Oklahoma Comprehensive Water Plan

OCWP

Panhandle

Watershed Planning Region Report

Version 1.1

Oklahoma Water Resources Board

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

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

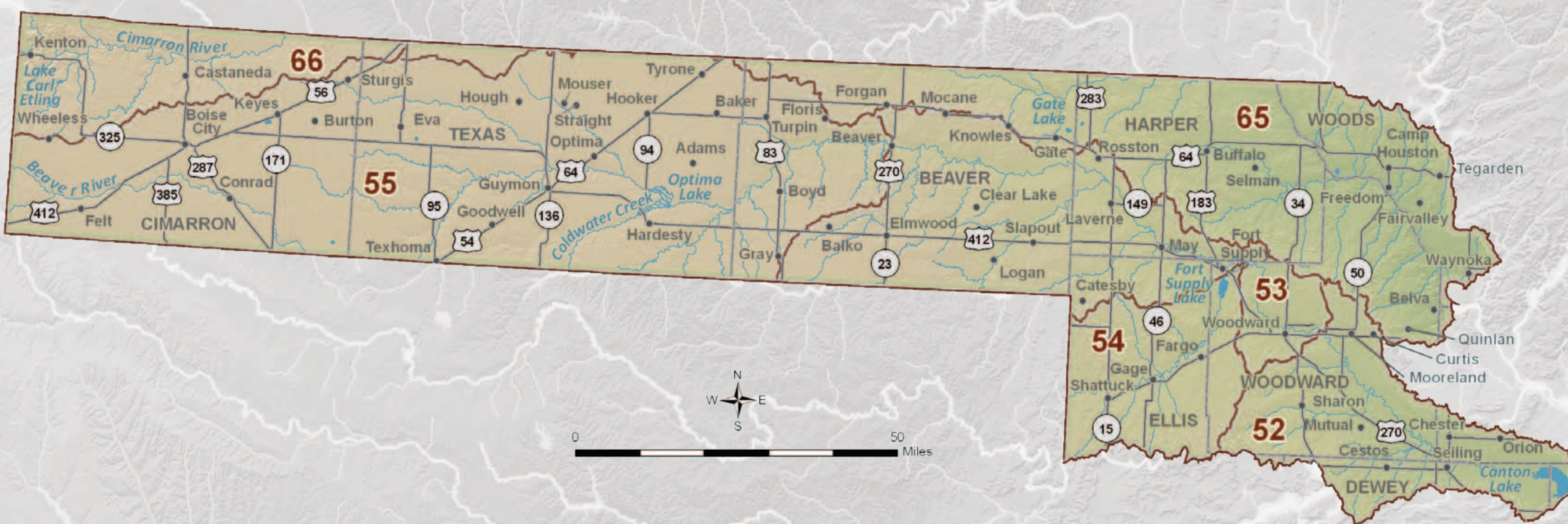
Oklahoma Comprehensive Water Plan

OCWP

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

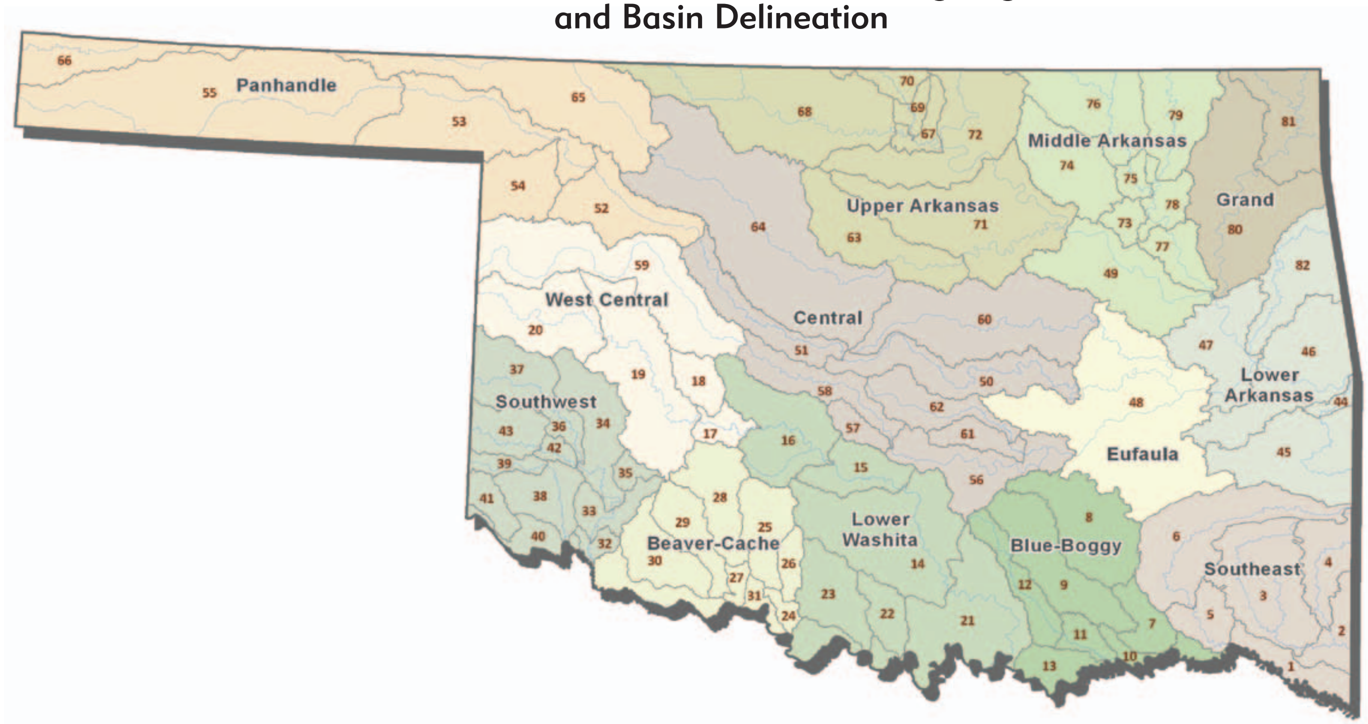
Oklahoma Comprehensive Water Plan

Panhandle Watershed Planning Region



Contents

Statewide OCWP Watershed Planning Region and Basin Delineation



Introduction

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

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

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

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

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

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

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

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

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

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

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

Regional Overview

The Panhandle Watershed Planning Region includes six basins (numbered 52-55 and 65-66 for reference). The region encompasses 9,426 square miles in northwest Oklahoma, spanning from the Panhandle counties of Cimarron, Texas, and Beaver, and extending to the southeast through all of Harper County and portions of Woods, Woodward, Major, Blaine, Dewey, and Ellis Counties.

The region is in the Great Plains and Central Lowland physiography provinces. Cimarron, Texas, and Beaver Counties in the Panhandle are generally flat while the remainder of the region is characterized by rough terrain marked with high sand hills and deep erosion. The highest elevation in Oklahoma, Black Mesa Plateau, is found in the far northwestern corner of Cimarron County.

The climate is semi-arid in the Panhandle and sub-humid in the remainder of the region, with mean annual temperatures ranging from 54°F in the Panhandle to 60°F in the southeast corner of the region. Precipitation ranges from 16 inches in the west to 28 inches in the southeast. Annual evaporation is significant, ranging from 56 to 64 inches.

The largest cities in the region include Woodward (2010 population of 12,051) and Guymon (11,442). The greatest demand is from Crop Irrigation water use.

By 2060, this region is projected to have a total demand of 473,840 acre-feet per year (AFY), an increase of approximately 83,000 AFY (21%) from 2010.

Panhandle Regional Summary

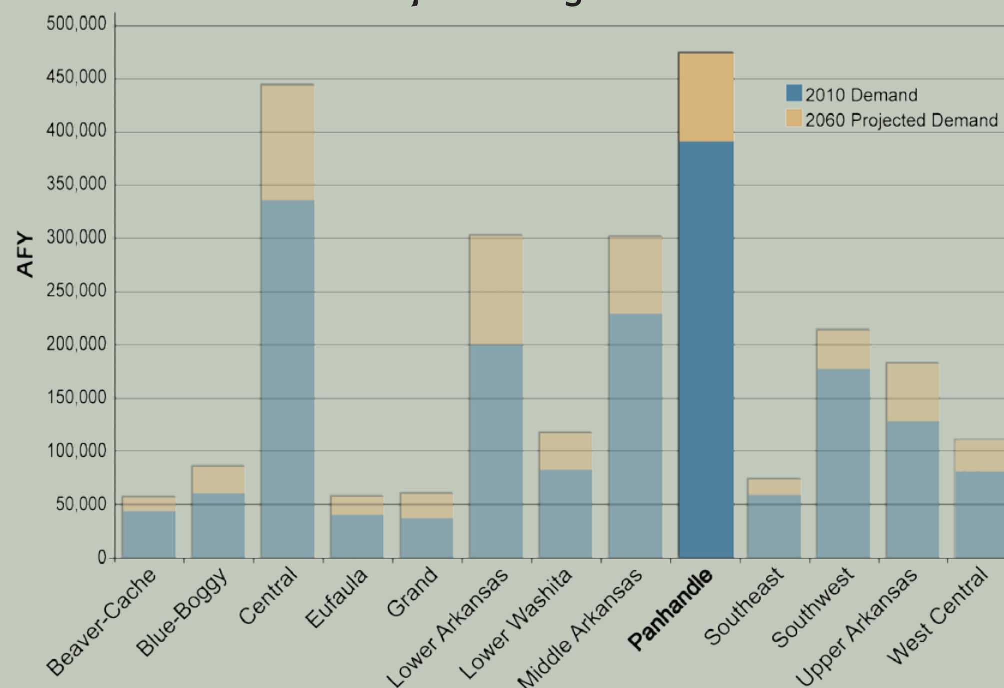
Synopsis

- The Panhandle Watershed Planning Region relies primarily on bedrock groundwater supplies from the Ogallala aquifer.
- It is anticipated that water users in the region will continue to rely on the Ogallala and minor aquifers to meet future demand.
- Surface water supplies will be typically insufficient to meet demand throughout the region.
- Groundwater storage depletions may lead to higher pumping costs, the need for deeper wells, and changes to well yields or water quality.
- Additional conservation could reduce surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.
- Surface water alternatives, such as increased use of groundwater supplies and/or development of small reservoirs, could eliminate gaps without major impacts to groundwater storage.
- Three basins (54, 55, and 66) within the region have been identified as "hot spots," areas where more pronounced water supply availability issues are forecasted. (See "Regional and Statewide Opportunities and Solutions" in the *OCWP Executive Report*.)

Panhandle Region Demand Summary

Current Water Demand:	390,690 acre-feet/year (21% of state total)		
Largest Demand Sector:	Crop Irrigation (86% of regional total)		
Current Supply Sources:	2% SW	7% Alluvial GW	91% Bedrock GW
Projected Demand (2060):	473,840 acre-feet/year		
Growth (2010-2060):	83,150 acre-feet/year (21%)		

Current and Projected Regional Water Demand



The Panhandle Region accounts for 21% of the state's total water demand. The largest demand sector is Crop Irrigation (86%).

Water Resources & Limitations

Surface Water

Surface water is used to meet about 2% of the region's demand. Basins throughout the region are projected to have surface water supply shortages in the future. The region is supplied by two rivers: the North Canadian River (known in the Panhandle as the Beaver River) and the Cimarron River. Historically, rivers and creeks in the region have had periods of low to no flow during any month of the year due to seasonal and long-term precipitation trends. Irrigation has had a significant effect on the Beaver River's streamflow, which has decreased substantially since the 1970s. Large reservoirs have been built on the North Canadian River (Canton and Optima Lakes) and on Wolf Creek (Fort Supply Lake) to provide flood control, recreation, and public water supply. Optima Lake regulates flow in the Beaver River at Beaver but does not sustain a water supply yield.

Relative to other regions, surface water quality in the region is considered fair to good. However, multiple rivers, creeks, and lakes, including the Beaver and Cimarron Rivers, are impaired for Agricultural use (Crop Irrigation demand sector) and Public and Private Water Supply (Municipal and Industrial demand sector) due to high levels of total dissolved solids (TDS), salts, and chlorophyll-a. These impairments are scheduled to be addressed through the Total Maximum Daily Loads (TMDL) process, but the use of these supplies may be limited in the interim.

Surface water in the region is fully allocated, limiting diversions to existing permitted amounts.

Alluvial Groundwater

Alluvial groundwater is used to meet 7% of the demand in the region. The majority of currently allocated alluvial groundwater withdrawals in the region are from the North Canadian River aquifer, and to a lesser extent, the Cimarron River and non-delineated minor aquifers. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions from these aquifers are likely to occur throughout the year, although these projected depletions will be minimal relative to the amount of water in storage and permit availability. The largest storage depletions are projected to occur in the summer. The availability of water rights is not expected to constrain the use of alluvial groundwater supplies to meet local demands through 2060.

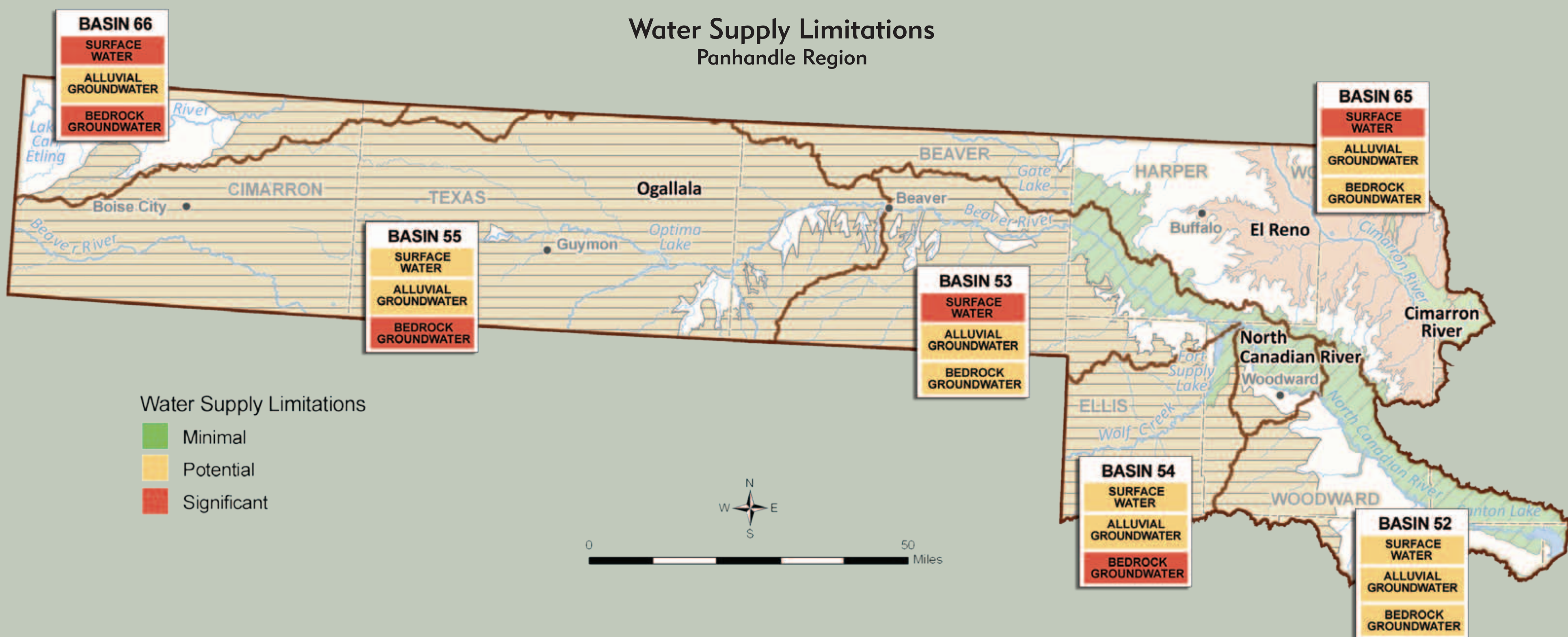
Bedrock Groundwater

Bedrock groundwater is used to meet 91% of the demand in the region. Currently allocated and projected withdrawals are primarily from the Ogallala aquifer, and to a much lesser extent, the El Reno and non-delineated minor aquifers. The Ogallala has substantial groundwater storage, commonly yielding 500 to 1,000 gpm, and can yield up to 2,000 gpm in thick, highly permeable areas. Aquifer storage depletions are likely to occur throughout the year, but will be largest in the summer months. These depletions are small relative to the amount of water in storage, but are expected to lead to adverse impacts on pumping costs, yields, and/or water quality.

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



Water Supply Options

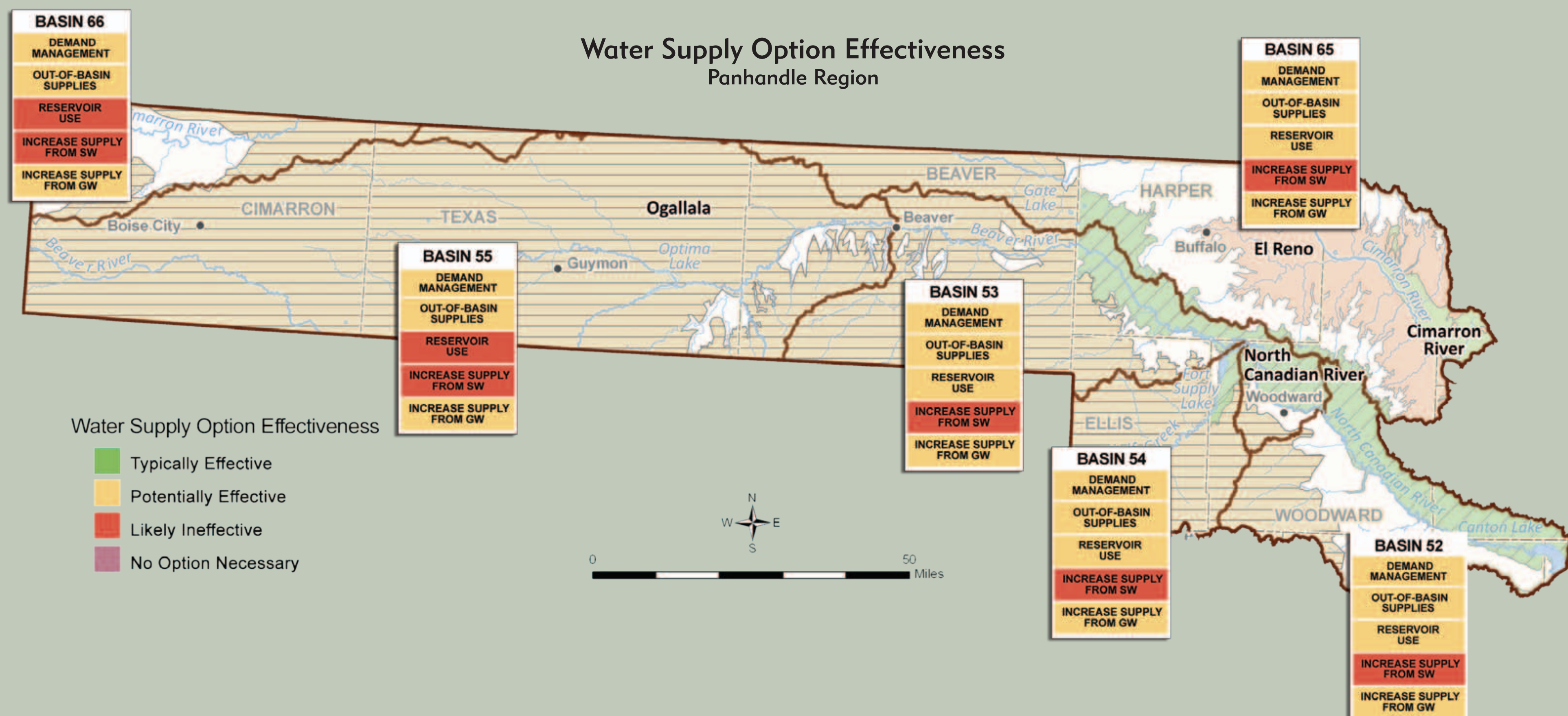
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. The Ogallala aquifer is expected to continue to supply the majority of demand in the region. The development of groundwater supplies should be considered a short-term water supply option. Over time, the Ogallala may no longer be the most cost-effective source of supply as water levels decrease. Basins and users that rely on surface water are projected to have physical surface water supply shortages (gaps) in the future. Alluvial groundwater storage depletions are also projected in the future. Therefore, additional long-term water supplies should be considered.

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

New small reservoirs (50 acre-feet) or less of storage) could enhance the dependability of surface water supplies, but are not expected to substantially decrease gaps. The OCWP Reservoir Viability Study, which evaluated the potential for reservoirs throughout the state, identified two potentially viable sites in the Panhandle Watershed Planning Region.

Alternatively, out-of-basin supplies could provide additional supplies to mitigate the region's storage depletions. However, due to the distance to dependable supplies, this water supply option may not be cost-effective for many users.

The projected growth in surface water and alluvial groundwater use could instead be supplied by the Ogallala aquifer, which would result in minimal increases in projected groundwater storage depletions. However, increased demands would still leave users susceptible to the adverse effects of storage depletions.



Effectiveness of water supply options in each basin in the Panhandle 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 only a small fraction of the supply used to meet demand in the Panhandle Region. The region's major streams include the upper North Canadian River (known in part of the region as the Beaver River) and the upper Cimarron River. Many streams in this region are characterized by frequent low-flow periods, although periodic flooding events can also occur.

The headwaters of the upper North Canadian River (Beaver River) are found in Texas, New Mexico, and Oklahoma. The mainstem runs the length of the Oklahoma panhandle turning toward the southeast, where it is known as the Beaver River before reaching the confluence of Wolf Creek. Wolf Creek (approximately 90 miles long, 50 miles in Oklahoma) is the only major tributary to the North Canadian/Beaver River within the Panhandle Region. The upper North Canadian River and its tributaries are located in Basins 52, 53, 54, and 55.

The upper Cimarron River originates in New Mexico and runs along the northern border of Oklahoma, winding in and out of Oklahoma, Colorado, and Kansas. The mainstem turns southeast through Oklahoma in the eastern portion of the Panhandle Region. The Cimarron River's two largest tributaries within the Panhandle Region are Sand Creek (50 miles long) and Buffalo Creek (50 miles). The Upper Cimarron River and its tributaries are located in Basins 65 and 66.

In the Panhandle Region, streamflow is generally intermittent, but has fair to good quality when available. There are three major reservoirs in the Panhandle Region, but only one provides water supply yield to the region. Canton Lake was constructed on the Upper North Canadian River in 1948 by the U.S. Army Corps of Engineers. However, the entire yield of Canton (18,480 AF/year) is contracted to Oklahoma City. Fort Supply Lake, located on the Wolf Creek tributary to the North Canadian River, was built by the U.S. Army Corps of Engineers in 1942 and provides a relatively small water supply yield to the region (224 AF/year). Optima Lake, built in 1978 and operated by the U.S. Army Corps of Engineers, regulates flow in the Beaver River at Beaver, Oklahoma, but does not sustain a dependable water supply yield. There are small privately owned lakes in the region that provide water for agricultural water supply and recreation.

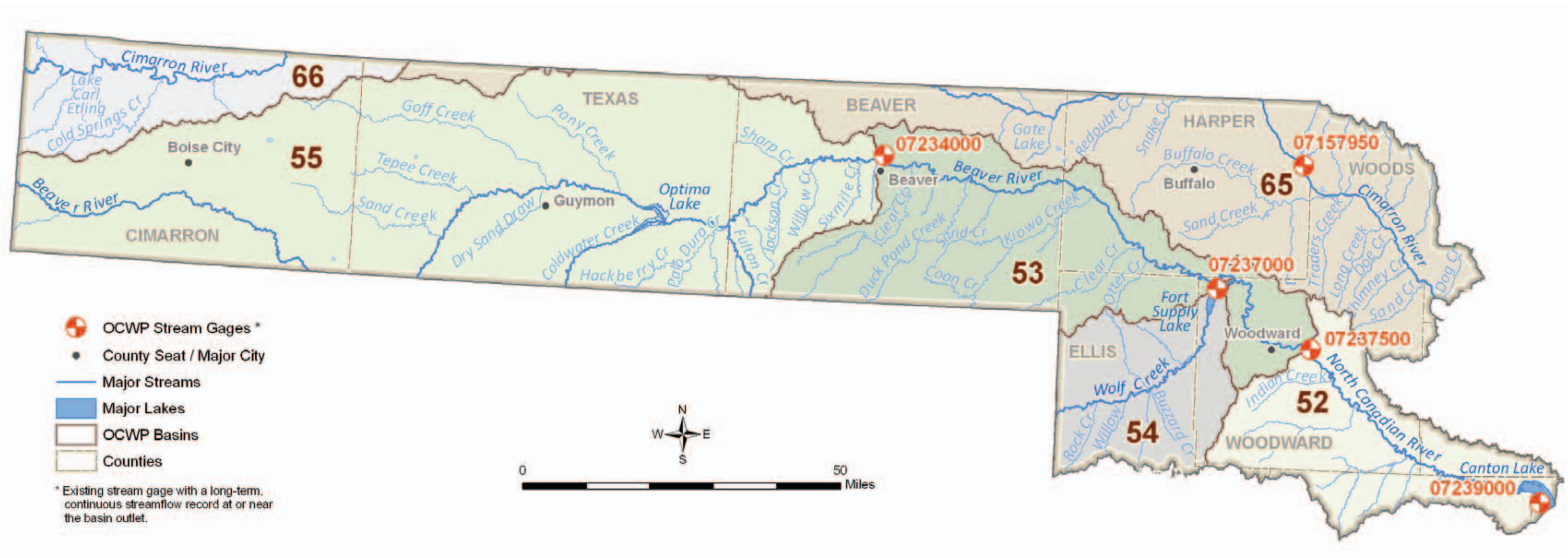
As important sources of surface water in Oklahoma, reservoirs and lakes help provide dependable water supply storage, especially when streams and rivers experience periods of low seasonal flow or drought.

Reservoirs
Panhandle 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
Canton	52	USACE	1948	FC, WS, IR	111,310	38,000	16,240	69,000	2,240	0	0	18,480	0
Fort Supply	54	USACE	1942	FC, C	13,900	400	224	0	0	0	0	0	224
Optima	55	USACE	1978	FC, WS, R, FW	129,000	117,650	---	0	0	0	0	0	No Yield

No known information is annotated as "---"
1 The "Purposes" represent the use(s), as authorized by the funding entity or dam owner(s), for the reservoir storage when constructed.
WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water

Surface Water Resources
Panhandle Region



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

Water Supply Availability Analysis

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

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

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

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

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

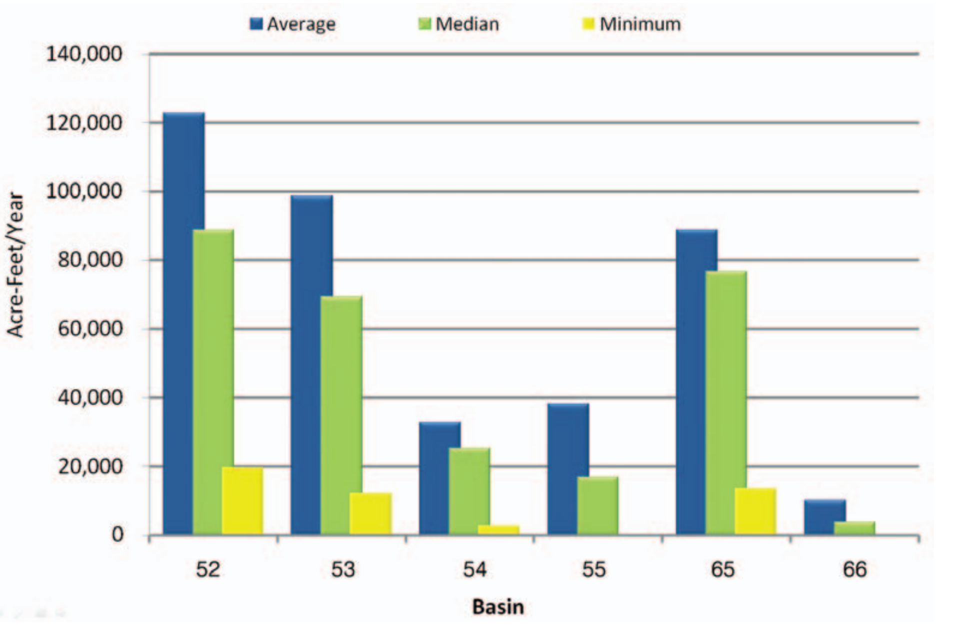
For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers,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

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

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

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

Surface Water Flows (1950-2007)
Panhandle Region



Surface water supplies only about 2% of the demand in the Panhandle Region. While the region's average physical surface water supply exceeds projected surface water demand in the region, gaps can occur due to seasonal, long-term hydrologic (drought) or localized variability in surface water flows.

