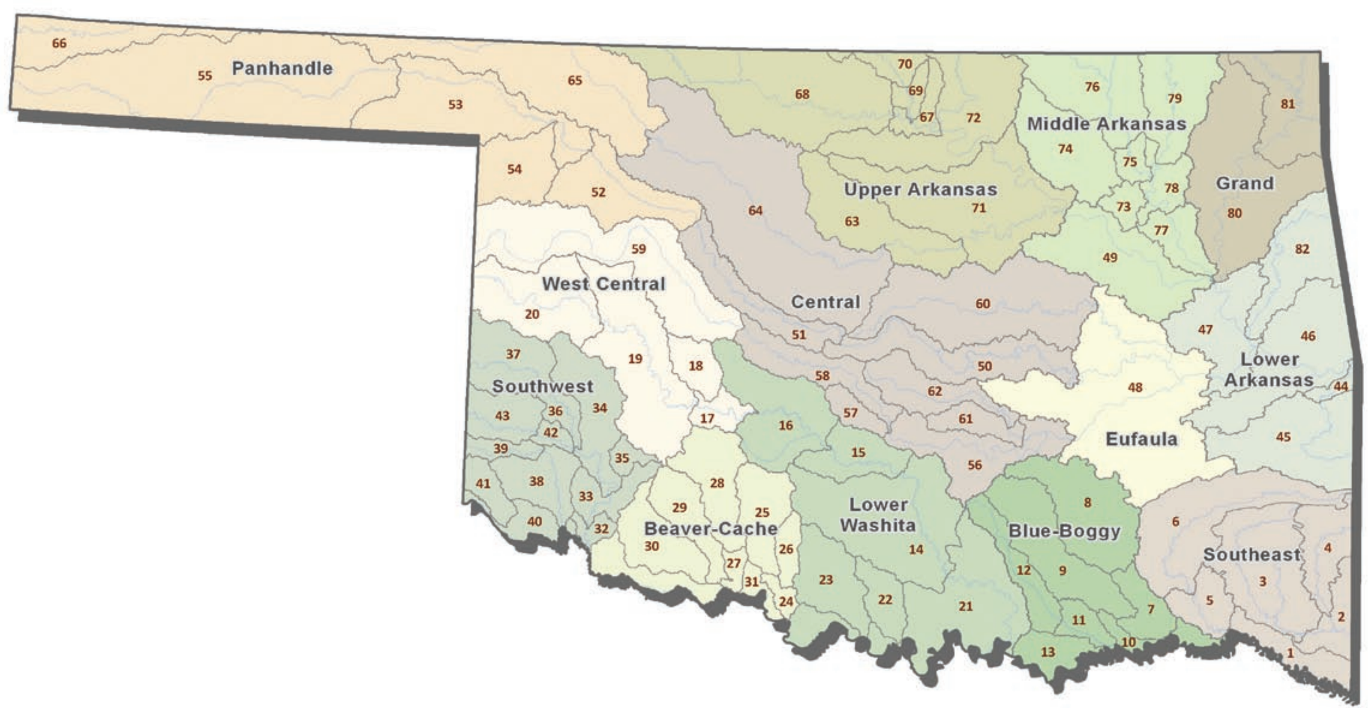
Oklahoma Comprehensive Water Plan

Beaver-Cache 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.

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

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

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

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

Integral to the development of these reports was the Oklahoma H2O tool, a sophisticated database and geographic information system (GIS) based analysis tool created to compare projected water demands 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, demands, 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 information gained during the development of the *2012 OCWP Update* is provided in various OCWP supplemental reports. Assessments of statewide physical water availability and potential shortages are documented in the OCWP *Physical Water Supply Availability Report*. Statewide water demand projection methods and results are presented 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 Beaver-Cache Watershed Planning Region includes eight basins (numbered 24-31 for reference). The region is in the Central Lowland physiography province, encompassing 3,288 square miles in southwest Oklahoma spanning from the southern portion of Caddo County in the north to the Red River on the south, and including all or portions of Tillman, Caddo, Comanche, Cotton, Grady, Stephens, and Jefferson Counties.

The region's terrain varies from lush pasture in the river bottoms and gently rolling plains to the Wichita Mountains in the northwest, which rise 400 to 1,100 feet above surrounding redbed plains. Mixed eroded plains occur over the southwest portion of the region, much of which has been converted for wheat or cotton production, transitioning east to tallgrass prairie and intergrading in the northeast to Post-Oak-Blackjack forest, known locally as the Cross Timbers.

The region has a generally mild climate with average monthly temperatures varying from 38°F in January to 84°F in July (Lawton Regional Airport). Annual average precipitation ranges from 28 inches in the west to 34 inches in the east. Annual evaporation ranges from 27 inches in the west to 33 inches in the east.

The largest cities in the region include Lawton (2010 population of 96,867), Duncan (23,431), Frederick (3,940), and Marlow (4,662). The greatest water demand is from municipal and industrial water use followed by crop irrigation.

By 2060, this region is projected to have a total water demand of 56,560 acre-feet per year (AFY), an increase of approximately 12,000 AFY (27%) from 2010.

Beaver-Cache Regional Summary

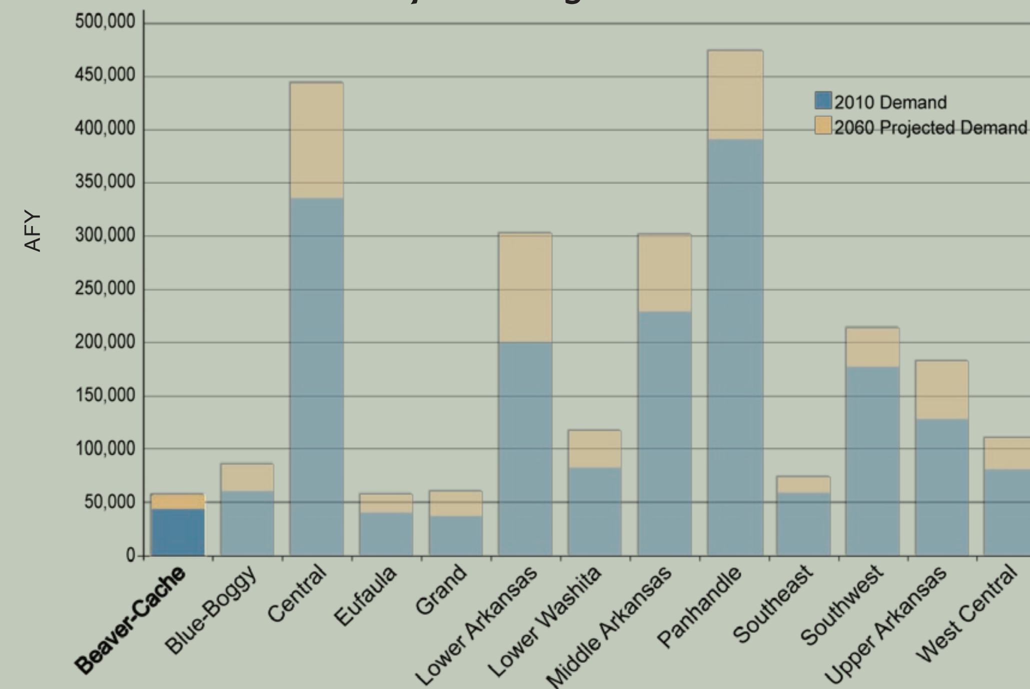
Synopsis

- The Beaver-Cache Watershed Planning Region relies primarily on surface water supplies (including reservoirs) and to a lesser extent, groundwater supplies.
- It is anticipated that water users in the region will continue to rely on existing reservoirs and major aquifers to meet future demand.
- Surface water supplies will be insufficient at times to meet demand in basins without major reservoirs.
- Groundwater storage depletions are anticipated but should be relatively small compared to the amount of water in storage.
- Construction of additional small reservoirs, new out-of-basin or other regional supplies, and increased reliance on groundwater may be effective solutions for areas with anticipated surface water gaps.
- Users with surface water gaps or who rely on minor aquifers can increase dependability of their supplies through emergency demand management and conservation, new reservoirs, and/or out-of-basin supplies.
- Basin 26 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*.)

Beaver-Cache Region Demand Summary

Current Water Demand:	44,590 acre-feet/year (2% of state total)		
Largest Demand Sector:	Municipal & Industrial (55% of regional total)		
Current Supply Sources:	64% SW	19% Alluvial GW	17% Bedrock GW
Projected Demand (2060):	56,560 acre-feet/year		
Growth (2010-2060):	11,970 acre-feet/year (27%)		

Current and Projected Regional Water Demand



The Beaver-Cache Region accounts for 2% of the state's total water demand. The largest demand sector is Municipal and Industrial (55%), followed by Crop Irrigation (28%).

Water Resources & Limitations

Surface Water

Surface water is used to meet two-thirds of the Beaver-Cache Region's demand. The region is supplied by three large creeks that flow into the Red River: Beaver Creek, Cache Creek, and Deep Red Creek. Historically, major creeks in the region experience seasonal low flows and extended periods of low flow due to droughts. Large reservoirs have been built on Cache Creek tributaries (Lake Lawtonka and Lake Ellsworth) and Beaver Creek (Waurika Lake) to supply public water systems and irrigators and provide other important regional benefits, such as flood control and recreation. Basins lacking access to major reservoirs are expected to experience physical surface water supply shortages in the future.

Water quality may constrain supplies for Municipal and Industrial and Crop Irrigation demand sectors. Public and private water and agriculture supplies in Lake Lawtonka, Waurika Lake, Cow Creek, Deep Red Creek, and Beaver Creek currently have water quality impairments due to elevated levels of total dissolved solids, sulfates, and chlorophyll-a. These impairments are scheduled to be addressed, in part, through the Total Maximum Daily Loads (TMDL) process, but the use of these supplies may be limited in the interim.

The availability of water rights is not expected to constrain the use of surface water supplies to meet local demand through 2060.

Alluvial Groundwater

Alluvial groundwater is used to meet 19% of the demand in the region. The majority of currently allocated alluvial groundwater (i.e., groundwater in alluvial and terrace deposits) withdrawals in the region are from the Tillman Terrace aquifer, and to a lesser extent, the Red River aquifer. If alluvial groundwater is used to supply a similar portion of demand in the future, depletions from these aquifers are likely to occur in summer months, although projected depletions will be small relative to the amount of water in storage and permit availability. Water quality issues will remain a concern for the region and may constrain some uses of alluvial groundwater.

The availability of water rights 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 17% of the demand in the region. Currently allocated groundwater and projected withdrawals are from the Rush Springs aquifer, and to a lesser extent, the Arbuckle-Timbered Hills and Hennessey-Garber aquifers. Aquifer storage depletions are likely to occur during summer months. These depletions are small relative to the amount of water in storage and maximum annual yields of the aquifers.

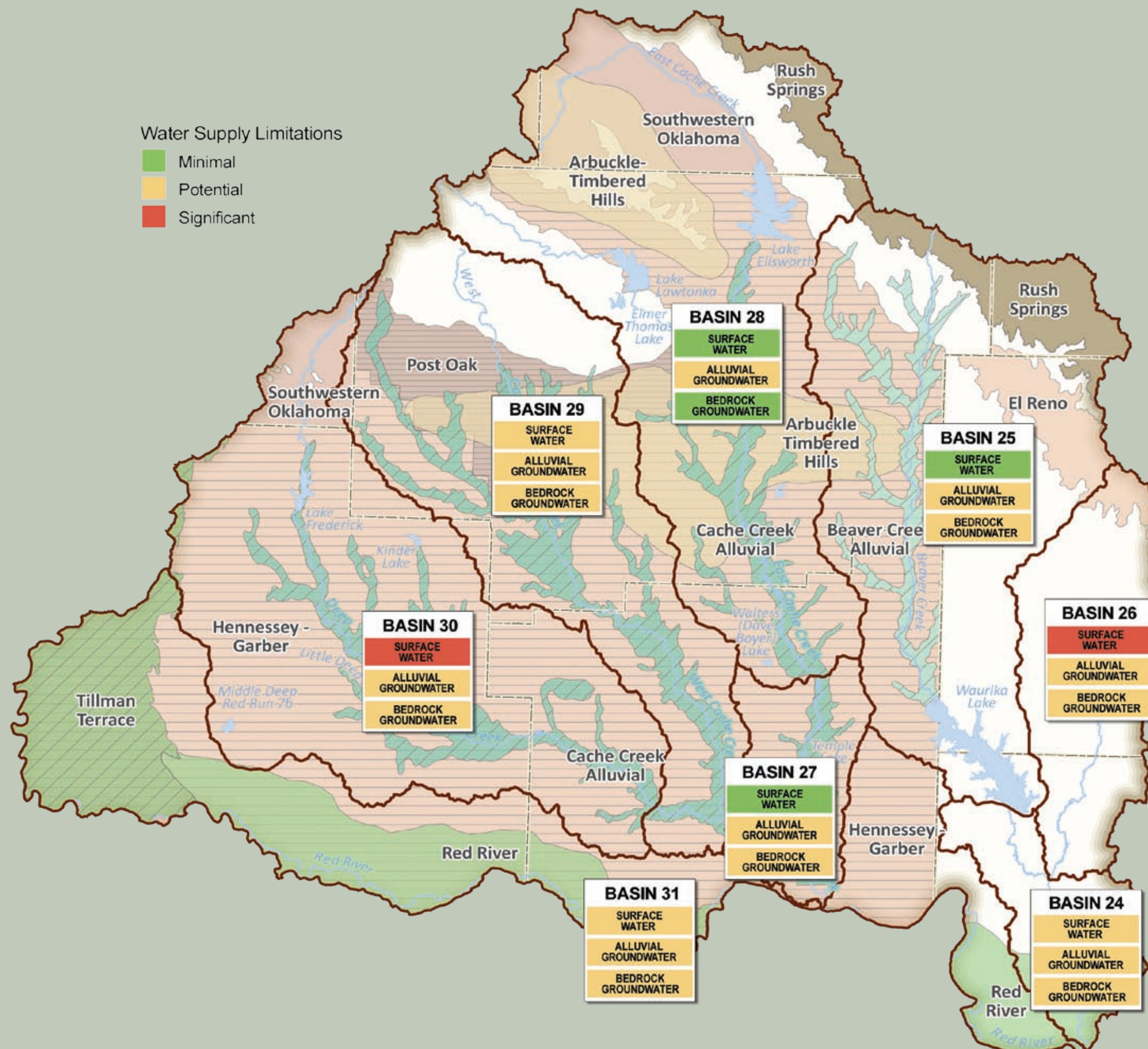
Water quality issues may constrain future Municipal and Industrial use (due to high fluoride levels) and Crop Irrigation use (due to high chloride levels) from portions of the Arbuckle-Timbered Hills aquifer.

The availability of water rights is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060.

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 Limitations
Beaver-Cache Region



Water Supply Options

To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local and existing out of basin supplies was assumed to continue in current (2010) proportions.

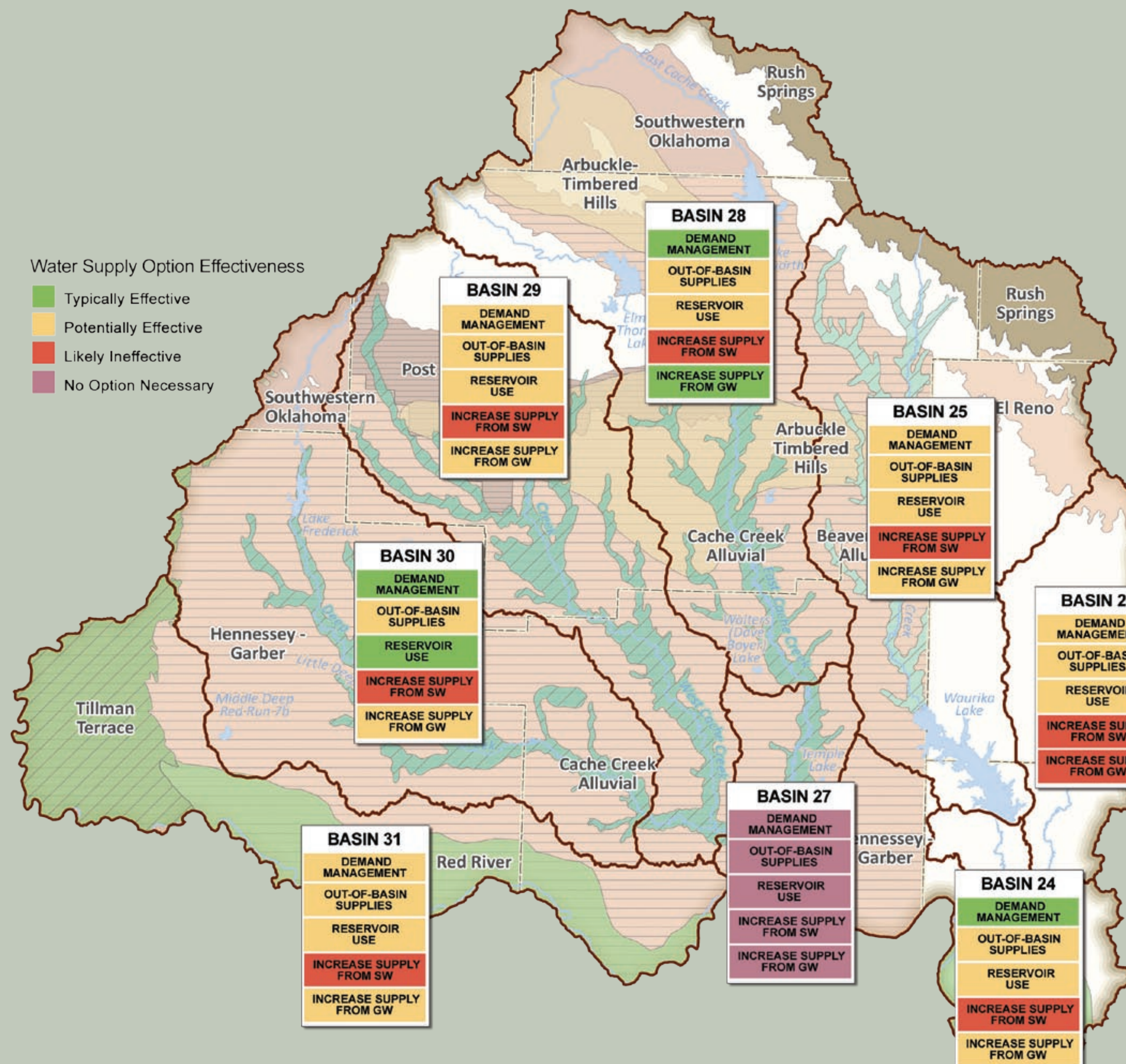
Existing major reservoirs are expected to be capable of supplying the majority of surface water demand in the Beaver-Cache region. Basins without access to major reservoirs are expected to experience physical surface water supply shortages (gaps) in the future. The demand in these basins is relatively small and broadly dispersed. Water conservation or emergency drought management practices can aid in reducing projected gaps or delaying the need for additional infrastructure. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state. Two potentially viable sites were identified in the OCWP Beaver-Cache Watershed Planning Region.

Due to extended dry periods, demand management measures alone will likely be insufficient to prevent gaps. New reservoirs at the basin outlet, typically holding less than 500 acre-feet (AF) of water, could enhance the dependability of surface water supplies in basins without a major reservoir (Basins 24, 26, 29, 30, and 31). Alternatively, interbasin transfer of water from existing major reservoirs or major aquifers could prevent gaps while minor aquifers could help domestic or small volume users meet future demands.

Depletions of groundwater storage are anticipated throughout the Beaver-Cache region, particularly during the summer. However, both bedrock and alluvial aquifer storage depletions are minimal compared to the amount of water in storage. Water rights are not expected to constrain the ability to meet local demand through 2060.

Users in portions of Basins 24, 25, and 26 currently utilize groundwater from non-delineated minor aquifers. These aquifers typically have low yields, and while providing a valuable source of water for domestic use, may not provide adequate supply for high-volume users. These users can reduce the potential of shortages through emergency demand management and conservation, new small reservoirs, or out-of-basin sources.

Water Supply Option Effectiveness
Beaver-Cache Region



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

Water Supply

Physical Water Availability

Surface Water Resources

Surface water has historically been the primary source of supply used to meet demand in the Beaver-Cache Region. The region's major streams include the Red River, Cache Creek, and Beaver Creek.

Water in the Red River mainstem (southern border of the Beaver-Cache region), which maintains substantial flows, is highly mineralized, 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 this analysis. 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 Red River Chloride Control Project by the U.S. Army Corps of Engineers (USACE) could reduce naturally occurring chloride levels in the Red River and its tributaries, thereby making it a more feasible source of future water supply.

Cache Creek, located in the central area of the region, consists of a short mainstem and three large tributaries: East Cache Creek (approximately 100 miles long), West Cache Creek (60 miles), and Deep Red Creek (90 miles). Downstream of its confluence with these tributaries, Cache Creek flows southwest to the Red River. Cache Creek and its tributaries are located in Basins 27, 28, 29, and 30.

Beaver Creek (80 miles long) originates in northwestern Comanche County and southwestern Grady County. Beaver Creek and its tributaries are located in Basins 24, 25, and 26.

Many streams in this region experience a wide range of flows, including both periodic no flow conditions and flooding events. Streamflow is not a dependable supply source for most purposes due to generally intermittent flow and poor water quality.

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. The largest is Waurika Lake, constructed on Beaver Creek by the USACE in 1977. Waurika Lake is unique in that the USACE was authorized to develop conveyance facilities as a part of the project. The USACE continues to direct flood control operations, but the Waurika Lake Master Conservancy District operates and maintains water supply facilities for its member cities of Comanche, Duncan, Lawton, Temple, and Walters.

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.

The City of Lawton impounds two large municipal lakes in the region: Lake Ellsworth, located on East Cache Creek in Comanche and Caddo Counties, and Lake Lawtonka, on Medicine Creek (tributary to East Cache Creek) near the slopes of Mount Scott in the Wichita Mountains of Comanche County. The reservoirs are owned and operated by Lawton for water supply, flood control, and recreation. Lake Lawtonka receives inflows from Lake Ellsworth to improve yields and maintain water levels. 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, agriculture, flood control, and recreation.

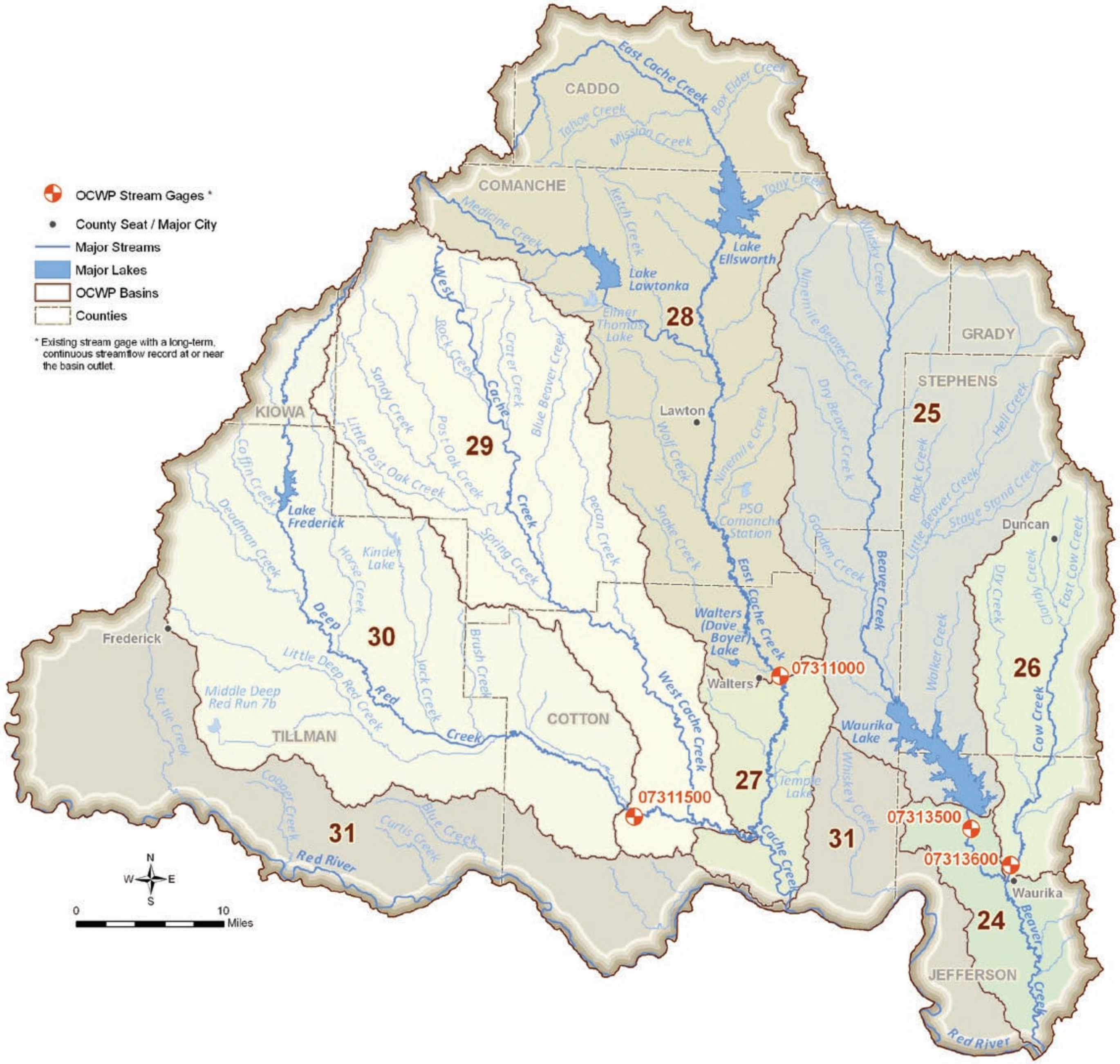
Reservoirs

Beaver-Cache 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
Dave Boyer	28	City of Walters	1936	WS, R	936	---	---	---	---	---	---	---	---
Ellsworth	28	City of Lawton	1962	WS, R	81,224	68,700	23,500	0	0	0	0	23,500	0
Frederick	30	City of Frederick	1974	WS, FC, R	9,663	---	---	0	0	0	0	3,400	---
Lawtonka	28	City of Lawton	1905	WS, R	55,171	64,000	23,500	0	0	0	0	23,500	0
Waurika	25	USACE	1977	FC, IR, WS, WQ, R, FW	203,100	151,400	40,549	16,200	5,041	0	0	44,806	784

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, FC = Flood Control, IR = Irrigation, WQ = Water Quality, FW = Fish & Wildlife, LF = Low Flow Regulation, N = Navigation
No known information is annotated as "---"

Surface Water Resources
Beaver-Cache Region



Reservoirs in the Beaver-Cache Region include Dave Boyer, Ellsworth, Frederick, Lawtonka, and Waurika. Reservoirs may serve multiple purposes, such as water supply, irrigation, recreation, hydroelectric power 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.

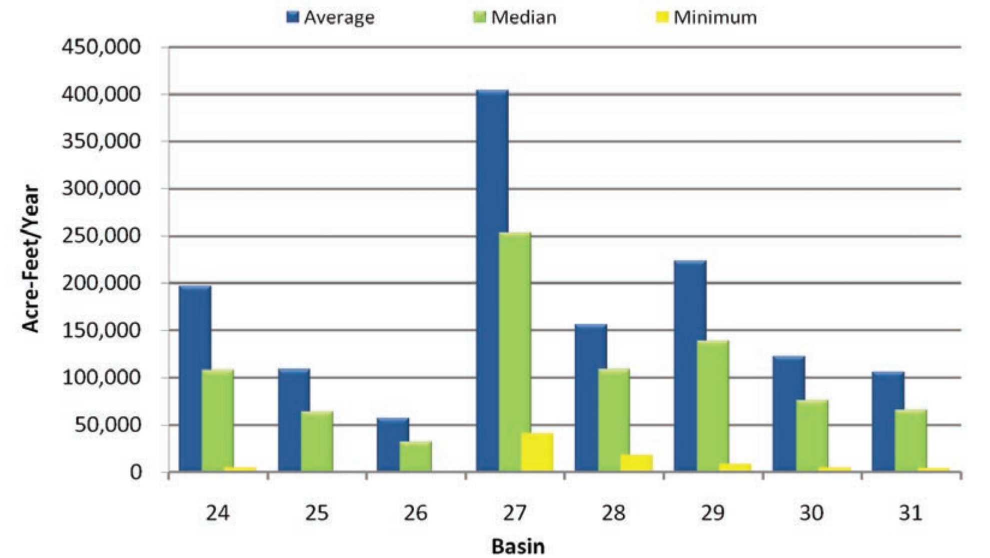
For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers,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



Surface water is the main source of supply in the Beaver-Cache Region. While the region's average physical surface water supply exceeds projected surface water demand in the region, localized or intermittent shortages can occur due to 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
Beaver-Cache Region

	Basins							
	24	25	26	27	28	29	30	31
Streamflow Statistic	AFY							
Average Annual Flow	195,300	107,000	57,000	399,300	151,000	222,900	122,200	105,800
Minimum Annual Flow	4,400	0	100	36,300	12,900	7,700	4,300	3,500

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

Groundwater Resources

Two major bedrock aquifers, the Arbuckle-Timbered Hills and Rush Springs, are present in the northern portion of the Beaver-Cache Region, and two major alluvial aquifers, the Tillman Terrace and Red River, are located in the southern portion of the region.

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

The Arbuckle-Timbered Hills aquifer underlies portions of Basins 25, 28, and 29, and consists predominantly of limestone and dolomite. The aquifer occurs in two areas: the Limestone Hills north of the Wichita Mountains, where the aquifer is exposed at land surface, and the Cache-Lawton area south of the Wichita Mountains, where the aquifer is buried under as much as 2,000 feet of younger rock. Availability of groundwater in the Limestone Hills is erratic because of faulting and folding. Most wells are 500 feet or deeper, and wells and springs yield as much as 100 gallons per minute (gpm). In the Cache-Lawton area, well depths range from 350 to more than 2,000 feet, and yields from 25 up to 600 gpm have been reported. Water from the Limestone Hills area is generally very hard; water from the Cache-Lawton area is generally soft. Fluoride concentrations from both areas generally exceed the drinking water standard, limiting use for public water supply. Water in parts of the Cache-Lawton area has high chloride concentrations, which may make the water unsuitable for irrigation.

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 use for drinking water. This aquifer underlies portions of Basins 25 and 28.

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

Both the Red River and Tillman Terrace alluvial aquifers consist of clay, sandy clay, sand, and gravel. The Red River aquifer, located in southern Tillman, Cotton, and Jefferson Counties, supplies water for municipal, irrigation, and domestic purposes. The average saturated thickness is estimated to be around 20-30 feet; however, little data are available concerning this aquifer and its potential as a major source of groundwater. The Red River aquifer is located in southern portions of Basins 24 and 31.

The Tillman Terrace aquifer, located in Tillman County, supplies large quantities of groundwater for irrigation purposes and smaller amounts for municipal and domestic use. The formation averages 70 feet in thickness with an average saturated thickness of about 23 feet. Wells in the aquifer produce 200 to 500 gpm. The water exhibits significant hardness and generally requires softening to address aesthetic issues for public water supply use. Nitrate concentrations in the aquifer often exceed drinking water standards, thereby limiting use for public water supply without significant treatment. The Tillman Terrace aquifer underlies portions of Basin 31.

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.

Minor bedrock aquifers in the region include the El Reno, Hennessey-Garber, Post Oak, and Southwestern Oklahoma. Minor alluvial aquifers include Beaver Creek and Cache-Creek. Minor aquifers may have a significant amount of water in storage and high recharge rates, but generally have lower well yields which may be insufficient for large volume users.

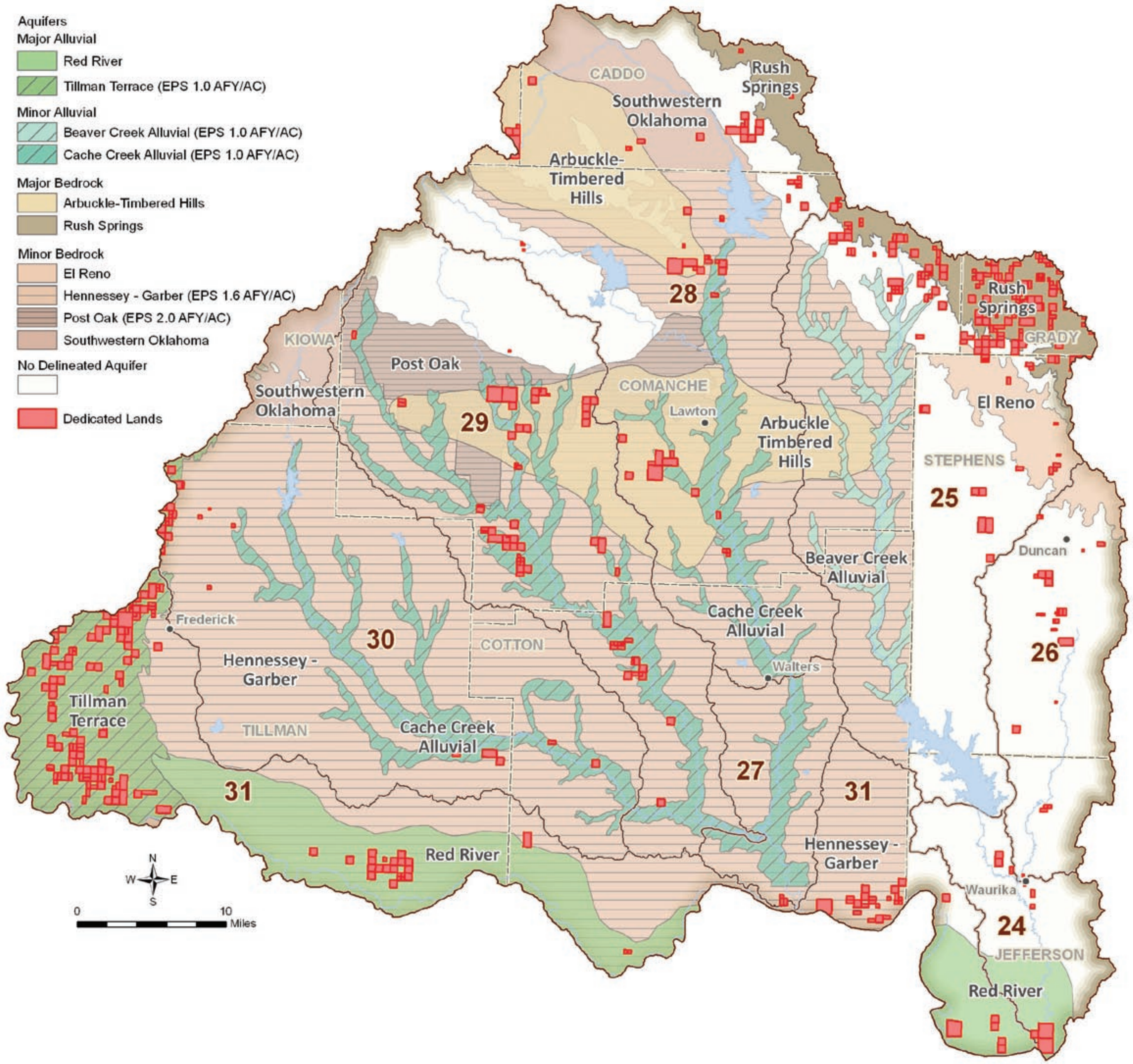
Groundwater Resources
Beaver-Cache Region

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
Arbuckle-Timbered Hills	Bedrock	Major	10%	0.3-0.6	5,300	883,000	temporary 2.0	429,800
Red River	Alluvial	Major	6%	2.5	6,900	287,000	temporary 2.0	254,100
Rush Springs	Bedrock	Major	3%	1.8	17,500	1,558,000	temporary 2.0	103,900
Tillman Terrace	Alluvial	Major	4%	2.9	11,900	598,000	1.0	68,200
Beaver Creek	Alluvial	Minor	2%	3.6	0	151,000	1.0	38,300
Cache Creek	Alluvial	Minor	9%	3.6	6,300	746,000	1.0	180,600
El Reno	Bedrock	Minor	2%	0.75	2,700	166,000	temporary 2.0	62,600
Hennessey-Garber	Bedrock	Minor	61%	2.7	3,500	5,579,000	1.6	2,024,400
Post Oak	Bedrock	Minor	5%	3.6	1,600	2,500,000	2.0	190,000
Southwestern Oklahoma	Bedrock	Minor	5%	2.25	0	293,000	temporary 2.0	217,100
Non-Delineated Groundwater Source	Alluvial	Minor			2,200			
Non-Delineated Groundwater Source	Bedrock	Minor			3,800			

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

Beaver-Cache Region



Major bedrock aquifers in the Beaver-Cache Region include Rush Springs and Arbuckle-Timbered Hills. Major alluvial aquifers in the region include Tillman Terrace and Red River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

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

In the Beaver-Cache Region, the Tillman Terrace aquifer's EPS is set at one acre-foot per year (AFY) per acre. For the Rush Springs, Arbuckle Timbered Hills, and Red River aquifers, temporary permits are issued, granting users two AFY per acre of land until the OWRB conducts hydrologic investigations and establishes the maximum annual yield of the basins.

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 groundwater available for new permits in all aquifers and surface water available for new permits in all basins in the Beaver-Cache region through 2060. However, there is substantially less surface water available for permits in Basins 25 and 26 than other basins in the region.

Surface Water Permit Availability

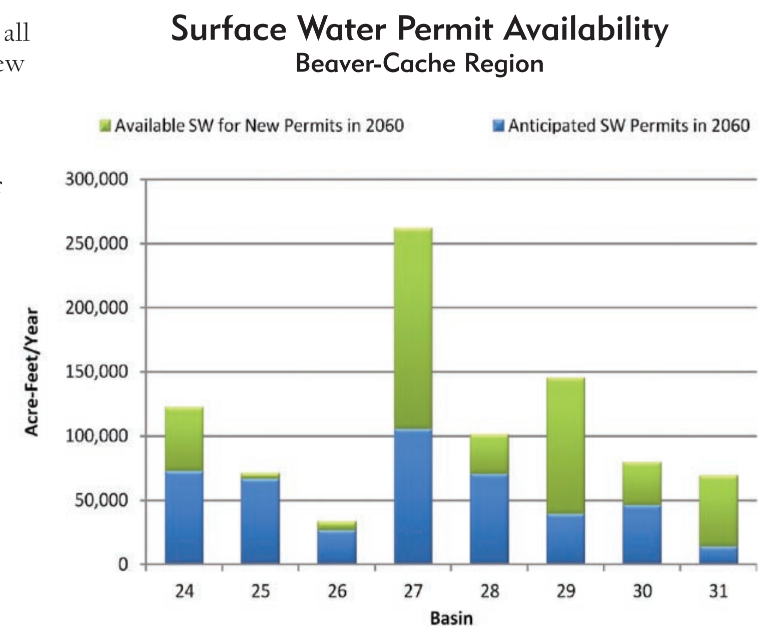
Oklahoma stream water laws are based on riparian and prior appropriation doctrines. Riparian rights to a reasonable use of water, in addition to domestic use, are not subject to permitting or oversight by the OWRB. An appropriative right to stream water is based on the prior appropriation doctrine, which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

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

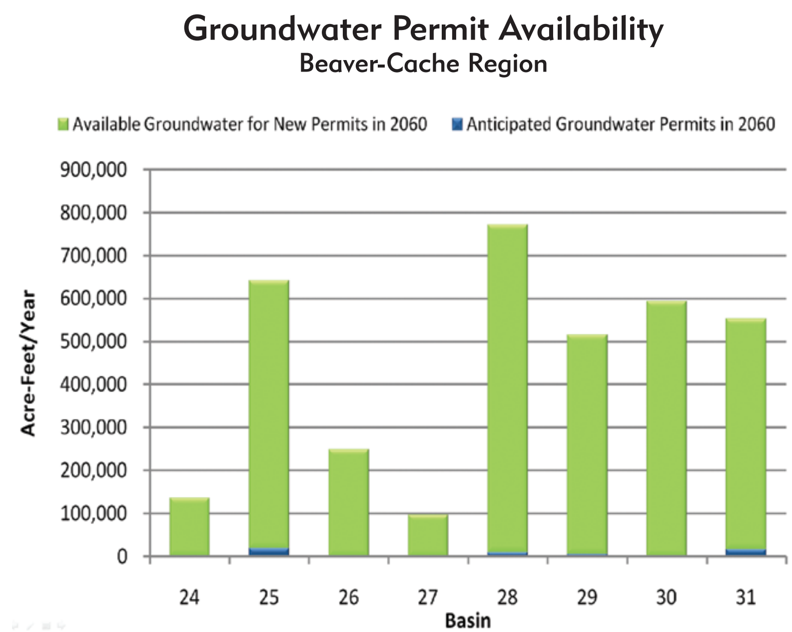
Groundwater Permit Availability

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

To calculate groundwater permit availability in 2060, the OCWP analysis determined the geographical area overlying all aquifers in each basin, utilized the respective EPS or temporary permit allocations, then applied current and future permit amounts.



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



Projections indicate that there will be groundwater available for new permits through 2060 in all aquifers in the Beaver-Cache region.

