Oklahoma Comprehensive Water Plan

OCWP

Lower Washita

Watershed Planning Region Report

Version 1.1

Oklahoma Water Resources Board

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

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

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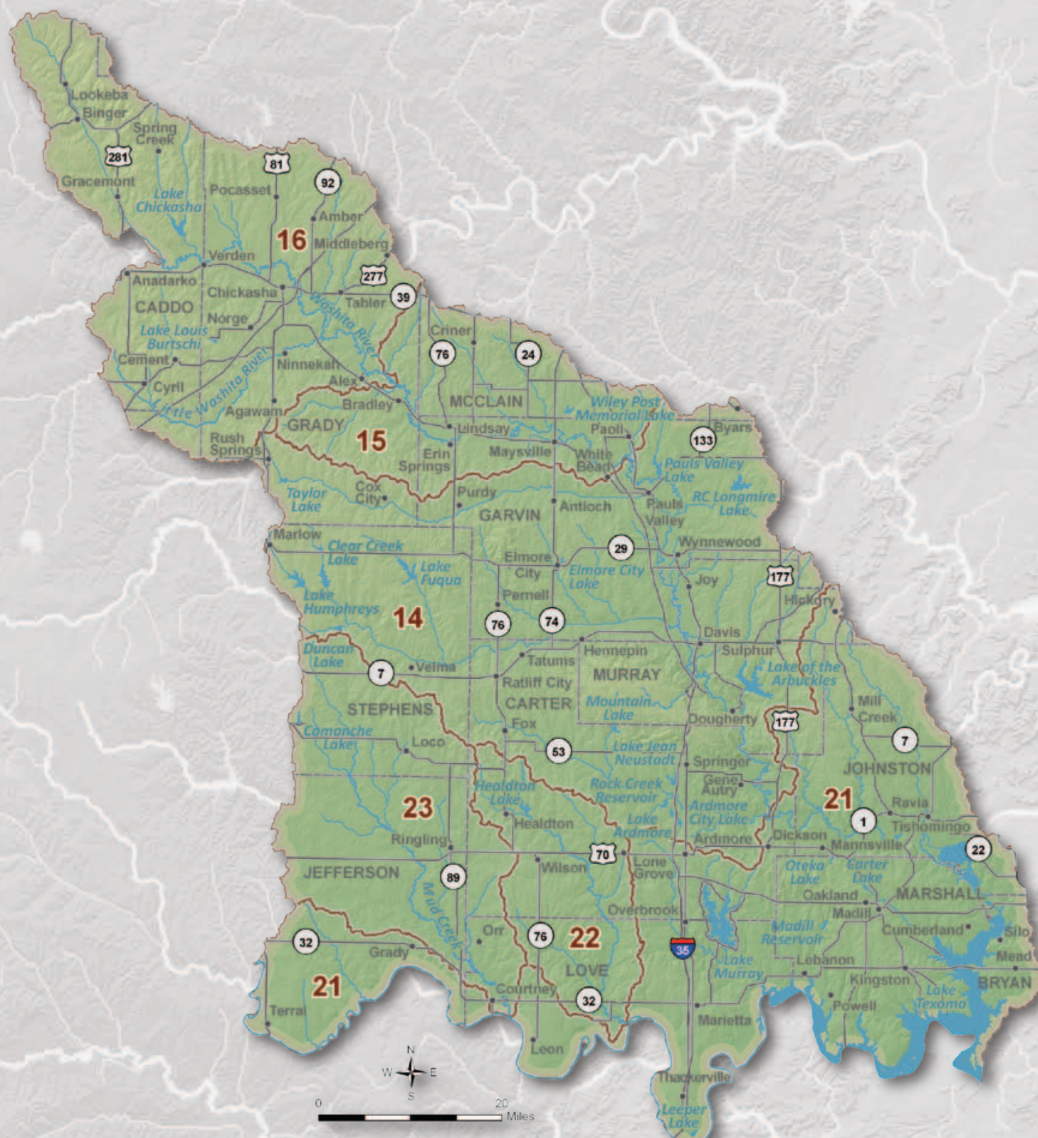
The online version of this 2012 OCWP Watershed Planning Region Report (Version 1.1) includes figures that have been updated since distribution of the original printed version. Revisions herein primarily pertain to the seasonality (i.e., the percent of total annual demand distributed by month) of Crop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

Cover photo: Travertine Creek in Flower Park, Chickasaw National Recreation Area

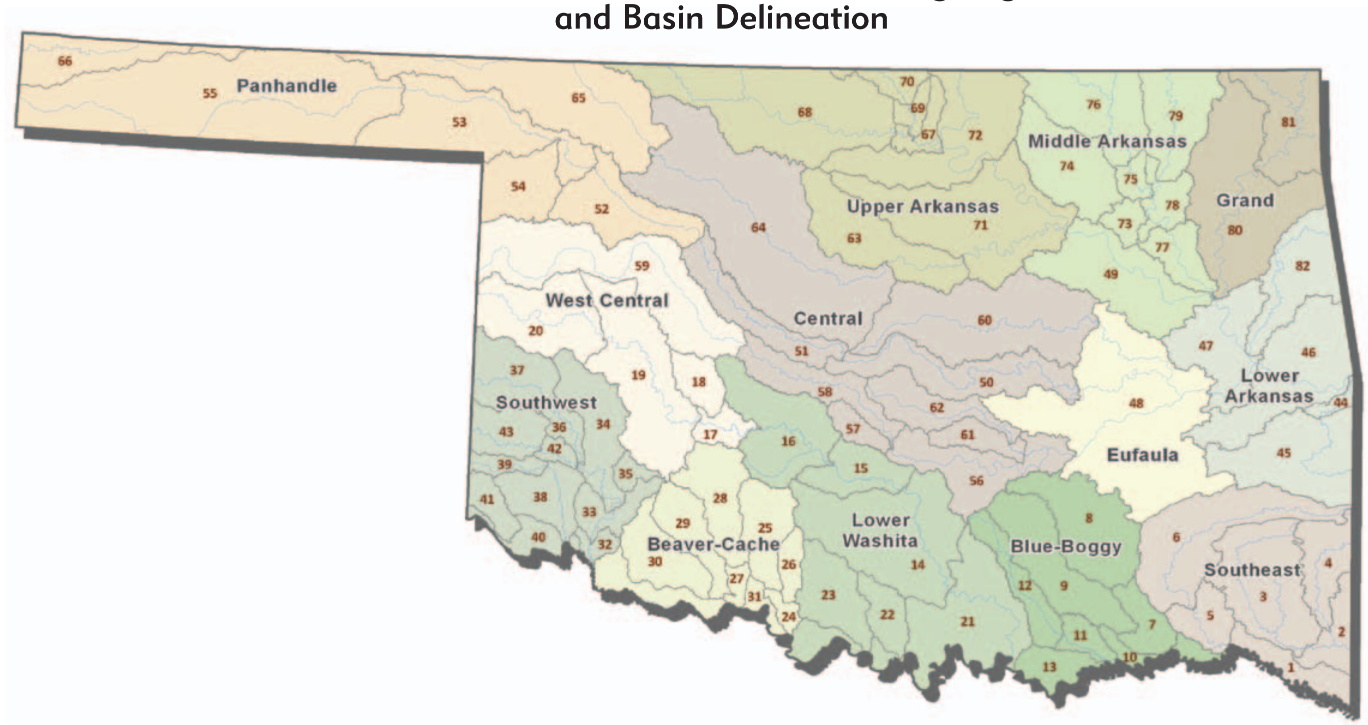
Oklahoma Comprehensive Water Plan

Lower Washita Watershed Planning Region



Contents

Statewide OCWP Watershed Planning Region and Basin Delineation



Introduction

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

1. Provide safe and dependable water supply for all Oklahomans while improving the economy and protecting the environment.

2. Provide information so that water providers, policy makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

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

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

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

This Watershed Planning Region report, one of 13 such documents prepared for the *2012 OCWP Update*, presents elements of technical studies pertinent to the Lower Washita 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 Lower Washita Watershed Planning Region includes six basins (numbered 14-16 and 21-23 for reference). The region is in the Central Lowland physiography province and encompasses 6,192 square miles in southern Oklahoma, spanning all of Carter, Love, and Marshall Counties and parts of Canadian, Caddo, Comanche, Grady, McClain, Garvin, Pontotoc, Stephens, Murray, Johnston, Jefferson, and Bryan Counties.

The region's terrain varies from lush pasture in the river bottoms to the rugged foothills of the Arbuckle Mountains. The region's climate is mild with annual mean temperatures varying from 61°F to 64°F. Annual evaporation within the region ranges from 63 inches per year in the west to 55 inches per year in the east. Annual average precipitation ranges from 27 inches in the west to 43 inches in the east.

The largest cities in the region include Ardmore (2010 population 24,283), Chickasha (16,036), Anadarko (6,762), and Pauls Valley (6,187). The greatest demand is from the Municipal and Industrial and Crop Irrigation water use sectors.

By 2060, this region is projected to have a total demand of 117,200 acre-feet per year (AFY), an increase of approximately 37,000 AFY (46%) from 2010.

Lower Washita Regional Summary

Synopsis

- The Lower Washita Watershed Planning Region relies primarily on surface water supplies (including reservoirs) and bedrock groundwater.
- It is anticipated that water users in the region will continue to rely on these sources to meet future demand.
- By 2020, surface water supplies may be insufficient at times to meet demand in basins without major reservoirs (Basins 15, 16, 22, and 23).
- By 2020, groundwater storage depletions may occur in all basins and eventually lead to higher pumping costs, the need for deeper wells, and potential changes to well yields or water quality.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps and groundwater storage depletions.
- Surface water alternatives, such as the use of bedrock groundwater supplies and/or developing new reservoirs, could mitigate gaps without major impacts to groundwater storage.
- One basin (Basin 22) in the region has been identified as a “hot spot,” an area where more pronounced water supply availability issues are forecasted. (See “Regional and Statewide Opportunities and Solutions,” *2012 OCWP Executive Report*.)

The Lower Washita Region accounts for about 4% of the state’s total water demand. The largest demand sectors are Municipal and Industrial (39% of the region’s overall demand) and Crop Irrigation (36%).

Water Resources & Limitations

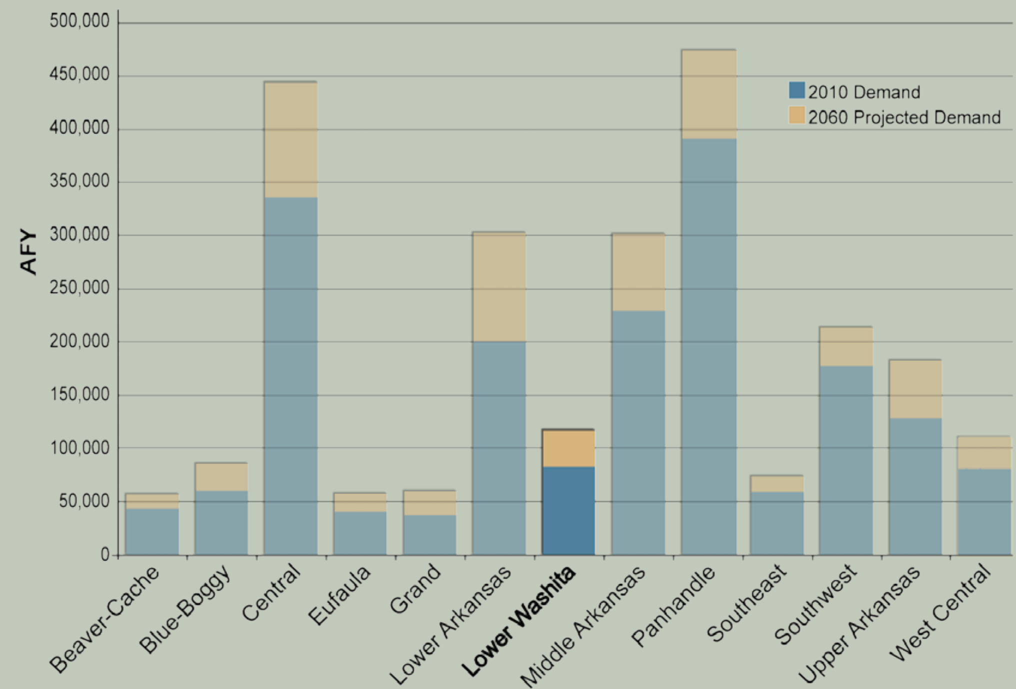
Surface Water

Surface water supplies, including reservoirs, are used to meet 49% of the Lower Washita Region’s demand. Surface water supply shortages are expected at times in Basins 15, 16, 22, and 23 by 2020. There is a low to moderate probability of shortages occurring in at least one month of the year by 2060, except in Basin 22 where the probability of shortages is much higher. There are four major rivers in the region: the Red River, the Washita River, Mud Creek, and Walnut Bayou. The Red River is not considered as a water supply source for this study due to water quality constraints. Historically, the Washita River has had substantial flows in the spring. However, periods of low flow can occur in any month of the year, particularly in the summer and fall, due to seasonal and long-term trends in precipitation. Lake Texoma, constructed by the U.S. Army Corps of Engineers, and Lake of the Arbuckles, a Bureau of Reclamation project, are the two major federal lakes in the region. Other large lakes have been built on tributaries in the Lower Washita Region to provide public water supply, flood control, and recreation. Large reservoirs in the region include: Murray (State of Oklahoma); Healdton (City of Healdton); Humphreys, Clear Creek, Fuqua, and Duncan (City of Duncan); Wiley Post Memorial (City of Maysville); Chickasha (City of Chickasha); and Pauls Valley and RC Longmire (City of Pauls Valley). Many other small lakes are located in the region and provide water for various purposes. All basins in the region, except Basin 16, are expected to have available surface water for new permitting to meet local demand through 2060. With the exception of the Red River, surface water quality in the region is considered generally fair relative to other regions in the state. However, several creeks in the region are impaired for Agricultural use due to high levels of chloride, sulfate and total dissolved solids (TDS).

Lower Washita Region Demand Summary

Current Water Demand:	80,440 acre-feet/year (4% of state total)
Largest Demand Sector:	Municipal & Industrial (39% of regional total)
Current Supply Sources:	49% SW 12% Alluvial GW 39% Bedrock GW
Projected Demand (2060):	117,230 acre-feet/year
Growth (2010-2060):	36,790 acre-feet/year (46%)

Current and Projected Regional Water Demand



Alluvial Groundwater

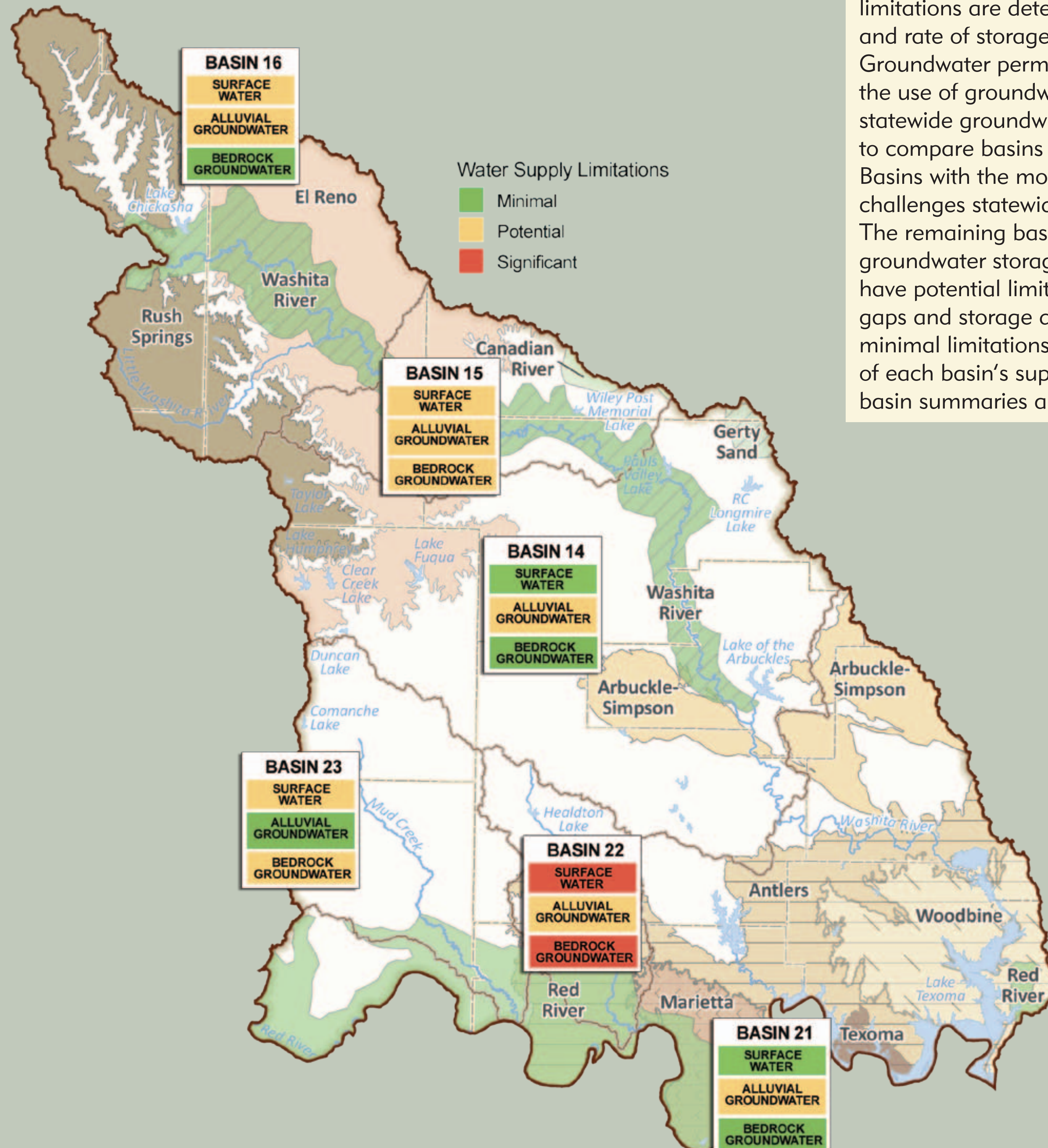
Alluvial groundwater is used to meet 12% of the demand in the region. The majority of currently permitted alluvial groundwater rights in the region are from the Washita River major alluvial aquifer. About one third of current alluvial groundwater withdrawals are from the Crop Irrigation demand sector, about 29% are from the Municipal and Industrial demand sector, and about 26% are from the

Self-Supplied Residential demand sector. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions may occur in all basins in the region by 2020 except Basin 23. The largest storage depletions are projected to occur in the summer. The availability of permits is not expected to constrain the use of alluvial groundwater supplies to meet local demand through 2060.

Bedrock Groundwater

Bedrock groundwater is used to meet 39% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Rush Springs major aquifer and the Antlers major aquifer. There are also substantial permits in the Arbuckle-Simpson major aquifer and in multiple minor aquifers. The Rush Springs aquifer has more than 10 million acre-feet (AF) of groundwater storage in the region. The Antlers aquifer has about 10.8 million AF of groundwater storage in the region. The Arbuckle-Simpson aquifer has about 5.7 million AF of groundwater storage in the region. The recharge to the major aquifers is expected to be sufficient to meet all of the region's bedrock groundwater demand through 2060, except in Basins 15, 22, and 23, where bedrock groundwater storage depletions may occur by 2020. The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060. Results of the *Arbuckle-Simpson Hydrology Study* indicate that in order to comply with 2003 Senate Bill 288, the equal proportionate share will be significantly lower than the current 2 AFY/acre allocation for temporary permits. There are no significant groundwater quality issues in the basin. However, localized areas with high levels of nitrate and fluoride have been found in the overall Rush Springs aquifer and may occur in Basins 14 and 16.

Water Supply Limitations
Lower Washita Region



Water Supply Limitations

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

Water Supply Options

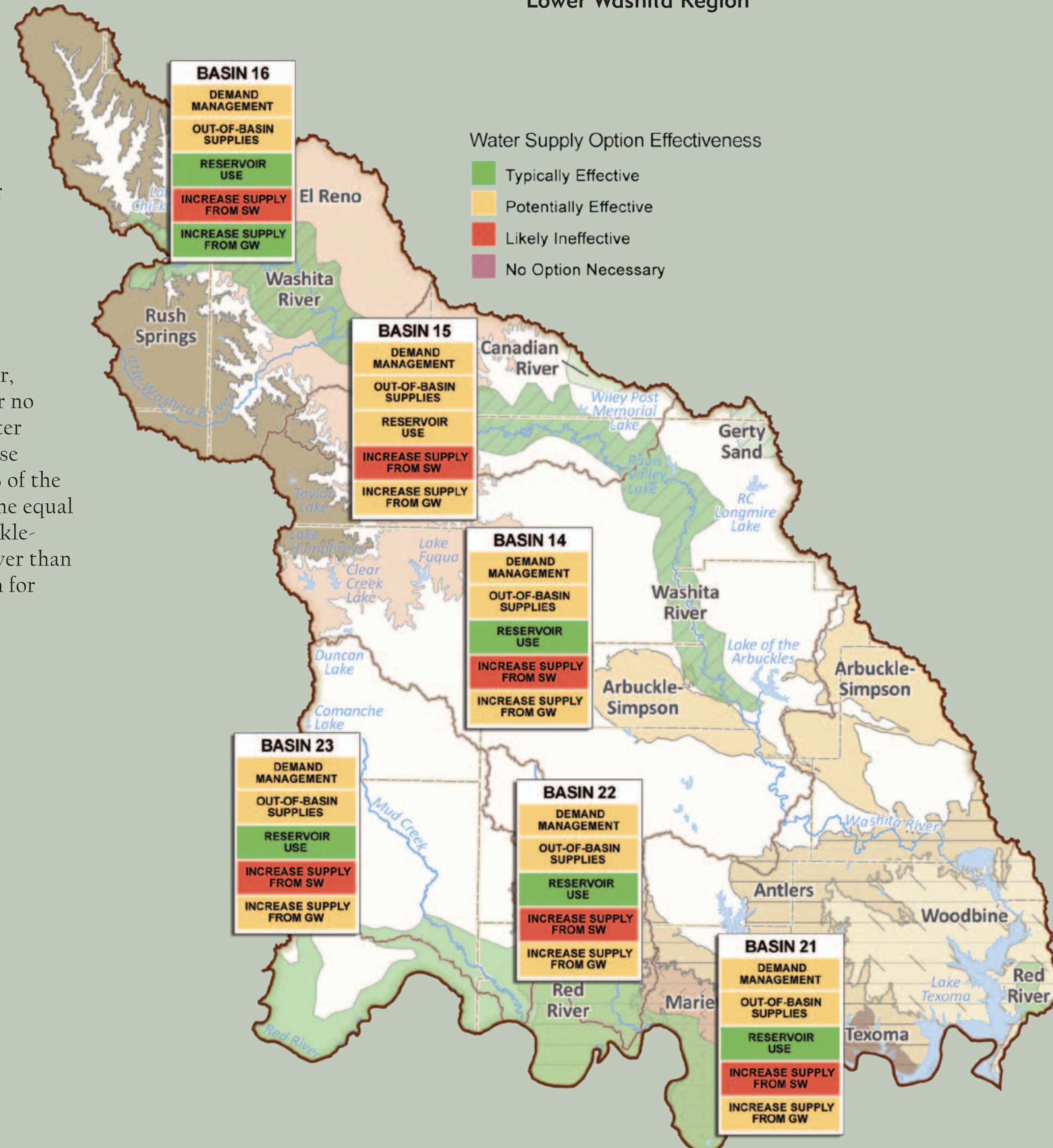
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Surface water supplies, reservoirs, and bedrock groundwater supplies are expected to continue to supply the majority of demand in the Lower Washita Region. Surface water users may have physical surface water supply shortages (gaps) in the future, except in Basins 14 and 21. Alluvial groundwater storage depletions of major and minor aquifers are also projected in the future and may occur in all basins in the region except Basin 23 by 2020. Bedrock groundwater depletions are expected by 2020 in Basins 15, 22, and 23. Additional long-term water supplies should be considered for surface water users and groundwater users.

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

New reservoirs and expanded use of existing reservoirs could enhance the dependability of surface water supplies and eliminate gaps throughout the region. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state. Twelve potentially viable sites were identified in the Lower Washita Region. Lake Texoma, in Basin 21, has substantial unpermitted yield to meet the needs of new users, but water quality concerns severely constrain its use. These water sources could serve as in-basin storage or out-of-basin supplies to provide additional supplies to mitigate the region's surface water gaps and groundwater storage depletions. However, depending on the distance from these reservoirs to demand points in each basin and the basins' substantial groundwater supplies, 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 alluvial and bedrock groundwater, which would result in minimal or no increases in projected groundwater storage depletions. However, these aquifers only underlie about 40% of the region, and pending changes to the equal proportionate share of the Arbuckle-Simpson may be significantly lower than the current 2 AFY/acre allocation for temporary permits.

Water Supply Option Effectiveness
Lower Washita Region



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

Water Supply

Physical Water Availability

Surface Water Resources

Surface water has historically been about half of the supply used to meet demand in the Lower Washita Region. The region's major rivers include the Red River, the Washita River, Mud Creek and Walnut Bayou. Many streams in this region experience a wide range of flows, including both periodic low-flow conditions and flooding events.

Water in the Red River mainstem (southern border of the Lower Washita Region), which maintains substantial flows, is highly mineralized above Lake Texoma, primarily due to high concentrations of chlorides from natural sources upstream. Without extensive water treatment or management techniques, the high chloride content of the Red River renders water generally unsuitable for most consumptive uses. For this reason, the Red River was not considered as a feasible source of supply in these analyses. As treatment technology evolves over time, treatment costs will likely decrease, and this source may become more attractive relative to other local and regional source options. Also, full implementation of the Corps of Engineers' Red River Chloride Control Project could reduce naturally occurring chloride levels in the Red River and its tributaries, thereby making it a more feasible source of future water supply.

The mainstem of the Washita River is located in the north and west areas of the region, flowing south before joining the Red River in Lake Texoma. About 530 miles of the Washita River mainstem are located in Oklahoma with 240 miles in the Lower Washita Region. The Washita is also highly mineralized, although tributary streams improve overall quality in the lower reaches. Major tributaries in the Lower Washita Region include Caddo Creek (45 miles). The Washita River and tributaries are located in Basins 14, 15, 16, and 21.

Mud Creek originates in Basin 23, where it flows 75 miles in a southeasterly direction before joining the Red River. Walnut Bayou heads in Basin 22 and flows 32 miles south to its confluence with the Red River.

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

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. Reservoirs in the region with the largest water supply yields are federal projects and include Lake Texoma (Denison Dam) and Lake of the Arbuckles. Another major lake in the region is Murray owned by the state of Oklahoma and operated primarily for recreation purposes.

Lake Texoma, a Corps of Engineer Project, was constructed on the main stem of the Red River in 1944 for the purposes of flood control, water supply, recreation, navigation, and hydropower purposes, as well as for regulation of the Red River. The lake is subject to the provisions of the Red River Compact, which equally allocates Texoma water supply storage and yield to Texas and Oklahoma. Each state is allotted a dependable water

Reservoirs
Lower Washita Region

Reservoir Name	Primary Basin Number	Reservoir Owner/ Operator	Year Built	Purposes[1]	Normal Pool Storage	Water Supply		Irrigation		Water Quality		Permitted Withdrawals	Remaining Water Supply Yield to be Permitted
						Storage	Yield	Storage	Yield	Storage	Yield		
					AF	AF	AFY	AF	AFY	AF	AFY	AFY	AFY
Arbuckle	14	Bureau of Reclamation	1967	WS, FC, FW, R	72,400	62,600	24,000	0	0	0	0	24,000	0
Chickasha	16	City of Chickasha	1958	WS, R	41,080	---	---	0	0	0	0	5,200	---
Clear Creek	14	City of Duncan	1948	WS, R	7,710	---	---	0	0	0	0	2,262	---
Duncan	14	City of Duncan	1937	WS, R	7,200	---	---	0	0	0	0	738	---
Fuqua	14	City of Duncan	1962	WS. FC, R	21,100	21,100	3,427	0	0	0	0	1,245	2,182
Healdton	22	City of Healdton	1979	WS, FC, R	3,766	---	413	0	0	0	0	1,473	0
Humphreys	14	City of Duncan	1958	WS, FC, R	14,041	---	3,226	0	0	0	0	5,408	0
Murray	21	State of Oklahoma	1938	R	153,250	111,921	1,008	0	0	0	0	12,860	0
Pauls Valley	14	City of Pauls Valley	1954	WS, R	8,730	---	---	---	---	---	---	1,993	---
RC Longmire	14	City of Pauls Valley	1989	WS, FC, R	N/A	13,162	3,360	0	0	0	0	3,361	0
Taylor	14	City of Marlow, Leased	1960	WS, FC, R	1,877	---	---	---	---	0	0	1,877	---
Texoma	21	USACE	1944	FC, WS, HP, LF, R	2,643,000	150,000	168,000	0	0	0	0	5,730	162,271
Wiley Post Memorial	15	City of Maysville	1971	WS, FC, R	2,082	0	538	0	0	0	0	700	0

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

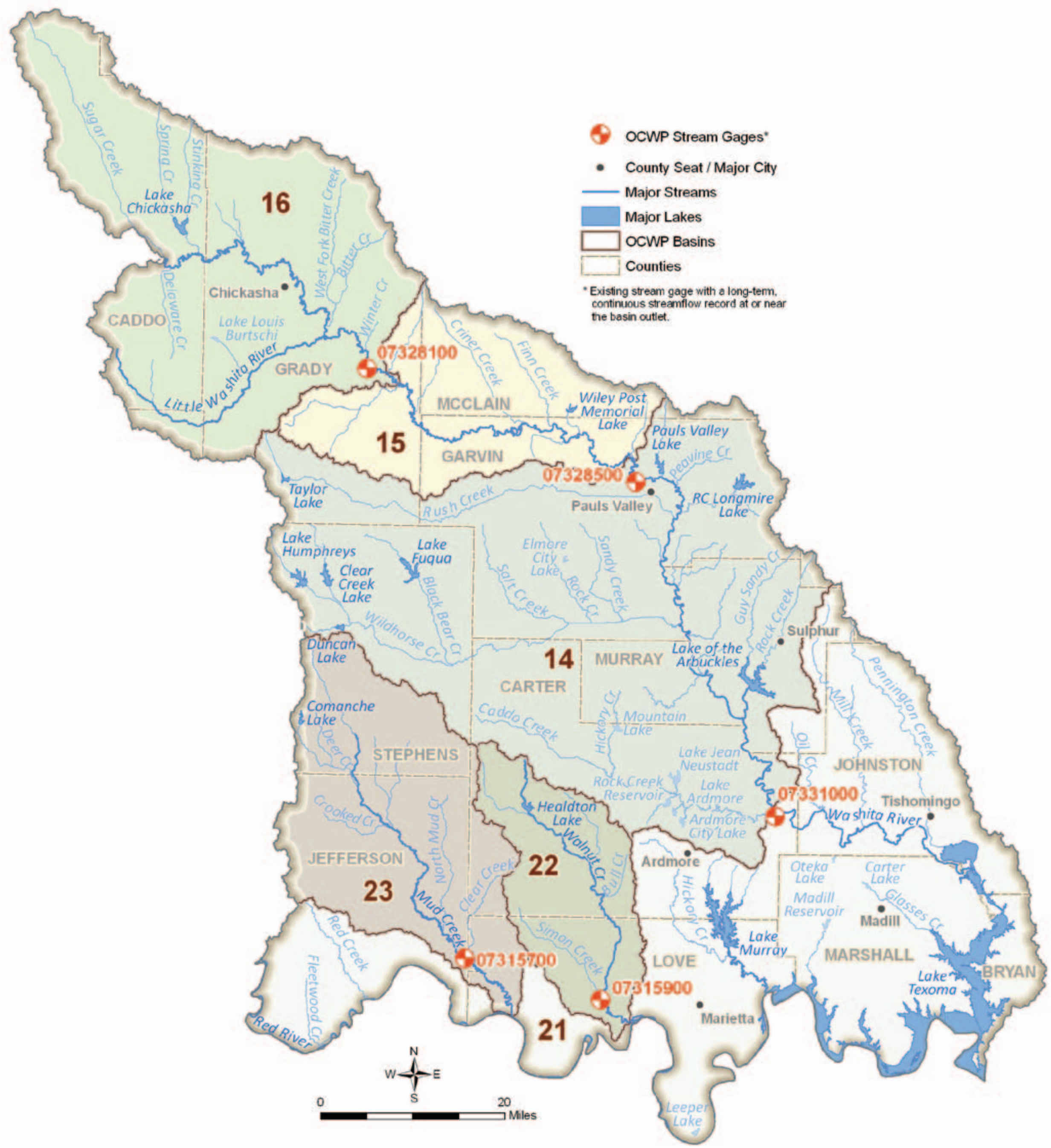
supply yield of 168,000 AFY. Unfortunately, the water is of very poor quality and is not suitable for most municipal and industrial uses without extensive treatment or blending. Of Oklahoma's equal share of water, only 5,730 AFY has been authorized for use by stream water rights (over 98% of that for irrigation purposes). More than 160,000 AFY of unpermitted yield is available for beneficial use in Oklahoma.