Estimated Annual Streamflow in 2060
Panhandle Region

Streamflow Statistic	Basins					
	52	53	54	55	65	66
	AFY					
Average Annual Flow	93,400	57,500	19,300	12,900	45,500	5,600
Minimum Annual Flow	10,200	500	1,300	0	4,700	0

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

Groundwater Resources

The Ogallala aquifer, which underlies all but the northeastern portion and the far northwest corner of the Panhandle Watershed Planning Region, is the single largest source of groundwater in Oklahoma. Three major alluvial aquifers, the Canadian River, Cimarron River, and North Canadian River, are located in the eastern portion of the region.

Regionally, the Ogallala aquifer is part of the High Plains aquifer that underlies 174,000 square miles in eight states in the central United States, including about 7,100 square miles in northwestern Oklahoma. The aquifer underlies portions of Basin 52, 53, 54, 55, 65, and 66, and consists predominantly of semi-consolidated sediment layers. The depth to water ranges from less than 10 feet to more than 300 feet below the land surface, and the saturated thickness ranges from nearly zero to almost 430 feet. The Ogallala commonly yields 500 to 1,000 gpm and can yield up to 2,000 gpm in thick, highly permeable areas. Historically, groundwater has been pumped out of the aquifer at rates significantly exceeding recharge, causing declining water levels throughout much of the aquifer. In small areas of Cimarron and Texas Counties, water levels have declined more than 50 to 100 feet. Elsewhere, local water quality has been impaired by high concentrations of nitrate. However, water quality of the aquifer is generally very good.

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 North Canadian River alluvial aquifer consists of fine- to coarse-grained sand with minor clay and silt and local lenses of basal gravel overlain by dune sand. Formation thickness generally averages 30 feet in the alluvium and 70 feet in the terrace deposits. Yields range between 300 and 600 gpm in the alluvium and between 100 and 300 gpm in the terrace formations. The water is a very hard calcium bicarbonate type with TDS concentrations of up to 1,000 mg/L. The aquifer underlies portions of Basins 52, 53, 54, and 65.

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

The Cimarron River alluvial aquifer tends to be silt and clay deposits changing downward to sandy clay, sand, and fine gravel. Maximum thickness reaches 80 feet with well yields ranging between 100 and 200 gpm in the alluvium and 100 and 500 gpm in the terrace deposits. The terrace deposits are overlain by sand dunes. The water is very hard and is classified as calcium magnesium bicarbonate type. Extensive pumping can make this formation susceptible to salt water intrusion. The aquifer underlies a portion of Basin 65.

The only delineated minor aquifer in the region is the El Reno bedrock aquifer. Minor aquifers may have a substantial amount of water in storage and high recharge rates, but generally low yields of less than 50 gpm per well. Groundwater from minor aquifers is an important source of water for domestic and stock water use for individuals in outlying areas, but may not provide sufficient water for large volume users.

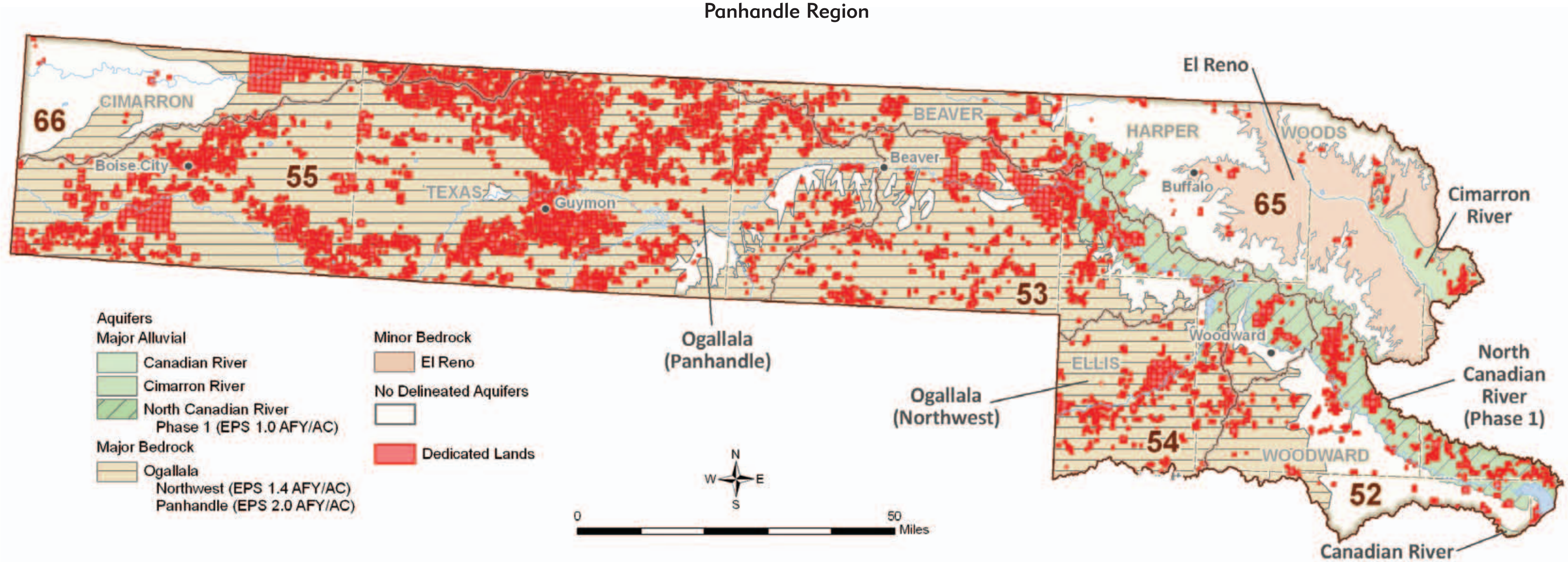
Permits to withdraw groundwater from aquifers (groundwater basins) where the maximum annual yield has not been set are "temporary" permits that allocate 2 AFY/acre. The temporary permit allocation is not based on storage, discharge or recharge amounts, but on a legislative (statute) estimate of maximum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

Groundwater Resources
Panhandle 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
Canadian River	Alluvial	Major	<1%	2.0	0	12,000	temporary 2.0	12,800
Cimarron River	Alluvial	Major	1%	2.3	10,800	327,000	temporary 2.0	140,100
El Reno	Bedrock	Minor	8%	0.75	4,700	2,555,000	temporary 2.0	978,700
North Canadian River	Alluvial	Major	8%	1.0	90,600	4,346,000	1.0	413,700
Ogallala	Bedrock	Major	65%	0.5	1,423,800	84,371,000	1.4 to 2.0	6,100,600
Non-Delineated Groundwater Source	Alluvial	Minor			10,500			
Non-Delineated Groundwater Source	Bedrock	Minor			4,500			

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
Panhandle Region



The Ogallala is the only major bedrock aquifer in the Panhandle Region. Major alluvial aquifers in the region include Canadian River, Cimarron River, and North Canadian River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

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

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

There is no surface water available for new permits in any basin in the Panhandle Region, limiting diversions to existing permitted amounts. For groundwater, the EPS has been set for all of the Ogallala aquifer with the exception of that underlying Roger Mills County, which is located in the West Central Watershed Planning Region. In the Panhandle Region, the Ogallala aquifer's EPS is set at two acre-feet per year (AFY) per acre in the three Panhandle counties and 1.4 AFY per acre for other counties in the Planning Region overlying the Ogallala. The EPS for the North Canadian River aquifer is set at one AFY per acre. For the Cimarron River, Canadian River, and El Reno aquifers, temporary permits are issued, granting users two AFY of water per acre of land until the OWRB conducts hydrologic investigations and establishes the maximum annual yield of the basins. Projections indicate that there will be groundwater available for new permits in all aquifers in the Panhandle Region through 2060.

Surface Water Permit Availability

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

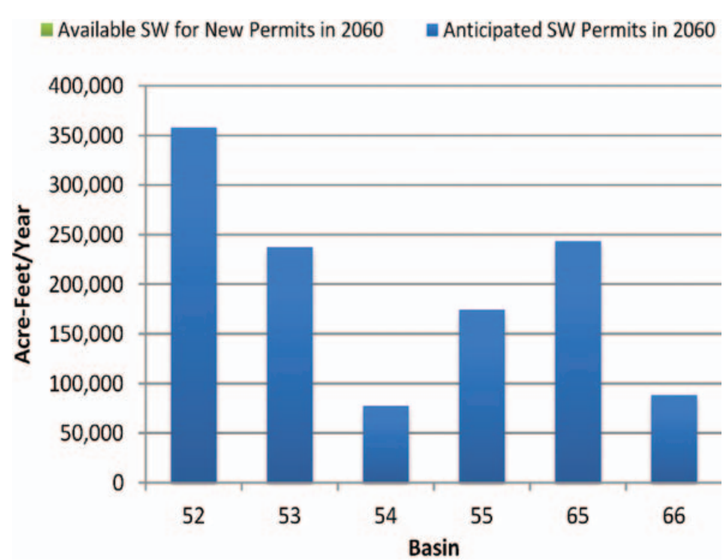
To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations,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

Groundwater Permit Availability

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

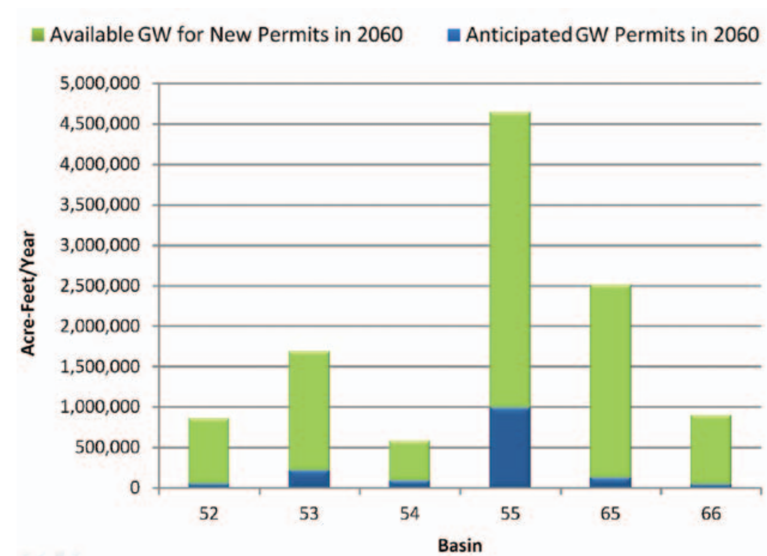
For OCWP analysis, the geographical area overlying all aquifers in each basin was determined and the respective EPS or temporary permit allocations were applied. Total current and anticipated future permit needs were then calculated to project remaining groundwater permit availability.

Surface Water Permit Availability
Panhandle Region



Projections indicate that there will be no surface water available for new permits through 2060 in all basins in the Panhandle Region.

Groundwater Permit Availability
Panhandle Region



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

Water Quality

Water quality of the Panhandle Watershed Planning Region is markedly different across two major river systems, the Cimarron and the Beaver/North Canadian. Although some differences are ecologically based, others are due to irrigation and other agricultural uses. From east to west, the region is contained within three distinct plains ecoregions. The terminus of the region is geographically not in Oklahoma's Panhandle but encompasses the far northwestern corner of the state. The eastern one-third of this portion of the region are part of the Central Great Plains ecoregion. To the west, the region transitions into the Southwestern Tablelands ecoregion. A portion of the ecoregion also covers the far northwestern tip of the Panhandle. Finally, the remainder of the region is covered by the High Plains ecoregion, portions of which are intermixed with the Southwestern Tablelands.

Water quality of the Central Great Plains is exemplified by sites along the Beaver/North Canadian River at Fort Supply, Woodward, and Seiling, as well as the Cimarron River near Buffalo. The North Canadian River also drains into Canton Reservoir, at the east end of the region. Nutrient concentrations are typical mean phosphorus concentrations ranging from 0.05 parts per million (ppm) along the Beaver River to 0.12 ppm on the North Canadian near Woodward. From the middle to lower end, as well as at Canton Reservoir, waters are considered eutrophic, but are mesotrophic along the Beaver River. Waters are phosphorus-limited. Water clarity is high in both the Cimarron and Beaver Rivers with average turbidity values ranging from 5 to 10 nephelometric turbidity units (NTUs). Clarity diminishes in the North Canadian River as turbidity averages increase to 15-25 NTU, but is still relatively low for the ecoregion. Clarity is considered good to fair in Canton with an average Secchi depth of 1.2 feet. The most divergent water quality indicator is conductivity. Along the Beaver/North Canadian Rivers and into Canton Reservoir, moderately to highly saline water is present, much like the rest of the Central Great Plains. Median conductivity values range from 1400-1570 microsiemens (µS). However, along the Cimarron River and tributaries, median conductivity values increase to more than 14,000 µS, and from Freedom to Waynoka are more than 150,000 µS. Freshwater ecological diversity is relatively diverse throughout the Beaver/North Canadian River watersheds and highly diverse in the Gypsum Hills and other areas with higher gradients and gravel/cobble substrates. However, due to high salinity, the majority of the upper Cimarron River has relatively low aquatic diversity with fewer than 8-10 fish species. The extremely highly saline areas of the watershed have only two species of fish.

Lake Trophic Status

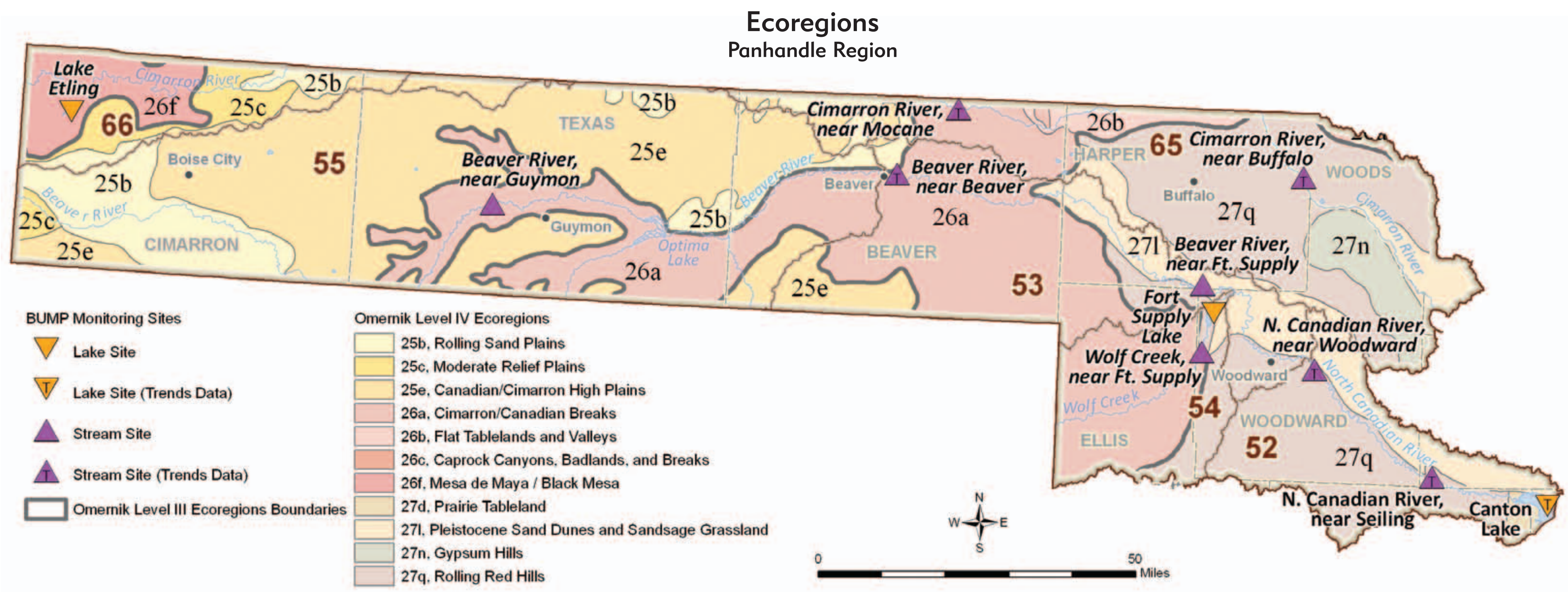
A lake's trophic state, essentially a measure of its biological productivity, is a major determinant of water quality.

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.



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

The Southwestern Tablelands ecoregion is underlain by the Ogallala Aquifer. The area has numerous springs and has historically supported a variety of ecosystems in lowland areas. Extensive irrigation, however, has diminished groundwater levels somewhat with a distinctive effect on streams and springs. Many perennial streams are now ephemeral, including considerable stretches of the Cimarron and Beaver Rivers.

Water quality can be characterized by the Cimarron River to the north, Beaver River through the central part of the ecoregion, and Wolf Creek near Fort Supply and Fort Supply Reservoir. The Beaver River and Wolf Creek have comparatively low nutrient concentrations with phosphorus values ranging from 0.05 to 0.06 ppm, and could be classified as mesotrophic. Total nitrogen concentrations range from 0.15 ppm along the Beaver River to near 0.64 ppm on Wolf Creek. Conversely, the Cimarron River has moderately high nutrient concentrations with total phosphorus and nitrogen averages greater than 0.50 and 1.43 ppm, respectively, and is considered hypereutrophic. Fort Supply Reservoir is co-limited for total phosphorus and nitrogen and is considered eutrophic. Water clarity is good throughout the area with turbidity averages from 11 NTU at Beaver to 21 NTU at Mocane. Fort Supply Reservoir has an average Secchi depth of 25 cm. However, as with the Central Great Plains, salinity is widely variable throughout the ecoregion. On the Beaver River near Guymon, average conductivity is less than 500 µS, which is extremely low for the western plains. Similar conductivity values have been recorded along other spring-fed reaches of the Southwestern Tablelands. Wolf Creek and Fort Supply Reservoir have average conductivity values ranging from 930-1000 µS. Conversely, at the Beaver station, average conductivity is 8100 µS, which is extremely saline and more characteristic of the Cimarron River. The Mocane site is also highly saline with an average conductivity of 4300 µS.

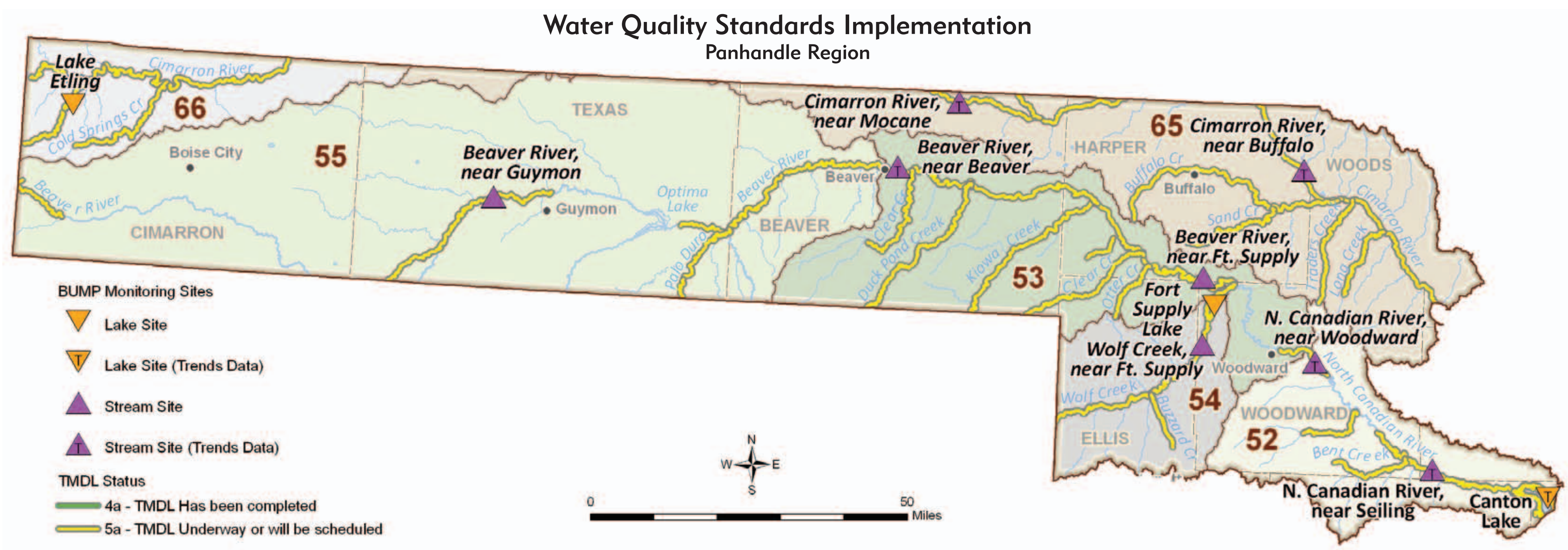
Water Quality Standards and Implementation

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.



BUMP monitoring sites and streams with TMDL studies completed or underway.

Water Quality Impairments

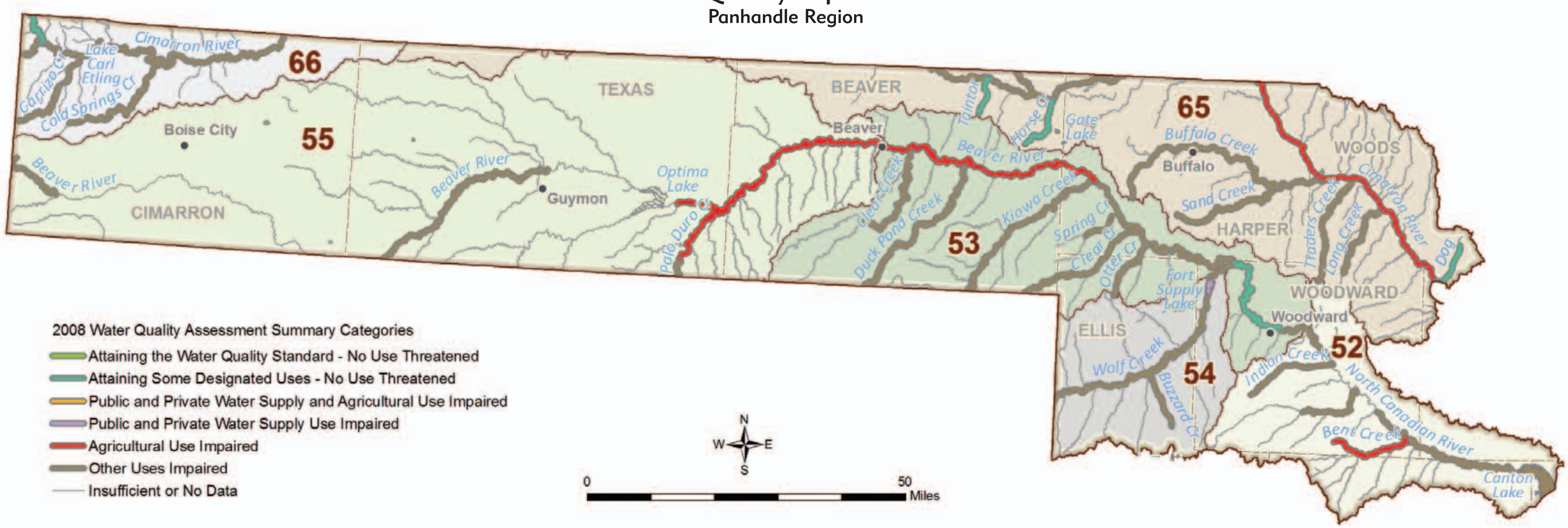
A waterbody is considered to be impaired when its quality does not meet the standards prescribed for its beneficial uses. For example, impairment of the Public and Private Water Supply beneficial use means the use of the waterbody as a drinking water supply is hindered. Impairment of the Agricultural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

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

In an individual waterbody, after impairments have been identified, a Total Maximum Daily Load (TMDL) study is conducted to establish the sources of impairments—whether from point sources (discharges) or nonpoint 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
Panhandle Region



Regional water quality impairments based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Surface water impairments in this region have occurred due to alterations of stream flow.

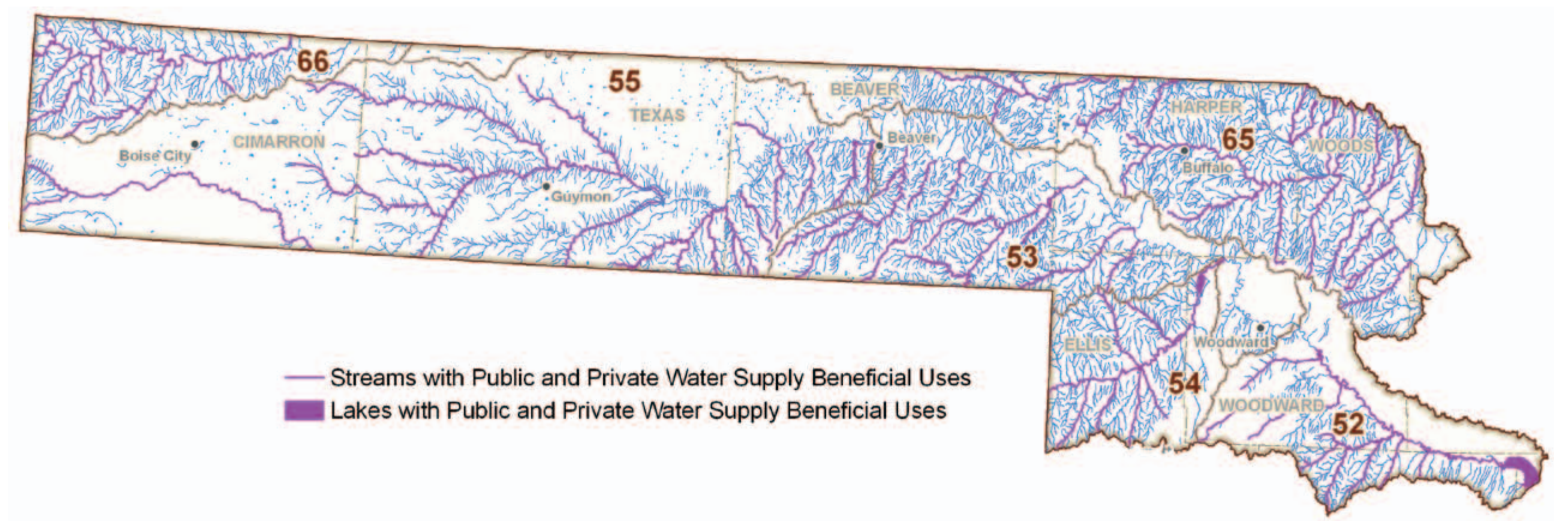
The northwestern tip of the Panhandle is encompassed by the diverse Mesa de Maya/Black Mesa ecoregion. Many streams are spring-fed and ephemeral and the Cimarron River is of much higher quality in this area. Although many streams have good water clarity, Lake Carl Etling is fair with an average Secchi depth of 0.75 feet. Nutrient values are relatively high in the lake with total phosphorus ranging from 0.12 to 0.29 ppm and total nitrogen from 2.31 to 4.51 ppm. It is also considered hyper-eutrophic. Conductivity is relatively high at an average of 2,000 µS, and closely resembles the upper portion of the North Canadian River.

The High Plains ecoregion in the OCWP Panhandle Region is mostly comprised of the Canadian/Cimarron High Plains, but is bordered on the northern and western edges by the Rolling Sand Plains and Moderate Relief Plains. Many streams and rivers are naturally ephemeral and little is known about surface water quality. Streams that may have been naturally perennial have become ephemeral as irrigation practices have exacerbated natural precipitation/evaporation issues. Also, many streams are shallow with low banks and very little native habitat for fish. The area does contain numerous playa lakes, which support native wetlands for waterfowl.