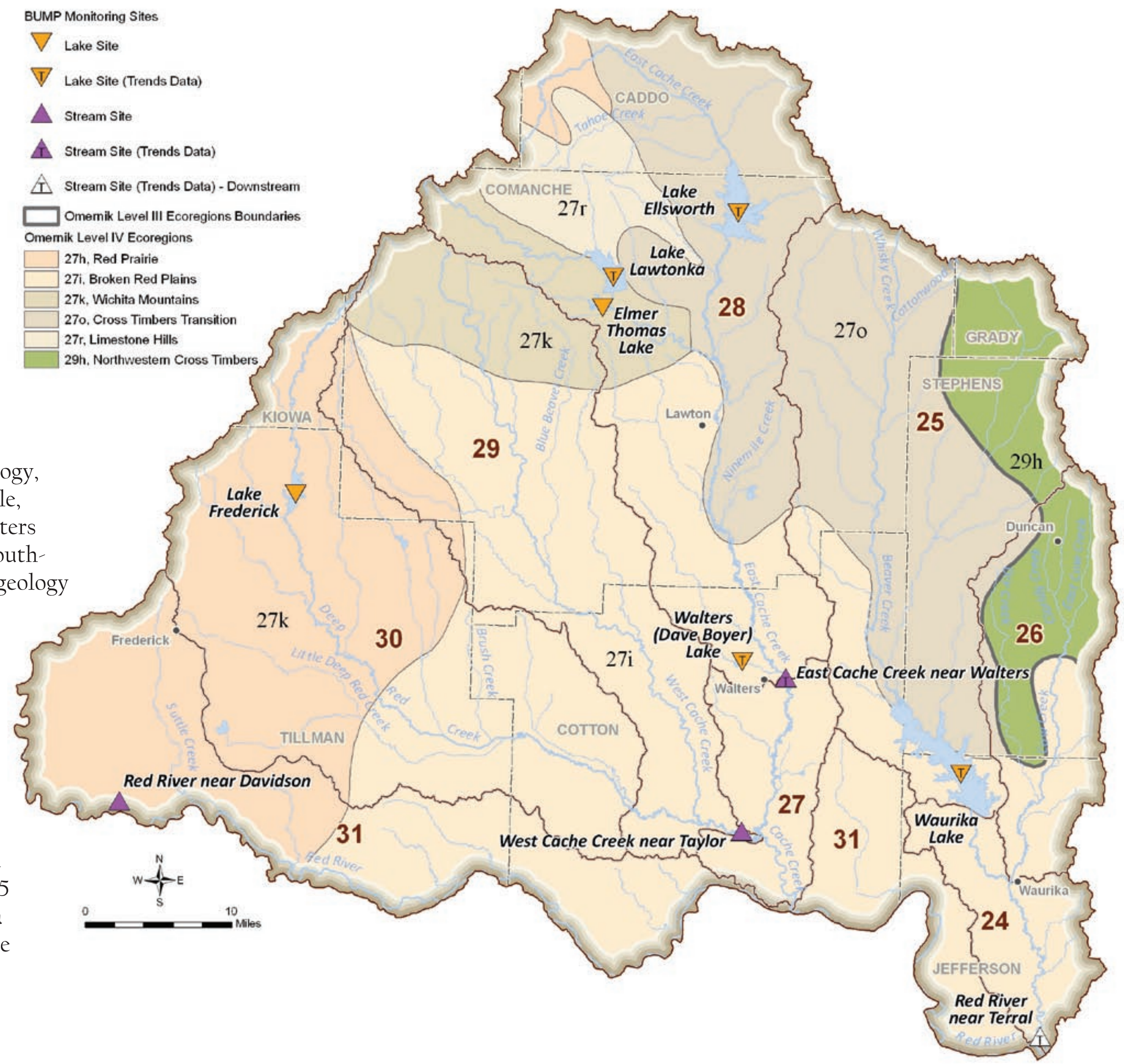
Water Quality

Water quality of the Beaver-Cache Watershed Planning Region is markedly different from north to south. Although wholly contained within the Central Great Plains ecoregion, the water quality differences are primarily due to dramatic geographical changes over a very small landmass. The northern third and much of the northeastern portion of the region is comprised of two distinct ecoregions, the Cross Timbers Transition and the Wichita Mountains, which is a mix of forested, irregular plains and steep highlands. Conversely, the southern and mostly western portion of the region is dominated by the Broken Red Plains ecoregion.

The Cross Timbers Transition runs from north to south over the eastern portion of the area. As its name denotes, the transitional area is a hybrid mix of rough plains, and the oak/elm forests that dominate much of the Cross Timbers ecoregion. Represented by the Lake Ellsworth and Lake Waurika watersheds, the transition is emblematic of the waters in the Central Great Plains, with more loose sediments, such as sand and silt, and typically higher salinity. Water clarity is poor to average, with an average turbidity of 25-40 NTU and Secchi depths of approximately 1.0-1.5 feet. Likewise, the water is neutral to slightly alkaline, with pH values ranging from 7.2-8.8 and an average hardness of approximately 200 parts per million (ppm). Waters are moderately saline, with conductivity ranging from approximately 380-550 microSiemens (uS). Lakes and streams are typically phosphorus limited and show moderate cultural eutrophication, which is indicative of higher than normal nutrient concentrations. Ecological diversity is higher and closely resembles the Cross Timbers ecoregion. It can be affected by habitat degradation and sedimentation/siltation.

Along the western edge of the transition in the north is the Wichita Mountains ecoregion, which may be the most ecologically diverse ecoregion of the Central Great Plains. Comprised mostly of steep mountains and rocky outcroppings, the Wichita Mountains also support thriving grasslands and dense scrub oak forests. Because of the native geology, the streams are a mixture of cobble, gravel, and sand and resemble waters found in the Arbuckle Uplift of south-central Oklahoma. Likewise, the geology also produces waters that have fair to excellent water clarity and, although slightly alkaline, comparatively low salinity. Characteristic watersheds include Lake Lawtonka and Lake Elmer Thomas. The lakes have good to excellent water clarity, with average turbidity values ranging from 2-8 NTU and Secchi depth readings from 3.5-5.5 feet. The water in Lake Lawtonka is slightly alkaline with an average pH of 8.1 and average hardness of 163.4 ppm. Conversely, with much less buffering capacity and an average hardness of less than 50 ppm, Lake Elmer Thomas has slightly acidic water with nearly 15% of all measured pH values of less than 6.5 units. Moreover, with

Ecoregions
Beaver-Cache Region



The Beaver-Cache region is comprised of several distinct ecoregions, as evidenced by its diverse geology and water quality, which ranges from excellent to poor.

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.

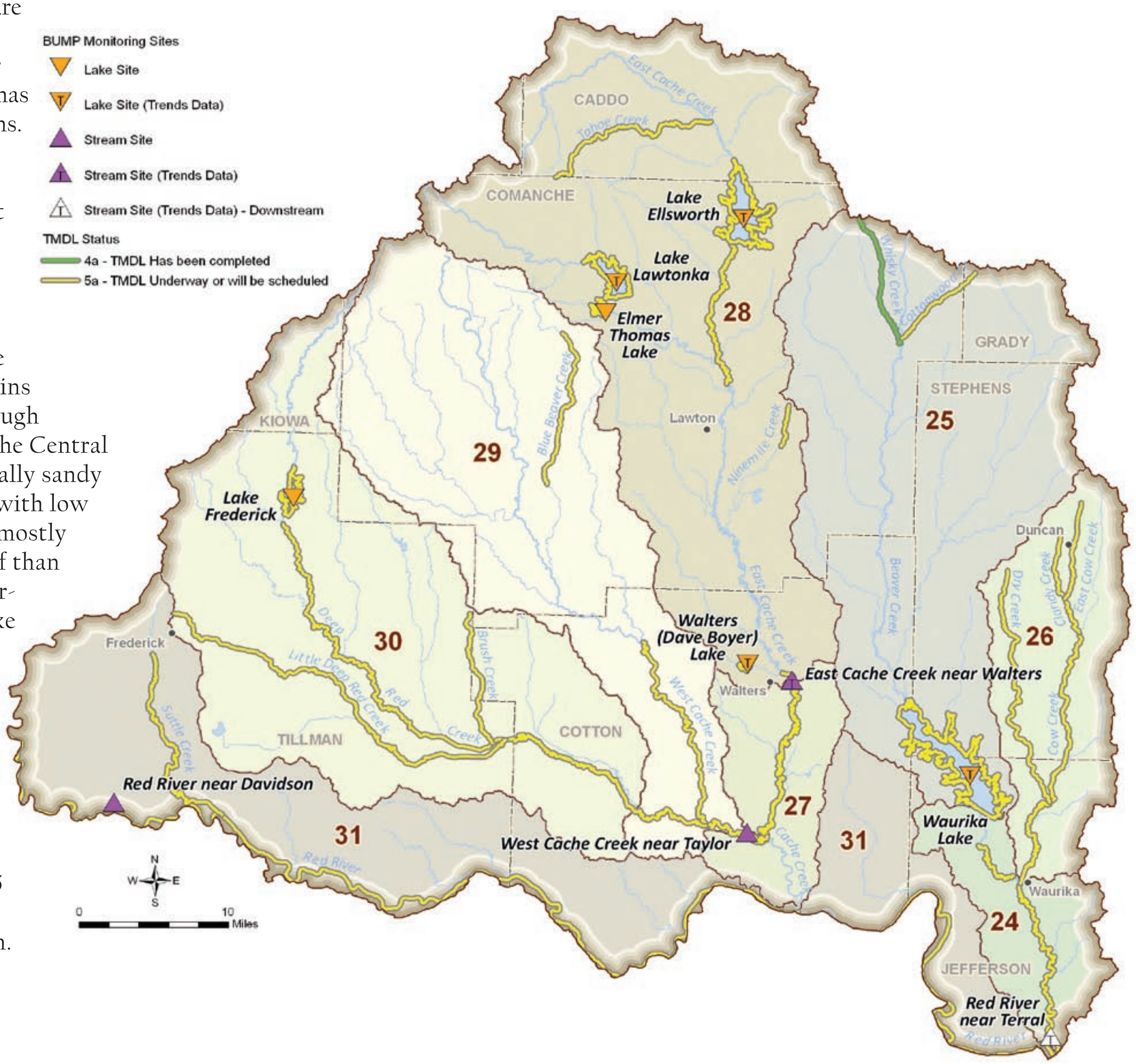
Hypereutrophic: Excessive primary productivity and excessive nutrients.

a conductivity average of 393.8 uS, Lawtonka resembles the salinity found in much of the southern Cross Timbers. However, Elmer Thomas is similar to waters of Southeastern Oklahoma with a mean conductivity of less than 85 uS. While both lakes are phosphorus limited, Lawtonka is moderately eutrophic, while Elmer Thomas remains oligotrophic and has much lower nutrient concentrations. Ecological diversity is higher than anywhere in the Central Great Plains. It can be affected by habitat degradation and sedimentation/ siltation.

Much of the central and mostly western portions of the region are dominated by the Broken Red Plains and Red Prairie ecoregions. Although still more irregular than most of the Central Great Plains, it has characteristically sandy soils and is grassland dominated with low density scrub forests. Creeks are mostly sand and silt with much less relief than the northern portion of the Beaver-Cache region. Reservoirs, like Lake Frederick and Lake Dave Boyer, are similar to reservoirs in the Cross Timbers Transition. They normally demonstrate poor water clarity with turbidity ranging on average from 50-100 NTU, and Secchi depths less than one foot. Water is typically alkaline with pH ranging from 7.5 to 8.5 units, and hardness values averaging approximately 200 ppm. Likewise, they are moderately saline with conductivity ranges between 250-650 uS. Additionally, these lakes are eutrophic and phosphorus limited. Conversely, surface water quality in rivers and streams are much more characteristic of water quality in the Central Great Plains. East and West Cache Creeks drain much of the

Water Quality Standards Implementation

Beaver-Cache Region



A 1997 demonstration project on the Beaver and Whiskey Creek watersheds by the Oklahoma Conservation Commission showed that additional non-point source restoration programs would be beneficial.

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

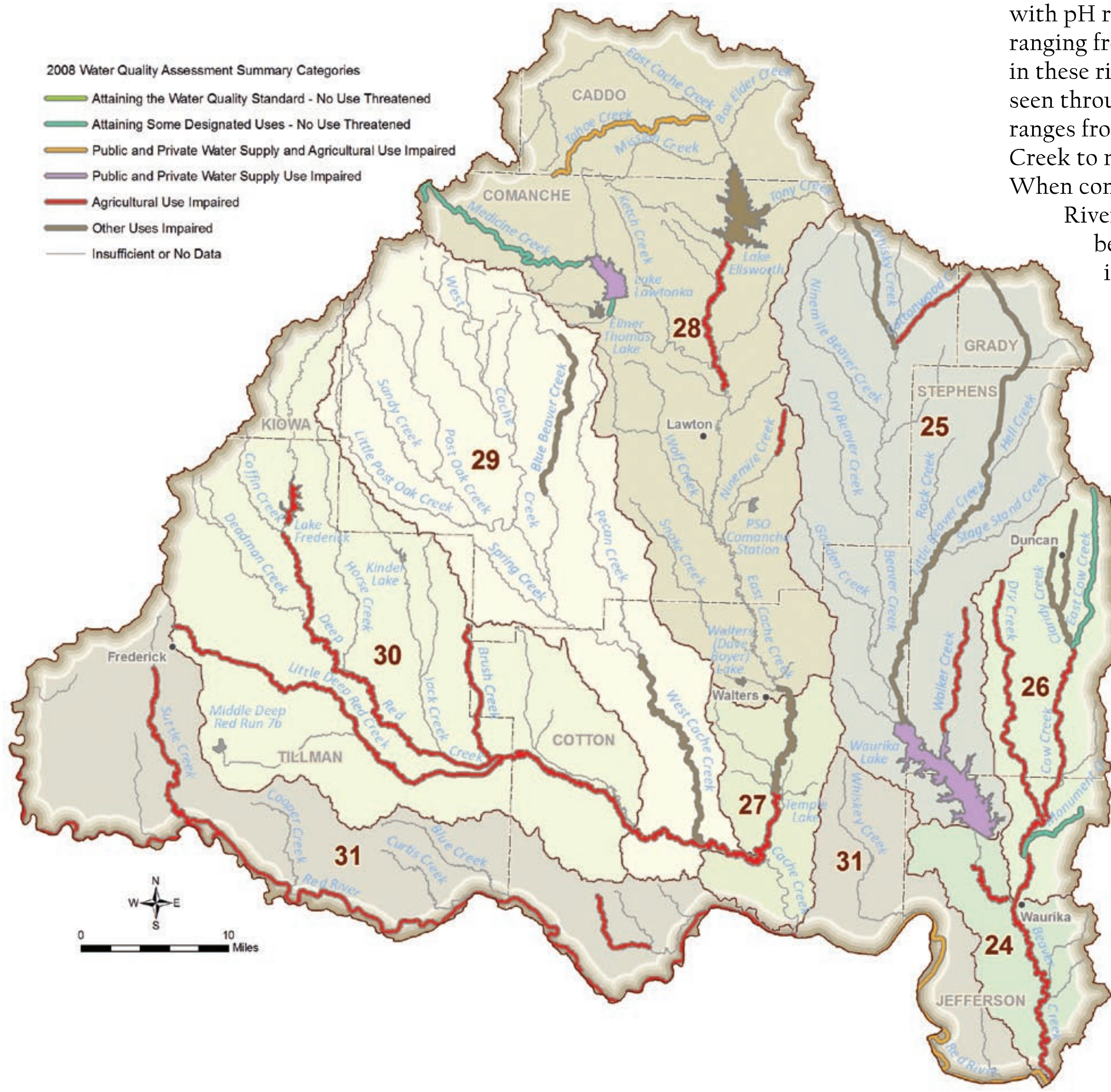
A waterbody is considered to be impaired when its quality does not meet the standards prescribed for its beneficial uses in the Oklahoma Water Quality Standards (OWQS). For example, impairment of the Public and Private Water Supply beneficial use means the use of the waterbody as a drinking water supply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

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

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

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

Water Quality Impairments
Beaver-Cache Region



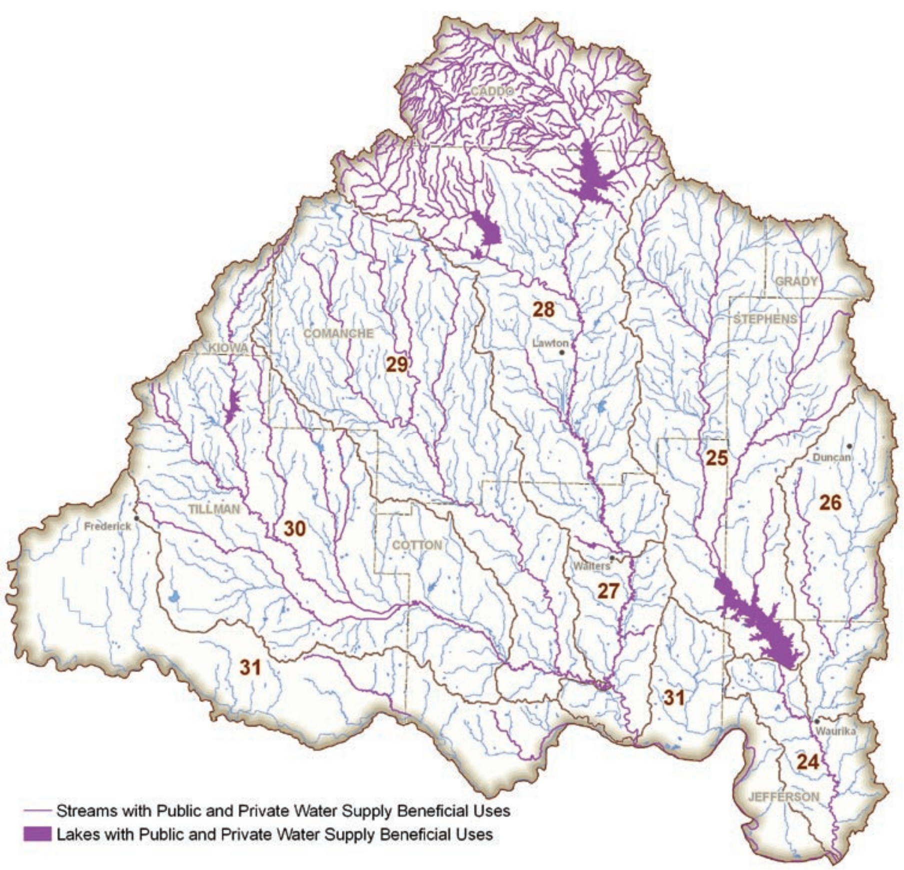
Regional water quality impairments are based on the 2008 Integrated Water Quality Assessment Report. Natural elevated levels of salinity in this region produce agricultural use impacts and make several streams unsuitable for use as public water supply. Waurika and Lawtonka lakes, which are both designated as Sensitive Water Supply (SWS) sources, are impaired due to high levels of chlorophyll-a.

central and western portions of the Broken Red Plains and in several ways resemble the reservoirs of the area. Water clarity is typically poor to fair with mean turbidities ranging from 31-48 NTU, and they are slightly alkaline with pH ranging from 7.4-8.5 and hardness ranging from 220-305 ppm. However, salinity in these rivers begins to approximate that seen throughout the plains. The conductivity ranges from a mean of 700 uS on East Cache Creek to near 1160 uS on West Cache Creek. When considering the mainstem of the Red River, the water quality differences become even starker. Water clarity is very poor with an average of 120 NTU. The Red River is moderately alkaline with a pH average of 8.2 but a maximum value of 9.0 units, and a hardness average of 860 ppm. Salinity shows a strong influence from the upper Red River ecoregions as conductivity averages approximately 4,860 uS. Like the reservoirs, rivers and streams are phosphorus limited and eutrophic, but phosphorus and nitrogen values are much higher, with an average of 1.149 ppm and 2.328 ppm, respectively, along East Cache Creek. Lastly, the area is much less diverse ecologically, and is more indicative of plains streams. Habitat degradation, flow modification, and sedimentation/siltation can decrease diversity.

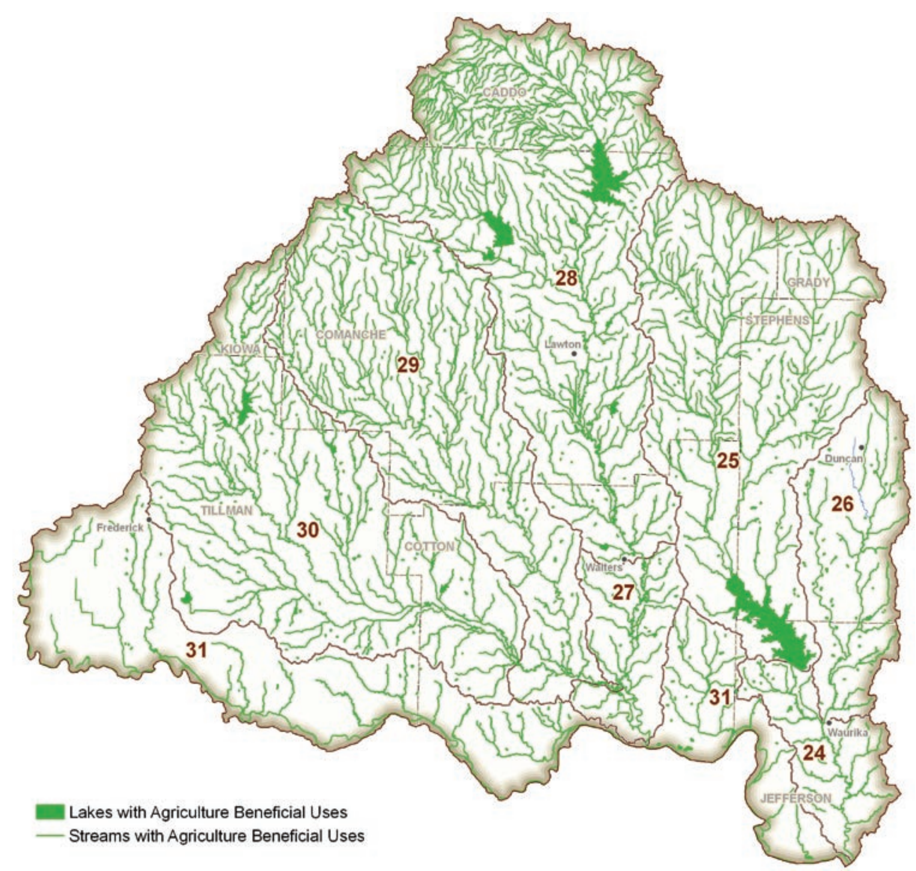
Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed, and data are available from municipal authorities and other sources. As was stated earlier in this document, the Beaver-Cache region is underlain by several major and minor bedrock and alluvial aquifers. In most southwest Oklahoma alluvial aquifers, water quality is good, and except for hardness and localized nitrate problems, the water is appropriate for domestic, irrigation, industrial and municipal use. Throughout much of southwestern Oklahoma, 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.

Major bedrock aquifers in the region include the Rush Springs Sandstone and Arbuckle-Timbered Hills Group. The Rush Springs Sandstone extends into the northeastern most portion of the region. Although comparatively hard, most of the water derived from it is suitable for domestic, municipal, irrigation and industrial use, with total dissolved solids (TDS) values generally less than 500 ppm. However, chloride, sulfate, and nitrate concentrations exceed drinking water standards in some areas. The Arbuckle-Timbered Hills Group occurs in two areas: in the Limestone Hills north of the Wichita Mountains and in the Cache-Lawton area south of the Wichita Mountains. Water from the Limestone Hills area sometimes contains hydrogen sulfide gas and is very hard, calcium bicarbonate water, with total dissolved solids ranging from 195 to 940 ppm. Water from the Cache-Lawton area is soft and of a sodium-chloride type with total dissolved solids ranging from 279 to 6,380 ppm. Where permeability is high, water in the Arbuckle-Timbered Hills Group may be suitable for industrial use. Because fluoride concentrations generally range from 1.6 to 17 ppm and exceed drinking water standards, public water supply use is limited.

Surface Waters with Designated Beneficial Use for Public/Private Water Supply
Beaver-Cache Region



Surface Waters with Designated Beneficial Use for Agriculture
Beaver-Cache 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.

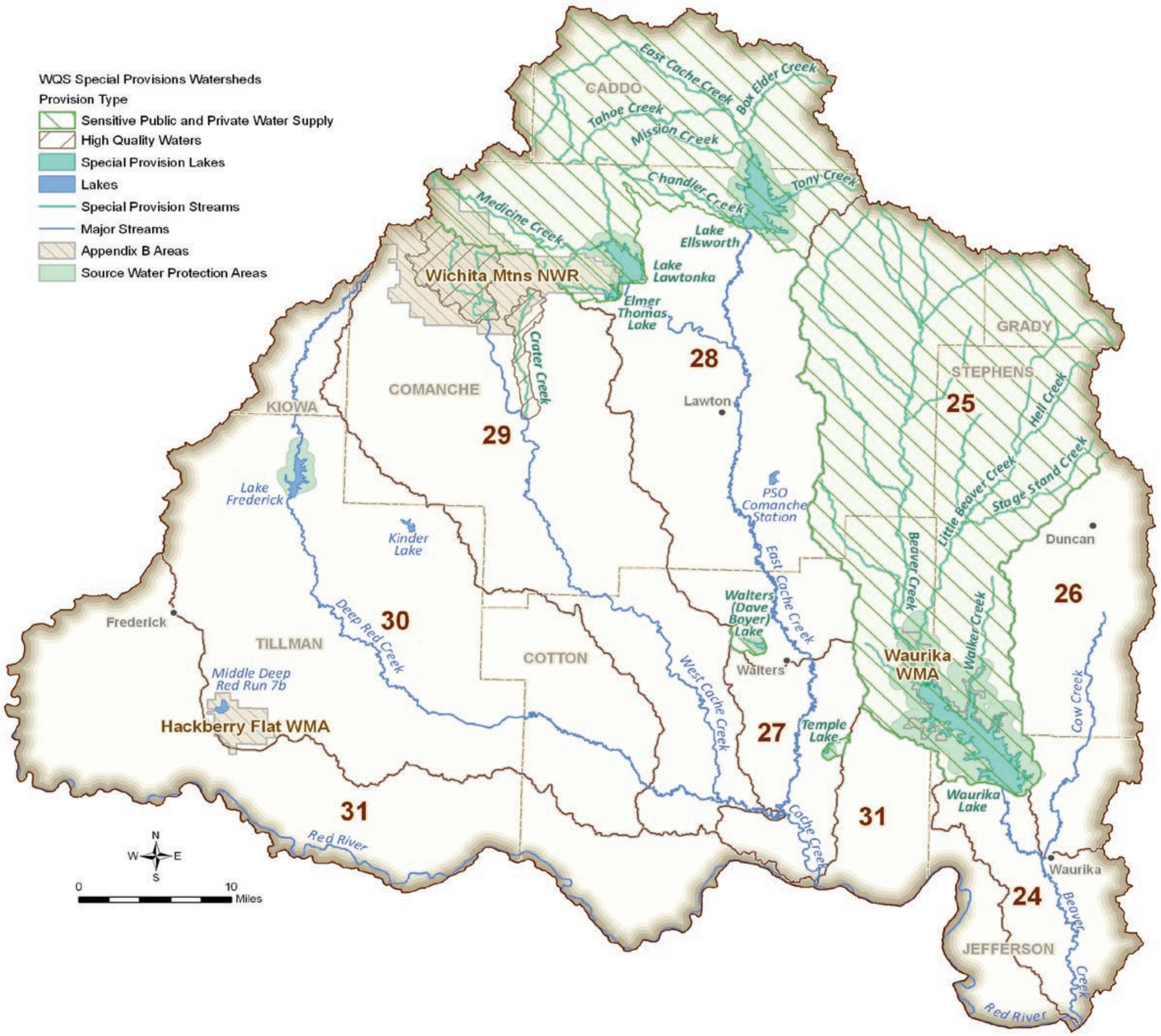
The **Sensitive Water Supplies (SWS)** designation applies to public and private water supplies possessing conditions making them more susceptible to pollution events, thus requiring additional protection. This designation restricts point source discharges in the watershed and institutes a 10 μg/L (micrograms 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.

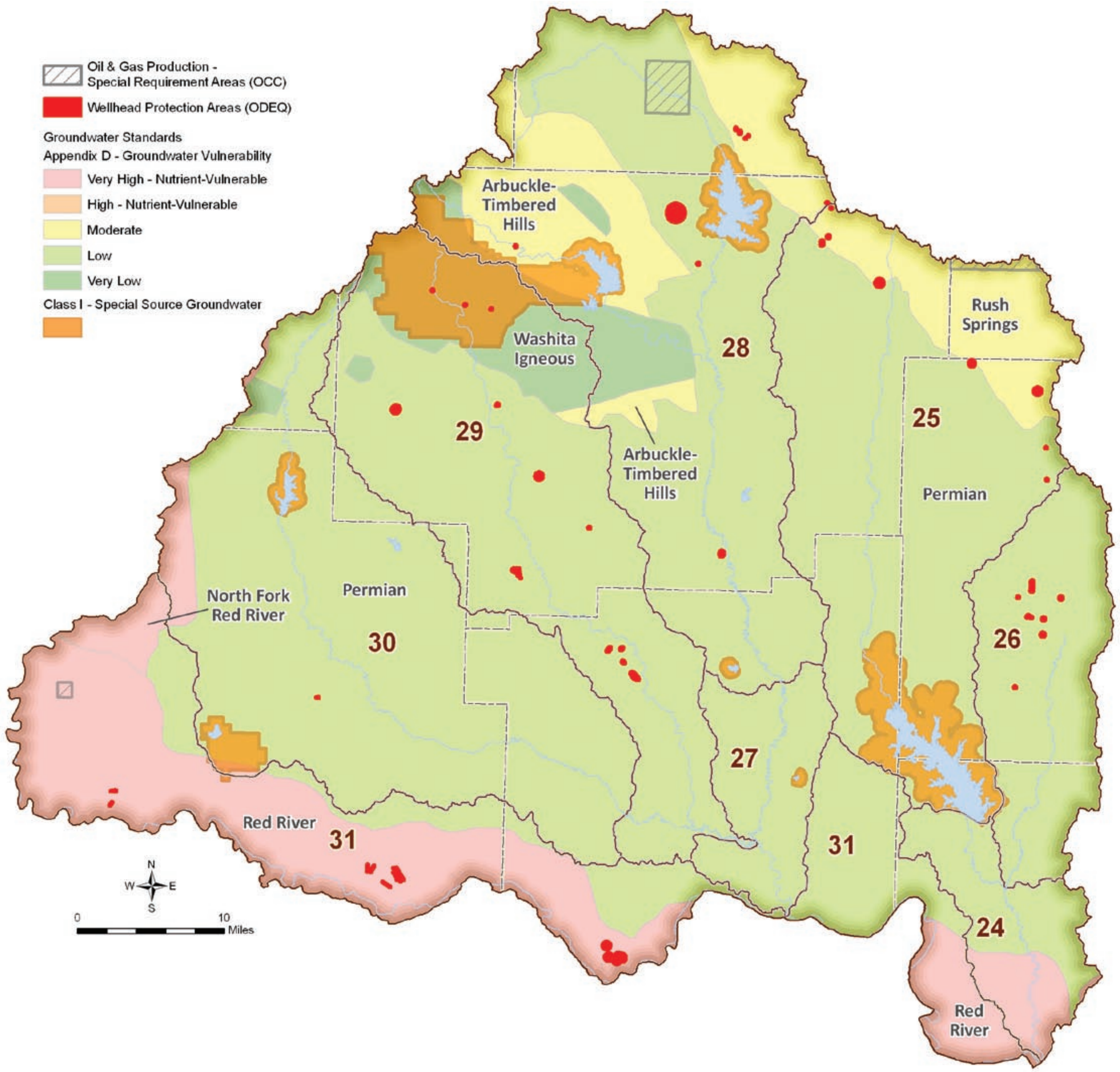
Nutrient Limited Watersheds are those containing a waterbody with a designated beneficial use that is adversely affected by excess nutrients.

Surface Water Protection Areas
Beaver-Cache Region



Lake Frederick, a public water supply reservoir, does not have a SWS designation, which could provide protection from new or increased loading from point sources in the watershed and provide limits for algae (chlorophyll-a) that can cause taste and odor problems and increased treatment costs.

Groundwater Protection Areas
Beaver-Cache Region



Various types of protection are in place to prevent degradation of groundwater based upon OWRB vulnerability modeling. The Red River alluvial aquifer has been identified by the OWRB as highly vulnerable but currently lacks protection to prevent degradation.

Groundwater Protection

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

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

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

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

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

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

NOTE: Although the State of Oklahoma has a mature and successful surface water quality monitoring program, no comprehensive approach or plan to monitor the quality of the state's groundwater resources has been developed.

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

Beaver-Cache Region

Parameter	Lake Ellsworth (1994-2009)	Lake Lawtonka (1998-2009)	Walters Lake (1995-2008)	Waurika Lake (1996-2008)
Chlorophyll-a (mg/m3)	↑	↑	↑	NT
Conductivity (us/cm)	NT	↑	↑	NT
Total Nitrogen (mg/L)	↑	↑	NT	↑
Total Phosphorus (mg/L)	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 trends both chlorophyll-a and total nitrogen on several reservoirs
- Significant upward trend in conductivity at both Lawtonka and Walters

Stream Water Quality Trends

Beaver-Cache Region

Parameter	Red River near Terral, OK: All Data Trend (1967-1995, 1998-2009)[1]	Red River near Terral, OK: Recent Trend (1998-2009)	East Cache Creek near Walters, OK: All Data Trend (1969-1993, 1998-2009)[1]	East Cache Creek near Walters, OK: Recent Trend (1998-2009)
Conductivity (us/cm)	↑	NT	↑	↑
Total Nitrogen (mg/L)	↓	NT	↓	↑
Total Phosphorus (mg/L)	↓	NT	↓	↑
Turbidity (NTU)	↑	↓	↑	↓

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 conductivity and nutrients on East Cache Creek
- Significant increase in turbidity over the entire period of record at all stations

Water Demand

The Beaver-Cache Region's water needs account for about 2% of the total statewide demand. Regional demand is projected to increase by 27% (12,000 AFY) from 2010 to 2060. The majority of demand and largest growth in demand over this period will be in the Municipal and Industrial and Crop Irrigation sectors.

Municipal and Industrial (M&I) demand is projected to account for approximately 51% of the region's 2060 demand. Currently, 89% of the demand from this sector is supplied by surface water, 3% by alluvial groundwater, and 8% by bedrock groundwater.

Crop Irrigation demand is projected to account for 28% of the 2060 demand. Currently, 25% of the demand from this sector is supplied by surface water, 48% by alluvial groundwater, and 27% by bedrock groundwater. Predominant irrigated crops in the Beaver-Cache Region include cotton, pasture grasses, and wheat.

Thermoelectric Power demand is projected to account for 8% of the 2060 demand. The Public Service Company of Oklahoma's Comanche Plant, which is supplied by surface water, is a large user of water for thermoelectric power generation in the region.

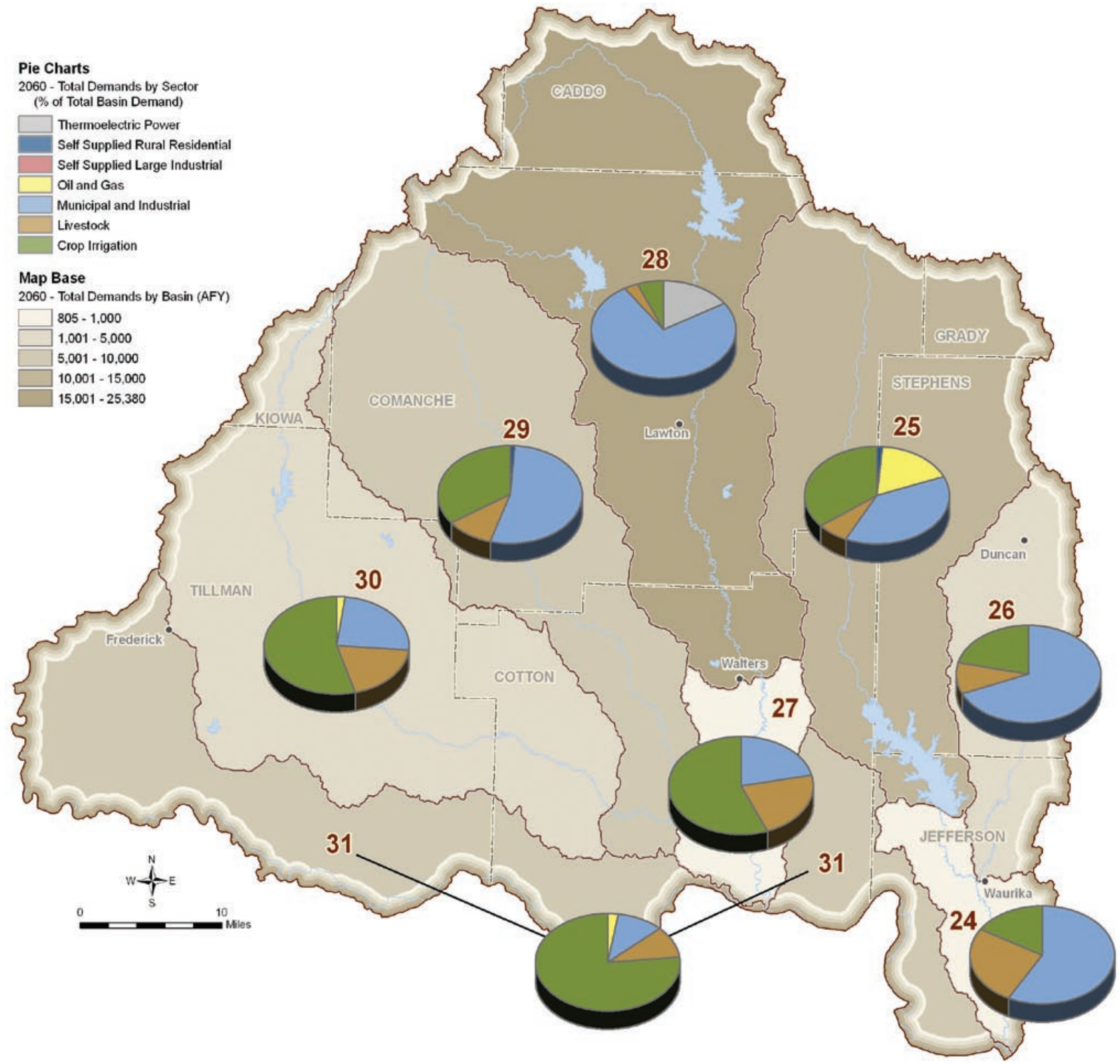
Livestock demand is projected to account for 7% of the 2060 demand. Currently, 35% of the demand for this sector is supplied by surface water, 29% by alluvial groundwater, and 36% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production.

Oil and Gas (O&G) demand is projected to account for 4% of the 2060 demand. Currently, 78% of the demand for this sector is supplied by surface water, 5% by alluvial groundwater, and 17% by bedrock groundwater.

Self-Supplied Residential (SSR) demand is projected to account for approximately 1% of the 2060 demand. Currently, 89% of the demand from this sector is supplied by alluvial groundwater and 11% by bedrock groundwater.

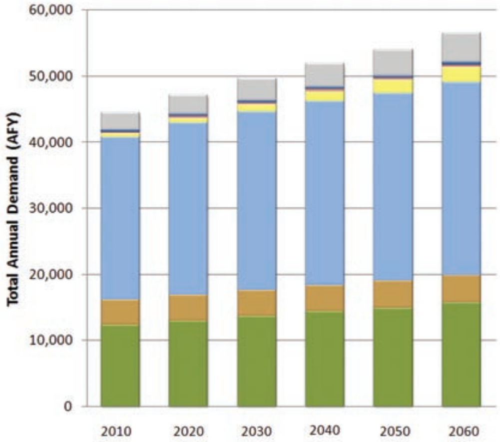
Self-Supplied Industrial demand is projected to account for less than 1% of the 2060 demand. Demand for this sector is supplied by surface water.

Total 2060 Water Demand by Sector and Basin
(Percent of Total Basin Demand)
Beaver-Cache Region

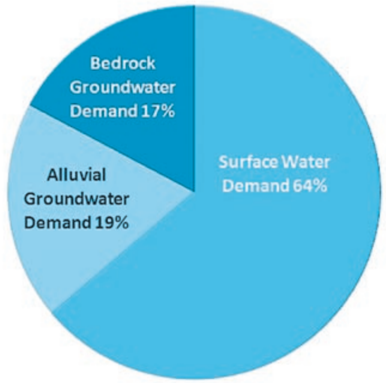


Municipal and Industrial demand is expected to remain the largest sector in the region, accounting for 51% of the projected total regional demand in 2060.

Total Water Demand by Sector
Beaver-Cache Region



Supply Sources Used to Meet Current Demand (2010)
Beaver-Cache Region



Water needs in the Beaver-Cache Region account for about 2% of the total statewide demand. Regional demand is projected to increase by 27% (11,970 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
Beaver-Cache Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	12,390	3,910	24,600	550	200	370	2,570	44,590
2020	13,090	3,950	25,980	810	200	400	2,860	47,290
2030	13,780	4,000	26,970	1,120	200	410	3,190	49,670
2040	14,480	4,040	27,780	1,470	210	430	3,560	51,970
2050	15,010	4,090	28,480	1,890	210	440	3,980	54,090
2060	15,860	4,140	29,110	2,350	220	450	4,440	56,560

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 use), 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 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 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% 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 Beaver-Cache Region includes 33 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 Lawton, Duncan, Caddo County Rural Water District (RWD) 3, Frederick, and Jefferson County Consolidated RWD 1. These five systems provide service for more than 75% of the population served by public water providers in the region.