The Lake of the Arbuckles was constructed by the Bureau of Reclamation in 1967 on Rock Creek, a tributary of the Washita River. The lake was built for the purposes of water supply, flood control, recreation, and fish and wildlife mitigation and contains 62,600 acre-feet of conservation storage yielding 24,000 AFY. The entire yield is allocated to the Arbuckle Master Conservancy District which provides water to the cities of Ardmore, Davis, Sulphur, Wynnewood, and Dougherty.

Lake Murray is a state-owned project that was constructed on Hickory Creek in 1937 for recreation purposes and is one of southern Oklahoma's largest tourist attractions. Located in Basin 21, the lake has 153,250 AF of conservation storage of which none is allocated to water supply, though several permits have been issued for recreation, fish and wildlife purposes.

Smaller water supply and recreation lakes include Healdton Lake in Basin 22, operated by the City of Healdton; Humphreys, Clear Creek, Duncan, and Fuqua in Basin 14, owned by the City of Duncan; Wiley Post Memorial in Basin 15, operated by the City of Maysville; Pauls Valley and RC Longmire in Basin 14, owned by the City of Pauls Valley; and Chickasha in Basin 16, owned by the City of Chickasha. There are many other small Natural Resources Conservation Service (NRCS), municipal and privately owned lakes in the region that provide water for public water supply, agricultural water supply, flood control and recreation.

Surface Water Resources
Lower Washita Region



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

Water Supply Availability Analysis

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

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

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

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

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

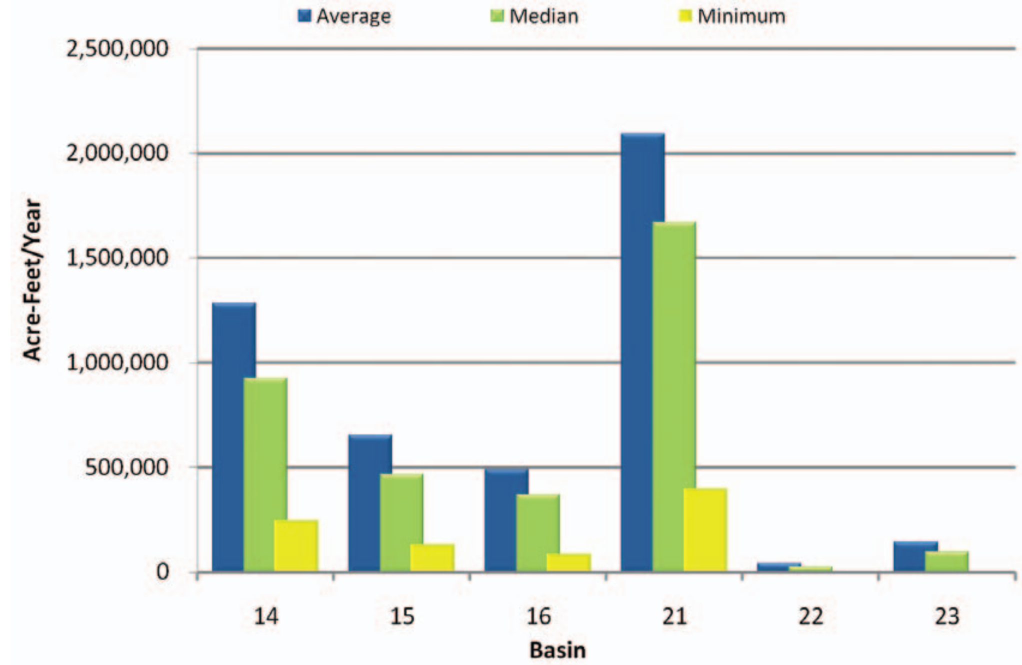
For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers,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

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

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

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

Surface Water Flows (1950-2007)
Lower Washita Region



Surface water sources supply about half of the demand in the Lower Washita Region. While the region's average physical surface water supply exceeds projected surface water demand, 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
Lower Washita Region

	Basins					
	14	15	16	21	22	23
Streamflow Statistic	AFY					
Average Annual Flow	1,253,200	628,300	466,900	2,054,800	42,300	143,300
Minimum Annual Flow	224,000	113,400	72,700	372,800	0	1,200

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

Groundwater Resources

Three major bedrock aquifers, the Antlers, Arbuckle-Simpson, and Rush Springs, underlie the Lower Washita Watershed Planning Region. The Antlers is found in the southeastern portion of the region, the Arbuckle-Simpson in the central-eastern area of the region, and the Rush Springs along the northern edge. Four major alluvial aquifers are located in the region: the Canadian River, Washita River, Gerty Sand, and Red River.

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

The Antlers aquifer is comprised of poorly cemented sandstone with some layers of sandy shale, silt, and clay. The depth to the top of the sandstone formation from the land surface varies from several feet to 1,000 feet and the saturated thickness ranges from less than 5 feet in the north to about 1,000 feet near the Red River. Large-capacity wells tapping the Antlers aquifer commonly yield 100 to 500 gallons per minute (gpm). Water quality is generally good with water becoming slightly saline (dissolved solids greater than 1,000 mg/L) in the southern portions of the aquifer. The Antlers bedrock aquifer underlies portions of Basins 21 and 22.

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

The Arbuckle-Simpson aquifer consists of several formations; about two-thirds of the aquifer consists of limestone and dolomite with sandstone and shale present in some areas. The saturated thickness is estimated to be from 2,000 to 3,500 feet. Common well yields vary from 25 to 600 gpm, depending on location in the aquifer, with deeper wells yielding more than 1,000 gpm in some areas. The aquifer is the source of many springs, including those at Chickasaw National Recreation Area, and contributes flow to several spring-fed streams, including Pennington, Travertine, and Honey Creeks. Water quality is good with dissolved solids generally less than 500 mg/L. The aquifer underlies portions of Basins 14 and 21.

The Rush Springs aquifer is a fine-grained sandstone aquifer with some shale, dolomite, and gypsum. Thickness of the aquifer ranges from 200 to 300 feet. Wells commonly yield 25 to 400 gpm. The water tends to be very hard, requiring water softening to address aesthetic issues for public water supply use. In some areas nitrate and sulfate concentrations exceed drinking water standards, limiting its use for drinking water. This aquifer underlies portions of Basins 14, 15, and 16.

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
Lower Washita Region

Aquifer			Portion of Region Overlaying Aquifer	Recharge Rate	Current Groundwater Rights	Aquifer Storage in Region	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	Inch/Yr	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	19%	0.3-1.7	44,100	10,894,000	2.1	1,461,100
Arbuckle-Simpson	Bedrock	Major	5%	5.58	21,400	5,756,000	temporary[2]	384,000
Canadian River	Alluvial	Major	<1%	2.0	0	48,000	temporary 2.0	25,600
Gerty Sand	Alluvial	Major	<1%	0.9	600	63,000	0.65	7,400
Red River	Alluvial	Major	7%	2.5	5,600	1,109,000	temporary 2.0	567,300
Rush Springs	Bedrock	Major	9%	1.8	48,100	10,009,000	temporary 2.0	614,400
Washita River	Alluvial	Major	8%	2.65-4.41	20,200	1,938,000	1.0-1.5	602,600
El Reno	Bedrock	Minor	14%	0.75	8,100	2,887,000	temporary 2.0	1,103,300
Marietta	Bedrock	Minor	3%	1.6	100	626,000	temporary 2.0	204,500
Texoma	Bedrock	Minor	<1%	1.8	0	101,000	temporary 2.0	38,400
Woodbine	Bedrock	Minor	5%	2.2	500	3,282,000	temporary 2.0	422,000
Non-Delineated Groundwater Source	Alluvial	Minor			3,800			
Non-Delineated Groundwater Source	Bedrock	Minor			23,900			

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

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

The Canadian River aquifer consists of clay and silt downgrading to fine- to coarse-grained sand with lenses of basal gravel. Formation thickness ranges from 20 to 40 feet in the alluvium with a maximum of 50 feet in the terrace deposits. Yields in the alluvium range between 100 and 400 gpm and between 50 and 100 gpm in the terrace. The water is a very hard calcium bicarbonate type with TDS concentrations of approximately 1,000 mg/L. However, the water is generally suitable for most municipal and industrial uses. The aquifer underlies a small portion of Basin 15.

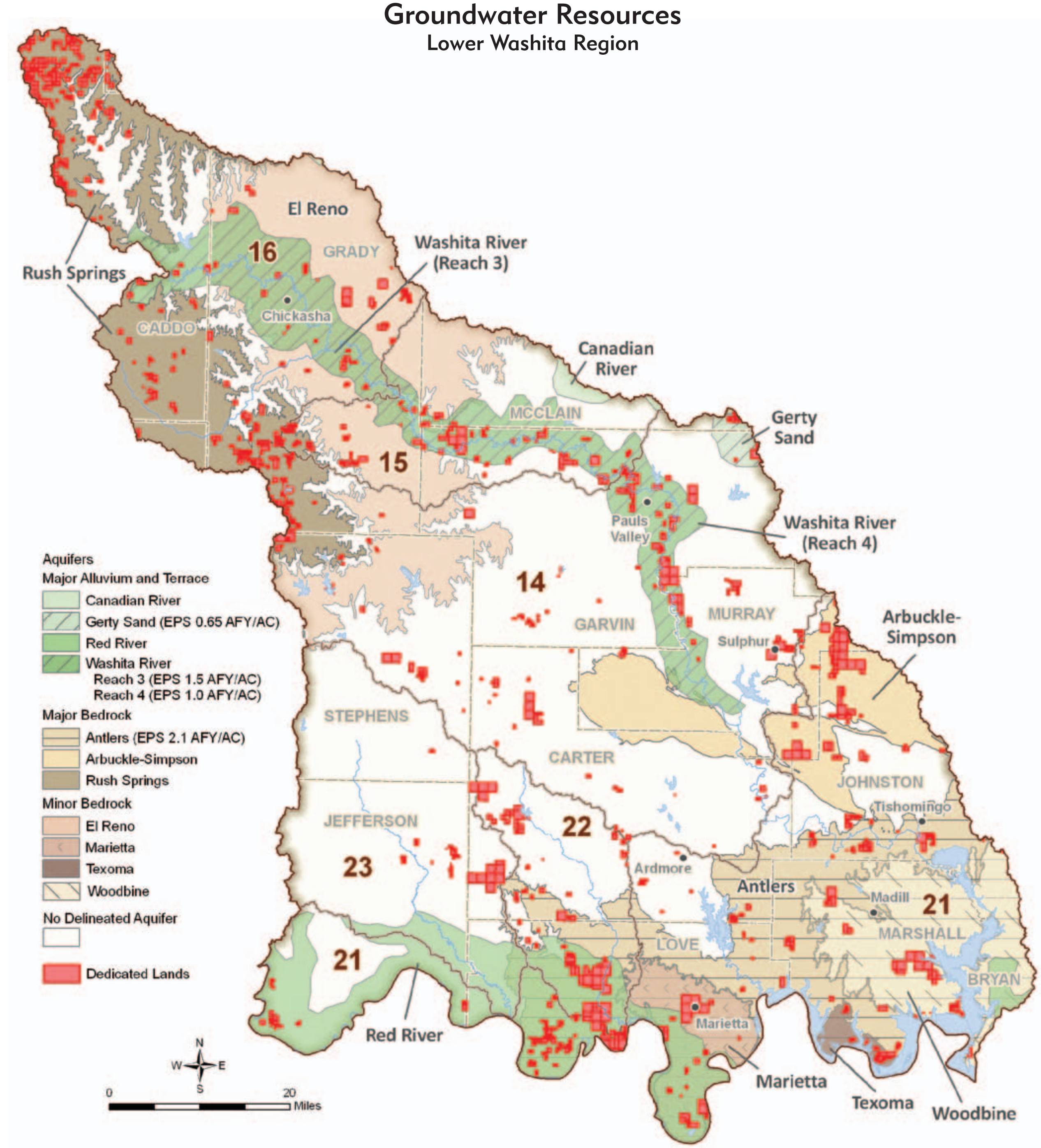
The Gerty Sand alluvial aquifer consists of gravel, sand, silt, clay, and volcanic ash. The saturated thickness varies from 5 to 75 feet, averaging 28 feet. Depth to water ranges from 10 to 110 feet. Typical well yields vary from 100 to 450 gpm with some wells yielding as much as 850 gpm. Water quality is fair to good and moderately hard with TDS values usually less than 1,000 mg/L. This aquifer underlies portions of Basin 14.

The Washita River alluvial aquifer consists of silt and clays downgrading into fine to coarse sand. Wells in this aquifer yield from 200 to 500 gpm, while formation deposits average 70 feet in thickness. The water is hard to very hard and generally of a calcium magnesium bicarbonate type. TDS values are usually less than 1,000 mg/L. This aquifer underlies portions of Basins 14, 15, and 16.

The Red River alluvial aquifer, underlying southern portions of basins 21, 22, and 23, consists of clay, sandy clay, sand, and gravel. Located in Jefferson, Love, and Bryan Counties, the aquifer supplies water for Municipal and Industrial, Crop Irrigation, and domestic purposes. The average saturated thickness is estimated to be around 20-30 feet; however, little data are available concerning the aquifer and its potential as a major source of groundwater.

Minor bedrock aquifers in the region include the El Reno, Marietta, Texoma, and Woodbine bedrock aquifers; there are no delineated minor alluvial aquifers. Minor Minor bedrock 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.

Groundwater Resources
Lower Washita Region



The major bedrock aquifers in the Lower Washita Region are the Antlers, Arbuckle-Simpson, and Rush Springs. Major alluvial aquifers in the region are the Canadian River, Gerty Sand, Red River, and Washita River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

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

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

Projections indicate that there will be surface water available for new permits through 2060 in all basins, except Basin 16, in the Lower Washita Region. For groundwater, equal proportionate shares in the Lower Washita Region range from 0.65 acre-foot per year (AFY) per acre to 2.1 AFY per acre. Results of the Arbuckle-Simpson Hydrology Study indicate that in order to comply with 2003 Senate Bill 288, the equal proportionate share will be significantly lower than the current 2 AFY/acre allocation for temporary permits.

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.

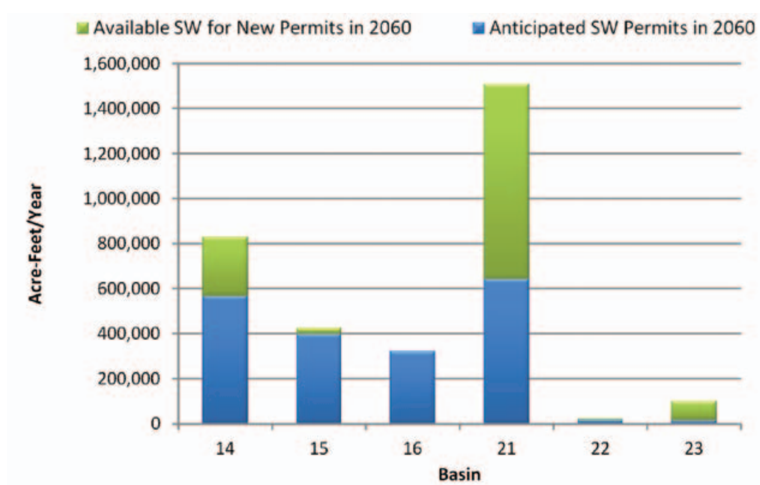
To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations,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

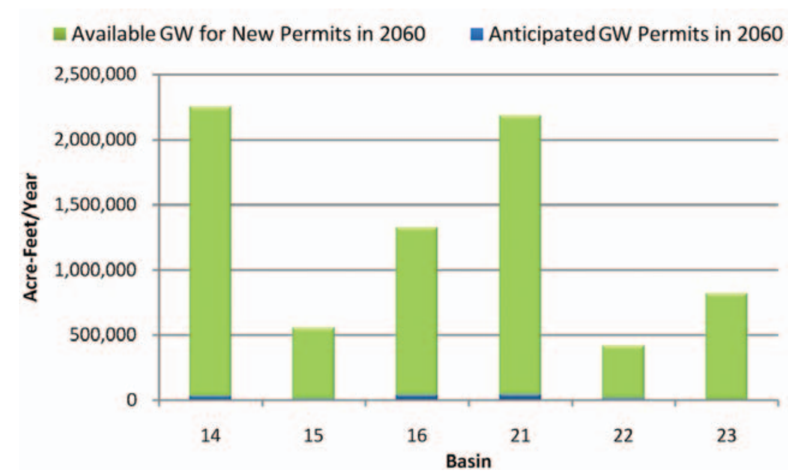
For OCWP analysis, the geographical area overlying all aquifers in each basin was determined and the respective EPS or temporary permit allocations were applied. Total current and anticipated future permit needs were then calculated to project remaining groundwater permit availability.

Surface Water Permit Availability
Lower Washita Region



Projections indicate that there will be surface water available for new permits through 2060 in all basins in the Lower Washita Region except Basin 16.

Groundwater Permit Availability
Lower Washita Region



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

Water Quality

Water quality of the Lower Washita Watershed Planning Region is defined by numerous water supply reservoirs and the middle Red River watershed, including the Washita River and Mud Creek. The area is dominated by the Cross Timbers (CT) ecoregion but has peripheral influences from the Central Great Plains (CGP).

The sub-ecoregions of the Cross Timbers run throughout much of the planning region. While the Northwestern Cross Timbers co-dominates in the north along with the Central Great Plains, an assortment of various sub-ecoregions are inter-mixed in the south. To the west and south are the Western and Eastern Cross Timbers; along the east central edge, but disconnected, lies the Northern Cross Timbers. Except for vegetation density, growing season, and floristic differences, these areas are similar. They are comprised of rolling hills, Cuestas, and ridges with dense oak savanna interspersed with prairie, rangeland and cropland. The Eastern and Western Cross Timbers are mostly underlain by sandstone, shale, and clay, while limestone becomes prevalent in both the Northern and Eastern Cross Timbers. Streams are morphologically diverse. While many are shallow with sandy soils, others have gravel/cobble bottoms with deep pools and riffles. While native habitat impacts ecological diversity, it is affected mostly by habitat degradation and sedimentation. Representative waterbodies in the Eastern Cross Timbers include the Lower Washita River and Hickory Creek as well as Murray, Texoma and Carter Lakes. In the Western Cross Timbers, Walnut Bayou and Healdton Lake are more typical, and in the Northern Cross Timbers, representative waters would be Chigley and Kickapoo Sandy Creeks, R.C. Longmire and Arbuckle Lakes. Stream salinity is variable. On Hickory and the Sandy Creeks, salinity is moderate with mean conductivity from 510 µS/cm (Hickory) to near 620 µS/cm on Kickapoo Sandy Creek. On Walnut Bayou and along the Washita River, conductivity means are high, from 915-1175 µS/cm. Lake conductivity is moderate, ranging from 200-400 µS/cm. However, Lake Texoma varies from 900 µS/cm (Washita arm) to greater than 3,500 µS/cm (Red River arm). Stream nutrient concentrations are low in the Eastern and Western Cross Timbers with mean total phosphorus (TP) from 0.04-0.06 ppm and mean total nitrogen (TN) from 0.35-0.40 ppm. On the Sandy Creeks, nutrient values are higher with TP of 0.07-0.13 ppm and TN of 0.55-1.15 ppm. The Washita River is hyper-eutrophic with mean TP of 0.40 ppm and TN of 1.73 ppm. All lakes are phosphorus limited and vary from oligotrophic (Carter and Murray) to mesotrophic (Healdton) to eutrophic (Arbuckle, Longmire, and Texoma). Texoma is hyper-eutrophic on the upper Red River arm. Water clarity is highly variable, ranging from nearly excellent to very poor. In the Eastern and Western Cross Timbers, both Walnut Bayou and Hickory Creek have turbidity means of 14 NTU, while turbidity varies from 42 on Chigley Sandy to 66 NTU on Kickapoo Sandy. Mean turbidity on the Washita River is 172 NTU. Likewise, lake clarity is excellent on Arbuckle, Carter, and Murray (mean Secchi depth = 120-180cm) but poor on Healdton (Secchi = 34 cm). On Texoma, the Washita arm and main lake have excellent clarity (114-143 cm) but is average to good along the upper (36 cm) and Lower (82 cm) Red River arms.

Adjacent to and interspersed among the previous ecoregions lay the Arbuckle Mountains and Uplift with significant relief, ledges, and ravines along the mountains giving way to rolling hills and plains along the uplift. The area is underlain by limestone, dolomite, sandstone, and shale with significant granite outcroppings. Oak savanna and grasslands

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
Lower Washita Region

The Lower Washita Planning Region is a transitional area with significant contributions from the Cross Timbers and Central Great Plains. Water quality is highly influenced by both geology and land use practices and ranges from poor to excellent depending on drainage and location.

dominate the plains and hills while much of the uplands are dominated by post-blackjack oak, winged-elm stands and prairie. Streams are mostly formed of gravel/cobble/bedrock and are typically clear. Gradients are high to moderate. Ecological diversity - as represented by Pennington, Mill, and Oil Creeks as well as Jean Neustadt and Ardmore City Lakes - is higher than anywhere in the Cross Timbers but may be affected by habitat degradation. Stream salinity is moderate, increasing from east (Pennington = 410 µS/cm) to west (Oil = 550 µS/cm), and lake conductivity ranges from 220-360 µS/cm. Stream nutrient concentrations also vary east to west. Pennington mean TP and TN equal 0.05 and 0.33 ppm. Mean TP and TN values are 0.10 and 0.80 ppm on Oil Creek. Both Jean Neustadt and Ardmore City Lakes are phosphorus limited and eutrophic. Stream clarity is excellent on both Pennington and Oil Creeks (6-7 NTU) and good on Mill (26 NTU). Lake clarity ranges from good on Neustadt (76 cm) to excellent on Ardmore City (106 cm).

The northern area of the region is co-dominated by the Northwestern Cross Timbers, Prairie Tablelands, and Cross Timbers Transition of the Central Great Plains. The Transition area consists of a hybrid mix of rough plains and oak/elm forests that dominate much of the ecoregion, while the Cross Timbers have much more extended stands of oak/elm forests and more relief including broad canyons. Sandstone underlies much of the area. The Prairie Tablelands are nearly flat with some relief and also underlain by sandstone and siltstone. Cropland is more prevalent in the transition and tablelands with rangeland and cropland along the Cross Timbers. Streams in this area are mostly sandy bottom with low to nearly moderate gradients. In the tablelands, streams are mostly shallow, low gradient, and choked by silt; gravel substrates exist in areas with relief. Ecological diversity is lower than in most parts of the Cross Timbers but higher than in much of the Central Great Plains. Diversity is impacted by habitat degradation,

Water Quality Standards Implementation
Lower Washita Region

The Oklahoma Department of Environmental Quality has completed TMDL studies on Oil Creek, Chigley Sandy Creek, Sand Creek, Roaring Creek, Laflin Creek, and Bitter 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.

channelization, and sedimentation. The Northwestern Timbers are best represented by Wildhorse Creek and several lakes, including Taylor (Marlow), Fuqua, Clear Creek, Duncan, Humphreys, and Louis Burtschi. The Washita River near Anadarko and Pauls Valley, as well as Ionine (tablelands) and Finn (transition) Creeks, exemplify the plains ecoregions. Lake Chickasha is a good example of the tablelands, whereas Pauls Valley and Wiley Post are example lakes for the Cross Timbers Transition. Stream salinity is high throughout all three regions with conductivity means ranging from near 700 µS/cm on Finn Creek to greater than 2,000 µS/cm on Ionine Creek. Means on Wildhorse Creek and the Washita River range from 1,100-1,685 µS/cm. Lake salinity is highly variable. In the lower Cross Timbers, lake salinity is moderate, varying from less than 250 to greater than 600 µS/cm; in the transition area, Wiley Post and Pauls Valley are lower, ranging from just over 200 to nearly 360 µS/cm. However, salinity is much higher in the northern portions with Burtschi greater than 1,100 and Chickasha greater than 2,000 µS/cm. The Washita River throughout is hyper-eutrophic with TP means from 0.36-0.58 ppm and TN means from 1.62-1.86. In other areas, TP and TN vary from 0.09 and 0.49 ppm on Wildhorse Creek to a TP of 0.23 ppm on Finn Creek and a TN of 0.83 on Ionine Creek. Lakes are phosphorus limited with varying levels of cultural eutrophication. While nearly all lakes are eutrophic, Pauls Valley has remained mesotrophic while Burtschi, Chickasha, and Taylor have progressed to hyper-eutrophic. Clarity is average to nearly poor on most creeks with both Finn and Ionine turbidity less than 50 NTU. However, with turbidity means from 76 to 214, the Washita has poor to very poor clarity. Lake clarity is poor (Wiley Post = 16 cm) to good (Burtschi = 72 cm) with all other lakes fair to average.

The Broken Red Plains intersect the planning region along the southwestern corner. Although more irregular than most of the Central Great Plains, it has much less relief

Water Quality Impairments
Lower Washita Region

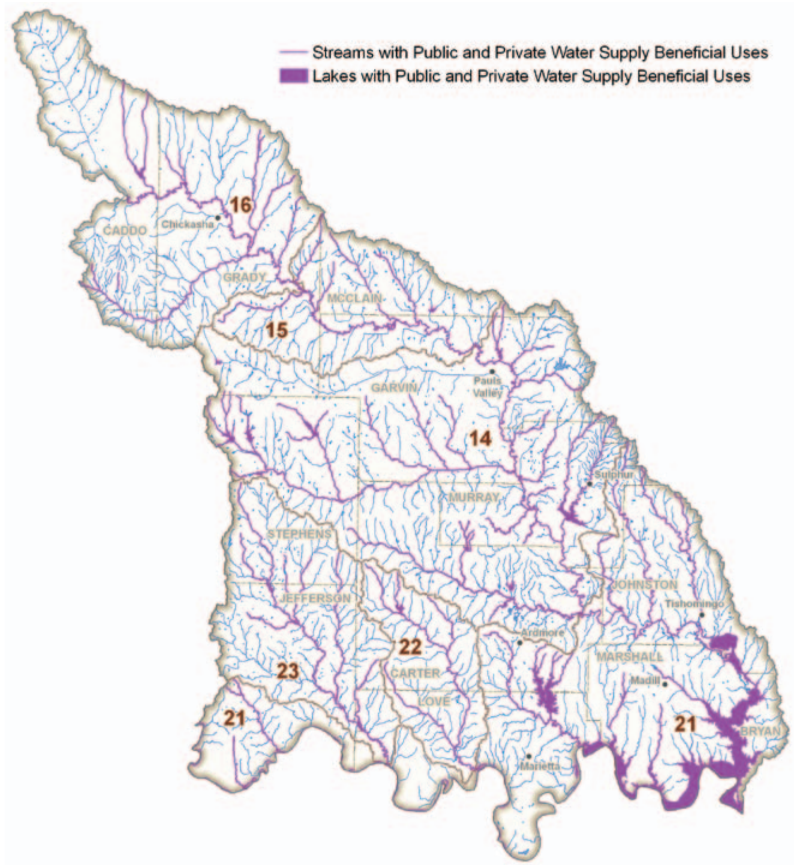
Regional water quality impairments based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Surface waters in this region are impacted by excessive levels of turbidity.

than surrounding ecoregions of the CT or CGP. Soils are characteristically sandy and the area is grassland dominated with low density scrub forests. Land uses include cropland/rangeland. Creeks are mostly sand/silt with low gradients and little diversity, which is affected by habitat degradation, channelization, and sedimentation. The Red River and Mud Creek, as well as Comanche Lake, exemplify the area. Stream salinity is high. Mud Creek mean conductivity is nearly 800 µS/cm but the Red is nearly 5,000 µS/cm with significant upstream effects. Comanche remains moderate, ranging from 260-345 µS/cm. Streams are hyper-eutrophic with TP means of 0.40-0.45 ppm and TN ranging from 1.25-1.86 ppm. Comanche Lake is phosphorus limited and hyper-eutrophic. Stream clarity is poor with turbidity means of 118-127 NTU; lake clarity is good at 82 cm.

The Lower Washita region is underlain by several alluvial and bedrock aquifers. Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed and data are available from various sources. Alluvial aquifers include the Canadian, Red, and Washita River alluvium and terrace. In most alluvial aquifers in the region, water quality is good and, except for hardness and localized nitrate problems, the water is appropriate for domestic, irrigation, industrial and municipal use. Thick deposits of salt and gypsum occur in many Permian-age formations creating high chloride and sulfate concentrations, which can migrate into portions of alluvial aquifers. The Canadian River alluvium is predominantly of a calcium magnesium bicarbonate type and variable in dissolved solids content, while the Red River alluvium typically has much higher concentrations of dissolved solids. They are generally suitable for most purposes. However, the alluvium and terrace aquifers are highly vulnerable to contamination from surface activities due to their high porosities and permeabilities and shallow water tables.

Major bedrock aquifers in the region include the Antlers, Rush Springs Sandstone, and Arbuckle-Simpson. The Rush Springs Sandstone extends into the northwestern portion of the region. Although comparatively hard, most of its water is suitable for domestic, municipal, irrigation and industrial use with total dissolved solids (TDS) values generally less than 500 ppm. However, sulfate and nitrate concentrations exceed drinking water standards in some areas. The Antlers Sandstone formation underlies the southeastern part of the region and water quality is generally good with dissolved solids between 200 and 1,000 mg/L. Water is slightly saline in the south with dissolved solids greater than 1,000 ppm. It is suitable for most uses but the ODEQ has identified several monitoring wells in this aquifer with elevated nitrate levels and some wells show consistently low pH values. The Arbuckle-Simpson aquifer underlies part of the region's eastern area; water is generally hard and of a calcium bicarbonate or calcium magnesium bicarbonate type. Pennington, Mill, and Oil Creeks, as well as Honey and Travertine Creeks, originate from headwater springs in the Arbuckle-Simpson. Most of the water in the aquifer is suitable for all regulated uses, including public drinking water supplies. Dissolved solids concentrations are low, with a median concentration of 347 mg/L. Some wells and springs on the edge of the aquifer have chloride and dissolved solids concentrations that exceed secondary drinking water standards.

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



Surface Waters with Designated Beneficial Use for Agriculture
Lower Washita 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.

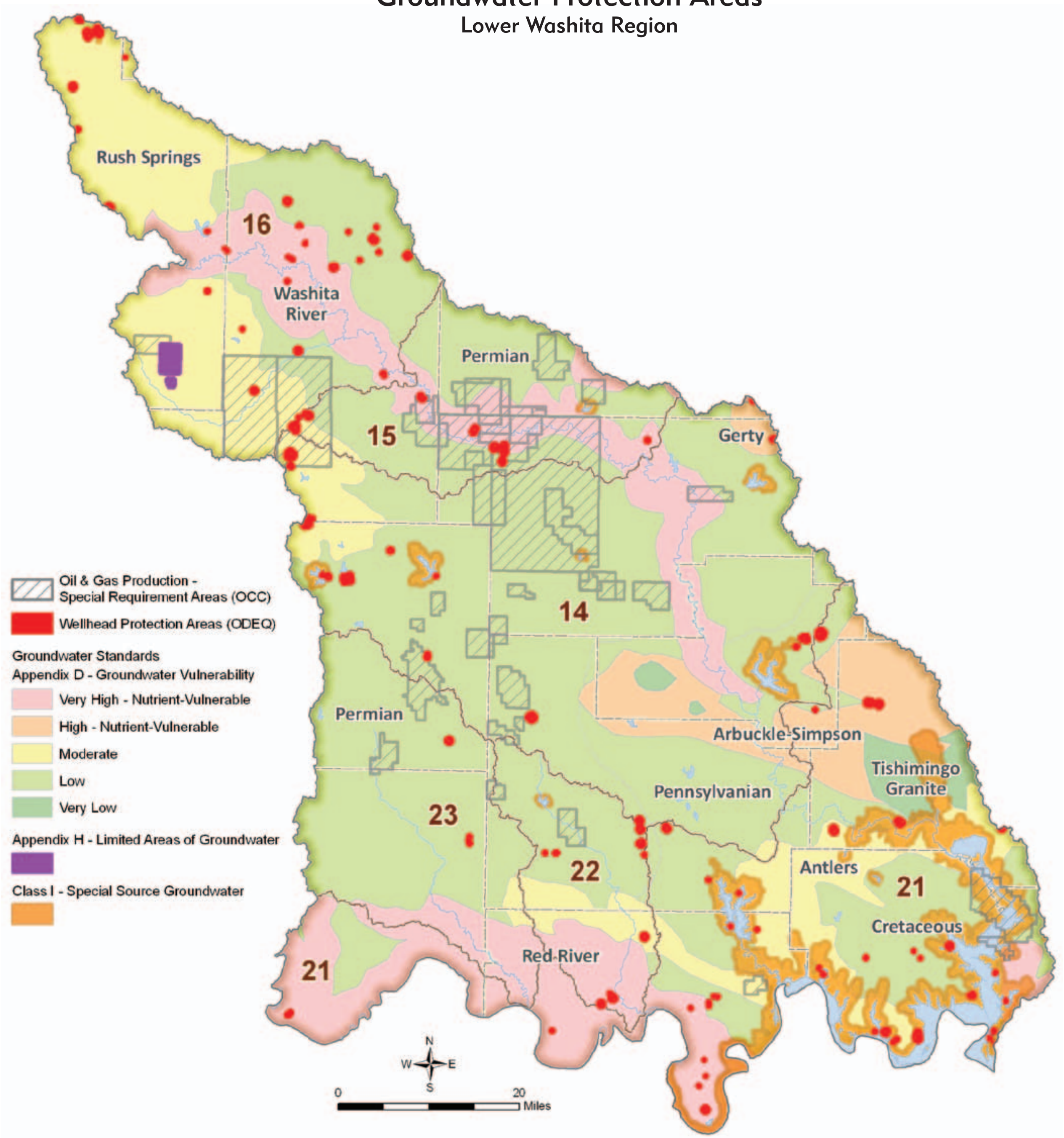
Nutrient-Limited Watersheds are those containing a waterbody with a designated beneficial use that is adversely affected by excess nutrients.