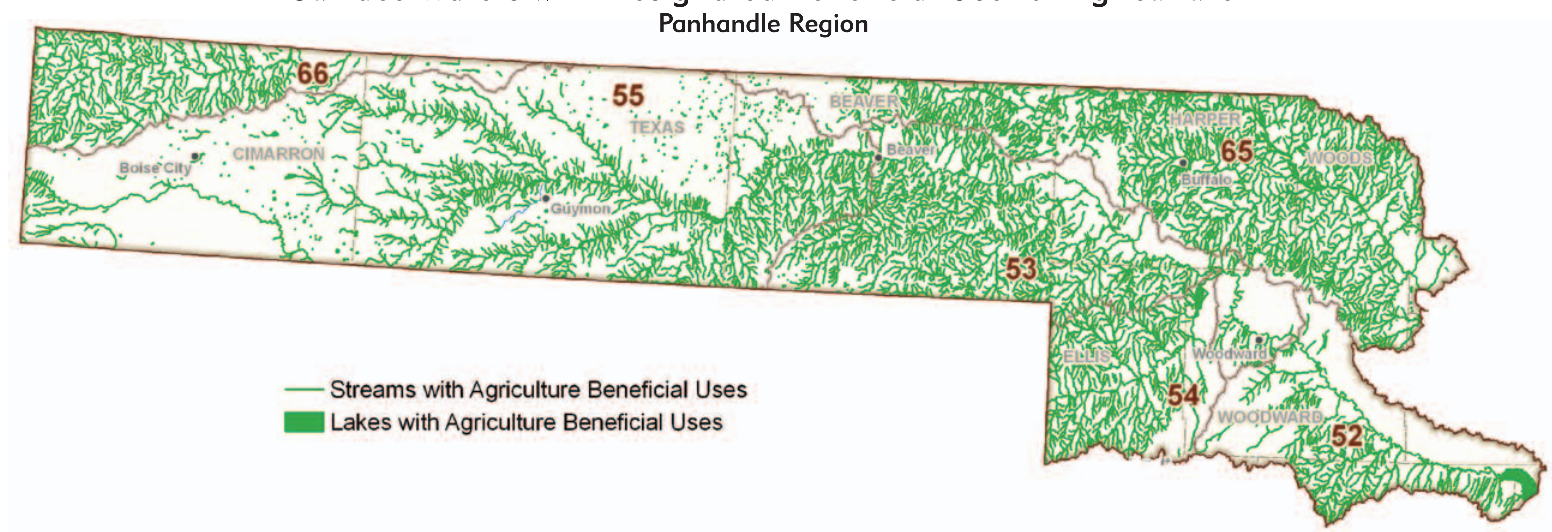
Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed and data are available from municipal and other sources. The Panhandle Region is underlain by the Ogallala aquifer. Most groundwater is used to irrigate crops, with the remainder used for livestock, municipal, and domestic needs. Water quality of the aquifer is generally very good. In some local areas, quality has been impaired by high concentrations of nitrate. Some deep portions of the aquifer have elevated concentrations of calcium, chloride, sodium, and sulfate, derived from upward movement of mineralized water from underlying Permian formations. Water from the Panhandle portion of the Ogallala is of a calcium-magnesium chloride-sulfate type and, although hard, is suitable for public supply. Excessive concentrations of chloride, sulfate and fluoride do make the water unsuitable in some areas. The Oklahoma Department of Environmental Quality (ODEQ) has identified a local well field with elevated nitrate levels; additional wells showed elevated levels of selenium, probably of natural origin.

The Panhandle region is also underlain by several alluvial aquifers and terrace deposits. In northwest Oklahoma, water quality in alluvium and terrace deposits is affected by adjacent streams. The quality is generally poor where the deposits directly overlie the Ogallala and are not in contact with Permian red beds.

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



Surface Waters with Designated Beneficial Use for Agriculture
Panhandle 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.

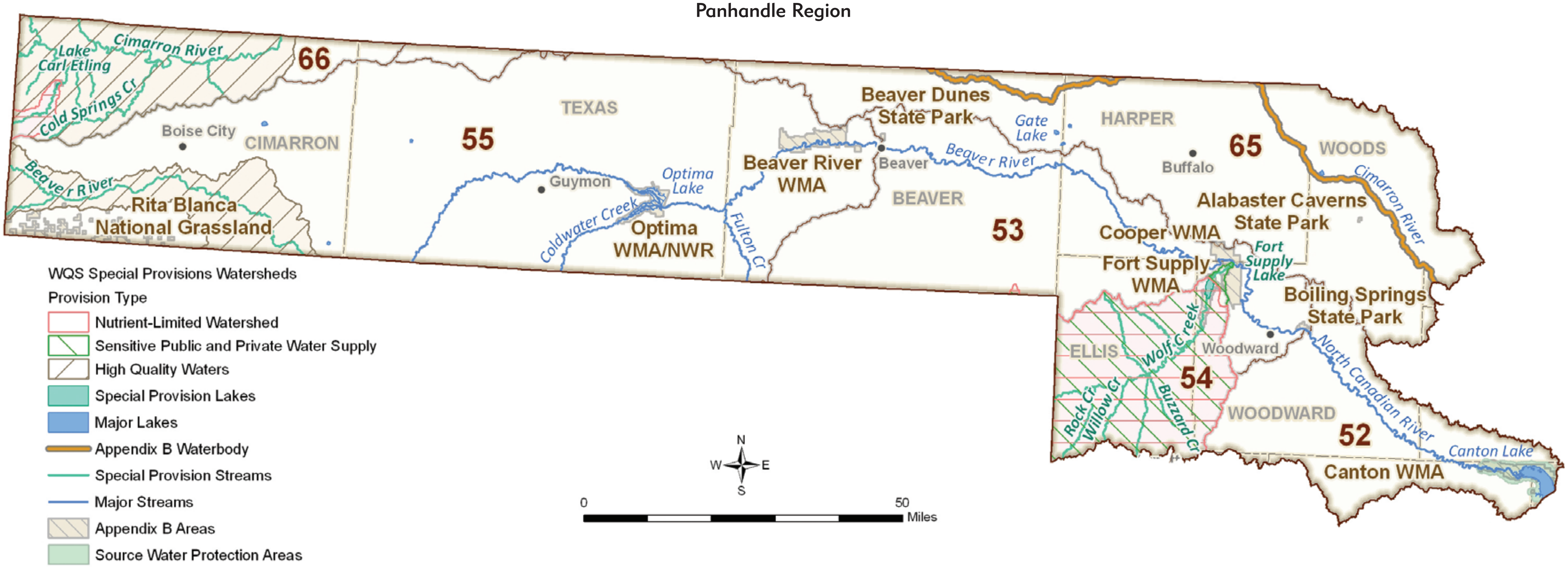
The **Sensitive Water Supplies (SWS)** designation applies to public and private water supplies possessing conditions making them more susceptible to pollution events, thus requiring additional protection. This designation restricts point source discharges in the watershed and institutes a 10 μg/L (micrograms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



The watersheds of Lake Carl Etling and Ft. Supply have been identified by OWRB as Nutrient-Limited Watersheds but currently lack protection to prevent degradation.

Groundwater Protection

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

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

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

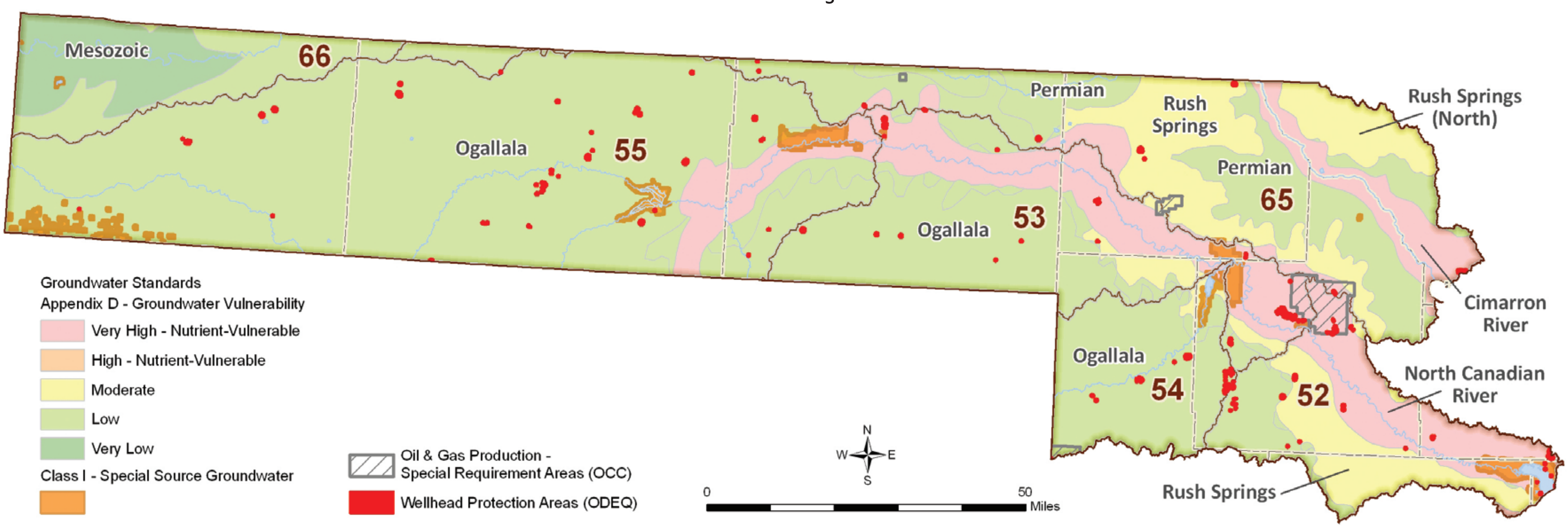
Nutrient-Vulnerable Groundwater is a designation given to certain hydrogeologic basins that are designated by the OWRB as having high or very high vulnerability to contamination from surface sources of pollution. This designation can impact land application of manure for regulated agriculture facilities.

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

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

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

Groundwater Protection Areas
Panhandle Region



Various types of protection are in place to prevent degradation of groundwater based upon OWRB vulnerability modeling. The North Canadian and Cimarron alluvial aquifers have been identified by the OWRB as very highly vulnerable but currently lack protection to prevent degradation.

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

Panhandle Region

Parameter	Canton Lake (1995-2009)
Chlorophyll-a (mg/m3)	↓
Conductivity (µS/cm)	NT
Total Nitrogen (mg/L)	↑
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.

A notable concern in the Panhandle Region is:

- Significant upward trend for total nitrogen and turbidity at Canton Reservoir.

Stream Water Quality Trends

Panhandle Region

Parameter	Beaver River near Beaver		Cimarron River near Buffalo		Cimarron River near Mocane		North Canadian River near Seiling		North Canadian River near Woodward	
	All Data Trend (1961-1994, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1968-1994, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1999-2009)[1]	Recent Trend (1999-2009)	All Data Trend (1967-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1960-1995, 1998-2009)[1]	Recent Trend (2000-2009)
Conductivity (µS/cm)	↑	↑	↑	↑	↓	↓	↓	↓	↓	↓
Total Nitrogen (mg/L)	NT	↓	↓	NT	↑	↑	↓	↑	↓	NT
Total Phosphorus (mg/L)	↓	↓	↓	NT	↑	↑	↓	NT	↓	NT
Turbidity (NTU)	NT	NT	↓	↓	NT	NT	↓	NT	NT	↑

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

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

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

Notable concerns in the Panhandle Region are:

- Significant upward trend for conductivity on the Beaver and Cimarron Rivers.
- Significant upward trend for total nitrogen throughout region.

Water Demand

The Panhandle Region's water needs account for about 21% of the total statewide demand. Regional demand will increase by 21% (83,150 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.

Crop Irrigation is expected to remain the largest demand sector in the region, accounting for 82% of the total regional demand in 2060. Currently, 6% of the demand from this sector is supplied by surface water, 19% by alluvial groundwater, and 75% by bedrock groundwater. Predominant irrigated crops in the Panhandle Region include corn, pasture grasses, and wheat.

Self Supplied Industrial demand is projected to account for approximately 5% of the 2060 demand. Currently, 33% of the demand from this sector is supplied by alluvial groundwater and 67% by bedrock groundwater.

Municipal and Industrial demand in the Panhandle Region is projected to account for approximately 4% of the 2060 demand. Currently, 5% of the demand from this sector is supplied by surface water, 24% by alluvial groundwater, and 71% by bedrock groundwater.

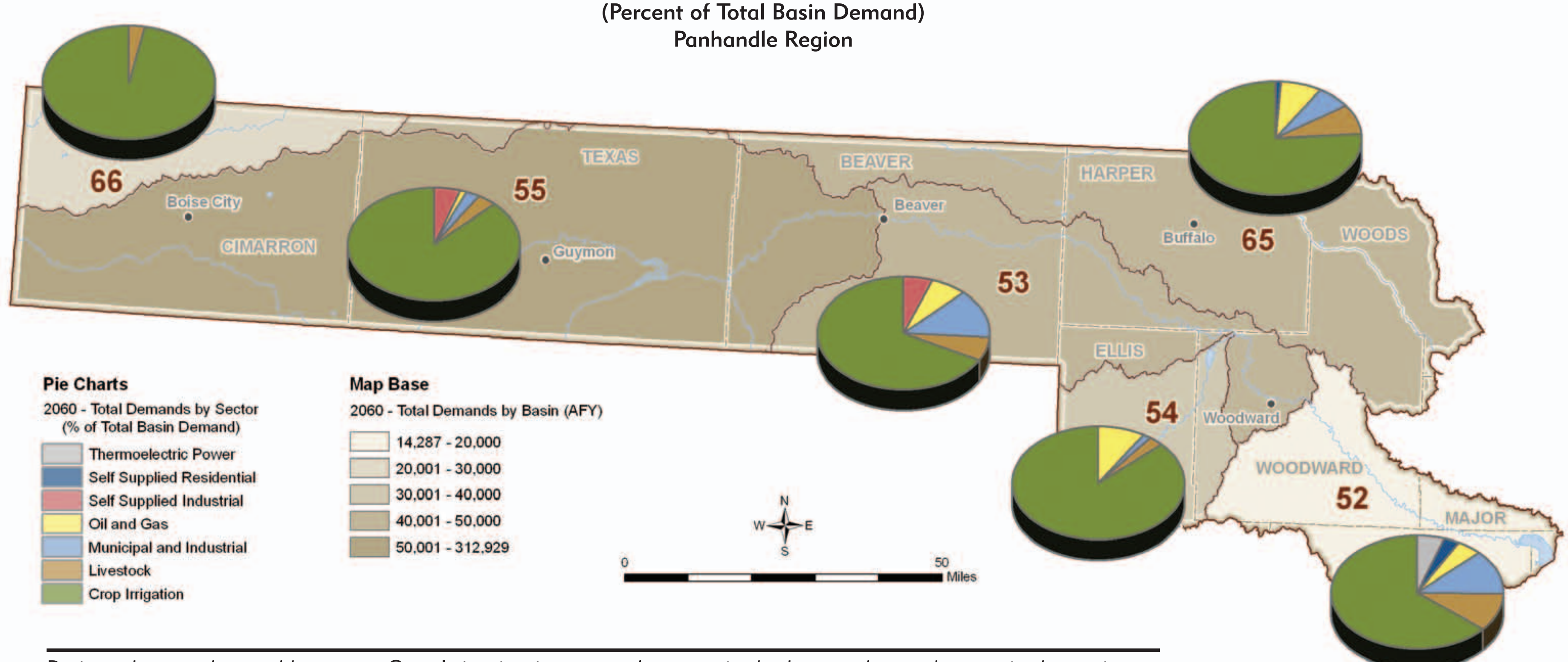
Livestock demand is projected to account for 4% of the 2060 demand. Currently, 2% of the demand from this sector is supplied by surface water, 10% by alluvial groundwater, and 88% by bedrock groundwater. Livestock use in the region is predominantly for beef cow and hog production. However, beef production is projected to drive the increases in livestock water demand.

Oil and Gas demand is projected to account for approximately 3% of the 2060 demand. Currently, 32% of the demand from this sector is supplied by surface water, 7% by alluvial groundwater, and 61% by bedrock groundwater.

Self Supplied Residential demand is projected to account for approximately 1% of the 2060 demand. Currently, 37% of the demand from this sector is supplied by alluvial groundwater and 63% by bedrock groundwater.

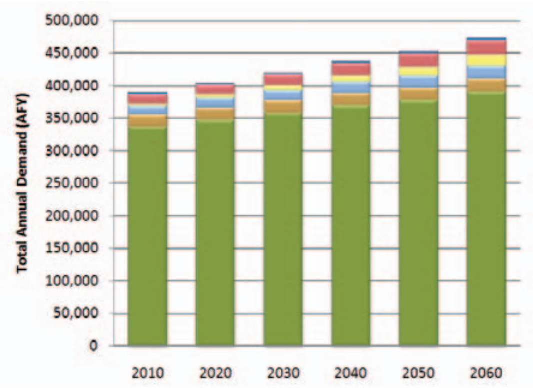
Thermoelectric Power demand is projected to account for less than 1% of the 2060 demand. The Western Farmers Electric Coop, which is supplied by alluvial groundwater, is a large user of water for thermoelectric power generation in Basin 52.

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

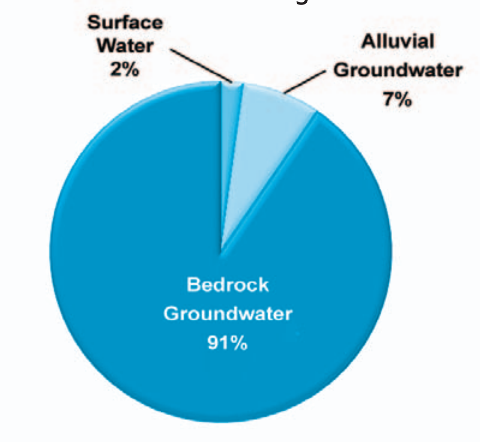


Projected water demand by sector. Crop Irrigation is expected to remain the largest demand sector in the region, accounting for 82% of the total regional demand in 2060.

Total Water Demand by Sector
Panhandle Region



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



The Panhandle Region's water needs account for about 21% of the total statewide demand. Regional demand will increase by 21% (83,150 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.

Total Water Demand by Sector
Panhandle Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	336,890	19,010	14,050	3,350	14,470	2,390	530	390,690
2020	347,680	19,220	15,180	5,150	14,490	2,540	590	404,860
2030	358,480	19,430	16,330	7,370	16,280	2,670	660	421,220
2040	369,270	19,640	17,390	10,020	18,400	2,780	740	438,250
2050	377,550	19,860	18,540	13,090	20,600	2,910	820	453,370
2060	390,860	20,070	19,630	16,580	22,740	3,030	920	473,840

Water Demand

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

Water Demand Sectors

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

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

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

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

Public Water Providers

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

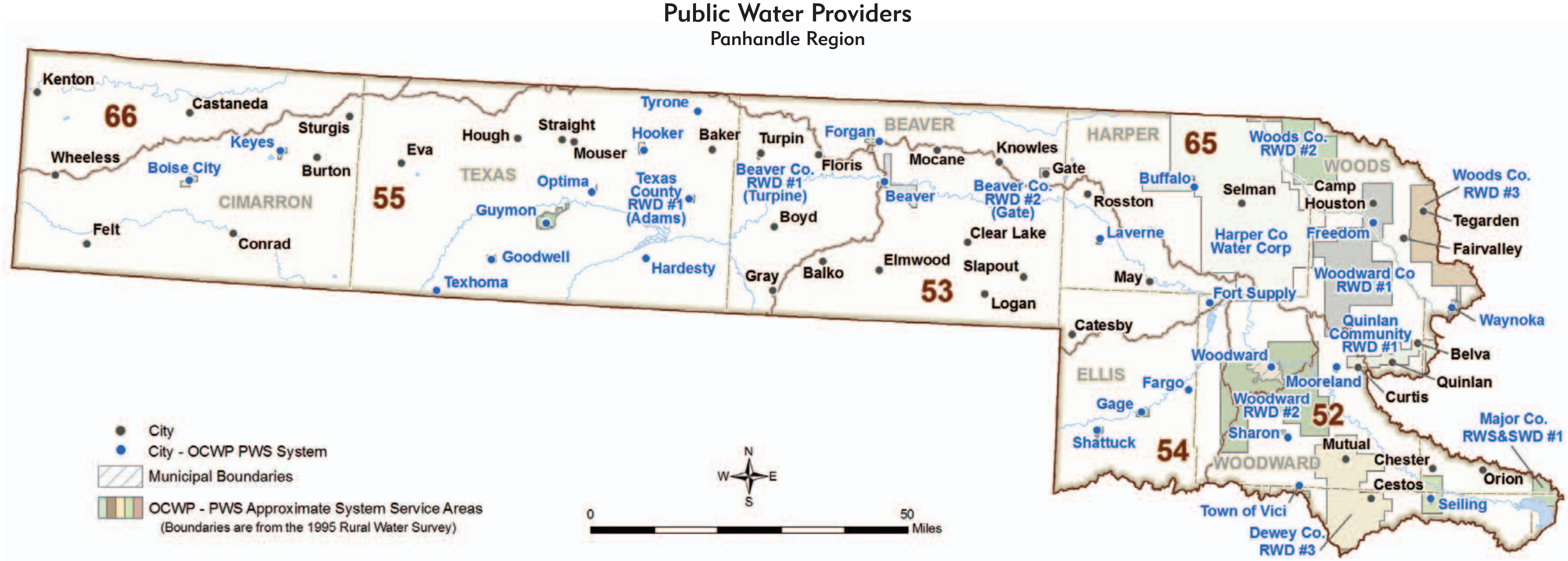
The Panhandle Region includes 32 of the 785 public supply systems analyzed for the *2012 OCWP Update*. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems often serve multiple counties and can extend into multiple planning basins and regions.)

In terms of 2010 population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are Woodward, Guymon, Hooker, Beaver, and Goodwell. These five systems provide service for more than 70 percent of the population served by public water providers in the region.

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

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

Public Water Providers
Panhandle Region



Population and Demand Projection Data

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

Public Water Providers/Retail Population Served

Panhandle Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
BEAVER	OK2000404	Beaver	252	1,593	1,623	1,654	1,684	1,704	1,734
BEAVER CO RWD #1 TURPIN	OK2000402	Beaver	147	480	488	496	503	511	519
BEAVER CO RWD #2 (GATE)	OK2000405	Beaver	140	100	100	109	109	109	118
BOISE CITY PWA	OK2001303	Cimarron	339	1,239	1,313	1,354	1,354	1,395	1,428
BUFFALO	OK2003003	Harper	188	1,182	1,182	1,182	1,182	1,212	1,212
DEWEY CO RWD #3	OK2007707	Woodward	88	693	722	744	759	776	790
FARGO	OK2002303	Ellis	147	294	294	294	284	284	294
FORGAN	OK2000406	Beaver	80	496	496	505	514	523	532
FORT SUPPLY PWA	OK3007701	Woodward	322	334	344	363	373	383	383
FREEDOM	OK3007601	Woods	74	271	271	281	281	291	291
GAGE	OK2002301	Ellis	186	423	412	412	402	402	412
GOODWELL	OK2007005	Texas	125	1,287	1,601	1,914	2,228	2,549	2,863
GUYMON	OK2007003	Texas	391	14,531	18,063	21,659	25,254	28,839	32,382
HARDESTY UTILITIES	OK2007004	Texas	162	243	304	365	426	486	547
HARPER CO WATER CORP	OK2003001	Harper	280	201	201	201	201	206	206
HOOKER	OK2007006	Texas	278	1,939	2,412	2,892	3,373	3,854	4,326
KEYES UTILITY AUTH	OK2001302	Cimarron	286	315	330	345	345	353	368
LAVERNE	OK2003002	Harper	381	1,081	1,081	1,081	1,081	1,112	1,112
MOORELAND	OK2007709	Woodward	244	1,242	1,300	1,340	1,369	1,398	1,428
OPTIMA	OK2007001	Texas	53	403	495	598	702	794	897
QUINLAN COMMUNITY RWD #1	OK2007708	Woodward	278	188	196	202	206	211	215
SEILING	OK2002205	Dewey	186	875	854	854	854	875	896
SHARON UTILITIES	OK2007741	Woodward	197	131	131	141	141	151	151
SHATTUCK	OK2002304	Ellis	290	1,224	1,194	1,194	1,163	1,163	1,194
TEXAS COUNTY RWD #1	OK2007010	Texas	148	269	335	401	468	534	600
TEXHOMA	OK2007009	Texas	253	1,005	1,252	1,500	1,747	1,994	2,241
TYRONE	OK2007013	Texas	267	945	1,175	1,414	1,652	1,882	2,112
WAYNOKA	OK2007604	Woods	120	1,005	1,005	1,015	1,025	1,035	1,055
WOODS CO RWD #2	OK3007603	Woods	65	42	42	43	43	44	44
WOODWARD	OK2007701	Woodward	347	15,193	15,822	16,303	16,624	17,019	17,328
WOODWARD CO RWD #1	OK2007706	Woodward	159	380	396	408	416	426	433
WOODWARD CO RWD #2	OK2007710	Woodward	288	829	863	889	907	929	945

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

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

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

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

Public Water Provider Demand Forecast
Panhandle Region

Provider	SDWIS ID[1]	County	Demand (AFY)					
			2010	2020	2030	2040	2050	2060
BEAVER	OK2000404	Beaver	450	459	467	476	481	490
BEAVER CO RWD #1 TURPIN	OK2000402	Beaver	79	80	82	83	84	86
BEAVER CO RWD #2 (GATE)	OK2000405	Beaver	16	16	17	17	17	19
BOISE CITY PWA	OK2001303	Cimarron	470	499	514	514	530	542
BUFFALO	OK2003003	Harper	248	248	248	248	255	255
DEWEY CO RWD #3	OK2007707	Woodward	68	71	73	75	76	78
FARGO	OK2002303	Ellis	48	48	48	47	47	48
FORGAN	OK2000406	Beaver	44	44	45	46	47	48
FORT SUPPLY PWA	OK3007701	Woodward	120	124	131	135	138	138
FREEDOM	OK3007601	Woods	22	22	23	23	24	24
GAGE	OK2002301	Ellis	88	86	86	84	84	86
GOODWELL	OK2007005	Texas	181	224	268	312	358	402
GUYMON	OK2007003	Texas	6,366	7,913	9,489	11,064	12,634	14,186
HARDESTY UTILITIES	OK2007004	Texas	44	55	66	77	88	99
HARPER CO WATER CORP	OK2003001	Harper	63	63	63	63	65	65
HOOKER	OK2007006	Texas	603	750	900	1,049	1,199	1,346
KEYES UTILITY AUTH	OK2001302	Cimarron	101	106	110	110	113	118
LAVERNE	OK2003002	Harper	461	461	461	461	475	475
MOORELAND	OK2007709	Woodward	339	355	366	374	382	390
OPTIMA	OK2007001	Texas	24	30	36	42	47	54
QUINLAN COMMUNITY RWD #1	OK2007708	Woodward	59	61	63	64	66	67
SEILING	OK2002205	Dewey	183	178	178	178	183	187
SHARON UTILITIES	OK2007741	Woodward	29	29	31	31	33	33
SHATTUCK	OK2002304	Ellis	397	387	387	377	377	387
TEXAS COUNTY RWD #1	OK2007010	Texas	45	55	66	78	89	99
TEXHOMA	OK2007009	Texas	285	355	425	495	566	636
TYRONE	OK2007013	Texas	282	351	422	494	562	631
WAYNOKA	OK2007604	Woods	135	135	136	138	139	142
WOODS CO RWD #2	OK3007603	Woods	3	3	3	3	3	3
WOODWARD	OK2007701	Woodward	5,900	6,144	6,331	6,455	6,609	6,729
WOODWARD CO RWD #1	OK2007706	Woodward	68	70	72	74	76	77
WOODWARD CO RWD #2	OK2007710	Woodward	268	279	287	293	300	305

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers (2010)

Panhandle 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
BUFFALO	OK2003003	Harper Co Water Corp	O	T			
FORT SUPPLY PWA	OK3007701				City of Woodward	O	T
FREEDOM	OK3007601				Woodward RWD #1	O	T
HARPER CO WATER CORP	OK2003001				Town of Buffalo	O	T
WAYNOKA	OK2007604	Woods County RWD #3	O	T			
WOODS CO RWD #2	OK3007603				Coldwater, KS	O	T
WOODWARD	OK2007701	Ft Supply PWA	O	T			
WOODWARD CO RWD #1	OK2007706	Town of Freedom	O	T			

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers

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

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

Provider Water Rights

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

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

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

Public Water Provider Water Rights and Withdrawals (2010)

Panhandle Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
BEAVER	OK2000404	Beaver	1,125	0%	0%	100%
BEAVER CO RWD #1 TURPIN	OK2000402	Beaver	218	0%	0%	100%
BEAVER CO RWD #2 (GATE)	OK2000405	Beaver	18	0%	100%	0%
BOISE CITY PWA	OK2001303	Cimarron	2,672	0%	0%	100%
BUFFALO	OK2003003	Harper	964	0%	0%	100%
DEWEY CO RWD #3	OK2007707	Woodward	743	0%	9%	91%
FARGO	OK2002303	Ellis	221	0%	0%	100%
FORGAN	OK2000406	Beaver	1,158	0%	0%	100%
FORT SUPPLY PWA	OK3007701	Woodward	17	---	100%	---
FREEDOM	OK3007601	Woods	2	---	100%	---
GAGE	OK2002301	Ellis	1,475	0%	80%	20%
GOODWELL	OK2007005	Texas	721	0%	0%	100%
GUYMON	OK2007003	Texas	12,385	0%	1%	99%
HARDESTY UTILITIES	OK2007004	Texas	278	0%	0%	100%
HARPER CO WATER CORP	OK2003001	Harper	1,200	0%	97%	3%
HOOKER	OK2007006	Texas	884	0%	0%	100%
KEYES UTILITY AUTH	OK2001302	Cimarron	697	0%	0%	100%
LAVERNE	OK2003002	Harper	1,972	0%	100%	0%
MOORELAND	OK2007709	Woodward	1,358	0%	100%	0%
OPTIMA	OK2007001	Texas	280	0%	0%	100%
QUINLAN COMMUNITY RWD #1	OK2007708	Woodward	91	---	100%	---
SEILING	OK2002205	Dewey	383	0%	100%	0%
SHARON UTILITIES	OK2007741	Woodward	40	0%	0%	100%
SHATTUCK	OK2002304	Ellis	1,931	0%	95%	5%
TEXAS COUNTY RWD #1	OK2007010	Texas	20	0%	0%	100%
TEXHOMA	OK2007009	Texas	1,068	0%	0%	100%
TYRONE	OK2007013	Texas	595	0%	0%	100%
WAYNOKA	OK2007604	Woods	1,280	0%	100%	0%
WOODS CO RWD #2	OK3007603	Woods	---	---	---	---
WOODWARD	OK2007701	Woodward	24,045	0%	30%	70%
WOODWARD CO RWD #1	OK2007706	Woodward	1122	0%	100%	0%
WOODWARD CO RWD #2	OK2007710	Woodward	278	0%	0%	100%

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey (1 of 2)
Panhandle Region

Town of Beaver (Beaver County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
New supply source: drill additional well.