Demand upon public water systems, which comprises the majority of the OCWP's Municipal and Industrial water demand sector, was 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 demand does 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

Beaver-Cache Region

Providers	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Planning Horizon					
				2010	2020	2030	2040	2050	2060
APACHE	OK2000806	Caddo	111	1,618	1,686	1,735	1,784	1,843	1,892
CACHE	OK2001607	Comanche	148	2,422	2,584	2,726	2,840	2,926	2,992
CHATTANOOGA PWS	OK2001608	Comanche	60	555	604	628	652	676	688
COMANCHE CO RWD #1	OK3001602	Comanche	179	2,858	3,053	3,220	3,350	3,452	3,536
COMANCHE CO RWD #2	OK2001604	Comanche	82	701	749	790	822	847	867
COMANCHE CO RWD #3	OK2001602	Comanche	80	806	861	909	945	974	998
COMANCHE CO RWD #4	OK3001654	Comanche	109	3,572	3,816	4,026	4,187	4,315	4,419
COMANCHE PUBLIC WORKS	OK1011101	Stephens	253	1,700	1,711	1,733	1,755	1,777	1,821
COTTON CO RWD #1	OK3001702	Cotton	116	607	615	624	632	652	660
COTTON CO RWD #2	OK2001702	Cotton	140	2,023	2,051	2,079	2,107	2,173	2,201
DAVIDSON	OK2007104	Tillman	270	150	154	158	162	166	170
DEVOL	OK3001701	Cotton	250	150	150	150	150	160	160
DUNCAN	OK1010809	Stephens	198	22,500	22,762	22,973	23,235	23,607	24,070
ELGIN PWS	OK2001610	Comanche	99	1,528	1,634	1,716	1,787	1,834	1,881
FAXON	OK3001675	Comanche	97	134	144	153	163	163	172
FLETCHER	OK2001612	Comanche	87	1,043	1,109	1,175	1,223	1,261	1,289
FREDERICK	OK1011401	Tillman	245	5,300	5,415	5,531	5,646	5,762	5,935
GERONIMO	OK3001680	Comanche	72	976	1,042	1,099	1,147	1,175	1,203
GRANDFIELD	OK2007103	Tillman	140	1,140	1,161	1,192	1,213	1,244	1,275
HOLLISTER	OK2007102	Tillman	64	60	60	60	60	60	60
INDIAHOMA	OK2001609	Comanche	57	355	382	400	418	426	435
JEFFERSON CO CONS RWD #1	OK3003401	Jefferson	197	4,146	4,213	4,280	4,343	4,469	4,595
LAWTON	OK1011303	Comanche	181	110,957	118,723	124,436	128,881	132,372	135,224
MANITOU	OK3007101	Tillman	196	286	286	296	306	306	317
MEDICINE PARK	OK3001603	Comanche	122	376	404	423	441	451	460
RYAN	OK3003405	Jefferson	214	894	904	915	925	956	986
STEPHENS CO RWD #3 (MERIDIAN)	OK2006905	Stephens	75	1,610	1,629	1,644	1,663	1,690	1,722
STERLING PWA	OK2001601	Comanche	105	779	827	874	912	941	960
TEMPLE	OK1011306	Cotton	98	1,152	1,172	1,192	1,213	1,243	1,263
TILLMAN CO RWD #1	OK2007107	Tillman	97	1,500	1,532	1,564	1,596	1,628	1,676
WALTERS	OK1011305	Cotton	107	2,760	2,802	2,843	2,885	2,968	3,010
WAURIKA LAKE MCD (Wholesaler Only)	None	Jefferson	0	0	0	0	0	0	0
WAURIKA PWA	OK1011201	Jefferson	295	2,200	2,234	2,269	2,303	2,372	2,441

1 SDWIS - Safe Drinking Water Information System

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

Projections of Retail Water Demand

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

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

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

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

Public Water Provider Demand Forecast
Beaver-Cache Region

Providers	SDWIS ID[1]	County	Retail Demand Including System Loss					
			2010	2020	2030	2040	2050	2060
			AFY					
APACHE	OK2000806	Caddo	202	210	216	222	230	236
CACHE	OK2001607	Comanche	402	428	452	471	485	496
CHATTANOOGA PWS	OK2001608	Comanche	37	41	42	44	46	46
COMANCHE CO RWD #1	OK3001602	Comanche	572	611	644	670	690	707
COMANCHE CO RWD #2	OK2001604	Comanche	64	69	73	75	78	80
COMANCHE CO RWD #3	OK2001602	Comanche	72	77	81	85	87	89
COMANCHE CO RWD #4	OK3001654	Comanche	435	464	490	509	525	538
COMANCHE PUBLIC WORKS	OK1011101	Stephens	482	485	491	497	504	516
COTTON CO RWD #1	OK3001702	Cotton	79	80	81	82	85	86
COTTON CO RWD #2	OK2001702	Cotton	317	322	326	330	341	345
DAVIDSON	OK2007104	Tillman	45	47	48	49	50	51
DEVOL	OK3001701	Cotton	42	42	42	42	45	45
DUNCAN	OK1010809	Stephens	4,998	5,056	5,103	5,161	5,244	5,347
ELGIN PWS	OK2001610	Comanche	170	182	191	199	204	209
FAXON	OK3001675	Comanche	15	16	17	18	18	19
FLETCHER	OK2001612	Comanche	101	108	114	119	123	125
FREDERICK	OK1011401	Tillman	1,456	1,488	1,520	1,551	1,583	1,631
GERONIMO	OK3001680	Comanche	79	84	89	92	95	97
GRANDFIELD	OK2007103	Tillman	179	182	187	191	196	200
HOLLISTER	OK2007102	Tillman	4	4	4	4	4	4
INDIAHOMA	OK2001609	Comanche	23	24	26	27	27	28
JEFFERSON CO CONS RWD #1	OK3003401	Jefferson	915	930	945	958	986	1,014
LAWTON	OK1011303	Comanche	22,461	24,033	25,190	26,089	26,796	27,373
MANITOU	OK3007101	Tillman	63	63	65	67	67	69
MEDICINE PARK	OK3001603	Comanche	51	55	58	60	61	63
RYAN	OK3003405	Jefferson	214	217	219	222	229	236
STEPHENS CO RWD #3 (MERIDIAN)	OK2006905	Stephens	134	136	137	139	141	144
STERLING PWA	OK2001601	Comanche	92	97	103	107	111	113
TEMPLE	OK1011306	Cotton	126	128	131	133	136	138
TILLMAN CO RWD #1	OK2007107	Tillman	164	167	171	174	177	183
WALTERS	OK1011305	Cotton	332	337	342	347	357	362
WAURIKA LAKE MCD (Wholesaler Only)	None	Jefferson	0	0	0	0	0	0
WAURIKA PWA	OK1011201	Jefferson	728	739	751	762	785	808

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers
Beaver-Cache 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
COMANCHE CO RWD #1	OK3001602				Lawton	O	T
COMANCHE CO RWD #2	OK2001604				Lawton	E	T
COMANCHE CO RWD #3	OK2001602				Lawton Stephens Co RWD #5 Walters	O E O	T T T
COMANCHE CO RWD #4	OK3001654	Indiahoma	O	T	Snyder	O	T
COMANCHE PUBLIC WORKS	OK1011101	Stephens Co RWD #3 (Meridian) Jefferson Co Cons RWD #1	O O	T R	Waurika Lake MCD	O	R
COTTON CO RWD #1	OK3001702				Grandfield	O	
DAVIDSON	OK2007104				Frederick	O	T
DEVOL	OK3001701				Grandfield	O	T
DUNCAN	OK1010809	Stephens Co RWD #5 Jefferson Co RWD #1	O O	T T	Waurika Lake MCD	O	R
FAXON	OK3001675				Tillman Co RWD #1	O	T
FREDERICK	OK1011401	Davidson Grandfield Manitou Tillman Co RWD #1 Tipton	O O O O O	T T T T T			
GERONIMO	OK3001680				Lawton	O	T
GRANDFIELD	OK2007103	Devol Cotton Co RWD #1	O O	T	Frederick	O	T
HOLLISTER	OK2007102				Tillman Co RWD #1	O	T
INDIAHOMA	OK2001609				Comanche Co RWD #4	O	T
JEFFERSON CO CONS RWD #1	OK3003401	Healdton	E	T	Duncan Comanche Public Works Waurika PWA	O O O	T T T
LAWTON	OK1011303	Comanche Co RWD #1 Comanche Co RWD #2 Comanche Co RWD #3 Medicine Park Geronimo	O E O O O	T T T T T	Waurika Lake MCD	O	R
MANITOU	OK3007101				Frederick	O	T
MEDICINE PARK	OK3001603				Lawton	O	T
RYAN	OK3003405				Waurika PWA	O	T
STEPHENS CO RWD #3 (MERIDIAN)	OK2006905				Comanche Public Works	O	T
STERLING PWA	OK2001601						
TEMPLE	OK1011306				Waurika Lake MCD	O	R
TILLMAN CO RWD #1	OK2007107	Faxon Hollister	O O	T T	Frederick	O	T
WALTERS	OK1011305	Comanche Co RWD #3	O	T	Waurika Lake MCD		
WAURIKA LAKE MCD	NONE	Comanche Duncan Lawton Temple Walters Waurika	O O O O O O	R R R R R R			
WAURIKA PWA	OK1011201	Jefferson Co Cons RWD #1 Ryan	O O	R T	Waurika Lake MCD		

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers

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

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

Provider Water Rights

Public water providers using surface water or groundwater obtain water rights from the OWRB. Water providers purchasing water from other suppliers or sources are not required to obtain water rights as long as the furnishing entity has the appropriate water right or other source of authority. Each public water provider's current water right(s), source of supply, and reported water use 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)

Beaver-Cache Region

Provider	SDWIS ID[1]	County	Water Rights	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
APACHE	OK2000806	Caddo	1,743	0%	0%	100%
CACHE	OK2001607	Comanche	258	0%	0%	100%
CHATTANOOGA PWS	OK2001608	Comanche	---	---	---	---
COMANCHE CO RWD #1	OK3001602	Comanche	---	---	---	---
COMANCHE CO RWD #2	OK2001604	Comanche	198	0%	0%	100%
COMANCHE CO RWD #3	OK2001602	Comanche	288	0%	59%	41%
COMANCHE CO RWD #4	OK3001654	Comanche	---	---	---	---
COMANCHE PUBLIC WORKS	OK1011101	Stephens	360	100%	0%	0%
COTTON CO RWD #1	OK3001702	Cotton	168	0%	0%	100%
COTTON CO RWD #2	OK2001702	Cotton	1,006	0%	61%	39%
DAVIDSON	OK2007104	Tillman	328	0%	100%	0%
DEVOL	OK3001701	Cotton	7	0%	100%	0%
DUNCAN	OK1010809	Stephens	6,653	100%	0%	0%
ELGIN PWS	OK2001610	Comanche	620	0%	0%	100%
FAXON	OK3001675	Comanche	---	---	---	---
FLETCHER	OK2001612	Comanche	156	0%	0%	100%
FREDERICK	OK1011401	Tillman	4,450	76%	24%	0%
GERONIMO	OK3001680	Comanche	219	0%	48%	52%
GRANDFIELD	OK2007103	Tillman	928	0%	100%	0%
HOLLISTER	OK2007102	Tillman	---	---	---	---
INDIAHOMA	OK2001609	Comanche	240	0%	0%	100%
JEFFERSON CO CONS RWD #1	OK3003401	Jefferson	---	---	---	---
LAWTON	OK1011303	Comanche	42,233	100%	0%	0%
MANITOU	OK3007101	Tillman	87	0%	100%	0%
MEDICINE PARK	OK3001603	Comanche	---	---	---	---
RYAN	OK3003405	Jefferson	---	---	---	---
STEPHENS CO RWD #3 (MERIDIAN)	OK2006905	Stephens	865	0%	0%	100%
STERLING PWA	OK2001601	Comanche	260	0%	0%	100%
TEMPLE	OK1011306	Cotton	---	---	---	---
TILLMAN CO RWD #1	OK2007107	Tillman	234	0%	100%	0%
WALTERS	OK1011305	Cotton	268	100%	0%	0%
WAURIKA LAKE MCD (Wholesaler Only)	None	Jefferson	44,806	100%	0%	0%
WAURIKA PWA	OK1011201	Jefferson	---	---	---	---

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey
Beaver-Cache Region

Apache PWA (Caddo County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace two miles of 4-inch clay tile water line with 6-inch water line. Replace 10 fire plugs.
Long-Term Needs
Infrastructure improvements: new water tower.

Town of Cache (Comanche County)
Current Source of Supply
Primary source: groundwater (Rush Springs Aquifer)
Short-Term Needs
Infrastructure improvements: treat supplies from two recently drilled wells for high levels of fluoride; replace a 3-inch water line with a 6-inch water line; add a new pump to existing booster station and pump housing to comply with DEQ requirements.
Long-Term Needs
Infrastructure improvements: increase the main water line size throughout the distribution system; treat supplies from 4 existing wells for fluoride.

Chattanooga PWS (Comanche County)
Current Source of Supply
Primary source: groundwater (West Cache Creek Alluvial Aquifer)
Short-Term Needs
New water supply sources: two new wells.
Infrastructure improvements: chlorine stations for new wells.
Long-Term Needs
None identified.

Comanche Co. RWD 1
Current Source of Supply
Primary source: City of Lawton
Short-Term Needs
New water supply sources: groundwater.
Infrastructure improvements: connect new well field to the north end of the distribution system; construct two new water towers.
Long-Term Needs
None identified.

Comanche County RWD 2
Current Source of Supply
Primary source: groundwater (Arbuckle Group Aquifer)
Short-Term Needs
New water supply sources: purchase additional water rights.
Infrastructure improvements: new distribution lines and storage.
Long-Term Needs
None identified.

Comanche County RWD 3
Current Source of Supply
Primary source: groundwater (West Cache Creek Alluvial Aquifer), surface water (Lawton, Walters).
Emergency source: Stephens RWD 5.
Short-Term Needs
New water supply sources: expand existing wellfield.
Long-Term Needs
None identified.

Comanche County RWD 4
Current Source of Supply
Primary source: Mountain Park MCD
Short-Term Needs
New water supply sources: potential contract for water from the City of Lawton. No infrastructure improvements identified.
Long-Term Needs
None identified.

Comanche Public Works (Stephens County)
Current Source of Supply
Primary source: Waurika MCD.
Emergency source: Comanche Lake.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Cotton County RWD 1
Current Source of Supply
Primary source: Grandfield PWA
Short-Term Needs
Infrastructure improvements: new water storage tank.
Long-Term Needs
None Identified.

Cotton County RWD 2
Current Source of Supply
Primary source: groundwater (Red River Terrace Aquifer)
Short-Term Needs
None identified.
Long-Term Needs
New water supply sources: additional well.

Town of Davidson (Tillman County)
Current Source of Supply
Primary source: Lake Frederick, groundwater (Tillman Terrace Aquifer)
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Devol (Cotton County)
Current Source of Supply
Primary source: Grandfield PWA
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Duncan (Stephens County)
Current Source of Supply
Primary source: Waurika Lake Waurika MCD, Lake Humphreys, Lake Fuqua
Short-Term Needs
Infrastructure improvements: add raw water lines from Lake Fuqua.
Long-Term Needs
None identified.

Elgin PWS (Comanche County)
Current Source of Supply
Primary source: groundwater (Rush Springs Aquifer)
Short-Term Needs
None identified.
Long-Term Needs
New water supply sources: two new wells.
Infrastructure improvements: new water tower; new 12" water line from well fields to town.

Town of Faxon (Comanche County)
Current Source of Supply
Primary source: Tillman County RWD 1
Short-Term Needs
Infrastructure improvements: replacement of water meters in some areas of town; upgrade water lines.
Long-Term Needs
Infrastructure improvements: replacement of major main water lines and possible expansion of new lines into new housing development.

Fletcher Water Dept. (Comanche County)
Current Source of Supply
Primary source: groundwater (Rush Springs Aquifer)
Short-Term Needs
No new water supply sources identified. Infrastructure improvements: one new well.
Long-Term Needs
New water supply sources: expand well system in Rush Springs Aquifer.
Infrastructure improvements: replace and expand water lines in the distribution system; add additional storage.

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
Beaver-Cache Region

City of Frederick (Tillman County)
Current Source of Supply
Primary source: Mountain Park MCD, Frederick Lake, & Tom Steed Reservoir
Short-Term Needs
Infrastructure improvements: complete water treatment, storage, and distribution improvement projects to attain TTHM compliance and other benefits.
Long-Term Needs
Infrastructure improvements: continue upgrades as needed.

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

City of Grandfield (Tillman County)
Current Source of Supply
Primary source: Frederick, groundwater (Red River Terrace Aquifer)
Short-Term Needs
Infrastructure improvements: correct order deficiencies to obtain TTHM compliance; construct facility to eliminate nitrates in groundwater.
Long-Term Needs
None identified.

Hollister PWA (Tillman County)
Current Source of Supply
Primary source: Tillman County RWD 1
Short-Term Needs
Infrastructure improvements: add new valves.
Long-Term Needs
None identified.

Town of Indiahoma (Comanche County)
Current Source of Supply
Primary source: Comanche County RWD 4
Short-Term Needs
Infrastructure improvements: treatment of well water.
Long-Term Needs
New water supply sources: use groundwater sources.
Infrastructure improvements: new system to remove impurities.

Jefferson County Cons RWD 1
Current Source of Supply
Primary source: Waurika PWA, Duncan, Comanche
Short-Term Needs
None identified.
Long-Term Needs
New water supply sources: use groundwater sources.
Infrastructure improvements: well field currently in progress.

City of Lawton (Comanche County)
Current Source of Supply
Primary source: Waurika MCD, Lake Ellsworth, Lake Lawtonka
Short-Term Needs
Infrastructure improvements: upgrade distribution capacity; purchase additional storage.
Long-Term Needs
Infrastructure improvements: Expansion of treatment capacity of the SEWTP; Installation of additional pumping capacity to convey water from SEWTP to Ft. Sill and industrial facilities west of the City; installation of additional pipes to upgrade the distribution system; improve pumping capacity from MPWTP.

Town of Manitou (Tillman County)
Current Source of Supply
Primary source: Frederick
Short-Term Needs
None identified.
Long-Term Needs
New water supply sources: groundwater from existing unused wells.
Infrastructure improvements: develop plan to utilize wells with a blending station.

Town of Medicine Park (Comanche County)
Current Source of Supply
Primary source: City of Lawton
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: extend infrastructure (piping and storage) to serve areas currently without water service.

Town of Ryan (Jefferson County)
Current Source of Supply
Primary source: Waurika PWA
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Stephens County RWD 3
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Sterling PWA (Comanche County)
Current Source of Supply
Primary source: groundwater (El Reno Group Aquifer)
Short-Term Needs
Infrastructure improvements: extend distribution line.
Long-Term Needs
New water supply sources: additional wells.
Infrastructure improvements: continue extending distribution system.

Temple
Current Source of Supply
Primary source: Waurika MCD.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Tillman County RWD 1
Current Source of Supply
Primary source: Frederick Lake, Cache Creek Alluvial Aquifer
Short-Term Needs
New water supply sources: new wells.
Long-Term Needs
Infrastructure improvements: construct a reverse osmosis system to remove nitrates from groundwater.)

Walters PWA (Cotton County)
Current Source of Supply
Primary source: Lake Dave Boyer, East Cache Creek, & Waurika MCD
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: increase pipeline capacity.

Waurika Lake MCD (Wholesaler Only)
No Information

Waurika PWA (Jefferson County)
Current Source of Supply
Primary source: Waurika MCD
Short-Term Needs
New water supply sources: one additional well.
Infrastructure improvements: install a microfiltration water treatment plant.
Long-Term Needs
New water supply sources: new wells.
Infrastructure improvements: install new water lines; add more filtration units to the water treatment plant; construct a bigger clearwell; add storage.

Infrastructure Cost Summary
Beaver-Cache Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present - 2020	2021 - 2040	2041 - 2060	Total Period
Small	$480	$140	$290	$910
Medium	$40	$250	$10	$300
Large	$160	$80	$70	$310
Reservoir	$60	$0	$0	$60
TOTAL	$740	$470	$370	$1,580

1 Large providers are defined as those serving more than 100,000 people, medium systems as those serving between 3,301 and 100,000 people, and small systems as those serving 3,300 and fewer people. The "reservoir" category is for rehabilitation projects.

- Approximately $1.6 billion is needed to meet the projected drinking water infrastructure needs of the Beaver-Cache 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 80% of the providers' estimated infrastructure costs, followed distantly by water treatment and source water projects.
- Small providers have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoirs comprise approximately 4% of the total costs.

Drinking Water Infrastructure Cost Summary

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

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

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

Water Supply Options

Limitations Analysis

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

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

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

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

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

Primary Options

To provide a range of potential solutions for mitigation of water supply shortages in each of the 82 OCWP basins, five primary options were evaluated for potential effectiveness: (1) demand management, (2) use of out-of-basin supplies, (3) reservoir use, (4) increasing reliance on surface water, and (5) increasing reliance on groundwater. For each basin, the potential effectiveness of each primary option was assigned one of three ratings: (1) typically effective, (2) potentially effective, and (3) likely ineffective (see Water Supply Option Effectiveness map on page 6). 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 three 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 workgroup and study is presented in the OCWP *Reservoir Viability Study*. Potential reservoir development sites for this Watershed Planning Region appear on the following chart and map.

Reservoir Project Viability Categorization

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

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

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

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

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

Potential Reservoir Sites (Categories 3 & 4)

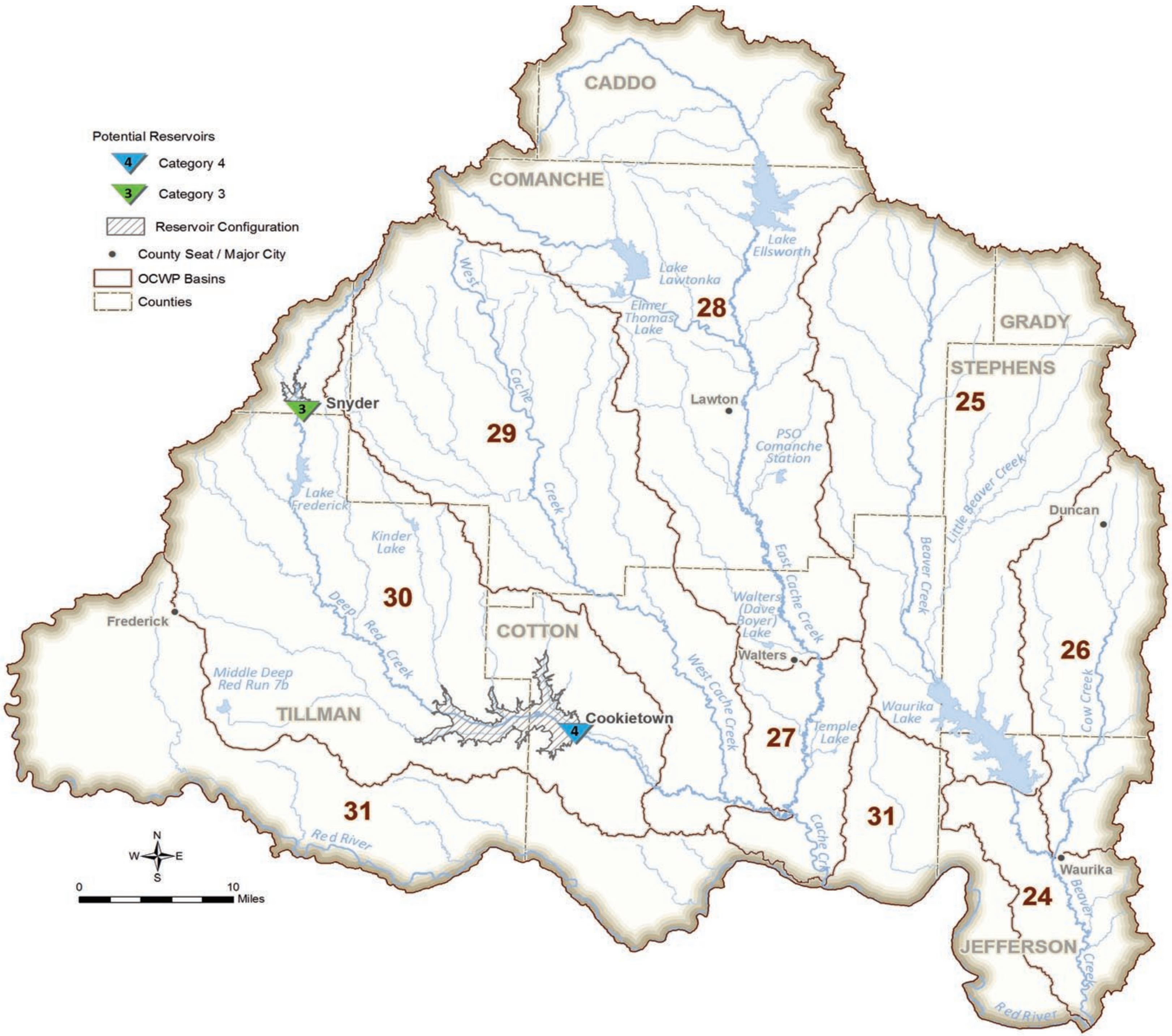
Beaver-Cache Region

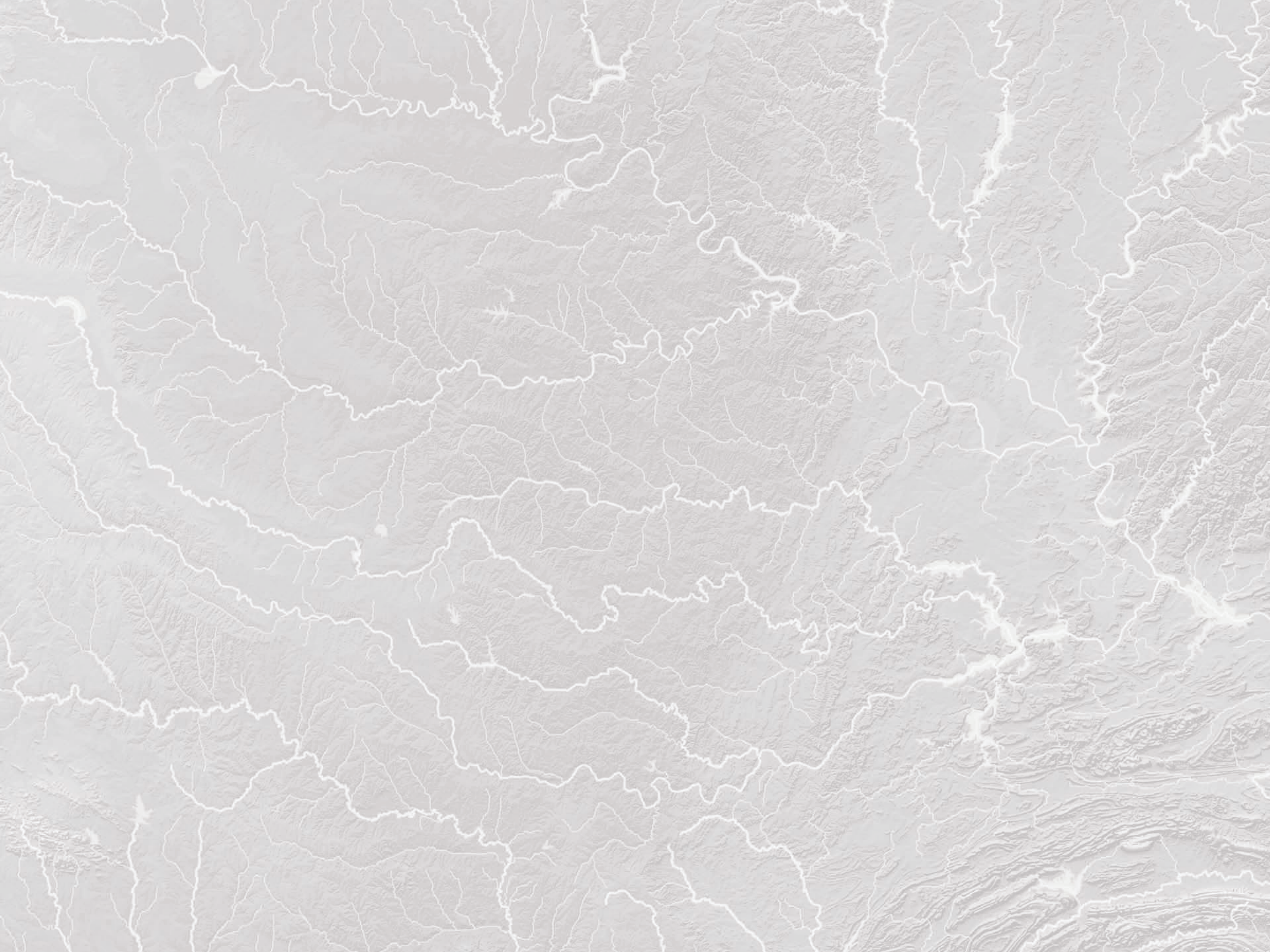
Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool: Surface Area	Conservation Pool: Storage	Conservation Pool: Dependable Yield	Primary Study: Date	Primary Study: Agency	Updated Cost Estimate[2] (2010 dollars)
					AF	AF	AF	AFY			
Cookietown	4	Deep Red Creek	30	WS, FC, F&W, R	400,000	13,100	208,190	34,700	1979	Bureau of Reclamation	$298,161,000
Snyder	3	Deep Red Creek	30	F&W, WS, R	110,000	3,668	90,000	10,600	1974	Bureau of Reclamation	$103,052,000

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

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
Beaver-Cache Region

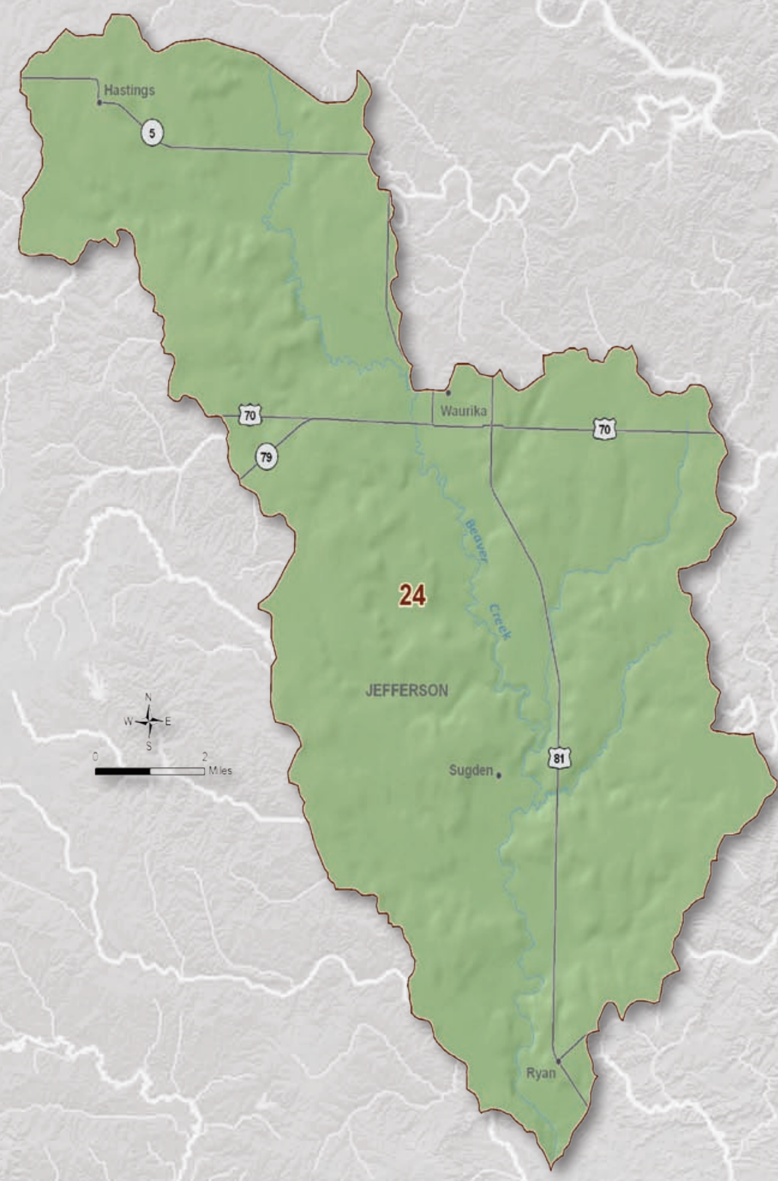




Oklahoma Comprehensive Water Plan

Data & Analysis
Beaver-Cache Watershed Planning Region

Basin 24



Basin 24 Summary

Synopsis

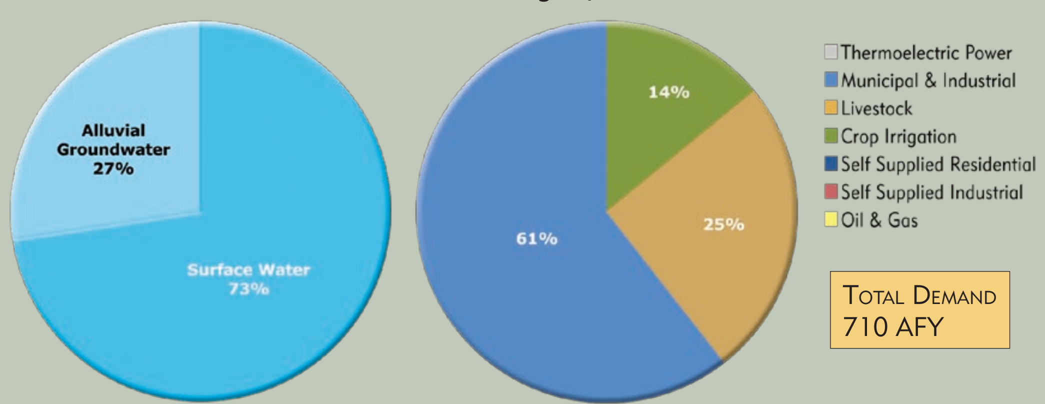
- Water users are expected to continue to rely mainly on surface water and to a lesser extent, alluvial groundwater.
- By 2030, there is a moderate probability of surface water gaps from increased demand on existing supplies during low flow periods.
- To reduce the risk of adverse effects on water supplies, it is recommended that gaps be decreased where economically feasible.
- Additional conservation measures could mitigate surface water gaps.
- To mitigate surface water gaps, dependable groundwater supplies, out-of-basin supplies, and/or developing new reservoirs could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

Basin 24 accounts for about 2% of the current demand in the Beaver-Cache Watershed Planning Region. About 61% of the basin's 2010 demand was from the Municipal and Industrial demand sector. Livestock was the second largest demand sector at 25%. Surface water satisfies about 73% of the current demand in the basin. Alluvial groundwater satisfies about 27% of the current demand. There are currently no permits for bedrock groundwater use and none expected in the future. The peak summer month total water demand in Basin 24 is about 2.5 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in Beaver Creek at its confluence with the Red River is typically greater than 400 AF/month throughout the year and greater than 3,700 AF/month in the spring. However, the creek can have periods of low to no flow in any month of the year. There are no major reservoirs in the basin; however, the City of Waurika receives out-of-basin supplies from Waurika Lake Master Conservancy District in Basin 25. Relative to other basins in the state, the surface water quality in Basin 24 is considered poor. Beaver Creek is impaired for Agricultural use due to elevated levels of total dissolved solids (TDS) and chlorides. However, individual lakes and streams may have acceptable water quality.

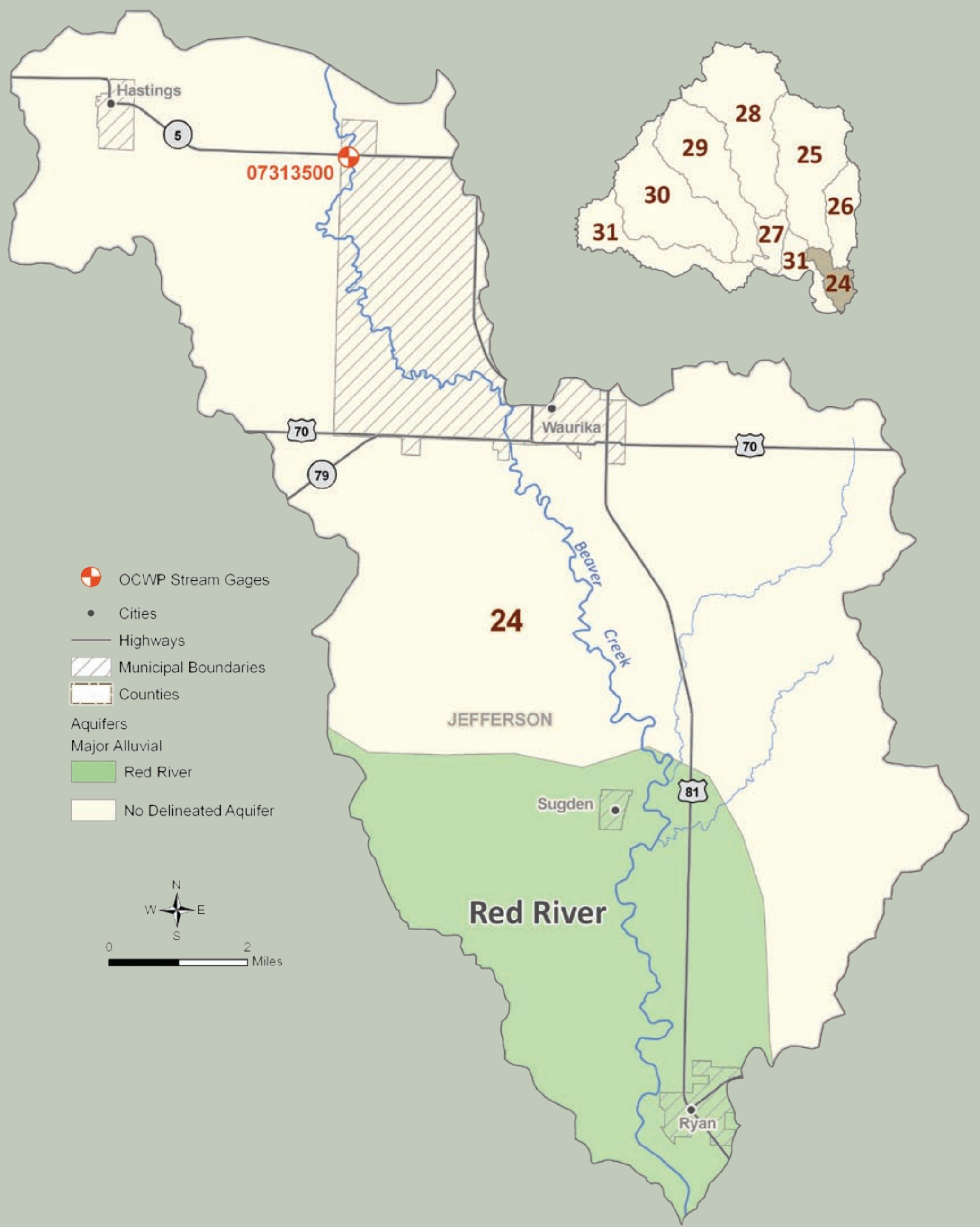
Current Demand by Source and Sector

Beaver-Cache Region, Basin 24

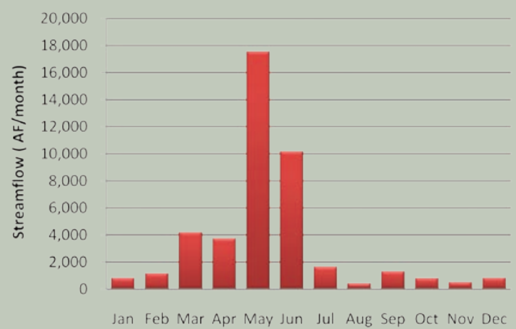


Water Resources

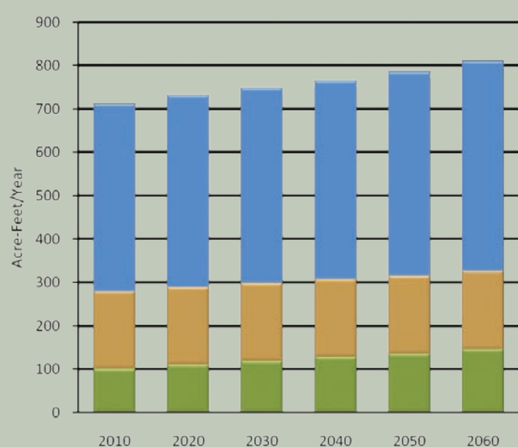
Beaver-Cache Region, Basin 24



Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 24



Projected Water Demand
Beaver-Cache Region, Basin 24



The Red River alluvial aquifer underlies the eastern portion of the basin, but currently allocated withdrawals from the aquifer are small. The majority of current water rights in the basin are from non-delineated minor alluvial aquifers along Beaver Creek. Site-specific information on the suitability of minor aquifers for supply should be considered before large scale use. There are currently no water rights in bedrock aquifers in the basin; therefore, no future withdrawals are expected from bedrock sources. There are no significant basin-wide groundwater quality issues. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The projected 2060 water demand of 810 AFY in Basin 24 reflects a 100 AFY increase (14%) over the 2010 demand. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2030. No groundwater storage depletions are expected through 2060. Surface water gaps may occur in summer, and by 2060, will be up to 30 AFY with a 45% probability of occurring in at least one month of the year.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors could mitigate surface water gaps. Temporary drought management activities may not be effective in this basin, since gaps have a moderate probability of occurring.

Currently, the City of Waurika obtains water from Waurika Lake in Basin 25 via the Waurika Master Conservancy District. Increased use of this source could effectively reduce surface water gaps. Waurika Lake is almost fully allocated at this time.

Out-of-basin supplies could mitigate surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region. However, because 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 24 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and less than 100 AF of reservoir storage at the basin outlet. Increasing the use of surface water supplies through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on alluvial groundwater supplies could mitigate surface water gaps, but may create alluvial groundwater storage depletions. Any storage depletions would be small relative to the volume of water stored in the Red River aquifer underlying the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Water Supply Limitations
Beaver-Cache Region, Basin 24

Source	Limitation
Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal Potential Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 24

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

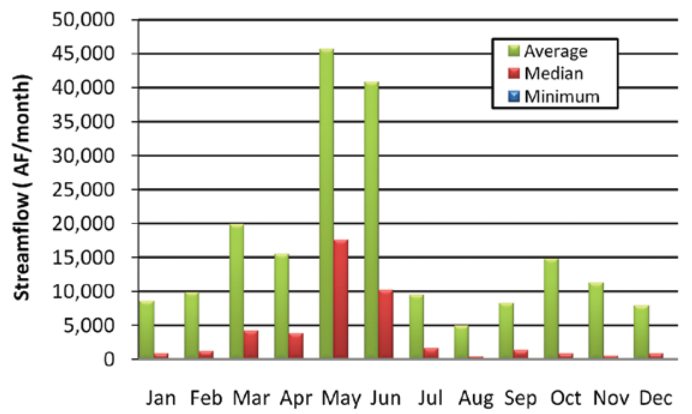
Typically Effective Potentially Effective Likely Ineffective No Option Necessary

Basin 24 Data & Analysis

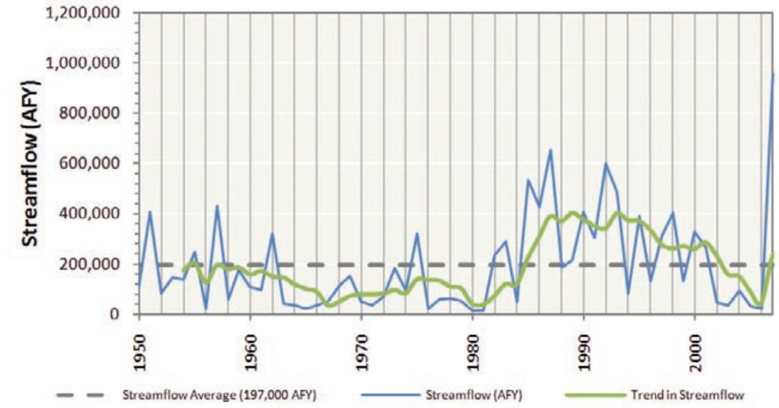
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the early 1960s to the mid 1980s. From the mid 1980s to the mid 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median, and minimum streamflow over a 58-year period of record. The median flow of Beaver Creek confluence with the Red River is greater than 400 AF/month throughout the year and greater than 10,000 AF/month in May and June. 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 24 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no significant reservoirs in the basin.

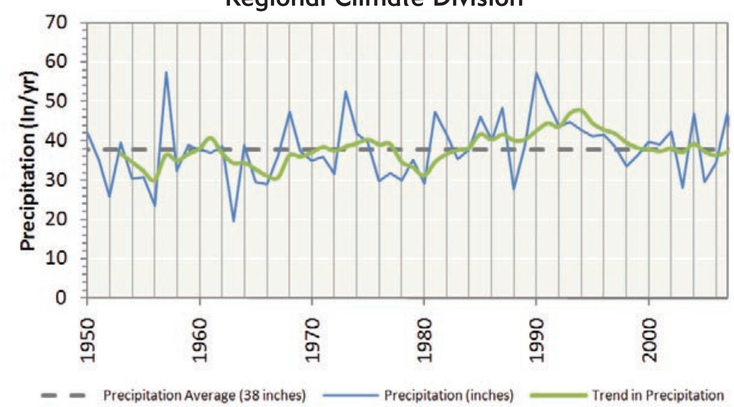
Monthly Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 24



Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 24



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)

Beaver-Cache Region, Basin 24

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Red River	Alluvial	Major	24%	300	36,000	temporary 2.0	38,100
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	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.