Surface Water Protection Areas

Lower Washita Region

Because Wiley Post Memorial Lake, R. C. Longmire Lake, Healdton City Lake, Carter Lake, Madill City Lake, and Elmore City Lake 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 watersheds. This additional protection would also provide limits for algae (chlorophyll a) that can cause taste and odor problems and increased treatment costs.

Groundwater Protection Areas
Lower Washita Region



Various types of protection are in place to prevent degradation of groundwater and levels of vulnerability. The Gerty and Arbuckle-Simpson aquifers have been identified by the OWRB as highly vulnerable, while the Red River and Washita River alluvial aquifers have been identified as very highly vulnerable. The eastern portion of the Arbuckle-Simpson aquifer has been designated as a sole source aquifer by the U.S. Environmental Protection Agency.

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
Lower Washita Region

Parameter	Arbuckle Lake (1996-2009)	Lake Chickasha (1994-2007)	Lake Fuqua (1994-2007)	Lake Murray (1995-2009)	Pauls Valley Lake (1995-2008)	Lake Texoma (1998-2009)
Chlorophyll-a (mg/m3)	NT	NT	↑	↓	NT	NT
Conductivity (us/cm)	↑	↑	↑	↑	NT	↓
Total Nitrogen (mg/L)	↑	↑	NT	NT	NT	↓
Total Phosphorus (mg/L)	NT	NT	NT	↓	NT	NT
Turbidity (NTU)	↑	NT	NT	NT	↓	↑

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

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

Notable concerns for reservoir water quality include the following:

- Significant upward trend for conductivity on numerous reservoirs.
- Significant upward trend for total nitrogen on Arbuckle and Chickasha reservoirs.
- Significant upward trend for turbidity on Arbuckle and Texoma reservoirs.

Stream Water Quality Trends
Lower Washita Region

Parameter	Mud Creek near Courtney		Red River near Terral, OK		Washita River near Anadarko		Washita River near Durwood		Washita River near Pauls Valley	
	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1967-1995, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1964-1993, 1999-2009)[1]	Recent Trend (1999-2009)	All Data Trend (1946-1995, 1996-2009)[1]	Recent Trend (1996-2009)	All Data Trend (1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	↓	↑	↑	NT	↑	NT	↑	↓	NT	NT
Total Nitrogen (mg/L)	↓	NT	↓	NT	↓	↑	↓	↑	↑	↑
Total Phosphorus (mg/L)	NT	NT	↓	NT	↓	NT	↑	↑	NT	NT
Turbidity (NTU)	↑	NT	↑	↓	↑	↓	↑	NT	↓	↓

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

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

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

Notable concerns for stream water quality include the following:

- Significant upward trend for total nitrogen and phosphorus on the Washita River.
- Significant upward trend for period of record turbidity throughout region.

Water Demand

Water needs in the Lower Washita Region account for about 4% of the total statewide demand. Regional demand will increase by 46% (36,790 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation and Municipal and Industrial sectors.

Municipal and Industrial (M&I) demand is projected to account for approximately 42% of the region's 2060 demand. Currently, 62% of the demand from this sector is supplied by surface water, 9% by alluvial groundwater, and 29% by bedrock groundwater.

Crop Irrigation demand is expected to account for 36% of the 2060 demand. Currently, 36% of the demand from this sector is supplied by surface water, 11% by alluvial groundwater, and 53% by bedrock groundwater. Predominant irrigated crops in the Lower Washita Region include pasture grasses, wheat, and peanuts.

Oil and Gas demand is projected to account for approximately 9% of the 2060 demand. Currently, 84% of the demand from this sector is supplied by surface water, 3% by alluvial groundwater, and 13% by bedrock groundwater.

The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Lower Washita Region, Basin 22) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin Total Demand by Sector tables.

Livestock demand is projected to account for 8% of the 2060 demand. Currently, 35% of the demand from this sector is supplied by surface water, 12% by alluvial groundwater, and 53% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production, followed distantly by chickens and sheep.

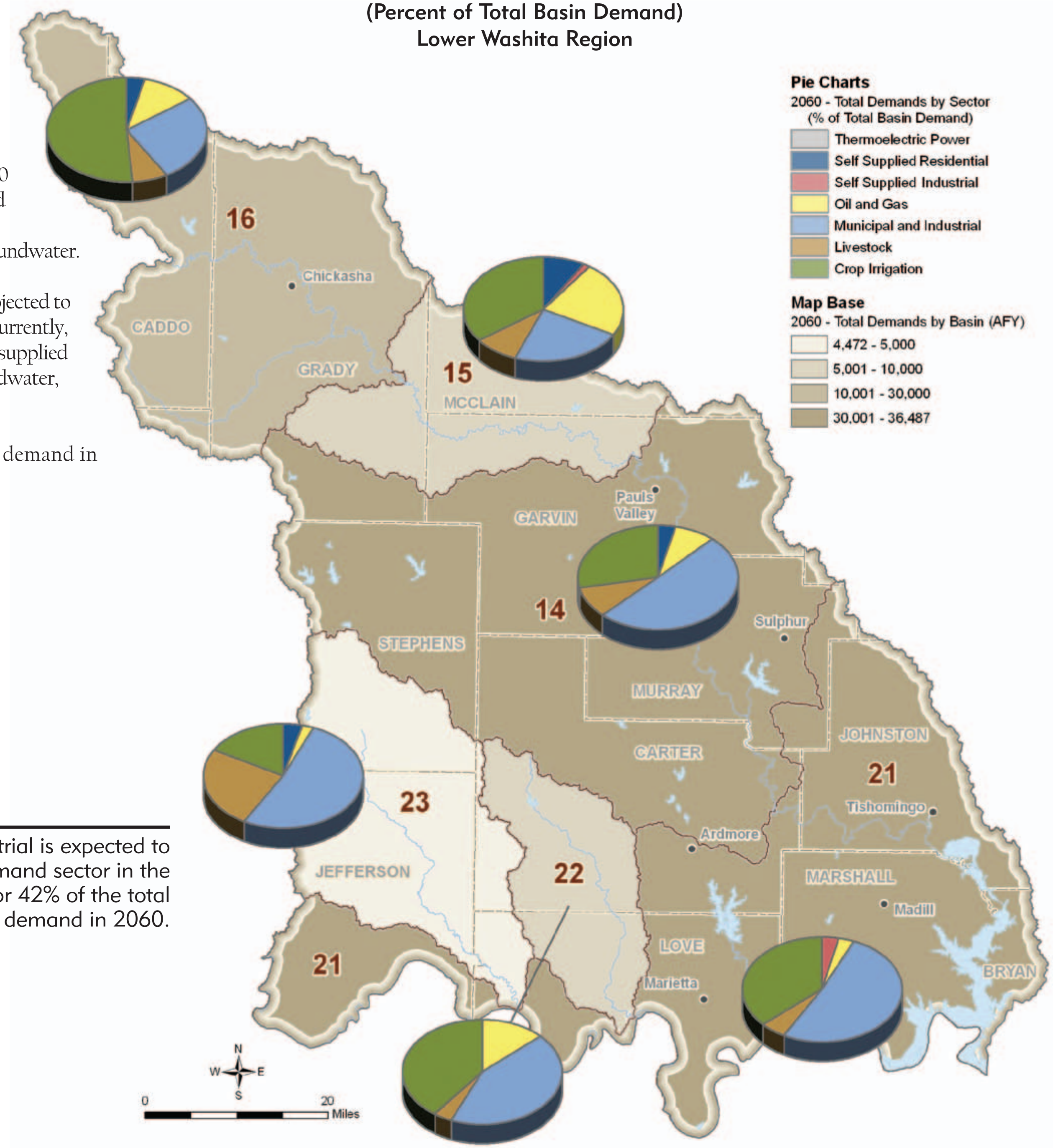
Self-Supplied Residential demand is projected to account for 4% of the 2060 demand. Currently, 77% of the demand from this sector is supplied by alluvial groundwater and 23% by bedrock groundwater.

Self-Supplied Industrial demand is projected to account for 2% of the 2060 demand. Currently, 80% of the demand from this sector is supplied by surface water, 2% by alluvial groundwater, and 18% by bedrock groundwater.

There is no Thermoelectric Power demand in the region.

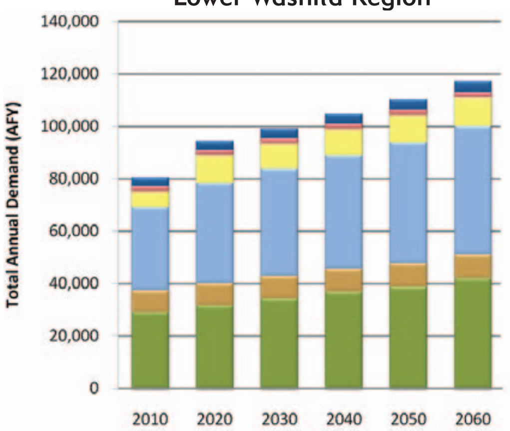
Municipal and Industrial is expected to remain the largest demand sector in the region, accounting for 42% of the total regional demand in 2060.

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



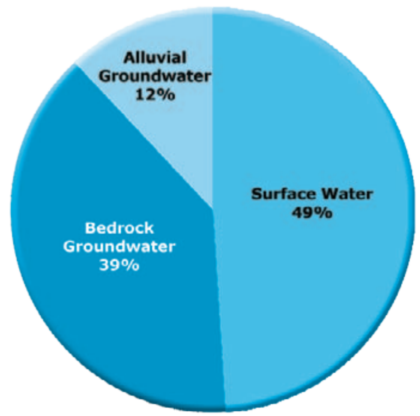
Total Water Demand by Sector

Lower Washita Region



Supply Sources Used to Meet Current Demand (2010)

Lower Washita Region



The Lower Washita accounts for about 4% of the total statewide demand. Regional demand will increase by 46% (36,790 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial and Crop Irrigation sectors.

Total Water Demand by Sector

Lower Washita Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas[1]	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	29,100	8,320	31,770	5,970	2,000	3,270	0	80,440
2020	31,680	8,480	38,390	10,450	2,000	3,510	0	94,510
2030	34,250	8,630	40,940	9,610	2,010	3,680	0	99,130
2040	36,830	8,790	43,470	9,840	2,030	3,850	0	104,800
2050	38,810	8,940	46,190	10,330	2,060	4,020	0	110,360
2060	41,990	9,100	49,010	10,810	2,120	4,210	0	117,230

1 The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Lower Washita Region, Basin 22) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin Total Demand by Sector tables.

Water Demand

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

Water Demand Sectors

- **Thermoelectric Power:** Thermoelectric power producing plants, using both self-supplied water and municipal-supplied water, are included in the thermoelectric power sector.
- **Self-Supplied Residential:** Households on private wells that are not connected to a public water supply system are included in the SSR sector.
- **Self-Supplied Industrial:** Demands from large industries that do not directly depend upon a public water supply system are included in the SSI sector. Water use data and employment counts were included in this sector, when available.
- **Oil and Gas:** Oil and gas drilling and exploration activities, excluding water used at oil and gas refineries (typically categorized as Self-Supplied Industrial users), are included in the oil and gas sector.
- **Municipal and Industrial:** These demands represent water that is provided by public water systems to homes, businesses, and industries throughout Oklahoma, excluding water supplied to thermoelectric power plants.
- **Livestock:** Livestock demands were evaluated by livestock group (beef, poultry, etc.) based on the 2007 Agriculture Census.
- **Crop Irrigation:** Water demands for crop irrigation were estimated using the 2007 Agriculture Census data for irrigated acres by crop type and county. Crop irrigation requirements were obtained primarily from the Natural Resource Conservation Service Irrigation Guide Reports.

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

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

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

Public Water Providers

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

The Lower Washita Watershed Planning Region includes 66 of the 785 public supply systems analyzed for the 2012 OCWP Update. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems often serve multiple counties and can extend into multiple planning basins and regions.)

In terms of population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are City of Ardmore, City of Chickasha, Marshall County Water Corp., Southern Oklahoma Water Corp., and Bryan County RWS & SWMD #2. Together, these five systems serve over 40 percent of the combined OCWP public water providers' population in the region.

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

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

Population and Demand Projection Data

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

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

Lower Washita Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
ALEX	OK2002603	Grady	126	646	694	732	770	808	837
ANADARKO WTP	OK1010806	Caddo	143	6,867	7,150	7,383	7,605	7,827	8,030
ARBUCKLE MCD (Wholesaler Only)	None	Murray	0	0	0	0	0	0	0
ARDMORE	OK1010814	Carter	304	25,011	26,483	27,904	29,275	30,757	32,340
BINGER PWA	OK2000803	Caddo	88	714	744	773	793	823	843
BRYAN CO RWS & SWMD #2	OK1010604	Bryan	82	7,760	8,559	9,378	10,197	11,016	11,856
BUCKHORN RWD	OK3005002	Murray	185	925	1,004	1,099	1,187	1,286	1,386
BYARS	OK2004709	McClain	71	291	343	387	431	484	528
CADDO CO RWD #1 (LOOKEBA)	OK2000802	Caddo	189	200	215	215	215	231	231
CEMENT	OK3000806	Caddo	135	536	556	576	596	615	625
CHICKASHA	OK1010821	Grady	171	16,100	17,314	18,312	19,206	20,099	21,031
CORNISH	OK3003404	Jefferson	151	172	172	172	172	182	182
CYRIL	OK3000805	Caddo	116	1,180	1,229	1,269	1,309	1,348	1,378
DAVIS	OK1010822	Murray	302	3,283	3,571	3,905	4,216	4,573	4,930
DOUGHERTY	OK1010824	Murray	174	230	258	278	297	325	354
ELMORE CITY	OK2002521	Garvin	93	756	776	796	806	826	846
ELMORE CITY RW CORP	OK3002505	Garvin	116	925	949	974	986	1,010	1,035
GARVIN CO RWD #6 (WELLS)	OK2002511	Garvin	14	2,762	2,833	2,884	2,934	2,994	3,054
GARVIN CO RWD #1	OK2002516	Garvin	67	1,406	1,443	1,468	1,494	1,524	1,555
GARVIN CO RWD #2	OK2002514	Garvin	85	1,699	1,743	1,774	1,805	1,842	1,879
GARVIN CO RWD #4	OK3002503	Garvin	94	1,215	1,247	1,269	1,291	1,317	1,344
GARVIN CO RWD #6 (SW PURCHASE)	OK3002515	Garvin	16	2,762	2,833	2,884	2,934	2,994	3,054
GRACEMONT PWA	OK2000811	Caddo	115	340	360	370	380	390	400
GRADY CO RWD #1	OK2002604	Grady	60	307	329	348	365	382	399
GRADY CO RWD #2	OK2002605	Grady	79	465	499	527	553	579	605
GRADY CO RWD #3	OK2002607	Grady	112	82	88	93	97	102	106
GRADY CO RWD #6	OK3002603	Grady	79	3,402	3,647	3,856	4,044	4,232	4,427
GRADY CO RWD #7 (NINNEKAH)	OK2002633	Grady	109	2,901	3,110	3,288	3,449	3,608	3,775
HEALDTON	OK1011102	Carter	127	2,904	3,085	3,246	3,407	3,577	3,758
JOHNSTON CO RWD #3	OK2003511	Johnston	122	2,657	2,979	3,321	3,662	4,032	4,421
KINGSTON PWA	OK2004501	Marshall	89	1,490	1,834	2,185	2,546	2,922	3,324
LEON RWD #1 (LOVE CO)	OK2004302	Love	120	111	131	151	172	192	212
LINDSAY PWA	OK2002501	Garvin	121	3,012	3,085	3,146	3,198	3,270	3,332
LONE GROVE	OK2001007	Carter	90	3,914	4,150	4,369	4,581	4,817	5,061

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

Lower Washita Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
MADILL	OK1010820	Marshall	176	3,656	4,501	5,363	6,249	7,178	8,149
MANNSVILLE PWA	OK2003505	Johnston	100	1,246	1,399	1,553	1,706	1,879	2,070
MARIETTA PWA	OK2004301	Love	92	2,578	7,480	7,896	8,339	8,808	9,269
MARLOW PWA	OK2006907	Stephens	149	4,800	4,863	4,905	4,958	5,042	5,137
MARSHALL CO WATER CORP	OK1010848	Marshall	90	14,878	18,313	21,838	25,455	29,239	33,191
MAYSVILLE	OK1010807	Garvin	125	1,326	1,356	1,376	1,396	1,426	1,456
MCCLAIN CO RWD #8	OK2004711	McClain	91	2,412	2,816	3,190	3,563	3,952	4,349
MILL CREEK	OK2003501	Johnston	103	361	399	447	495	542	599
MURRAY CO RWD #1	OK2005012	Murray	114	4,521	4,909	5,372	5,801	6,289	6,778
NORGE WATER COMPANY	OK3002601	Grady	112	954	954	1,060	1,060	1,165	1,165
OAKLAND	OK3004513	Marshall	106	605	746	893	1,041	1,196	1,358
OAKVIEW WATER CORP	OK2004506	Marshall	106	992	1,221	1,456	1,697	1,949	2,213
PAOLI	OK2002502	Garvin	76	663	673	683	693	713	723
PAULS VALLEY	OK1010808	Garvin	211	6,173	6,330	6,447	6,554	6,691	6,828
RATLIFF CITY	OK3001004	Carter	153	137	137	147	156	166	166
RAVIA	OK2003504	Johnston	100	476	532	588	653	709	784
RINGLING	OK2003404	Jefferson	100	1,200	1,222	1,233	1,255	1,287	1,320
RUSH SPRINGS	OK2002609	Grady	129	1,278	1,371	1,446	1,521	1,586	1,660
SOUTHERN OKLA WATER CORP	OK1010830	Carter	105	13,691	14,497	15,278	16,023	16,841	17,709
STEPHENS CO RW & SD #1	OK2006906	Stephens	135	900	911	919	930	945	963
STEPHENS CO RWD #4 (LOCO)	OK2006904	Stephens	113	215	215	215	215	215	229
STEPHENS CO RWD #5	OK2006969	Stephens	138	3,635	3,678	3,712	3,755	3,815	3,888
SULPHUR	OK2005001	Murray	167	5,135	5,586	6,105	6,586	7,144	7,703
TERRAL	OK2003405	Jefferson	91	386	396	396	407	417	428
THACKERVILLE	OK2004303	Love	177	1,053	5,121	5,194	5,267	5,349	5,431
TISHOMINGO WTP	OK1010815	Johnston	96	3,220	3,607	4,022	4,437	4,880	5,351
VERDEN	OK4002619	Grady	89	676	724	762	800	838	876
WAYNE	OK2004702	McClain	140	789	919	1,040	1,160	1,290	1,420
WEST DAVIS RWD	OK3005004	Murray	158	917	998	1,091	1,178	1,278	1,377
WESTERN CARTER CO WATER CORP	OK2001003	Carter	125	1,414	1,497	1,578	1,655	1,739	1,829
WILSON MUNICIPAL AUTHORITY	OK2001001	Carter	91	1,713	1,806	1,910	2,004	2,107	2,211
WYNNEWOOD WATER & LIGHT	OK1010812	Garvin	180	2,379	2,439	2,488	2,528	2,588	2,638

1 SDWIS - Safe Drinking Water Information System

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

Public Water Provider Demand Forecast (1 of 2)
Lower Washita Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
ALEX	OK2002603	Grady	91	98	103	109	114	118
ANADARKO WTP	OK1010806	Caddo	1,099	1,145	1,182	1,218	1,253	1,286
ARBUCKLE MCD (Wholesaler Only)	None	Murray	0	0	0	0	0	0
ARDMORE	OK1010814	Carter	8,521	9,023	9,507	9,974	10,479	11,018
BINGER PWA	OK2000803	Caddo	70	73	76	78	81	83
BRYAN CO RWS & SWMD #2	OK1010604	Bryan	710	783	858	933	1,008	1,085
BUCKHORN RWD	OK3005002	Murray	192	209	228	246	267	288
BYARS	OK2004709	McClain	23	27	31	35	39	42
CADDO CO RWD #1 (LOOKEBA)	OK2000802	Caddo	42	46	46	46	49	49
CEMENT	OK3000806	Caddo	81	84	87	90	93	95
CHICKASHA	OK1010821	Grady	3,094	3,316	3,508	3,679	3,850	4,028
CORNISH	OK3003404	Jefferson	29	29	29	29	31	31
CYRIL	OK3000805	Caddo	153	159	164	169	175	178
DAVIS	OK1010822	Murray	1,109	1,206	1,319	1,424	1,545	1,665
DOUGHERTY	OK1010824	Murray	45	50	54	58	63	69
ELMORE CITY	OK2002521	Garvin	78	80	83	84	86	88
ELMORE CITY RW CORP	OK3002505	Garvin	120	123	127	128	131	134
GARVIN CO RWD #6 (WELLS)	OK2002511	Garvin	43	44	45	46	47	48
GARVIN CO RWD #1	OK2002516	Garvin	106	108	110	112	115	117
GARVIN CO RWD #2	OK2002514	Garvin	162	166	169	172	176	179
GARVIN CO RWD #4	OK3002503	Garvin	128	132	134	136	139	142
GARVIN CO RWD #6 (SW PURCHASE)	OK3002515	Garvin	49	51	52	53	54	55
GRACEMONT PWA	OK2000811	Caddo	44	47	48	49	50	52
GRADY CO RWD #1	OK2002604	Grady	21	22	23	25	26	27
GRADY CO RWD #2	OK2002605	Grady	41	44	47	49	51	54
GRADY CO RWD #3	OK2002607	Grady	10	11	12	12	13	13
GRADY CO RWD #6	OK3002603	Grady	301	323	341	358	375	392
GRADY CO RWD #7 (NINNEKAH)	OK2002633	Grady	355	381	402	422	442	462
HEALDTON	OK1011102	Carter	413	439	461	484	509	534
JOHNSTON CO RWD #3	OK2003511	Johnston	363	407	454	500	551	604
KINGSTON PWA	OK2004501	Marshall	149	183	218	254	292	332
LEON RWD #1 (LOVE CO)	OK2004302	Love	15	18	20	23	26	29
LINDSAY PWA	OK2002501	Garvin	409	419	428	435	444	453

Projections of Retail Water Demand

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

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

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

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

Public Water Provider Demand Forecast (2 of 2)
Lower Washita Region

Provider	SDWIS ID[1]	County	Demand 2010	2020	2030	2040	2050	2060
			AFY					
LONE GROVE	OK2001007	Carter	394	418	440	461	485	510
MADILL	OK1010820	Marshall	721	887	1,057	1,232	1,415	1,606
MANNSVILLE PWA	OK2003505	Johnston	140	157	174	191	210	232
MARIETTA PWA	OK2004301	Love	266	771	814	860	908	955
MARLOW PWA	OK2006907	Stephens	801	811	818	827	841	857
MARSHALL CO WATER CORP	OK1010848	Marshall	1,500	1,847	2,202	2,567	2,948	3,347
MAYSVILLE	OK1010807	Garvin	186	190	193	195	200	204
MCCLAIN CO RWD #8	OK2004711	McClain	247	288	326	365	405	445
MILL CREEK	OK2003501	Johnston	42	46	52	57	63	69
MURRAY CO RWD #1	OK2005012	Murray	576	625	684	738	801	863
NORGE WATER COMPANY	OK3002601	Grady	120	120	133	133	147	147
OAKLAND	OK3004513	Marshall	72	88	106	123	142	161
OAKVIEW WATER CORP	OK2004506	Marshall	117	144	172	201	231	262
PAOLI	OK2002502	Garvin	57	57	58	59	61	62
PAULS VALLEY	OK1010808	Garvin	1,462	1,499	1,526	1,552	1,584	1,617
RATLIFF CITY	OK3001004	Carter	23	23	25	27	28	28
RAVIA	OK2003504	Johnston	53	60	66	73	80	88
RINGLING	OK2003404	Jefferson	134	137	138	141	144	148
RUSH SPRINGS	OK2002609	Grady	184	198	209	219	229	240
SOUTHERN OKLA WATER CORP	OK1010830	Carter	1,603	1,697	1,798	1,876	1,972	2,073
STEPHENS CO RW & SD #1	OK2006906	Stephens	136	138	139	141	143	146
STEPHENS CO RWD #4 (LOCO)	OK2006904	Stephens	27	27	27	27	27	29
STEPHENS CO RWD #5	OK2006969	Stephens	560	567	572	579	588	599
SULPHUR	OK2005001	Murray	961	1,045	1,142	1,232	1,336	1,441
TERRAL	OK2003405	Jefferson	39	40	40	41	42	43
THACKERVILLE	OK2004303	Love	209	1,015	1,030	1,044	1,061	1,077
TISHOMINGO WTP	OK1010815	Johnston	347	389	433	478	526	576
VERDEN	OK4002619	Grady	67	72	76	80	83	87
WAYNE	OK2004702	McClain	124	144	163	182	202	223
WEST DAVIS RWD	OK3005004	Murray	162	177	193	208	226	244
WESTERN CARTER CO WATER CORP	OK2001003	Carter	197	209	220	231	243	255
WILSON MUNICIPAL AUTHORITY	OK2001001	Carter	175	185	195	205	215	226
WYNNEWOOD WATER & LIGHT	OK1010812	Garvin	480	492	502	510	522	532

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers (1 of 2)
Lower Washita 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
ARBUCKLE MCD	None	Ardmore Davis Wynnewood Dougherty Sulphur (future use)	O O O O	R R R R			
ARDMORE	OK1010814	Southern Oklahoma Water Corp Lone Grove	O E	B T	Southern Oklahoma Water Corp	O	T
BRYAN CO RWS & SWMD #2	OK1010604	Bryan Co RWD #5	E	T	Durant	O	T
BUCKHORN RWD	OK3005002				Murray Co RWD #1	O	T
CEMENT	OK3000806				Grady Co RWD # 7	O	T
CHICKASHA	OK1010821	Grady Co RWD #6 Norge Water Co	O O	T T	Fort Cobb MCD	O	T
CYRIL	OK3000805	Caddo Co RWD #3	O	T			
DAVIS	OK1010822	Western Carter Co Water Corp West Davis RWD	O O	T T			
DOUGHERTY	OK1010824				Murray Co RWD #1	E	R
ELMORE CITY	OK2002521				Elmore City RW Corp	O	T
ELMORE CITY RW CORP	OK3002505	Elmore City	O	T	Pauls Valley	O	T
GARVIN CO RWD #4	OK3002503				Pauls Valley		T
GRADY CO RWD #2	OK2002605				Grady Co RWD #6	E	T
GRADY CO RWD #6	OK3002603	Grady Co RWD #2	E	T	Chickasha Tuttle	O O	T T
GRADY CO RWD #7 (NINNEKAH)	OK2002633	Cement	O	T			
HEALDTON	OK1011102				Jefferson Co RWD #1	E	T
KINGSTON PWA	OK2004501				Marshall County Water Corp	E	T
LONE GROVE	OK2001007				Ardmore	E	T
JOHNSTON CO RWD #3	OK2003511	Ravia Milburn Public Works Authority	E	T T			
MADILL	OK1010820	Marshall County Water Corp Oakland	E O	T T	Marshall County Water Corp	E	T
MANNSVILLE PWA	OK2003505				Marshall County Water Corp	E	T
MARSHALL CO WATER CORP	OK1010848	Kingston PWA Madill Mannsville Public Works Authority	E E E	T T T	Madill	E	T
MURRAY CO RWD #1	OK2005012	Dougherty Buckhorn RWD	O O	T T			

Wholesale Water Transfers

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

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

Wholesale Water Transfers (2 of 2)
Lower Washita 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
NORGE WATER CO	OK3002601				Chickasha	O	T
OAKLAND	OK3004513				Madill	O	T
PAULS VALLEY	OK1010808	Garvin Co RWD #4 Elmore City RW Corp	O O	T T			
RATLIFF CITY	OK3001004				Western Carter Co Water Corp	O	T
RAVIA	OK2003504				Johnston Co RWD # 3	E	T
RINGLING	OK2003404	Cornish	O	T			
SOUTHERN OKLA WATER CORP	OK1010830				Ardmore	O	T
STEPHENS CO RWD #5	OK2006969	Comanche Co RWD #3	E	T	Duncan	E	T
WEST DAVIS RWD	OK3005004				Davis Western Carter Co Water Corp	O E	T T
WESTERN CARTER CO WATER CORP	OK2001003	Ratliff City West Davis RWD	O E	T T	City of Davis	O	B

1 SDWIS - Safe Drinking Water Information System

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

Lower Washita Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
ALEX	OK2002603	Grady	174	---	---	100%
ANADARKO WTP	OK1010806	Caddo	1,319	71%	0%	29%
ARBUCKLE MCD	None	Murray	24,000	100%	0%	0%
ARDMORE	OK1010814	Carter	6,092	85%	15%	0%
BINGER PWA	OK2000803	Caddo	180	0%	100%	0%
BRYAN CO RWS & SWMD #2	OK1010604	Bryan	921	100%	0%	0%
BUCKHORN RWD	OK3005002	Murray	---	---	---	---
BYARS	OK2004709	McClain	100	0%	0%	100%
CADDO CO RWD #1 (LOOKEBA)	OK2000802	Caddo	20	0%	100%	0%
CEMENT	OK3000806	Caddo	320	---	100%	---
CHICKASHA	OK1010821	Grady	5,274	100%	0%	0%
CORNISH	OK3003404	Jefferson	---	---	---	---
CYRIL	OK3000805	Caddo	580	0%	100%	0%
DAVIS	OK1010822	Murray	5,625	100%	0%	0%
DOUGHERTY	OK1010824	Murray	---	---	---	---
ELMORE CITY	OK2002521	Garvin	298	80%	20%	0%
ELMORE CITY RW CORP	OK3002505	Garvin	---	---	---	---
GARVIN CO RWD #1	OK2002516	Garvin	---	---	---	---
GARVIN CO RWD #2	OK2002514	Garvin	525	0%	77%	23%
GARVIN CO RWD #4	OK3002503	Garvin	---	---	---	---
GARVIN CO RWD #6 (SW PURCHASE)	OK3002515	Garvin	---	---	---	---
GARVIN CO RWD #6 (WELLS)	OK2002511	Garvin	400	0%	0%	100%
GRACEMONT PWA	OK2000811	Caddo	243	0%	100%	0%
GRADY CO RWD #1	OK2002604	Grady	11	0%	100%	0%
GRADY CO RWD #2	OK2002605	Grady	34	0%	56%	44%
GRADY CO RWD #3	OK2002607	Grady	35	0%	0%	100%
GRADY CO RWD #6	OK3002603	Grady	886	---	100%	---
GRADY CO RWD #7 (NINNEKAH)	OK2002633	Grady	---	---	---	---
HEALDTON	OK1011102	Carter	1,873	79%	21%	0%
JOHNSTON CO RWD #3	OK2003511	Johnston	507	0%	0%	100%
KINGSTON PWA	OK2004501	Marshall	1,250	0%	100%	0%
LEON RWD #1 (LOVE CO)	OK2004302	Love	130	0%	23%	77%
LINDSAY PWA	OK2002501	Garvin	2,168	1%	0%	99%

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 2)

Lower Washita Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
LONE GROVE	OK2001007	Carter	562	0%	100%	0%
MADILL	OK1010820	Marshall	3,442	100%	0%	0%
MANNSVILLE PWA	OK2003505	Johnston	---	---	---	---
MARIETTA PWA	OK2004301	Love	1,885	0%	100%	0%
MARLOW PWA	OK2006907	Stephens	5,994	32%	68%	0%
MARSHALL CO WATER CORP	OK1010848	Marshall	1,616	100%	0%	0%
MAYSVILLE	OK1010807	Garvin	700	100%	0%	0%
MCCLAIN CO RWD #8	OK2004711	McClain	647	0%	0%	100%
MILL CREEK	OK2003501	Johnston	575	0%	0%	100%
MURRAY CO RWD #1	OK2005012	Murray	764	0%	0%	100%
NORGE WATER COMPANY	OK3002601	Grady	---	---	---	---
OAKLAND	OK3004513	Marshall	---	---	---	---
OAKVIEW WATER CORP	OK2004506	Marshall	310	0%	100%	0%
PAOLI	OK2002502	Garvin	---	---	---	---
PAULS VALLEY	OK1010808	Garvin	5,354	100%	0%	0%
RATLIFF CITY	OK3001004	Carter	244	0%	100%	0%
RAVIA	OK2003504	Johnston	149	0%	100%	0%
RINGLING	OK2003404	Jefferson	233	0%	100%	0%
RUSH SPRINGS	OK2002609	Grady	137	0%	100%	0%
SOUTHERN OKLA WATER CORP	OK1010830	Carter	530	36%	64%	0%
STEPHENS CO RW & SD #1	OK2006906	Stephens	55	0%	100%	0%
STEPHENS CO RWD #4 (LOCO)	OK2006904	Stephens	160	---	100%	---
STEPHENS CO RWD #5	OK2006969	Stephens	640	0%	100%	0%
SULPHUR	OK2005001	Murray	1,377	0%	0%	100%
TERRAL	OK2003405	Jefferson	25	---	---	100%
THACKERVILLE	OK2004303	Love	299	0%	96%	4%
TISHOMINGO WTP	OK1010815	Johnston	1,144	45%	55%	0%
VERDEN	OK4002619	Grady	212	---	---	100%
WAYNE	OK2004702	McClain	105	0%	0%	100%
WEST DAVIS RWD	OK3005004	Murray	135	0%	100%	0%
WESTERN CARTER CO WATER CORP	OK2001003	Carter	57	0%	100%	0%
WILSON MUNICIPAL AUTHORITY	OK2001001	Carter	160	0%	100%	0%
WYNNEWOOD WATER & LIGHT	OK1010812	Garvin	600	0%	0%	100%

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey
Lower Washita Region

Town of Alex (Grady County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: drill new wells.
Long-Term Needs
Infrastructure improvements: replace a portion of distribution system lines; Upgrade water treatment plant.