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

Beaver County RWD 2
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
None identified.

Boise City PWA (Cimarron County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New water supply sources: drill new wells.
Long-Term Needs
None identified.

Town of Buffalo (Harper County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Construct new water lines.

Dewey County RWD 3 (Woodward County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Town of Vici.
Long-Term Needs
Drill additional wells, includes land acquisition.

Town of Fargo (Ellis County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: improve existing wells.
Long-Term Needs
New supply source: drill additional wells.

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

Fort Supply PWA (Woodward County)
Current Source of Supply
Primary sources: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Freedom (Woods County)
Current Source of Supply
Primary source: Woodward County RWD 1
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Gage (Ellis County)
Current Source of Supply
Primary source: Ogallala, Wolf Creek Alluvial Aquifer
Short-Term Needs
None identified.
Long-Term Needs
New supply source: drill additional well.
Infrastructure improvements: relocate cast iron water mains.

Town of Goodwell (Texas County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: water reuse.
Long-Term Needs
New supply source: drill additional well.

City of Guymon (Texas County)
Current Source of Supply
Primary source: Ogallala Aquifer
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
Infrastructure improvements: replace water lines and meters; construct additional storage; rehabilitate water tower and pump station.

Hardesty Utilities (Texas County)
Current Source of Supply
Primary source: groundwater
Emergency source: groundwater (impacted by MtBE)
Short-Term Needs
Infrastructure improvements: construct new water line.
Long-Term Needs
None identified.

Harper County Water Corp.
Current Source of Supply
Primary source: groundwater.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Hooker (Texas County)
Current Source of Supply
Primary source: Ogallala Aquifer
Short-Term Needs
None identified.
Long-Term Needs
New supply source: drill additional well(s).

Keyes Utility Auth. (Cimarron County)
Current Source of Supply
Primary source: Groundwater
Short-Term Needs
Infrastructure improvements: construct new storage tank.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace water lines.

Town of Laverne (Harper County)
Current Source of Supply
Primary source: Beaver River Aquifer
Short-Term Needs
None required.
Long-Term Needs
Infrastructure improvements: possibly replace water mains and upgrade storage.

Town of Mooreland (Woodward County)
Current Source of Supply
Primary sources: groundwater
Short-Term Needs
None required.
Long-Term Needs
None required.

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.

Town of Optima (Texas County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None required.
Long-Term Needs
Infrastructure improvements: construct one additional well.

Quinlan Community RWD 1 (Woodward County)
Current Source of Supply
Primary source: N. Canadian Alluvial and Terrace aquifer
Short-Term Needs
None identified.
Long-Term Needs
New water supply sources: drill additional wells or purchase from nearby system.
Infrastructure improvements: expand transmission and treatment capacity.

City of Seiling (Dewey County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None required.
Long-Term Needs
None required.

Sharon Utilities (Woodward County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None required.
Long-Term Needs
None required.

Town of Shattuck (Ellis County)
Current Source of Supply
Primary source: Oscar B aquifer
Short-Term Needs
Infrastructure improvements: expand existing well system and storage.
Long-Term Needs
Infrastructure improvements: expand existing well system and storage.

Texas County RWD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: distribution system may need replacement.

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

Town of Tyrone (Texas County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: possibly drill one additional well.
Long-Term Needs
Infrastructure improvements: replace distribution lines and refurbish water tower.

City of Waynoka (Woods County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace reverse osmosis units
Long-Term Needs
New water supply sources: drill new wells.

Woods County RWD 2
Current Source of Supply
Primary source: Coldwater, Kansas
Short-Term Needs
None required.
Long-Term Needs
None required.

City of Woodward (Woodward County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: expand existing well field.
Long-Term Needs
New water supply sources: expand existing well field.

Woodward County RWD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: drill one additional well.
Long-Term Needs
None required.

Woodward County RWD 2
Current Source of Supply
Primary source: Groundwater
Short-Term Needs
Infrastructure improvements: drill one additional well.
Long-Term Needs
None required.

Infrastructure Cost Summary

Panhandle Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present - 2020	2021 - 2040	2041 - 2060	Total Period
Small	$288	$291	$129	$708
Medium	$48	$68	$68	$184
Large	$0	$0	$0	$0
Reservoir[2]	$0	$0	$38	$38
Total	$336	$359	$235	$930

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

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

- Approximately $930 million is needed to meet the projected drinking water infrastructure needs of the Panhandle region over the next 50 years. The infrastructure costs are expected to occur at a relatively constant rate over time.
- Distribution and transmission projects account for more than 85% of the providers' estimated infrastructure costs, followed distantly by water treatment and source water projects.
- Small providers, which include nearly all providers in the Panhandle Region, have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoirs comprise approximately 4% of the total costs. These costs are expected to be incurred after 2040.

Drinking Water Infrastructure Cost Summary

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

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

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

Water Supply Options

Limitations Analysis

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

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

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

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

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

Primary Options

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

Demand Management

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

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

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

Out-of-Basin Supplies

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

Reservoir Use

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

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

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

Increasing Reliance on Surface Water

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

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

Increasing Reliance on Groundwater

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

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

Expanded Options

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

Expanded Conservation Measures

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

Artificial Aquifer Recharge

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

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

Marginal Quality Water Sources

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

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

Potential Reservoir Development

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

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

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

Reservoir Project Viability Categorization

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

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

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

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

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

Potential Reservoir Sites (Categories 3 & 4)

Panhandle Region

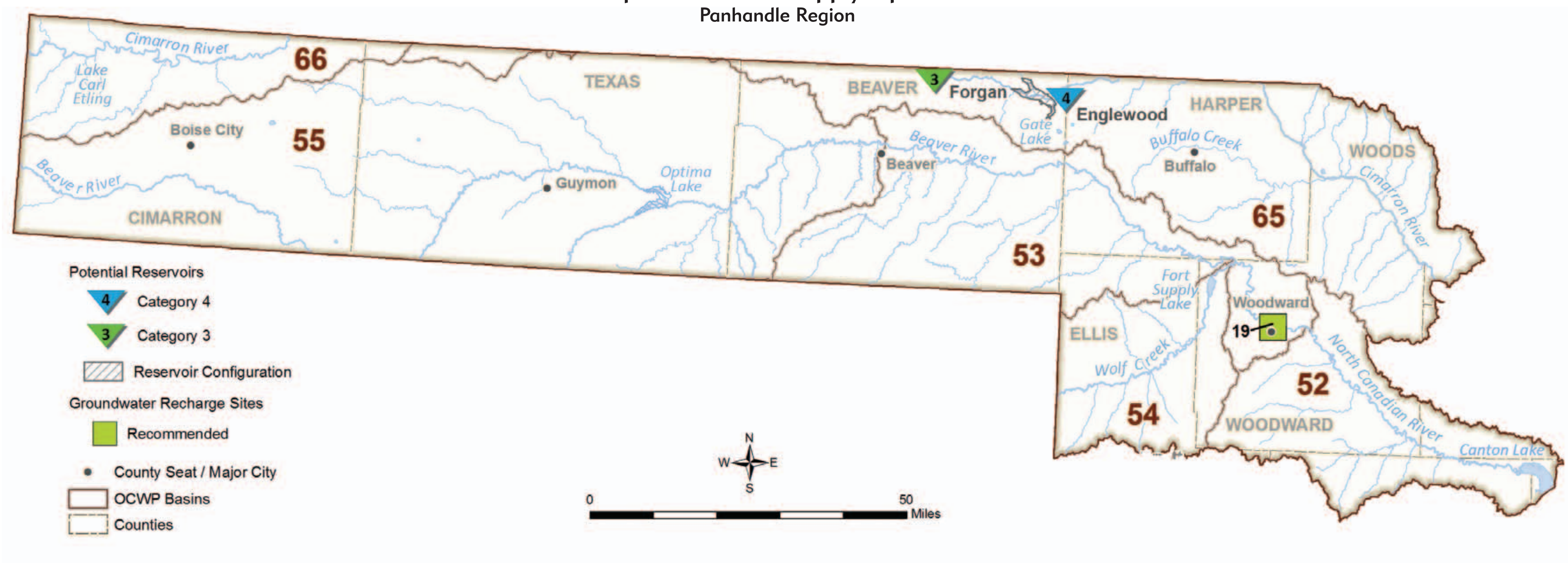
Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool: Surface Area	Conservation Pool: Storage	Conservation Pool: Dependable Yield	Primary Study: Date	Primary Study: Agency	Updated Cost Estimate[2] (2010 dollars)
					AF	Acres	AF	AFY			
Englewood	4	Cimarron River	65	IR, FC, FW, R	424,400	7,400	63,500	36,967	1947	Bureau of Reclamation	$431,898,000
Forgan	3	Cimarron River	65	WS, FW, R	129,000	3,668	77,500	24,100	1991	Bureau of Reclamation	$225,777,000

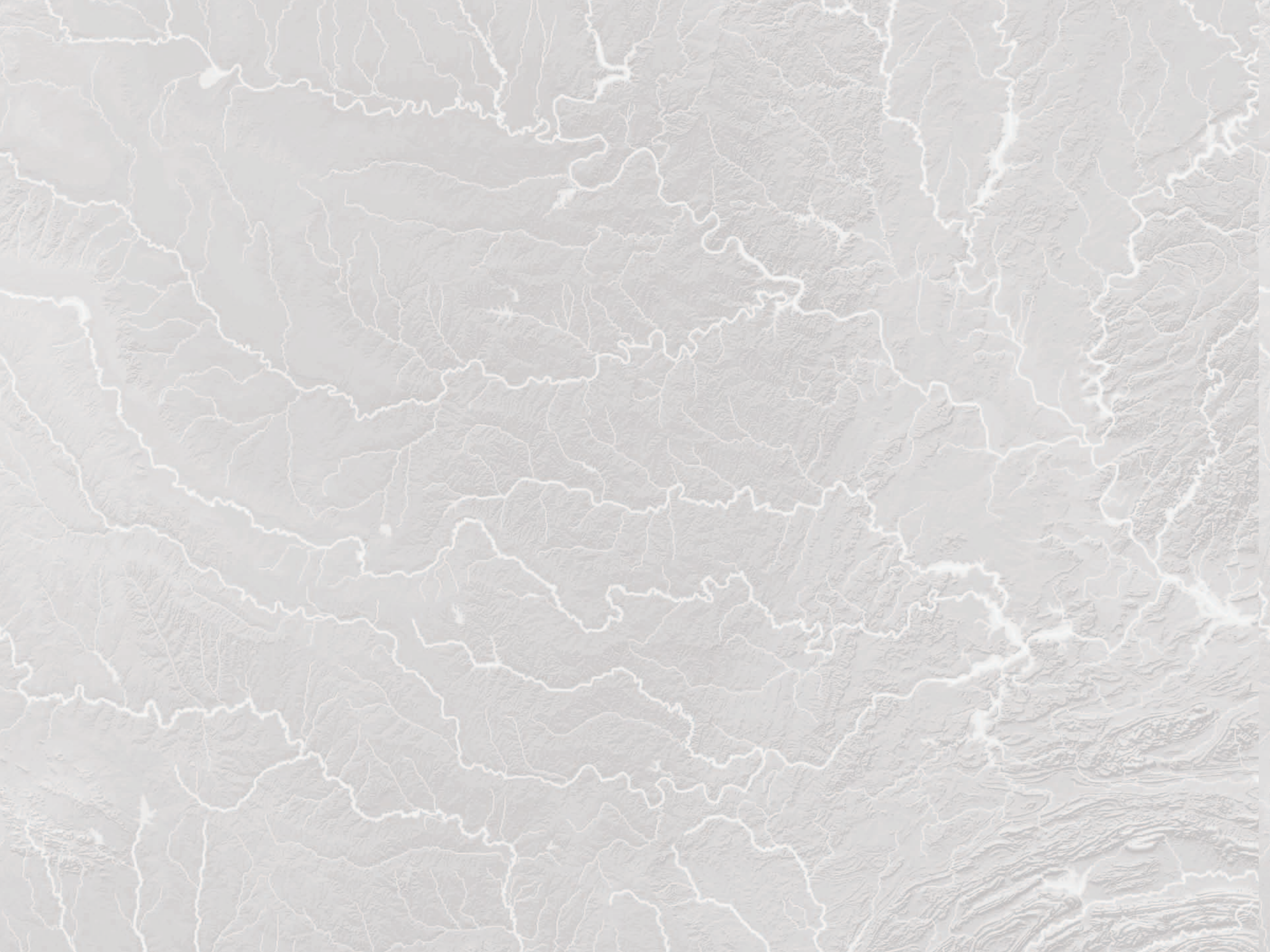
1 WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water

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

Expanded Water Supply Options

Panhandle Region



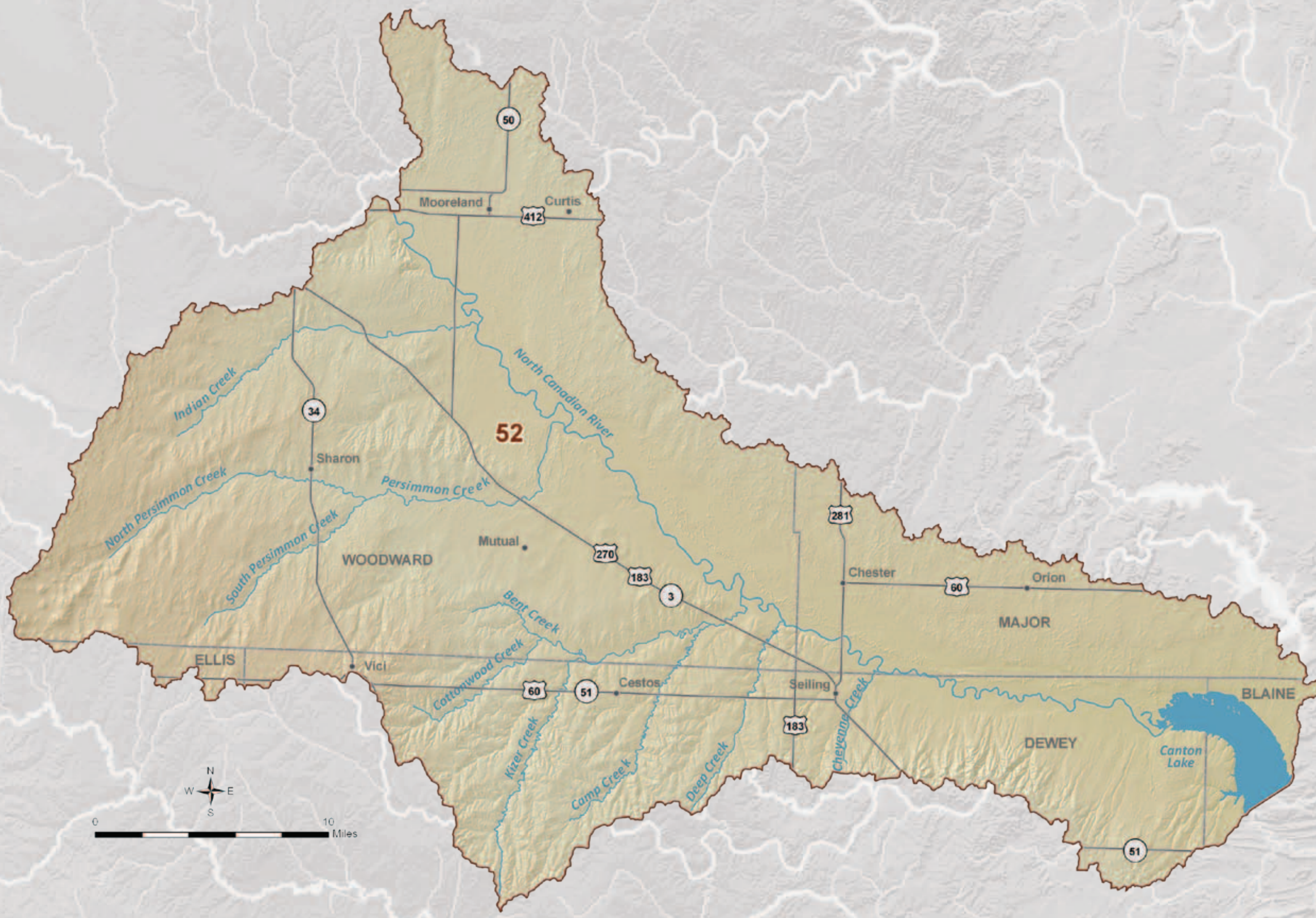


Oklahoma Comprehensive Water Plan

Data & Analysis

Panhandle Watershed Planning Region

Basin 52



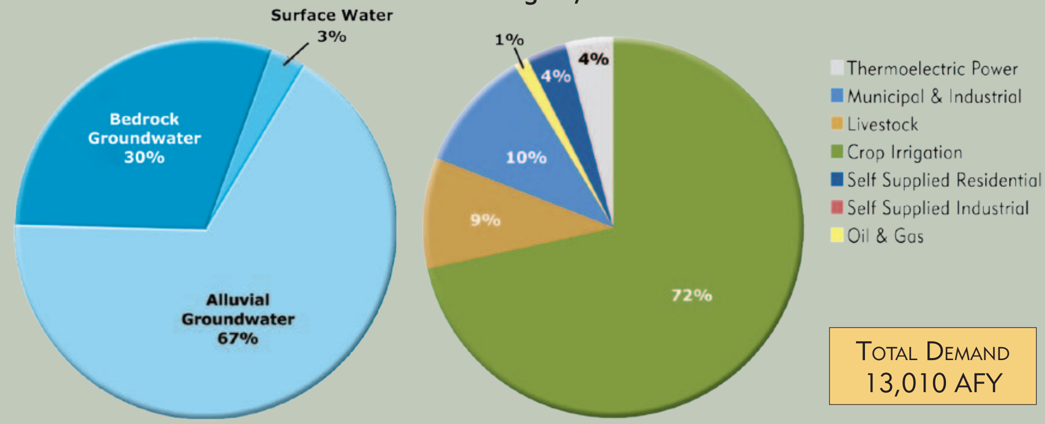
Basin 52 Summary

Synopsis

- Most water users are expected to continue to rely primarily on the basin's alluvial and bedrock aquifers.
- By 2020, alluvial and bedrock groundwater use is expected to exceed recharge rates and thus draw from aquifer storage.
- There is a high probability that periodic surface water gaps will occur by 2050.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation or new small reservoirs could reduce the adverse effects of localized groundwater storage depletions.
- Alternatives to direct surface water diversions, such as groundwater supplies and/or developing new small reservoirs, could eliminate gaps.

Current Demand by Source and Sector

Panhandle Region, Basin 52



Basin 52 accounts for about 3% of the current water demand in the Panhandle Watershed Planning Region. About 72% of the demand is from the Crop Irrigation demand sector. The second largest demand sector is Municipal and Industrial at 10%, which includes a number of small municipal providers and rural water districts. Surface water satisfies only about 3% of the total demand in the basin. Groundwater satisfies about 97% of the demand (67% alluvial and 30% bedrock). The peak summer month demand in Basin 52 is 9.9 times the winter demand, which is more pronounced than the overall statewide pattern.

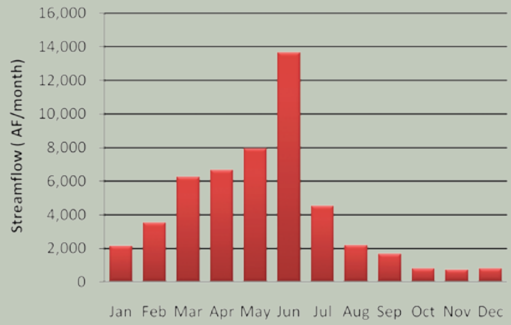
The entire water supply yield of Canton Lake, which is located at the basin outlet, is fully allocated to Oklahoma City (Basin 50) and is not expected to provide additional supplies in Basin 52. Historically, the North Canadian River at Canton has undergone frequent periods of very low flows in each month of the year. Relative to other basins in the state, surface water quality in Basin 52 is considered good. However, Bent Creek, a tributary to the North Canadian River, is impaired for Agricultural use due to high levels of sulfate. The North Canadian stream system is currently fully allocated and has no permit availability.

The majority of current delineated groundwater rights are in the Ogallala, North Canadian River, and non-delineated bedrock aquifers. Each of these aquifers has approximately 1.8 million acre-feet of water stored within the basin. There are no significant basin-wide groundwater quality issues. Localized areas with high levels of nitrate have been found in the overall boundaries of the Ogallala and North Canadian River aquifers and may occur in Basin 52. 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 14,290 AFY in Basin 52 reflects a 1,280 AFY increase (10%) over 2010

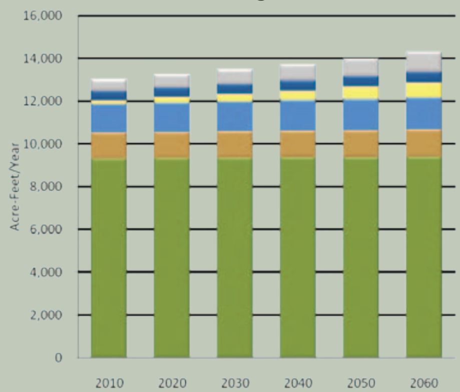
Median Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 52



Projected Water Demand

Panhandle Region, Basin 52



demand. The Crop Irrigation demand sector will be the largest demand sector in the basin; however, minimal growth is expected. The largest growth in demand will occur from two currently minor demand sectors: Oil and Gas and Thermoelectric Power.

Gaps & Depletions

Based on projected demand and historical hydrology, groundwater storage depletions are expected to occur as early as 2020, and surface water gaps are expected by 2050. By 2060, surface water gaps have a 76% probability of occurring in at least one month during the year and will total as much as 70 AFY. Alluvial storage depletions will occur in almost every year in amounts up to 890 AFY. By 2060, bedrock storage depletions are expected to increase to 170 AFY. Alluvial and bedrock groundwater storage depletions are minimal compared to the total groundwater storage in the basin and should not constrain use over the planning horizon. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

Options

Most water users are expected to continue to rely heavily on groundwater supplies. To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. The basin should focus on permanent conservation activities, instead of temporary drought management activities, since gaps and storage depletions will occur in almost every year.

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning Region. However, out-of-basin supplies may not be cost-effective for all users based on the availability of groundwater resources and distance to reliable surface water supplies.

New reservoir storage could potentially mitigate surface water gaps in the basin. However, as the stream system is currently fully allocated, substantial permit issues would have to be resolved in order to construct new reservoir storage, and any new reservoirs could not impact Canton Lake's yield.

Increased reliance on surface water through direct diversions, without reservoir storage, would increase gaps and is not recommended on a basin scale. Also, there is no additional surface water permit availability in the basin.

Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase the amount of groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water in aquifer storage in the basin.

Water Supply Limitations

Panhandle Region, Basin 52

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Panhandle Region, Basin 52

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

Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

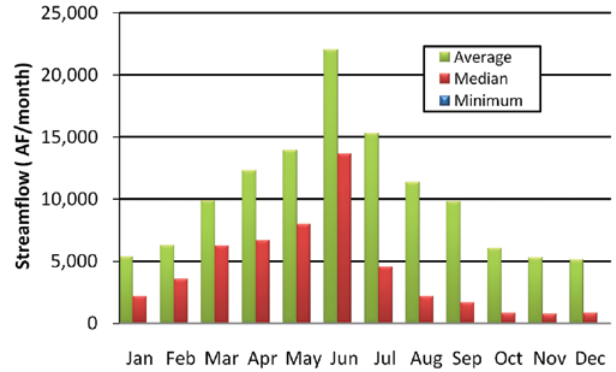
Basin 52 Data & Analysis

Surface Water Resources

- Basin 52 receives more precipitation than other basins in the Panhandle Region. However, the majority of the streamflow in the North Canadian River at Canton has historically been generated in upstream basins. Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The North Canadian River at Canton had prolonged periods of below-average streamflow from the early 1960s to the mid 1980s. From the mid 1990s to the early 2000s, the basin went through a prolonged period of above-average flow and precipitation, demonstrating the hydrologic variability in the basin.
- The portion of the North Canadian River in Basin 52 is considered perennial (flows throughout the year). The median monthly streamflow is greater than 750 AF/month in all months and greater than 2,000 AF/month in the spring and summer. However, the river can experience prolonged periods of low flow in any month of the year. Relative to other basins in the state, the surface water quality in Basin 52 is considered good.
- Streamflow at the basin outlet is regulated by Canton Lake, which provides 18,480 AFY of dependable yield to Oklahoma City. Canton is not expected to provide future supplies for Basin 52.

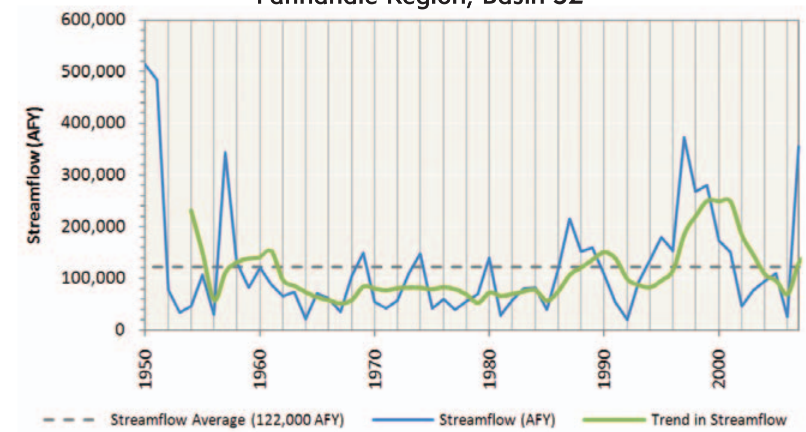
Monthly Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 52



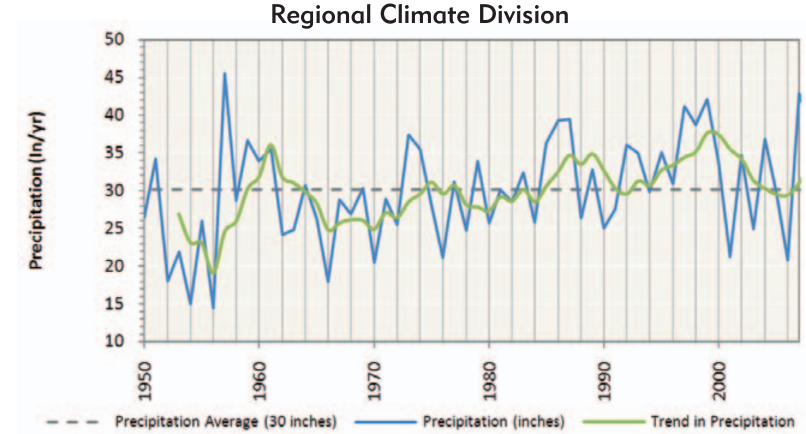
Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 52



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)

Panhandle Region, Basin 52

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Canadian River	Alluvial	Major	1%	0	12,000	temporary 2.0	12,800
North Canadian River	Alluvial	Major	36%	40,000	1,778,000	1.0	165,700
Ogallala	Bedrock	Major	24%	9,900	1,881,000	1.4	268,500
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	10,100	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of water rights in the basin are from the North Canadian River, Ogallala, and non-delineated aquifers. The North Canadian River aquifer is located along the northern border of the basin and has approximately 1.8 million acre-feet of in-basin storage. The Ogallala aquifer is located in the southwestern portion of the basin and has approximately 1.9 million acre-feet of in-basin storage. Estimated Ogallala aquifer recharge in the basin is 3,000 AFY. The water rights from non-delineated bedrock aquifers are in roughly the central and southeastern portions of the basin.
- There are no significant groundwater quality issues in Basin 52.