Groundwater Resources

- The majority of current groundwater rights in the basin are from non-delineated minor alluvial groundwater sources along Beaver Creek. There are additional groundwater rights in the Red River major alluvial aquifer.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

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

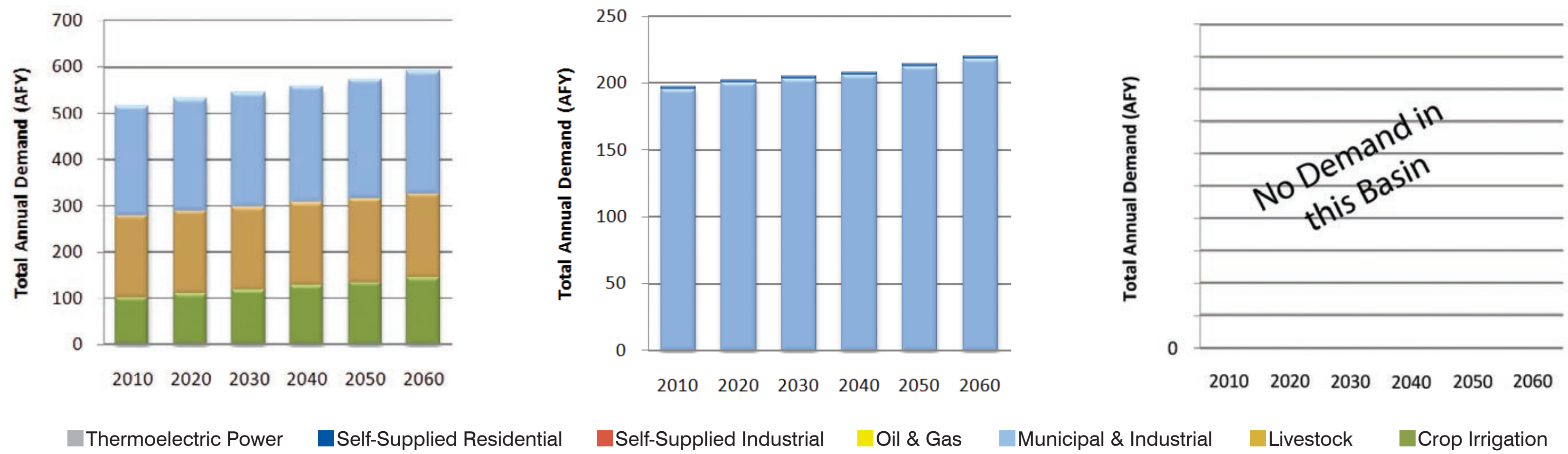
Water Demand

- Basin 24's water needs make up about 2% of the total demand in the Beaver-Cache Watershed Planning Region and will increase by 14% (100 AFY) from 2010 to 2060. However, demand growth in the basin is expected to occur in the Municipal and Industrial and Crop Irrigation demand sectors. The majority of demand will be from the Municipal and Industrial and Livestock demand sectors.
- Surface water is used to meet 73% of the total demand in Basin 24 and its use will increase by 15% (70 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use will be in the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 27% of the total demand in Basin 24 and its use will increase by 12% (20 AFY) from 2010 to 2060. Alluvial groundwater use will be solely from the Municipal and Industrial demand sector.
- There is no current bedrock groundwater use in Basin 24; no future demand is expected.

Surface Water Demand by Sector
Beaver-Cache Region, Basin 24

Alluvial Groundwater Demand by Sector
Beaver-Cache Region, Basin 24

Bedrock Groundwater Demand by Sector
Beaver-Cache Region, Basin 24



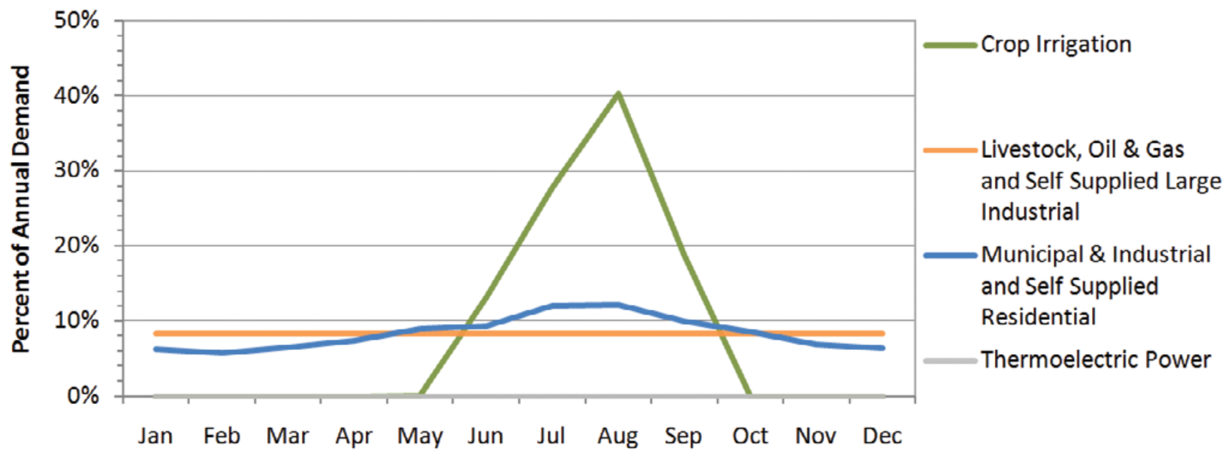
Total Demand by Sector
Beaver-Cache Region, Basin 24

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	100	180	430	0	0	0	0	710
2020	110	180	440	0	0	0	0	730
2030	120	180	450	0	0	0	0	750
2040	130	180	460	0	0	0	0	770
2050	130	180	470	0	0	0	0	780
2060	150	180	480	0	0	0	0	810

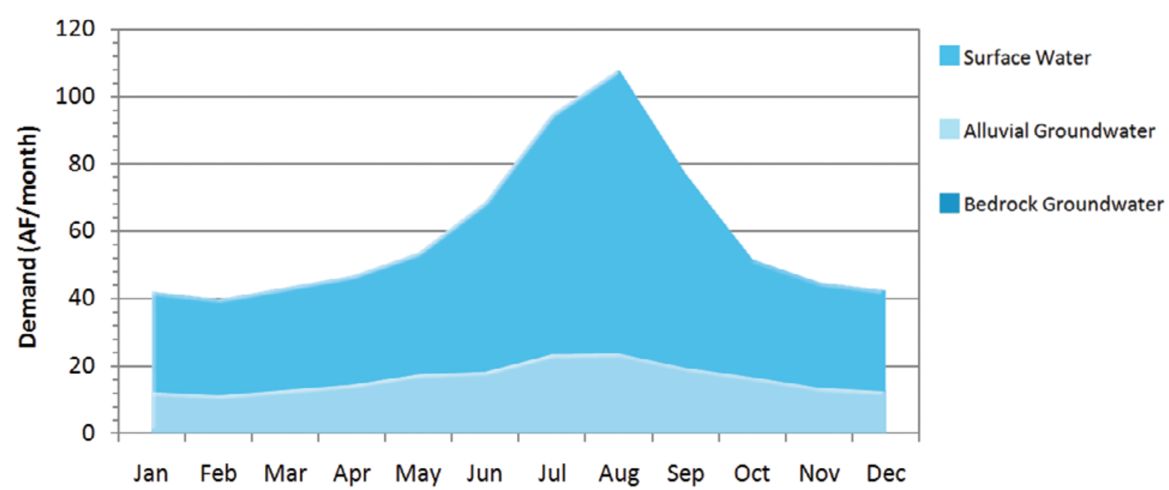
Notes & Assumptions

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

Monthly Demand Distribution by Sector (2010)
Beaver-Cache Region, Basin 24



Monthly Demand Distribution by Source (2010)
Beaver-Cache Region, Basin 24



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial demand sector uses 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. Livestock demand has a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 24 is about 2.5 times the winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.8 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 1.9 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps are projected to occur by 2030. No alluvial groundwater depletions are expected through 2060. There is no current or projected bedrock groundwater use.
- Surface water gaps in Basin 24 may occur during the summer. Surface water gaps in 2060 will be up to 18% (20 AF/month) of the surface water demand in the peak summer month. Return flows from upstream basins are expected to supplement Basin 24's historical flow, preventing additional gaps in the future. By 2060, there will be a 45% probability of gaps occurring in at least one month of the year. Gaps are expected to occur during the summer.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 24

	Maximum Gap[1]	Median Gap	Probability
Months (Season)	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	20	20	45%
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)

Beaver-Cache Region, Basin 24

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 24

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	10	0	0	29%	0%
2040	20	0	0	36%	0%
2050	20	0	0	41%	0%
2060	30	0	0	45%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 24

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

1 Amount shown 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

Beaver-Cache Region, Basin 24

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	30	0	0	45%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	20	0	0	41%	0%
Moderately Expanded Conservation in M&I Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 24

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

Water Supply Options & Effectiveness

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

Demand Management

(Typically Effective) Moderately expanded permanent conservation activities could mitigate surface water gaps. Temporary drought management activities may not be effective since gaps have a moderate probability of occurring and groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

(Potentially Effective) Out-of-basin supplies may be developed to supplement the basin's limited water supplies and eliminate gaps. The Waurika Master Conservancy District in Basin 25 is currently supplying the City of Waurika, Basin 24's largest water user. Additional out-of-basin supplies are expected to meet the city's future needs. Waurika Lake is almost fully allocated; therefore, any future use of this source would need to take existing water rights into consideration. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region: Cookietown Reservoir and Snyder Lake, both in Basin 30. 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

(Potentially Effective) New reservoir storage in Basin 24 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and less than 100 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

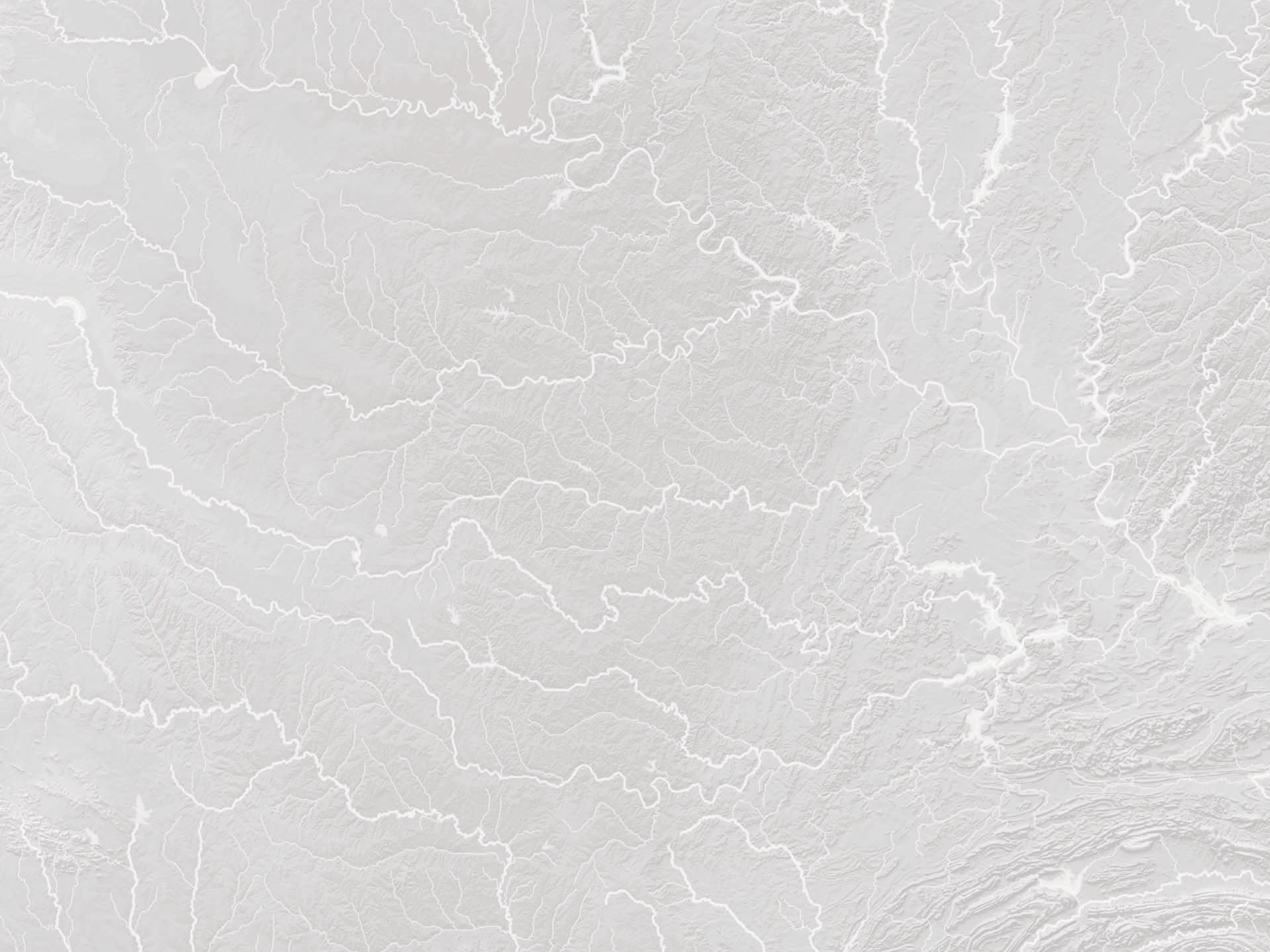
(Likely Ineffective) Increasing the use of surface water supplies, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

(Potentially Effective) Increased reliance on alluvial groundwater supplies could mitigate surface water gaps, but may create alluvial groundwater storage depletions. Any storage depletions would be small relative to the volume of water stored in the Red River aquifer underlying the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

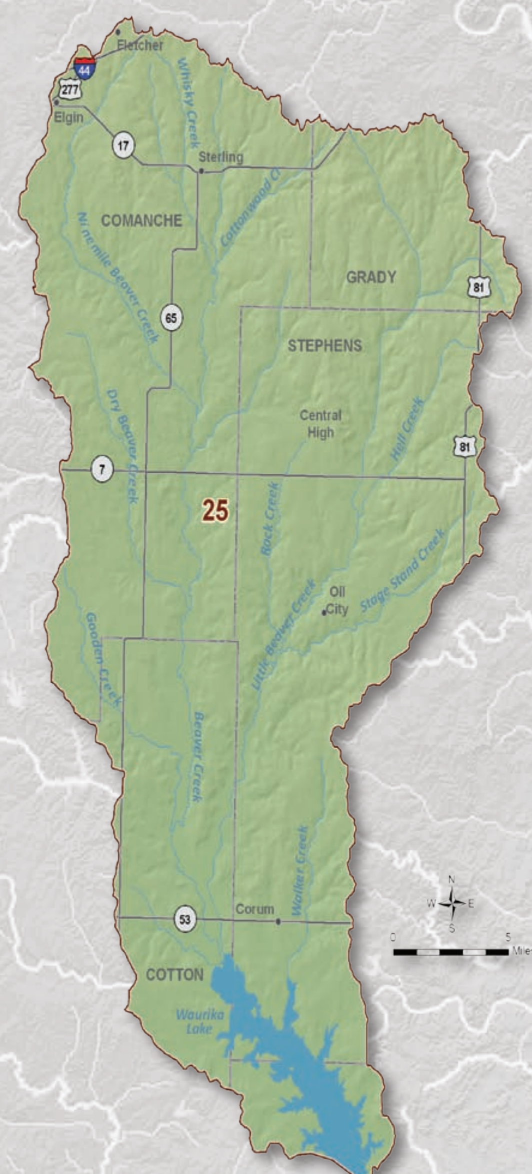
Notes & Assumptions

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



Data & Analysis
Beaver-Cache Watershed Planning Region

Basin 25



Basin 25 Summary

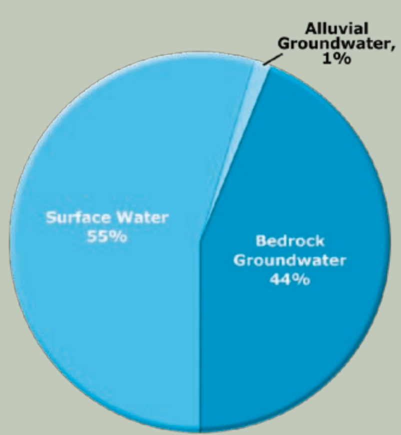
Synopsis

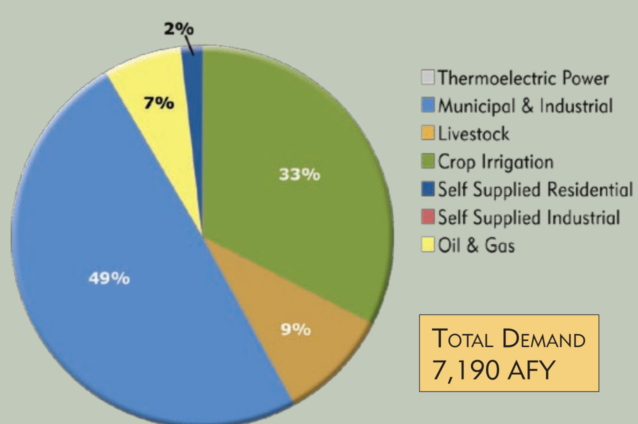
- Water users are expected to continue to rely primarily on surface water and bedrock groundwater.
- Bedrock groundwater storage depletions may occur by 2020, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.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

Basin 25 accounts for about 16% of the current demand in the Beaver-Cache Watershed Planning Region. About 49% of the basin's 2010 demand was from the Municipal and Industrial demand sector. Crop Irrigation was the second largest demand sector at 33%. Surface water satisfies about 55% of the current demand in the basin. Groundwater satisfies about 45% of the current demand (1% alluvial and 44% bedrock). The peak summer month total water demand in Basin 25 is about 4 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in Beaver Creek near Waurika is typically greater than 300 AF/month throughout the year and greater than 3,000 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. There is one major federal lake in Basin 25. Waurika

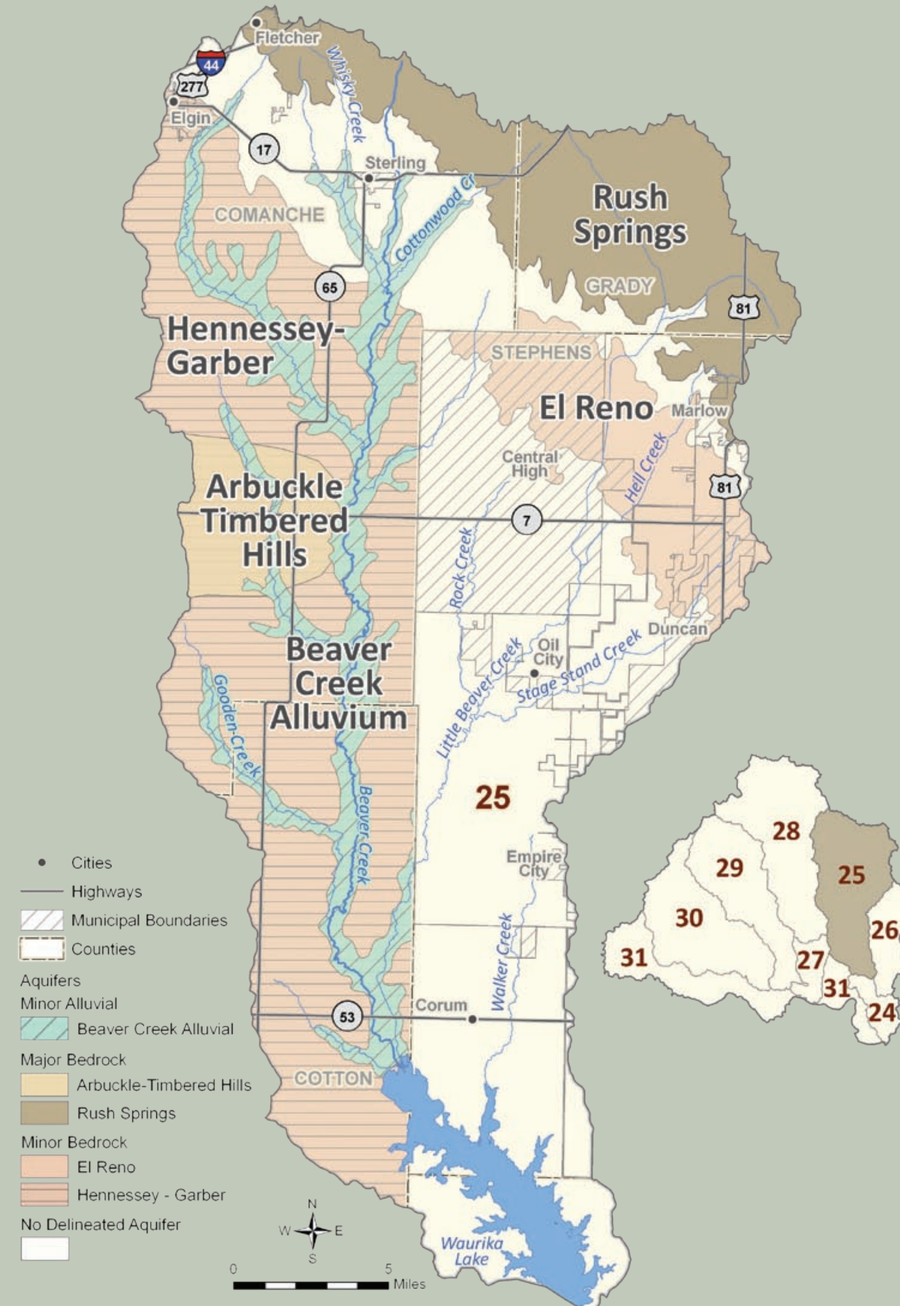
Current Demand by Source and Sector
Beaver-Cache Region, Basin 25



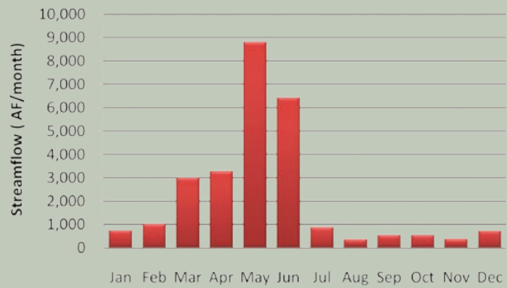


Total Demand
7,190 AFY

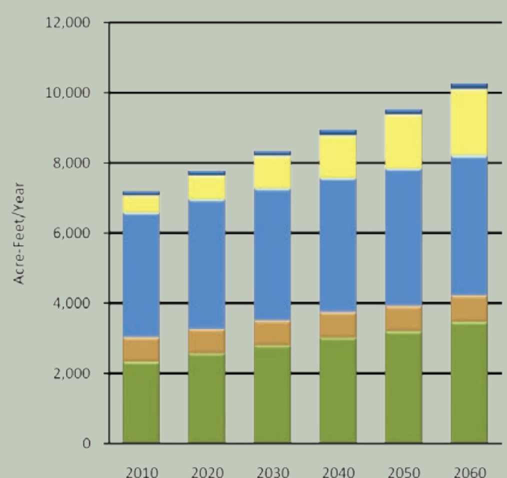
Water Resources
Beaver-Cache Region, Basin 25



Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 25



Projected Water Demand
Beaver-Cache Region, Basin 25



Lake was constructed by the U.S. Army Corps of Engineers in 1982 and is located on Beaver Creek at the basin's outlet. Project purposes include water supply, flood control, irrigation, water quality, recreation, and fish and wildlife mitigation. The project provides a dependable yield of 45,590 AFY and water rights are almost fully allocated to the Waurika Master Conservancy District, which provides water out-of-basin to the Cities of Duncan, Lawton, Waurika, Temple, and Comanche. 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 25 is considered poor. However, individual lakes and streams may have acceptable water quality. Waurika Lake is impaired for Public and Private Water Supply use due to elevated levels of chlorophyll-a.

The majority of groundwater rights are in the Rush Springs aquifer and to a lesser extent the El Reno aquifer. The Rush Springs aquifer has over 760,000 AF of storage in Basin 25 and underlies the northern portion of the basin. The estimated recharge in the basin to the Rush Springs and Arbuckle Timbered Hills aquifers is 7,000 AFY. There are also groundwater rights from non-delineated bedrock groundwater sources. Site-specific information on the suitability of the minor aquifers for supply, including the El Reno aquifer, should be considered before large scale use. There are no major alluvial aquifers in Basin 25. 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. Localized areas with high levels of nitrate and fluoride have been found in the overall Rush Springs aquifer and may occur in Basin 25.

The projected 2060 water demand of 10,250 AFY in Basin 25 reflects a 3,060 AFY increase (43%) over the 2010 demand. The largest demand over this period will be in the Municipal and Industrial demand sector, but the largest growth in demand will be in the Crop Irrigation and Oil and Gas demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, bedrock groundwater storage depletions may occur by 2020. No surface water gaps or alluvial groundwater storage depletions are expected through 2060. Bedrock groundwater storage depletions may occur in summer, and by 2060, will be up to 840 AFY. Projected annual groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Water Supply Limitations
Beaver-Cache Region, Basin 25

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal · Potential · Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 25

Demand Management	Potentially Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Potentially Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	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, bedrock 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 bedrock groundwater storage depletions. Temporary drought management activities may not be effective or needed for groundwater supplies, since groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate bedrock groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region. 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 25 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 18,000 AF of reservoir storage at the basin outlet.

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

Increased reliance on bedrock and alluvial groundwater supplies from non-delineated minor aquifers is not recommended without site-specific information.

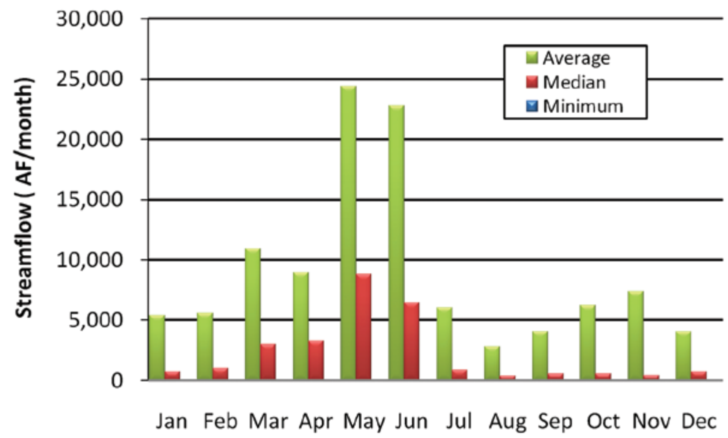
The Aquifer Recharge Workgroup identified a site near Marlow (site # 9) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from Beaver Creek to recharge the Rush Springs aquifer.

Basin 25 Data & Analysis

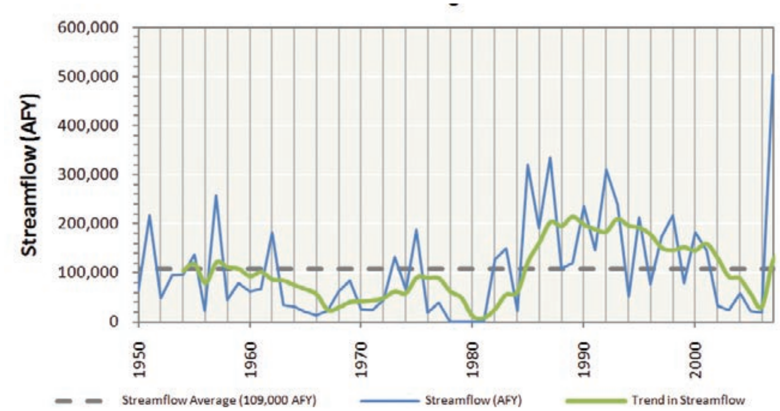
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the late 1960s to the early 1980s. From the mid-1980s through the 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of Beaver Creek near Waurika is greater than 300 AF/month throughout the year and greater than 3,000 AF/month in spring and early summer. However, the creek can have periods of low to no flow in any month of the year. Relative to other basins in the state, the surface water quality in Basin 25 is considered poor. However, individual lakes and streams may have acceptable water quality.
- Waurika Lake is located at the basin's outlet and provides about 45,500 AFY of dependable yield to members of the Waurika Master Conservancy District.

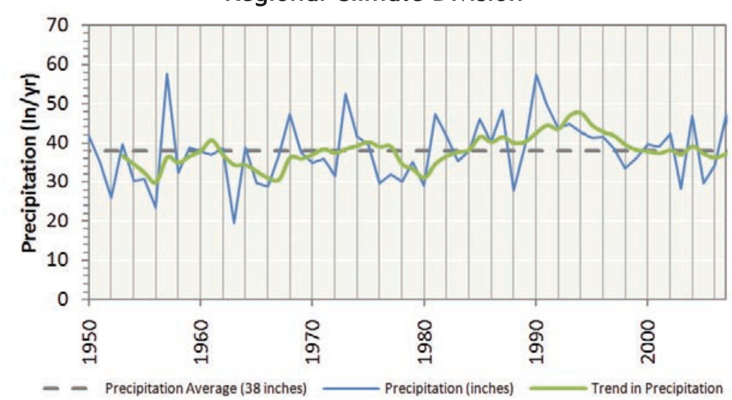
Monthly Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 25



Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 25



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)

Beaver-Cache Region, Basin 25

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
Arbuckle-Timbered Hills	Bedrock	Major	4%	0	58,000	temporary 2.0	25,600
Rush Springs	Bedrock	Major	13%	15,600	763,000	temporary 2.0	67,300
Beaver Creek	Alluvial	Minor	10%	0	151,000	1.0	38,300
El Reno	Bedrock	Minor	7%	2,700	133,000	temporary 2.0	49,800
Hennessey-Garber	Bedrock	Minor	38%	0	617,000	1.6	225,300
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	1,300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of current groundwater rights are in the Rush Springs major bedrock aquifer, which is located in the northern portion of the basin (about 13% of the basin area). The Rush Springs aquifer has more than 760,000 AF of groundwater storage in Basin 25. There are also groundwater rights from the El Reno minor bedrock aquifer and non-delineated bedrock groundwater sources. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use.
- There are no significant basinwide groundwater quality issues. Localized areas with high levels of nitrate and fluoride have been found in the Rush Springs aquifer and may occur in Basin 25.

Notes & Assumptions

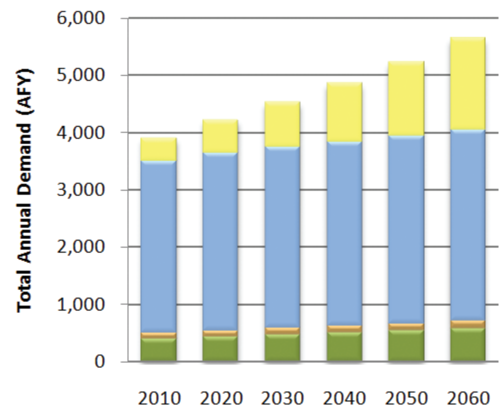
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater 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

- This basin's water needs are about 16% of the total demand in the Beaver-Cache Watershed Planning Region and will increase by 43% (3,060 AFY) from 2010 to 2060. The largest demand over this period will be in the Municipal and Industrial demand sector. However, the largest growth in demand from 2010 to 2060 will be in the Oil and Gas and Crop Irrigation demand sectors.
- Surface water is used to meet 55% of the total demand in Basin 25 and its use will increase by 44% (1,730 AFY) from 2010 to 2060. The majority of surface water use over this period is in the Municipal and Industrial demand sector. The largest growth in demand will be in the Oil and Gas demand sector.
- Alluvial groundwater is used to meet 1% of the total demand in Basin 25 and supplies the Self-Supplied Residential demand sector. Alluvial groundwater use will increase by 28% (30 AF) from 2010 to 2060.
- Bedrock groundwater is used to meet 44% of the total demand in Basin 25 and its use will increase by 41% (1,300 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use over this period is in the Crop Irrigation demand sector.

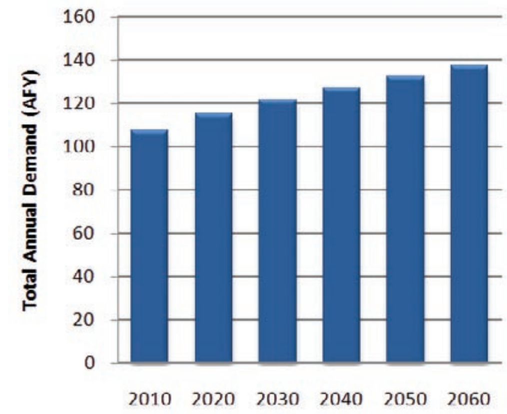
Surface Water Demand by Sector

Beaver-Cache Region, Basin 25



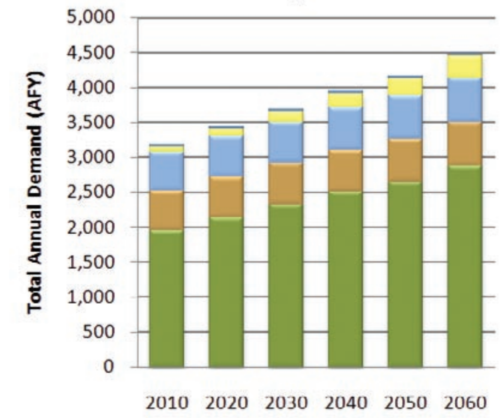
Alluvial Groundwater Demand by Sector

Beaver-Cache Region, Basin 25



Bedrock Groundwater Demand by Sector

Beaver-Cache Region, Basin 25



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

Total Demand by Sector

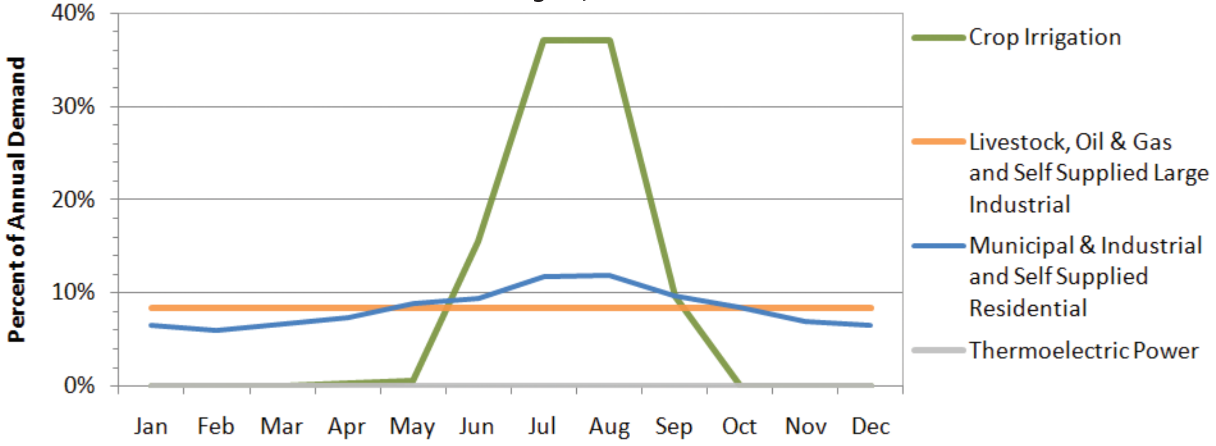
Beaver-Cache Region, Basin 25

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,340	680	3,560	480	0	130	0	7,190
2020	2,570	700	3,690	690	0	140	0	7,790
2030	2,790	710	3,760	930	0	140	0	8,330
2040	3,020	720	3,820	1,220	0	150	0	8,930
2050	3,190	740	3,890	1,540	0	160	0	9,520
2060	3,460	750	3,970	1,910	0	160	0	10,250

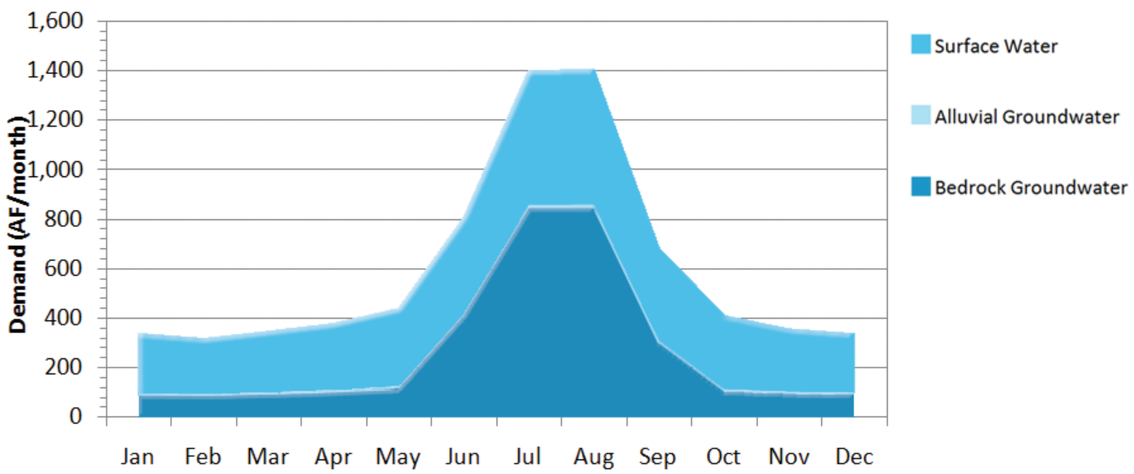
Notes & Assumptions

- 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)
Beaver-Cache Region, Basin 25



Monthly Demand Distribution by Source (2010)
Beaver-Cache Region, Basin 25



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 a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 25 is about 4 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.3 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 1.8 times the winter monthly use. Bedrock groundwater use peaks in the summer at about 9 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, bedrock groundwater storage depletions are projected to occur by 2020. Surface water gaps and alluvial groundwater storage depletions are not expected through 2060.
- Bedrock groundwater storage depletions will occur in the summer and will be 31% of 2060 bedrock groundwater demand (380 AF/month) on average in the peak summer month. Bedrock storage depletions are minimal compared to the groundwater storage in the Rush Springs aquifer. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.
- Waurika Lake is capable of providing reliable water supplies to its existing users, and with new infrastructure, could supply sufficient water to meet all of Basin 25's future surface water demand during periods of low streamflow. However, Waurika Lake is currently fully allocated; any future use of this source would need to take existing water rights into consideration.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 25

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 25

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 25

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	160	0%	0%
2030	0	0	300	0%	0%
2040	0	0	470	0%	0%
2050	0	0	620	0%	0%
2060	0	0	840	0%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 25

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	380
Sep-Nov (Fall)	0

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 25

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	0	0	840	0%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	0	700	0%	0%
Moderately Expanded Conservation in M&I Water Use	0	0	790	0%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	650	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	260	0%	0%

1 Conservation Activities are documented in the OCWP Demand Forecast Report

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 25

Reservoir Storage	Diversion
AF	AFY
100	200
500	400
1,000	600
2,500	1,000
5,000	1,400
Required Storage to Meet Growth in Demand (AF)	18,000
Required Storage to Meet Growth in Surface Water Demand (AF)	7,800

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, Self-Supplied Residential, and Crop Irrigation demand sectors could reduce bedrock groundwater storage depletions by about 20%. Temporary drought management activities may not be effective or needed for groundwater users, since groundwater storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate bedrock groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region: Cookietown Reservoir and Snyder Lake, both in Basin 30. 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 25 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 18,000 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future storage depletions. No viable reservoir sites were identified in Basin 25.