Anadarko WTP (Caddo County)
Current Source of Supply
Primary source: Fort Cobb MCD
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage tank; add membrane to WTP.

Arbuckle MCD
Current Source of Supply
Primary source: Arbuckle Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: new primary source pipeline for Sulphur municipal water supply.

City of Ardmore (Carter County)
Current Source of Supply
Primary source: Arbuckle Lake, Mountain Lake/City Lake, Lake Jean Neustadt, Lake Scott King
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Binger PWA (Caddo County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Bryan County RWS & SWMD 2
Current Source of Supply
Primary source: Blue River, Eagle Lake
Short-Term Needs
Infrastructure improvements: add storage tanks.
Long-Term Needs
Infrastructure improvements: construct new reservoir or additional wells.

Buckhorn RWD (Murray County)
Current Source of Supply
Primary source: Murray County District 1
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: add and replace distribution system lines.

Town of Byars (McClain County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: drill additional wells.

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

Town of Cement (Caddo County)
Current Source of Supply
Primary source: Grady County RWD 7
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: add storage tank.

City of Chickasha (Grady County)
Current Source of Supply
Primary source: Ft. Cobb MCD
Short-Term Needs
Infrastructure improvements: replace water main lines.
Long-Term Needs
Infrastructure improvements: replace distribution system distribution system lines; add storage tanks; refurbish existing water tanks.
Supply: seeking long-term source.

Town of Cornish (Jefferson County)
Current Source of Supply
Primary source: town of Ringling.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Cyril (Caddo County)
Current Source of Supply
Primary source: RWD 3
Short-Term Needs
Infrastructure improvements: add storage.
Long-Term Needs
Infrastructure improvements: add storage.

City of Davis (Murray County)
Current Source of Supply
Primary source: Arbuckle Lake, Honey Creek
Short-Term Needs
Infrastructure improvements: replace distribution system lines; construct new WTP.
Long-Term Needs
Infrastructure improvements: refurbish or drill wells; add storage.

Town of Dougherty (Murray County)
Current Source of Supply
Primary source: Arbuckle Lake, Murray County 1
Short-Term Needs
Infrastructure improvements: replace distribution system lines; add storage tower fencing; refurbish storage tower; replace water meters.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage; new WTP.

Elmore City (Garvin County)
Current Source of Supply
Primary source: Pauls Valley/Lake Longmire, Elmore City RWC, groundwater.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Elmore City RWC (Garvin County)
Current Source of Supply
Primary sources: Pauls Valley PWA
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Garvin County RWD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

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
Lower Washita Region

Garvin County RWD 2
Current Source of Supply
Primary source: groundwater
Emergency source: City of Lindsay
Short-Term Needs
Infrastructure improvements: drill additional wells.
Long-Term Needs
Infrastructure improvements: drill additional wells.

Garvin County RWD 4
Current Source of Supply
Primary source: Pauls Valley Municipal Authority
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Garvin County RWD 6
Current Source of Supply
Primary source: Gerty Sands Aquifer and City of Wynnewood
Short-Term Needs
Infrastructure improvements: drill additional wells; add storage.
Long-Term Needs
New supply source: Oscar aquifer.
Infrastructure improvements: add additional wells to Oscar.

Garvin County RWD 6 (SW Purchase)
Current Source of Supply
Primary source: City of Wynnewood
Short-Term Needs
New supply source: groundwater.
Infrastructure improvements: add distribution system lines.
Long-Term Needs
New supply source: groundwater.
Infrastructure improvements: add distribution system lines.

Gracemont PWA (Caddo County)
Current Source of Supply
Primary source: Groundwater
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: add distribution system lines.

Grady County RWD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage.

Grady County RWD 2
Current Source of Supply
Primary source: groundwater, Grady County RWD 6
Short-Term Needs
Infrastructure improvements: drill additional well.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add storage.

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

Grady County RWD 6
Current Source of Supply
Primary source: Cities of Chickasha and Tuttle
Short-Term Needs
Infrastructure improvements: add standpipe (Tuttle area).
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Grady County RWD 7
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: drill additional wells.
Long-Term Needs
Infrastructure improvements: drill additional wells.

Town of Healdton (Carter County)
Current Source of Supply
Primary source: Healdton Municipal Lake, groundwater
Short-Term Needs
Infrastructure improvements: drill additional well (Oscar aquifer).
Long-Term Needs
Infrastructure improvements: drill additional well; add storage.

Johnston County RWD 3
Current Source of Supply
Primary source: groundwater (Arbuckle-Simpson)
Short-Term Needs
Infrastructure improvements: drill additional well; add distribution lines.
Long-Term Needs
Infrastructure improvements: drill additional wells; add storage.

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

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

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

City of Lone Grove (Carter County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: redrill well.
Long-Term Needs
Infrastructure improvement: drill additional wells; add storage.

City of Madill (Marshall County)
Current Source of Supply
Primary source: City Lake, Carter Lake, Hauani Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Mannsville PWA (Johnston County)
Current Source of Supply
Primary source: groundwater (Antlers Sandstone aquifer)
Emergency source: Marshall County Water Corp.
Short-Term Needs
Infrastructure improvement: add storage.
Long-Term Needs
Infrastructure improvement: add storage; drill additional wells.

Marietta RWD (Love County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: drill additional wells; replace distribution system lines; add storage.
Long-Term Needs
Infrastructure improvement: drill additional wells; replace distribution system lines; add storage.

Marlow PWA (Stephens County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: replace distribution system lines; add storage.
Long-Term Needs
None identified.

Marshall County Water Corp.
Current Source of Supply
Primary source: Lakes Rex Smith, Oteaka and Ruel
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Maysville (Garvin County)
Current Source of Supply
Primary source: Maysville Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvement: replace distribution system lines; add storage and booster stations; new WTP.

McClain County RWD 8
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: drill additional wells; add storage.
Long-Term Needs
None identified.

Town of Mill Creek (Johnston County)
Current Source of Supply
Primary source: groundwater (Arbuckle-Simpson)
Short-Term Needs
Infrastructure improvement: refurbish water tower.
Long-Term Needs
Infrastructure improvement: drill additional well; replace water main lines and cut-off valves.

Murray County 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Norge Water Company (Grady County)
Current Source of Supply
Primary source: City of Chickasha
Short-Term Needs
Infrastructure improvement: replace distribution system lines; add storage.
Long-Term Needs
None identified.

Town of Oakland (Marshall County)
Current Source of Supply
Primary source: City of Madill
Short-Term Needs
None identified.
Long-Term Needs
New supply source: groundwater
Infrastructure improvement: drill additional wells.

Oakview Water Corp. (Marshall County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

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

Pauls Valley (Garvin County)
Current Source of Supply
Primary source: R.C. Longmire Lake and Valley City Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvement: upsize raw water line; add storage

Ratliff City (Carter County)
Current Source of Supply
Primary source: Western Carter County Water & Sewer
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Ravia (Johnston County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: surface water
Long-Term Needs
Infrastructure improvement: replace distribution system lines.

Town of Ringling (Jefferson County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: drill additional well.
Long-Term Needs
Infrastructure improvement: replace distribution system lines; add storage; drill additional wells.

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

Southern Oklahoma Water Corp. (Carter County)
Current Source of Supply
Primary source: Arbuckle Lake, Lake Murray, groundwater
Short-Term Needs
Infrastructure improvement: drill additional wells.
Long-Term Needs
Infrastructure improvement: drill additional wells.

Stephens County RW & SD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Stephens County RWD 4
Current Source of Supply
Primary source: groundwater
Emergency source: Jefferson County RWD
Short-Term Needs
Infrastructure improvement: refurbish additional well.
Long-Term Needs
None identified.

Stephens County RWD 5
Current Source of Supply
Primary source: groundwater
Emergency source: City of Duncan
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvement: drill additional wells.

City of Sulphur (Murray County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: replace portion of water main lines; replace pump station pump.
Long-Term Needs
Infrastructure improvement: drill additional wells; add pump station; refurbish existing wells.

Town of Terral PWA (Stephens County)
Current Source of Supply
Primary source: groundwater, Jefferson County RWD 1
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvement: drill additional wells.

Thackerville (Love County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvement: drill additional wells.
Long-Term Needs
Infrastructure improvement: drill additional wells.

Tishomingo WTP (Johnston County)
Current Source of Supply
Primary source: Pennington Creek
Short-Term Needs
Infrastructure improvement: add pump and valves in distribution system; upgrade water treatment plant.
Long-Term Needs
Infrastructure improvement: replace distribution system lines.

Town of Verden (Grady County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
New supply source: groundwater (Rush Springs aquifer).
Infrastructure improvement: drill additional wells; add storage and standpipe.

Town of Wayne (McClain County)
Current Source of Supply
Primary source: groundwater
Emergency source: McClain County RWD 8
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvement: replace distribution system lines.

West Davis RWD (Murray County)
Current Source of Supply
Primary source: City of Davis
Short-Term Needs
Infrastructure improvement: replace distribution system lines.
Long-Term Needs
Infrastructure improvement: drill additional wells; replace distribution system lines; add storage.

Western Carter County Water Corp.
Current Source of Supply
Primary source: groundwater, City of Davis.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Wilson Municipal Authority (Carter County)
Current Source of Supply
Primary source: groundwater (Oscar B aquifer)
Short-Term Needs
Infrastructure improvement: drill additional wells.
Long-Term Needs
Infrastructure improvement: drill additional wells.

Wynnewood Water & Light (Garvin County)
Current Source of Supply
Primary source: Lake Arbuckle
Short-Term Needs
None identified.
Long-Term Needs
None identified.

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
Lower Washita Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present - 2020	2021 - 2040	2041 - 2060	Total Period
Small	$375	$202	$36	$613
Medium	$824	$933	$212	$1,969
Large	$0	$0	$0	$0
Reservoir[2]	$0	$7	$222	$229
Total	$1,199	$1,142	$470	$2,811

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

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

- Approximately $2.8 billion is needed to meet the projected drinking water infrastructure needs of the Lower Washita region over the next 50 years. The largest infrastructure costs are expected to occur within the next 20 years.
- Distribution and transmission projects account for more than 75 percent of the providers' estimated infrastructure costs, followed distantly by water treatment projects.
- Medium-sized providers have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoir comprise approximately eight 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 Sites (Categories 3 & 4)

Lower Washita Region

Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool			Primary Study		Updated Cost Estimate[2] (2010 dollars)
						Surface Area	Storage	Dependable Yield	Date	Agency	
					AF	Acres	AF	AFY			
Burneyville	3	Walnut Bayou & Simon Creek	22	WS, FW, R	194,000	8,546	119,000	25,000	1973	Bureau of Reclamation	$162,429,000
Caddo Creek	4	Caddo Creek	14	WS, FC, FW, R	333,980	9,787	236,000	40,000	1973	Bureau of Reclamation	$164,362,000
Chickasha	3	Little Washita	16	FC, FW, R	80,500	1,950	7,500	0	1951	USACE	$116,512,000
Courtney (Criner Hills)	4	Mud Creek	23	WS, FW, R	303,400	11,430	206,800	53,000	1976	Bureau of Reclamation	$165,473,000
Cox City	3	Rush Creek	14	WS, FC, FW, R	87,060	1,800	18,000	8,000	1981	USACE	$75,787,000
Durwood	4	Washita River	21	P, FC, R, FW	770,000	16,000	306,000	232,000	1951	Bureau of Reclamation,	$166,429,000
Gainesville	3	Red River	21	FC, WS, FW, R, P	82,151	4,268	35,000	17,500	1995	USACE	$106,705,000
Gracemont	3	Sugar Creek	16	FC, WS, FW, R	120,000	3,748	49,000	5,000	1973	Bureau of Reclamation	$80,378,000
Kechi	4	Little Washita River	16	FC, FW, R, WS	131,000	2,939	51,400	8,000	1973	Bureau of Reclamation	$95,795,000
Purdy	4	Rush Creek	14	WS, FC, FW, R	236,000	5,792	126,000	20,000	1973	Bureau of Reclamation	$165,473,000
Ravia	4	Mill Creek	21	WS, FW, R	0	1,718	100,800	25,300	1969	Bureau of Reclamation	$146,816,000
Verden	3	Spring Creek	16	WS, FW, R	46,000	2,048	34,000	5,000	1973	Bureau of Reclamation	$56,222,000

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

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

Expanded Water Supply Options
Lower Washita Region

Data & Analysis
Lower Washita Watershed Planning Region

Basin 14

Basin 14 Summary

Synopsis

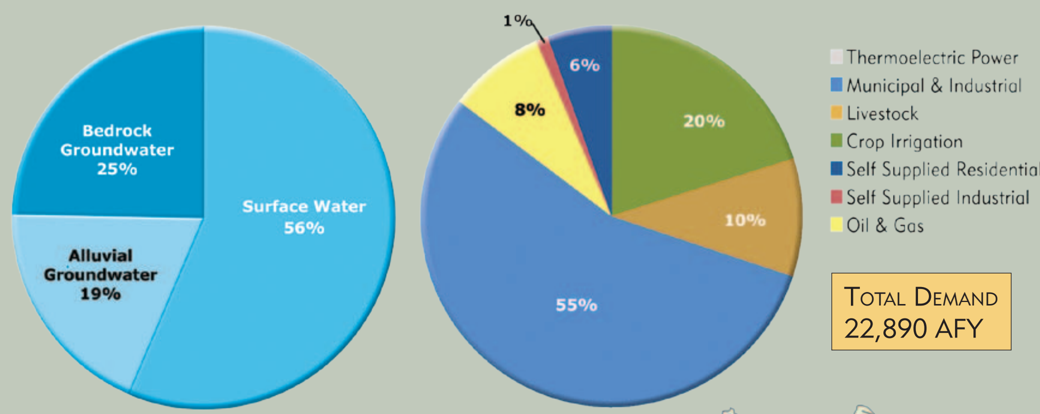
- Water users are expected to continue to rely mainly on surface water and to a lesser extent alluvial and bedrock groundwater.
- Alluvial groundwater storage depletions may occur by 2020, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation measures could reduce alluvial groundwater storage depletions.
- Reservoir storage could be used as an alternative to mitigate alluvial groundwater storage depletions.

Basin 14 accounts for about 28% of the current demand in the Lower Washita Watershed Planning Region. About 55% of the basin's demand is from the Municipal and Industrial sector. Crop Irrigation is the second largest demand sector at 20%. Surface water satisfies about 56% of the current demand in the basin. Groundwater satisfies about 44% of the demand (19% alluvial and 25% bedrock). The peak summer month demand in Basin 14 is about 2.9 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in the Washita River near Dickson is typically greater than 22,000 AF/month throughout the year and greater than 60,000 AF/month in the spring and early summer. However, the river can have periods of low flow in the summer, fall, and winter. There is one major federal reservoir and six large municipal lakes in Basin 14. Lake of the Arbuckles was constructed by the Bureau of Reclamation in 1967 on Rock Creek, a tributary of t he Washita River. The lake was built for the purposes of water supply, flood control, recreation, and fish and wildlife mitigation and contains 62,600 acre-feet of conservation storage yielding 24,000 AFY. The entire yield is allocated to the Arbuckle Master Conservancy District, which provides water to the cities of Ardmore, Davis, Sulphur, Wynnewood, and Dougherty.

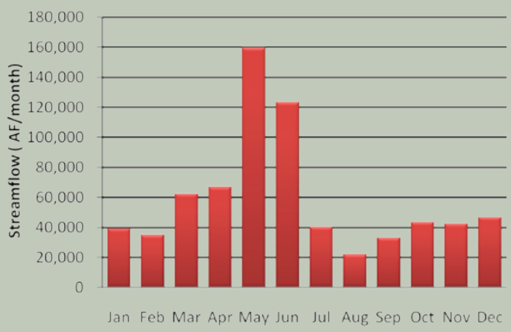
Humphreys (yield of 3,226 AFY), Fuqua (yield of 3,427 AFY), Duncan (unknown yield), and Clear Creek (unknown yield) are municipal lakes used by the City of Duncan for water supply and recreation. Duncan and Humphreys are on tributaries of Wildhorse Creek and Fuqua is on Black Bear Creek. Humphreys and Fuqua are NRCS projects that also provide flood control storage. The City of Pauls Valley obtains water supplies from Pauls Valley Lake (unknown yield) and RC Longmire (yield of 3,360 AFY). Pauls Valley is located on Washington Creek and RC Longmire, an NRCS structure, is located Keel Sandy Creek. All lakes in Basin 14 are fully allocated except Fuqua, which currently has 2,182 AFY of unpermitted yield. Future use of these sources would need to take into consideration existing water rights. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 14 is considered good. However, there are multiple creeks impaired for Agricultural use due to high levels of

Current Demand by Source and Sector
Lower Washita Region, Basin 14

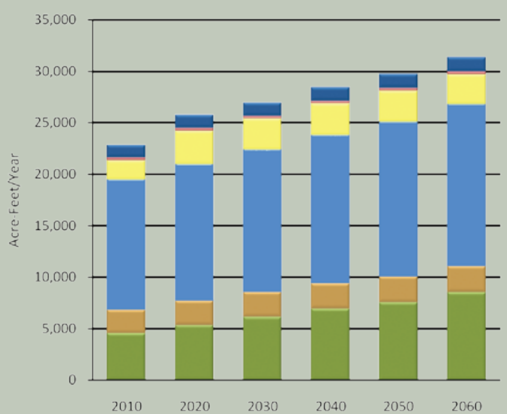


Water Resources
Lower Washita Region, Basin 14

Median Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 14



Projected Water Demand
Lower Washita Region, Basin 14



chloride, sulfate, and total dissolved solids (TDS), including Caddo Creek, Wildhorse Creek, Rush Creek, a segment of the Washita River, and Pauls Valley Lake.

The majority of groundwater rights in Basin 14 are from the Washita River major alluvial aquifer, Rush Springs major bedrock aquifer, and non-delineated minor bedrock aquifers. There are also substantial rights in the Arbuckle-Simpson major bedrock aquifer, which has over 2.4 million AF of water in storage in the basin, and in non-delineated minor alluvial aquifers. While these aquifers have substantial volumes of water in storage in Basin 14, the major aquifers underlie only relatively small portions of the basin and minor aquifers may have insufficient yields for large volume users. Another potential limitation is that the OWRB is currently studying the Arbuckle-Simpson aquifer to set a maximum annual yield and equal proportionate share that will likely decrease the amount of permitted water available for withdrawal. Basin 14 contributes about 42,000 AFY of recharge to the Rush Springs and Arbuckle-Simpson aquifers. There are additional permits in other minor aquifers. Domestic users do not require a permit and are assumed to be obtaining supplies from groundwater sources in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin. However, localized areas with high levels of nitrate and fluoride have been found in other areas of the Rush Springs aquifer and may occur in Basin 14.

The projected 2060 water demand of 31,400 AFY in Basin 14 reflects an 8,510 AFY increase (37%) over the 2010 demand. The largest demand will be in the Municipal and Industrial sector. However, largest growth in demand will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2020. No surface water gaps or bedrock groundwater depletions are expected through 2060.

Lake of the Arbuckles is capable of providing dependable water supplies to its existing users and with new infrastructure could be used to meet all of Basin 14 future surface water demand during periods of low streamflow. However, the lake is currently fully allocated. Therefore, any future use of this source would need to take into consideration existing water rights.

Alluvial groundwater storage depletions are expected to be up to 390 AFY and have a 17% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in Basin 14 may occur during the summer and fall. Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in Basin 14's major aquifers. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Water Supply Limitations
Lower Washita Region, Basin 14

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal · Potential · Significant

Water Supply Option Effectiveness
Lower Washita Region, Basin 14

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

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

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce alluvial groundwater storage depletions. Temporary drought management activities may not be needed for groundwater demand since groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified nine potentially viable out-of-basin sites in the region. Additionally, Lake Texoma, in Basin 21, has substantial unpermitted yield to meet the needs of new users but its use is limited by water quality considerations. In light of the distance to reliable water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Additional reservoir storage in Basin 14 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 2,600 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified three potential sites in Basin 14.

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

Increased reliance on the Rush Springs or Arbuckle-Simpson bedrock aquifers could mitigate alluvial groundwater storage depletions, but could create bedrock groundwater depletions. While depletions would be minimal compared to the amount of water in storage in these aquifers, the Rush Springs and Arbuckle-Simpson underlies only relatively small portions of the basin.

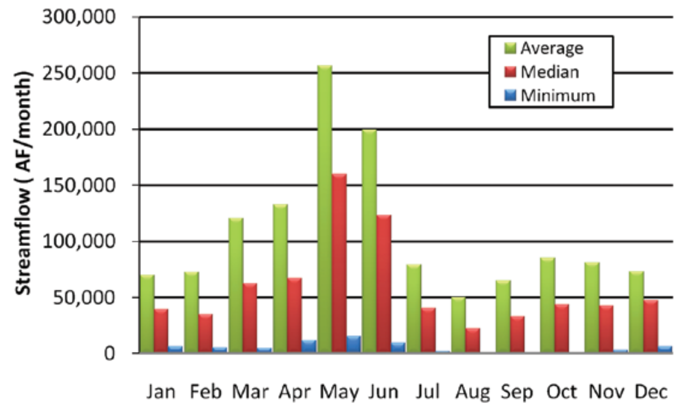
Basin 14 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Washita River near Dickson had a period of below-average streamflow from the early 1960s to the mid 1970s. From the late 1980s through the late 1990s, 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 Washita River near Dickson is greater than 22,000 AF/month throughout the year and greater than 60,000 AF/month in the spring and early summer. However, the river can have periods of low flow in the summer, fall, and winter.
- Relative to other basins in the state, the basin's surface water quality is considered good.
- There is one major and six large lakes in Basin 14. Lake of the Arbuckles provides 24,000 AFY of dependable water supply yield for the Arbuckle Master Conservancy District and its members. The City of Duncan obtains water supplies from Lake Humphreys (yield of 3,226 AFY), Fuqua (yield of 3,427AFY), Duncan (unknown yield), and Clear Creek (unknown yield). The City of Pauls Valley obtains water supplies from Pauls Valley Lake (unknown yield) and RC Longmire (yield of 3,360 AFY). With the exception of 2,182 AFY of unpermitted yield from Fuqua, Basin 14's reservoirs are fully allocated.

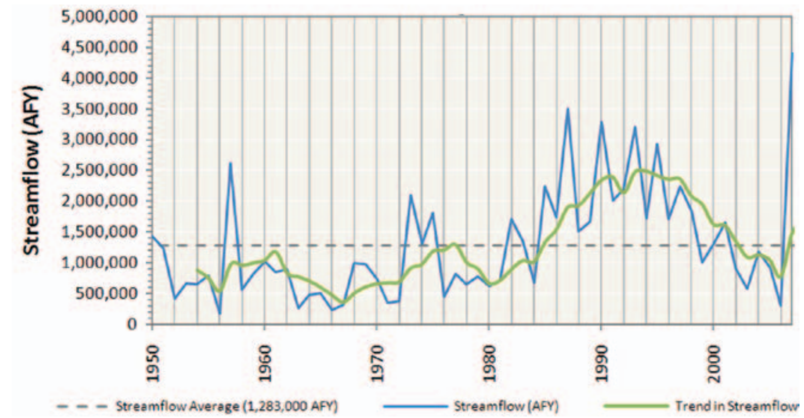
Monthly Historical Streamflow at the Basin Outlet

Lower Washita Region, Basin 14



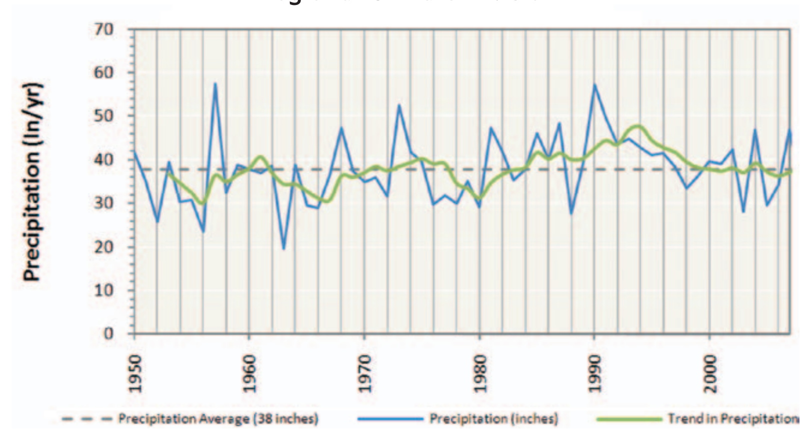
Historical Streamflow at the Basin Outlet

Lower Washita Region, Basin 14



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

Lower Washita Region, Basin 14

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	<1%	0	37,000	2.1	13,400
Arbuckle-Simpson	Bedrock	Major	7%	4,300	2,420,000	temporary 2.0[2]	165,500
Gerty Sand	Alluvial	Major	1%	600	63,000	0.65	7,400
Rush Springs	Bedrock	Major	4%	8,600	609,000	temporary 2.0	86,600
Washita River	Alluvial	Major	8%	11,700	701,000	1.0	159,800
El Reno	Bedrock	Minor	10%	300	631,000	temporary 2.0	242,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	9,100	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	1,100	N/A	temporary 2.0	N/A

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

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

Groundwater Resources

- The majority of groundwater rights in Basin 14 are from the Washita River and Rush Springs major aquifers and non-delineated minor groundwater sources. There are also substantial rights in the Arbuckle-Simpson aquifer, which has more than 2.4 million AF of groundwater stored in Basin 14. While these aquifers may have substantial volumes of water in storage, the major aquifers underlie only a small portion of the basin, and minor aquifers typically have lower yields which might be insufficient for large scale users. Another potential limitation is that the OWRB is currently studying the Arbuckle-Simpson aquifer to set a maximum annual yield and equal proportionate share that will likely decrease the amount of permitted water available for withdrawal. Basin 14 contributes about 42,000 AFY of recharge to the Rush Springs and Arbuckle-Simpson aquifers.
- There are no significant groundwater quality issues in the basin. However, localized areas with high levels of nitrate and fluoride have been found in portions of the Rush Springs aquifer and may occur in Basin 14.

Notes & Assumptions

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

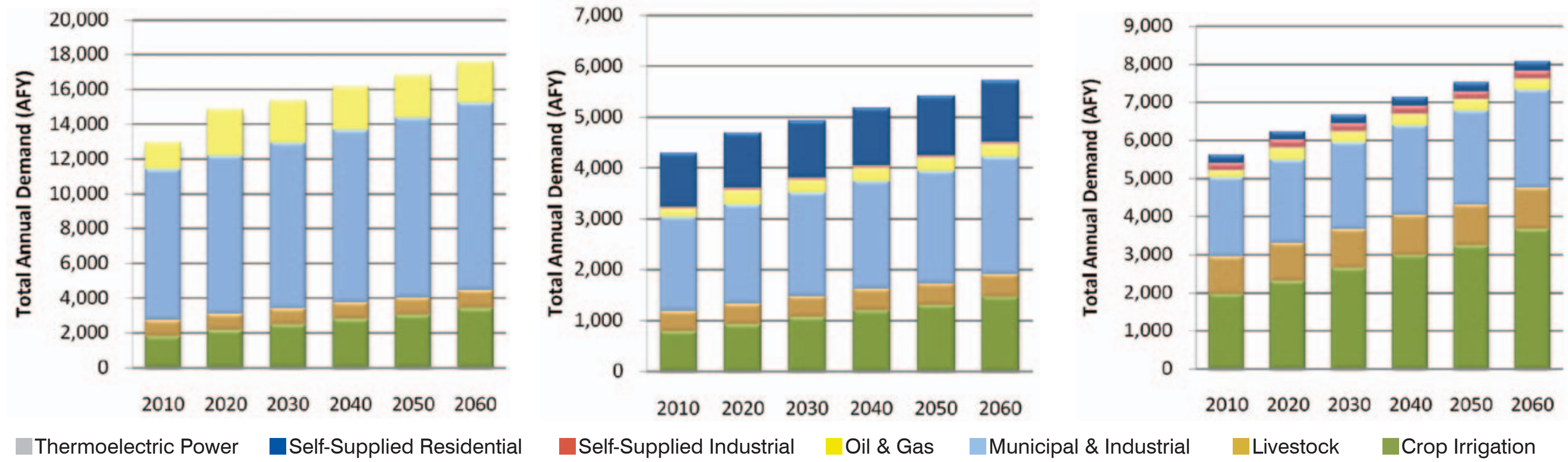
Water Demand

- Basin 14's water needs account for about 28% of the demand in the Lower Washita Watershed Planning Region and will increase by 37% (8,510 AFY) from 2010 to 2060. The largest demand will be in the Municipal and Industrial sector. However, the largest growth in demand will be from the Crop Irrigation demand sector.
- Surface water is used to meet 56% of total demands in the basin and its use will increase by 36% (4,630 AFY) from 2010 to 2060. The majority of the surface water use and largest growth in surface water use during this period will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 19% of total demand in the basin and its use will increase by 33% (1,420 AFY) from 2010 to 2060. The majority of alluvial groundwater use during this period will be from the Municipal and Industrial demand sector. However, the highest growth in alluvial groundwater use from 2010 to 2060 will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 25% of total demand in the basin and its use will increase by 44% (2,460 AFY) from 2010 to 2060. The majority of bedrock groundwater use by 2060 and the highest growth in bedrock groundwater use will be from the Crop Irrigation demand sector.