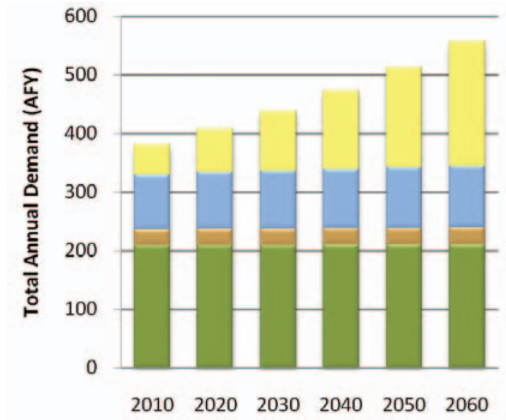
Notes & Assumptions

- 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.

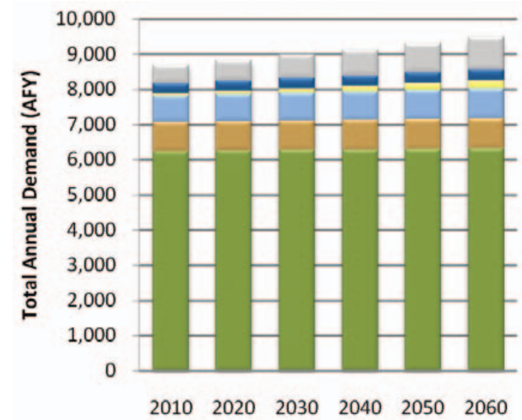
Water Demand

- Basin 52's water demand is about 3% of the Panhandle Region's total demand and will increase by 10% (1,280 AFY) from 2010 to 2060. The Crop Irrigation demand sector will be the largest demand sector over the next 50 years; however minimal growth is expected. The majority of growth in demand will occur from two currently minor demand sectors: Oil and Gas and Thermoelectric Power.
- Surface water is used to supply 3% of the total demand in Basin 52 and its use will increase by 46% (180 AFY) from 2010 to 2060. Oil and Gas surface water use is expected to be as large as Crop Irrigation surface water use by 2060.
- Alluvial groundwater is used to supply 67% of the total demand in Basin 52 and will increase by 9% (790 AFY) from 2010 to 2060. The Thermoelectric Power demand sector will account for approximately 50% of the growth in alluvial groundwater use.
- Bedrock groundwater is used to supply 30% of the total demand in Basin 52 and will increase by 8% (310 AFY) from 2010 to 2060.

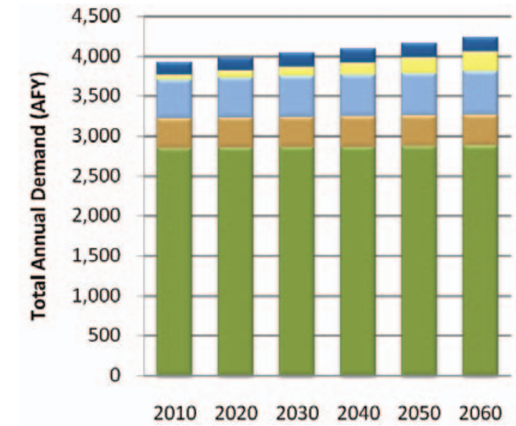
Surface Water Demand by Sector
Panhandle Region, Basin 52



Alluvial Groundwater Demand by Sector
Panhandle Region, Basin 52



Bedrock Groundwater Demand by Sector
Panhandle Region, Basin 52



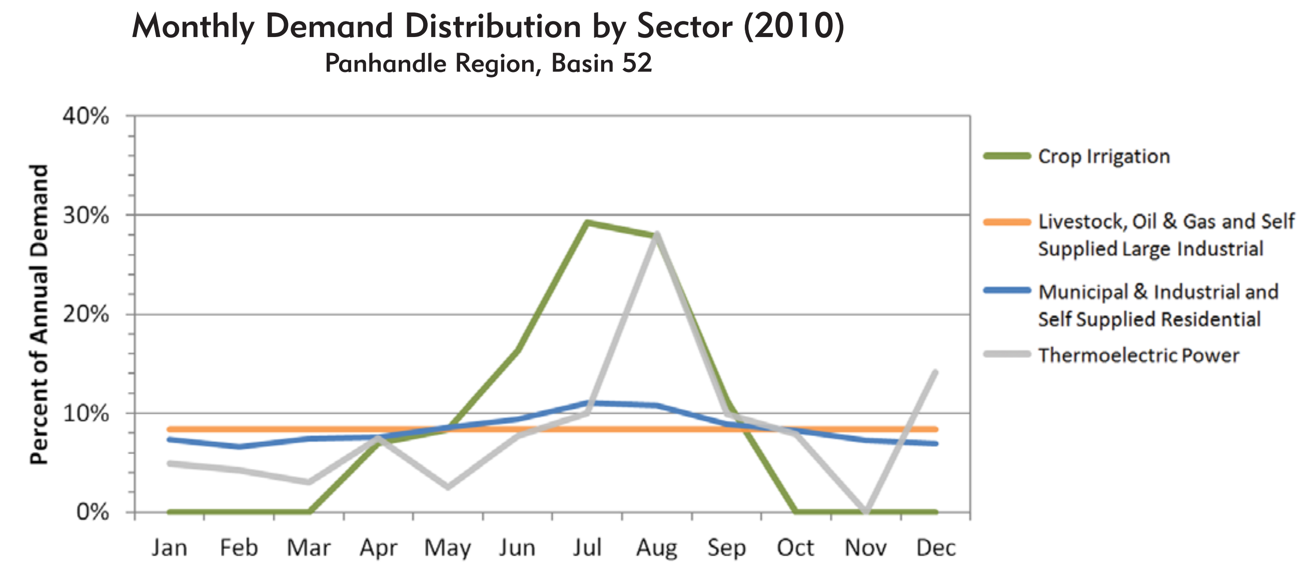
Thermoelectric Power | Self Supplied Residential | Self Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

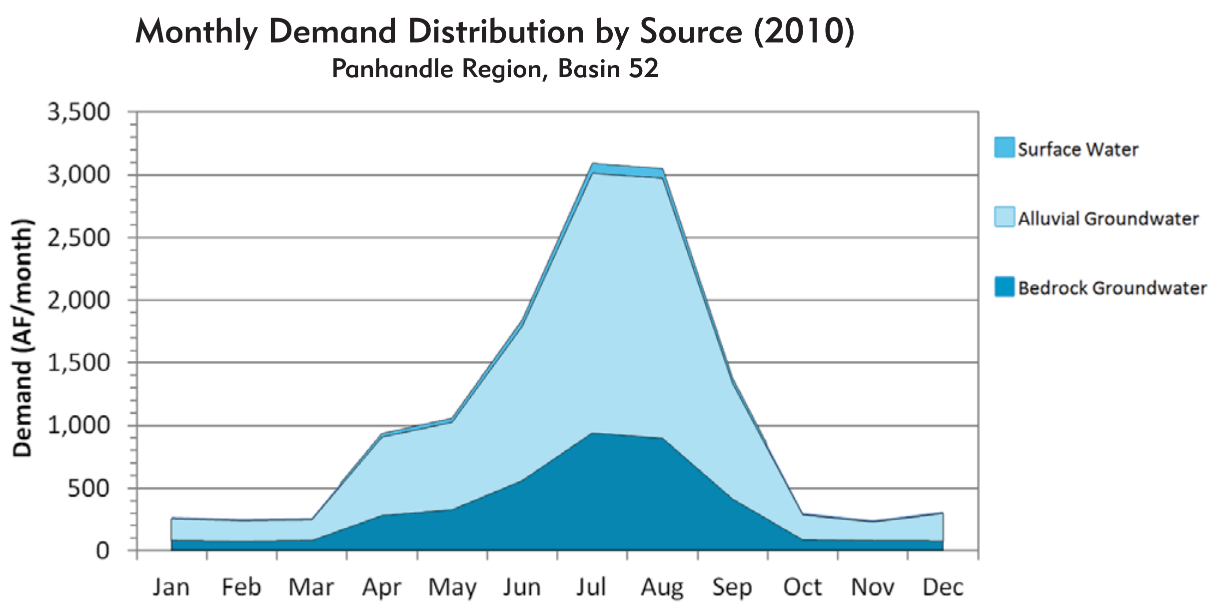
Total Demand by Sector
Panhandle Region, Basin 52

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	9,310	1,220	1,340	170	0	440	530	13,010
2020	9,330	1,230	1,380	240	0	450	590	13,220
2030	9,350	1,240	1,420	330	0	470	660	13,470
2040	9,370	1,250	1,440	440	0	470	740	13,710
2050	9,380	1,260	1,470	560	0	480	820	13,970
2060	9,410	1,270	1,500	700	0	490	920	14,290

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. The Livestock and Oil and Gas demand sectors have more consistent demand throughout the year. Thermoelectric Power water use peaks in August and is near zero in November.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 52 is 9.9 times the monthly winter demand, which is more pronounced than the overall statewide pattern. The peak summer month surface water demand is 5.8 times the monthly winter demand. The peak summer month alluvial and bedrock groundwater demands are 9.4 and 11.4 times, respectively, the monthly winter demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, groundwater storage depletions are projected to occur by 2020 and surface water gaps by 2050.
- Surface water gaps in Basin 52 may occur throughout the year. Surface water gaps in 2060 will be up to 11% (10 AF/month) of the surface water demand in the peak summer month, and as much as 33% (10 AF/month) of the peak winter month's surface water demand. By 2060, there will be a 76% probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during winter months.
- Alluvial groundwater storage depletions in Basin 52 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 8% (170 AF/month) of the alluvial groundwater demand in the peak summer month. Storage depletions are smaller in size during the winter, but will be as much as 30% (90 AF/month) of the peak winter months' alluvial groundwater demand. There will be a 93% probability of storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are least likely to occur in spring months.
- Bedrock groundwater storage depletions in Basin 52 may occur during the spring, summer, and fall. Bedrock groundwater storage depletions in 2060 will be 5% (30 AF/month) of the bedrock groundwater demand on average in the peak summer month's, and 8% (30 AF/month) on average of the peak spring month's bedrock groundwater demand.
- Projected groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely impact water well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Panhandle Region, Basin 52

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	60%
Mar-May (Spring)	10	10	31%
Jun-Aug (Summer)	10	10	34%
Sep-Nov (Fall)	10	10	38%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 52

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	90	50	66%
Mar-May (Spring)	70	50	48%
Jun-Aug (Summer)	170	100	60%
Sep-Nov (Fall)	80	70	59%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Panhandle Region, Basin 52

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	130	40	0%	93%
2030	0	320	60	0%	93%
2040	0	500	100	0%	93%
2050	30	680	140	57%	93%
2060	70	880	170	76%	93%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 52

Months (Season)	Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	30
Jun-Aug (Summer)	30
Sep-Nov (Fall)	30

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

Panhandle Region, Basin 52

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	70	890	170	76%	93%
Moderately Expanded Conservation in Crop Irrigation Water Use	60	590	30	71%	93%
Moderately Expanded Conservation in M&I Water Use	60	770	140	74%	93%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	50	480	20	69%	91%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	40	300	0	69%	78%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Panhandle Region, Basin 52

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

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce bedrock storage depletions by 88% and alluvial groundwater depletions by 46%. It is recommended that water users in the basin consider additional permanent conservation activities, instead of temporary drought management activities, since gaps and storage depletions will occur in almost every year.

Out-of-Basin Supplies

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning Region: Englewood and Forgan, both in Basin 65. However, due to the available groundwater resources in Basin 52, the distance to reliable surface water supplies, and the geographically dispersed nature of the Crop Irrigation sector, out-of-basin supplies may be less cost-effective than increased use of in-basin supplies.

Reservoir Use

Reservoir storage could mitigate surface water gaps and groundwater storage depletions. The flow in Basin 52 has been fully permitted and the yield of Canton Lake must be protected, which is expected to severely limit the size and location of new reservoirs. However, if legally feasible, a river diversion and 1,600 AF of reservoir storage at the basin outlet could provide dependable water supplies to all new users in the basin through 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps.

Increasing Reliance on Surface Water

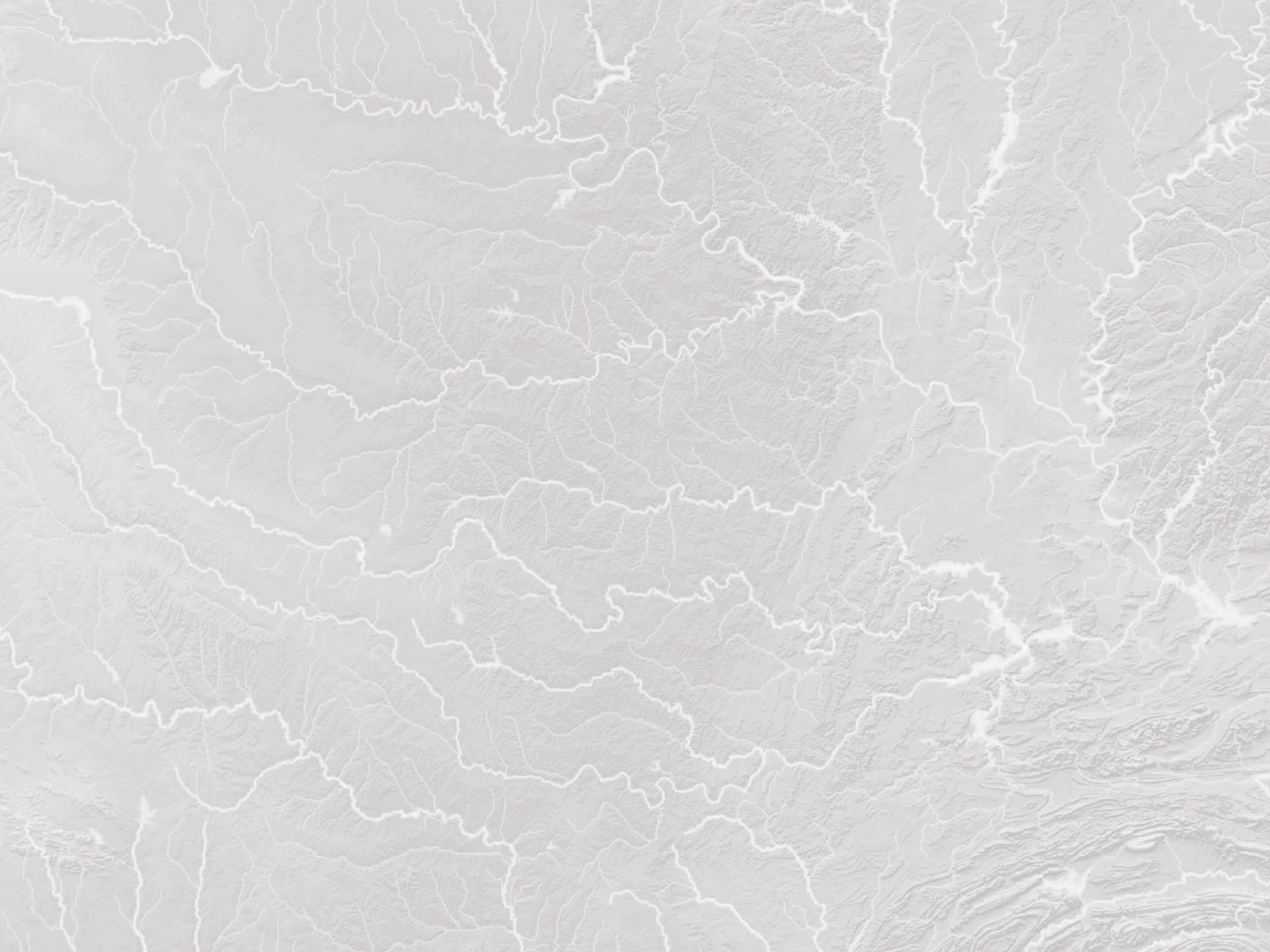
Increased reliance on surface water through direct diversions, without reservoir storage, would increase surface water gaps in the basin and is not recommended. There is also no additional surface water permit availability in the basin.

Increasing Reliance on Groundwater

Increased reliance on alluvial or bedrock groundwater use could mitigate surface water gaps, but groundwater storage depletions will be increased. Any increases in storage depletions would be minimal relative to the volume of water in major alluvial or major bedrock aquifer storage in the basin.

Notes & Assumptions

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



Data & Analysis

Panhandle Watershed Planning Region

Basin 53

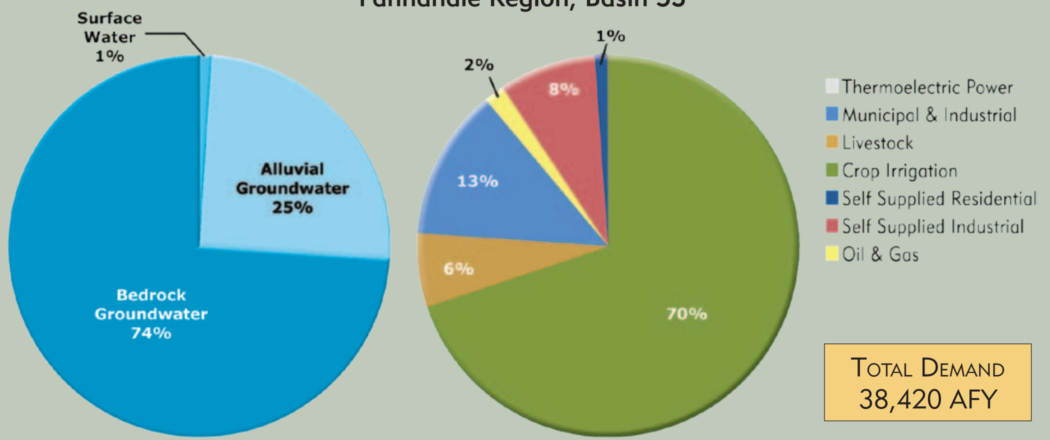
Basin 53 Summary

Synopsis

- Most water users are expected to continue to rely primarily on the basin's alluvial and bedrock aquifers.
- By 2030, surface water gaps may have a moderate probability of occurring during months with low streamflow conditions.
- Water quality is a potential concern for surface water users.
- By 2020, alluvial and bedrock groundwater use is expected to exceed recharge rates and thus draw from aquifer storage.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation could reduce surface water gaps and the adverse effects of localized storage depletions.
- Alternatives to direct surface water diversions, such as additional groundwater supplies and/or developing additional small reservoir storage, could eliminate gaps.

Current Demand by Source and Sector

Panhandle Region, Basin 53



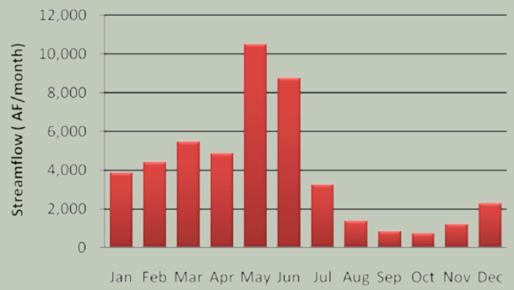
Basin 53 accounts for about 10% of the water demand in the Panhandle Watershed Planning Region. About 70% of the current demand is from the Crop Irrigation demand sector. The second largest demand sector is Municipal and Industrial at 13%, which includes public water supply for the City of Woodward. Surface water satisfies only about 1% of the total demand in the basin. Groundwater satisfies about 99% of the total demand (25% alluvial and 74% bedrock). The peak summer month demand in Basin 53 is 10.2 times the winter demand, which is more pronounced than the overall statewide pattern.

There are no major reservoirs in Basin 53. Historically, the North Canadian River at Woodward has undergone frequent periods of very low flows in each month of the year. Relative to other basins in the state, surface water quality in Basin 53 is generally poor, but individual lakes and streams may have acceptable water quality. The North Canadian River (which is named the Beaver River above its confluence with Wolf Creek near Ft. Supply Lake) is impaired for Agricultural supply use above Kiowa Creek due to high levels of total dissolved solids (TDS) and chloride, raising potential water quality

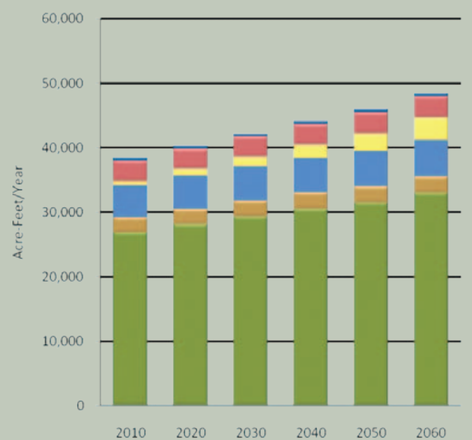
Water Resources

Panhandle Region, Basin 53

Median Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 53



Projected Water Demand
Panhandle Region, Basin 53



concerns. The North Canadian stream system is currently fully allocated and has no permit availability.

The majority of current groundwater rights are from the Ogallala and North Canadian River aquifers. The North Canadian River aquifer has approximately 1.7 million acre-feet in storage and the Ogallala aquifer has approximately 14 million acre-feet in storage in Basin 53. While there are no significant basin-wide groundwater quality issues, localized areas with high levels of nitrate have been found within the extent of the Ogallala in Oklahoma and may occur in Basin 53.The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The expected 2060 water demand of 48,340 AFY in Basin 53 reflects a 9,920 AFY increase (26%) over 2010 demand. The majority of the demand over this period will be in the Crop Irrigation and Municipal and Industrial demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, groundwater storage depletions are projected to occur by 2020 and surface water gaps may occur by 2030. By 2060, surface water gaps have a 53% probability of occurring in at least one month during the year and will total as much as 170 AFY. By 2060, bedrock storage depletions will increase to 7,070 AFY and alluvial groundwater depletions will be up to 2,110 AFY, with about a 59% probability of alluvial storage depletions occurring in at least one month during the year. Alluvial and bedrock groundwater storage depletions are minimal relative to aquifer storage volumes in Basin 53. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

Options

Most water users are expected to continue to rely on groundwater supplies. To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Water users in the basin should focus on permanent conservation activities, instead of temporary drought management activities, since gaps and storage depletions have a high probability of occurring each year.

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning

Water Supply Limitations
Panhandle Region, Basin 53

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Panhandle Region, Basin 53

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

Region. However, out-of-basin supplies may not be cost-effective for all users based on the availability of groundwater resources and distance to reliable surface water supplies.

New reservoir storage could potentially mitigate surface water gaps in the basin. However, as the stream system is currently fully allocated, substantial permit issues would have to be resolved in order to construct new reservoir storage.

Increased reliance on surface water through direct diversions, without reservoir storage, would increase gaps and is not recommended on a basin scale. Also, there is no additional surface water permit availability in the basin.

Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase the amount of groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of aquifer water storage in the basin.

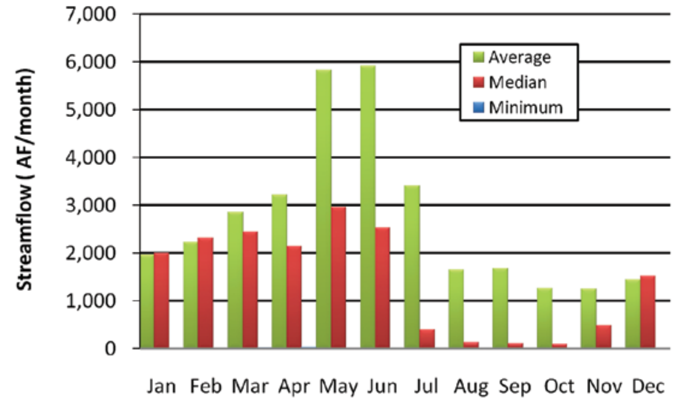
Basin 53 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The North Canadian River at Woodward has had multiple periods of below-average streamflows, most recently during the 2000s. In the mid to late 1980s, the basin went through periods of above-average flow and precipitation, demonstrating the hydrologic variability in the basin.
- The median streamflow in the North Canadian River at Woodward is greater than 2,000 AF/month, except during August and the fall when the median flow is as low as 750 AF/month. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, surface water quality in Basin 53 is generally poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in the basin.

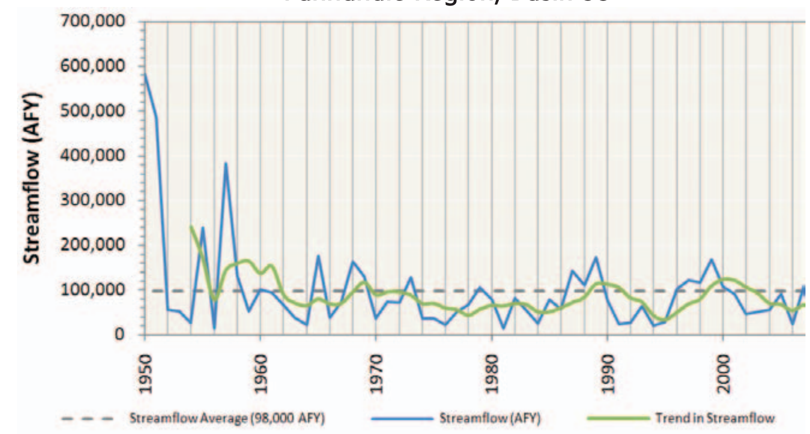
Monthly Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 53



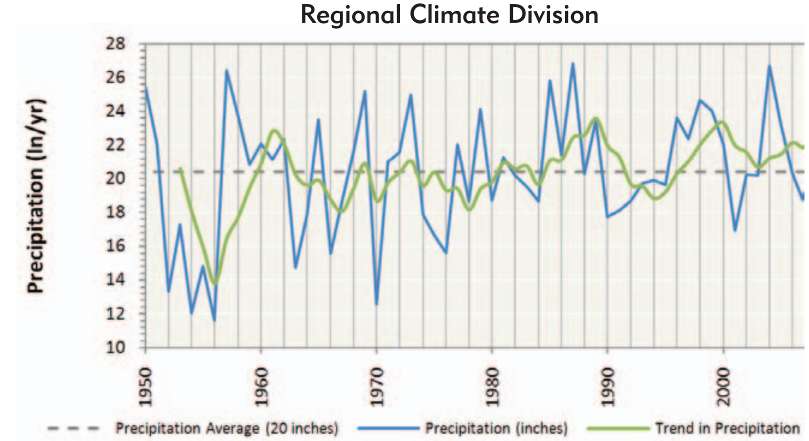
Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 53



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)

Panhandle Region, Basin 53

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
North Canadian River	Alluvial	Major	20%	42,000	1,669,000	1.0	153,300
Ogallala	Bedrock	Major	70%	162,400	14,072,000	1.4 to 2.0	1,166,300
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	5,800	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	7,900	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 53 are from the Ogallala aquifer. The Ogallala aquifer underlies the western portion of the basin and has more than 14 million acre-feet of in-basin storage. There are substantial water rights from the North Canadian River aquifer, which has more than 1.6 million acre-feet of storage in the Basin 53 portion of the aquifer. There are additional groundwater rights in non-delineated groundwater sources in Basin 53. Estimated Ogallala aquifer recharge in the basin is 8,000 AFY.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

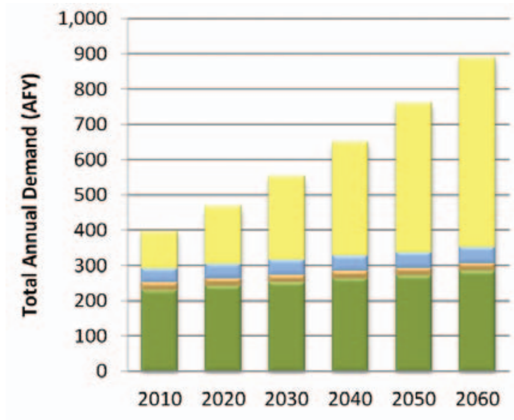
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- Basin 53's water needs make up about 10% of the demand in the Panhandle Region and will increase by 26% (9,920 AF) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.
- Surface water is used to meet 1% of total demand in the basin and its use will increase by 124% (490 AFY) from 2010 to 2060. The Oil and Gas surface water use will surpass Crop Irrigation surface water use by 2040 and become the largest surface water use.
- Alluvial groundwater is used to meet 25% of total demand in the basin. Alluvial groundwater use will increase by 20% (1,950 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 74% of the total demand in the basin. Bedrock groundwater use will increase by 26% (7,480 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector.