Increasing Reliance on Surface Water

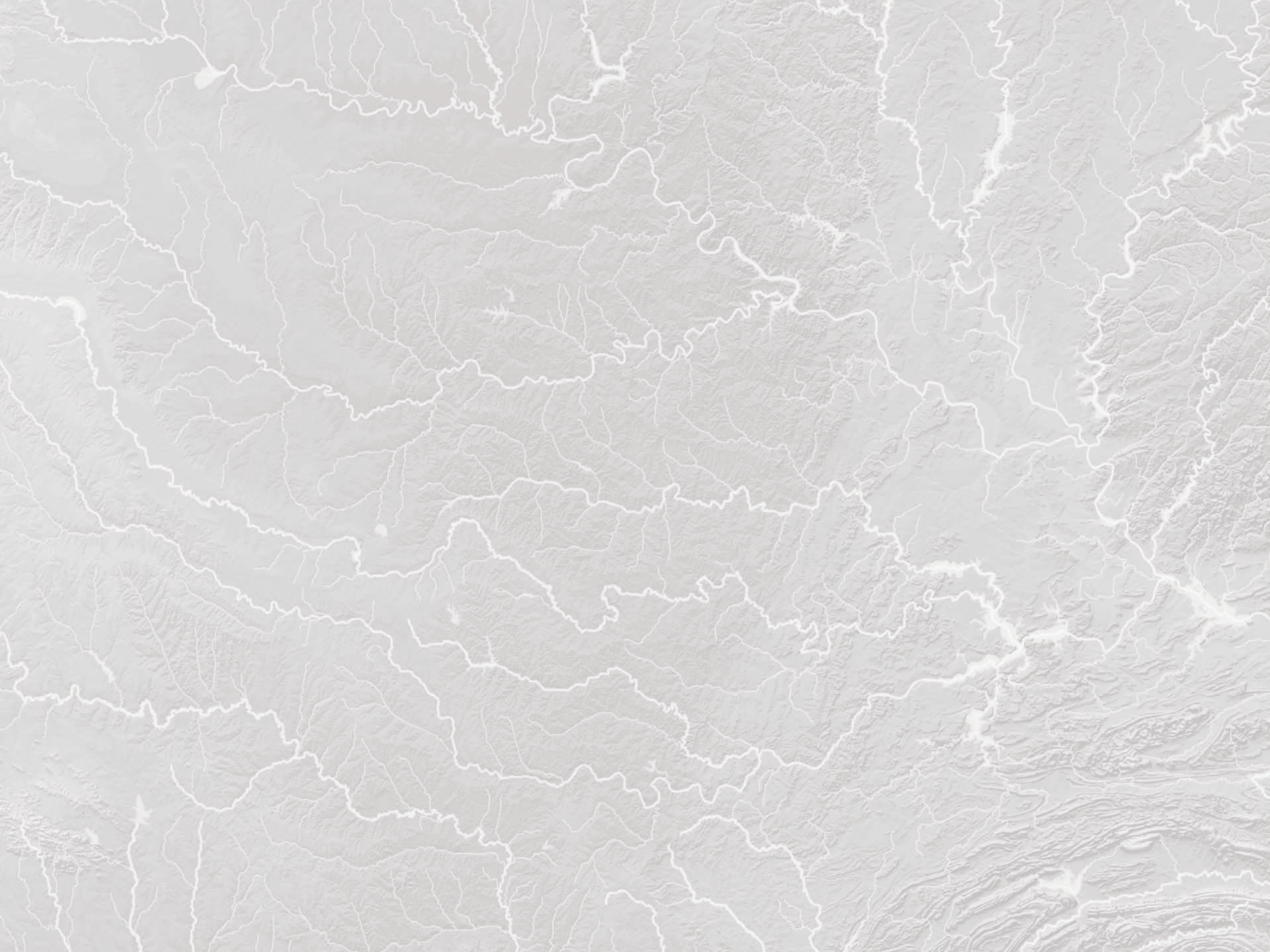
Increased reliance on surface water, without reservoir storage, may create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on bedrock groundwater would increase bedrock groundwater depletions, but groundwater depletions would be minimal relative to aquifer storage in the basin. There are no major alluvial aquifers in the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Notes & Assumptions

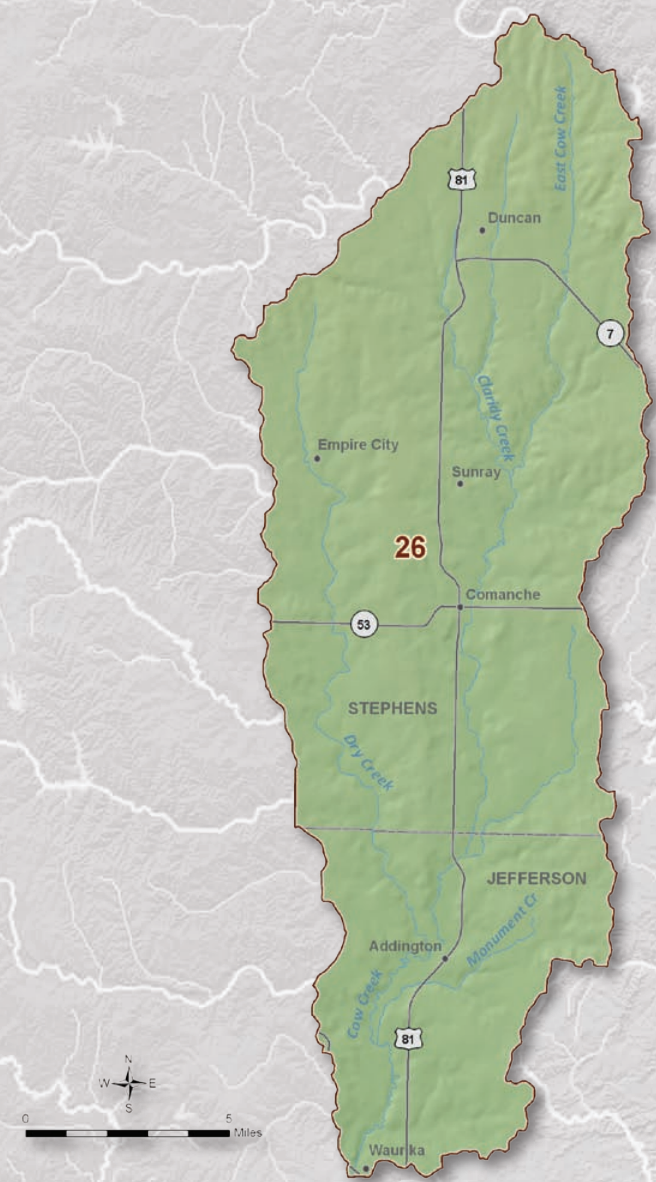
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands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

Basin 26



Basin 26 Summary

Synopsis

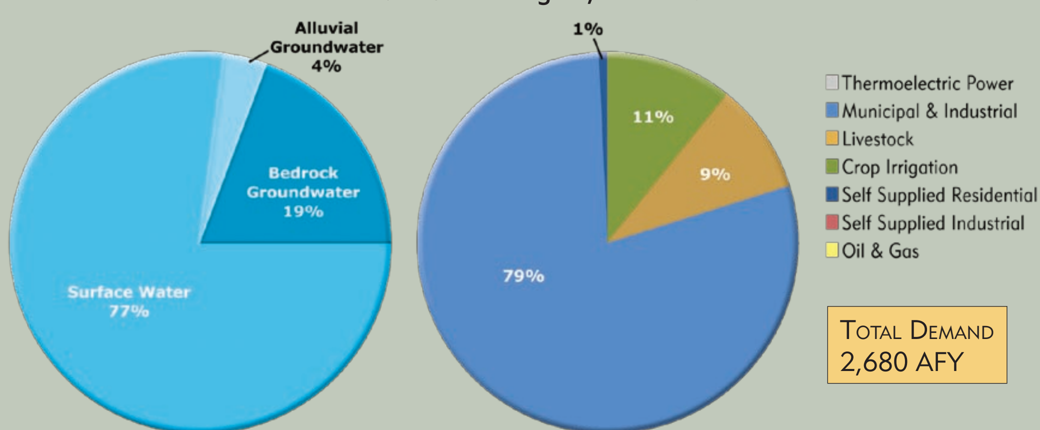
- Water users are expected to continue to rely primarily on surface water, and to a lesser extent, bedrock and alluvial groundwater.
- Surface water gaps have a high probability of occurring by 2020. Bedrock groundwater storage depletions may occur by 2020, but will be minimal in size relative to aquifer storage in the basin. Alluvial groundwater storage depletions from minor aquifers may occur by 2060. Localized storage depletions in both sources may cause adverse effects for users.
- To reduce the risk of adverse effects on water supplies, it is recommended that surface water gaps and groundwater storage depletions be decreased where economically feasible.
- Additional conservation measures could mitigate or reduce surface water gaps and groundwater storage depletions.
- Reservoir storage could be used as an alternative to mitigate surface water gaps and groundwater storage depletions.
- Basin 26 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 26 accounts for about 6% of the current demand in the Beaver-Cache Watershed Planning Region. About 79% of the basin's 2010 demand was from the Municipal and Industrial demand sector. Crop Irrigation was the second largest demand sector at 11%. Surface water satisfies about 77% of the current demand in the basin. Groundwater satisfies about 23% of the current demand (4% alluvial and 19% bedrock). The peak summer month total water demand in Basin 26 was about 2.7 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in Cow Creek is typically low or zero throughout most of the year, except for

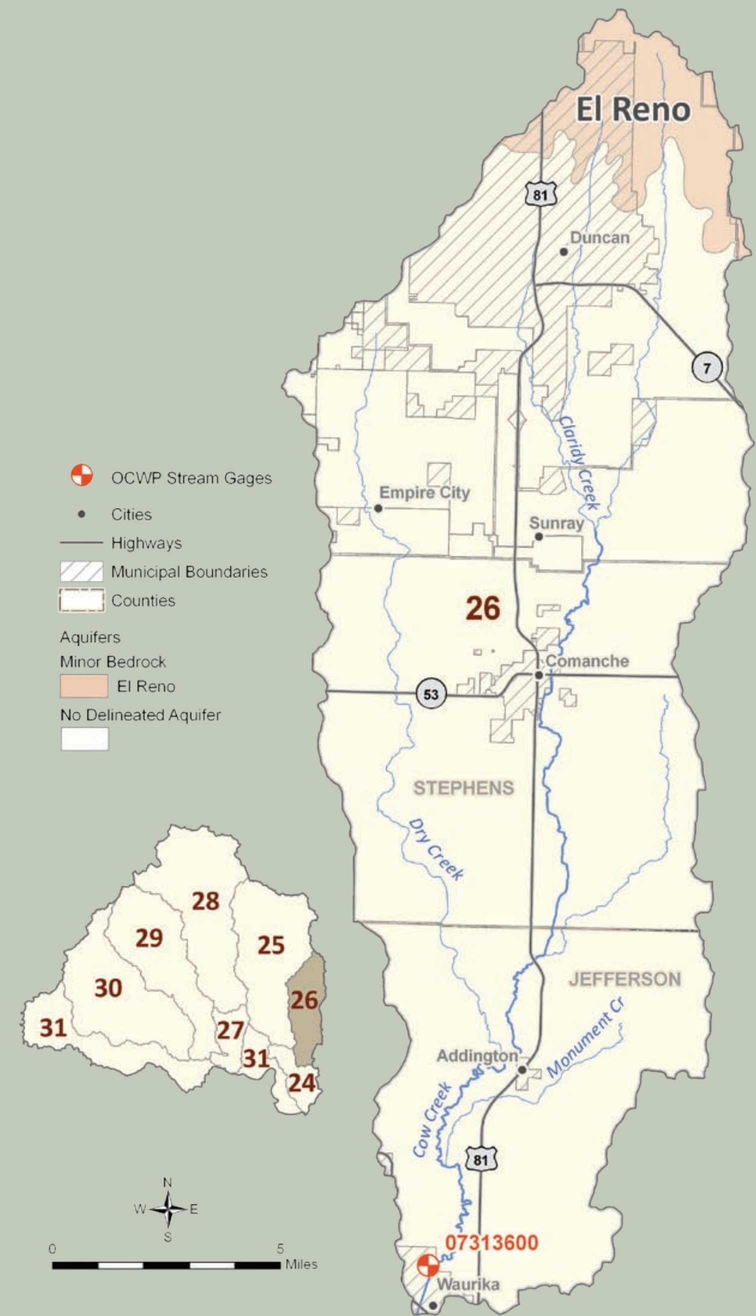
Current Demand by Source and Sector

Beaver-Cache Region, Basin 26

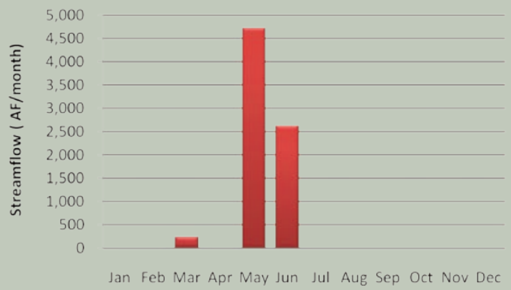


Water Resources

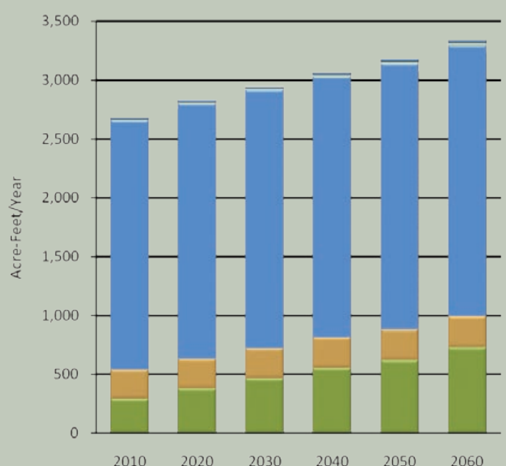
Beaver-Cache Region, Basin 26



Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 26



Projected Demand
Beaver-Cache Region, Basin 26



May and June when it is typically greater than 2,500 AF/month. There are no major reservoirs in the basin. However, the Cities of Duncan and Comanche receive water from Waurika Reservoir in Basin 25. 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 26 is considered poor. However, individual lakes and streams may have acceptable water quality.

A small number of groundwater rights are from the El Reno aquifer. The majority of groundwater rights in the basin are from non-delineated minor bedrock aquifers, and to a lesser extent, non-delineated minor alluvial aquifers. Site-specific information on the suitability of supply from minor aquifers, including the El Reno aquifer, should be considered before large scale use. There are no major alluvial or bedrock aquifers in Basin 26. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant basin-wide groundwater quality issues.

The projected 2060 water demand of 3,340 AFY in Basin 26 reflects a 660 AFY increase (25%) over the 2010 demand. The majority of demand over this period will be in the Municipal and Industrial demand sector, but the largest growth in demand will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions may occur by 2020. Alluvial groundwater depletions may occur by 2060. Surface water gaps may occur in summer, and by 2060, will be up to 100 AFY with a 79% probability of occurring in at least one month of the year. Alluvial groundwater storage depletions may occur in summer, and by 2060, will be up to 10 AFY with a 69% probability of occurring in at least one month of the year. Bedrock groundwater storage depletions may occur in spring, summer, and fall, and by 2060, will be up to 300 AFY. Future alluvial and bedrock groundwater withdrawals are expected to occur from minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated. 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, to a lesser extent, bedrock and alluvial 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.

Water Supply Limitations
Beaver-Cache Region, Basin 26

Surface Water	Significant
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal Potential Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 26

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

Typically Effective Potentially Effective Likely Ineffective No Option Necessary

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could mitigate alluvial groundwater storage depletions and reduce surface water gaps and bedrock groundwater depletions. Temporary drought management activities may not be effective in this basin, since gaps have a relatively high probability of occurring and groundwater storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The Waurika Master Conservancy District provides reliable supplies to the Cities of Duncan and Comanche, but Waurika Lake is almost fully allocated. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region. 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 26 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 900 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.

Bedrock and alluvial groundwater supplies are from minor and non-delineated aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. Localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

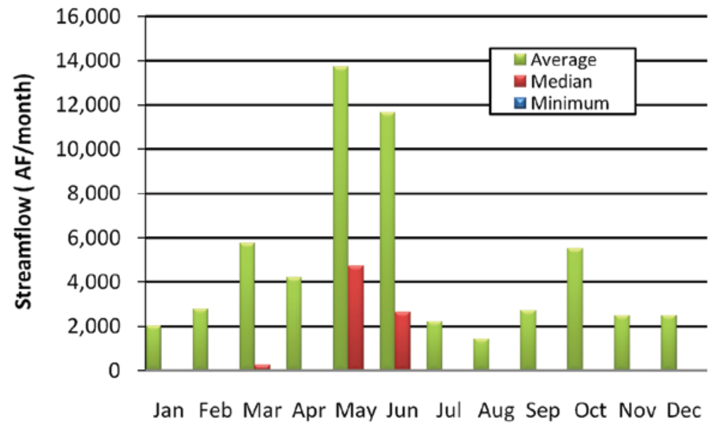
Basin 26 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the early 1960s to the early 1980s. From the late 1980s to the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of Cow Creek at Waurika has low to no flow from July through April, but greater than 2,600 AF/month in May and June. However, the creek can have periods of low or zero flow in any month of the year. Relative to other basins in the state, the surface water quality in Basin 26 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no significant reservoirs in the basin.

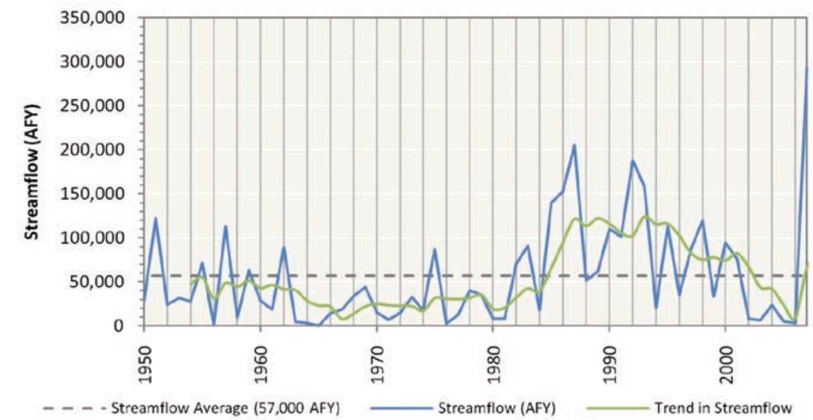
Monthly Historical Streamflow at the Basin Outlet

Beaver-Cache Region, Basin 26



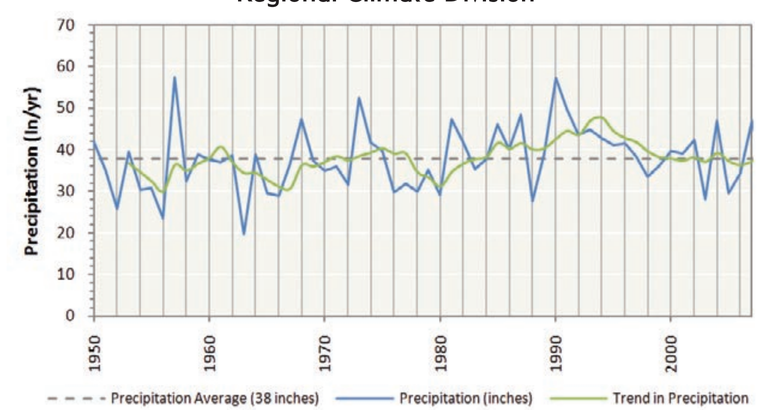
Historical Streamflow at the Basin Outlet

Beaver-Cache Region, Basin 26



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)

Beaver-Cache Region, Basin 26

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
El Reno	Bedrock	Minor	6%	<50	33,000	temporary 2.0	12,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	1,300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	300	N/A	temporary 2.0	N/A

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

Groundwater Resources

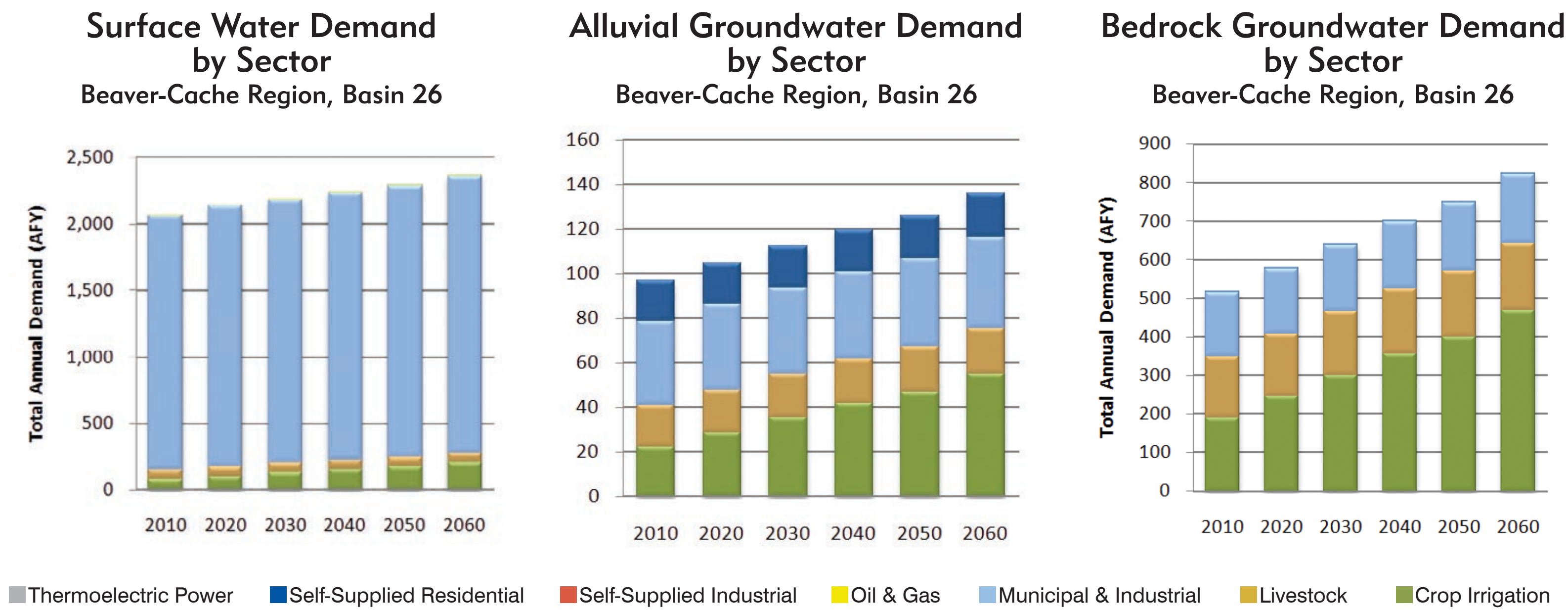
- The majority of groundwater rights in Basin 26 are from non-delineated minor aquifers. There are less than 50 AFY of groundwater rights in the El Reno minor bedrock aquifer.
- There are no significant basin-wide groundwater quality issues.

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

- This basin's water needs are about 6% of the total demand in the Beaver-Cache Watershed Planning Region and will increase by 24% (660 AFY) from 2010 to 2060. The majority of the demand over this period is in the Municipal and Industrial demand sector. However, the largest growth in demand over this period will be in the Crop Irrigation demand sector.
- Surface water is used to meet 77% of the total demand in the basin and its use will increase by 15% (310 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 4% of the total demand in the basin and its use will increase by 40% (40 AFY) from 2010 to 2060. The largest alluvial groundwater use by 2060 and the majority of growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 19% of the total demand in the basin and its use will increase by 60% (310 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector.



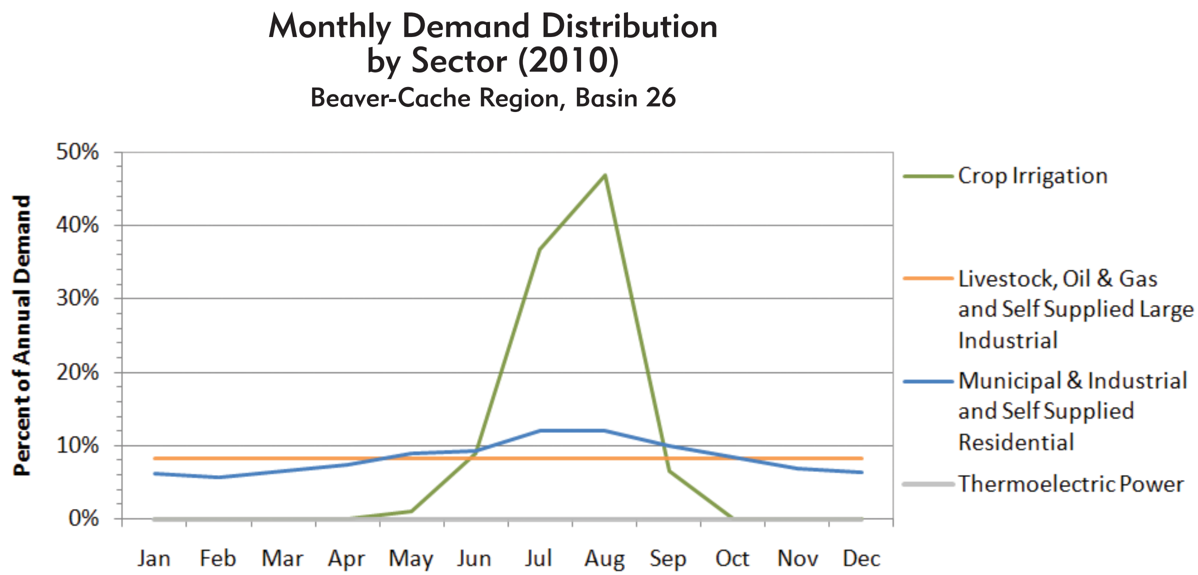
Total Demand by Sector

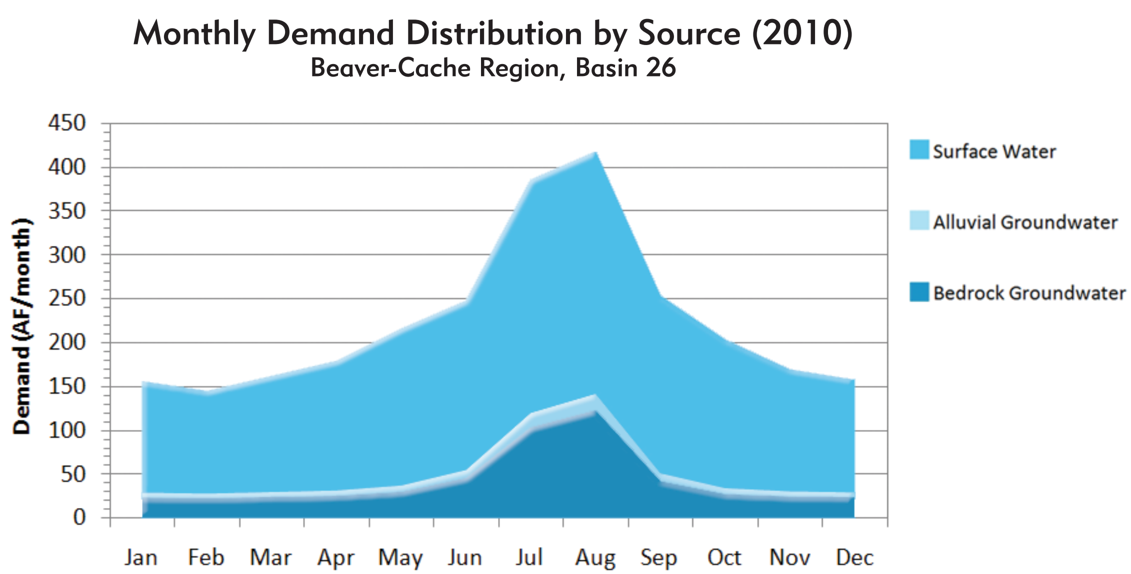
Beaver-Cache Region, Basin 26

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	290	250	2,120	0	0	20	0	2,680
2020	380	250	2,170	10	0	20	0	2,830
2030	470	260	2,190	10	0	20	0	2,950
2040	550	260	2,220	10	0	20	0	3,060
2050	620	260	2,250	10	0	20	0	3,160
2060	730	270	2,300	20	0	20	0	3,340

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 about 80% more water in summer months than in winter months. Crop Irrigation also has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 26 is about 2.7 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.3 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 1.8 times the monthly winter use. Bedrock groundwater use peaks in the summer at about 7 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demands and available supplies, surface water gaps and bedrock groundwater storage depletions are projected to occur by 2020. Alluvial groundwater storage depletions are expected by2060.
- Out-of-basin supplies from the Waurika Master Conservancy District help mitigate gaps in Basin 26; however, surface water gaps in Basin 26 may occur during the summer. Surface water gaps in 2060 will be up to 17% (60 AF/month) of the surface water demand in the peak summer month. By 2060, there will be a 79% probability of surface water gaps occurring in at least one month of the year by 2060.
- Alluvial groundwater storage depletions in Basin 26 may occur during the summer and will be up to 33% (10 AF/month) of the 2060 alluvial groundwater demand in the peak summer month. There will be a 69% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060.
- Bedrock storage depletions from minor aquifers will be used to meet demand in the spring, summer and fall, peaking in size during the summer. Bedrock groundwater storage depletions will be up to 50% (130 AF/month) of the bedrock groundwater demand in the peak summer month, and as much as 25% (10 AF/month) of the bedrock groundwater demand in the spring. Future bedrock groundwater withdrawals are expected to occur from minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 26

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)	60	60	79%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 26

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	10	10	69%
Sep-Nov (Fall)	0	0	0%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 26

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AF			Percent	
2020	20	0	60	76%	0%
2030	40	0	110	76%	0%
2040	60	0	170	78%	0%
2050	70	0	220	79%	0%
2060	100	10	300	79%	69%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 26

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	10
Jun-Aug (Summer)	130
Sep-Nov (Fall)	20

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 26

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	100	10	300	79%	69%
Moderately Expanded Conservation in Crop Irrigation Water Use	90	0	270	79%	0%
Moderately Expanded Conservation in M&I Water Use	30	0	270	76%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	10	0	250	69%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	140	0%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 26

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

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could mitigate alluvial groundwater storage depletions, reduce surface water gaps by 90%, and reduce bedrock groundwater depletions by 17%. Temporary drought management activities may not be effective in this basin, since gaps have a relatively high probability of occurring and 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 Waurika Master Conservancy District provides reliable supplies to users in the basin, but Waurika Lake is almost fully allocated. Therefore out-of-basin supplies will be limited to existing permitted withdrawals. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region: Cookietown Reservoir and Snyder Lake, both in Basin 30. 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 26 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 900 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. No viable reservoir sites were identified in Basin 26.

Increasing Reliance on Surface Water

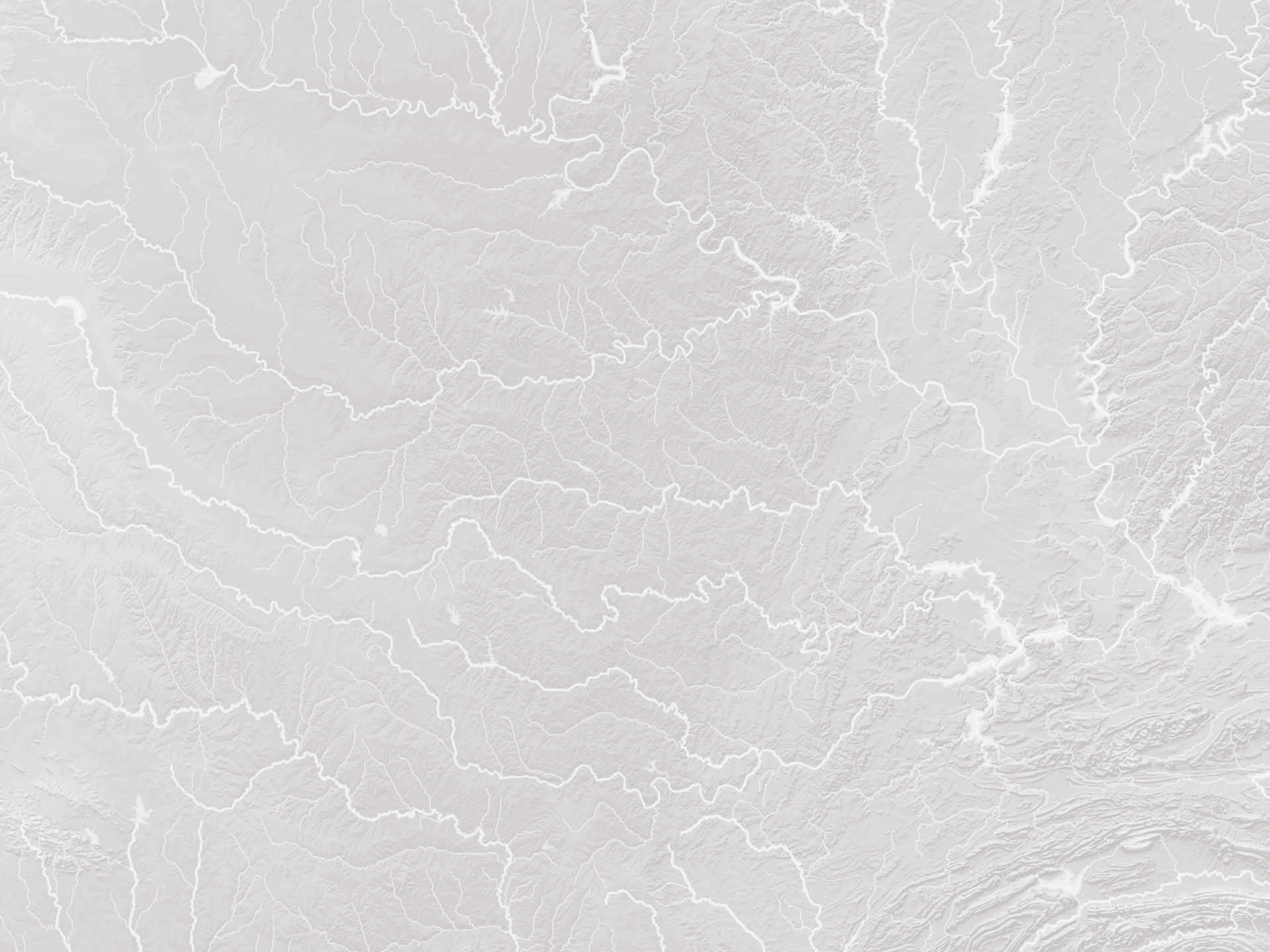
Increased reliance on surface water, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Bedrock and alluvial groundwater supplies are from minor and non-delineated aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. Localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Notes & Assumptions

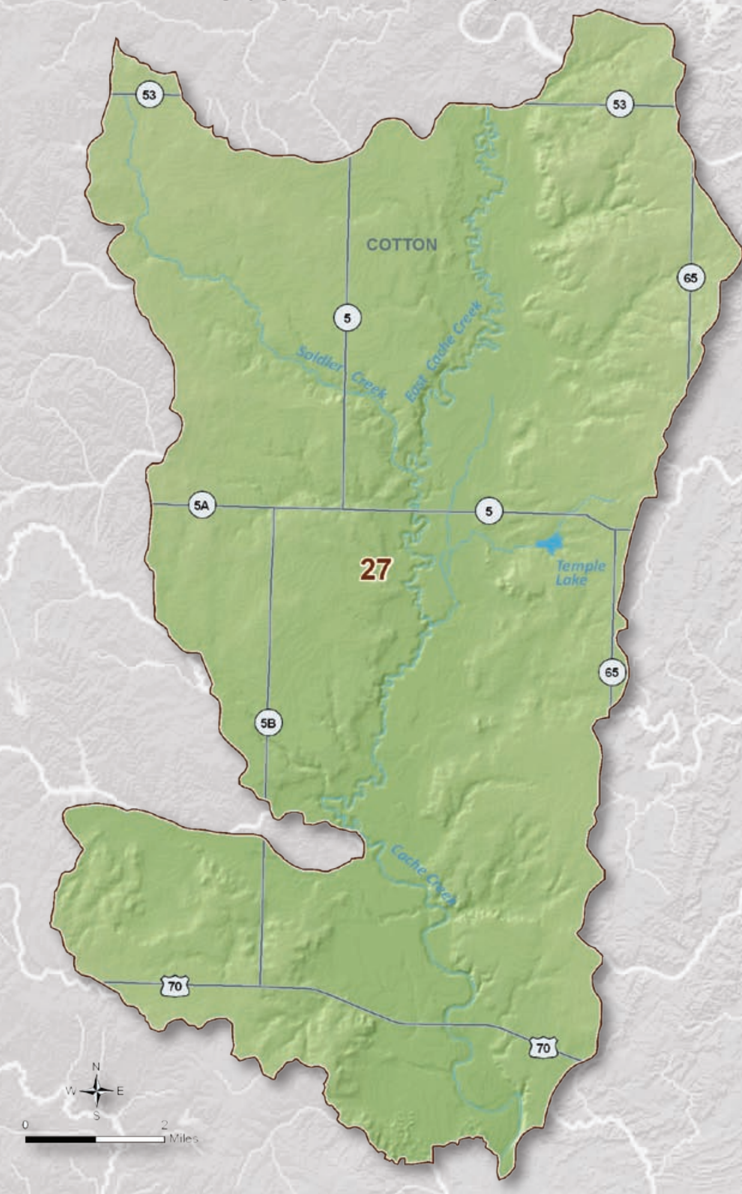
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands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

Basin 27



Basin 27 Summary

Synopsis

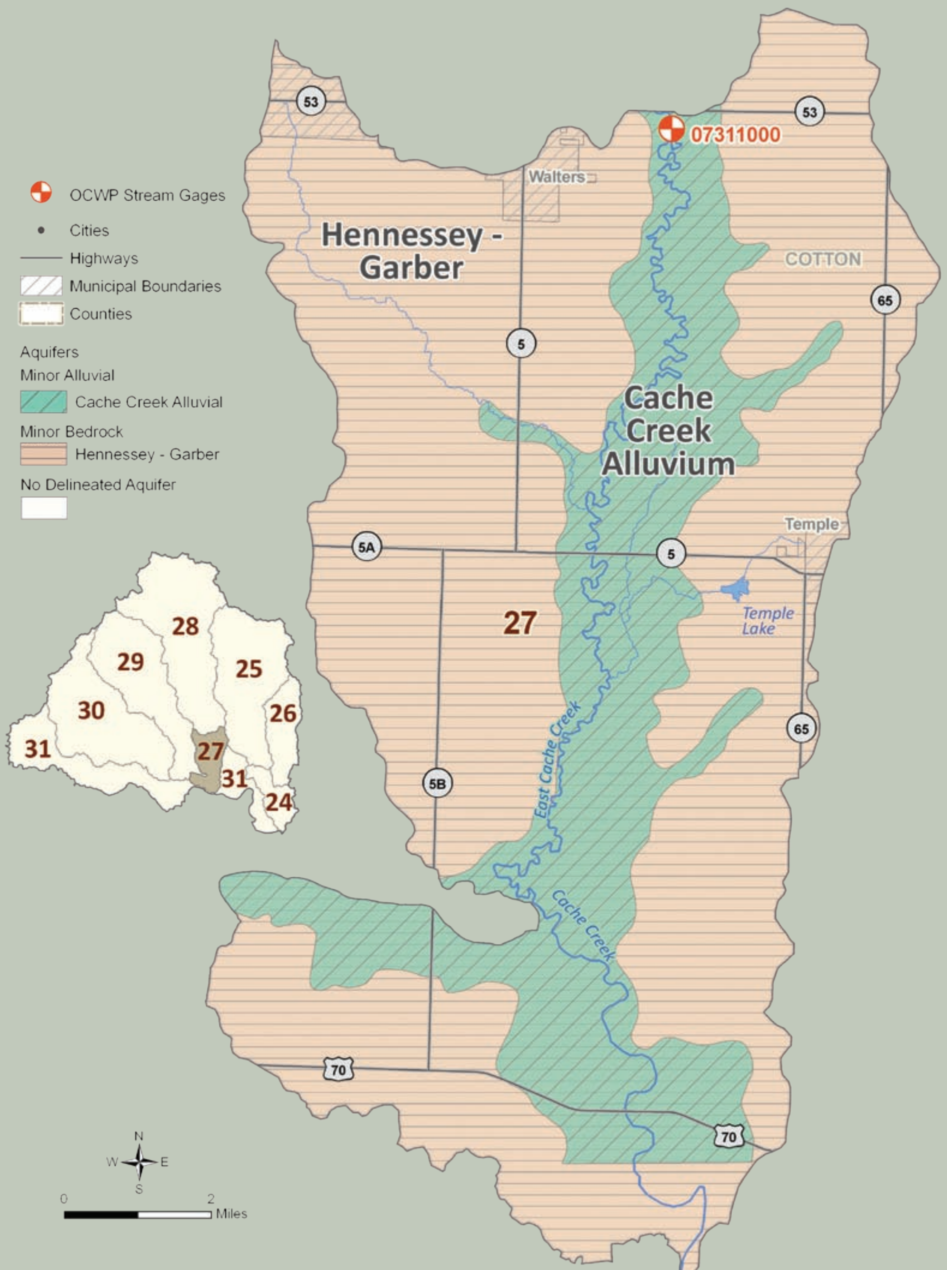
- Water users are expected to continue to rely primarily on surface water, and to a lesser extent, alluvial groundwater.
- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not expected to occur in this basin through 2060. Therefore, no supply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

Basin 27 accounts for about 1% of the current demand in the Beaver-Cache Watershed Planning Region. About 43% of the basin's 2010 demand was from the Crop Irrigation demand sector. The remaining demand was from the Livestock and Municipal and Industrial demand sectors. Surface water satisfies about 84% of the current demand in the basin. Groundwater satisfies about 16% of the current demand (all bedrock). The peak summer month total water demand in Basin 27 is about 5 times the winter monthly demand, which is similar to the overall statewide pattern.

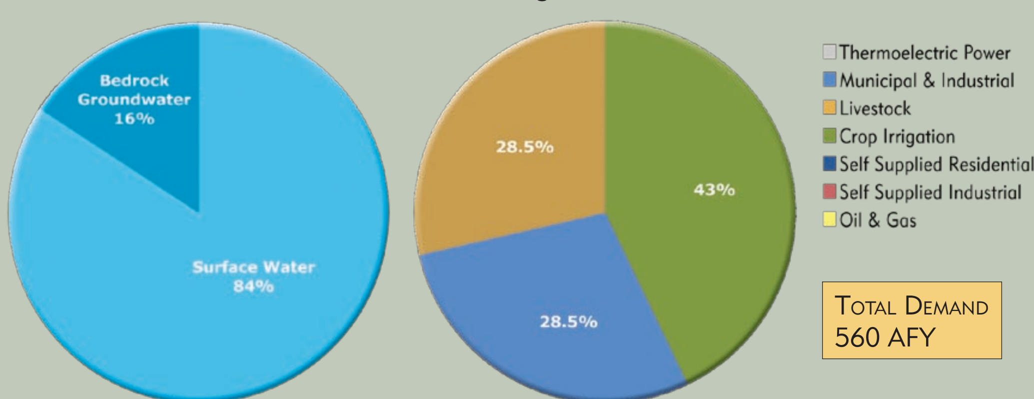
The flow in Cache Creek upstream of the Red River is greater than 3,000 AF/month throughout the year and greater than 8,700 AF/month in the spring and early summer. There are no major reservoirs in the basin. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 27 is considered poor. However, individual lakes and streams may have acceptable water quality.

Groundwater rights in the basin are from the Hennessey-Garber minor bedrock aquifer. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. There are no major alluvial or bedrock aquifers in Basin 27. The Cache Creek minor alluvial aquifer has 77,000 AF of storage in Basin 27 and underlies about a quarter of the basin. The Hennessey-Garber minor bedrock aquifer has 308,000 AF of storage in Basin 27 and underlies the entire 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

Water Resources
Beaver-Cache Region, Basin 27

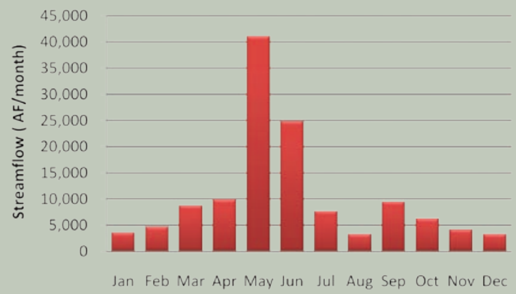


Current Demand by Source and Sector
Beaver-Cache Region, Basin 27

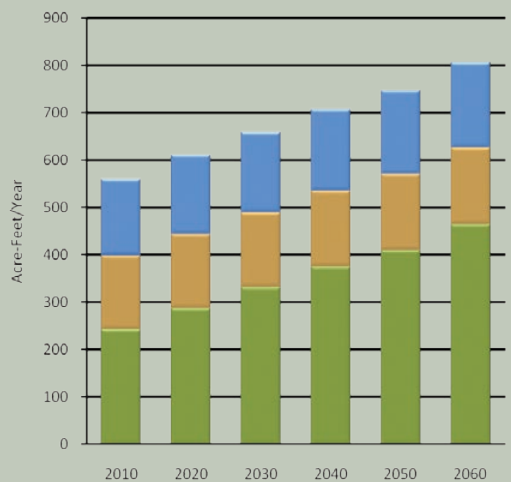


Total Demand
560 AFY

Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 27



Projected Water Demand
Beaver-Cache Region, Basin 27



no significant groundwater quality issues in the basin.