Surface Water Demand by Sector
Lower Washita Region, Basin 14

Alluvial Groundwater Demand by Sector
Lower Washita Region, Basin 14

Bedrock Groundwater Demand by Sector
Lower Washita Region, Basin 14



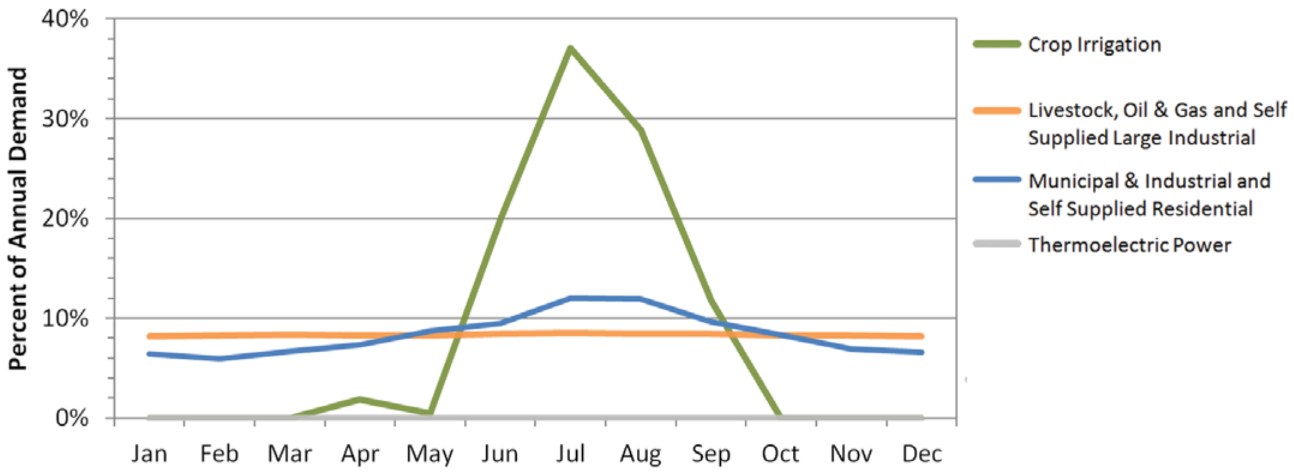
Total Demand by Sector
Lower Washita Region, Basin 14

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	4,610	2,280	12,630	1,890	230	1,250	0	22,890
2020	5,390	2,340	13,270	3,270	230	1,290	0	25,790
2030	6,180	2,400	13,840	3,010	230	1,330	0	26,990
2040	6,970	2,450	14,390	3,060	230	1,360	0	28,460
2050	7,580	2,510	15,020	3,030	230	1,400	0	29,770
2060	8,550	2,570	15,680	2,920	240	1,440	0	31,400

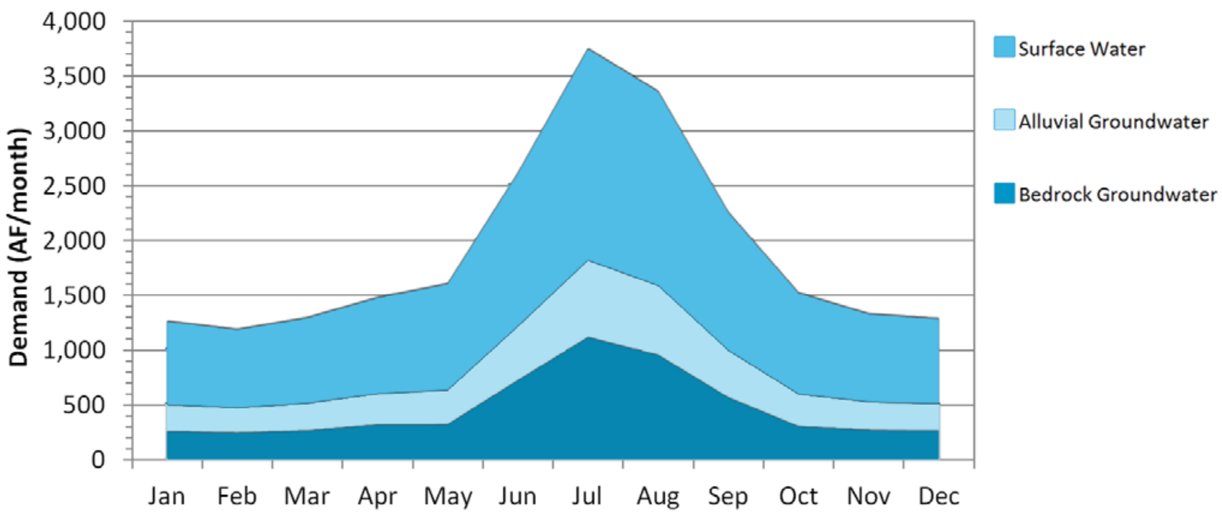
Notes & Assumptions

- 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)
Lower Washita Region, Basin 14



Monthly Demand Distribution by Source (2010)
Lower Washita Region, Basin 14



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 76% 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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 14 is 2.9 times the winter monthly demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.5 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at about 2.9 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 4.3 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2020. No surface water gaps or bedrock groundwater depletions are expected in Basin 14 through 2060.
- Lake of the Arbuckles is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of the Basin 14 future surface water demand during periods of low streamflow. However, the lake is currently fully allocated. Therefore, any future use of this source would need to take into consideration existing water rights.
- Alluvial groundwater storage depletions in Basin 14 may occur during the summer and fall, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 28% (250 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 25% (140 AF/month) of the fall month's 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 summer months.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water stored in the basin's major aquifers. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Lower Washita Region, Basin 14

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Washita Region, Basin 14

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)	250	245	14%
Sep-Nov (Fall)	140	70	3%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Washita Region, Basin 14

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	50	0	0%	2%
2030	0	120	0	0%	3%
2040	0	210	0	0%	7%
2050	0	320	0	0%	14%
2060	0	390	0	0%	17%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Washita Region, Basin 14

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Lower Washita Region, Basin 14

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	390	0	0%	17%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	370	0	0%	16%
Moderately Expanded Conservation in M&I Water Use	0	270	0	0%	12%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	240	0	0%	12%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	100	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

Lower Washita Region, Basin 14

Reservoir Storage	Diversion
AF	AFY
100	300
500	1,600
1,000	3,300
2,500	8,200
5,000	15,000
Required Storage to Meet Growth in Demand (AF)	2,600
Required Storage to Meet Growth in Surface Water Demand (AF)	1,300

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, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce alluvial groundwater storage depletions by 38%. Temporary drought management activities are not expected to be needed for groundwater demand, since groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate alluvial and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified nine potential out-of-basin sites in the Lower Washita Region: Chickasha, Gracemont, Kechi and Verden in Basin 16; Durwood, Gainesville and Ravia in Basin 21; Burneyville in Basin 22; and Courtney in Basin 23. In addition, Lake Texoma in Basin 21 has substantial unpermitted yield to meet the needs of new users, but its use is limited by water quality considerations. In light of the distance to reliable water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Additional reservoir storage in Basin 14 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 2,600 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future storage depletions. - The OCWP *Reservoir Viability Study* also identified Caddo Creek, Cox City and Purdy Reservoirs as potentially viable sites in Basin 14

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

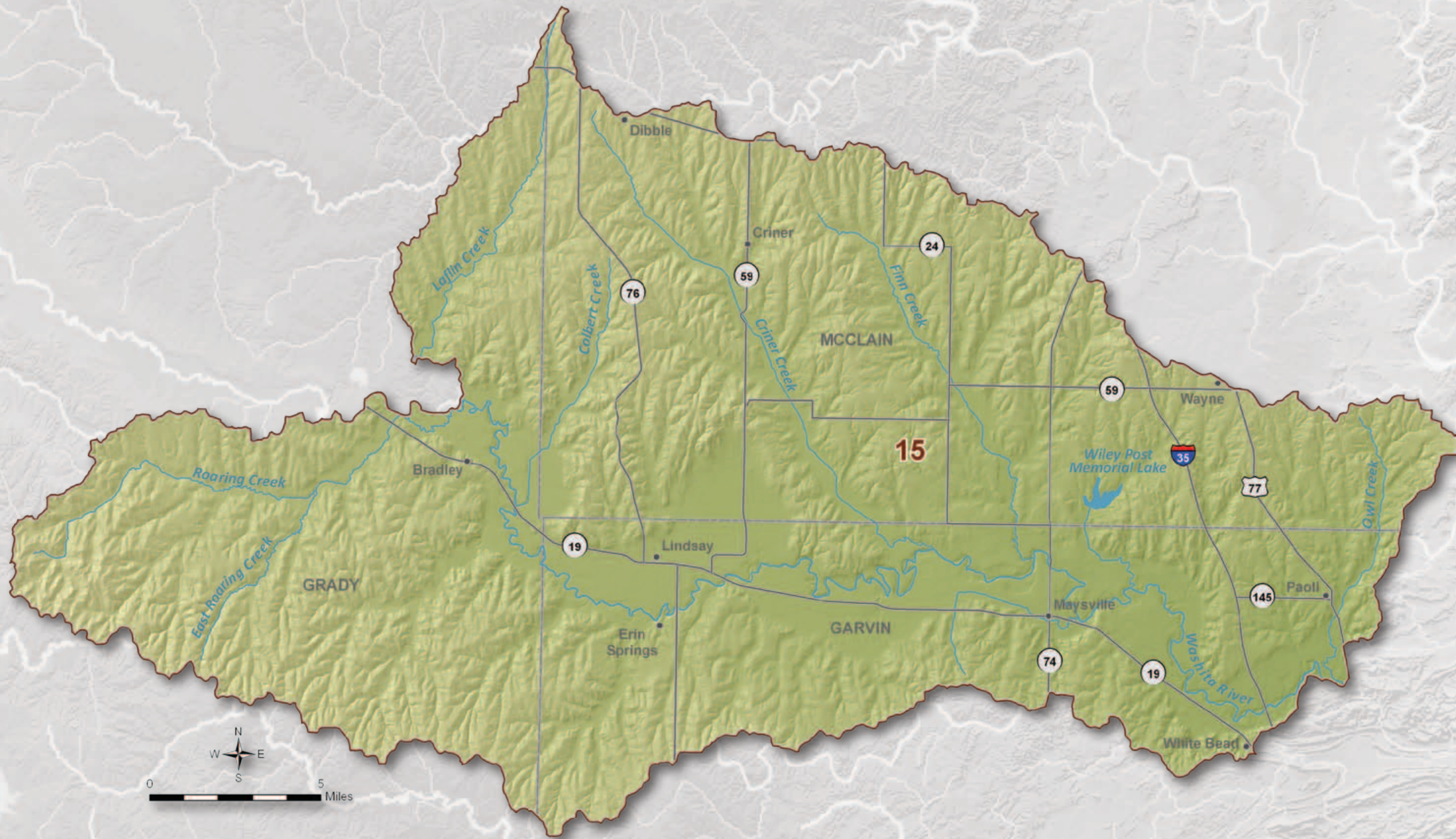
Increased reliance on the Rush Springs or Arbuckle-Simpson bedrock aquifers could mitigate alluvial groundwater storage depletions but could create bedrock groundwater depletions. While depletions would be minimal compared to the amount of water in storage in these aquifers, the Rush Springs and Arbuckle-Simpson underlie only relatively small portions of the basin. In addition, the preliminary results of the *Arbuckle-Simpson Hydrology Study* indicate that in order to comply with 2003 Senate Bill 288, the equal proportionate share will be significantly lower than the current 2 AFY/acre allocation for temporary permits.

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
Lower Washita Watershed Planning Region
Basin 15



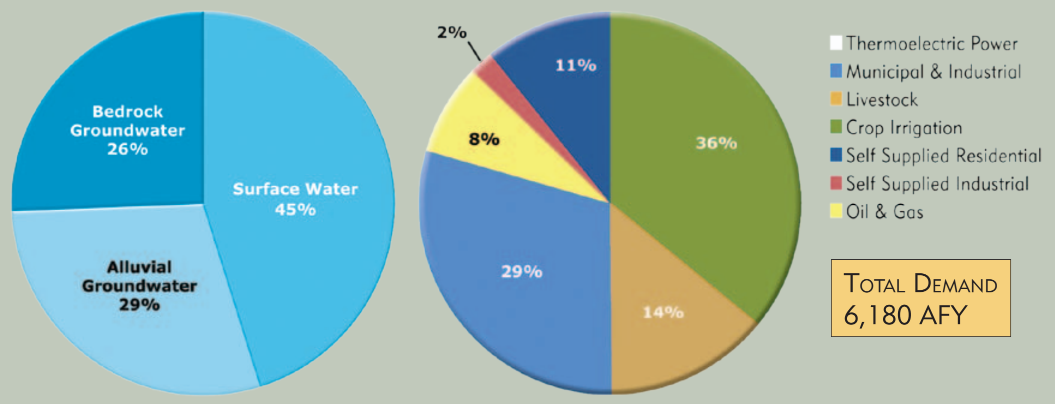
Basin 15 Summary

Synopsis

- Water users are expected to continue to rely on all sources: surface water, alluvial groundwater, and bedrock groundwater.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial and bedrock groundwater storage depletions may occur by 2020, but will be small 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 or temporary drought management measures could reduce surface water gaps and groundwater storage depletions.
- Use of additional dependable groundwater supplies and/or developing new small reservoirs could be used mitigate surface water gaps without major impacts to groundwater storage.

Current Demand by Source and Sector

Lower Washita Region, Basin 15



Basin 15 accounts for about 8% of the current demand in the Lower Washita Watershed Planning Region. About 36% of the basin's demand is from the Crop Irrigation demand sector. Municipal and Industrial is the second largest demand sector at 29%. Surface water satisfies about 45% of the current demand in the basin. Groundwater satisfies about 55% of the current demand (29% alluvial and 26% bedrock). The peak summer month total water demand in Basin 15 is about 4.8 times the winter monthly demand, which is similar to the overall statewide pattern.

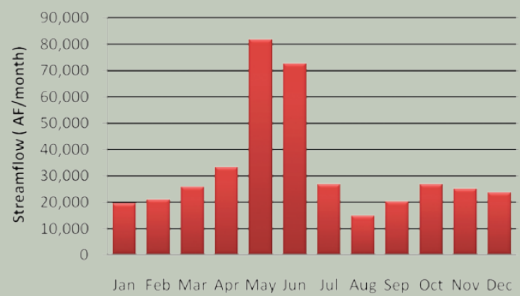
The flow in the Washita River near Pauls Valley is typically greater than 14,900 AF/month throughout the year and greater than 25,000 AF/month in the spring. However, the river can have periods of low flow in any month of the year. Wiley Post Memorial Lake provides 538 AFY of dependable yield to the City of Maysville and is currently fully allocated. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 15 is considered

Water Resources

Lower Washita Region, Basin 15

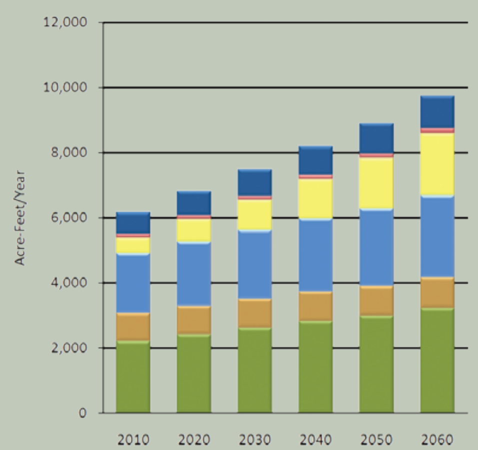
Median Historical Streamflow at the Basin Outlet

Lower Washita Region, Basin 15



Projected Water Demand

Lower Washita Region, Basin 15



poor. Stealy Creek is impaired for Agricultural use due to high levels of chloride.

The greatest quantity of groundwater permits in Basin 15 are from the Washita River major alluvial aquifer. This aquifer has 681,000 AF of storage in Basin 15 and underlies 28% of the basin. There are also substantial permits in the Rush Springs major bedrock aquifer, El Reno minor bedrock aquifer, and non-delineated minor bedrock aquifers. Basin 15 contributes about 1,000 AFY of recharge to the Rush Springs aquifer. Domestic users (Self-Supplied Residential demand sector) do not require a permit and are assumed to be obtaining supplies from aquifers in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin. However, localized areas with high levels of nitrate and fluoride have been found in the overall Rush Springs aquifer and may occur in Basin 15.

The projected 2060 water demand of 9,750 AFY in Basin 15 reflects a 3,570 AFY increase (58%) over the 2010 demand. The largest demand over this period will be in the Crop Irrigation demand sector. However, the largest growth in demand will be in the Oil and Gas demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020. Surface water gaps will be up to 420 AFY and have a 16% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions will be up to 220 AFY and have a 16% probability of occurring in at least one month of the year by 2060. Surface water gaps and alluvial groundwater storage depletions in Basin 15 may occur during the summer and fall. Bedrock groundwater storage depletions will be up to 580 AFY and will occur throughout the year, peaking in summer. Relative to the amount of water in storage in the basin, projected groundwater storage depletions are small. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps and groundwater storage depletions. Due to the low probability of gaps, temporary drought management may be effective in reducing surface water use and subsequent gaps. Temporary drought management activities are not expected to be needed for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified twelve potentially viable out-of-basin sites in the Lower Washita Region. In addition, Lake Texoma, in Basin 21, has substantial unpermitted yield to meet the needs of new users, but its use may be limited by water quality constraints. In light of the low probability of gaps and distance to reliable water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Additional reservoir storage in Basin 15 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new reservoir diversion and 800 AF of 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 alluvial aquifer could mitigate surface water gaps and bedrock groundwater storage depletions, but would increase the Washita River alluvial aquifer storage depletions. Any increases in storage depletions would be small relative to the volume of water stored in the Washita River alluvial aquifer. However, the aquifer only underlies about 30% of the basin.

Water Supply Limitations

Lower Washita Region, Basin 15

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Lower Washita Region, Basin 15

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

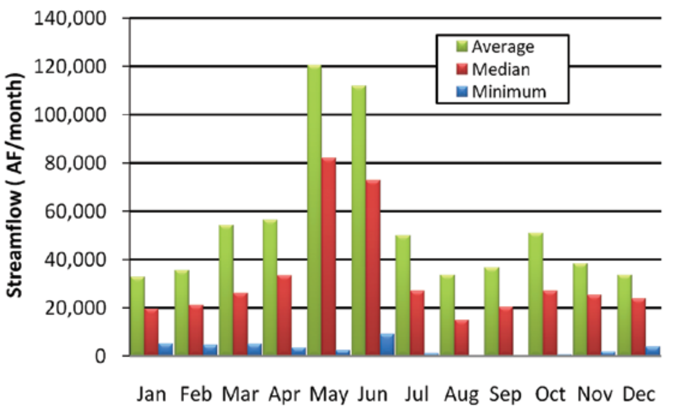
Typically Effective Potentially Effective

Likely Ineffective No Option Necessary

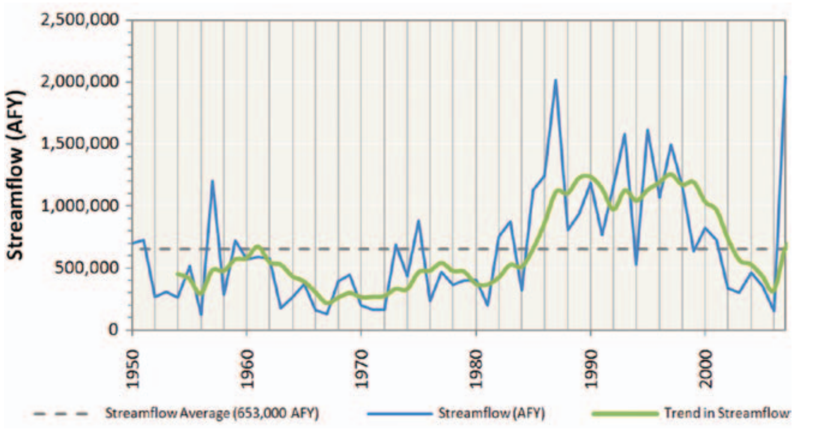
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Washita River near Pauls Valley had a period of below-average streamflow from the early 1960s to the early 1980s. From the mid 1980s through the late 1990s, 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 Washita River near Pauls Valley is greater than 14,900 AF/month throughout the year and greater than 25,000 AF/month in the spring. However, the river can have periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 15 is considered poor. However, individual lakes and streams may have acceptable water quality.
- Wiley Post Memorial Lake provides 538 AFY of dependable yield to the City of Maysville and is currently fully allocated.

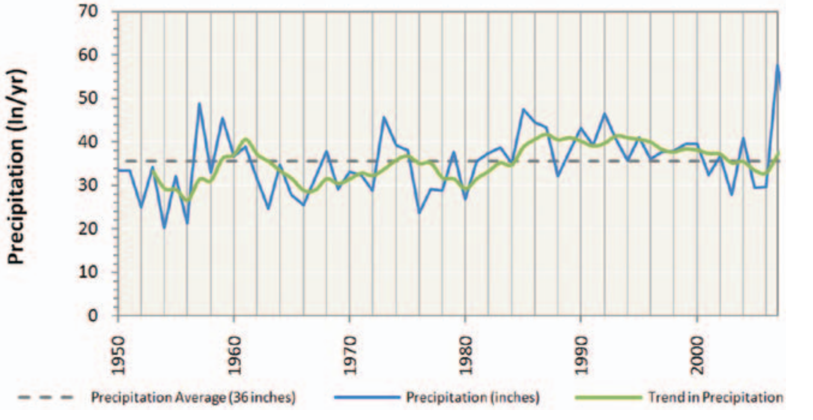
Monthly Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 15



Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 15



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)

Lower Washita Region, Basin 15

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
Canadian River	Alluvial	Major	3%	0	48,000	temporary 2.0	25,600
Rush Springs	Bedrock	Major	2%	3,300	97,000	temporary 2.0	9,000
Washita River	Alluvial	Major	28%	6,100	681,000	1.5	152,900
El Reno	Bedrock	Minor	43%	2,300	763,000	temporary 2.0	291,500
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	2,000	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in Basin 21 are from the Washita River, Rush Springs, and El Reno aquifers. There are also substantial water rights from non-delineated minor groundwater sources. Basin 15 contributes about 1,000 AFY of recharge to the Rush Springs aquifer.
- There are no significant groundwater quality issues in the basin; however, localized areas with high levels of nitrate and fluoride have been found in the Rush Springs aquifer and may occur in Basin 15.

Notes & Assumptions

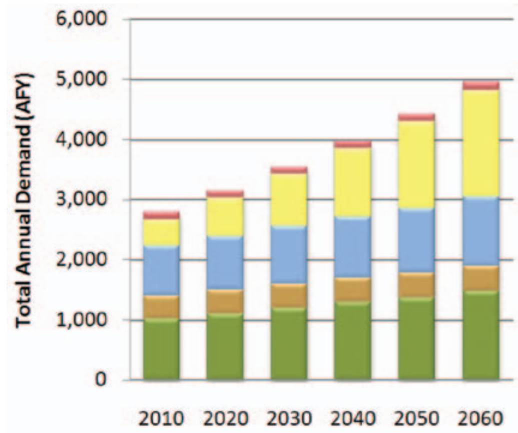
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- Basin 15's water needs account for about 8% of the demand in the Lower Washita Watershed Planning Region and will increase by 58% (3,570 AFY) from 2010 to 2060. The largest demand during this period will be in the Crop Irrigation demand sector. However, the largest growth in demand will be from the Oil and Gas demand sector.
- Surface water is used to meet 45% of total demand in the basin and its use will increase by 77% (2,160 AFY) from 2010 to 2060. The largest surface water demand will initially be from the Crop Irrigation demand sector, which will be superseded by Oil and Gas water demand by 2060.
- Alluvial groundwater is used to meet 29% of total demand in the basin and its use will increase by 43% (770 AFY) from 2010 to 2060. The largest alluvial groundwater demand and growth in demand over this period will be in the Municipal and Industrial and Self-Supplied Residential demand sectors.
- Bedrock groundwater is used to meet 26% of total demand in the basin and its use will increase by 41% (640 AFY) from 2010 to 2060. The largest bedrock groundwater demand and growth in demand during this perios will be from the Crop Irrigation and Municipal and Industrial demand sectors.

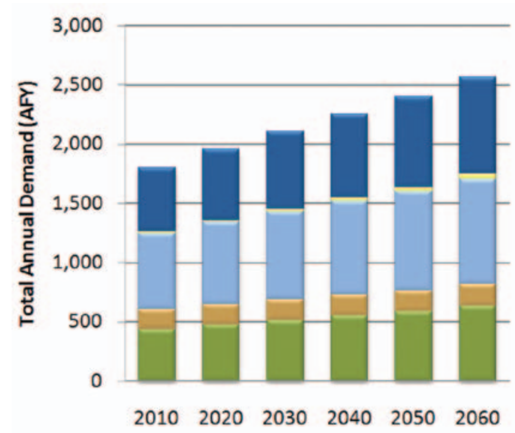
Surface Water Demand by Sector

Lower Washita Region, Basin 15



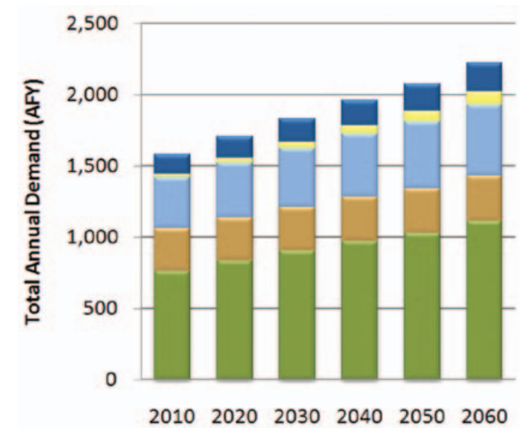
Alluvial Groundwater Demand by Sector

Lower Washita Region, Basin 15



Bedrock Groundwater Demand by Sector

Lower Washita Region, Basin 15



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

Total Demand by Sector

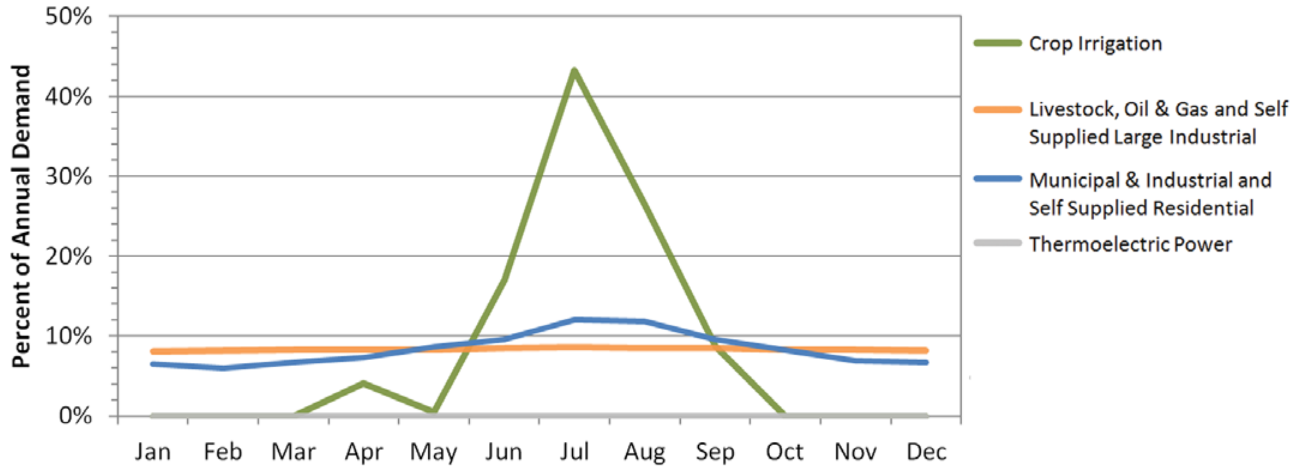
Lower Washita Region, Basin 15

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,220	860	1,830	480	120	670	0	6,180
2020	2,420	870	1,980	680	120	750	0	6,820
2030	2,620	890	2,110	930	120	810	0	7,480
2040	2,830	900	2,250	1,210	130	880	0	8,200
2050	2,980	910	2,390	1,540	130	940	0	8,890
2060	3,230	930	2,540	1,900	140	1,010	0	9,750

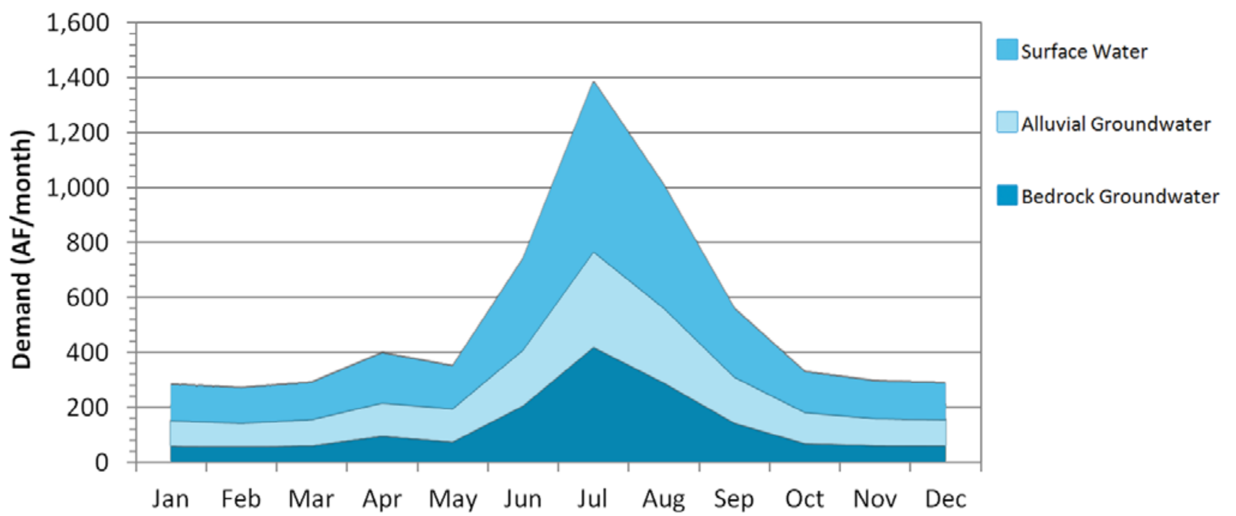
Notes & Assumptions

- 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)
Lower Washita Region, Basin 15



Monthly Demand Distribution by Source (2010)
Lower Washita Region, Basin 15



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 74% 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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 15 is 4.8 times the winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 4.6 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at 3.7 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 7.1 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020.
- Surface water gaps in Basin 15 may occur during the summer and fall, peaking in size during the summer. Surface water gaps in 2060 will be up to 31% (300 AF/month) of the surface water demand in the peak summer month, and as much as 32% (140 AF/month) of the fall monthly surface water demand. There will be a 16% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during summer months.
- Alluvial groundwater storage depletions in Basin 15 may occur during the summer and fall, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 30% (150 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 33% (80 AF/month) of the fall monthly alluvial groundwater demand. There will be a 16% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 15 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 30% (180 AF/month) of the bedrock groundwater demand in the peak summer month, and 13% (10 AF/month) of the winter monthly bedrock groundwater demand.
- Relative to the amount of water in storage in the basin, projected groundwater storage depletions are small. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Lower Washita Region, Basin 15

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)	300	230	12%
Sep-Nov (Fall)	140	120	5%

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

Alluvial Groundwater Storage Depletion by Season (2060 Demand)

Lower Washita Region, Basin 15

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)	150	120	12%
Sep-Nov (Fall)	80	70	5%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Washita Region, Basin 15

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	50	30	90	3%	3%
2030	80	50	190	5%	5%
2040	210	120	300	7%	7%
2050	280	160	400	10%	10%
2060	420	220	580	16%	16%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Washita Region, Basin 15

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	10
Mar-May (Spring)	40
Jun-Aug (Summer)	180
Sep-Nov (Fall)	60

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Lower Washita Region, Basin 15

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	420	220	580	16%	16%
Moderately Expanded Conservation in Crop Irrigation Water Use	350	190	520	14%	14%
Moderately Expanded Conservation in M&I Water Use	310	160	450	12%	12%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	280	150	380	10%	10%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	160	80	250	7%	7%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Washita Region, Basin 15

Reservoir Storage	Diversion
AF	AFY
100	700
500	2,300
1,000	4,400
2,500	10,500
5,000	17,100
Required Storage to Meet Growth in Demand (AF)	800
Required Storage to Meet Growth in Surface Water Demand (AF)	400

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps, alluvial and bedrock groundwater depletions by 30% to 35%. Due to the low probability of gaps, temporary drought management may be effective in reducing surface water use and subsequent gaps. Temporary drought management activities may not be needed for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified twelve potential out-of-basin sites in the Lower Washita Region: Caddo Creek, Cox City and Purdy in Basin 14; Chickasha, Gracemont, Kechi and Verden in Basin 16; Durwood, Gainesville and Ravia in Basin 21; Burneyville in Basin 22; and Courtney in Basin 23. In addition, Lake Texoma, in Basin 21, has substantial unpermitted yield to meet the needs of new users, but water quality issues may constrain its use. However, in light of the low probability of gaps and distance to reliable water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Additional reservoir storage in Basin 15 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 800 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's 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

Increased reliance on the Washita River alluvial aquifer could mitigate surface water gaps and bedrock groundwater storage depletions but would increase alluvial storage depletions. Any increases in storage depletions would be small relative to the volume of water stored in the Washita River alluvial aquifer. However, the aquifer only underlies about 30% 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
Lower Washita Watershed Planning Region

Basin 16

Basin 16 Summary

Synopsis

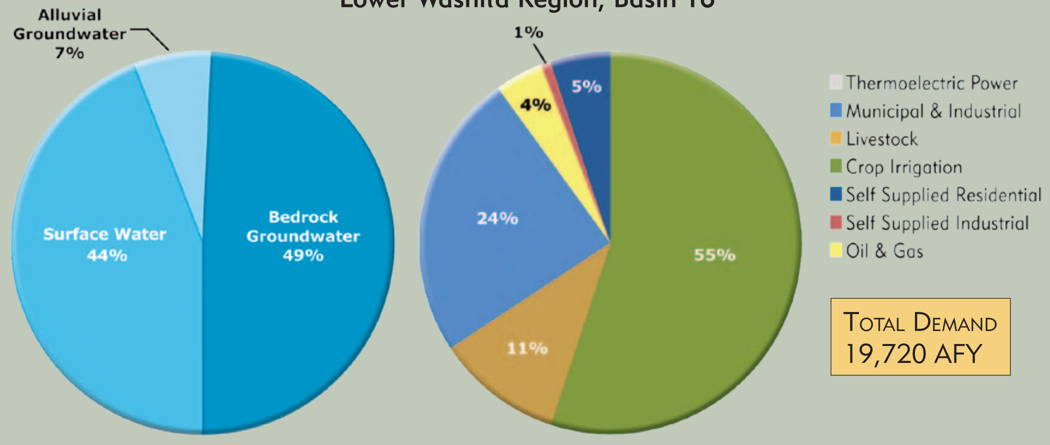
- Water users are expected to continue to rely primarily surface water and bedrock groundwater.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater storage depletions may occur by 2020, but will be minimal 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 or temporary drought management measures could reduce surface water gaps and groundwater storage depletions.
- Increasing use of dependable groundwater supplies and/or developing new reservoirs could mitigate surface water gaps without major impacts to groundwater storage.