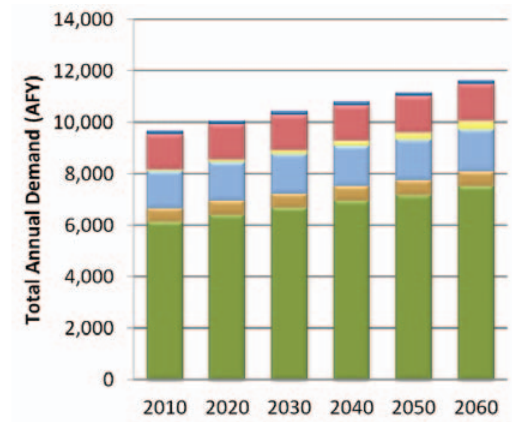
Surface Water Demand by Sector

Panhandle Region, Basin 53



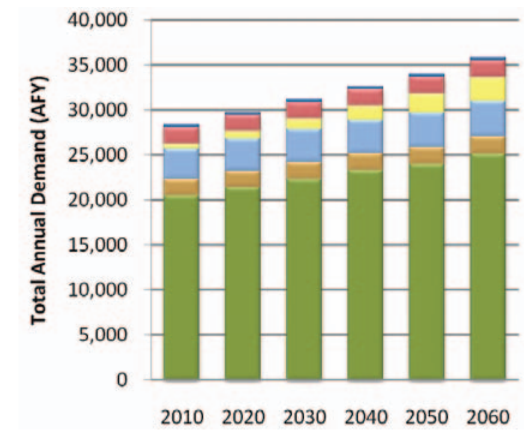
Alluvial Groundwater Demand by Sector

Panhandle Region, Basin 53



Bedrock Groundwater Demand by Sector

Panhandle Region, Basin 53



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

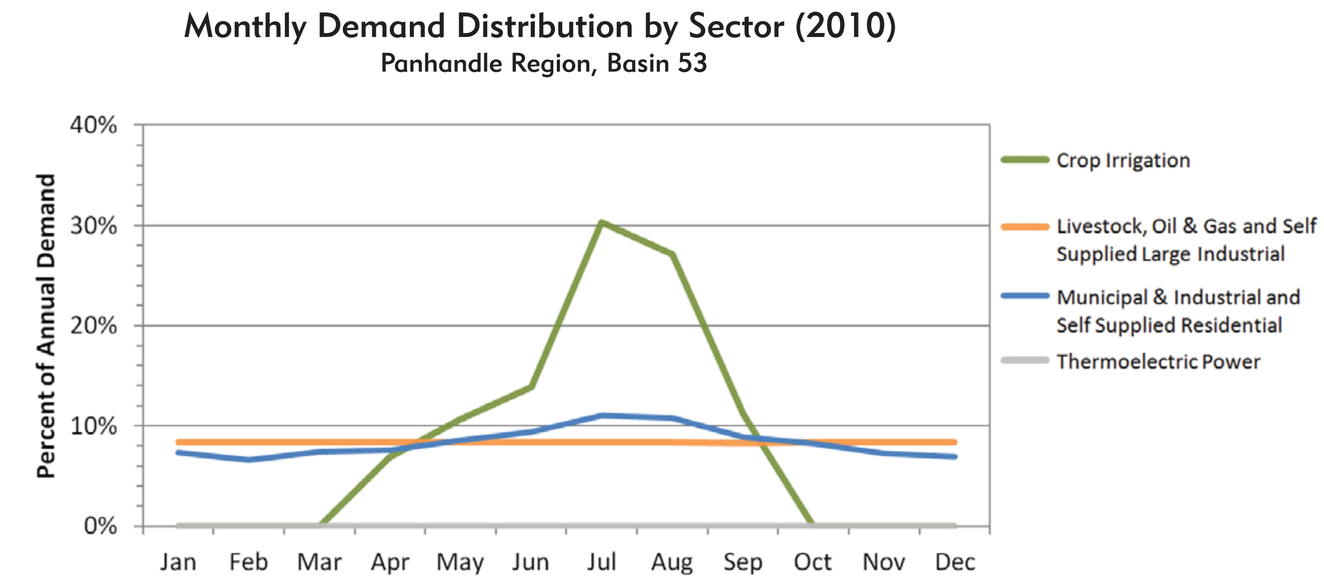
Total Demand by Sector

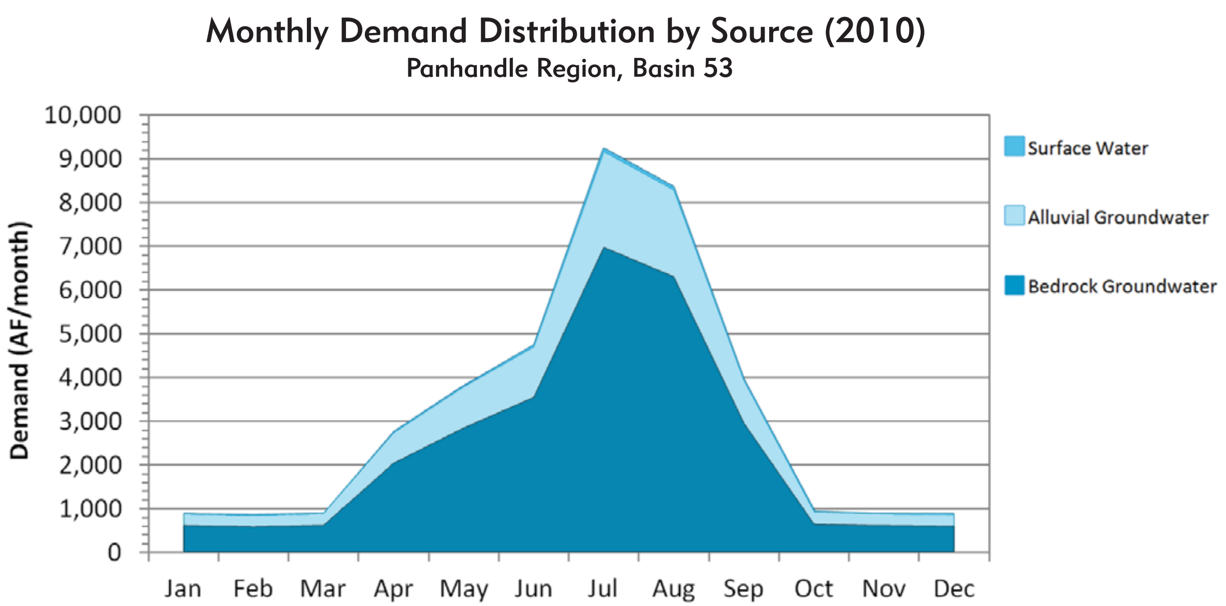
Panhandle Region, Basin 53

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	26,850	2,380	4,920	690	3,160	420	0	38,420
2020	28,080	2,410	5,140	1,070	3,160	420	0	40,280
2030	29,300	2,440	5,270	1,550	3,160	430	0	42,150
2040	30,520	2,470	5,370	2,120	3,170	430	0	44,080
2050	31,460	2,500	5,490	2,780	3,240	440	0	45,910
2060	32,960	2,530	5,580	3,530	3,300	440	0	48,340

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 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 total water demand in Basin 53 is 10.2 times the monthly winter demand, which is more pronounced than the overall statewide pattern. The peak summer month surface water demand is 6.3 times the monthly winter demand. The peak summer month alluvial and bedrock groundwater demands are about 7.9 and 11.3 times, respectively, the monthly winter demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, groundwater storage depletions are projected to occur by 2020 and surface water gaps by 2030.
- Surface water gaps in Basin 53 may occur throughout the year. Surface water gaps in 2060 will be up to 22% (20 AF/month) of the surface water demand in the peak summer month, and up to 20% (10 AF/month) of the peak winter month's surface water demand. By 2060, there will be a 53% probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during fall and summer months.
- Alluvial groundwater storage depletions in minor aquifers in Basin 53 may occur throughout the year; peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 17% (460 AF/month) of the alluvial groundwater demand in the peak summer month, and up to 22% (70 AF/month) of the peak winter month's alluvial groundwater demand. By 2060, there will be a 59% probability of storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during fall and summer months.
- Bedrock groundwater storage depletions in Basin 53 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 19% (1,660 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 19% (160 AF/month) on average of the peak winter month's bedrock groundwater demand. These storage depletions are in addition to any current storage depletions.
- Projected groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Panhandle Region, Basin 53

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	17%
Mar-May (Spring)	20	10	17%
Jun-Aug (Summer)	20	20	45%
Sep-Nov (Fall)	20	10	36%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 53

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	70	70	17%
Mar-May (Spring)	210	160	17%
Jun-Aug (Summer)	460	420	48%
Sep-Nov (Fall)	220	70	40%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Panhandle Region, Basin 53

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	360	1,190	0%	52%
2030	20	720	2,440	31%	52%
2040	50	1,160	3,870	50%	52%
2050	130	1,550	5,250	52%	53%
2060	170	2,110	7,070	53%	59%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 53

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	160
Mar-May (Spring)	730
Jun-Aug (Summer)	1,660
Sep-Nov (Fall)	760

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

Panhandle Region, Basin 53

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	170	2,110	7,070	53%	59%
Moderately Expanded Conservation in Crop Irrigation Water Use	140	1,750	5,740	52%	53%
Moderately Expanded Conservation in M&I Water Use	140	1,960	6,700	53%	55%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	130	1,590	5,390	52%	53%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	60	380	920	21%	50%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Panhandle Region, Basin 53

Reservoir Storage	Diversion
AF	AFY
100	100
500	400
1,000	800
2,500	1,900
5,000	3,700
Required Storage to Meet Growth in Demand (AF)	Detailed Analysis Required
Required Storage to Meet Growth in Surface Water Demand (AF)	600

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions by about 25%. Temporary drought management activities will likely be ineffective due to the high probability of gaps and storage depletions each year.

Out-of-Basin Supplies

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning Region: Englewood and Forgan, both in Basin 65. However, due to the available groundwater resources in Basin 53, distance to reliable surface water supplies, and the geographically dispersed nature of the Crop Irrigation sector, out-of-basin supplies may be less cost-effective than increased use of in-basin supplies.

Reservoir Use

Reservoir storage could mitigate surface water gaps. The flow in Basin 53 has been fully permitted, which is expected to severely limit the size and location of new reservoirs. However, if permittable, river diversion and 600 AF of reservoir storage at the basin outlet could provide dependable water supply for all new surface water demands in the basin from 2010 to 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps. A detailed analysis is needed to determine the feasibility of using reservoir storage to meet future groundwater demands.

Increasing Reliance on Surface Water

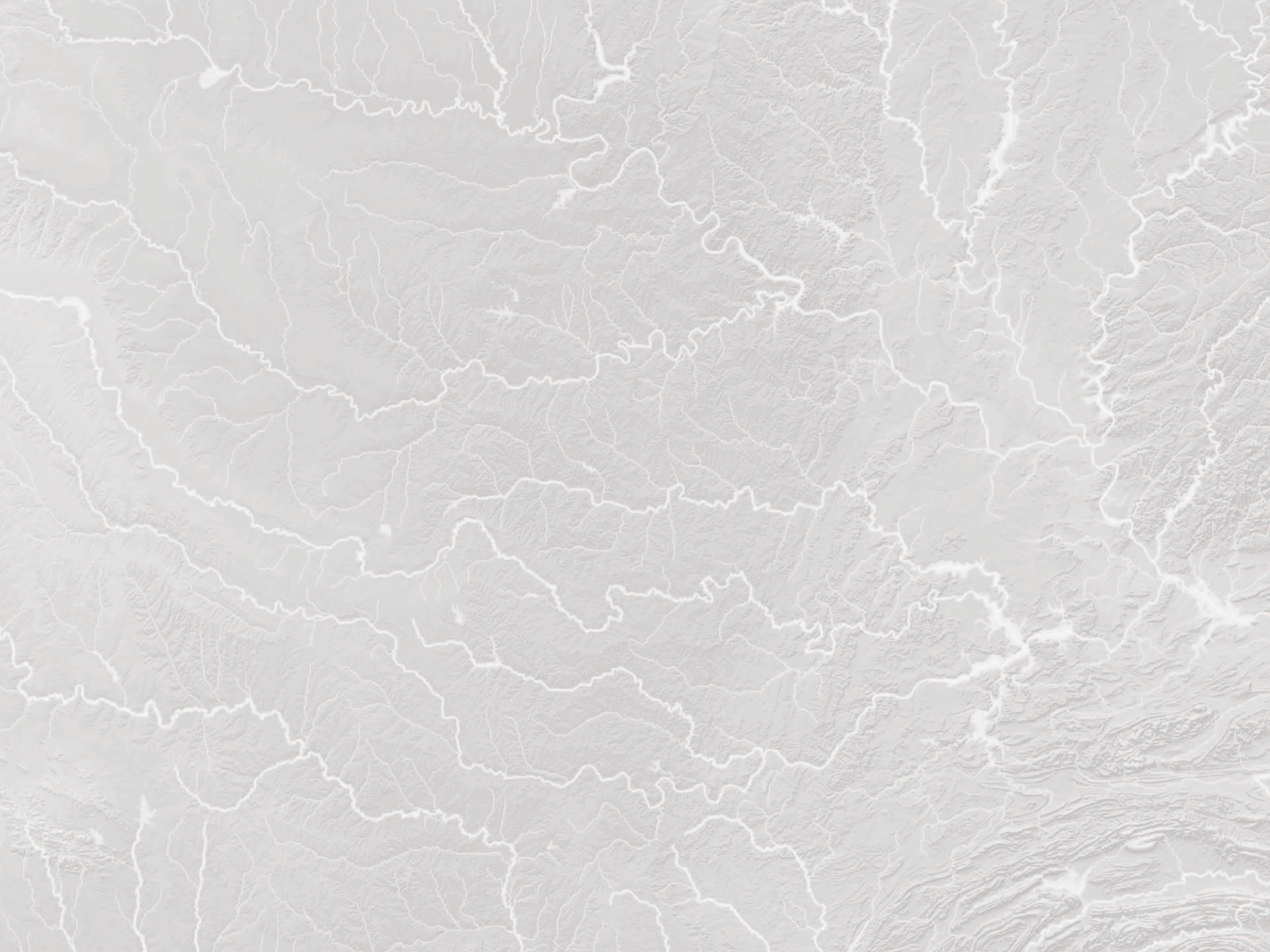
Increased reliance on surface water through direct diversions, without reservoir storage, would increase surface water gaps in the basin and is not recommended. Also, there is no additional surface water permit availability in the basin.

Increasing Reliance on Groundwater

Increased reliance on alluvial and bedrock groundwater supplies could mitigate surface water gaps, but will increase storage depletions. Any increases in storage depletions would be minimal relative to the storage in major aquifers in Basin 53; however, localized storage depletions may adversely affect groundwater users.

Notes & Assumptions

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



Data & Analysis

Panhandle Watershed Planning Region

Basin 54

Basin 54 Summary

Synopsis

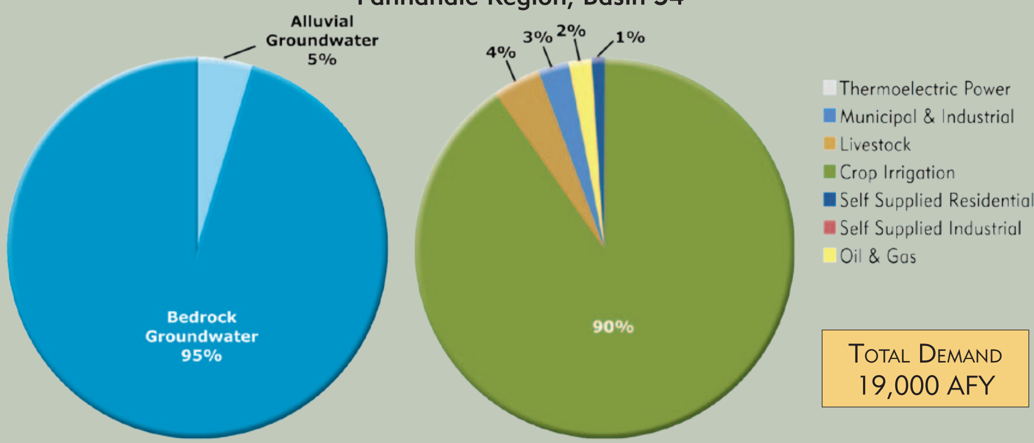
- Water users are expected to continue to rely primarily on the basin's alluvial and bedrock aquifers.
- By 2030, surface water gaps may occur during summer months with low streamflow conditions.
- Currently alluvial and bedrock groundwater use is exceeding recharge rates and thus draws from aquifer storage.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation could reduce surface water gaps and the adverse effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could eliminate gaps.
- Basin 54 has been identified as a water availability "hot spot" due to bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *OCWP Executive Report*.)

Basin 54 accounts for about 5% of the water demand in the Panhandle Watershed Planning Region. More than 90% of the current demand is from the Crop Irrigation demand sector. Surface satisfies less than 1% of the total demand in the basin. Groundwater satisfies almost 100% of the total demand (5% alluvial and 95% bedrock). The peak summer month demand in Basin 54 is 35 times the winter demand, which is much more pronounced than the overall statewide pattern.

Historically, Wolf Creek upstream of the North Canadian River has undergone frequent prolonged periods of very low flows in each month of the year. Relative to other basins statewide, the surface water quality in Basin

Current Demand by Source and Sector

Panhandle Region, Basin 54

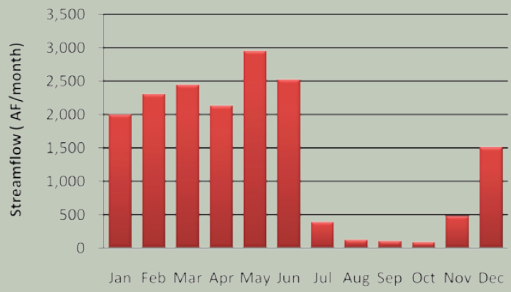


Water Resources

Panhandle Region, Basin 54

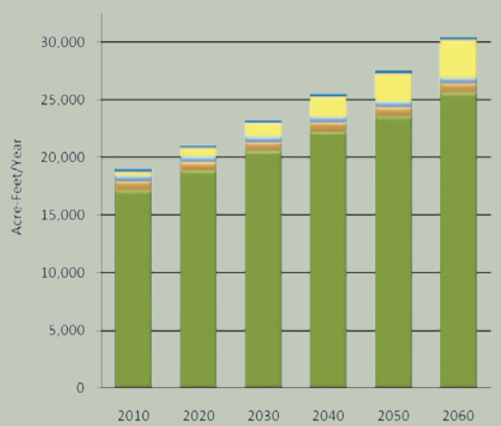
Median Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 54



Projected Water Demand

Panhandle Region, Basin 54



54 is considered fair. Fort Supply Lake is impaired for Public and Private water supply use due to high levels of chlorophyll-a. The North Canadian River is currently fully allocated and has no permit availability.

The Ogallala aquifer has approximately 6.1 million acre-feet of storage in the basin and underlies the vast majority of the basin. There are no significant basin-wide groundwater quality issues; however, localized areas with high levels of nitrate have been found within the extent of the Ogallala in Oklahoma and may occur in Basin 54. 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 30,400 AFY reflects an 11,400 AFY increase (60%) over 2010 demand. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.

Gaps & Depletions

Based on projected demand and historical hydrology, groundwater storage depletions are projected to occur by 2020, while surface water gaps are expected by 2030. By 2060, bedrock storage depletions are expected to be up to 9,260 AFY and alluvial groundwater depletions are expected to be up to 380 AFY, with a 74% probability of alluvial storage depletions occurring in at least one month during the year. These rates of depletions are small compared to the total groundwater storage in the basin. However, localized storage depletions may adversely impact users' yields, water quality, and pumping costs. Surface water gaps have over a 71% probability of occurring in at least one month during the year based on 2060 demand and are expected to be up to 160 AFY.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Water users in the basin should focus on permanent conservation activities, instead of temporary drought management activities, since gaps and storage depletions have a high probability of occurring each year.

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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

Water Supply Limitations

Panhandle Region, Basin 54

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Panhandle Region, Basin 54

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

Typically Effective Potentially Effective

Likely Ineffective No Option Necessary

the Panhandle Watershed Planning Region. However, out-of-basin supplies may not be cost-effective for all users based on the availability of groundwater resources and distance to reliable surface water supplies.

New reservoir storage could potentially mitigate surface water gaps in the basin. However, as the stream system is currently fully allocated, substantial permit issues would have to be resolved in order to construct new reservoir storage.

Increased reliance on surface water supplies, without reservoir storage, would only reduce a portion of groundwater storage depletions and would increase surface water gaps. Also, there is no additional surface water permit availability in the basin. Therefore, this water supply option is not recommended.

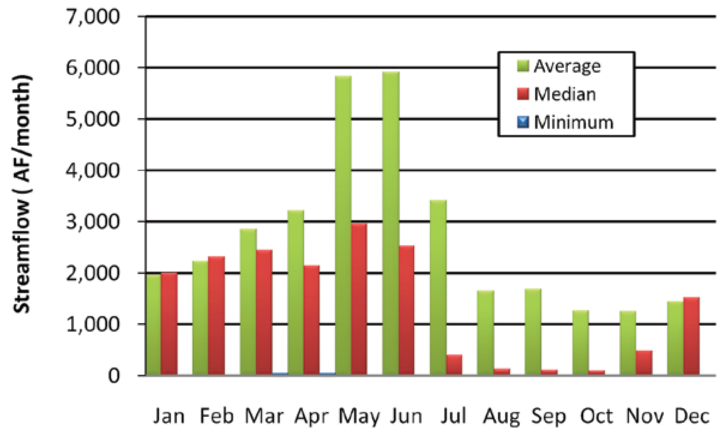
Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in major aquifers in the basin.

Basin 54 Data & Analysis

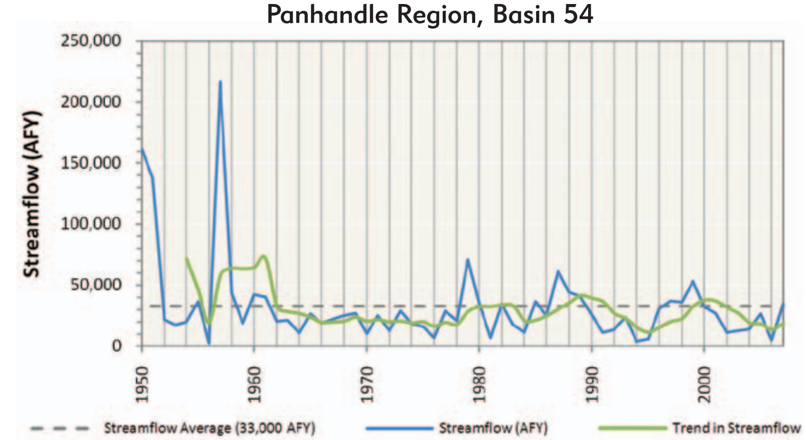
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Wolf Creek upstream of the North Canadian River had extremely large flows in the 1950s, which have not occurred since. From the mid 1960s to the late 1970s, the basin had a prolonged period of below-average streamflow. From the late 1990s to the early 2000s, the basin had a period of above-average flow and precipitation, demonstrating the hydrologic variability in the basin.
- The median flow in Wolf Creek upstream of the North Canadian River decreases from above 1,500 AF/month in the winter, spring, and early summer to less than 500 AF/month in the late summer and fall. However, the river can have prolonged periods of low flow in any month of the year. Relative to other basins statewide, the surface water quality in Basin 54 is considered fair.
- Fort Supply Lake is located at the basin outlet. The lake includes 400 AF of water supply storage yielding 224 AF/year. Fort Supply Lake is operated by the U.S. Corps of Engineers and may provide additional supplies in the future.

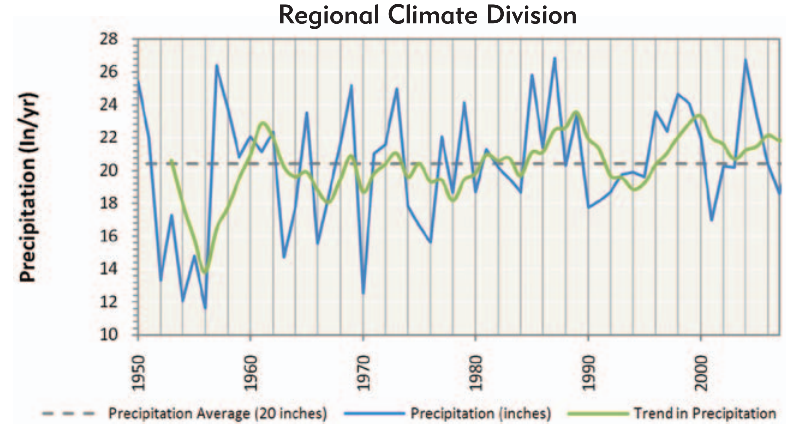
Monthly Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 54



Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 54



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)

Panhandle Region, Basin 54

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
North Canadian River	Alluvial	Major	5%	800	185,000	1.0	17,400
Ogallala	Bedrock	Major	93%	84,500	6,134,000	1.4	663,700
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	2,300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	100	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of water rights in the basin are from the Ogallala aquifer. The Ogallala aquifer has abundant storage and underlies the vast majority of the basin. There are water rights from the North Canadian River aquifer and non-delineated groundwater sources. Estimated in-basin recharge to the Ogallala aquifer is 10,000 AFY.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

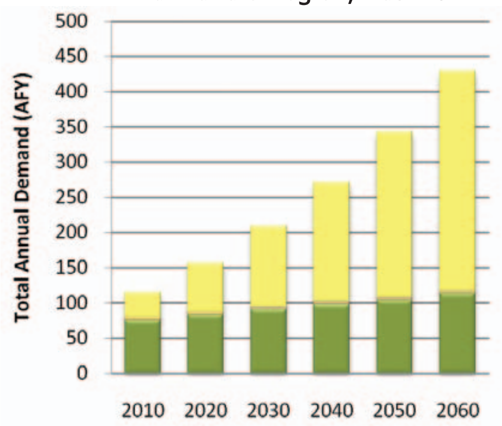
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

Water Demand

- Basin 54's demand is about 5% of the Panhandle Region's total demand and will increase by 60% (11,400 AF) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.
- Surface water is used to meet less than 1% of total demand in the basin and its use will increase by 320 AFY from 2010 to 2060. Oil and Gas surface water use will surpass Crop Irrigation surface water use by 2030 and become the largest surface water use.
- Alluvial groundwater is used to meet 5% of total demand in the basin and its use will increase by 43% (390 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 95% of total demand in the basin and its use will increase by 59% (10,690 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock use over this period will be in the Crop Irrigation demand sector.