The projected 2060 water demand of 800 AFY in Basin 27 reflects a 240 AFY increase (43%) over the 2010 demand. Most demand and nearly all growth in demand during this period will be in the Crop Irrigation demand sector.

Gaps & Depletions

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

Water Supply Limitations
Beaver-Cache Region, Basin 27

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 27

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

Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Options

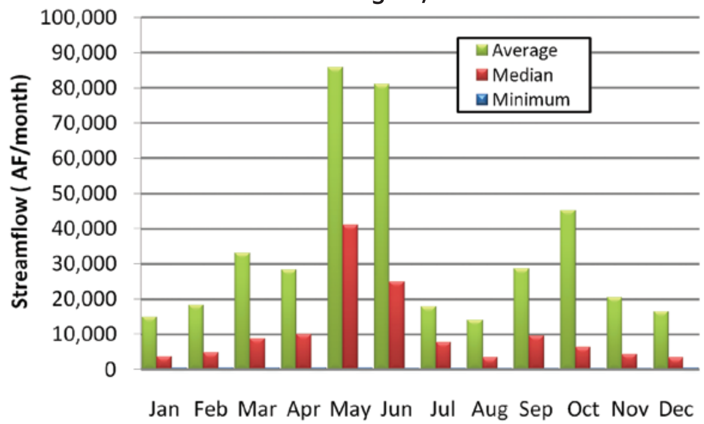
Surface water gaps and groundwater storage depletions are not expected through 2060; therefore, no supply options are necessary.

Basin 27 Data & Analysis

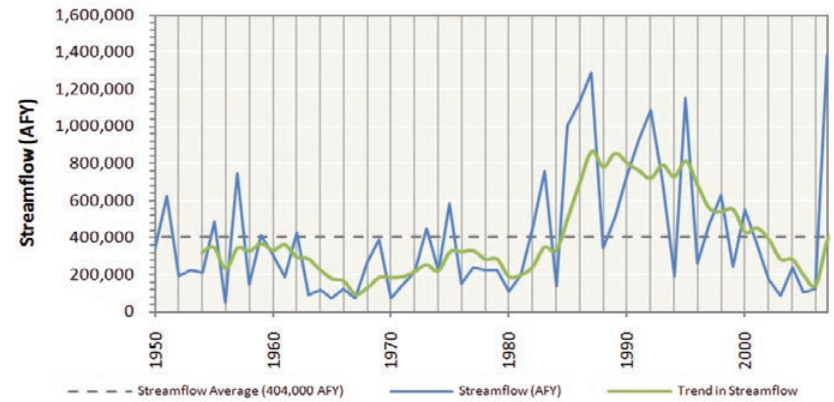
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow mid 1960s to the early 1980s, corresponding to a period of below-average precipitation. From the late 1980s to the mid 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of Cache Creek upstream of the Red River is greater than 3,300 AF/month throughout the year and greater than 24,000 AF/month in May and June. However, the creek 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 27 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in the basin.

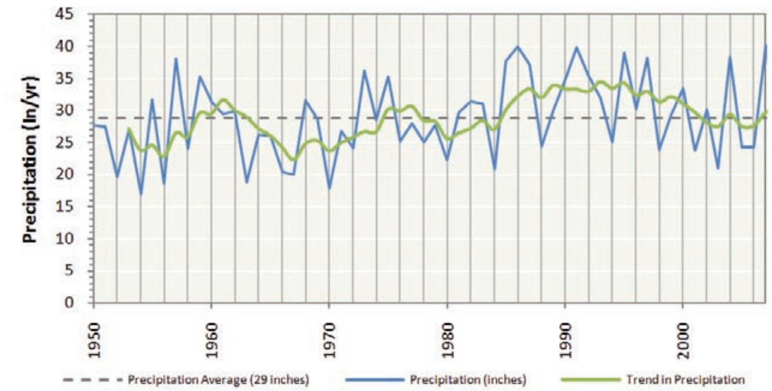
Monthly Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 27



Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 27



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)

Beaver-Cache Region, Basin 27

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
Cache Creek	Alluvial	Minor	28%	0	77,000	1.0	19,200
Hennessey-Garber	Bedrock	Minor	100%	600	308,000	1.6	112,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- All groundwater rights in Basin 27 are from non-delineated minor aquifers.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

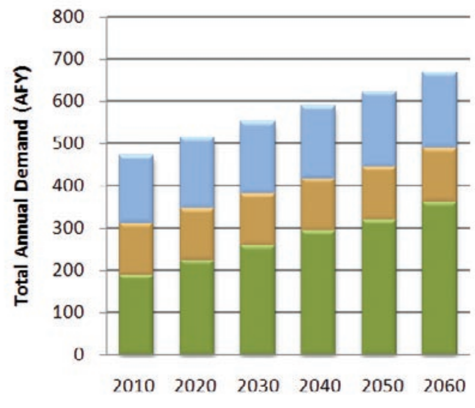
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- The water needs in Basin 27 are about 21% of the total demand in the Beaver-Cache Region and will increase by 43% (240 AFY) from 2010 to 2060. The majority of the demand by 2060 and the majority of growth in demand over this period will be in the Crop Irrigation demand sector.
- Surface water is used to meet 84% of the total demand in the basin and will increase by 41% (190 AFY) from 2010 to 2060. The largest use of surface water and the majority of growth in surface water use over this period will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 16% of the total demand in the basin and will increase by 57% (50 AFY) from 2010 to 2060. The majority of bedrock aquifer use and growth in bedrock aquifer use over this period will be in the Crop Irrigation demand sector.
- There is no alluvial groundwater use in Basin 27 at this time; no future demand is expected.

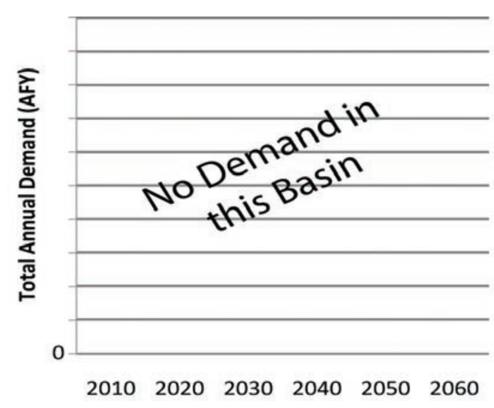
Surface Water Demand by Sector

Beaver-Cache Region, Basin 27



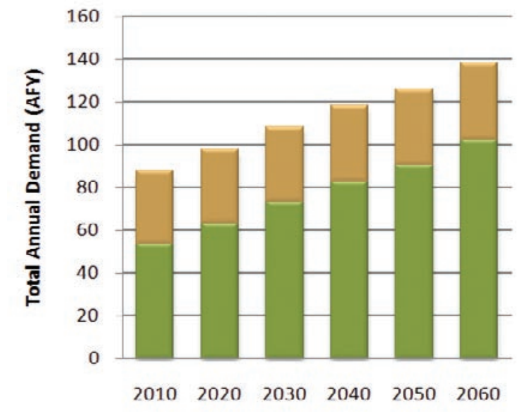
Alluvial Groundwater Demand by Sector

Beaver-Cache Region, Basin 27



Bedrock Groundwater Demand by Sector

Beaver-Cache Region, Basin 27



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

Total Demand by Sector

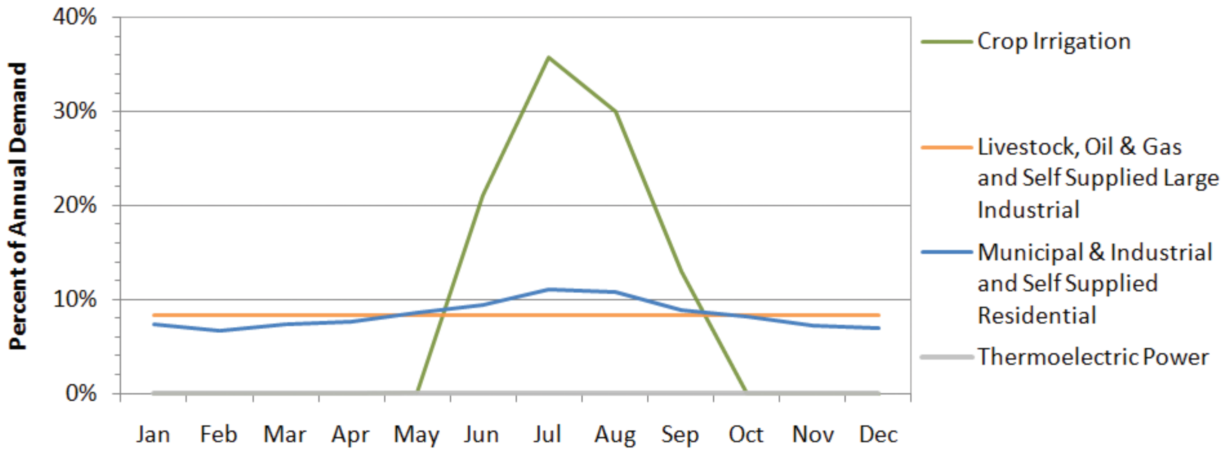
Beaver-Cache Region, Basin 27

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	240	160	160	0	0	0	0	560
2020	290	160	170	0	0	0	0	620
2030	330	160	170	0	0	0	0	660
2040	380	160	170	0	0	0	0	710
2050	410	160	180	0	0	0	0	750
2060	460	160	180	0	0	0	0	800

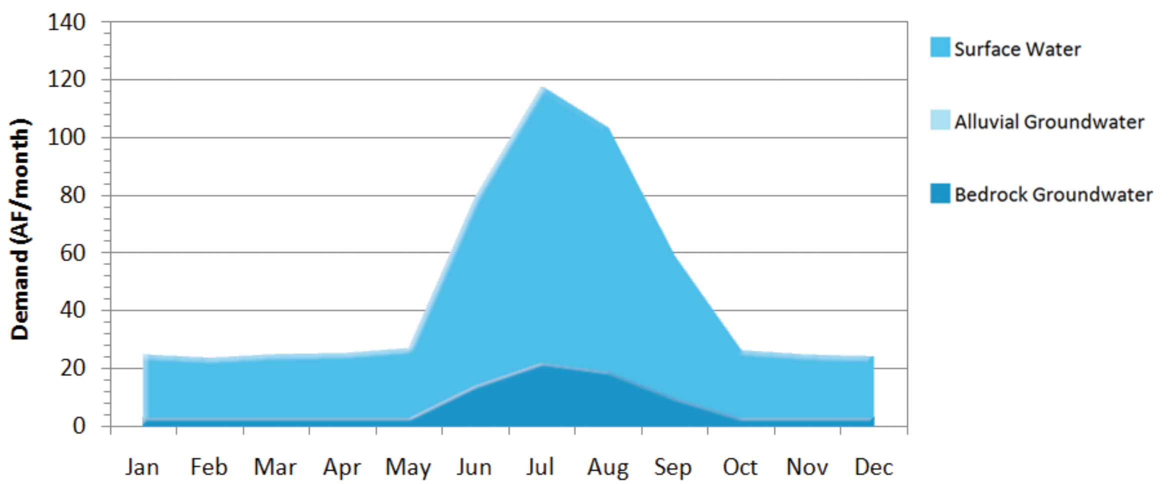
Notes & Assumptions

- 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)
Beaver-Cache Region, Basin 27



Monthly Demand Distribution by Source (2010)
Beaver-Cache Region, Basin 27



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% 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. The Livestock sector has a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 27 is about 5 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 4 times the monthly winter use. Bedrock groundwater use peaks in the summer at about 8 times the monthly winter use.

Gaps and Storage Depletions

- Based on historical hydrology, surface water gaps and bedrock groundwater storage depletions are not expected to occur in this basin through 2060. Alluvial groundwater is not expected to be used as a source of supply in this basin.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 27

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 27

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 27

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

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 27

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 27

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

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 27

Reservoir Storage	Yield
AF	AFY
100	800
500	1,500
1,000	2,100
2,500	4,100
5,000	7,300
Required Storage to Meet Growth in Demand (AF)	0
Required Storage to Meet Growth in Surface Water Demand (AF)	0

Water Supply Options & Effectiveness

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

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

Demand Management

No option necessary.

Out-of-Basin Supplies

No option necessary.

Reservoir Use

No option necessary.

Increasing Reliance on Surface Water

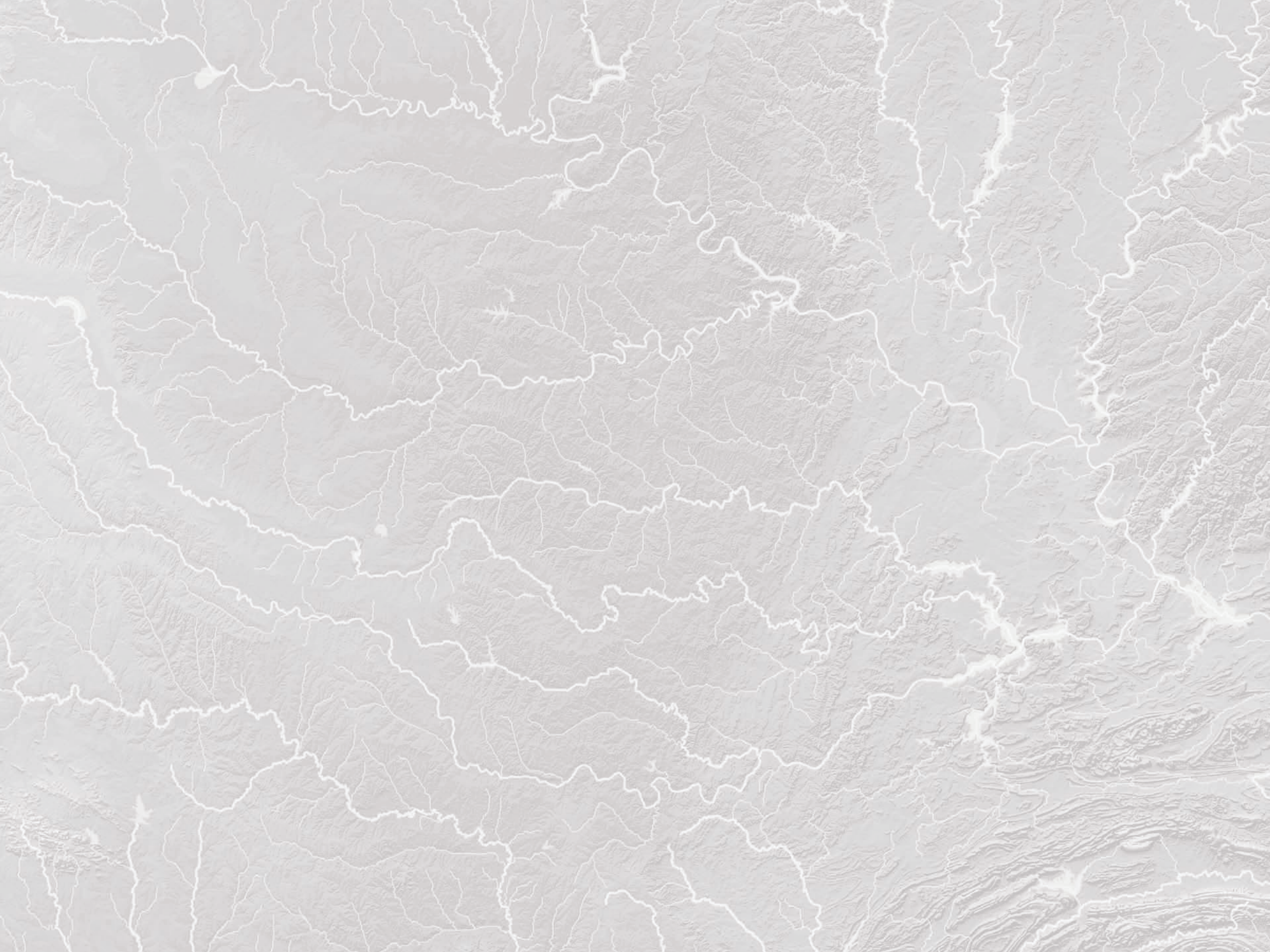
No option necessary.

Increasing Reliance on Groundwater

No option necessary.

Notes & Assumptions

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



Data & Analysis
Beaver-Cache Watershed Planning Region

Basin 28

Basin 28 Summary

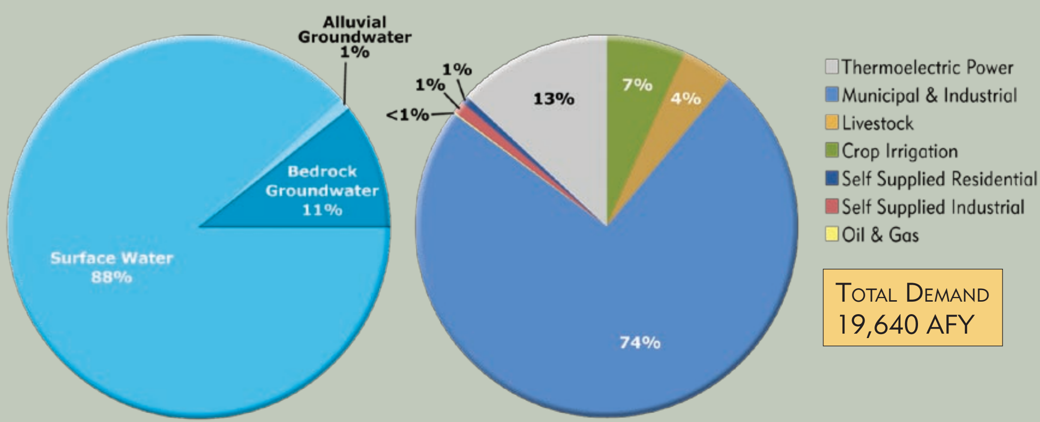
Synopsis

- Water users are expected to continue to rely primarily on surface water.
- Alluvial groundwater depletions have a very small probability of occurring by 2060 and will be minimal in size. Bedrock groundwater storage depletions and surface water gaps are not expected through 2060.
- To reduce the risk of adverse impacts on water supplies, it is recommended that alluvial groundwater storage depletions be decreased where economically feasible.
- Additional conservation measures could mitigate alluvial groundwater storage depletions.
- Reservoir storage could be used as an alternative to mitigate alluvial groundwater storage depletions.

Basin 28 accounts for about 44% of the current demand in the Beaver-Cache Watershed Planning Region. About 74% of the basin's 2010 demand was from the Municipal and Industrial demand sector. Thermoelectric Power was the second largest demand sector at 13%. Surface water satisfies about 88% of the current demand in the basin. Groundwater satisfies about 12% of the current demand (1% alluvial and 11% bedrock). The peak summer month total water demand in Basin 28 is about 1.9 times the winter monthly demand, which is less pronounced than the overall statewide pattern.

The flow in Cache Creek is typically greater than 1,700 AF/month throughout the year and greater than 10,000 AF/month in May and June. There are two major municipal lakes in Basin 28, Lake Lawtonka and Lake Ellsworth, which provide water to the City of Lawton. Relative to other basins in the state, the surface water quality in Basin 28 is considered fair. Lake Lawtonka was built in 1905 on Medicine Creek for water supply, recreation, and flood control. The lake has a yield of 23,500 AFY which can be maintained by inflows from Lake Ellsworth. Lake Ellsworth was constructed in 1962 on East Cache Creek for the purposes of water supply and flood control. Similar to Lake Lawtonka, Ellsworth has a yield of 23,500 AFY. The entire dependable yield of both lakes (47,000 AFY) is fully allocated to the City of Lawton. The availability of permits is

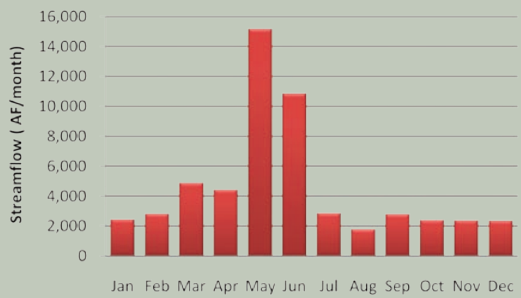
Current Demand by Source and Sector
Beaver-Cache Region, Basin 28



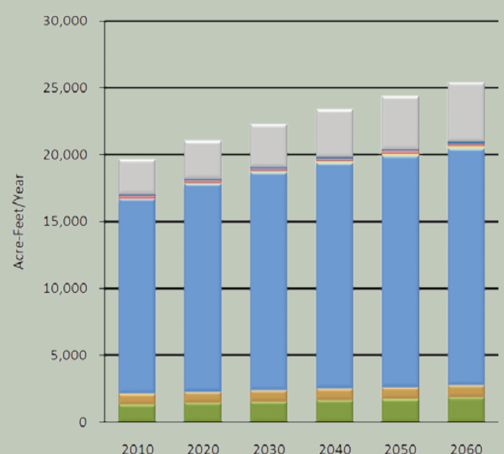
TOTAL DEMAND
19,640 AFY

Water Resources
Beaver-Cache Region, Basin 28

Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 28



Projected Water Demand
Beaver-Cache Region, Basin 28



not expected to limit the development of surface water supplies for in-basin use through 2060.

Groundwater rights in the basin are from the Arbuckle-Timbered Hills and Rush Springs aquifers, as well as minor bedrock and alluvial aquifers and non-delineated minor bedrock groundwater sources. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. The Arbuckle-Timbered Hills aquifer underlies a large portion of the basin, but high fluoride and chloride concentrations may limit the use of the aquifer for some water use sectors. The basin contributes 8,000 AFY of recharge to the Arbuckle-Timbered Hills and Rush Springs aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The projected 2060 water demand of 25,390 AFY in Basin 28 reflects a 5,750 AFY increase (29%) over the 2010 demand. The majority of demand and growth in demand over this period will be in the Municipal and Industrial demand sector. Significant growth is also anticipated in the Thermoelectric Power demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions have a small probability of occurring by 2060. Lakes Ellsworth and Lawtonka are capable of providing dependable water supplies to existing users, and with new infrastructure, could be used to meet all of Basin 28's future surface water demand during periods of low streamflow. However, these lakes are currently fully allocated. Alluvial groundwater storage depletions may occur in the summer, and by 2060, will be up to 10 AFY with a 3% probability of occurring in at least one month of the year. Future alluvial groundwater withdrawals are expected to occur from minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated due to insufficient information. Bedrock groundwater storage depletions and surface water gaps are not expected through 2060.

Options

Water users are expected to continue to rely primarily on surface water. 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 and Self-Supplied Residential demand sectors could mitigate alluvial groundwater storage depletions. Temporary drought management activities may not be necessary in this basin, since groundwater storage could continue to provide supplies during droughts.

Water Supply Limitations
Beaver-Cache Region, Basin 28

Source	Limitation
Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal · Potential · Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 28

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

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

Out-of-basin supplies could mitigate groundwater storage depletions. Waurika Master Conservancy District, in Basin 25, supplies the City of Lawton via pipeline to Lake Ellsworth. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region. However, in light of the distance to reliable water supplies and substantial groundwater supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Additional reservoir storage in Basin 28 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,500 AF of reservoir storage at the basin outlet.

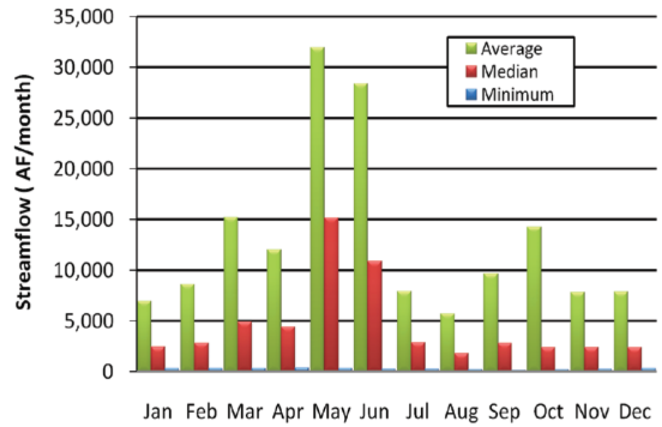
Increased reliance on surface water through direct diversions, without reservoir storage, may create surface water gaps and is not recommended.

Increased reliance on bedrock groundwater could be used to offset alluvial groundwater depletions. Any bedrock groundwater storage depletions would be minimal relative to aquifer storage in the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

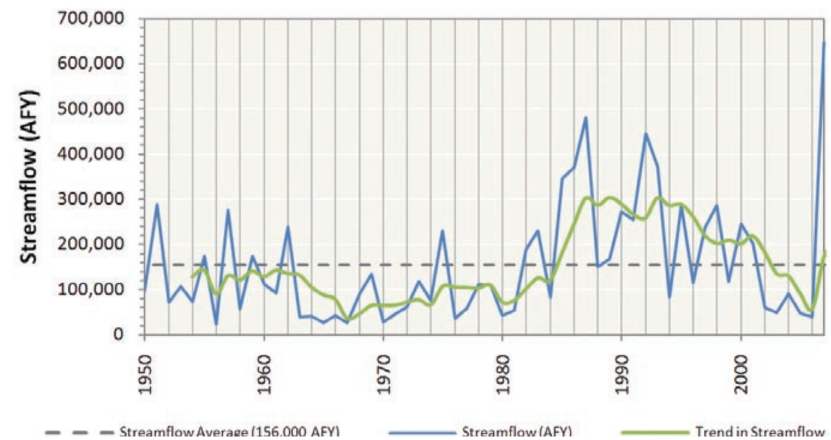
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the mid 1960s to the early 1980s , corresponding to a period of below-average precipitation. From the late 1980s through the 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of East Cache Creek near Walters is greater than 1,700 AF/month throughout the year and greater than 10,800 AF/month in May and June. However, the creek 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 28 is considered fair.
- Two major reservoirs, Lake Lawtonka and Lake Ellsworth, serve the City of Lawton and provide 47,000 AFY of dependable yield.

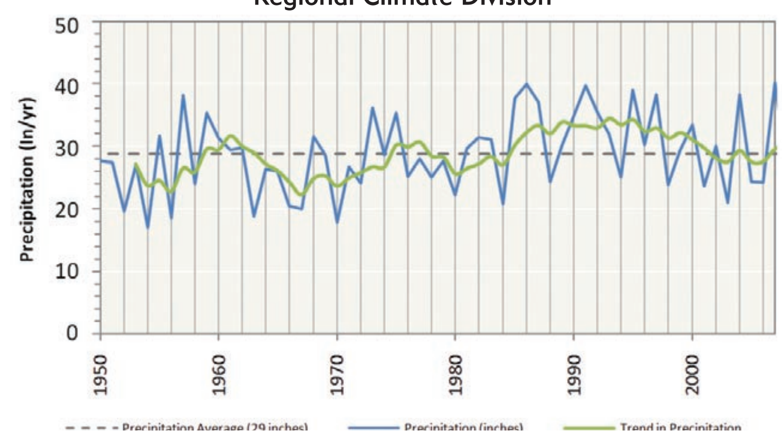
Monthly Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 28



Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 28



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)

Beaver-Cache Region, Basin 28

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
Arbuckle-Timbered Hills	Bedrock	Major	34%	4,000	611,000	temporary 2.0	303,400
Rush Springs	Bedrock	Major	5%	1,900	795,000	temporary 2.0	36,600
Cache Creek	Alluvial	Minor	9%	1,000	154,000	1.0	37,800
Hennessey-Garber	Bedrock	Minor	52%	2,300	1,009,000	1.6	366,400
Post Oak	Bedrock	Minor	5%	0	667,000	2.0	51,200
Southwestern Oklahoma	Bedrock	Minor	17%	0	207,000	temporary 2.0	153,100
Non-Delineated Groundwater Source	Bedrock	Minor	NA	1,200	0	temporary 2.0	NA
Non-Delineated Groundwater Source	Alluvial	Minor	NA	0	0	temporary 2.0	NA

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 the basin are in the Arbuckle-Timbered Hills major bedrock aquifer, Rush Springs major bedrock aquifer, and Hennessey-Garber minor bedrock aquifer. Alluvial groundwater permits are in the Cache Creek minor alluvial aquifer.
- The Arbuckle-Timbered Hills aquifer may be high in fluoride and chloride, which may limit the supply by some water use sectors.

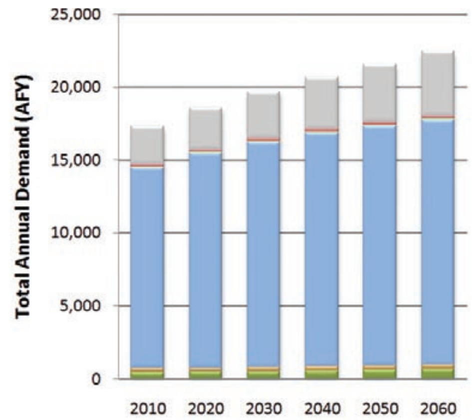
Notes & Assumptions

- 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.

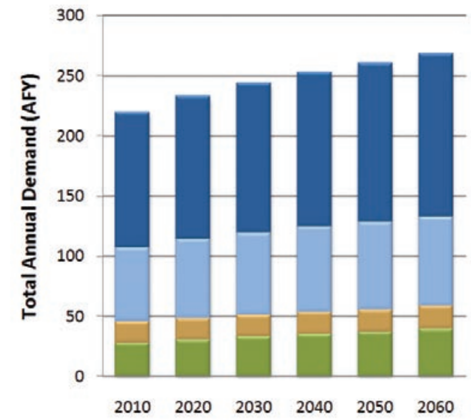
Water Demand

- This basin's water needs account for about 45% of the total demand in the Beaver-Cache Region and will increase by 29% (5,750 AFY) from 2010 to 2060. The majority of the demand and growth in demand will be in the Municipal and Industrial demand sector.
- Surface water is used to meet 88% of the total demand in the basin and will increase by 30% (5,140 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 1% of the total demand in the basin and its use will increase by 22% (50 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Self-Supplied Residential and Municipal and Industrial demand sectors.
- Bedrock groundwater is used to meet 11% of the total demand in the basin and its use will increase by 26% (560 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation and Municipal and Industrial demand sectors.

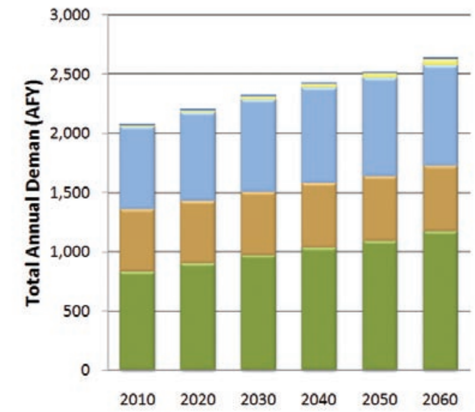
Surface Water Demand by Sector
Beaver-Cache Region, Basin 28



Alluvial Groundwater Demand by Sector
Beaver-Cache Region, Basin 28



Bedrock Groundwater Demand by Sector
Beaver-Cache Region, Basin 28



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

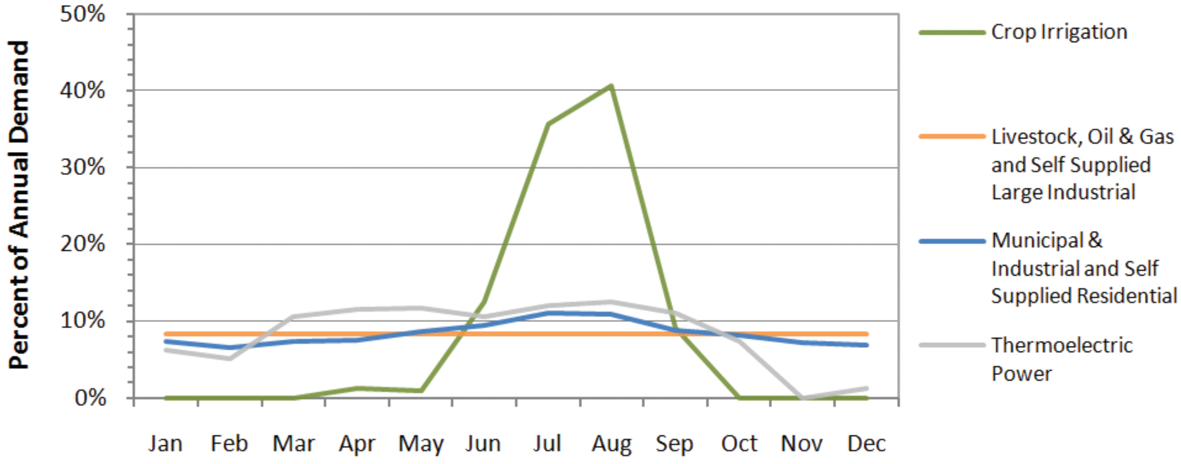
Total Demand by Sector
Beaver-Cache Region, Basin 28

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,330	840	14,550	30	200	120	2,570	19,640
2020	1,440	850	15,540	40	200	120	2,860	21,050
2030	1,540	860	16,290	50	200	130	3,190	22,260
2040	1,650	870	16,880	70	210	130	3,560	23,370
2050	1,730	880	17,350	90	210	140	3,980	24,380
2060	1,870	890	17,730	100	220	140	4,440	25,390

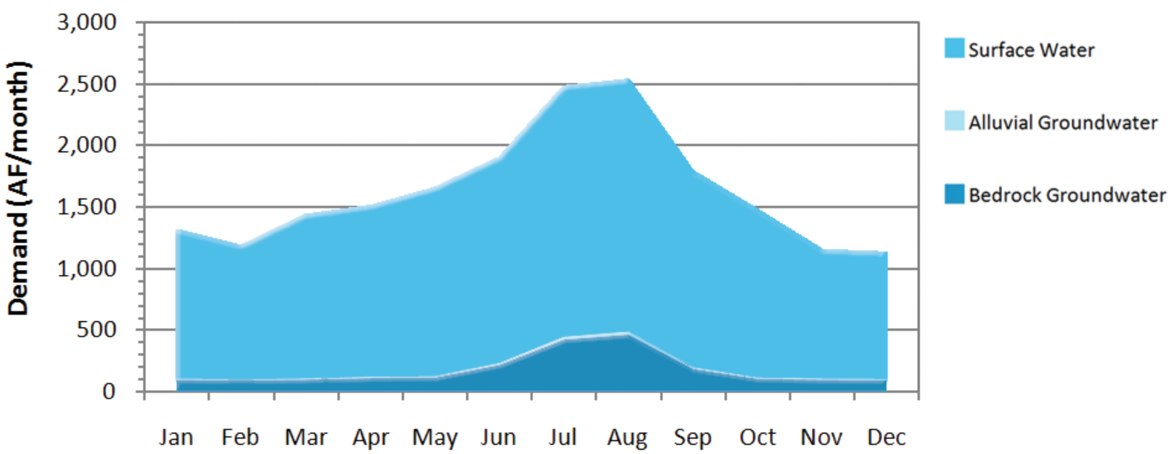
Notes & Assumptions

- 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)
Beaver-Cache Region, Basin 28



Monthly Demand Distribution by Source (2010)
Beaver-Cache Region, Basin 28



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Thermoelectric power demand is more consistent throughout the spring and summer. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 28 is about 1.9 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 1.7 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 2.2 times the monthly winter use. Bedrock groundwater use peaks in the summer at about 5 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater depletions are projected to occur by 2060. Surface water gaps and bedrock groundwater storage depletions are not expected through 2060.
- Alluvial groundwater storage depletions in Basin 28 may occur during the summer and will be up to 25% (10 AF/month) of the 2060 summer alluvial groundwater demand. By 2060, there will be a 3% probability of storage depletions occurring in at least one month of the year.
- Lake Lawtonka and Lake Ellsworth are capable of providing dependable water supply to existing users, and with new infrastructure, could supply sufficient water to meet all of Basin 28's future surface water demand during periods of low streamflow. However, the lakes are currently fully allocated, and existing water rights would need to be taken into consideration for future planning purposes.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 28

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 28

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 28

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

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 28

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 28

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	0	10	0	0%	3%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	10	0	0%	3%
Moderately Expanded Conservation in M&I Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 28

Reservoir Storage	Diversion
AF	AFY
100	2,000
500	3,500
1,000	4,700
2,500	7,800
5,000	12,200
Required Storage to Meet Growth in Demand (AF)	1,500
Required Storage to Meet Growth in Surface Water Demand (AF)	1,100

Water Supply Options & Effectiveness

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

Demand Management

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

Out-of-Basin Supplies

Out-of-basin supplies could mitigate groundwater storage depletions. Waurika Master Conservancy District, in Basin 25, supplies the City of Lawton via Lake Ellsworth. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region: Cookietown Reservoir and Snyder Lake, both in Basin 30. However, in light of the distance to reliable water supplies and substantial groundwater resources, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Additional reservoir storage in Basin 28 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 1,500 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future storage depletions. No viable reservoir sites were identified in Basin 28.

Increasing Reliance on Surface Water

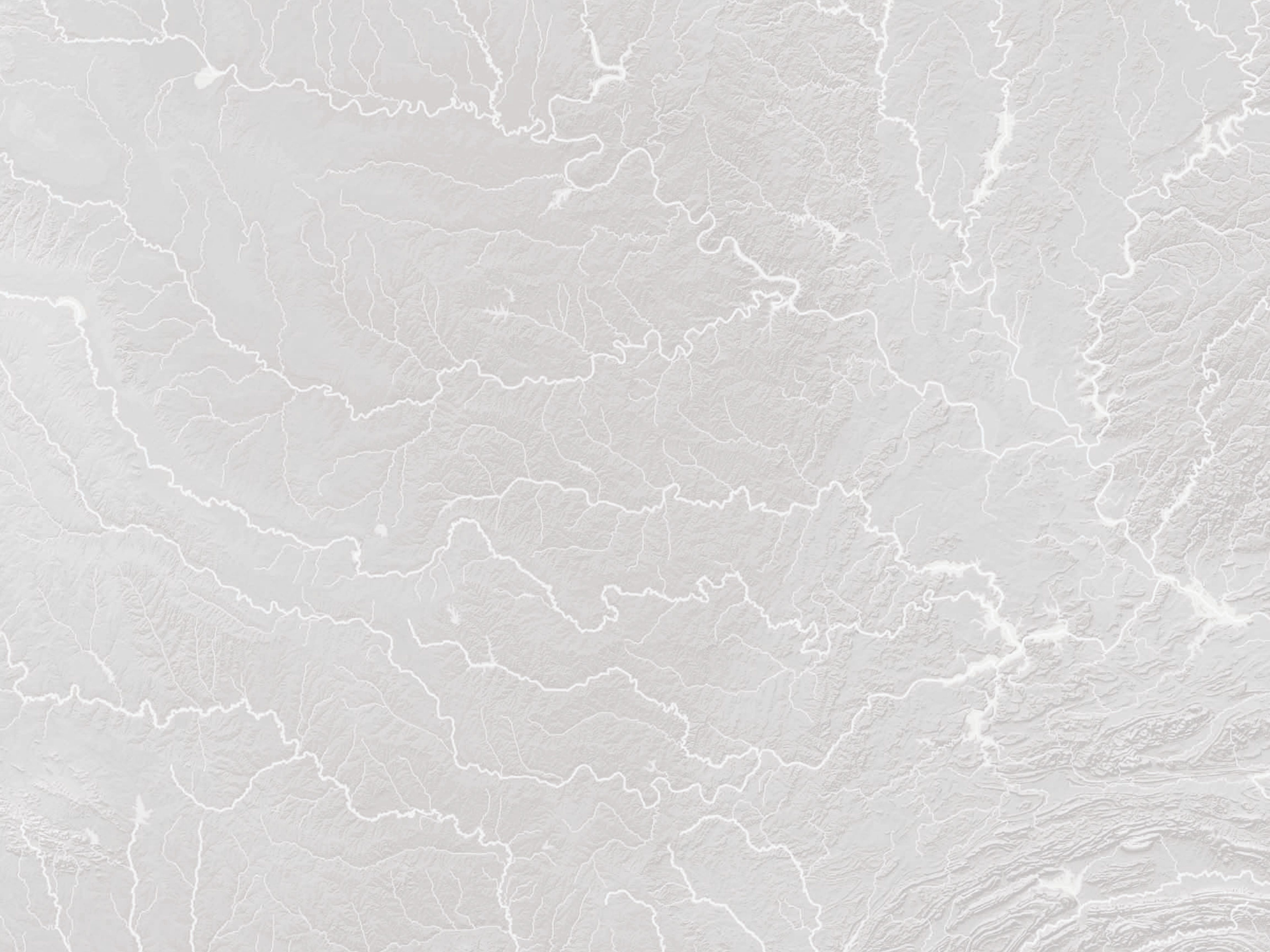
Increased reliance on surface water, without reservoir storage, may create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on bedrock groundwater could be used to offset alluvial groundwater depletions. Any bedrock groundwater storage depletions would be minimal relative to aquifer storage in the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Notes & Assumptions

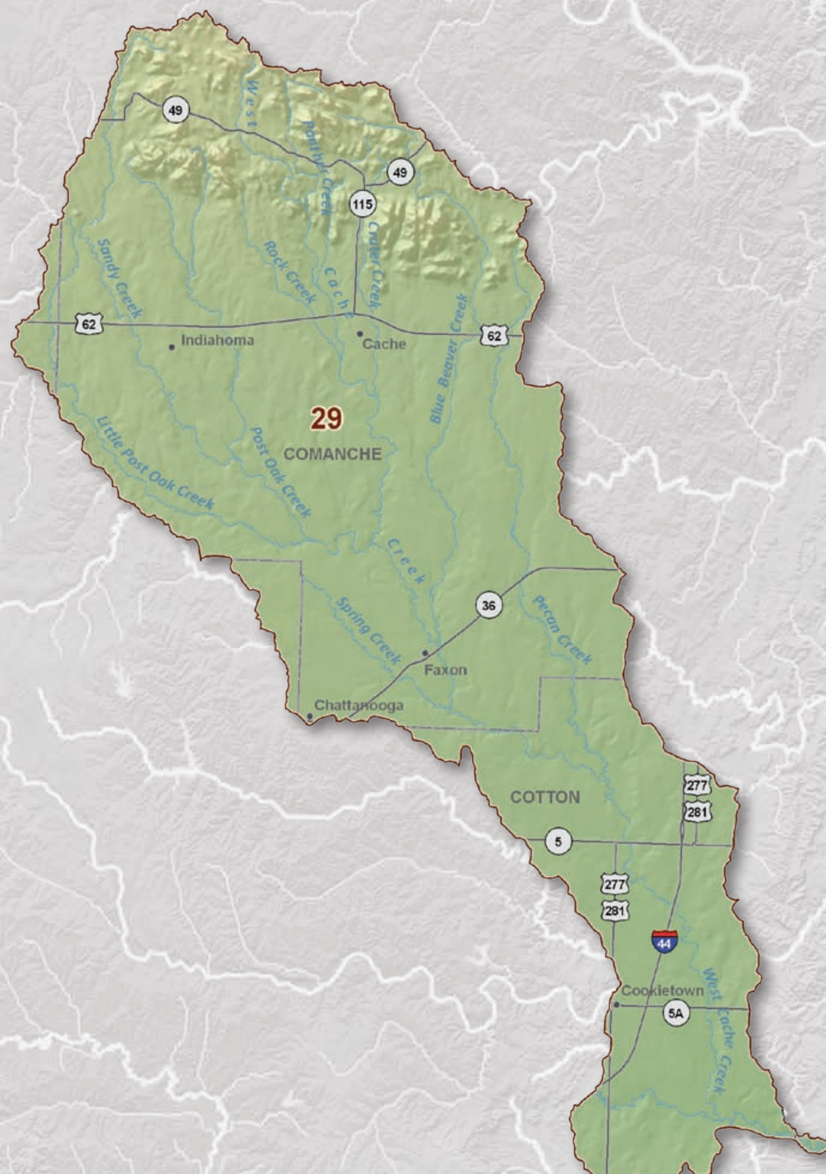
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands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



Data & Analysis

Beaver-Cache Watershed Planning Region

Basin 29



Basin 29 Summary

Synopsis

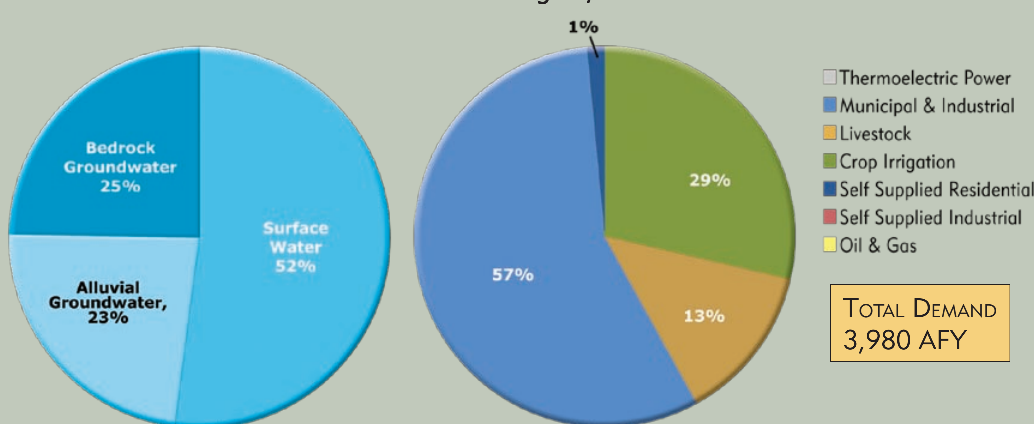
- Water users are expected to continue to rely on surface water, alluvial groundwater, and bedrock groundwater.
- By 2020, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial and bedrock groundwater storage depletions may occur by 2020, but will be 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 effects on water supplies, it is recommended that surface water gaps and groundwater depletions be decreased where economically feasible.
- Additional conservation measures could reduce surface water gaps and groundwater storage depletions.
- Reservoir storage could be used as an alternative to mitigate surface water gaps and groundwater storage depletions.