Basin 16 accounts for about 25% of the current demand in the Lower Washita Watershed Planning Region. About 55% of the basin's demand is from the Crop Irrigation demand sector. Municipal and Industrial is the second largest demand sector at 24%. Surface water satisfies about 44% of the current demand in the basin. Groundwater satisfies about 56% of the current demand (7% alluvial and 49% bedrock). The peak summer month total water demand in Basin 16 is about 7.3 times the winter monthly demand, which is more pronounced than the overall statewide pattern.

The flow in the Washita River at Alex is typically greater than 12,900 AF/month throughout the year and greater than 20,000 AF/month in the spring and early summer. However, the river can have periods of low flow in any month of the year, particularly in late summer and early fall. Lake Chickasha is the only large reservoir in the region. It was

Current Demand by Source and Sector

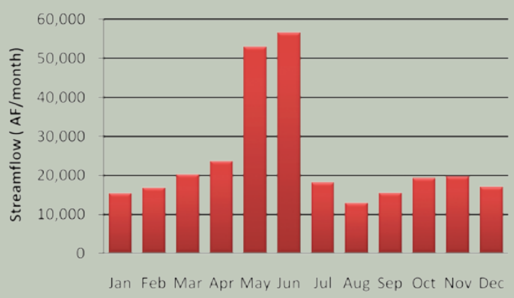
Lower Washita Region, Basin 16



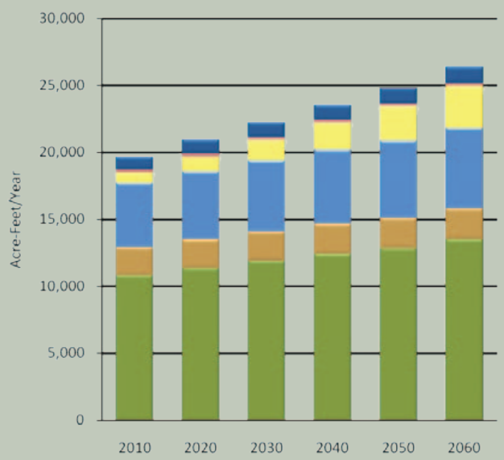
Water Resources

Lower Washita Region, Basin 16

Median Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 16



Projected Water Demand
Lower Washita Region, Basin 16



built on Spring Creek in 1958 for water supply and recreation for the City of Chickasha. The lake is currently not being used as a source of water supply due to poor water quality. While Basin 16 currently has water available for new surface water permits, the basin is expected to be fully allocated by 2060. Relative to other basins in the state, the surface water quality in Basin 16 is considered poor. Stealy Creek is impaired for Agricultural use due to high levels of chloride.

The majority of groundwater permits in Basin 16 are from the Rush Springs major bedrock aquifer. This aquifer has over 9 million AF of storage in Basin 16 and underlies about 40% of the basin. There are also substantial permits in the El Reno minor bedrock aquifer and the Washita River major alluvial aquifer. Basin 16 contributes about 43,000 AFY of recharge to the Rush Springs aquifer. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Domestic users (Self-Supplied Residential demand sector) do not require a permit and are assumed to be obtaining supplies from aquifers in the basin. There are no significant groundwater quality issues in the basin. However, localized areas with high levels of nitrate and fluoride have been found in the overall Rush Springs aquifer and may occur in Basin 16.

The projected 2060 water demand of 26,380 AFY in Basin 16 reflects a 6,660 AFY increase (34%) over the 2010 demand. The majority of the demand and the largest growth in demand will be in the Crop Irrigation demand sector. However, there will also be substantial growth in the Oil and Gas and Municipal and Industrial demand sectors.

Gaps And Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2020. No bedrock groundwater storage depletions are expected through 2060. Surface water gaps and alluvial groundwater storage depletions in Basin 16 may occur during the summer. Surface water gaps will be up to 420 AFY and have a 5% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions will be up to 50 AFY and have a 5% probability of occurring in at least one month of the year by 2060. Projected alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the Washita River aquifer. 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 bedrock groundwater. To reduce the risk of adverse impacts to the basin's water users, surface

Water Supply Limitations
Lower Washita Region, Basin 16

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal · Potential · Significant

Water Supply Option Effectiveness
Lower Washita Region, Basin 16

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

water gaps and alluvial groundwater storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps and alluvial groundwater storage depletions. Due to the low probability of gaps, temporary drought management may be effective in reducing surface water use and subsequent gaps. Temporary drought management activities may not be needed for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eight potentially viable out-of-basin sites in the Lower Washita Region. However, in light of the low probability of gaps and substantial groundwater supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Additional reservoir storage in Basin 16 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new reservoir diversion and 1,200 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified four potentially viable sites in Basin 16.

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

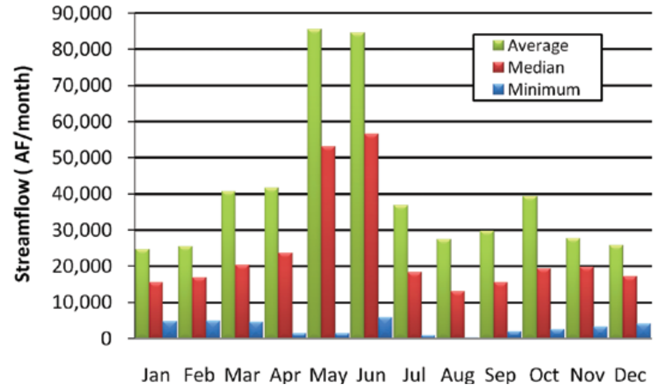
Increased reliance on bedrock groundwater could mitigate surface water gaps and alluvial groundwater storage depletions but could also create bedrock storage depletions. Any storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Rush Springs aquifer. However, this aquifer only underlies 40% of the basin.

Basin 16 Data & Analysis

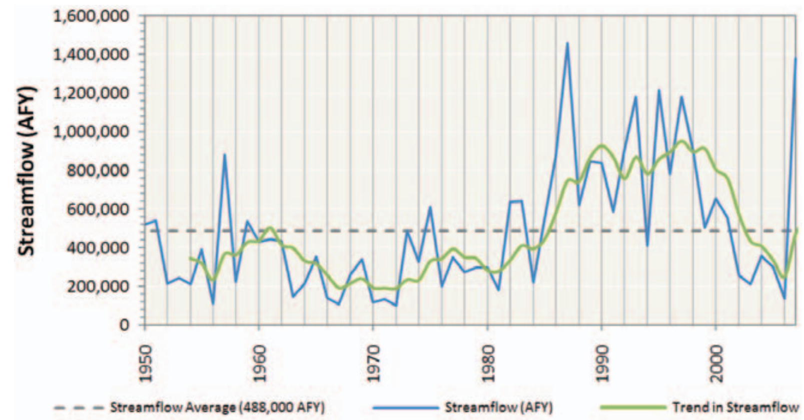
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Washita River at Alex had a period of below-average streamflow from the early 1960s to the early 1980s. From the mid 1980s through the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Washita River at Alex is greater than 12,900 AF/month throughout the year and greater than 20,000 AF/month in the spring and early summer. However, the river can have periods of low flow in any month of the year, particularly in late summer and early fall.
- Relative to other basins in the state, the surface water quality in Basin 16 is considered poor. However, individual lakes and streams may have acceptable water quality.
- Lake Chickasha is owned by the City of Chickasha. The lake is currently not being used as a major source of water supply due to poor water quality.

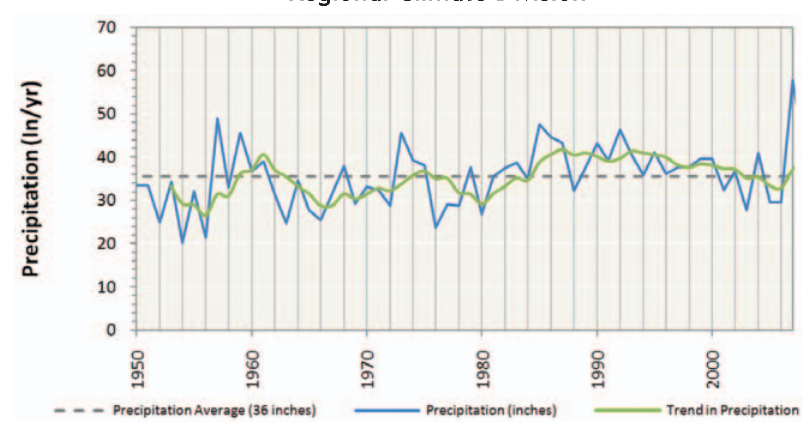
Monthly Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 16



Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 16



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)

Lower Washita Region, Basin 16

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
Rush Springs	Bedrock	Major	40%	36,200	9,303,000	temporary 2.0	518,800
Washita River	Alluvial	Major	20%	2,400	556,000	1.5	289,900
El Reno	Bedrock	Minor	40%	5,500	1,493,000	temporary 2.0	569,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater permits in Basin 16 are from the Rush Springs aquifer. This aquifer has more than 9 million AF of storage in Basin 16 and underlies 40% of the basin. There are also substantial permits in the El Reno aquifer and the Washita River aquifer. Basin 16 contributes about 43,000 AFY of recharge to the Rush Springs aquifer.
- There are no significant groundwater quality issues in basin. However, localized areas with high levels of nitrate and fluoride have been found in the Rush Springs aquifer and may occur in Basin 16.

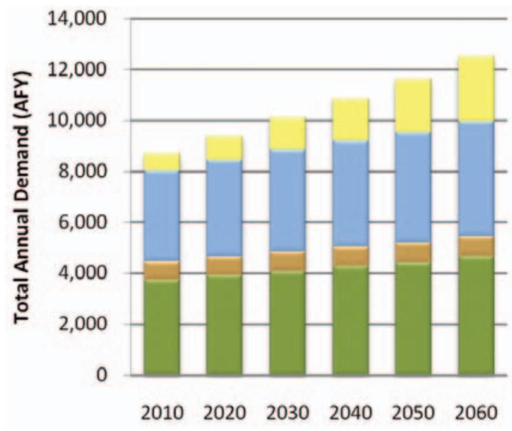
Notes & Assumptions

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

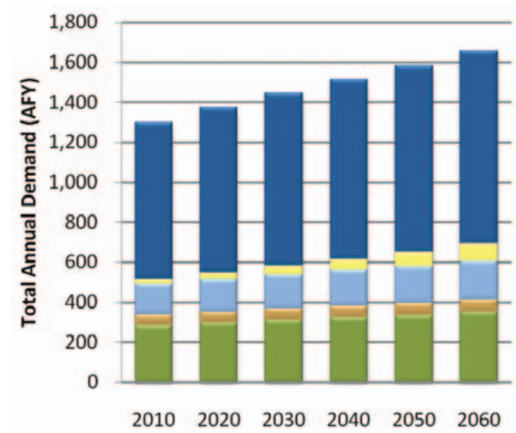
Water Demand

- Basin 16's water needs account for about 25% of the demand in the Lower Washita Watershed Planning Region and will increase by 34% (6,660 AFY) from 2010 to 2060. The majority of the demand and the largest growth in demand will be from the Crop Irrigation demand sector. However, there will also be substantial growth in the Oil and Gas and Municipal and Industrial demand sectors.
- Surface water is used to meet 44% of total demand in the basin and its use will increase by 44% (3,820 AFY) from 2010 to 2060. The majority of the surface water use will be in the Crop Irrigation and Municipal and Industrial demand sectors. However, the Oil and Gas demand sector will have the largest growth in surface water demand.
- Alluvial groundwater is used to meet 7% of total demand in the basin and its use will increase by 27% (360 AFY) from 2010 to 2060. The majority of the alluvial groundwater demand and growth in demand during this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 49% of total demand in the basin and its use will increase by 26% (2,480 AFY) from 2010 to 2060. The majority of the bedrock groundwater demand and growth in demand during this period will be from the Crop Irrigation demand sector.

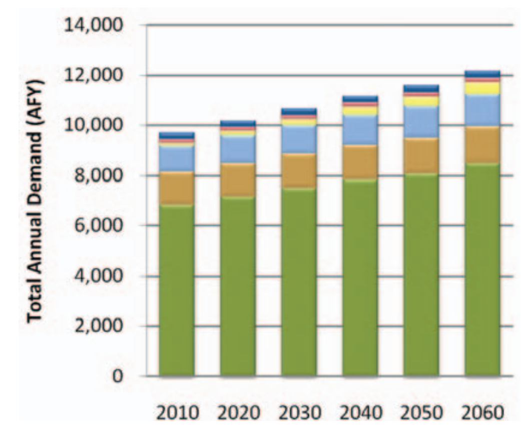
Surface Water Demand by Sector
Lower Washita Region, Basin 16



Alluvial Groundwater Demand by Sector
Lower Washita Region, Basin 16



Bedrock Groundwater Demand by Sector
Lower Washita Region, Basin 16



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

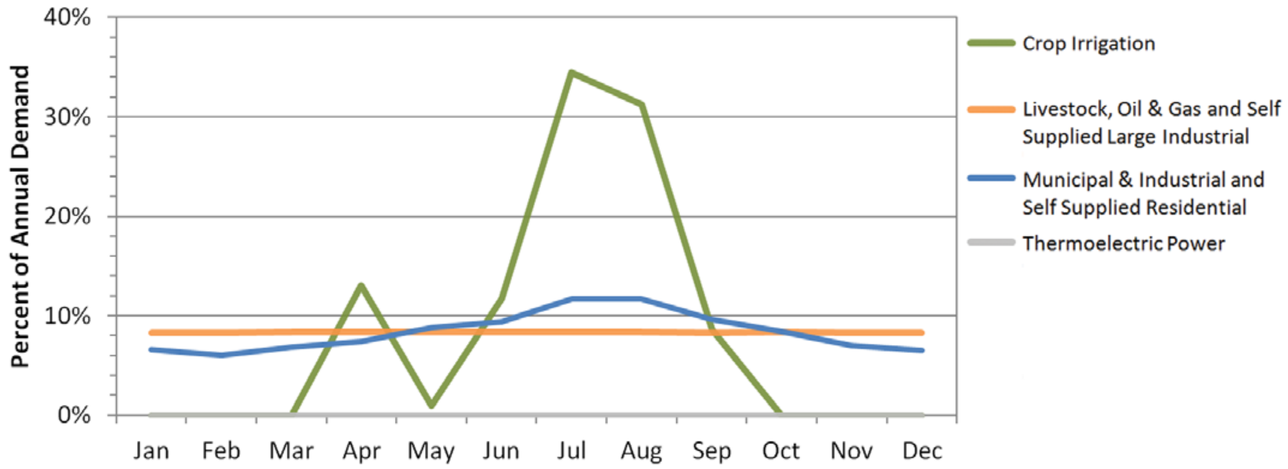
Total Demand by Sector
Lower Washita Region, Basin 16

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	10,860	2,100	4,790	810	160	1,000	0	19,720
2020	11,390	2,140	5,080	1,150	160	1,060	0	20,980
2030	11,920	2,180	5,330	1,550	160	1,100	0	22,240
2040	12,450	2,220	5,560	2,010	170	1,150	0	23,560
2050	12,860	2,270	5,790	2,530	170	1,190	0	24,810
2060	13,510	2,310	6,030	3,120	180	1,230	0	26,380

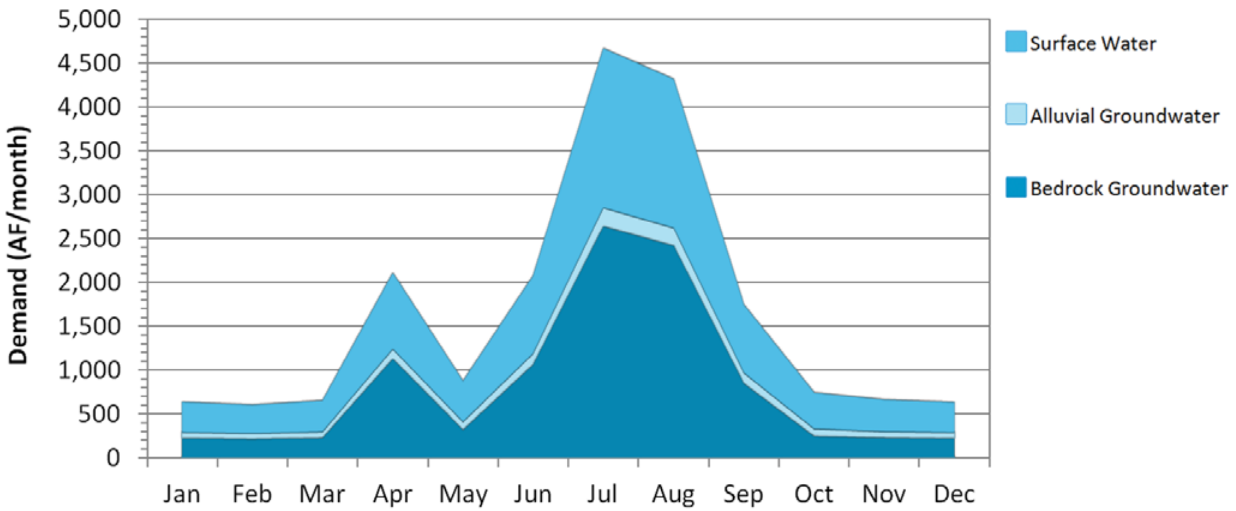
Notes & Assumptions

- 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)
Lower Washita Region, Basin 16



Monthly Demand Distribution by Source (2010)
Lower Washita Region, Basin 16



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 71% 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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 16 is 7.3 times the winter monthly demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is 5.2 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at 3.1 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 12.2 times the winter monthly use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2020. No bedrock groundwater storage depletions are expected through 2060.
- Surface water gaps in Basin 16 have a 5% probability of occurring during the summer by 2050. Surface water gaps in 2060 will be up to 17% (420 AF/month) of the surface water demand in the peak summer month.
- Alluvial groundwater storage depletions in Basin 16 have a 5% probability of occurring during the summer by 2050. Alluvial groundwater storage depletions in 2060 will be up to 19% (50 AF/month) of the alluvial groundwater demand in the peak summer month. Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water stored in Basin 16's major aquifers. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Lower Washita Region, Basin 16

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)	420	390	5%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Lower Washita Region, Basin 16

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Lower Washita Region, Basin 16

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	60	10	0	2%	2%
2030	130	20	0	2%	2%
2040	220	30	0	3%	2%
2050	310	40	0	5%	5%
2060	420	50	0	5%	5%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Lower Washita Region, Basin 16

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Lower Washita Region, Basin 16

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	420	50	0	5%	5%
Moderately Expanded Conservation in Crop Irrigation Water Use	350	40	0	5%	5%
Moderately Expanded Conservation in M&I Water Use	300	30	0	5%	5%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	240	30	0	5%	5%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	80	10	0	3%	2%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Washita Region, Basin 16

Reservoir Storage	Diversion
AF	AFY
100	1,000
500	3,000
1,000	5,500
2,500	11,000
5,000	17,400
Required Storage to Meet Growth in Demand (AF)	1,200
Required Storage to Meet Growth in Surface Water Demand (AF)	500

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps and alluvial groundwater storage depletions by about 40%. Due to the low probability of gaps, temporary drought management may be effective in reducing surface water use and subsequent gaps. Temporary drought management activities may not be needed for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eight potential out-of-basin sites in the Lower Washita Region: Caddo Creek, Cox City and Purdy in Basin 14; Durwood, Gainesville and Ravia in Basin 21; Burneyville in Basin 22; and Courtney in Basin 23. However, in light of the low probability of gaps and substantial groundwater supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Additional reservoir storage in Basin 16 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,200 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Chickasha (proposed), Gracemont, Kechi and Verden Reservoirs as potentially viable sites in Basin 16.

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 the Rush Springs aquifer could mitigate surface water gaps and alluvial groundwater storage depletions, but could create bedrock storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Rush Springs aquifer. However, this aquifer only underlies 40% of the basin.

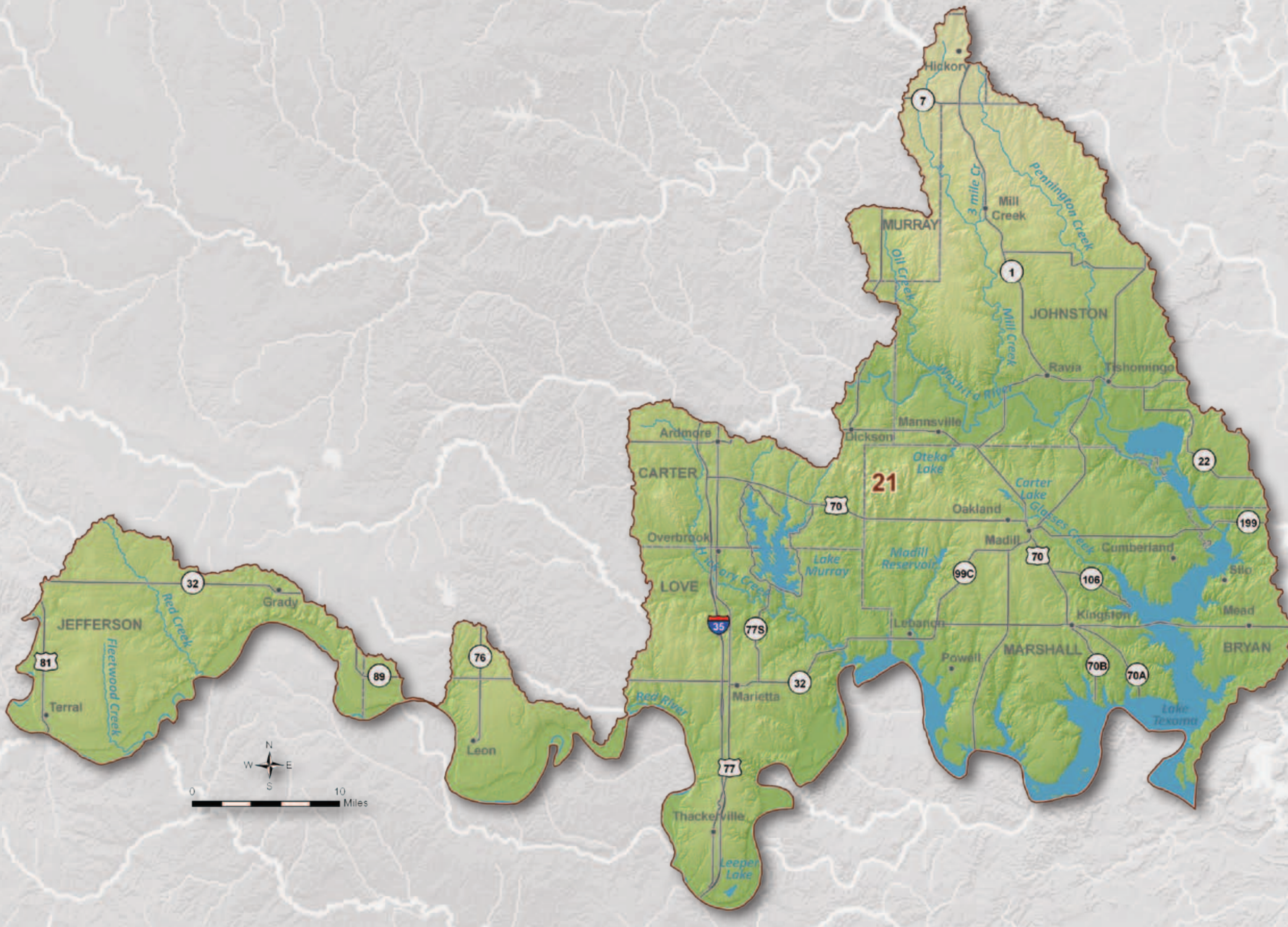
Notes & Assumptions

- 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
Lower Washita Watershed Planning Region

Basin 21



Basin 21 Summary

Synopsis

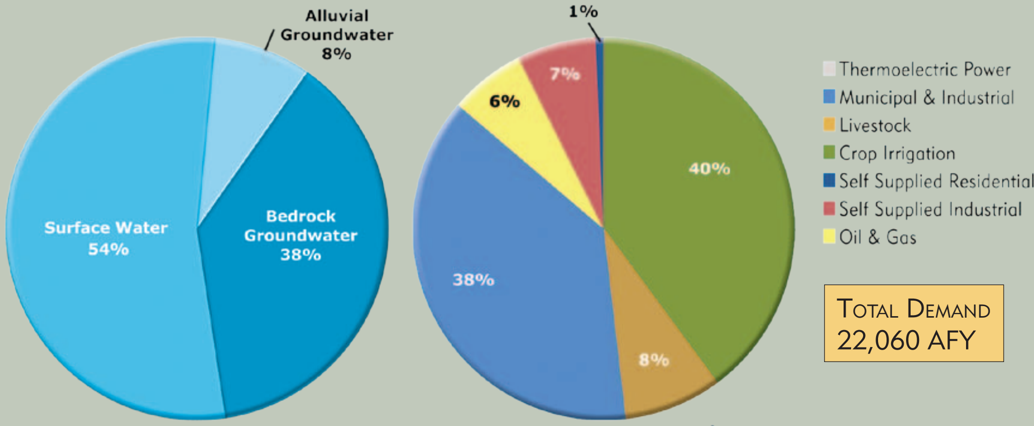
- Water users are expected to continue to rely mainly on surface water and bedrock groundwater.
- Alluvial groundwater storage depletions may occur by 2020, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation measures could reduce alluvial groundwater storage depletions.
- Reservoir storage or dependable bedrock groundwater supplies could be used as alternatives to mitigate alluvial groundwater storage depletions.

Basin 21 accounts for about 27% of the current demand in the Lower Washita Watershed Planning Region. About 40% of the basin's demand is from the Crop Irrigation demand sector and 38% is from the Municipal and Industrial demand sector. Surface water satisfies about 54% of the current demand in the basin. Groundwater satisfies about 46% of the current demand (8% alluvial and 38% bedrock). The peak summer month total water demand in Basin 21 is 4.4 times the winter monthly demand, which is similar to the overall statewide pattern.

The Red River, the major river in Basin 21, is not considered as a feasible water supply source at this time due to severe water quality constraints. Flow in Basin 21 represents the flow in Lake Texoma from the Washita River and tributaries in the basin. Flow in the basin is greater than 34,000 AF/month throughout the year and greater than 120,000 AF/month in the spring and early summer. However, both the Washita River and its tributaries can have periods of low flow in the winter, summer, and fall. Lake Texoma, a Corps of Engineer Project, was constructed on the Red River in 1944 for the purposes of flood control, water supply, recreation, navigation, and hydropower purposes, as well as for low flow regulation of the Red River. The lake is subject to provisions of the Red River Compact, which equally allocates water supplies to Texas and Oklahoma. Each state is allotted a dependable water supply yield of 168,000 AFY; over 160,000 AFY of unpermitted yield is available for allocation in Oklahoma. However, the water quality is very poor and is not suitable for most municipal and industrial uses without extensive treatment or blending. Lake Murray is a state-owned lake that was constructed on Hickory Creek in 1937 for recreation purposes and is one of southern Oklahoma's major tourists' attractions. The lake has 153,250 AF of conservation storage, but none is allocated to water supply. Several permits have been issued for recreation, fish and wildlife purposes. The availability of permits is not expected to limit the development of surface water supplies for

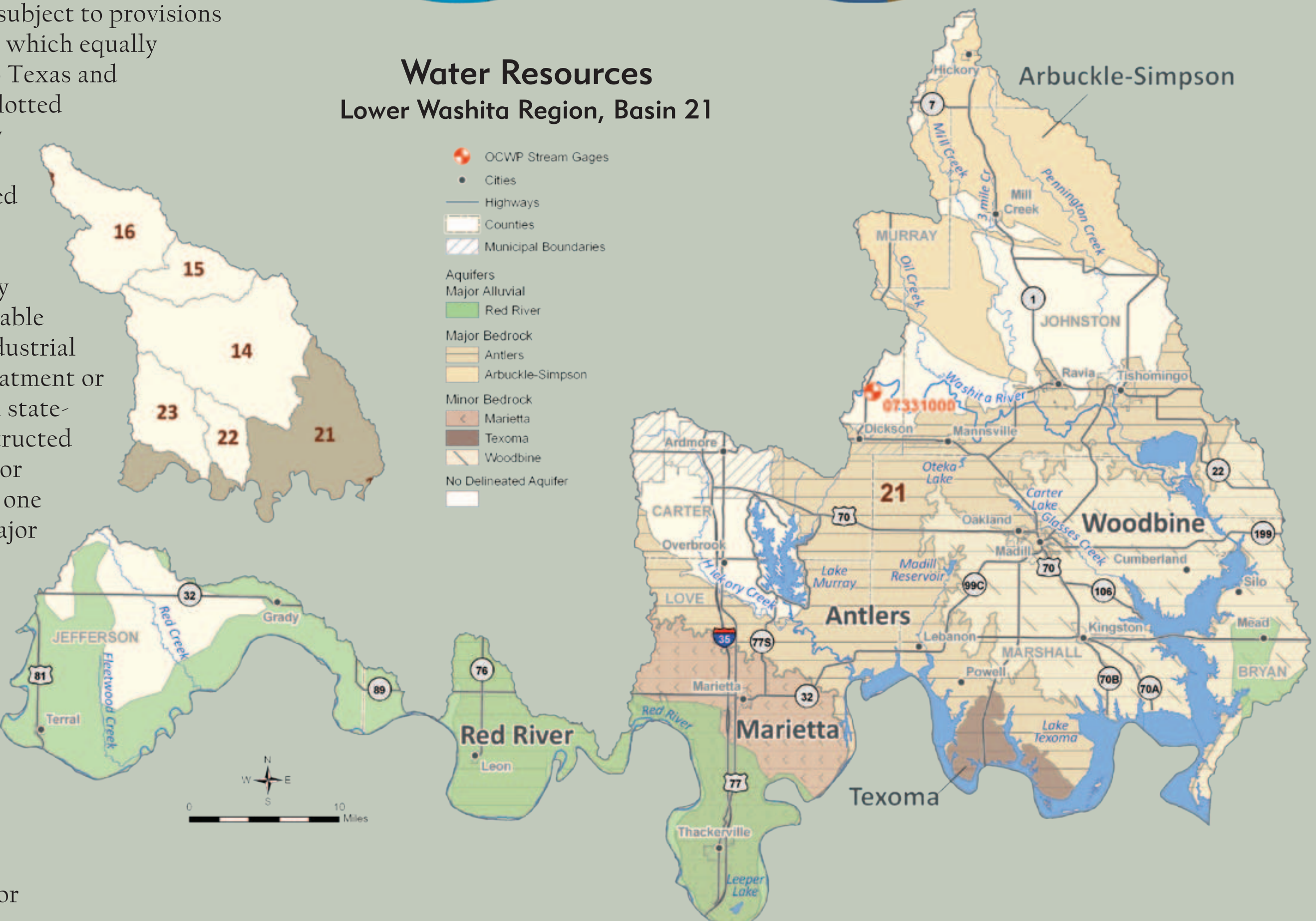
Current Demand by Source and Sector

Lower Washita Region, Basin 21

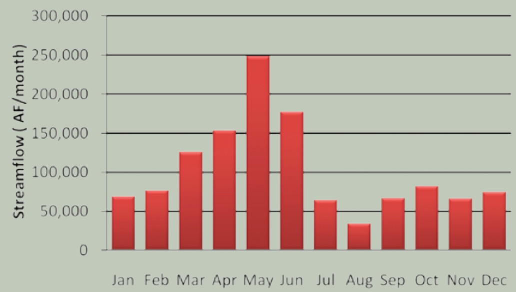


Water Resources

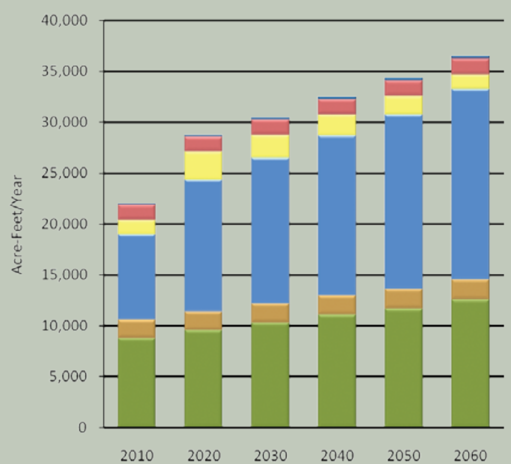
Lower Washita Region, Basin 21



Median Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 21



Projected Water Demand
Lower Washita Region, Basin 21



in-basin use through 2060. With the exception of the Red River and Lake Texoma, the surface water quality in Basin 21 is considered fair relative to other basins in the state. However, the Old Channel of the Washita River is impaired for Agricultural use due to high levels of chloride.