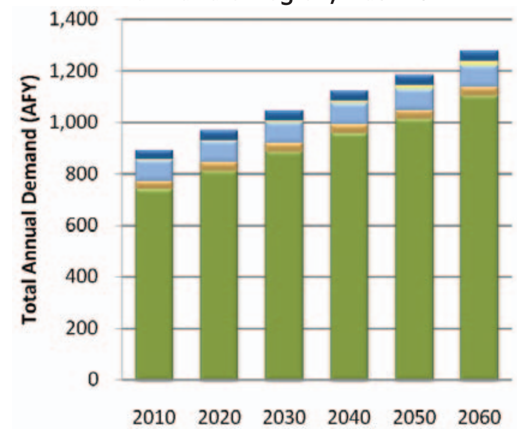
Surface Water Demand by Sector

Panhandle Region, Basin 54



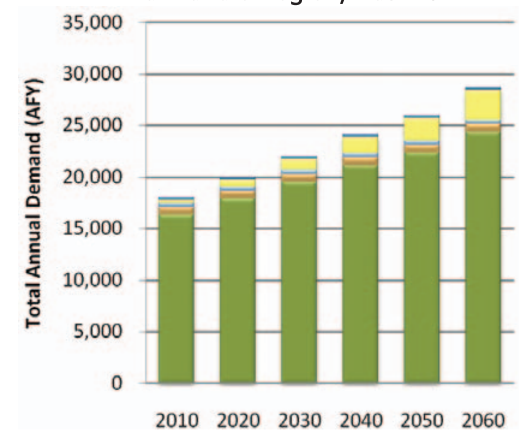
Alluvial Groundwater Demand by Sector

Panhandle Region, Basin 54



Bedrock Groundwater Demand by Sector

Panhandle Region, Basin 54



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

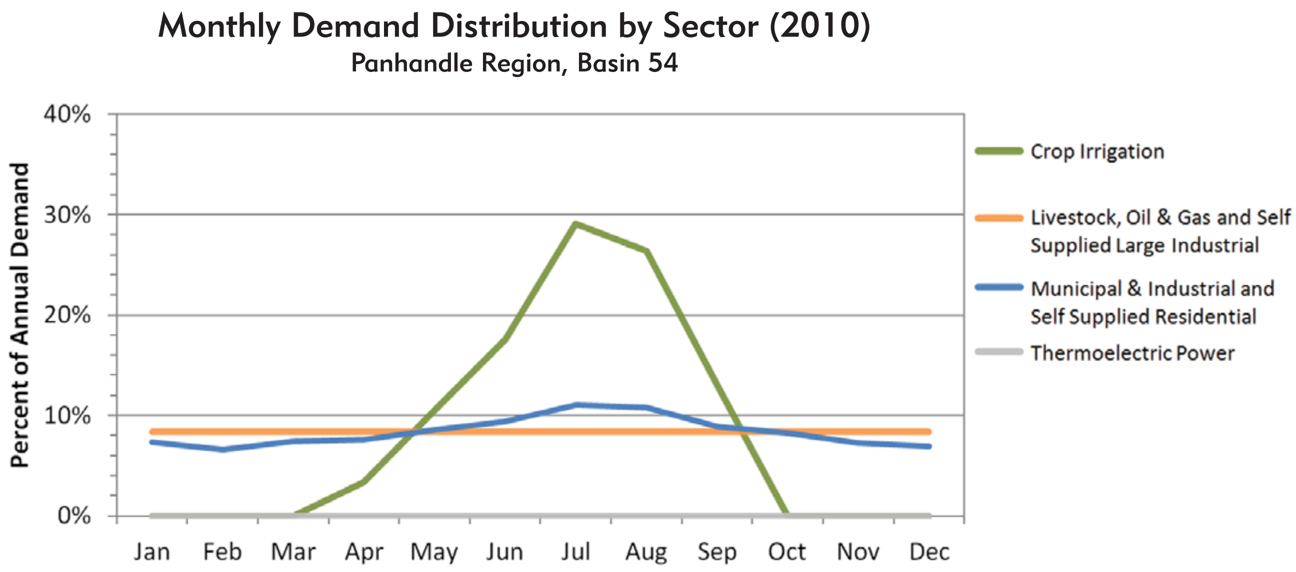
Total Demand by Sector

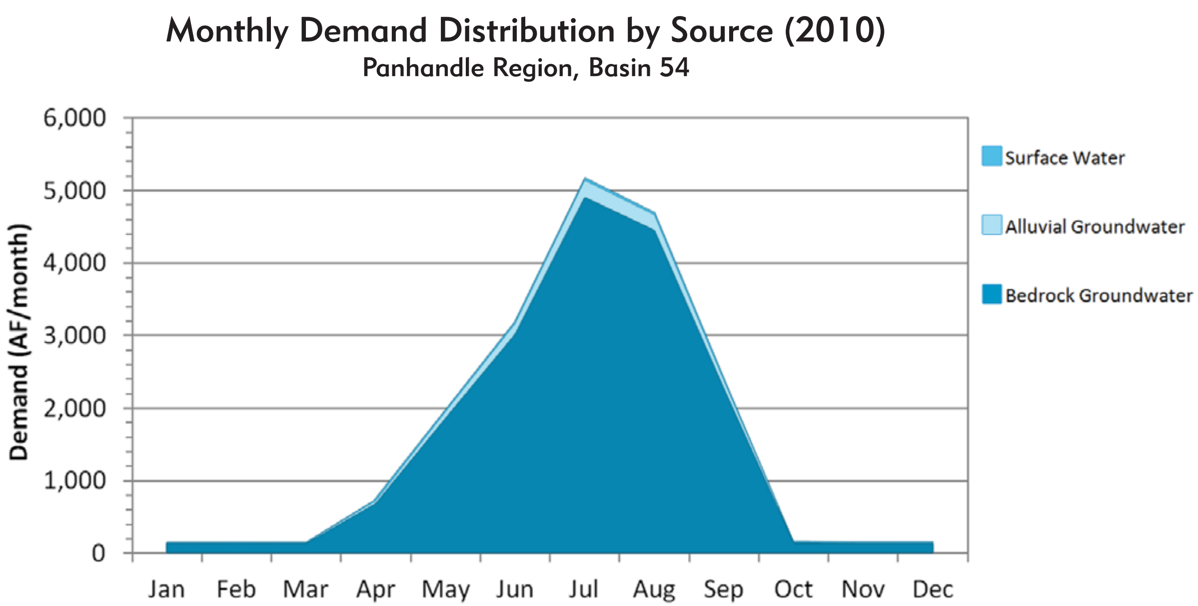
Panhandle Region, Basin 54

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	17,150	770	490	380	0	210	0	19,000
2020	18,840	780	490	730	0	220	0	21,060
2030	20,530	780	500	1,200	0	220	0	23,230
2040	22,230	790	500	1,780	0	220	0	25,520
2050	23,520	790	500	2,460	0	230	0	27,500
2060	25,610	800	500	3,260	0	230	0	30,400

Notes & Assumptions

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





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 total water demand in Basin 54 is 35 times the monthly winter demand, which is much more pronounced than the overall statewide pattern. The peak summer month surface water demand is 7.6 times the monthly winter demand. The peak summer month alluvial and bedrock groundwater demands are 20.2 and 37 times, respectively, the monthly winter demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, groundwater storage depletions are projected to occur by 2020, while surface water gaps are expected by 2030.
- Surface water gaps in Basin 54 may occur throughout the year. Surface water gaps in 2060 will be up to 40% (20 AF/month) of the surface water demand in the peak summer month, and 67% (20 AF/month) of the peak winter month's surface water demand. By 2060, there will be a 71% probability of 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 54 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 32% (110 AF/month) of the alluvial groundwater demand in the peak summer month, and up to 100% (10 AF/month) of the peak winter month's alluvial groundwater demand. By 2060, there will be a 74% probability of 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.
- Bedrock groundwater storage depletions in Basin 54 may occur in spring, summer, and fall, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 37% (1,070 AF/month) of the bedrock groundwater demand on average in the peak spring month and 34% (2,570 AF/month) on average of the peak summer month's demand.
- Projected groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Panhandle Region, Basin 54

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	20	12%
Mar-May (Spring)	10	10	3%
Jun-Aug (Summer)	20	10	60%
Sep-Nov (Fall)	20	20	47%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 54

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	9%
Mar-May (Spring)	50	30	3%
Jun-Aug (Summer)	110	70	64%
Sep-Nov (Fall)	60	30	48%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Panhandle Region, Basin 54

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	1,710	0%	17%
2030	20	130	3,470	10%	47%
2040	80	240	5,370	45%	59%
2050	80	300	6,910	57%	69%
2060	160	380	9,260	71%	74%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 54

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	1,070
Jun-Aug (Summer)	2,570
Sep-Nov (Fall)	1,270

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

Panhandle Region, Basin 54

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	380	9,260	71%	74%
Moderately Expanded Conservation in Crop Irrigation Water Use	150	340	7,910	64%	71%
Moderately Expanded Conservation in M&I Water Use	160	380	9,200	71%	74%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	150	330	7,880	62%	71%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	110	60	240	22%	24%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Panhandle Region, Basin 54

Reservoir Storage	Diversion
AF	AFY
100	100
500	600
1,000	1,200
2,500	2,700
5,000	3,300
Required Storage to Meet Growth in Demand (AF)	Detailed Analysis Required
Required Storage to Meet Growth in Surface Water Demand (AF)	200

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about 6%, alluvial groundwater storage depletions by 13% and bedrock groundwater storage depletions by 15%. Temporary drought management activities will likely be ineffective due to the high probability of gaps and storage depletions each year.

Out-of-Basin Supplies

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning Region: Englewood and Forgan, both in Basin 65. However, due to availability of groundwater resources in Basin 54, the distance to reliable surface water supplies, and the geographically dispersed nature of the Crop Irrigation sector, out-of-basin supplies may be less cost-effective than increased use of in-basin supplies.

Reservoir Use

Reservoir storage could mitigate surface water gaps. The flow in Basin 54 has been fully permitted and is expected to severely limit the size and location of new reservoirs. However, if permittable, a river diversion and 200 AF of reservoir storage at the basin outlet could supply the entire increase in surface water use through 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps. A detailed analysis is needed to determine the feasibility of using reservoir storage to meet future groundwater demands.

Increasing Reliance on Surface Water

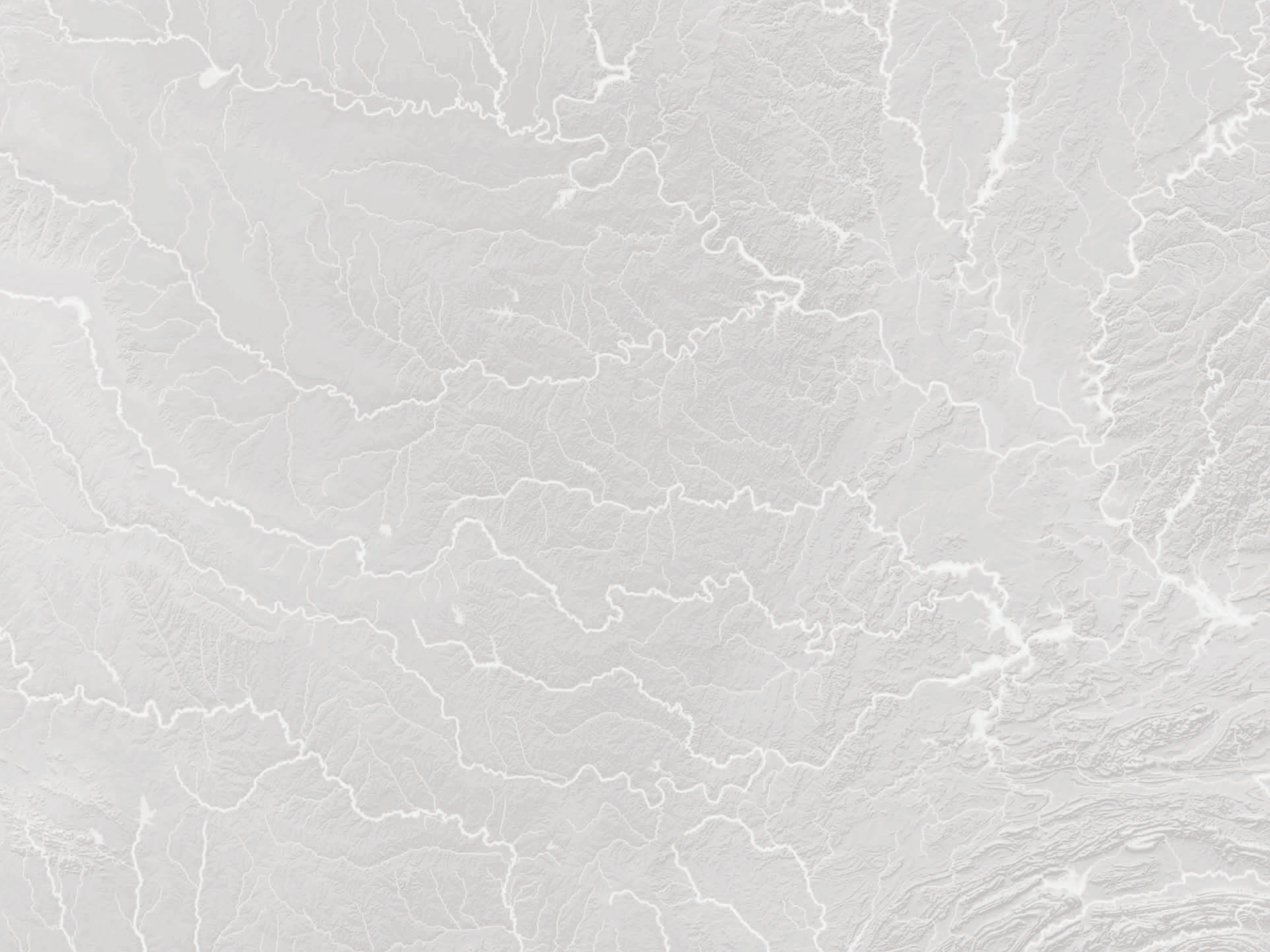
Increased reliance on surface water through direct diversions, without reservoir storage, would increase surface water gaps in the basin and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on alluvial or bedrock groundwater supplies could mitigate surface water gaps, but will increase storage depletions. Any increases in storage depletions would be minimal relative to the storage in major aquifers in Basin 54; however, localized storage depletions may adversely affect groundwater users.

Notes & Assumptions

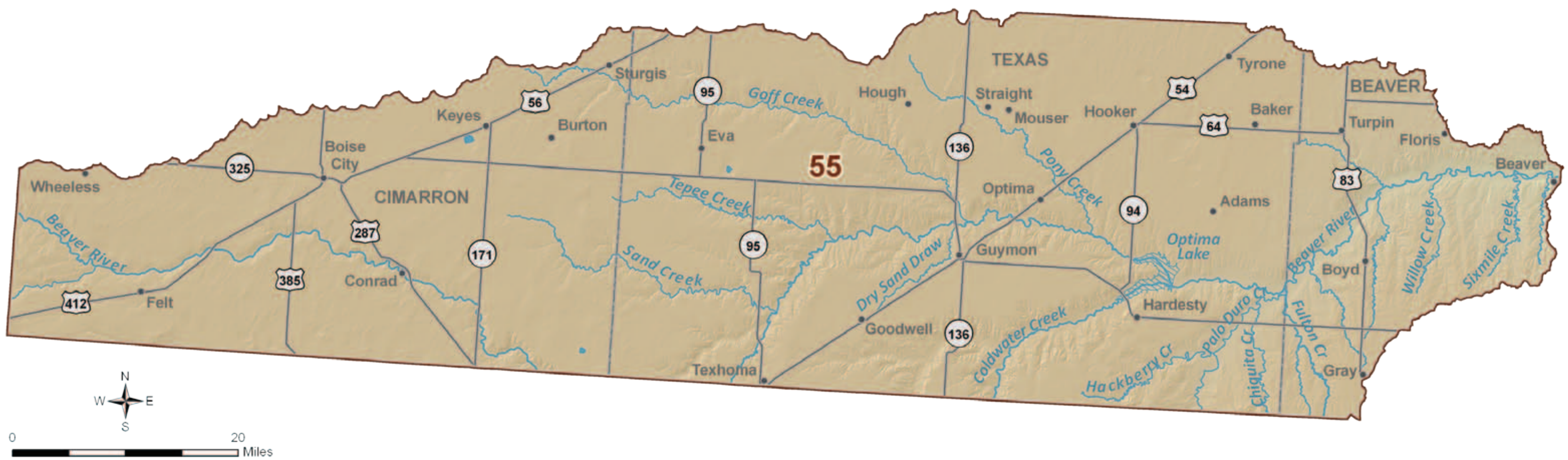
- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands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



Data & Analysis

Panhandle Watershed Planning Region

Basin 55

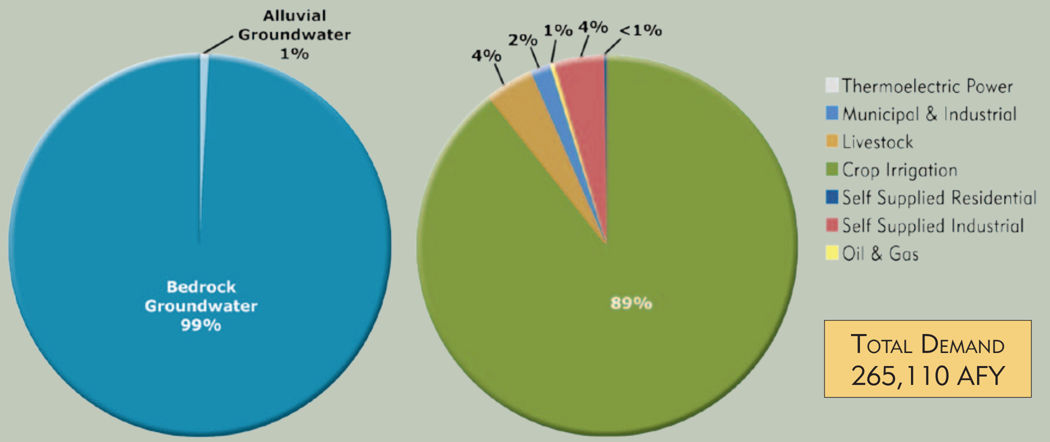


Basin 55 Summary

Synopsis

- Water users are expected to continue to rely primarily on the basin's alluvial and bedrock aquifers.
- By 2020, surface water gaps may occur throughout the year with low streamflow conditions.
- By 2020, alluvial and bedrock groundwater use is expected to exceed recharge rates and thus draw from aquifer storage.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation could reduce the adverse surface water gaps and the effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could eliminate gaps.
- Basin 55 has been identified as a water availability "hot spot" due to bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *OCWP Executive Report*.)

Current Demand by Source and Sector
Panhandle Region, Basin 55



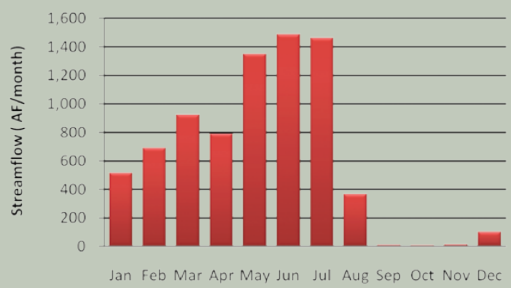
Basin 55 accounts for about 13% of the water demand in Oklahoma and 68% of the demand in the Panhandle Watershed Planning Region. More than 89% of the demand is in the Crop Irrigation demand sector. Surface water satisfies less than 1% of the total demand in the basin and future development of surface supplies is expected to be limited. Groundwater satisfies almost 100% of current demand (99% bedrock and less than 1% alluvial). The peak summer month demand in Basin 55 is 32.6 times the winter demand, which is much more pronounced than the overall statewide pattern.

The Beaver River has historically undergone frequent periods of very low flows. Relative to basins statewide, surface water quality in Basin 55 is considered good. However, the Beaver River (North Canadian) is impaired for Agricultural supply use below Optima Lake due to high

Water Resources
Panhandle Region, Basin 55

Median Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 55



Projected Water Demand

Panhandle Region, Basin 55

levels of total dissolved solids (TDS) and chloride. Surface water supplies in the basin are currently fully allocated and have no permit availability.

The Ogallala aquifer, which underlies most of Basin 55, has approximately 53 million acre-feet of storage. While there are no significant groundwater quality issues in the basin, localized areas with high levels of nitrate have been found within the extent of the Ogallala in Oklahoma and may occur in Basin 55.

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 312,940 AFY reflects a 47,830 AFY increase (18%) over 2010 demand. The majority of demand and largest growth in demand from 2010 to 2060 will be in the Crop Irrigation demand sector. Bedrock groundwater is the main supply source in the basin.

Gaps & Depletions

Based on projected demand and historical hydrology, gaps and groundwater storage depletions are projected to occur by 2020. The Ogallala aquifer, which is the basin's predominant source of supply, is the only aquifer in Oklahoma known to be currently experiencing significant storage depletions. Historically, this basin has experienced the largest increase in water level declines in the Ogallala, with localized declines as much as 100 feet in Texas County to more than 50 feet in Cimarron County. By 2060, existing storage depletions will increase to 47,090 AFY. This rate of depletion is still considered minimal compared to the significant amount of storage in the aquifer. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs. Surface water gaps will be up to 320 AFY and occur in at least one month of nearly every year. By 2060, alluvial groundwater storage depletions from minor aquifers will be up to 380 AFY and occur in at least one month of nearly every year.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Water users in the basin should focus on permanent conservation activities, instead of temporary drought management activities, since gaps and storage depletions have a high probability of occurring each year.

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and storage depletions. The

Water Supply Limitations

Panhandle Region, Basin 55

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal   Potential   Significant

Water Supply Option Effectiveness

Panhandle Region, Basin 55

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

OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Panhandle Watershed Planning Region. However, out-of-basin supplies may not be cost-effective for all users based on the availability of groundwater resources and distance to reliable surface water supplies.

Reservoir storage is not recommended without a detailed feasibility analysis, due to limited surface water supplies and lack of future permit availability.

Increased reliance on surface water supplies, without reservoir storage, could only reduce a small amount of storage depletions and would increase surface water gaps. Also, there is no additional surface water permit availability in the basin. Therefore, this water supply option is not recommended.

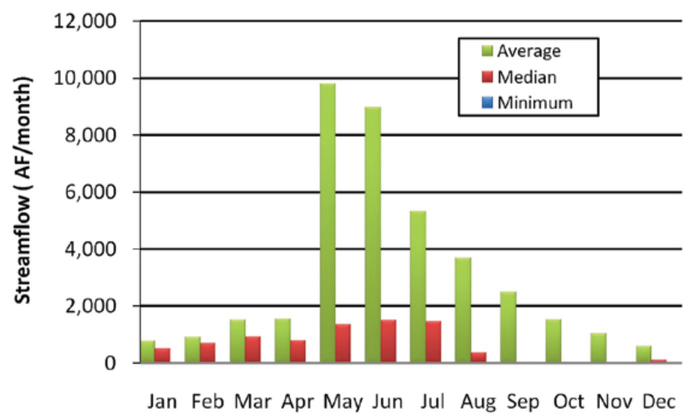
Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase the amount of groundwater storage depletions. The increases in storage depletions would be minimal relative to the volume of water in storage for Basin 55's portion of the Ogallala aquifer. However, localized depletions may adversely impact groundwater users.

Basin 55 Data & Analysis

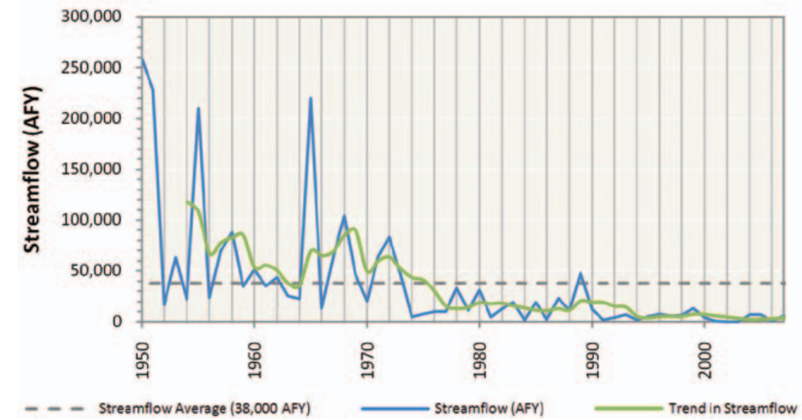
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Irrigation has had a significant effect on streamflow in the Beaver River since 1978 (USGS 1997), where streamflow has decreased substantially since the 1970s.
- The median flow over the period of record in the Beaver River at Beaver is about 1,400 AF/month in summer, but only 10 AF/month in fall. However, the river can have prolonged periods of low to no flow in any month of the year. If the effects of irrigation persist, the median flow is expected to decrease in the future.
- Optima Lake regulates flow in the Beaver River at Beaver but does not sustain a water supply yield.

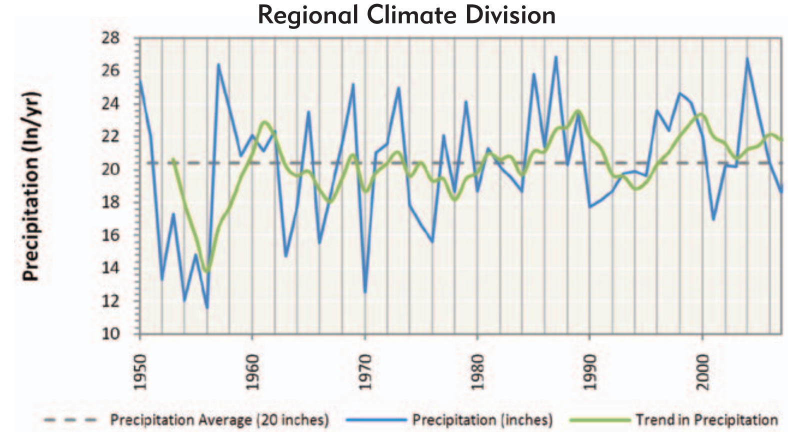
Monthly Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 55



Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 55



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)

Panhandle Region, Basin 55

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
Ogallala	Bedrock	Major	96%	1,009,600	53,175,000	2.0	3,271,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	400	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

- Virtually all water rights in Basin 55 are from the Ogallala aquifer. The aquifer has high yields, abundant storage, and is available over almost the entire basin. However, the Ogallala aquifer in this basin has experienced the most significant declines in groundwater levels—more than 100 feet in localized areas of Texas County and more than 50 feet in Cimarron County. There are relatively minimal water rights from non-delineated groundwater sources. Estimated Ogallala aquifer recharge in the basin is 25,000 AFY.
- Localized areas with high levels of nitrate have been found in the Ogallala and may occur in Basin 55.

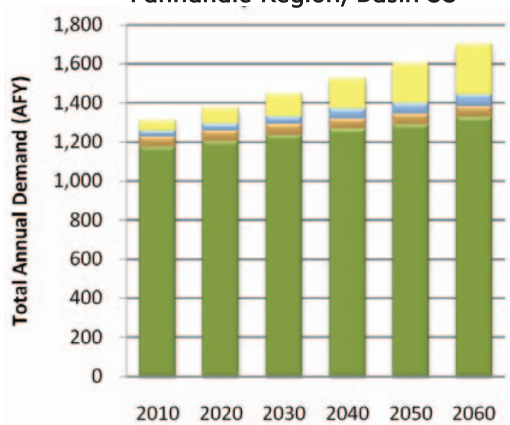
Notes & Assumptions

- 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.

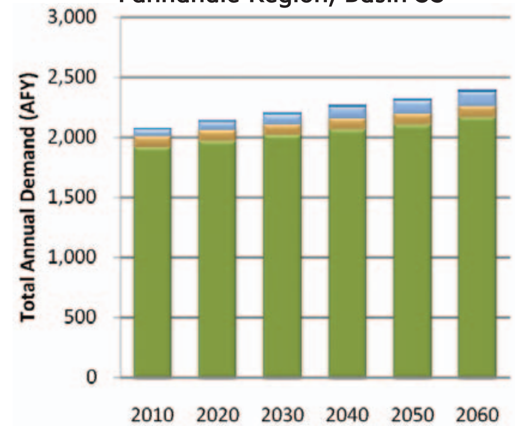
Water Demand

- The water needs of Basin 55 are 13% of the state's total demand and about 68% of the regional demand. Water use will increase by 18% (47,830 AFY) from 2010 to 2060. The majority of demand and growth in demand from 2010 to 2060 will be in the Crop Irrigation sector. Bedrock groundwater is the main supply source in the basin.
- Surface water is used to meet less than 1% of the total demand in the basin and its use will increase by 30% (390 AFY) from 2010 to 2060. The majority of surface water use over this period in the Crop Irrigation sector. The largest growth in surface water use will be from the Oil and Gas sector.
- Alluvial groundwater is used to meet less than 1% of the total demand in Basin 55 and its use will increase by 15% (320 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 use in Basin 55 represents 37% of the total bedrock groundwater use in the state. The basin's bedrock groundwater use will increase by 18% (47,120 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector. The Municipal and Industrial, Oil and Gas, and Self Supplied Industrial sectors represent a small but important part of Basin 55's demand.

