one month of the year and less than 5% probability in a given season. Alluvial groundwater storage depletions in 2060 will be up to 50% (20 AF/month) of the alluvial groundwater demand in the peak summer month and peak fall month. The aquifers used to meet future alluvial groundwater demands are unknown; therefore the severity of the storage depletions cannot be evaluated.

Surface Water Gaps by Season (2060 Demand)

Middle Arkansas Region, Basin 79

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 79

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	5%
Sep-Nov (Fall)	20	10	3%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Middle Arkansas Region, Basin 79

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	20	0	0%	3%
2050	0	30	0	0%	7%
2060	0	50	0	0%	7%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Middle Arkansas Region, Basin 79

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 79

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	50	0	0%	7%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	50	0	0%	7%
Moderately Expanded Conservation in M&I Water Use	0	20	0	0%	5%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	20	0	0%	5%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	20	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

Middle Arkansas Region, Basin 79

Reservoir Storage	Diversion
AF	AFY
100	1,200
500	2,600
1,000	4,300
2,500	8,200
5,000	13,400
Required Storage to Meet Growth in Demand (AF)	900
Required Storage to Meet Growth in Surface Water Demand (AF)	800

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce alluvial groundwater storage depletions by 60%. Due to the low probability and size of depletions, temporary drought management, largely from outdoor water use restrictions, could be an effective means of reducing demand and mitigating alluvial groundwater storage depletions.

Out-of-Basin Supplies

New out-of-basin supplies could be used to mitigate storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. However, due to the substantial in-basin reservoir storage, and distance to new out-of-basin sources out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

New reservoir storage or increased use of Oologah Lake could increase the dependability of available surface water supplies and mitigate alluvial groundwater storage depletions in the basin. To supply all of the increase in demand from 2010 to 2060, a new river diversion and approximately 900 AF of new reservoir storage would be needed at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future storage depletions.

Increasing Reliance on Surface Water

Increased reliance on surface water beyond the current proportion, without reservoir storage, may create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on the Cherokee Group and/or Northeastern Oklahoma Pennsylvanian minor bedrock aquifers for domestic use may mitigate alluvial groundwater depletions. Increased reliance on the Roubidoux major bedrock groundwater may also mitigate alluvial groundwater storage depletions. However, this aquifer only underlies the northeastern portion of the basin.

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

Initial Unit \ Desired 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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