Basin 29 accounts for about 9% of the current demand in the Beaver-Cache Watershed Planning Region. About 57% of the basin's 2010 demand was from the Municipal and Industrial demand sector. Crop Irrigation was the second largest demand sector at 29%. Surface water satisfies about 52% of the current demand in the basin. Groundwater satisfies about 48% of the current demand (23% alluvial and 25% bedrock). The peak summer month total water demand in Basin 29 is about 4 times the winter monthly demand, which is similar to the overall statewide pattern.

The flow in West Cache Creek downstream of Deep Red Creek is typically greater than 500 AF/month throughout the year and greater than 15,000 AF/month in May and June. There are no major reservoirs in Basin 29. Relative to other basins in the state, the surface water quality in Basin 29 is considered

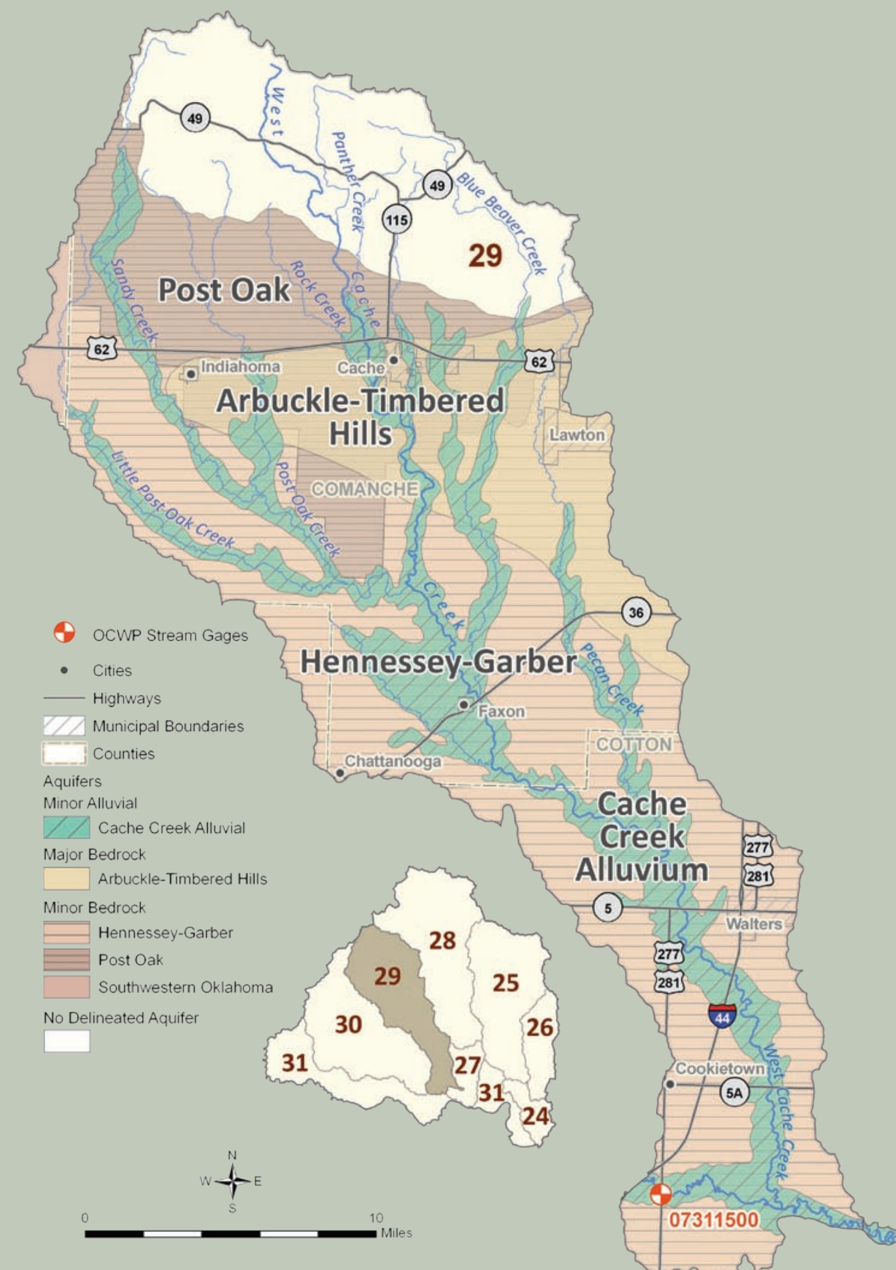
Current Demand by Source and Sector

Beaver-Cache Region, Basin 29

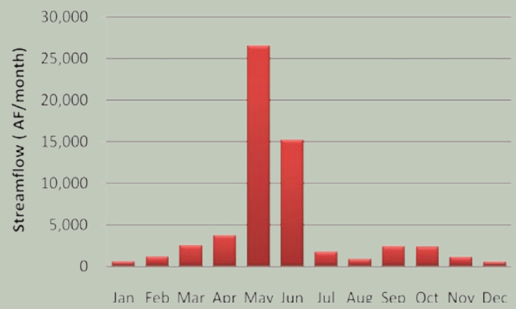


Water Resources

Beaver-Cache Region, Basin 29



Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 29



Projected Water Demand
Beaver-Cache Region, Basin 29

poor. However, individual lakes and streams may have acceptable water quality. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

The majority of current groundwater rights are in the Cache Creek minor alluvial aquifer. Groundwater rights are also from the Arbuckle-Timbered Hills major bedrock aquifer, as well as minor bedrock and alluvial aquifers. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. The Arbuckle-Timbered Hills aquifer underlies less than 20% of the basin but high fluoride and chloride concentrations may limit its use for some water use sectors. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The projected 2060 water demand of 5,010 AFY in Basin 29 reflects a 1,030 AFY increase (26%) over the 2010 demand. The majority of demand over this period will be in the Municipal and Industrial demand sector, but the largest growth in demand will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial and bedrock groundwater storage depletions may occur by 2020. Surface water gaps in Basin 29 may occur throughout the year, peaking in size in the summer, and by 2060 will be up to 340 AFY with a 52% probability of occurring in at least one month of the year. Alluvial groundwater storage depletions may occur throughout the year, peaking in size in the summer, and by 2060 will be up to 210 AFY with a 47% probability of occurring in at least one month of the year. Future alluvial groundwater withdrawals are expected to occur from minor aquifers. Bedrock groundwater storage depletions may occur in the summer and fall, peaking in size in the summer, and by 2060, will be up to 180 AFY. Projected annual bedrock groundwater storage depletions are minimal relative to aquifer storage in the basin. However, localized storage depletions may adversely affect well yields, water quality, and pumping costs.

Options

Water users are expected to continue to rely primarily on surface water and to a lesser extent alluvial 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 and Self-Supplied Residential demand sectors could reduce surface water gaps and groundwater storage depletions. Temporary drought management activities will not be effective due to the moderate to high probability of surface water gaps and aquifers could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate both surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Beaver-Cache Region. 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 28 could effectively supplement supplies 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.

Water Supply Limitations
Beaver-Cache Region, Basin 29

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 29

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

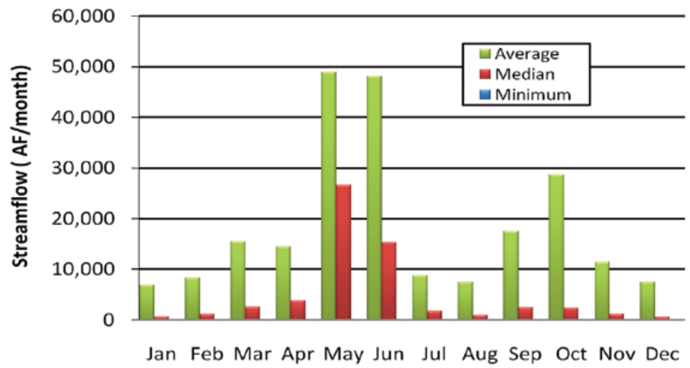
Increased reliance on surface water through direct diversions, without reservoir storage, may create surface water gaps and is not recommended.

Increased reliance on bedrock groundwater could be used to offset surface water gaps and alluvial groundwater storage depletions. Any bedrock groundwater storage depletions would be minimal relative to aquifer storage in the basin but may cause adverse local impacts for users.

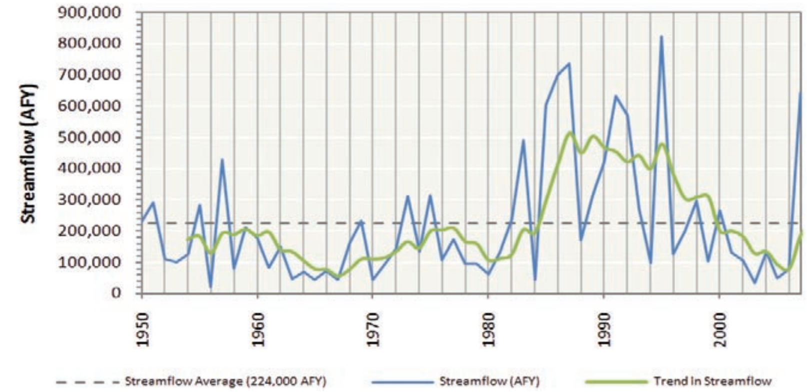
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the early 1960s to the mid 1980s. From the mid 1980s to the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of West Cache Creek downstream of Deep Red Creek is greater than 500 AF/month throughout the year and greater than 15,000 AF/month in May and June. 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 29 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in the basin.

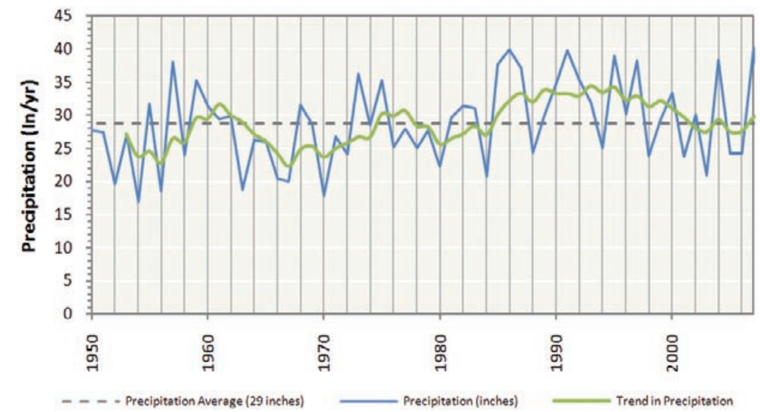
Monthly Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 29



Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 29



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)

Beaver-Cache Region, Basin 29

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
Arbuckle-Timbered Hills	Bedrock	Major	17%	1,300	214,000	temporary 2.0	100,800
Cache Creek	Alluvial	Minor	22%	4,900	283,000	1.0	66,700
Hennessey-Garber	Bedrock	Minor	60%	900	841,000	1.6	305,500
Post Oak	Bedrock	Minor	22%	1,600	1,833,000	2.0	138,800
Southwestern Oklahoma	Bedrock	Minor	1%	0	17,000	temporary 2.0	12,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	<50	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in Basin 29 are from the Cache Creek and Post Oak aquifers. There are also water rights in the Arbuckle-Timbered Hills major bedrock aquifer and other minor aquifers.
- Water quality issues–high flourides and chlorides–may limit the use of the Arbuckle-Timbered Hills aquifer for some demand sectors.

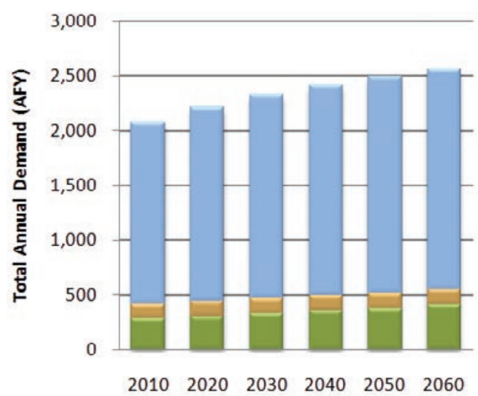
Notes & Assumptions

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

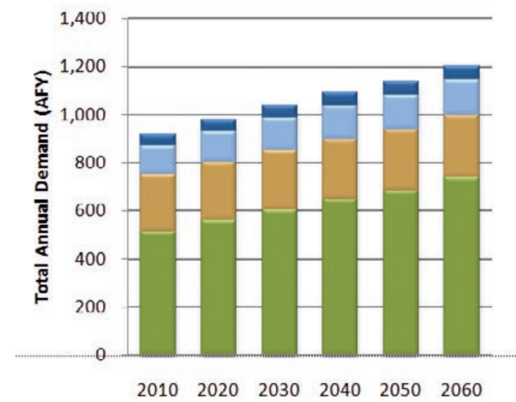
Water Demand

- The water needs of Basin 29 are about 9% of the total demand in the Beaver-Cache Watershed Planning Region and will increase by 26% (1,030 AFY) from 2010 to 2060. The majority of the demand and growth in demand from 2010 to 2060 will be in the Crop Irrigation and Municipal and Industrial demand sectors.
- Surface water is used to meet 52% of the total demand in the basin and its use will increase by 23% (480 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 23% of the total demand in the basin and its use will increase by 31% (280 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 25% of the total demand in the basin and its use will increase by 27% (270 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Municipal and Industrial and Crop Irrigation demand sectors.

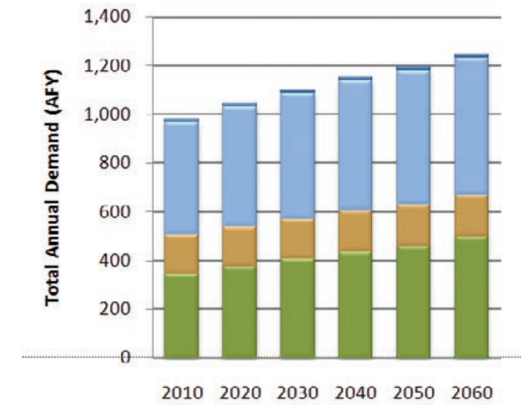
Surface Water Demand by Sector
Beaver-Cache Region, Basin 29



Alluvial Groundwater Demand by Sector
Beaver-Cache Region, Basin 29



Bedrock Groundwater Demand by Sector
Beaver-Cache Region, Basin 29



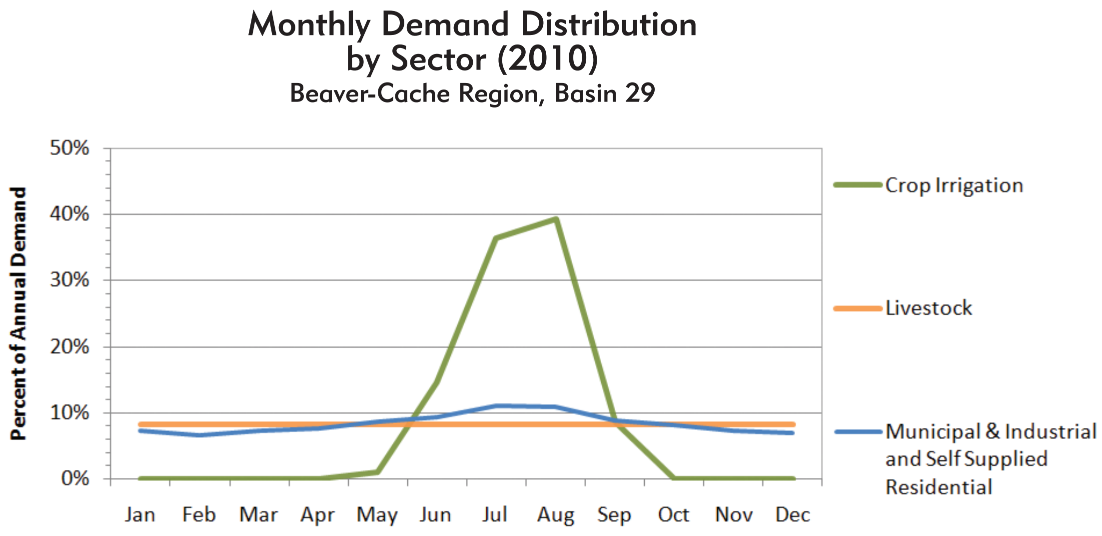
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

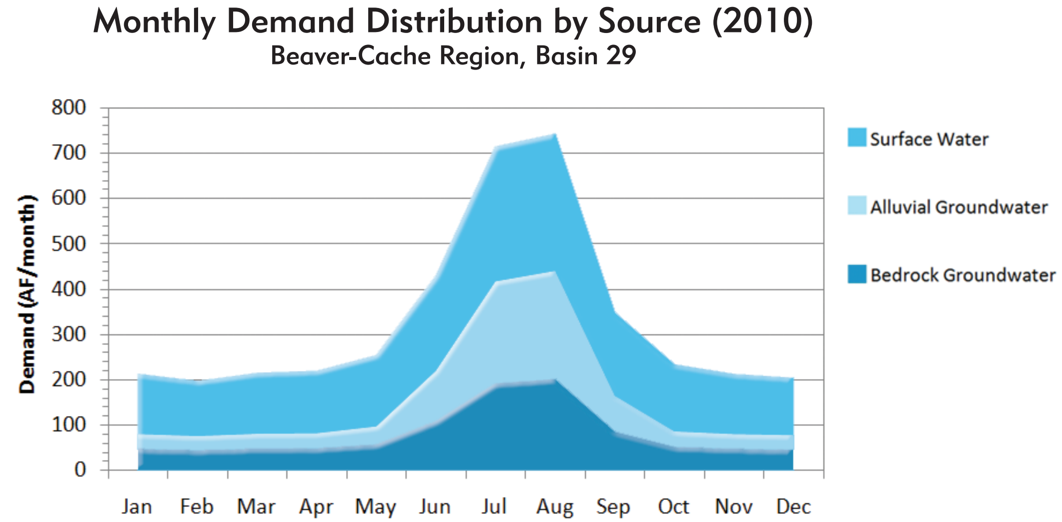
Total Demand by Sector
Beaver-Cache Region, Basin 29

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,140	530	2,250	0	0	60	0	3,980
2020	1,250	540	2,390	0	0	60	0	4,240
2030	1,350	550	2,510	0	0	70	0	4,480
2040	1,450	560	2,590	0	0	70	0	4,670
2050	1,530	560	2,660	0	0	70	0	4,820
2060	1,650	570	2,720	0	0	70	0	5,010

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 29 is about 4 times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.3 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 8 times the monthly winter use. Bedrock groundwater use peaks in the summer at about 4 times the monthly winter use.

Gaps and Storage Depletions

- Based on demand and historical hydrology, surface water gaps and groundwater storage depletions are projected to occur by 2020.
- Surface water gaps in Basin 29 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 24% (90 AF/month) of the surface water demand in the peak summer month, and as much as 13% (20 AF/month) of the winter months' surface water demand.
- By 2060, there will be a 52% probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during summer and fall.
- Alluvial groundwater storage depletions from minor aquifers in Basin 29 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 24% (80 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 25% (10 AF/month) of the winter alluvial groundwater demand.
- By 2060, there will be a 47% probability of alluvial groundwater storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 29 may occur during the summer and fall. Bedrock groundwater storage depletions in 2060 will be 27% (70 AF/month) of the bedrock groundwater demand in the peak summer month, and 9% (10 AF/month) of the fall months' bedrock groundwater demand.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 29

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	20	16%
Mar-May (Spring)	30	25	5%
Jun-Aug (Summer)	90	70	38%
Sep-Nov (Fall)	40	30	29%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 29

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	10%
Mar-May (Spring)	10	10	3%
Jun-Aug (Summer)	80	55	38%
Sep-Nov (Fall)	20	10	22%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 29

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	30	40	29%	16%
2030	150	60	70	40%	29%
2040	240	100	100	40%	31%
2050	280	160	150	43%	41%
2060	340	210	180	52%	47%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 29

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	70
Sep-Nov (Fall)	10

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 29

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	340	210	180	52%	47%
Moderately Expanded Conservation in Crop Irrigation Water Use	320	190	160	47%	45%
Moderately Expanded Conservation in M&I Water Use	90	90	120	28%	28%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	60	60	90	24%	24%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	20	0%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 29

Reservoir Storage	Diversion
AF	AFY
100	200
500	700
1,000	1,300
2,500	3,200
5,000	6,300
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 and Crop Irrigation sectors could reduce surface water gaps by 82%, alluvial storage depletions by 71%, and bedrock groundwater depletions by 50%. Temporary drought management activities may not be effective, since there is a moderate to high probability of surface water gaps and aquifers 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 two potentially viable out-of-basin sites in the Beaver-Cache Region: Cookietown Reservoir and Snyder Lake, both in Basin 30. 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 28 could effectively supplement supplies 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 outlet may increase the amount of storage necessary to eliminate future gaps and storage depletions. No viable reservoir sites were identified in Basin 29.

Increasing Reliance on Surface Water

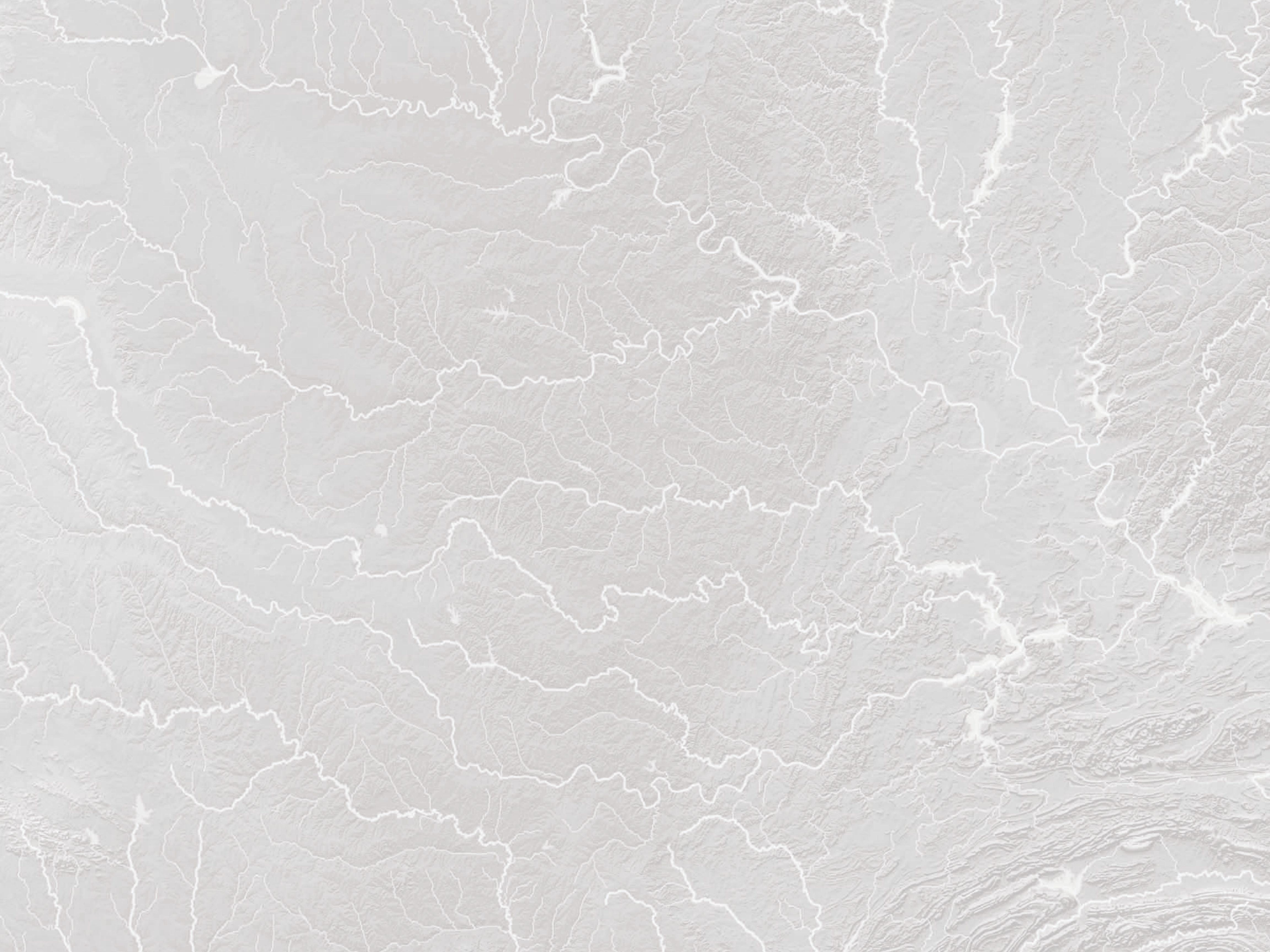
Increased reliance on surface water, without reservoir storage, would increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on groundwater could be used to offset surface water gaps, but would increase groundwater storage depletions. Increases in groundwater storage depletions would be minimal relative to aquifer storage in the basin. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

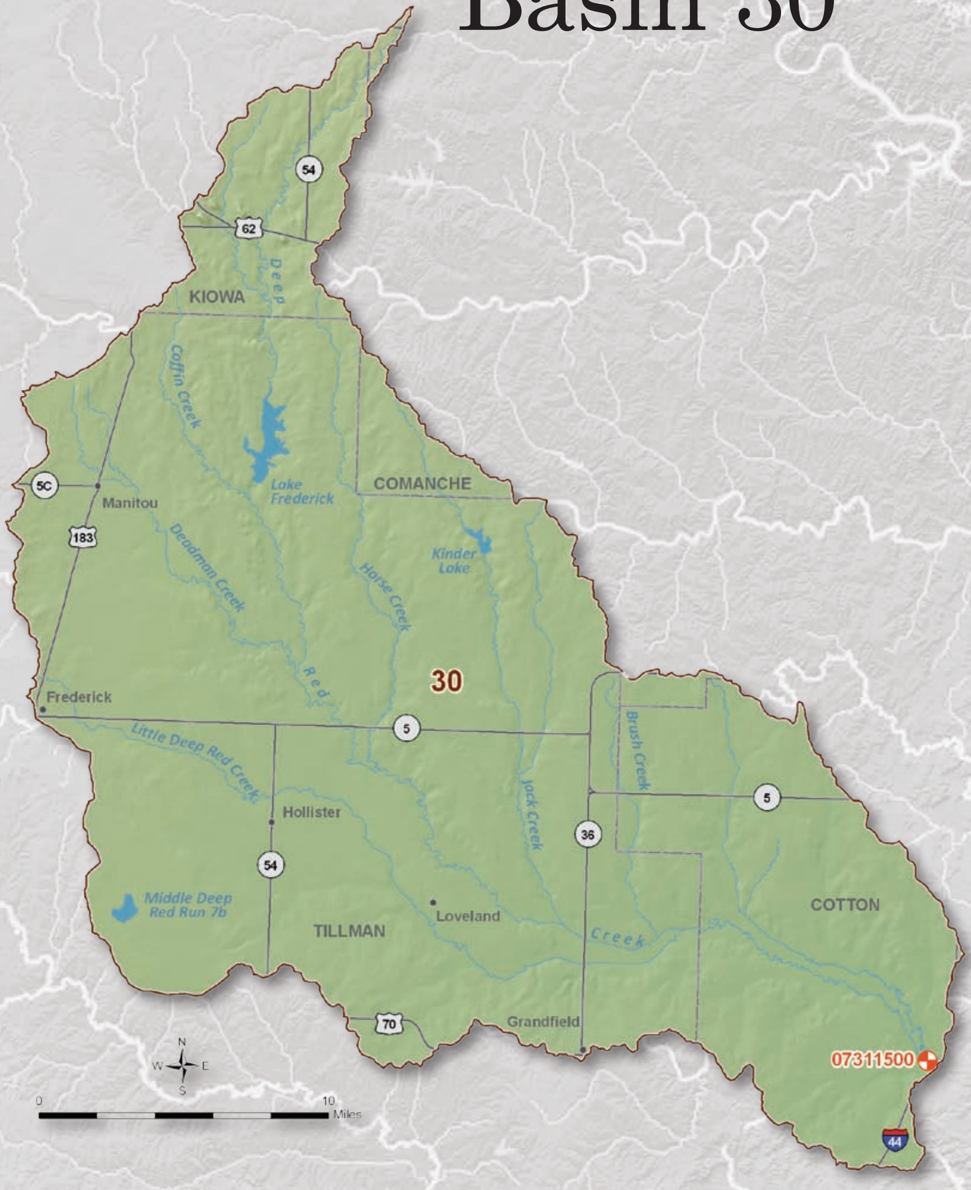
Notes & Assumptions

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



Data & Analysis
Beaver-Cache Watershed Planning Region

Basin 30



Basin 30 Summary

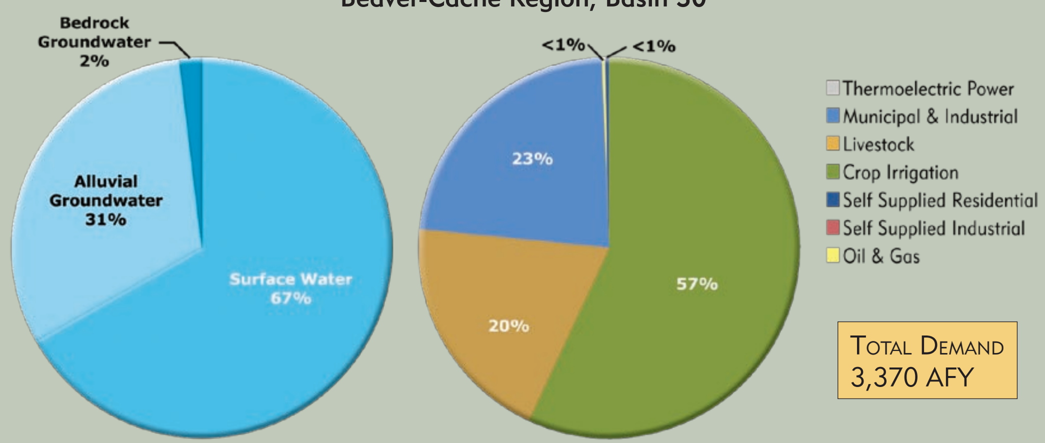
Synopsis

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

Basin 30 accounts for about 8% of the total current demand in the Beaver-Cache Watershed Planning Region. About 57% of the basin's 2010 demand was from the Crop Irrigation demand sector, followed by the Municipal and Industrial demand sector at 23% and the Livestock demand sector at 20%. Surface water satisfies about 67% of the current demand in the basin. Groundwater satisfies about 33% of the current demand (31% alluvial and 2% bedrock). The peak summer month total water demand in Basin 30 is about 7 times the winter monthly demand, which is more pronounced than the overall statewide pattern.

The median streamflow in Deep Red Creek near Randlett is at least 300 AF/month throughout the year and greater than 1,400 AF/month in the spring. However, the river can have prolonged periods of low to no flow in any month of the year. One of the larger lakes in the basin is Lake

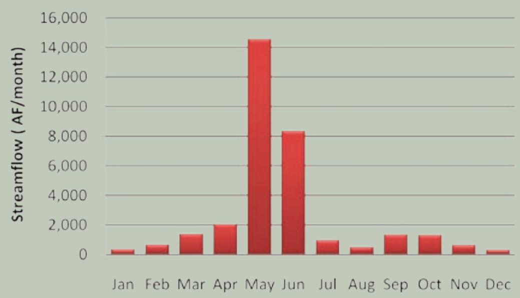
Current Demand by Source and Sector
Beaver-Cache Region, Basin 30



Total Demand
3,370 AFY

Water Resources
Beaver-Cache Region, Basin 30

Median Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 30



Projected Water Demand
Beaver-Cache Region, Basin 30

Frederick, which has approximately 9,600 AF in normal pool storage. Relative to other basins in the state, the surface water quality in Basin 30 is considered poor. However, individual lakes and streams may have acceptable water quality.

The majority of current groundwater rights are in the Tillman Terrace aquifer. The Tillman Terrace aquifer underlies only about 1% of the basin, but has 27,000 AF of storage in the basin. There are also groundwater rights in the basin from the Cache Creek minor alluvial aquifer and Hennessey-Garber minor bedrock aquifer. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 3,740 AFY in Basin 30 reflects a 370 AFY increase (11%) over the 2010 demand. The majority of demand and largest growth in demand over this period will be in the Crop Irrigation demand sector.

Gaps & Depletions

Based on historical hydrology and projected demand, surface water gaps may occur by 2020 and alluvial groundwater depletions may occur by 2030. Surface water gaps will be up to 160 AFY in 2060 and have a 41% probability of occurring in at least one month in the year. Surface water gaps may occur throughout the year, peaking in size during the summer. Alluvial groundwater depletions will be up to 50 AFY in 2060 and have a 31% probability of occurring in at least one month in the year. Alluvial groundwater storage depletions may occur in the summer and fall. The projected groundwater depletions are minimal relative to the volume of water stored in the major alluvial aquifer underlying the basin. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs. No bedrock groundwater depletions are expected in this basin through 2060.

Options

Water users are expected to continue to rely primarily on surface water and alluvial 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 mitigate surface water gaps and groundwater storage depletions. Temporary drought management activities may not be effective in this basin, since there

Water Supply Limitations
Beaver-Cache Region, Basin 30

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal · Potential · Significant

Water Supply Option Effectiveness
Beaver-Cache Region, Basin 30

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

is a moderate to high probability of surface water gaps and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate groundwater storage depletions. 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 30 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 300 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified two potentially viable sites in Basin 30: Cookietown Reservoir and Snyder Lake.

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

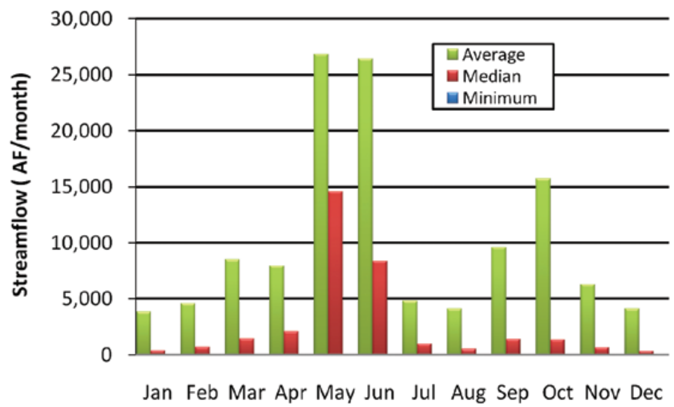
Increased reliance on bedrock groundwater could be used to offset surface water gaps and alluvial groundwater storage depletions. However, there are no major bedrock aquifers in the basin and localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use.

Basin 30 Data & Analysis

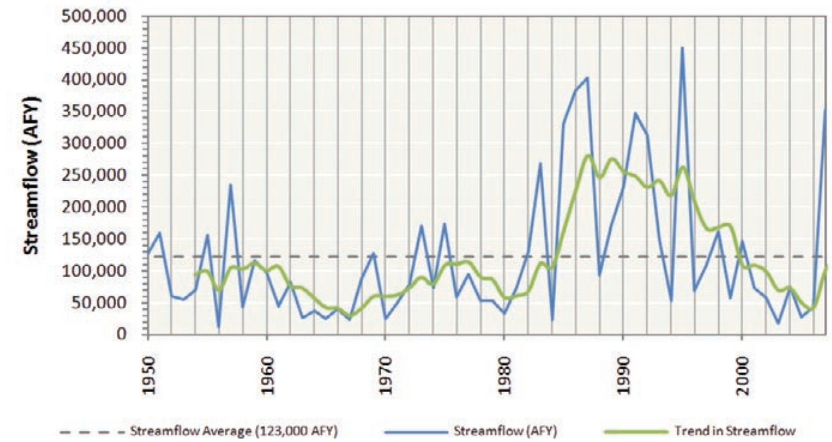
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the mid 1960s to the early 1980s, corresponding to a period of below-average precipitation. From the mid 1980s to the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of Deep Red Creek near Randlett is greater than 300 AF/month throughout the year and greater than 8,000 AF/month in May and June. 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 30 is considered poor. However, individual lakes and streams may have acceptable water quality.
- Streamflow in Deep Red Creek is regulated by Lake Frederick, which has approximately 9,600 AF of normal pool storage and is the largest lake in the region.

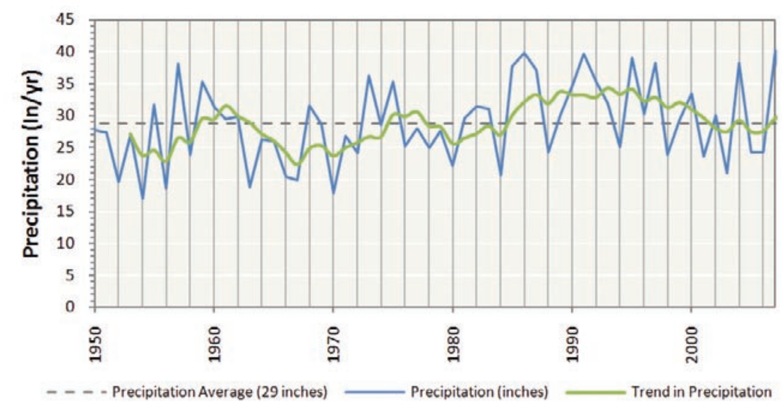
Monthly Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 30



Historical Streamflow at the Basin Outlet
Beaver-Cache Region, Basin 30



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)

Beaver-Cache Region, Basin 30

Aquifer			Portion of Basin Overlying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Cache Creek	Alluvial	Minor	14%	400	232,000	1.0	56,900
Tillman Terrace	Alluvial	Major	1%	900	27,000	1.0	5,000
Hennessey-Garber	Bedrock	Minor	93%	100	1,570,000	1.6	573,100
Southwestern Oklahoma	Bedrock	Minor	7%	0	69,000	temporary 2.0	51,200
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of current groundwater rights are in the Tillman Terrace aquifer, which only underlies 1% of the basin area. There are also groundwater rights in minor aquifers.
- There are no significant groundwater quality issues in the basin.

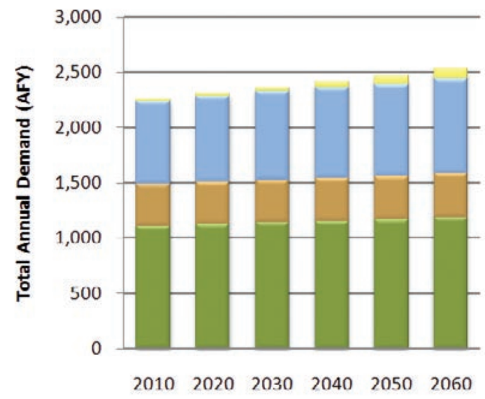
Notes & Assumptions

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

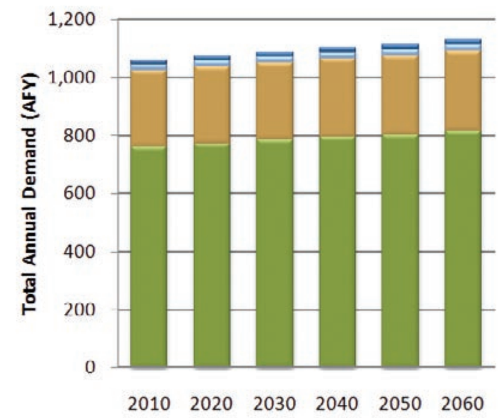
Water Demand

- The water needs of Basin 30 are about 8% of the total demand in the Beaver-Cache Watershed Planning Region and will increase by 10% (370 AFY) from 2010 to 2060. The majority of the demand and largest growth in demand over this period will be in the Crop Irrigation demand sector.
- Surface water is used to meet 67% of the total demand and its use will increase by 12% (290 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Crop Irrigation and Municipal and Industrial demand sectors.
- Alluvial groundwater is used to meet 31% of the total demand in the basin and its use will increase by 7% (70 AFY) from 2010 to 2060. The majority of the alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 2% of the total demand in the basin and its use is expected to increase by 6% (less than 10 AFY) from 2010 to 2060. The growth in bedrock groundwater use is minimal on a basin scale.