The majority of groundwater rights in Basin 21 are from the Antlers major bedrock aquifer, the Arbuckle-Simpson major bedrock aquifer, and the Red River major alluvial aquifer. The Antlers aquifer underlies southern portion of the basin (about 60% of the basin area) and has about 10 million AF of storage in Basin 21. The Arbuckle-Simpson aquifer underlies the northeastern portion of the basin and has about 3.3 million AF of storage in the basin. The OWRB is currently studying the Arbuckle-Simpson aquifer to set a maximum annual yield and equal proportionate share that will likely decrease the amount of permitted water available for withdrawal. Basin 21 contributes about 94,000 AFY of recharge to the Rush Springs and Arbuckle-Simpson aquifers. The Red River aquifer underlies the southern border of the basin, excluding Lake Texoma, and has over 700,000 AF of storage in the basin. There are also permits in minor bedrock and alluvial aquifers. Domestic users (Self-Supplied Residential demand sector) do not require a permit and are assumed to be obtaining supplies from aquifers in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 36,490 AFY in Basin 21 reflects a 14,430 AFY increase (65%) over the 2010 demand. The largest demand and growth in demand over this period will be in the Municipal and Industrial demand sector. However, substantial growth in Crop Irrigation demand is also projected.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2020. No surface water gaps or bedrock groundwater depletions are expected in Basin 21 through 2060. Alluvial groundwater storage depletions are expected to be up to 320 AFY and have a 3% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in Basin 21 may occur during the summer and fall. Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the aquifer. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Lake Texoma is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 21's future surface water demand during periods of low streamflow. However, water quality limits the potential uses of the supply.

Water Supply Limitations
Lower Washita Region, Basin 21

Source	Limitation
Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal Potential Significant

Water Supply Option Effectiveness
Lower Washita Region, Basin 21

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

Typically Effective Potentially Effective Likely Ineffective No Option Necessary

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce alluvial groundwater storage depletions. Temporary drought management activities may not be needed for groundwater demand, since the groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified nine potentially viable out-of basin sites in the Lower Washita Region. However, in light of substantial available groundwater resources in the basin, out-of-basin supplies may not be cost-effective for many users.

Lake Texoma could effectively supplement supply during dry months. However, the use of Lake Texoma is severely restricted by water quality constraints. The entire increase in demand from 2010 to 2060 could be supplied by a new reservoir diversion and 3,900 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Durwood, Gainesville, and Ravia Reservoirs as potentially viable sites in Basin 21.

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

Increased reliance on the Antlers or Arbuckle-Simpson bedrock aquifers could mitigate alluvial groundwater storage depletions. Any consequential bedrock storage depletions would be minimal relative to the volume of water stored in the basin's major aquifers. However, forthcoming changes regarding the maximum annual yield and equal proportionate share for the Arbuckle-Simpson aquifer may decrease the availability of water under existing and/or new permits.

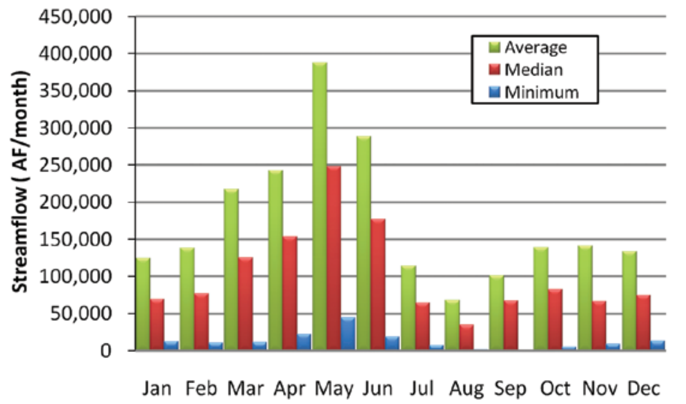
Basin 21 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The basin had a period of below-average streamflow from the early 1960s to the mid 1970s. From the mid 1980s through the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- Lake Texoma, at the outlet of Basin 21, impounds both the Washita River and Red River downstream of Rock Creek. However, the Red River is not considered a supply source due to water quality constraints.
- The median flow in the basin is greater than 34,000 AF/month throughout the year and greater than 120,000 AF/month in the spring and early summer. However, the basin can have periods of low flow in the winter, summer, and fall.
- With the exception of the Red River, water quality is considered fair relative to other basins in the state.
- Lake Texoma, constructed by the Corps of Engineers, provides Oklahoma 168,000 AFY of dependable water supply yield of which 160,000 AFY is unpermitted. However, water quality constrains potential uses. Lake Murray is a state-owned lake used for recreational purposes only.

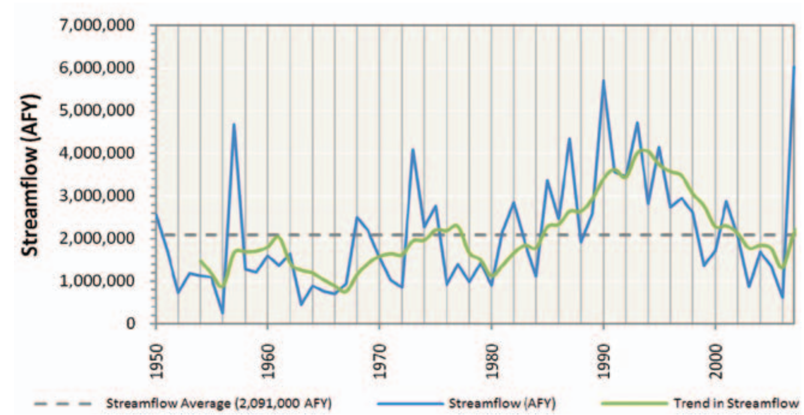
Monthly Historical Streamflow at the Basin Outlet

Lower Washita Region, Basin 21



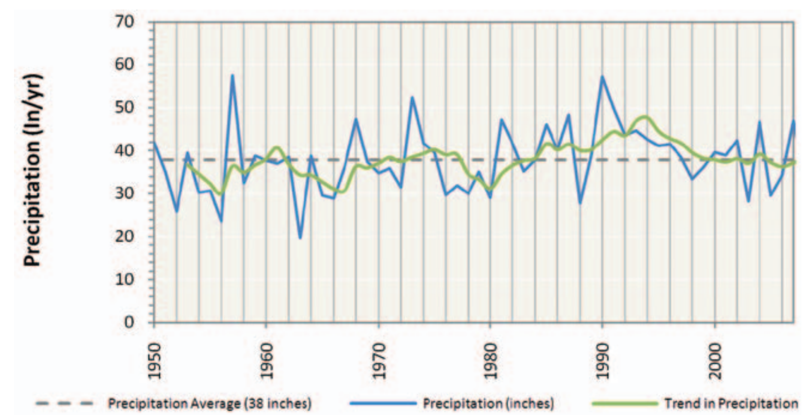
Historical Streamflow at the Basin Outlet

Lower Washita Region, Basin 21



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)

Lower Washita Region, Basin 21

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	59%	23,400	10,016,000	2.1	1,281,500
Arbuckle-Simpson	Bedrock	Major	11%	17,100	3,336,000	temporary 2.0[2]	218,500
Red River	Alluvial	Major	18%	4,900	724,000	temporary 2.0	389,700
Marietta	Bedrock	Minor	9%	100	587,000	temporary 2.0	191,700
Texoma	Bedrock	Minor	1%	0	101,000	temporary 2.0	38,400
Woodbine	Bedrock	Minor	19%	500	3,282,000	temporary 2.0	422,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	600	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	1,300	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.

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

Groundwater Resources

- The majority of groundwater rights in Basin 21 are from the Antlers, Arbuckle-Simpson, and Red River aquifers. The Antlers aquifer underlies the southern portions of the basin (59% of the basin area) and has more than 10 million AF of storage in Basin 21. The Arbuckle-Simpson aquifer underlies the northeastern portion of the basin and has more than 3.3 million AF of storage in the basin. The OWRB is currently studying the Arbuckle-Simpson aquifer to set a maximum annual yield and equal proportionate share that will likely decrease the amount of permitted water available for withdrawal. Basin 21 contributes about 94,000 AFY of recharge to the Antlers and Arbuckle-Simpson aquifers. The Red River aquifer underlies the southern boundary of the basin, excluding Lake Texoma, and has more than 700,000 AF of storage in the basin. There are also rights in minor bedrock and alluvial aquifers.
- There are no significant groundwater quality issues in the basin.

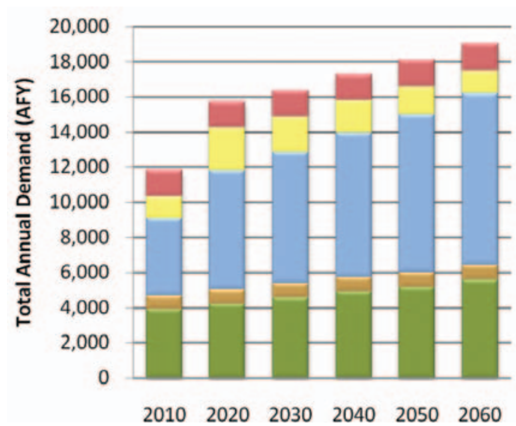
Notes & Assumptions

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

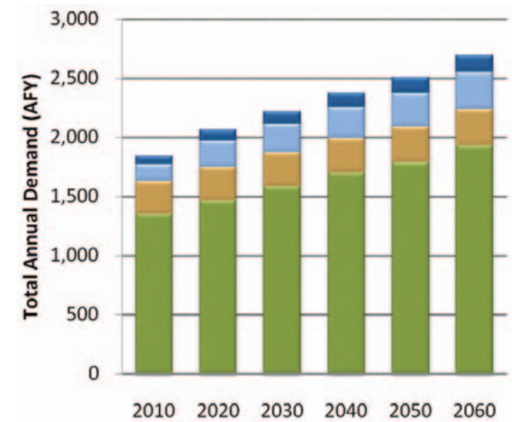
Water Demand

- Basin 21's water needs account for about 27% of the demand in the Lower Washita Watershed Planning Region and will increase by 65% (14,430 AFY) from 2010 to 2060. The largest demand and growth in demand during this period will be from the Municipal and Industrial demand sector. However, substantial growth from Crop Irrigation demand is also projected.
- Surface water is used to meet 54% of total basin demand and its use will increase by 61% (7,190 AFY) from 2010 to 2060. The largest surface water use and growth in surface water use during this period will be in the Municipal and Industrial sector. However, substantial growth in surface water use from the Crop Irrigation sector is also projected.
- Alluvial groundwater is used to meet 8% of total demand in the basin and its use will increase by 46% (850 AFY) from 2010 to 2060. The majority of the alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 38% of total demand in the basin and its use will increase by 77% (6,390 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use during this period will be in the Municipal and Industrial demand sector. However, substantial growth in bedrock groundwater use from the Crop Irrigation demand sector is also projected.

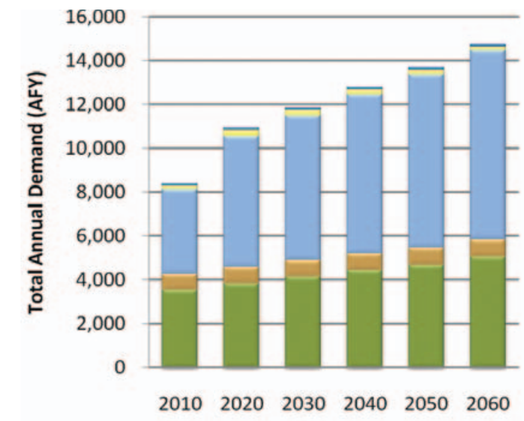
Surface Water Demand by Sector
Lower Washita Region, Basin 21



Alluvial Groundwater Demand by Sector
Lower Washita Region, Basin 21



Bedrock Groundwater Demand by Sector
Lower Washita Region, Basin 21



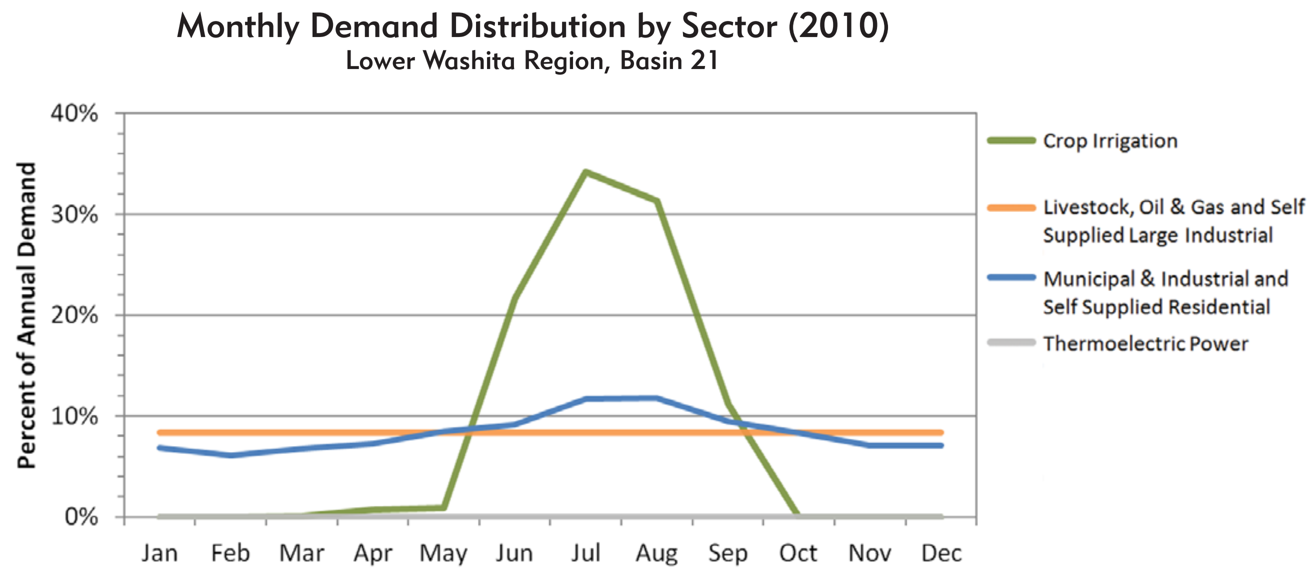
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

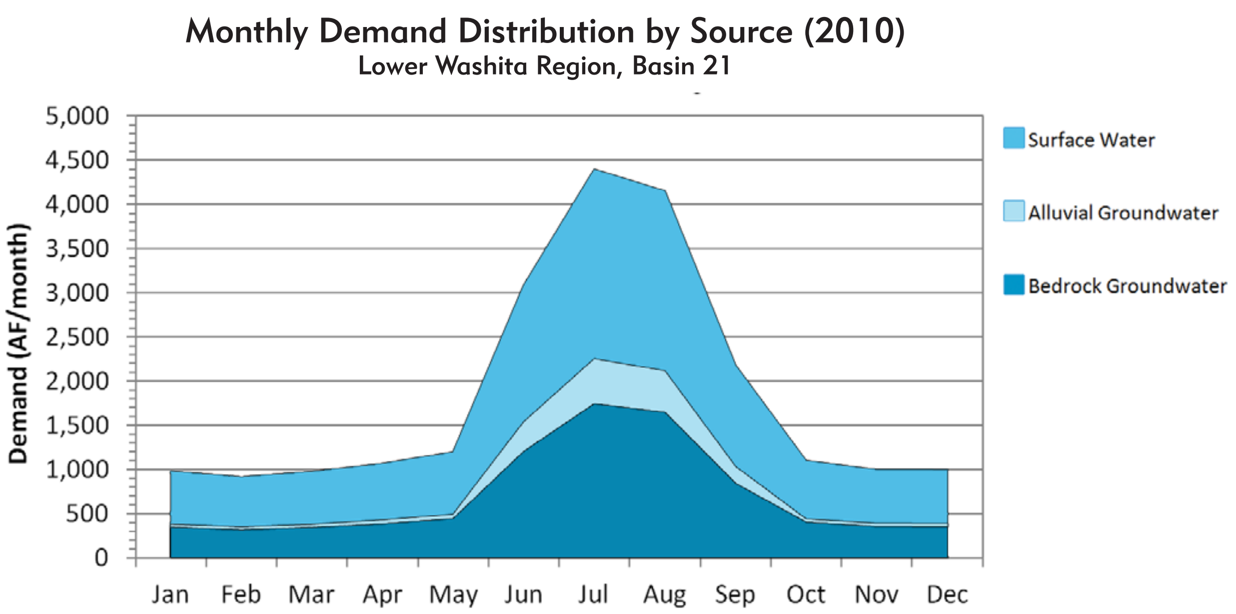
Total Demand by Sector
Lower Washita Region, Basin 21

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	8,800	1,820	8,400	1,420	1,490	130	0	22,060
2020	9,550	1,840	12,960	2,730	1,490	170	0	28,740
2030	10,310	1,870	14,330	2,240	1,490	200	0	30,440
2040	11,070	1,900	15,710	2,070	1,500	220	0	32,470
2050	11,650	1,930	17,170	1,800	1,520	240	0	34,310
2060	12,580	1,960	18,700	1,430	1,560	260	0	36,490

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 63% 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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 21 is 4.4 times the winter monthly demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 3.5 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at 13.4 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 5.0 times the winter monthly use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2020. No surface water gaps or bedrock groundwater depletions are expected in Basin 21 through 2060.
- Lake Texoma is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 21's future surface water demand during periods of low streamflow. However, water quality limits the potential uses of the supply.
- Alluvial groundwater storage depletions in Basin 21 may occur during the summer and fall, peaking in size during the summer. There will be a 3% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2040. Alluvial groundwater storage depletions in 2060 will be up to 32% (220 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 36% (100 AF/month) of the fall monthly alluvial groundwater demand. There is a low probability of alluvial groundwater storage depletions occurring during both summer and fall months.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the aquifer. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Lower Washita Region, Basin 21

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Lower Washita Region, Basin 21

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)	220	170	3%
Sep-Nov (Fall)	100	100	2%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Lower Washita Region, Basin 21

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	60	0	0%	2%
2030	0	140	0	0%	2%
2040	0	180	0	0%	3%
2050	0	220	0	0%	3%
2060	0	320	0	0%	3%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Lower Washita Region, Basin 21

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Lower Washita Region, Basin 21

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	320	0	0%	3%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	270	0	0%	3%
Moderately Expanded Conservation in M&I Water Use	0	260	0	0%	3%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	210	0	0%	3%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	140	0	0%	2%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Washita Region, Basin 21

Reservoir Storage	Diversion
AF	AFY
100	400
500	1,800
1,000	3,700
2,500	9,200
5,000	17,900
Required Storage to Meet Growth in Demand (AF)	3,900
Required Storage to Meet Growth in Surface Water Demand (AF)	1,900

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce alluvial groundwater storage depletions by 34%. Temporary drought management activities may not be needed for alluvial groundwater demand, since groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified nine potential out-of-basin sites in the Lower Washita Region: Caddo Creek, Cox City and Purdy in Basin 14; Chickasha, Gracemont, Kechi and Verden in Basin 16; Burneyville in Basin 22; and Courtney in Basin 23. However, in light of substantial available groundwater resources in the basin, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

Lake Texoma or new reservoir storage in Basin 21 could effectively supplement supply during dry months. However, the use of Texoma is constrained by water quality. Alternatively, the entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 3,900 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Durwood, Gainesville, and Ravia Reservoirs as potentially viable sites in Basin 21.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on the Antlers or Arbuckle-Simpson bedrock aquifers could mitigate alluvial groundwater storage depletions. Any resulting bedrock storage depletions would be minimal relative to the volume of water stored in the basin's major aquifers. However, results of the *Arbuckle-Simpson Hydrology Study* indicate that in order to comply with 2003 Senate Bill 288, the equal proportionate share will be significantly lower than the current 2 AFY/acre allocation for temporary permits.

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
Lower Washita Watershed Planning Region

Basin 22

Basin 22 Summary

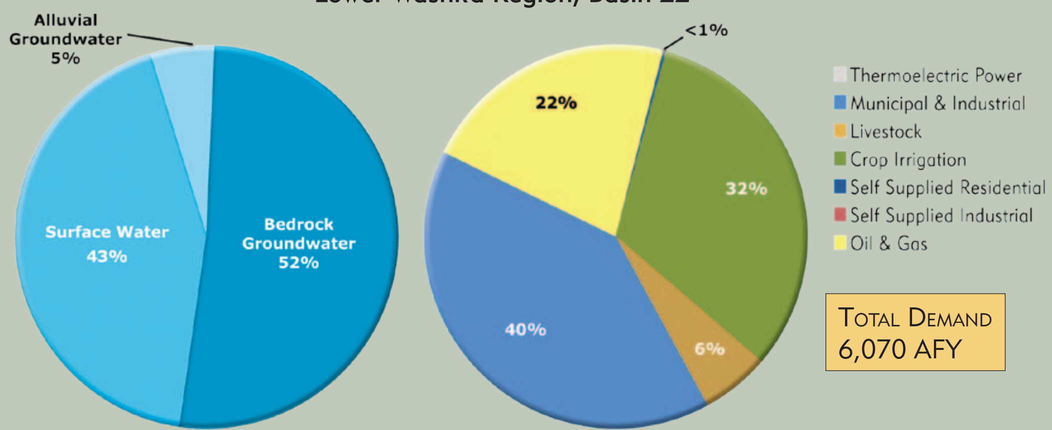
Synopsis

- Water users are expected to continue to rely primarily on surface water and bedrock groundwater.
- By 2020, there is a very high probability of surface water gaps from increased demands on existing supplies.
- Alluvial and bedrock groundwater storage depletions are likely by 2020, but will be minimal 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 measures could reduce surface water gaps and groundwater storage depletions.
- To mitigate surface water gaps, dependable groundwater supplies and/or developing new reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.
- Basin 22 has been identified as a "hot spot" where more pronounced water supply availability issues are forecasted. (See "Regional and Statewide Opportunities and Solutions" in the 2012 *OCWP Executive Report*.)

Basin 22 accounts for about 8% of the current demand in the Lower Washita Watershed Planning Region. About 40% of the basin's demand is from the Municipal and Industrial demand sector. Crop Irrigation is the second largest demand sector at 32%, followed by the Oil and Gas demand sector at 22%. Surface water satisfies about 43% of the current demand in the basin. Groundwater satisfies about 57% of the current demand (5% alluvial and 52% bedrock). The peak summer month demand in Basin 22 is 3.7 times the winter monthly demand, which is similar to the overall statewide pattern.

Current Demand by Source and Sector

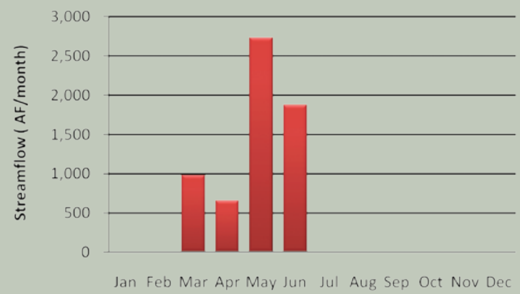
Lower Washita Region, Basin 22



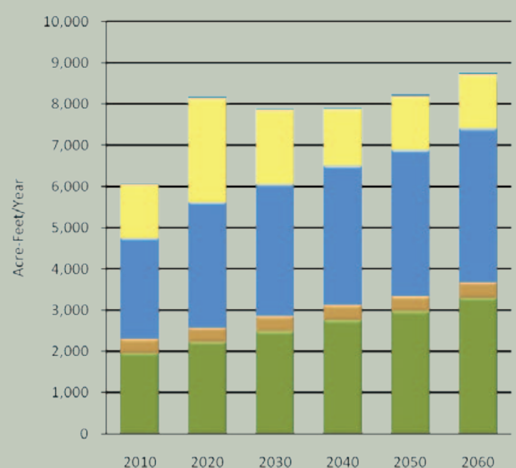
Water Resources

Lower Washita Region, Basin 22

Median Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 22



Projected Water Demand
Lower Washita Region, Basin 22



The flow in the Walnut Bayou upstream of the Red River is typically very low or zero from July through February. The flow is typically greater than 500 AF/month from March and April, and greater than 1,500 AF/month in May and June. However, the river can have periods of low flow in these months as well. Healdton Lake is an NRCS structure that provides flood control and recreation, as well as a dependable water supply yield of 413 AFY to the City of Healdton. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 22 is considered fair.

The majority of groundwater permits in Basin 22 are from the Antlers major bedrock aquifer. This aquifer has 758,000 AF of storage in Basin 22 and underlies about 40% of the basin. There are also rights in the Red River major alluvial aquifer and minor non-delineated alluvial and bedrock aquifers. Basin 22 contributes about 8,000 AFY of recharge to the Antlers aquifer. Domestic users (Self-Supplied Residential demand sector) do not require a permit and are assumed to be obtaining supplies from aquifers in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 8,750 AFY in Basin 22 reflects a 2,680 AFY increase (44%) over the 2010 demand. The majority of the demand over this period will be in the Municipal and Industrial and Crop Irrigation demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020. Surface water gaps will be up to 820 AFY and have a 98% probability of occurring in at least one month of the year by 2060. Surface water gaps may occur throughout the year, peaking in summer. Alluvial groundwater storage depletions will be up to 130 AFY and have a 95% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in Basin 22 may occur during the summer and fall, peaking in summer. Bedrock groundwater storage depletions will be 920 AFY in 2060 and will occur during the summer. Projected annual alluvial and bedrock groundwater storage depletions are minimal relative to the amount of water in storage in the aquifer. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Water Supply Limitations
Lower Washita Region, Basin 22

Source	Limitation
Surface Water	Significant
Alluvial Groundwater	Potential
Bedrock Groundwater	Significant

Minimal | Potential | Significant

Water Supply Option Effectiveness
Lower Washita Region, Basin 22

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

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

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps and groundwater storage depletions. Permanent conservation activities will be more effective than temporary drought management, since gaps will occur in almost every year and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eleven potentially viable out-of-basin sites in the Lower Washita Region. Additionally, Lake Texoma in Basin 21 has substantial unpermitted yield to meet the needs of new users, but its use is limited by water quality constraints. However, in light of the distance to reliable water supplies, out-of-basin supplies may not be cost-effective for some users in the basin.

Additional reservoir storage in Basin 22 could effectively supplement supply during dry months. The entire increase in surface water use from 2010 to 2060 could be supplied by a new river diversion and 5,700 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Burneyville Reservoir as a potentially viable reservoir site in Basin 22.

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

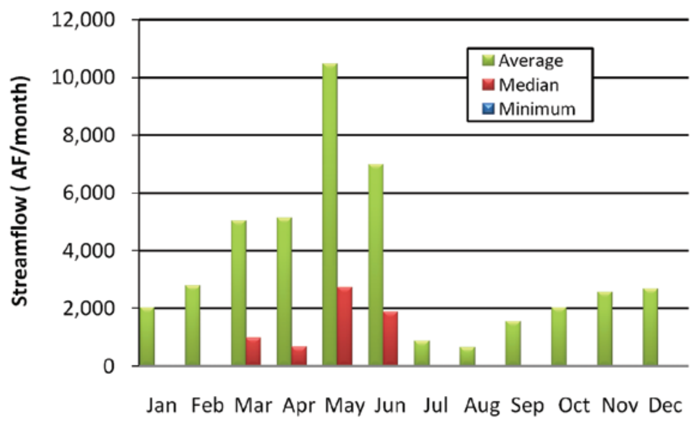
Increased reliance on major aquifers could mitigate surface water gaps, but would increase storage depletions. Any increases in storage depletions would be small relative to the volume of water stored in the Antlers and Red River aquifers. However, the aquifers only underlie the southern portion of the basin.

Basin 22 Data & Analysis

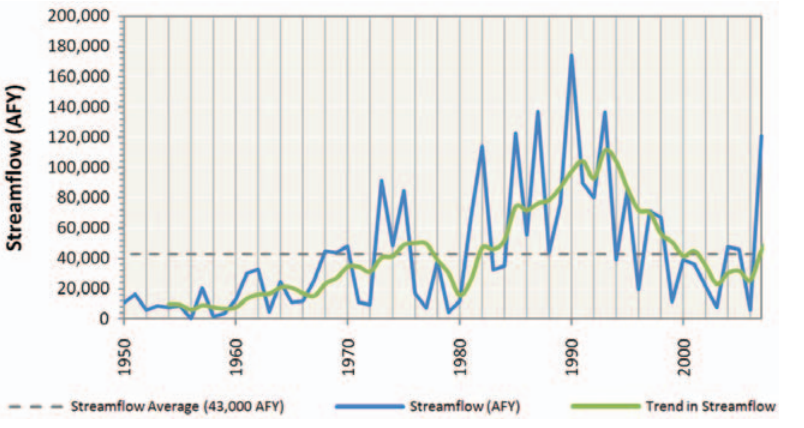
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Walnut Bayou upstream of the Red River had a period of below-average streamflow from the early 1950s to the early 1970s. From the early 1980s through the mid 1990s, 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 Walnut Bayou upstream of the Red River is very low or zero from July through February. The median flow is greater than 500 AF/month from March through June and greater than 1,500 AF/month in May and June. However, the bayou can have periods of low flow in these months as well.
- Relative to other basins in the state, the surface water quality in Basin 22 is considered fair.
- Healdton Lake provides 413 AFY of dependable yield to the City of Healdton and is fully allocated.

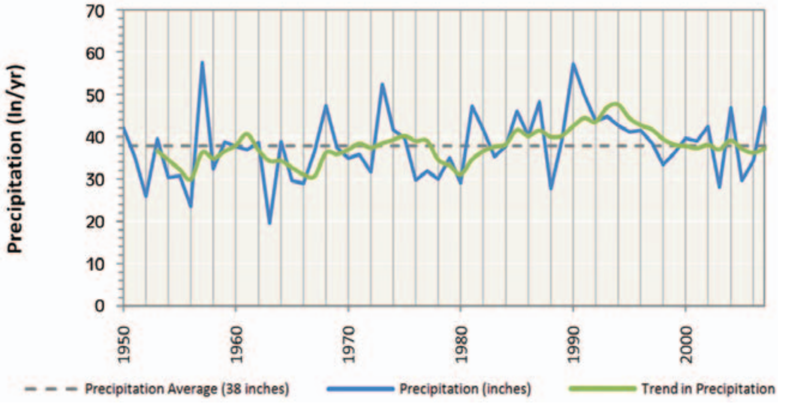
Monthly Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 22



Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 22



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)

Lower Washita Region, Basin 22

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type[1]	Class[2]	Percent	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	40%	20,700	778,000	2.1	152,800
Red River	Alluvial	Major	21%	700	214,000	temporary 2.0	88,000
Marietta	Bedrock	Minor	2%	0	39,000	temporary 2.0	12,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	2,400	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	1,600	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in Basin 22 are from the Antlers aquifer. This aquifer has 778,000 AF of storage in Basin 22 and underlies about 40% of the basin. Basin 22 contributes about 8,000 AFY of recharge to the Antlers aquifer. There are also rights in the Red River aquifer and from minor non-delineated groundwater sources.
- There are no significant groundwater quality issues in basin.