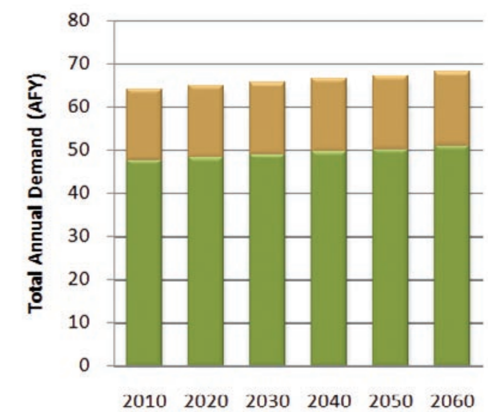
Surface Water Demand by Sector
Beaver-Cache Region, Basin 30



Alluvial Groundwater Demand by Sector
Beaver-Cache Region, Basin 30



Bedrock Groundwater Demand by Sector
Beaver-Cache Region, Basin 30



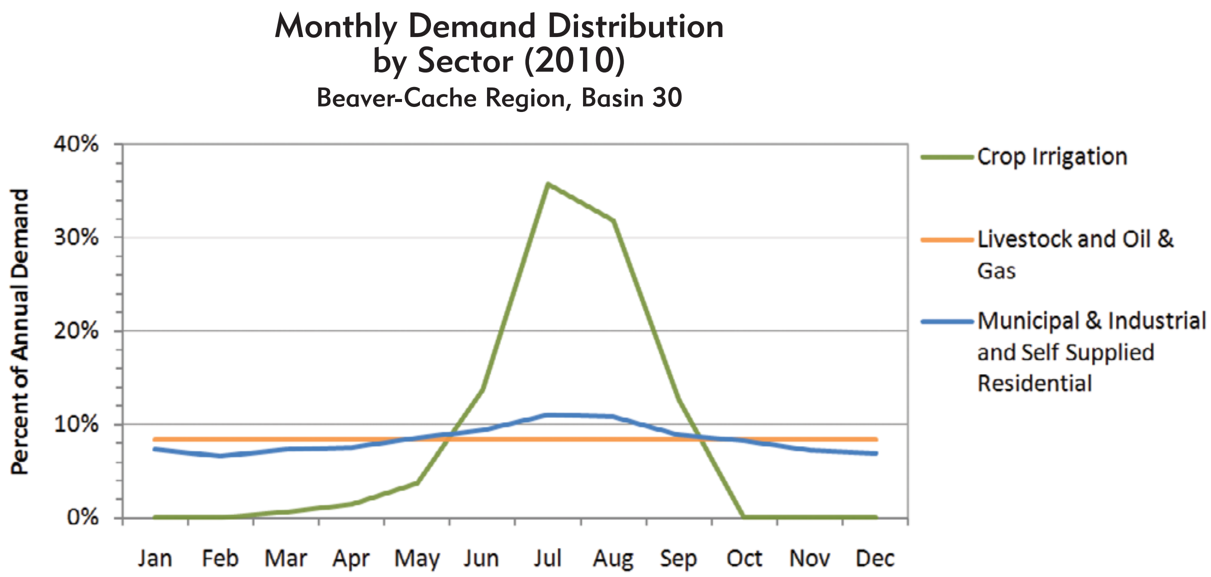
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

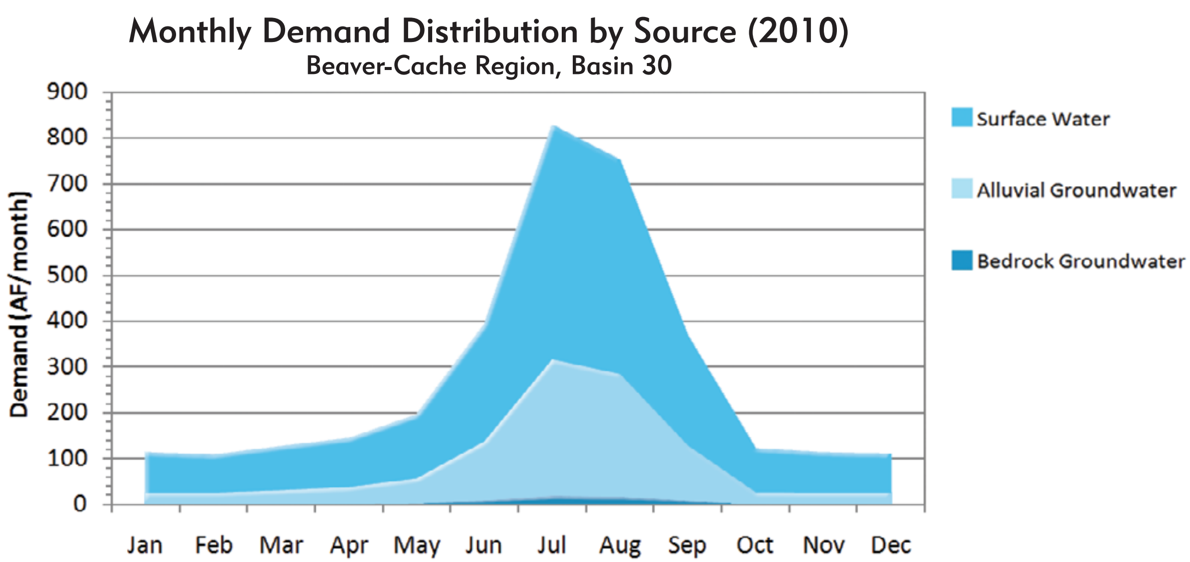
Total Demand by Sector
Beaver-Cache Region, Basin 30

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,920	660	770	10	0	10	0	3,370
2020	1,940	670	800	20	0	20	0	3,450
2030	1,970	670	820	40	0	20	0	3,520
2040	2,000	680	830	50	0	20	0	3,580
2050	2,020	680	850	70	0	20	0	3,640
2060	2,060	690	880	90	0	20	0	3,740

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 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 30 is about 7 times the monthly winter demand, which is more pronounced then the overall statewide pattern. Surface water use in the peak summer month is about 6 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 12 times the monthly winter use. Bedrock groundwater use peaks in the summer at about 13 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps will occur by 2020, while alluvial groundwater storage depletions are expected by 2030. Bedrock groundwater storage depletions are not expected through 2060.
- Surface water gaps in Basin 30 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 7% (40 AF/month) of the surface water demand in the peak summer month, and as much as 10% (10 AF/month) of the winter surface water demand.
- By 2060, there will be a 41% probability of surface water gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during summer and fall months.
- Alluvial groundwater storage depletions in Basin 30 may occur during the summer and fall. Alluvial groundwater storage depletions in 2060 will be up to 6% (20 AF/month) of the alluvial groundwater demand in the peak summer month and as much as 8% (10 AF/month) of the winter alluvial groundwater demand. Projected alluvial storage depletions are minimal relative to the amount of groundwater in storage in major aquifers in the basin.
- By 2060, there will be a 31% probability of alluvial groundwater storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during summer months.

Surface Water Gaps by Season (2060 Demand)

Beaver-Cache Region, Basin 30

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	14%
Mar-May (Spring)	10	10	5%
Jun-Aug (Summer)	40	30	29%
Sep-Nov (Fall)	20	10	26%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Beaver-Cache Region, Basin 30

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	20	20	28%
Sep-Nov (Fall)	10	10	17%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 30

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	20	0	0	12%	0%
2030	50	20	0	29%	14%
2040	100	30	0	38%	21%
2050	140	40	0	40%	31%
2060	160	50	0	41%	31%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Beaver-Cache Region, Basin 30

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 30

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	160	50	0	41%	31%
Moderately Expanded Conservation in Crop Irrigation Water Use	80	0	0	34%	0%
Moderately Expanded Conservation in M&I Water Use	60	40	0	31%	26%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 30

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

(Typically Effective) Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could mitigate surface water gaps and groundwater storage depletions. Temporary drought management activities may not be effective in this basin, since there is a moderate to high probability of surface water gaps and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

(Potentially Effective) Out-of-basin supplies could mitigate groundwater storage depletions. 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

(Typically Effective) Additional reservoir storage in Basin 30 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 300 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified two potentially viable sites in Basin 30: Cookietown Reservoir and Snyder Lake.

Increasing Reliance on Surface Water

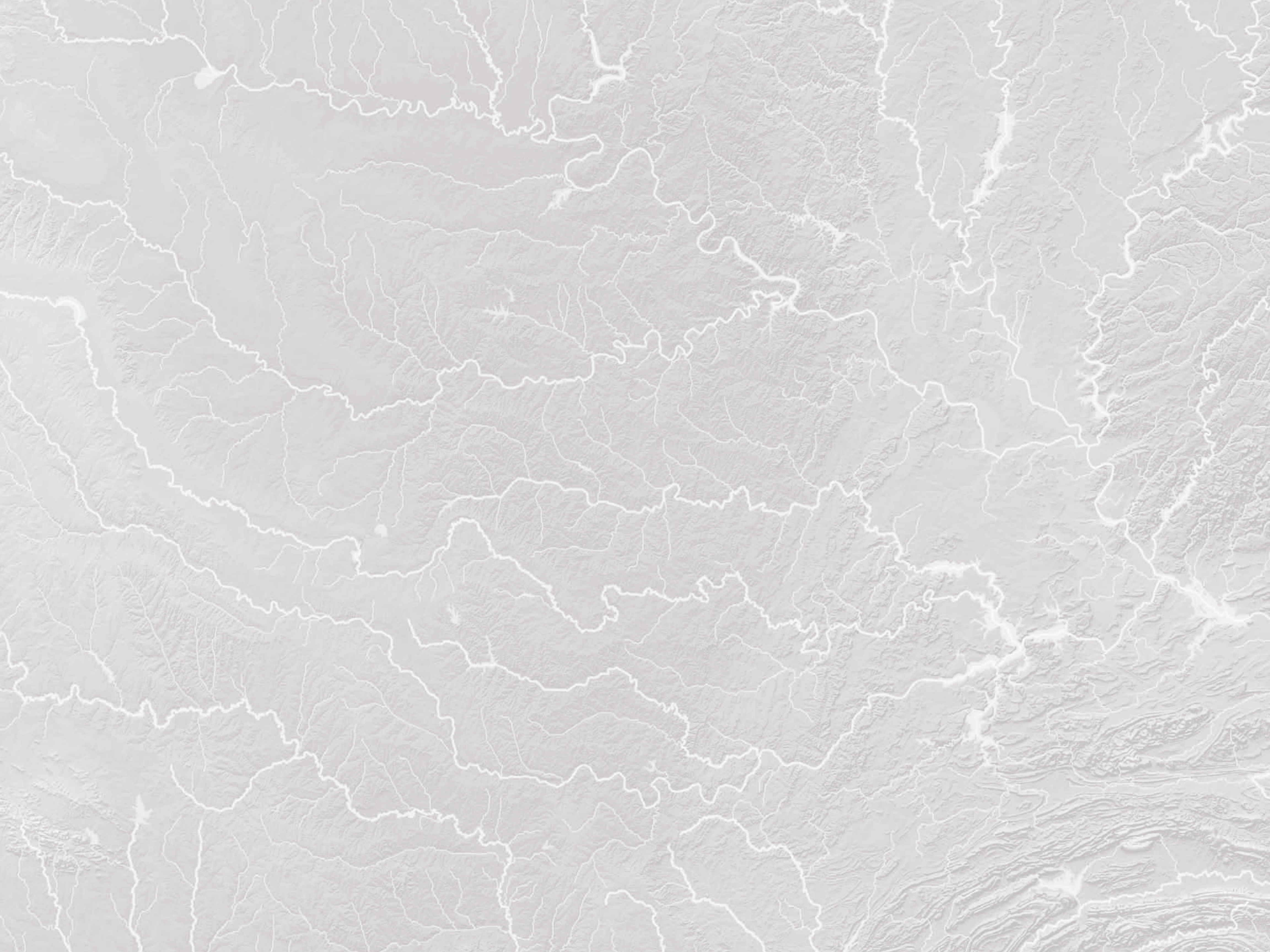
(Likely Ineffective) Increased reliance on surface water, without reservoir storage, would increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

(Potentially Effective) Increased reliance on bedrock groundwater could be used to offset surface water gaps and alluvial groundwater storage depletions, but there are no major bedrock aquifers in the basin. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. Increased use of alluvial groundwater will increase alluvial groundwater storage depletions, but any increases will be minimal compared to major aquifer storage in Basin 30. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Notes & Assumptions

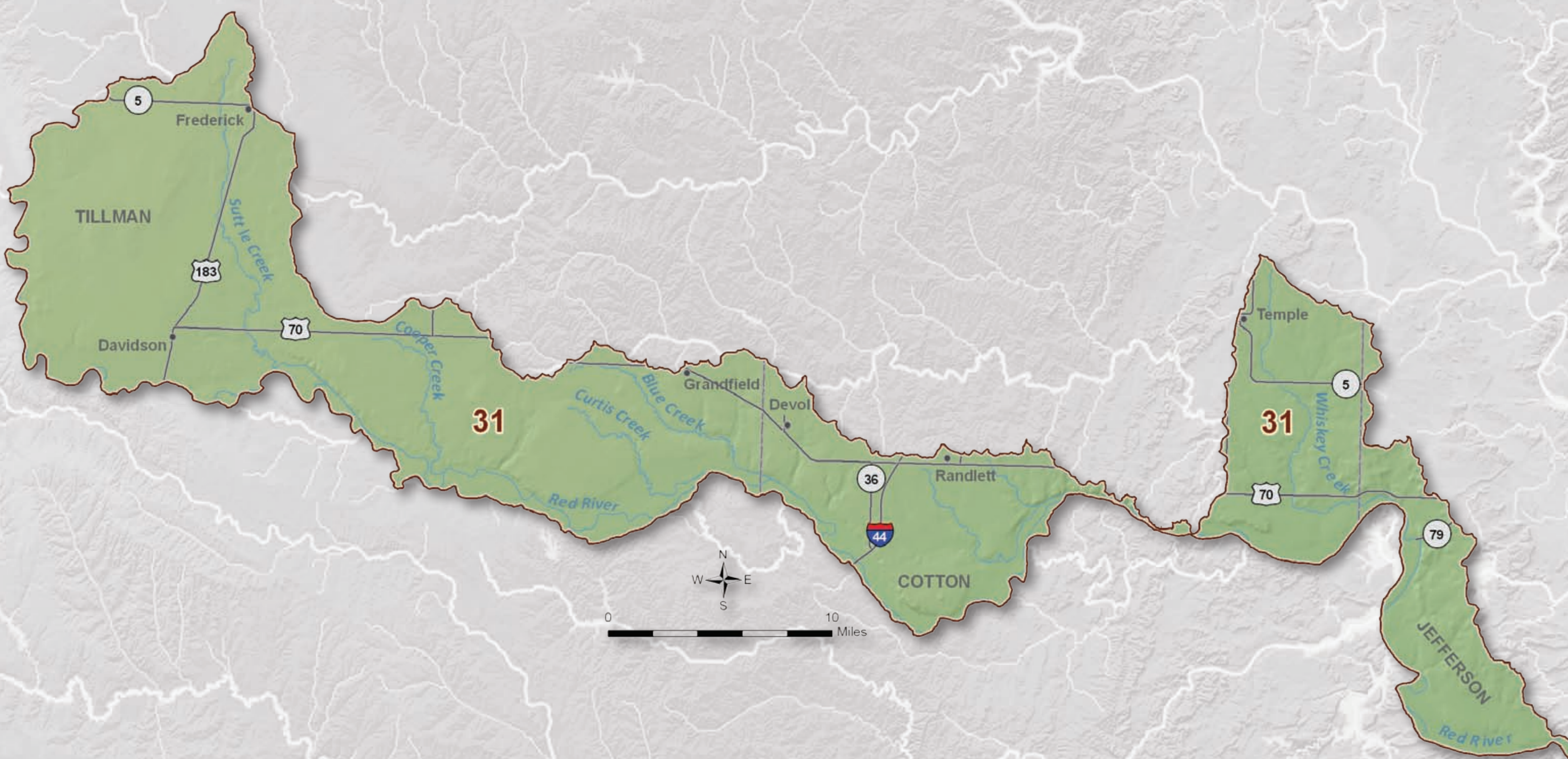
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands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

Basin 31



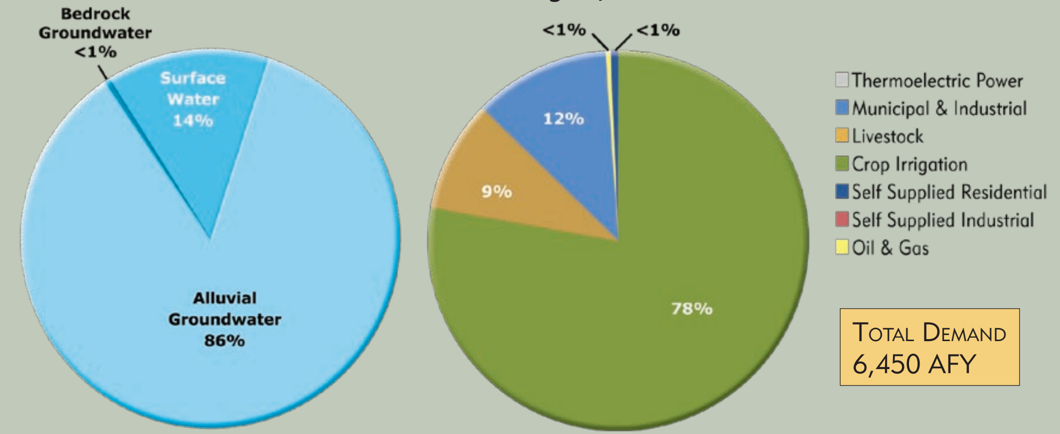
Basin 31 Summary

Synopsis

- Water users are expected to continue to rely primarily on alluvial groundwater and, to a lesser extent surface water.
- By 2030, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater depletions have a moderate probability of occurring by 2020. Bedrock groundwater storage depletions are not expected through 2060.
- To reduce the risk of adverse impacts on water supplies, it is recommended that surface water gaps and alluvial groundwater storage depletions be decreased where economically feasible.
- Additional conservation measures could mitigate surface water gaps and significantly reduce alluvial groundwater storage depletions.
- Developing additional groundwater supplies and/or developing new reservoirs could mitigate surface water gaps without major impacts to groundwater storage.

Current Demand by Source and Sector

Beaver-Cache Region, Basin 31

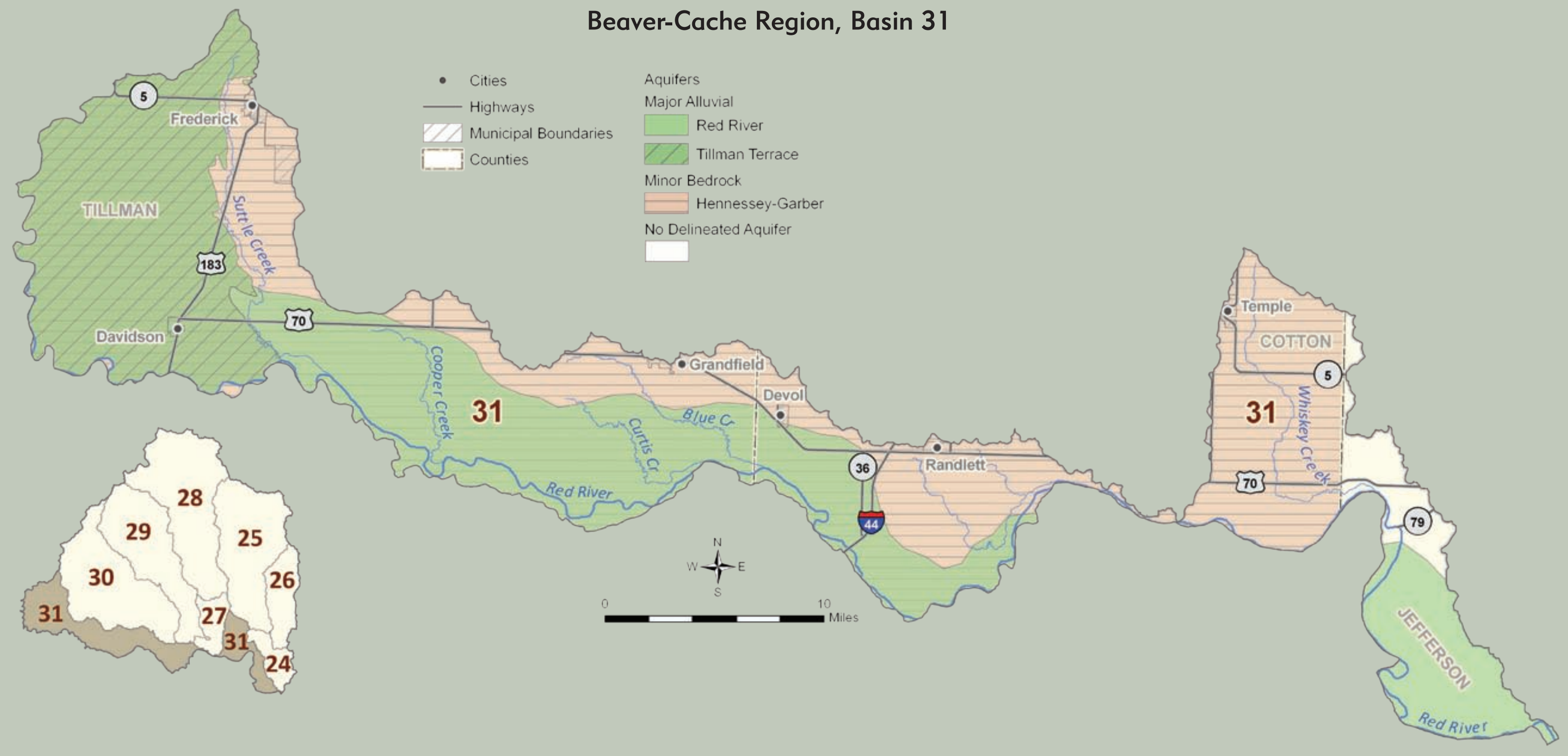


Basin 31 accounts for about 14% of the total current demand in the Beaver-Cache Watershed Planning Region. About 78% of the basin's 2010 demand was from the Crop Irrigation demand sector. Municipal and Industrial was the second largest demand sector at 12%. Surface water satisfies about 14% of the current demand in the basin. Groundwater satisfies about 86% of the current demand (86% alluvial and 0% bedrock). The peak summer month demand in Basin 31 is about 17 times the winter monthly demand, which is more pronounced than the overall statewide pattern.

The flow in tributaries to the Red River upstream of Beaver Creek is typically greater than 200 AF/month throughout the year and greater than 7,200 AF/month in May and June. The Red River is generally not considered a source due to high salinity and related issues. There are no major reservoirs in the basin. However, the Town of Temple is supplied water from Waurika Lake in Basin 25. 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 31 is considered

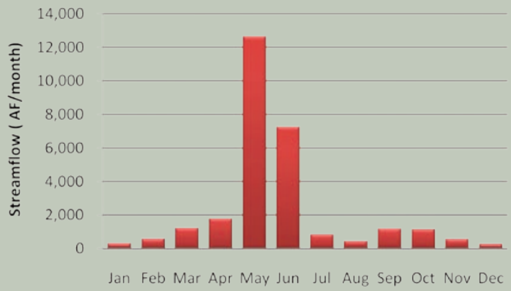
Water Resources

Beaver-Cache Region, Basin 31



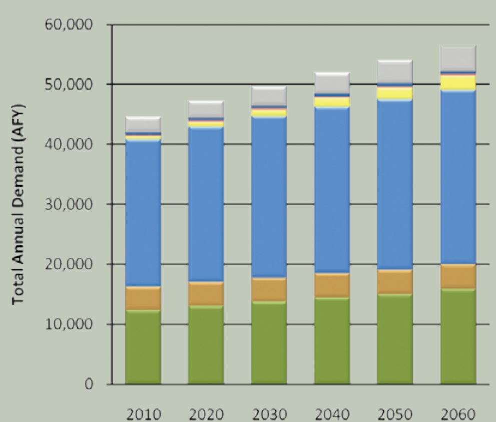
Median Historical Streamflow at the Basin Outlet

Beaver-Cache Region, Basin 31



Projected Water Demand

Beaver-Cache Region, Basin 31



poor. However, individual lakes and streams may have acceptable water quality.

The majority of groundwater rights in the basin are from the Tillman Terrace and Red River major alluvial aquifers. Lesser amounts are permitted in the Hennessey-Garber minor bedrock aquifer and non-delineated alluvial groundwater sources. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. The Tillman Terrace aquifer underlies about one-quarter of the basin, and has 571,000 AF of storage in the basin. The Red River aquifer underlies one-third of the basin, and has 251,000 AF of storage in the basin. High nitrate concentrations in the Tillman Terrace aquifer limits its use for public water supply. Otherwise, there are no major bedrock aquifers in this 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 basinwide groundwater quality issues.

The projected 2060 water demand of 7,230 AFY in Basin 31 reflects a 780 AFY increase (12%) over the 2010 demand. The majority of demand and growth in demand over this period will be in the Crop Irrigation sector.

Gaps & Depletions

Based on historical hydrology and projected demand, surface water gaps may occur by 2030 and alluvial groundwater depletions may occur by 2020. Surface water gaps will be up to 100 AFY in 2060, peaking in size during the summer, and have a 55% probability of occurring in at least one month in the year. Alluvial groundwater depletions will be up to 490 AFY in 2060, peaking in size during the summer, and having a 62% probability of occurring in at least one month in the year. The projected groundwater depletions are minimal relative to the volume of water stored in the major alluvial aquifers underlying the basin. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs. No bedrock groundwater depletions are expected in this basin through 2060.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could mitigate surface water gaps and significantly reduce alluvial groundwater storage depletions. Temporary drought management activities may not be effective in this basin, since gaps have a moderate probability of occurring and 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 two potentially viable out-of-basin sites in the Beaver-Cache Region. However, in light of the distance to reliable water supplies and available in-basin supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Additional reservoir storage in Basin 31 could effectively supplement supplies 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.

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

Increased reliance of minor bedrock groundwater could be used to offset alluvial groundwater storage depletions, but site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. Also, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

Water Supply Limitations

Beaver-Cache Region, Basin 31

Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal / Potential / Significant

Water Supply Option Effectiveness

Beaver-Cache Region, Basin 31

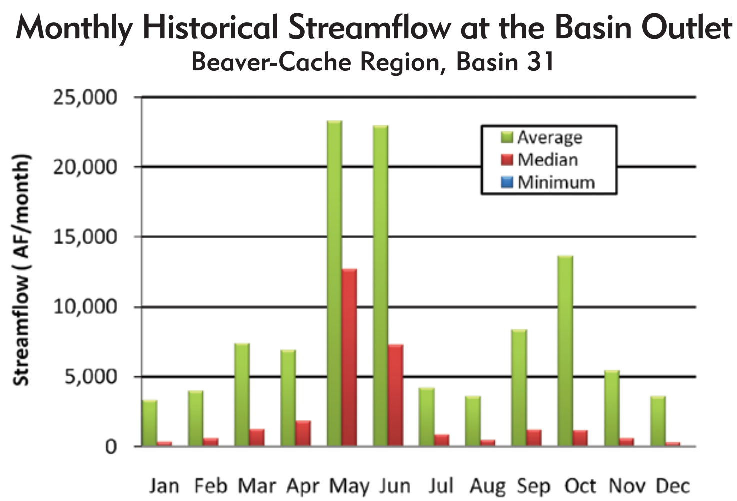
Demand Management	Potentially Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Potentially Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Potentially Effective

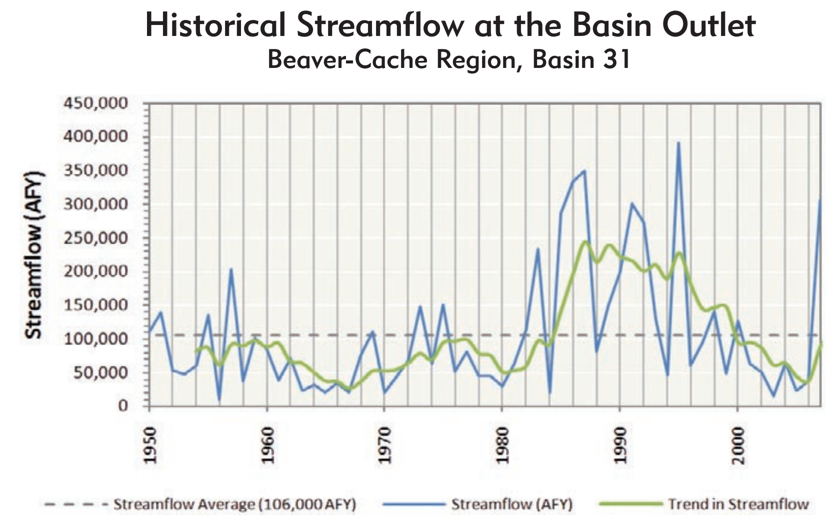
Typically Effective / Potentially Effective / Likely Ineffective / No Option Necessary

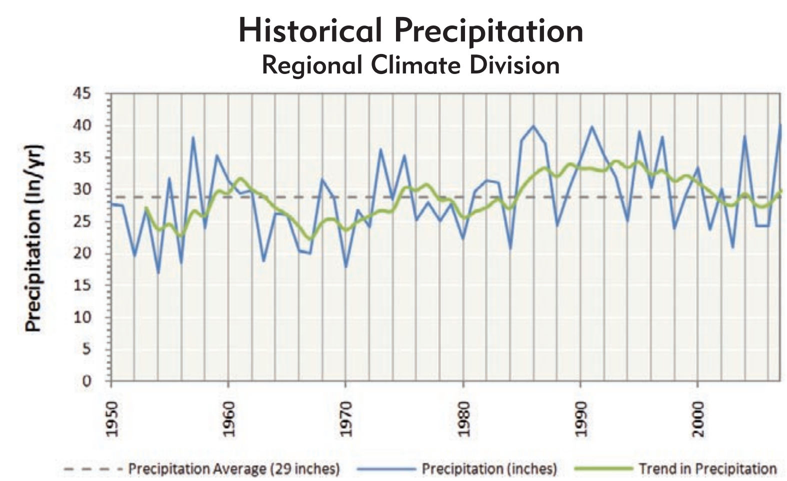
Basin 31 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the early 1960s to the early 1980s, corresponding to a period of below-average precipitation. From the mid 1980s to the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median flow of tributaries to the Red River upstream of Beaver Creek is greater than 200 AF/month throughout the year and greater than 7,000 AF/month in May and June. However, the tributaries 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 31 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in the basin.







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)

Beaver-Cache Region, Basin 31

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Red River	Alluvial	Major	32%	6,600	251,000	temporary 2.0	216,000
Tillman Terrace	Alluvial	Major	24%	11,000	571,000	1.0	63,200
Hennessey-Garber	Bedrock	Minor	84%	200	1,234,000	1.6	441,700
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	500	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of the groundwater rights are in the Tillman Terrace and Red River major alluvial aquifers. Combined these aquifers underlie more than half the basin and have more than 800,000 AF of storage in the basin. There are also groundwater rights in minor aquifers.
- High nitrate concentrations in the Tillman Terrace aquifer limits its use for public water supply. Otherwise, there are no known significant basin-wide groundwater quality issues in the basin.

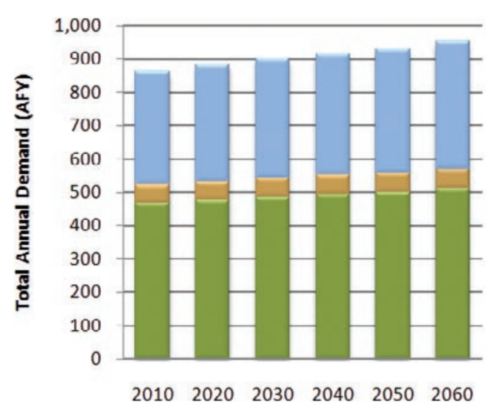
Notes & Assumptions

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

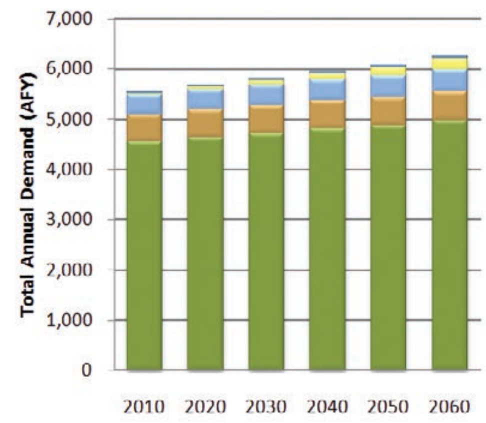
Water Demand

- The water needs of Basin 31 are about 14% of the total demand in the Beaver-Cache Watershed Planning Region and will increase by 12% (780 AFY) from 2010 to 2060. The majority of the demand and growth in demand from 2010 to 2060 will be in the Crop Irrigation demand sector.
- Surface water is used to meet 14% of the total demand in the basin and its use will increase by 10% (90 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Crop Irrigation and Municipal and Industrial demand sectors.
- Alluvial groundwater is used to meet 86% of the total demand in the basin and its use will increase by 12% (690 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet less than 1% of the total demand in the basin and its use is expected to increase by 13% (less than 10 AFY) from 2010 to 2060. The growth in bedrock groundwater use is minimal on a basin scale.

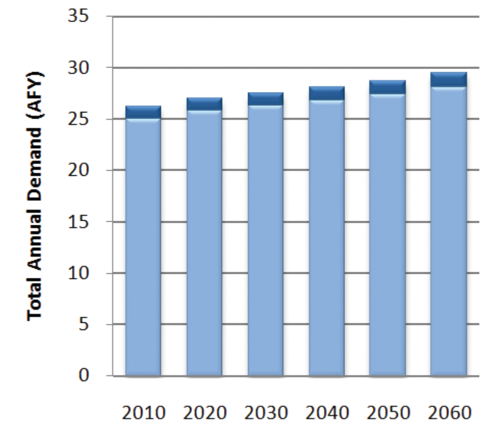
Surface Water Demand by Sector
Beaver-Cache Region, Basin 31



Alluvial Groundwater Demand by Sector
Beaver-Cache Region, Basin 31



Bedrock Groundwater Demand by Sector
Beaver-Cache Region, Basin 31



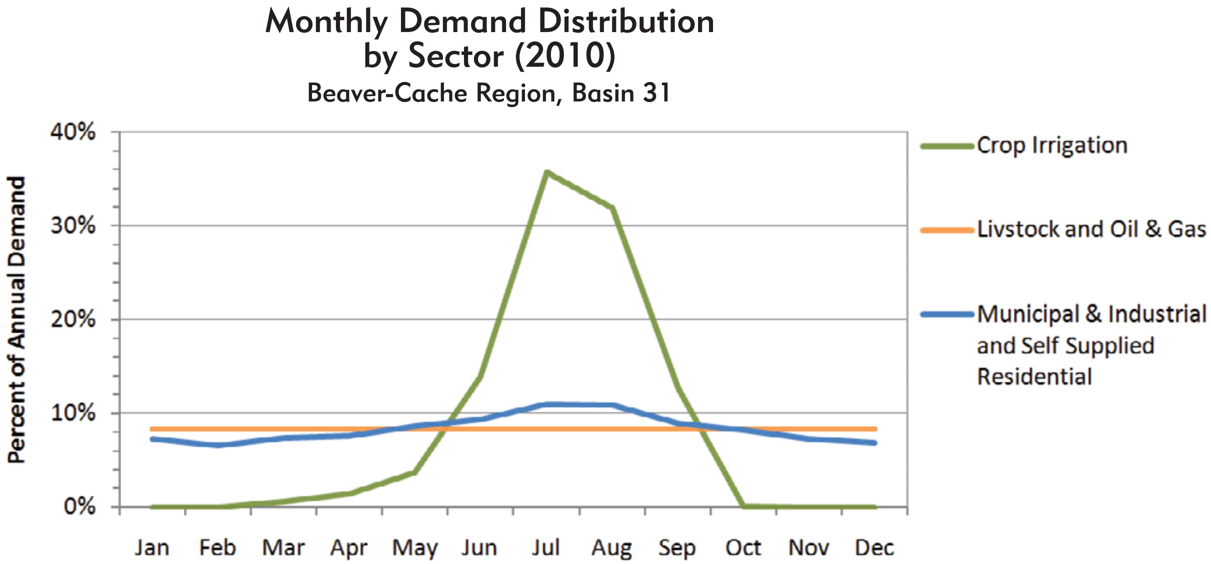
Thermoelectric Power Self-Supplied Residential Self-Supplied Industrial Oil & Gas Municipal & Industrial Livestock Crop Irrigation

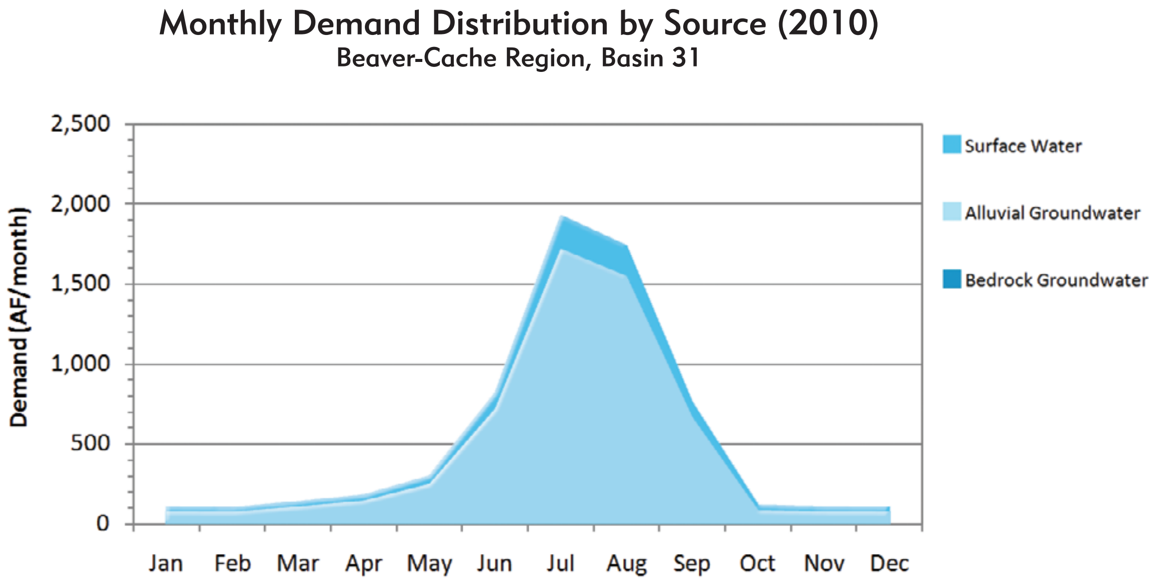
Total Demand by Sector
Beaver-Cache Region, Basin 31

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	5,020	610	750	30	0	40	0	6,450
2020	5,120	610	780	50	0	40	0	6,600
2030	5,210	620	790	90	0	40	0	6,750
2040	5,300	620	810	120	0	40	0	6,890
2050	5,380	620	830	170	0	40	0	7,040
2060	5,490	630	850	220	0	40	0	7,230

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 31 is about 17 times the monthly winter demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 7 times the monthly winter use. Alluvial groundwater use peaks in the summer at about 21 times the monthly winter use. Bedrock groundwater use peaks in the summer at about 1.5 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions are projected to occur by 2020, while surface water gaps are expected by 2030. No bedrock groundwater storage depletions are expected through 2060.
- Surface water gaps in Basin 31 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 9% (20 AF/month) of the surface water demand in the peak summer month, and as much as 33% (10 AF/month) of the winter surface water demand.
- By 2060, there will be a 55% probability of surface water gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during summer and fall months.
- Alluvial groundwater storage depletions in Basin 31 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 8% (160 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 20% (20 AF/month) of the winter months' alluvial groundwater demand.
- By 2060, there will be a 62% probability of alluvial groundwater storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during summer and fall months.

Surface Water Gaps by Season (2060 Demands)

Beaver-Cache Region, Basin 31

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	10%
Mar-May (Spring)	10	10	3%
Jun-Aug (Summer)	20	20	43%
Sep-Nov (Fall)	10	10	28%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 31

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	10	22%
Mar-May (Spring)	30	20	7%
Jun-Aug (Summer)	160	120	43%
Sep-Nov (Fall)	70	20	33%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Beaver-Cache Region, Basin 31

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%	31%
2030	20	200	0	21%	43%
2040	30	280	0	33%	52%
2050	40	330	0	47%	57%
2060	100	490	0	55%	62%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)

Beaver-Cache Region, Basin 31

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Beaver-Cache Region, Basin 31

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	100	490	0	55%	62%
Moderately Expanded Conservation in Crop Irrigation Water Use	50	210	0	14%	48%
Moderately Expanded Conservation in M&I Water Use	50	390	0	41%	55%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	100	0	0%	34%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	10	0	0%	5%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Beaver-Cache Region, Basin 31

Reservoir Storage	Diversion
AF	AFY
100	100
500	600
1,000	1,300
2,500	3,200
5,000	6,300
Required Storage to Meet Growth in Demand (AF)	600
Required Storage to Meet Growth in Surface Water Demand (AF)	100

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial, Self-Supplied Residential, and Crop Irrigation demand sectors could mitigate surface water gaps and reduce alluvial groundwater storage depletions by 80%. Temporary drought management activities may not be effective in this basin, since gaps have a moderate probability of occurring and 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 two potentially viable out-of-basin sites in the Beaver-Cache Region: Cookietown Reservoir and Snyder Lake, both in Basin 30. However, in light of the distance to reliable water supplies and available in-basin supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

Additional reservoir storage in Basin 31 could effectively supplement supplies 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 outlet may increase the amount of storage necessary to eliminate future gaps and storage depletions. No viable reservoir sites were identified in Basin 31.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on bedrock groundwater could be used to offset alluvial groundwater depletions, but there are no major bedrock aquifers in the basin. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. Increased use of alluvial groundwater will increase alluvial groundwater storage depletions, but any increases will be minimal compared to major aquifer storage in Basin 31. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.

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: Human derived by-products and common pollutants washed into lakes and streams, primarily nitrogen and phosphorus, which can lead to increases in algae growth and depleted oxygen levels, in turn resulting in taste and odor problems for drinking water as well as accelerated sedimentation of a reservoir.

CWSRF: see State Revolving Fund (SRF).

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

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

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

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

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

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

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

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

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

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

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

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

DWSRF: see State Revolving Fund (SRF).

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

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

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

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

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

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

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

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

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

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

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

Groundwater: fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut bank of a definite stream.

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

Groundwater recharge: see Recharge.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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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