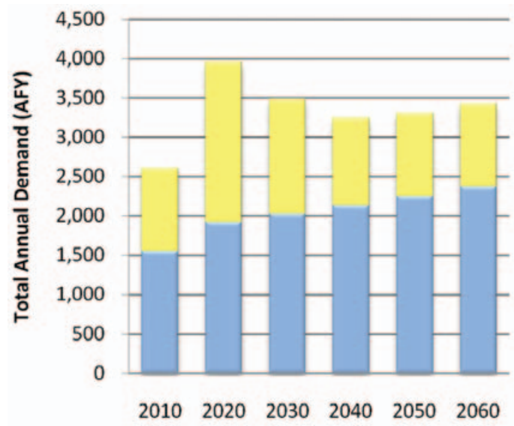
Notes & Assumptions

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

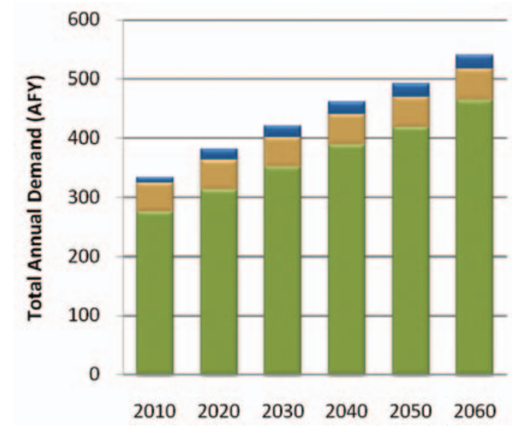
Water Demand

- Basin 22's water needs account for about 8% of the demand in the Lower Washita Watershed Planning Region and will increase by 44% (2,680 AFY) from 2010 to 2060. The majority of the demand during this period will be from the Municipal and Industrial and Crop Irrigation demand sectors.
- Surface water is used to meet 43% of total demands in the basin and its use will increase by 31% (820 AFY) from 2010 to 2060. The majority of the 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 total demands in the basin and its use will increase by 62% (210 AFY) from 2010 to 2060. The majority of the alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 52% of total demands in the basin and its use will increase by 53% (1,650 AFY) from 2010 to 2060. The majority of the bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

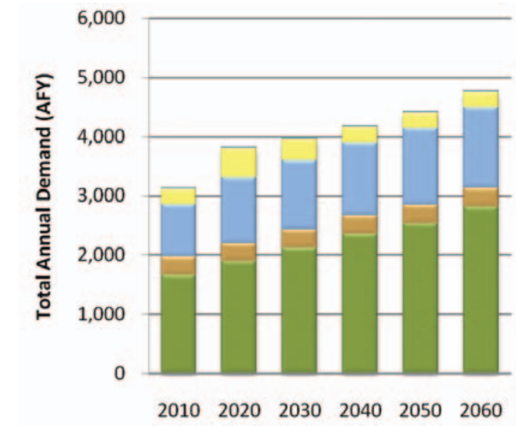
Surface Water Demand by Sector
Lower Washita Region, Basin 22



Alluvial Groundwater Demand by Sector
Lower Washita Region, Basin 22



Bedrock Groundwater Demand by Sector
Lower Washita Region, Basin 22



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

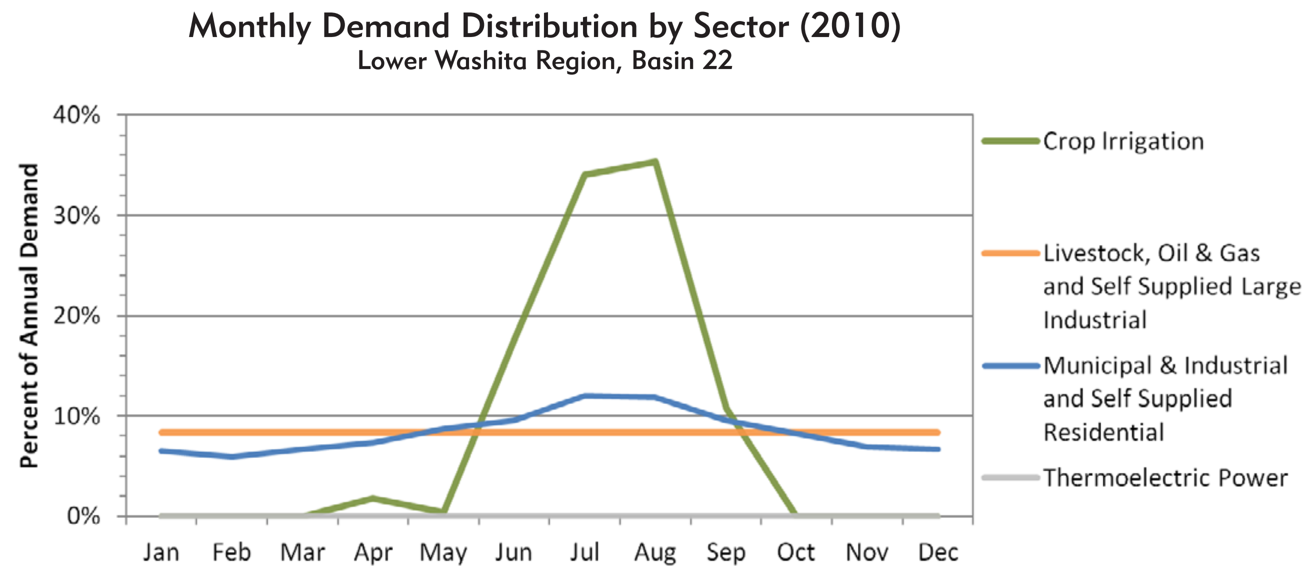
Total Demand by Sector
Lower Washita Region, Basin 22

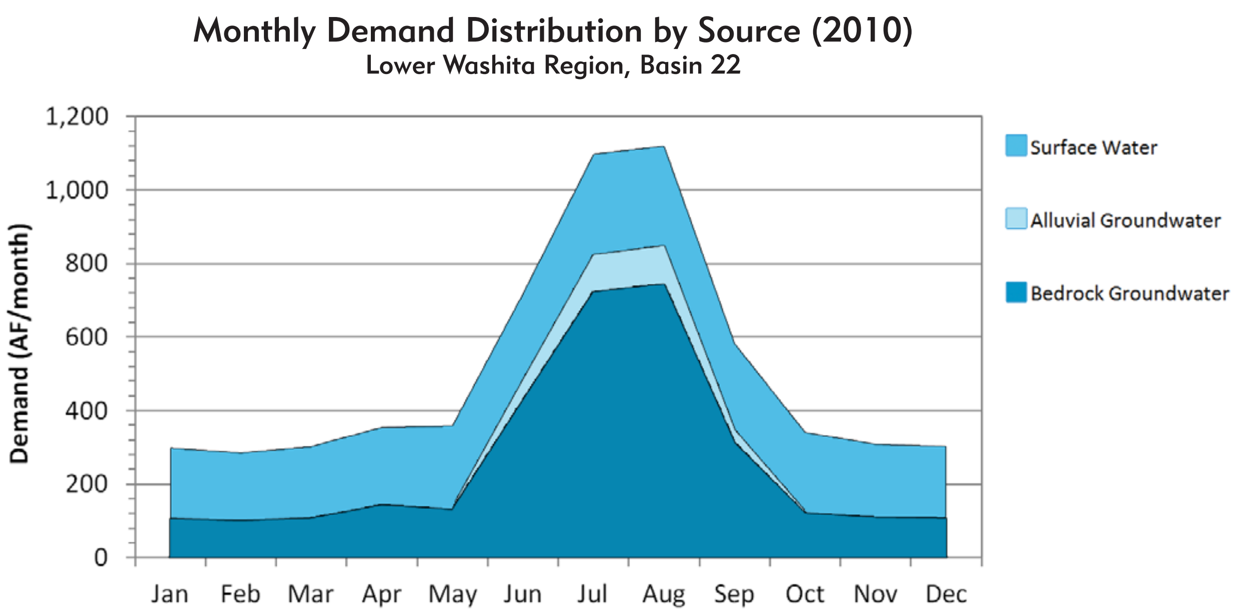
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas[1]	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,950	350	2,440	1,320	0	10	0	6,070
2020	2,220	350	3,030	2,530	0	30	0	8,160
2030	2,490	360	3,200	1,810	0	30	0	7,890
2040	2,750	360	3,370	1,380	0	30	0	7,890
2050	2,960	370	3,550	1,320	0	30	0	8,230
2060	3,290	370	3,730	1,320	0	40	0	8,750

1 The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, where applicable, basin demands (in the Lower Washita Region, Basin 22) are assumed to never fall below the 2010 base year demand levels. This is reflected in the Region and Basin Total Demand by Sector tables.

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 74% 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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 22 is 3.7 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 1.4 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at 22 times the winter monthly use. Monthly bedrock groundwater use peaks in the summer at 7 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020.
- Surface water gaps in Basin 22 may occur throughout the year, peaking in size during the summer. There will be a 98% probability of gaps occurring in at least one month of the year by 2020. Surface water gaps in 2060 will be up to 30% (110 AF/month) of the surface water demand in the peak summer month, and as much as 21% (50 AF/month) of the winter monthly surface water demand. Surface water gaps have a high probability of occurring in all seasons.
- Alluvial groundwater storage depletions in Basin 22 may occur during the summer and fall, peaking in size during the summer. There will be a 95% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2020. Alluvial groundwater storage depletions in 2060 will be up to 29% (50 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 17% (10 AF/month) of the fall monthly alluvial groundwater demand. Alluvial groundwater storage depletions have a high probability of occurring in both the summer and fall.
- Bedrock groundwater storage depletions in Basin 22 may occur during the summer. Bedrock groundwater storage depletions in 2060 will be 38% (460 AF/month) of the bedrock groundwater demand on average in the peak summer month.
- Projected annual alluvial and bedrock groundwater storage depletions are minimal relative to the amount of water in storage in major aquifers. However, localized storage depletions may adversely affect well yields, water quality, or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Lower Washita Region, Basin 22

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	50	50	81%
Mar-May (Spring)	70	60	55%
Jun-Aug (Summer)	110	110	90%
Sep-Nov (Fall)	70	70	83%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Lower Washita Region, Basin 22

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	50	50	90%
Sep-Nov (Fall)	10	10	57%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Lower Washita Region, Basin 22

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	1,300	80	260	98%	95%
2030	840	80	400	98%	95%
2040	640	80	570	98%	95%
2050	710	100	710	98%	95%
2060	820	130	920	98%	95%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Lower Washita Region, Basin 22

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	460
Sep-Nov (Fall)	0

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Lower Washita Region, Basin 22

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	820	130	920	98%	95%
Moderately Expanded Conservation in Crop Irrigation Water Use	820	110	810	98%	95%
Moderately Expanded Conservation in M&I Water Use	470	90	860	98%	93%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	460	80	750	98%	93%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	230	40	580	97%	88%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Washita Region, Basin 22

Reservoir Storage	Diversion
AF	AFY
100	100
500	200
1,000	500
2,500	1,200
5,000	2,300
Required Storage to Meet Growth in Demand (AF)	5,700
Required Storage to Meet Growth in Surface Water Demand (AF)	1,800

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 demand sectors could reduce surface water gaps by about 44%. Alluvial groundwater storage depletions could be reduced by about 38% and bedrock storage depletions could be reduced by about 18%. Permanent conservation activities will be more effective temporary drought management measures, since gaps will occur in almost every year and aquifers storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eleven potential out-of-basin sites in the Lower Washita Region: Caddo Creek, Cox City and Purdy in Basin 14; Chickasha, Gracemont, Kechi and Verden in Basin 16; Durwood, Gainesville and Ravia in Basin 21; and Courtney in Basin 23. In addition, Lake Texoma in Basin 21 has substantial unpermitted yield to meet the needs of new users. However, its use is severely constrained by water quality issues. However, in light of the distance to reliable water supplies, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

Additional reservoir storage in Basin 22 could effectively supplement supply during dry months. The entire increase in water use from 2010 to 2060 could be supplied by a new reservoir diversion and 5,700 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Burneyville Reservoir as a potentially viable reservoir site in Basin 22.

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 major aquifers could mitigate surface water gaps, but would increase storage depletions. Any increases in storage depletions would be small relative to the volume of water stored in the Antlers and Red River aquifers. However, the aquifers only underlie the southern 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.

Oklahoma Comprehensive Water Plan

Data & Analysis
Lower Washita Watershed Planning Region

Basin 23

Basin 23 Summary

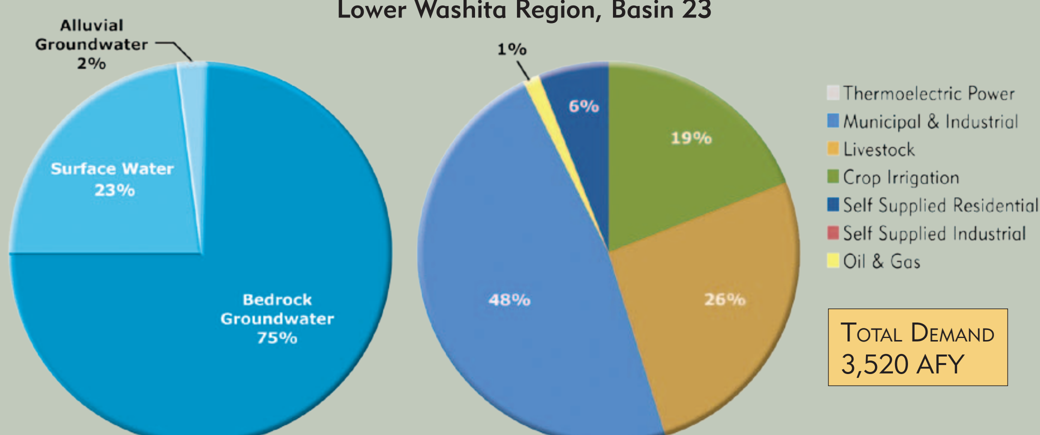
Synopsis

- Water users are expected to continue to rely primarily on bedrock groundwater and, to a lesser extent, surface water.
- By 2020, there is a moderate probability of surface water gaps from increased demand on existing supplies during low flow periods.
- Bedrock groundwater storage depletions may occur by 2020. Future bedrock groundwater withdrawals are expected to occur from non-delineated minor aquifers. 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 measures could reduce surface water gaps and groundwater storage depletions.
- To mitigate surface water gaps, major aquifers and/or developing new small reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

Basin 23 accounts for about 4% of the current demand in the Lower Washita Watershed Planning Region. About 48% of the basin's demand is from the Municipal and Industrial demand sector. Livestock is the second largest demand sector at 26%, followed by Crop Irrigation at 19% of the basin's demand. Surface water satisfies about 23% of the current demand in the basin. Groundwater satisfies about 77% of the current demand (2% alluvial and 75% bedrock). The peak summer month demand in Basin 23 is 2.6 times the winter monthly demand, which is similar to the overall statewide pattern.

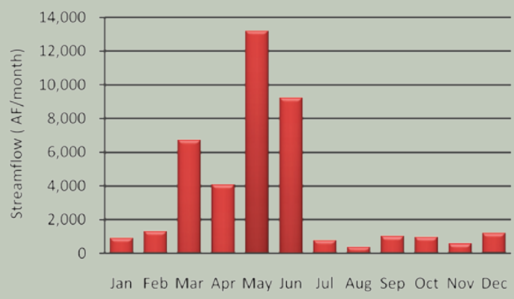
The flow in Mud Creek upstream of the Red River is typically greater than 350 AF/month throughout the year and greater than 4,000 AF/month in the spring and early summer. However, the creek can have periods of low

Current Demand by Source and Sector
Lower Washita Region, Basin 23

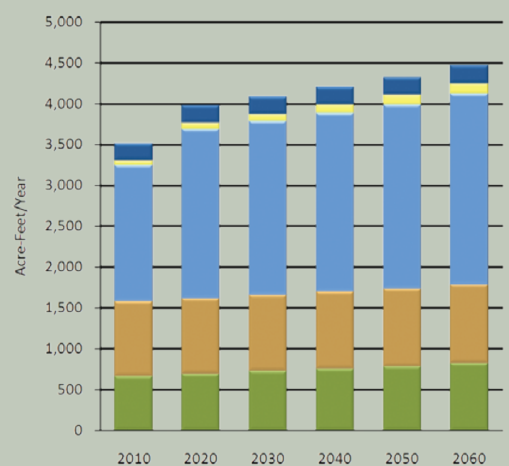


Water Resources
Lower Washita Region, Basin 23

Median Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 23



Projected Water Demand
Lower Washita Region, Basin 23



to no flow in any month of the year. There are no major reservoirs in Basin 23. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 23 is considered fair. Fox Branch and Oak Creek are impaired for Agricultural use due to high levels of chloride, sulfate, and total dissolved solids (TDS).

The majority of groundwater rights (9,800 AFY) in Basin 23 are from non-delineated minor bedrock aquifers. There are also 100 AFY of groundwater rights in non-delineated minor alluvial aquifers. The major Red River alluvial aquifer and major Antlers bedrock aquifer underlie small portions of the basin, but are not used. The basin contributes 1,000 AFY of recharge to the Antlers aquifer. Domestic users do not require a permit and are assumed to be obtaining supplies from aquifers in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 4,480 AFY in Basin 23 reflects a 960 AFY increase (27%) over the 2010 demand. The largest demand and growth in demand over this period will be in the Municipal and Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions may occur by 2020. Surface water gaps will be up to 170 AFY and have a 43% probability of occurring in at least one month of the year by 2060. Surface water gaps in Basin 23 may occur throughout the year, but are most likely to occur in summer and fall months. Bedrock groundwater storage depletions will be 600 AFY and occur throughout the year, peaking in summer. Future bedrock groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the extent of the storage depletions cannot fully be evaluated due to insufficient information. 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 bedrock groundwater and surface water. To reduce the risk of adverse impacts to the basin's water users, surface water gaps and bedrock groundwater storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial,

Water Supply Limitations
Lower Washita Region, Basin 23

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Lower Washita Region, Basin 23

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

Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps and groundwater storage depletions. Temporary drought management activities may not be effective for this basin, since there is a moderate probability of surface water gaps and storage in bedrock aquifers may continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eleven potentially viable out-of-basin sites in the Lower Washita Region. In additional, Lake Texoma, in Basin 21, has substantial unpermitted yield to meet the needs of new users, but the lake's water quality severely limits its use. However, in light of the distance to reliable water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Additional reservoir storage in Basin 23 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 600 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Courtney Reservoir as a potentially viable site in Basin 23.

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

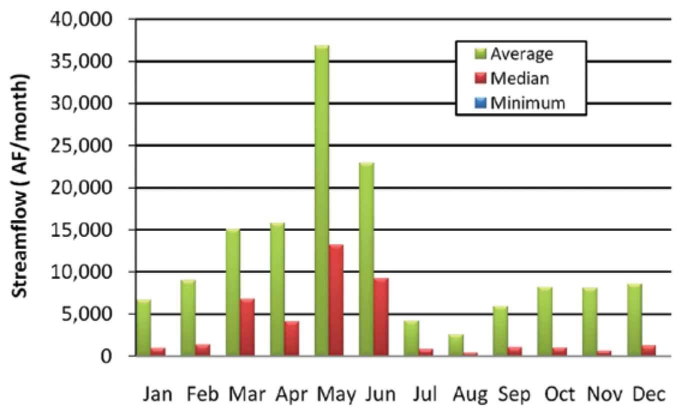
Increased reliance on major alluvial aquifers could mitigate surface water gaps, but may create storage depletions. Any increases in storage depletions would be small relative to the volume of water stored in the Red River aquifer. However, this aquifer only underlies the extreme southern portion of the basin (about 12% of the basin area).

Basin 23 Data & Analysis

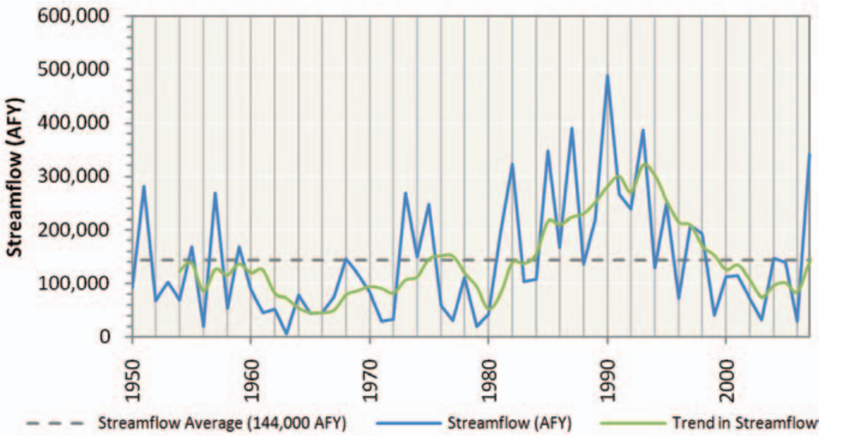
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Mud Creek upstream of the Red River had a period of below-average streamflow from the early 1960s to the early 1970s. From the early 1980s through the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in Mud Creek upstream of the Red River is greater than 350 AF/month throughout the year and greater than 4,000 AF/month in the spring and early summer. However, the creek can have periods of low to no flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 23 is considered fair.
- There are no major reservoirs in Basin 23.

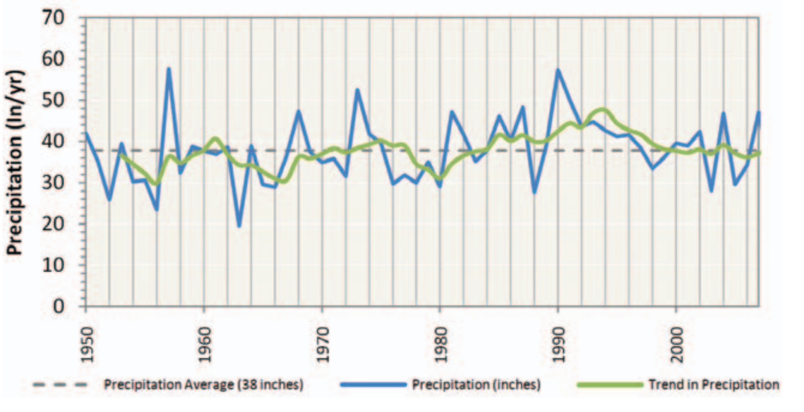
Monthly Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 23



Historical Streamflow at the Basin Outlet
Lower Washita Region, Basin 23



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)

Lower Washita Region, Basin 23

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Antlers	Bedrock	Major	2%	0	63,000	2.1	13,400
Red River	Alluvial	Major	12%	0	171,000	temporary 2.0	89,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	9,800	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	100	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in Basin 23 are from non-delineated minor bedrock groundwater sources. There are also 100 AFY of groundwater rights in non-delineated minor alluvial aquifers. While minor aquifers may have a large amount of water in storage, they typically provide lower yields which may not be sufficient for large-scale users. The Red River and Antlers major aquifers underlie small portions of the basin, but currently have no water rights. The basin contributes 1,000 AFY of recharge to the Antlers aquifer.
- There are no significant groundwater quality issues in basin.

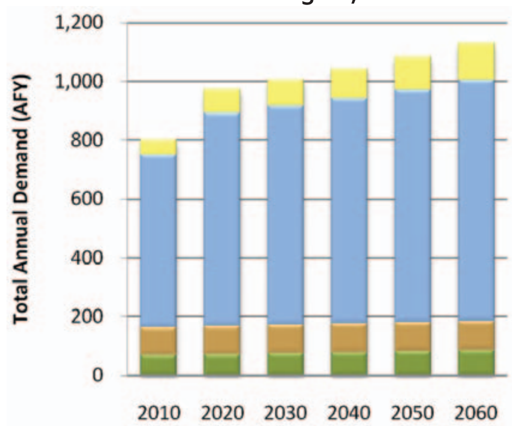
Notes & Assumptions

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

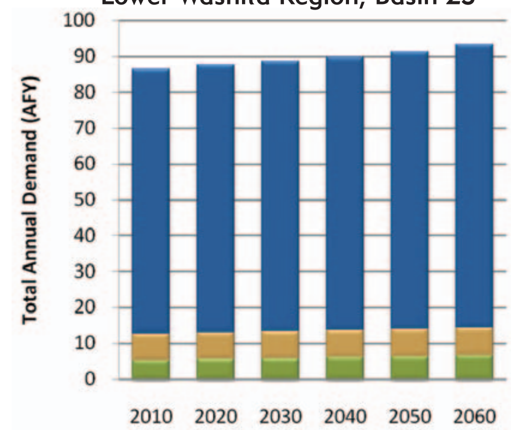
Water Demand

- Basin 23's water needs account for about 4% of the demand in the Lower Washita Watershed Planning Region and will increase by 27% (960 AFY) from 2010 to 2060. The largest demand and growth in demand during this period will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 23% of total demand in the basin and its use will increase by 41% (330 AFY) from 2010 to 2060. The majority of the 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 2% of total demand in the basin and its use will increase by 8% (10 AFY) from 2010 to 2060. This increase in alluvial groundwater use is minimal on a basin-scale. The majority of the alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 75% of total demand in the basin and its use will increase by 24% (620 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Municipal and Industrial demand sector.

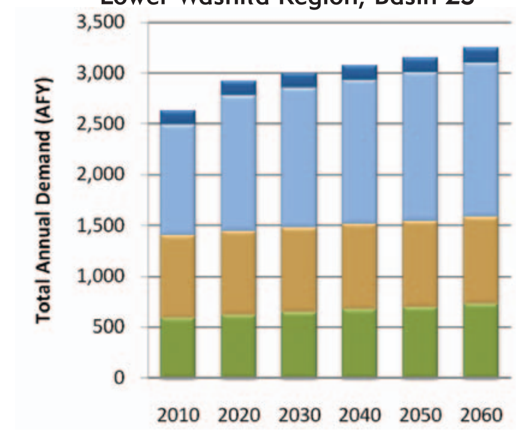
Surface Water Demand by Sector
Lower Washita Region, Basin 23



Alluvial Groundwater Demand by Sector
Lower Washita Region, Basin 23



Bedrock Groundwater Demand by Sector
Lower Washita Region, Basin 23



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

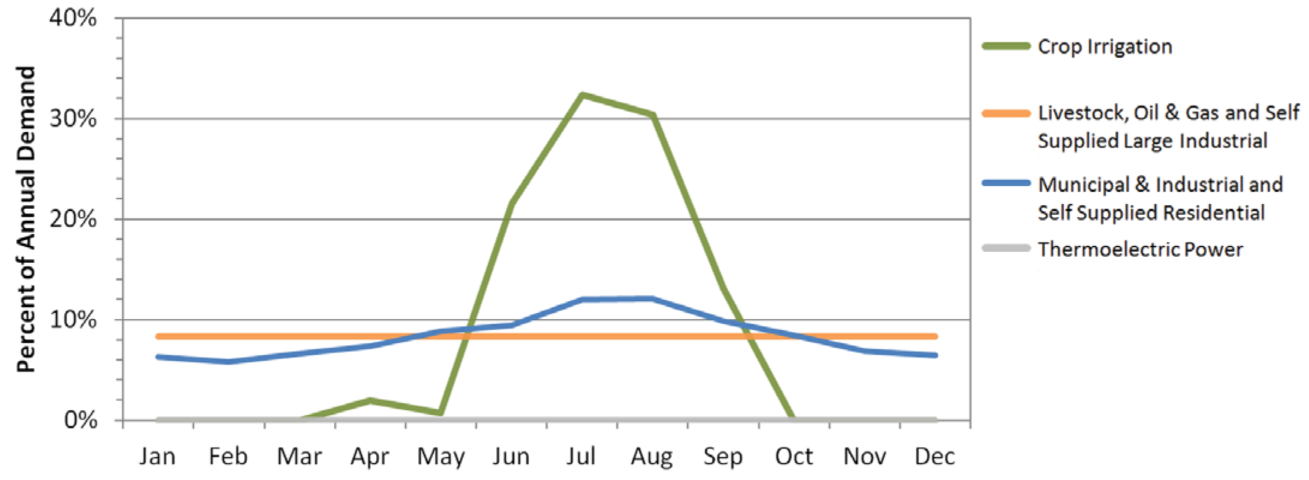
Total Demand by Sector
Lower Washita Region, Basin 23

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	670	920	1,670	50	0	210	0	3,520
2020	700	930	2,070	80	0	210	0	3,990
2030	730	930	2,120	90	0	210	0	4,080
2040	760	940	2,190	100	0	220	0	4,210
2050	790	950	2,260	110	0	220	0	4,330
2060	830	960	2,340	130	0	220	0	4,480

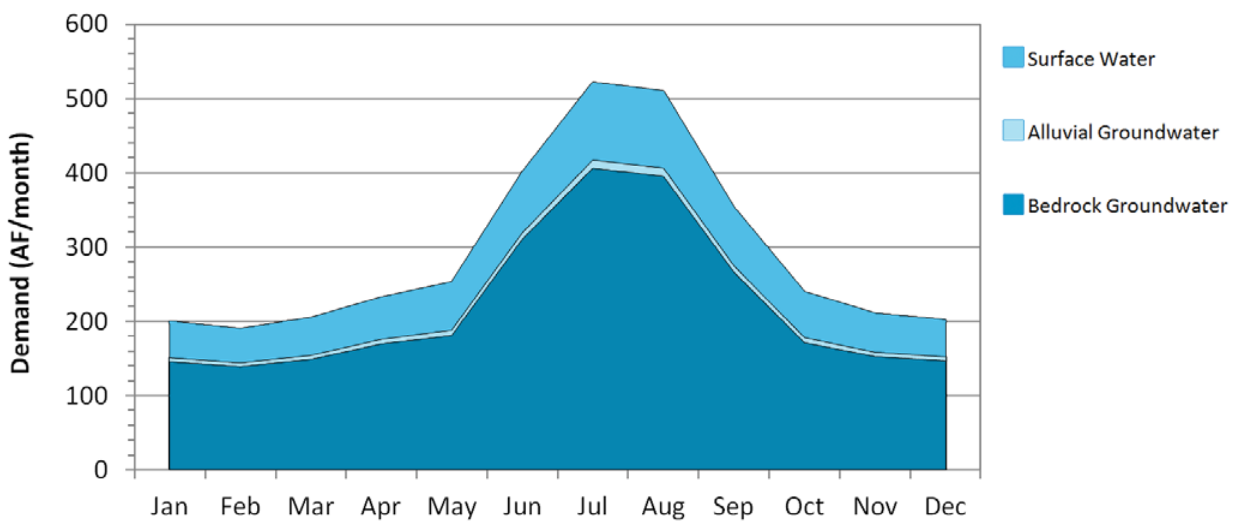
Notes & Assumptions

- 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)
Lower Washita Region, Basin 23



Monthly Demand Distribution by Source (2010)
Lower Washita Region, Basin 23



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 80% 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 more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 23 is 2.6 times the winter monthly demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 2.1 times the winter monthly use. Monthly alluvial groundwater use peaks in the summer at about 2.1 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 2.8 times the winter monthly use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions may occur by 2020. No alluvial groundwater storage depletions are expected through 2060.
- Surface water gaps in Basin 23 may occur throughout the year. Surface water gaps in 2060 will be up to 29% (40 AF/month) of the surface water demand in the peak summer month, and as much as 29% (20 AF/month) of the winter monthly surface water demand. There will be a 43% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during summer and fall months.
- Bedrock groundwater storage depletions in Basin 23 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 20% (100 AF/month) of the bedrock groundwater demand in the peak summer month, and 17% (30 AF/month) on average of the winter monthly bedrock groundwater demand.
- Future bedrock groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the extent of the storage depletions cannot be fully evaluated due to insufficient information.

Surface Water Gaps by Season (2060 Demand)

Lower Washita Region, Basin 23

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	10	19%
Mar-May (Spring)	20	20	5%
Jun-Aug (Summer)	40	40	29%
Sep-Nov (Fall)	30	20	33%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Washita Region, Basin 23

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Washita Region, Basin 23

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	90	0	300	38%	0%
2030	100	0	360	40%	0%
2040	130	0	440	40%	0%
2050	150	0	520	40%	0%
2060	170	0	600	43%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Washita Region, Basin 23

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	30
Mar-May (Spring)	40
Jun-Aug (Summer)	100
Sep-Nov (Fall)	60

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation
Lower Washita Region, Basin 23

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	170	0	600	43%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	170	0	580	43%	0%
Moderately Expanded Conservation in M&I Water Use	80	0	270	34%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	80	0	250	34%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	30	0	50	22%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage
Lower Washita Region, Basin 23

Reservoir Storage	Diversion
AF	AFY
100	200
500	800
1,000	1,500
2,500	3,100
5,000	4,700
Required Storage to Meet Growth in Demand (AF)	600
Required Storage to Meet Growth in Surface Water Demand (AF)	200

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce surface water gaps by about 53%. Bedrock groundwater storage depletions could be reduced by 58%. Temporary drought management activities will not be effective for this basin, since there is a moderate probability of surface water gaps and storage in bedrock aquifers may continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eleven potential out-of-basin sites in the Lower Washita Region: Caddo Creek, Cox City and Purdy in Basin 14; Chickasha, Gracemont, Kechi and Verden in Basin 16; Durwood, Gainesville and Ravia in Basin 21; and Burneyville in Basin 22. In addition, Lake Texoma, in Basin 21, has substantial unpermitted yield to meet the needs of new users, but its use is severely constrained by water quality issues. However, in light of the distance to reliable water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Additional reservoir storage in Basin 23 could effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 600 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* identified Courtney Reservoir as a potentially viable site in Basin 23.

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 major alluvial aquifers could mitigate surface water gaps, but may create storage depletions. Any increases in storage depletions would be small relative to the volume of water stored in the Red River aquifer. However, this aquifer only underlies the extreme southern portion of the basin (about 12% of the basin area).

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.

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.

Non-delineated groundwater source: an area where no major or minor aquifer has been studied that may or may not supply a well yield; also referred to as a "non-delineated minor aquifer."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Potable: describing water suitable for drinking.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Withdrawal: water removed from a supply source.

AF: acre-foot or acre-feet

AFD: acre-feet per day

AFY: acre-feet per year

BMPs: best management practices

BOD: biochemical oxygen demand

cfs: cubic feet per second

CWAC: Cool Water Aquatic Community

CWSRF: Clean Water State Revolving Fund

DO: dissolved oxygen

DWSRF: Drinking Water State Revolving Fund

EPS: equal proportionate share

FACT: Funding Agency Coordinating Team

gpm: gallons per minute

HLAC: Habitat Limited Aquatic Community

HQW: High Quality Waters

HUC: hydrologic unit code

M&I: municipal and industrial

MAY: maximum annual yield

mgd: million gallons per day

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

mg/L: milligrams per liter

NLW: nutrient-limited watershed

NPS: nonpoint source

NPDES: National Pollutant Discharge Elimination System

NRCS: Natural Resources Conservation Service

NTU: Nephelometric Turbidity Unit (see "Turbidity")

OCWP: Oklahoma Comprehensive Water Plan

ODEQ: Oklahoma Department of Environmental Quality

O&G: Oil and Gas

ORW: Outstanding Resource Water

OWQS: Oklahoma Water Quality Standards

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

pH: hydrogen ion activity

ppm: parts per million

RD: Rural Development

REAP: Rural Economic Action Plan

SBCR: Secondary Body Contact Recreation

SDWIS: Safe Drinking Water Information System

SRF: State Revolving Fund

SSI: Self-Supplied Industrial

SSR: Self-Supplied Residential

SWS: Sensitive Water Supply

TDS: total dissolved solids

TMDL: total maximum daily load

TSI: Trophic State Index

TSS: total suspended solids

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WLA: wasteload allocation

WWAC: Warm Water Aquatic Community

Water Quantity Conversion Factors

Desired Unit (columns) / Initial Unit (rows)

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

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

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

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