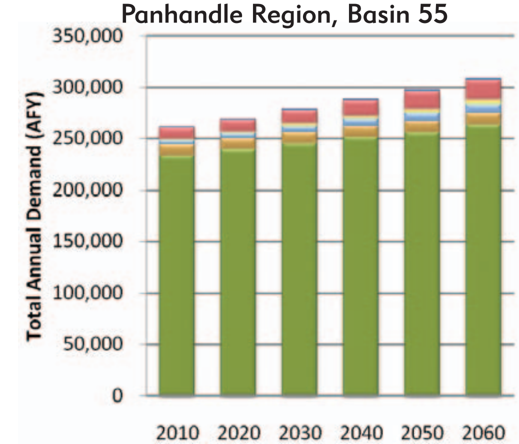
Surface Water Demand by Sector
Panhandle Region, Basin 55



Alluvial Groundwater Demand by Sector
Panhandle Region, Basin 55



Bedrock Groundwater Demand by Sector
Panhandle Region, Basin 55



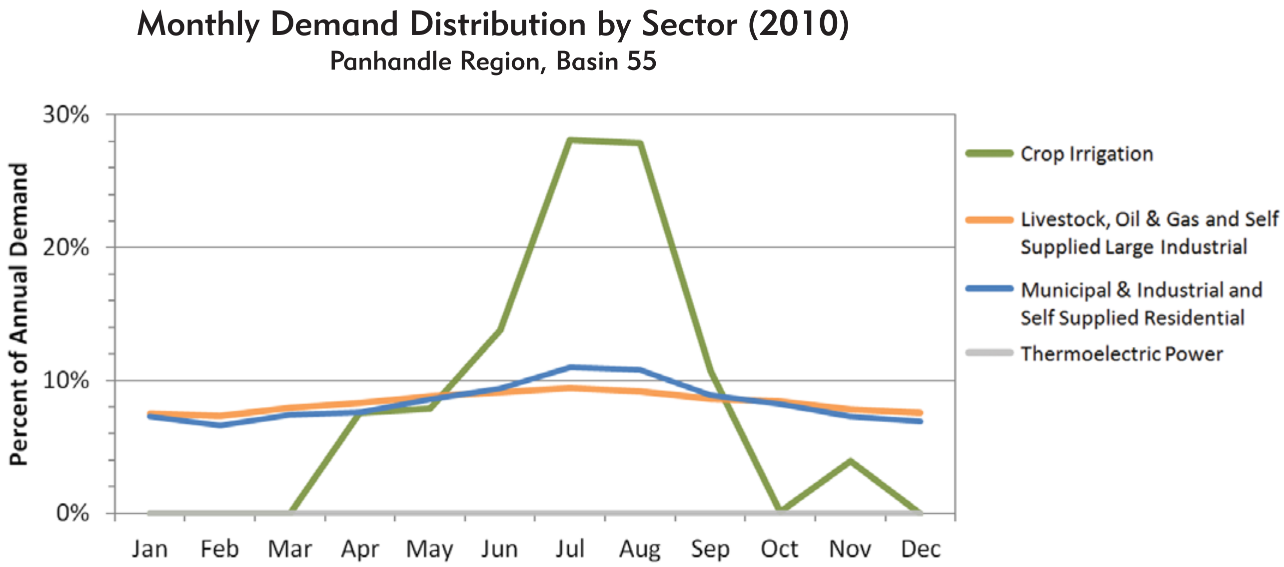
Thermoelectric Power | Self Supplied Residential | Self Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

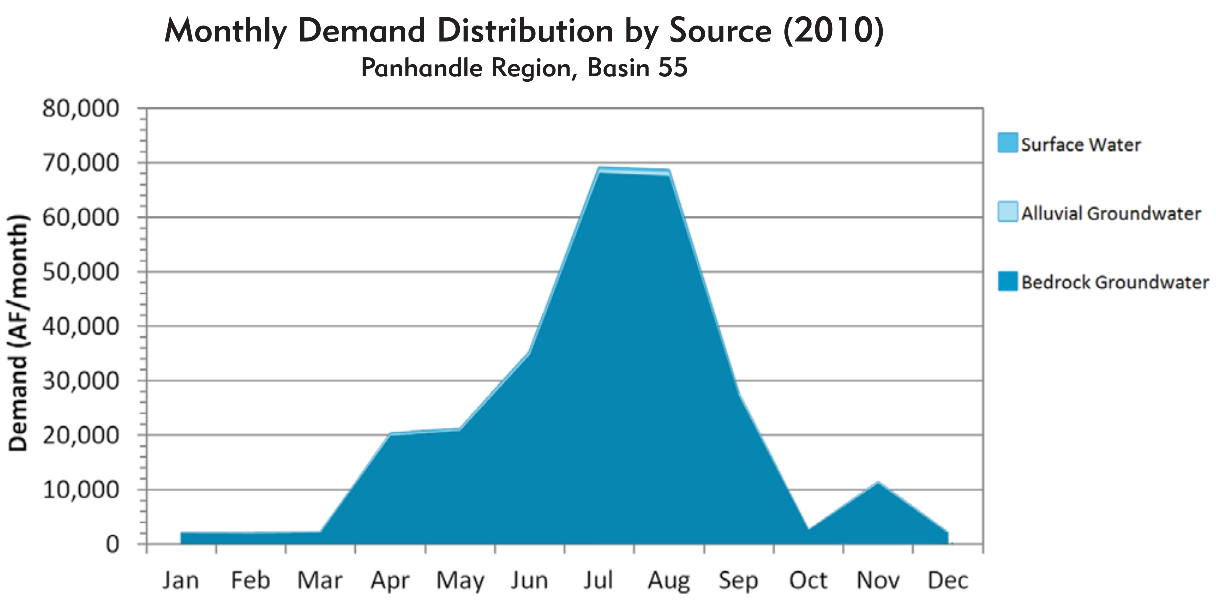
Total Demand by Sector
Panhandle Region, Basin 55

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	236,750	10,820	4,580	990	11,310	660	0	265,110
2020	242,810	10,940	5,410	1,510	11,330	760	0	272,760
2030	248,860	11,070	6,340	2,150	13,120	850	0	282,390
2040	254,920	11,190	7,260	2,910	15,240	940	0	292,460
2050	259,560	11,320	8,200	3,780	17,350	1,040	0	301,250
2060	267,030	11,440	9,120	4,780	19,440	1,130	0	312,940

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 total water demand in Basin 55 is 32.6 times the monthly winter demand, which is much more pronounced than the overall statewide pattern. The peak summer month surface water and bedrock groundwater demands are 33.1 and 32.6 times the monthly winter use, respectively. Monthly alluvial groundwater use peaks in the summer at 46.9 times the winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, gaps and storage depletions are projected to occur by 2020.
- Surface water gaps in Basin 55 may occur throughout the year. Surface water gaps in 2060 will be up to 12% (50 AF/month) of the surface water demand in the peak summer month, and as much as 67% (20 AF/month) of the peak winter month's surface water demand. By 2060, there will be a 93% probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during winter and summer months.
- Alluvial groundwater storage depletions in minor aquifers in Basin 55 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 13% (80 AF/month) of the alluvial groundwater demand in the peak summer month and up to 50% (10 AF/month) of the peak winter month's alluvial groundwater demand. By 2060, there will be a 95% probability of storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during fall and summer months.
- Bedrock groundwater storage depletions in Basin 55 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 13% (10,140 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 37% (1,250 AF/month) on average of the peak winter month's bedrock groundwater demand.
- Projected groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely impact yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Panhandle Region, Basin 55

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	10	53%
Mar-May (Spring)	20	20	24%
Jun-Aug (Summer)	50	50	52%
Sep-Nov (Fall)	30	20	78%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Panhandle Region, Basin 55

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	52%
Mar-May (Spring)	30	20	24%
Jun-Aug (Summer)	80	70	55%
Sep-Nov (Fall)	40	20	78%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Panhandle Region, Basin 55

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
2020	30	60	7,510	36%	60%
2030	90	120	17,010	81%	83%
2040	170	250	26,940	91%	91%
2050	220	290	35,600	93%	93%
2060	320	380	47,090	93%	95%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Panhandle Region, Basin 55

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	1,250
Mar-May (Spring)	3,880
Jun-Aug (Summer)	10,140
Sep-Nov (Fall)	4,710

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

Panhandle Region, Basin 55

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	320	380	47,090	93%	95%
Moderately Expanded Conservation in Crop Irrigation Water Use	250	270	32,950	91%	91%
Moderately Expanded Conservation in M&I Water Use	270	370	45,740	93%	93%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	200	270	31,590	91%	91%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	60	60	6,350	69%	67%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Panhandle Region, Basin 55

Reservoir Storage	Diversion
AF	AFY
100	0
500	100
1,000	300
2,500	500
5,000	1,000
Required Storage to Meet Growth in Demand (AF)	Detailed Analysis Required
Required Storage to Meet Growth in Surface Water Demand (AF)	Detailed Analysis Required

Water Supply Options & Effectiveness

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

Demand Management

(Potentially Effective) Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps by about 38%, alluvial groundwater storage depletions by 29% and bedrock groundwater storage depletions by 33%. Temporary drought management activities will likely be ineffective due to the high probability of gaps and storage depletions each year.

Out-of-Basin Supplies

(Potentially Effective) Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning Region: Englewood and Forgan, both in Basin 65. However, due to the available groundwater resources in Basin 55, the distance to reliable surface water supplies, and the geographically dispersed nature of the Crop Irrigation sector, out-of-basin supplies may be less cost-effective than increased use of in-basin supplies.

Reservoir Use

(Likely Ineffective) Reservoir storage is not recommended as a water supply option without a detailed analysis to determine the viability of any reservoir in Basin 55. The flow in Basin 55 has been fully permitted, which is expected to severely limit the size and location of new reservoirs. Optima Lake has substantial storage available, but does not sustain a water supply yield. The basin has numerous small agricultural lakes, but the yield of these lakes is unknown.

Increasing Reliance on Surface Water

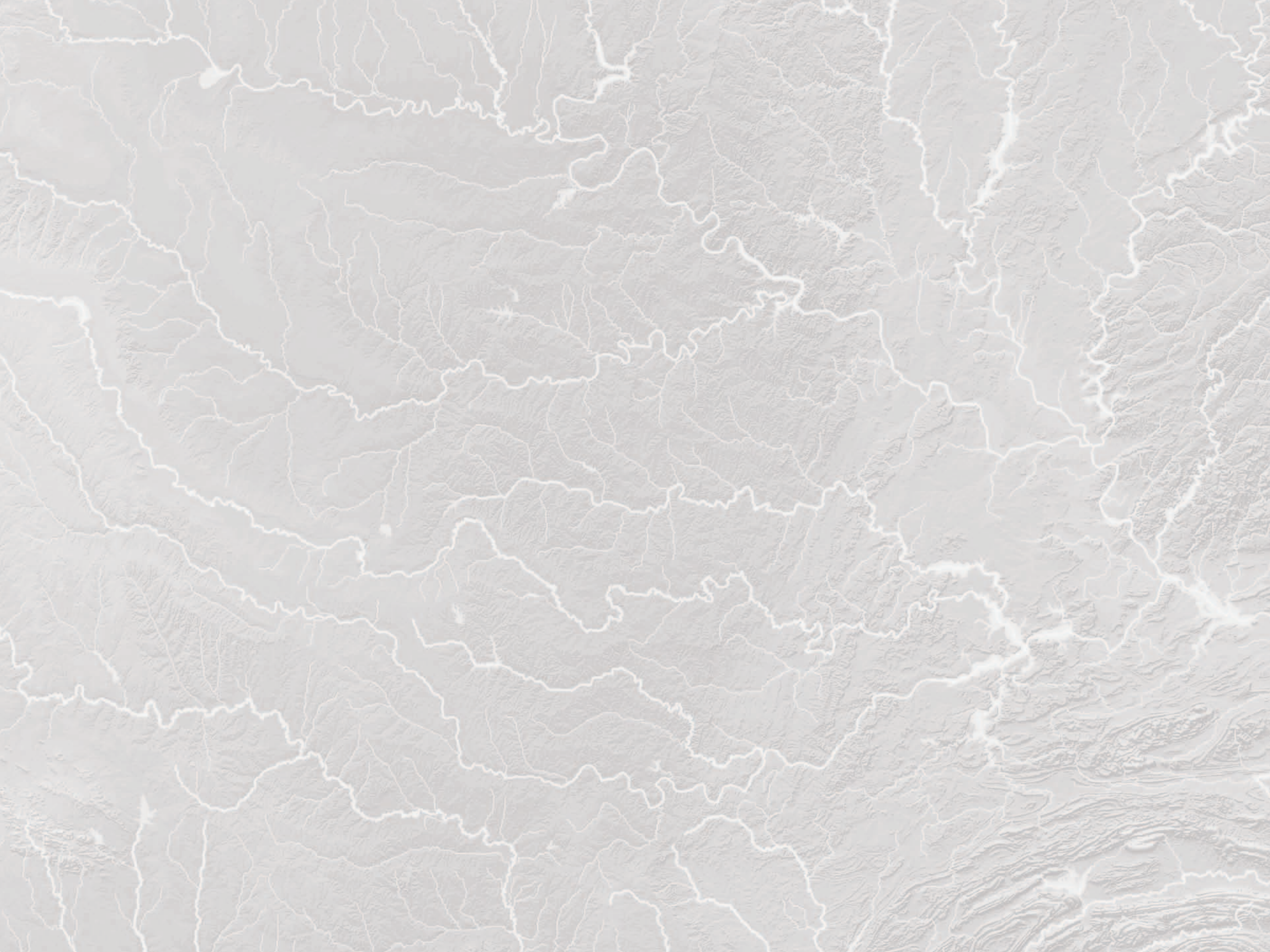
(Likely Ineffective) Increased reliance on surface water through direct diversions, without reservoir storage, would increase surface water gaps in the basin and is not recommended. Also, there is no additional surface water permit availability in the basin.

Increasing Reliance on Groundwater

(Typically Effective) Increased reliance on groundwater supplies could mitigate surface water gaps, but will increase storage depletions. Any increases in storage depletions would be minimal relative to the storage in Basin 55's portion of the Ogallala aquifer; however, localized storage depletions may adversely affect groundwater users. Site-specific information on the suitability of the minor alluvial aquifers for supply should be considered before large scale or increased use.

Notes & Assumptions

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



Data & Analysis

Panhandle Watershed Planning Region

Basin 65

Basin 65 Summary

Synopsis

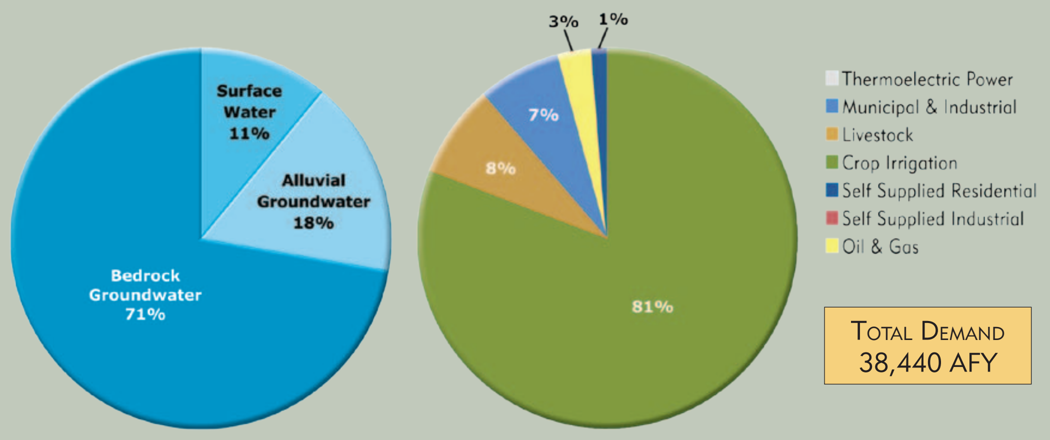
- Water users are expected to continue to rely primarily on the basin's alluvial and bedrock aquifers.
- By 2020, surface water gaps may occur during spring, summer, and fall months with low streamflow conditions.
- By 2020, alluvial and bedrock groundwater use is expected to exceed recharge rates and thus draw from aquifer storage.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation could reduce surface water gaps and the adverse effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could eliminate gaps.

Basin 65 accounts for about 10% of the demand in the Panhandle Watershed Planning Region. About 81% of the demand is from the Crop Irrigation demand sector. Surface water satisfies about 11% of the total demand in Basin 65. Groundwater satisfies about 89% of the total demand (71% bedrock and 18% alluvial). The peak summer month demand in Basin 65 is 16.7 times the winter demand, which is more pronounced than the overall statewide pattern.

No major reservoirs exist in Basin 65. Historically, the Cimarron River upstream of West Creek has undergone frequent prolonged periods of low flows in each month of the year. However, the Old Settlers Irrigation Ditch diverts water from the river for irrigation. This ditch runs parallel and immediately south of the Cimarron River primarily in Harper county. The Ditch, built in 1893 to 1905 by local farmers who organized into the Settlers Milling Canal and Reservoir Company, remains a viable irrigation canal capable of providing water to over 6,000 acres of agricultural land. (Listed in the National Register of Historic Places, 7/27/1983). Surface water quality in Basin 65 is considered fair. Surface water in the basin is currently fully allocated and has no permit availability.

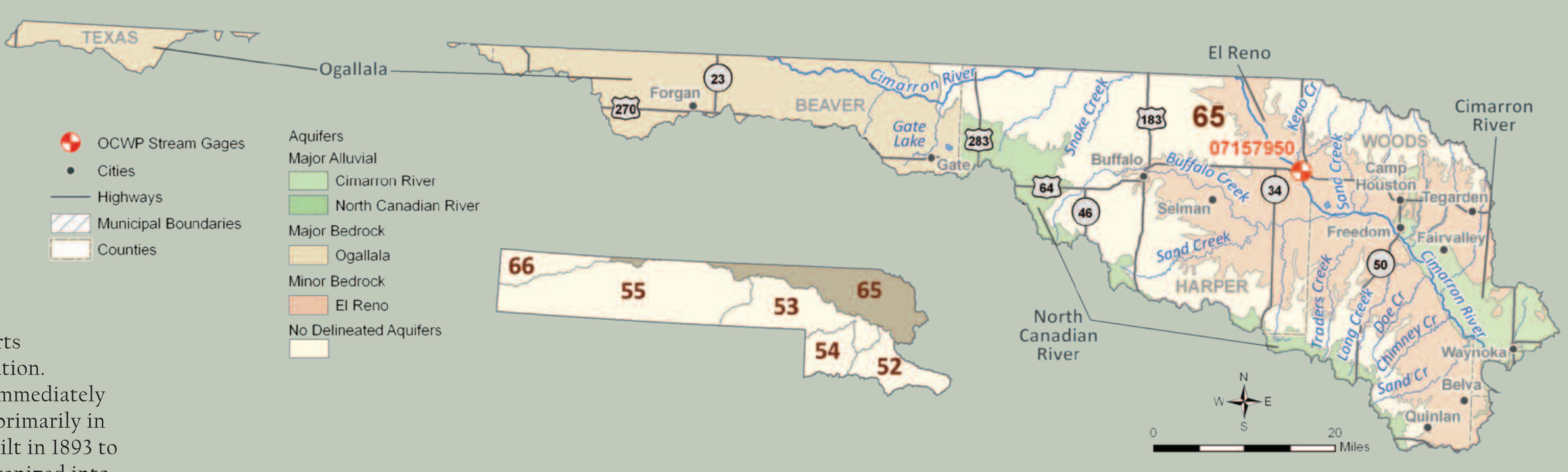
Current Demand by Source and Sector

Panhandle Region, Basin 65



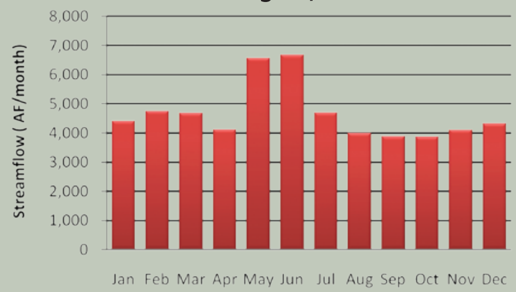
Water Resources

Panhandle Region, Basin 65



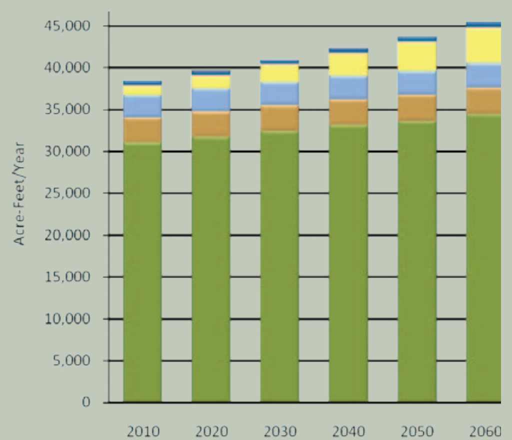
Median Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 65



Projected Water Demand

Panhandle Region, Basin 65



The Ogallala aquifer has approximately 6.6 million acre-feet of in-basin storage and underlies the western portion of the basin. The Cimarron River and North Canadian River aquifers have combined storage of more than 1 million acre-feet and underlie the eastern portion of the basin. While, there are no significant basin-wide groundwater quality issues, localized areas with high levels of nitrate have been found within the extent of the Ogallala in Oklahoma and may occur in Basin 65. 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 45,380 AFY reflects a 6,940 AFY increase (18%) over the 2010 demand. The majority of the demand is expected to continue to be from the Crop Irrigation demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are projected to occur by 2020. By 2060, surface water gaps will be up to 830 AFY and have a 66% probability of occurring in at least one month of each year. Alluvial groundwater storage depletions will be up to 1,010 AFY and have a 66% probability of occurring in at least one month of each year. Bedrock storage will be up to 3,260 AFY in 2060. Projected alluvial and bedrock storage depletions are minimal relative to the amount of water in storage. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Water users in the basin should focus on permanent conservation activities, instead of temporary drought management activities, since gaps and storage depletions have a high probability of occurring each year.

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and storage depletions. However, out-of-basin supplies may not be cost-effective for all users based on the availability of groundwater resources and distance to reliable surface water supplies.

New reservoir storage could potentially mitigate surface water gaps in the basin. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable sites in Basin 65. However, the stream system is currently fully allocated so substantial permit issues would have to be resolved in order to construct new reservoir storage.

Increased reliance on surface water supplies, without reservoir storage, would only reduce a portion of storage depletions and would increase surface water gaps. Also, there is no additional surface water permit availability in the basin. Therefore, this water supply option is not recommended.

Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase the amount of groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in major aquifers in the basin.

Water Supply Limitations

Panhandle Region, Basin 65

Source	Limitation
Surface Water	Significant
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal Potential Significant

Water Supply Option Effectiveness

Panhandle Region, Basin 65

Option	Effectiveness
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

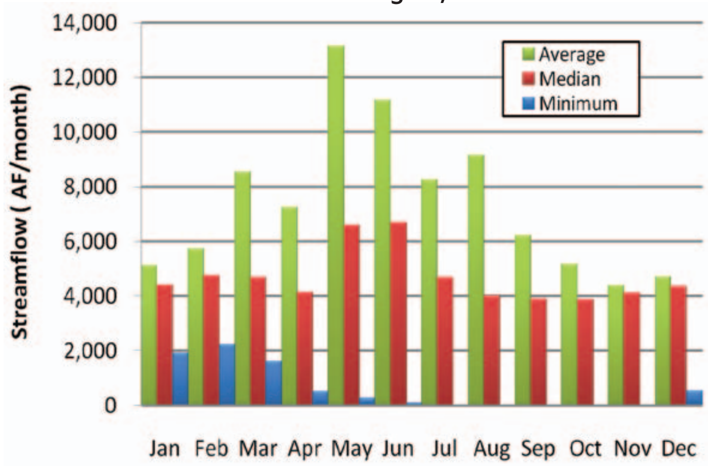
Typically Effective Potentially Effective Likely Ineffective No Option Necessary

Basin 65 Data & Analysis

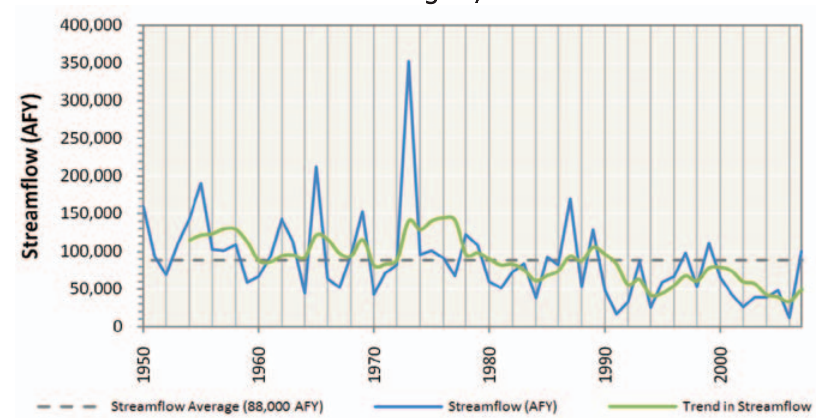
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. There is substantial annual hydrologic variation in Basin 65. Historically, the Cimarron River upstream of West Creek has undergone prolonged periods of very low to no flow in the summer and fall.
- The median monthly streamflow at Basin 65's outlet is between about 4,000 to 7,000 AF. However, the long-term trends in annual flow of the Cimarron River upstream of West Creek appear to be trending downwards since the late 1970s while long-term precipitation has been trending upwards. The surface water quality in Basin 65 is considered fair.
- There are no major reservoirs in this basin. However, Old Settlers Irrigation Ditch, which diverts water from the Cimarron River and runs parallel to the river primarily in Harper County, was built in 1893 to 1905 by local farmers who organized into the Settlers Milling Canal and Reservoir Company. In most places the ditch bed is twelve feet wide but the top expanse is sixty feet in places. The ditch remains a viable irrigation canal capable of providing water to over 6,000 acres of agricultural land.

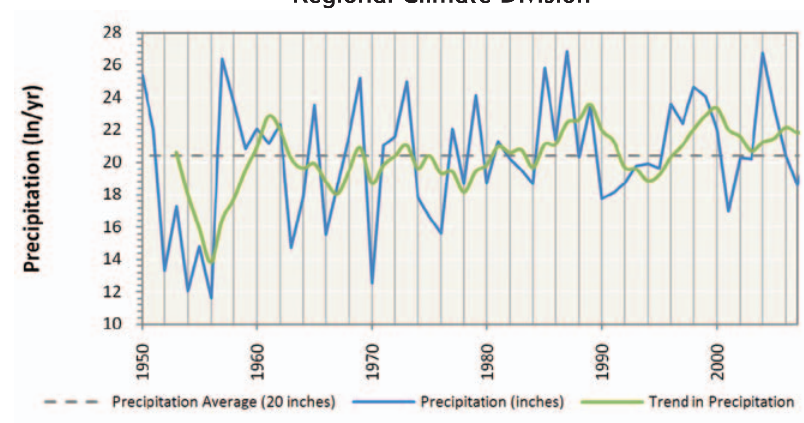
Monthly Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 65



Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 65



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)

Panhandle Region, Basin 65

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
Cimarron River	Alluvial	Major	6%	10,800	327,000	temporary 2.0	140,100
North Canadian River	Alluvial	Major	6%	7,800	714,000	1.0	77,300
El Reno	Bedrock	Minor	38%	4,200	2,555,000	temporary 2.0	978,700
Ogallala	Bedrock	Major	22%	112,000	6,676,000	2.0	444,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	4,500	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	2,000	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of water rights in the basin are from the Ogallala aquifer in the western portion of the basin. Water rights from the North Canadian and Cimarron River alluvial aquifers provide supplies in the central and eastern portion of the basin. There are also water rights in the El Reno minor aquifer and non-delineated groundwater sources. Estimated Ogallala aquifer recharge in the basin is 2,000 AFY.
- There are no significant basin-wide groundwater quality issues in the basin.

Notes & Assumptions

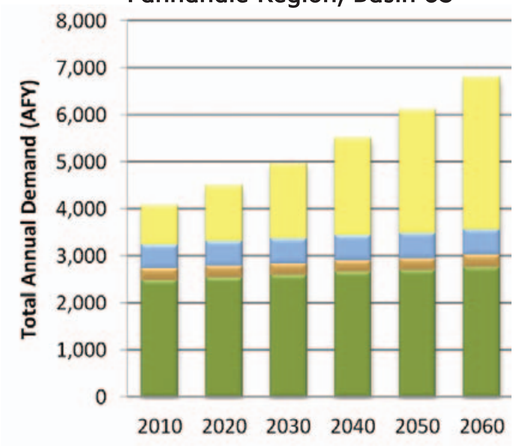
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

- Basin 65's water demand makes up 10% of the demand in the Panhandle Watershed Planning Region. The demand is expected to increase by 18% (6,940 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 11% of the total demand in Basin 65 and will increase by 66% (2,710 AFY) from 2010 to 2060. Oil and Gas surface water use is expected to be as large as Crop Irrigation surface water use by 2060.
- Alluvial groundwater is used to meet 18% of the total demand in the basin and will increase by 14% (980 AFY) from 2010 to 2060. The majority of alluvial groundwater water use and growth in alluvial groundwater use is in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 71% of the total demand in Basin 65 and is expected to increase by 12% (3,250 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use is in the Crop Irrigation demand sector.

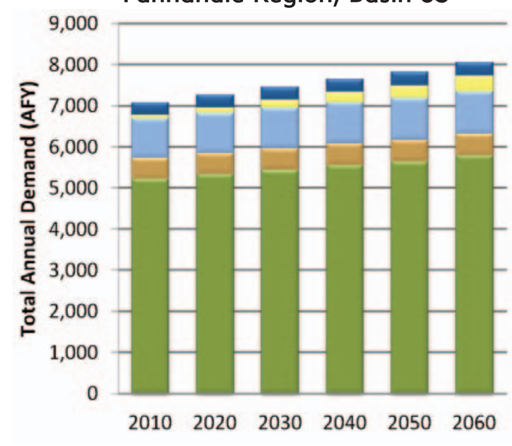
Surface Water Demand by Sector

Panhandle Region, Basin 65



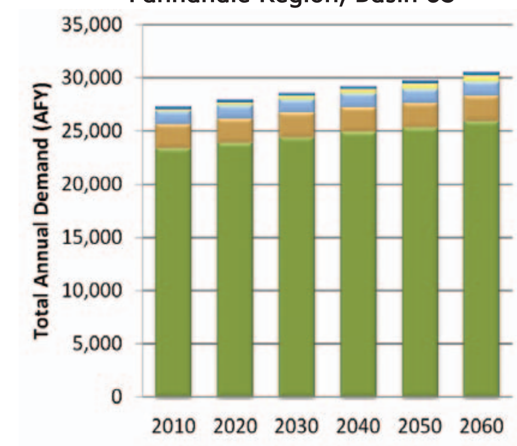
Alluvial Groundwater Demand by Sector

Panhandle Region, Basin 65



Bedrock Groundwater Demand by Sector

Panhandle Region, Basin 65



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

Total Demand by Sector

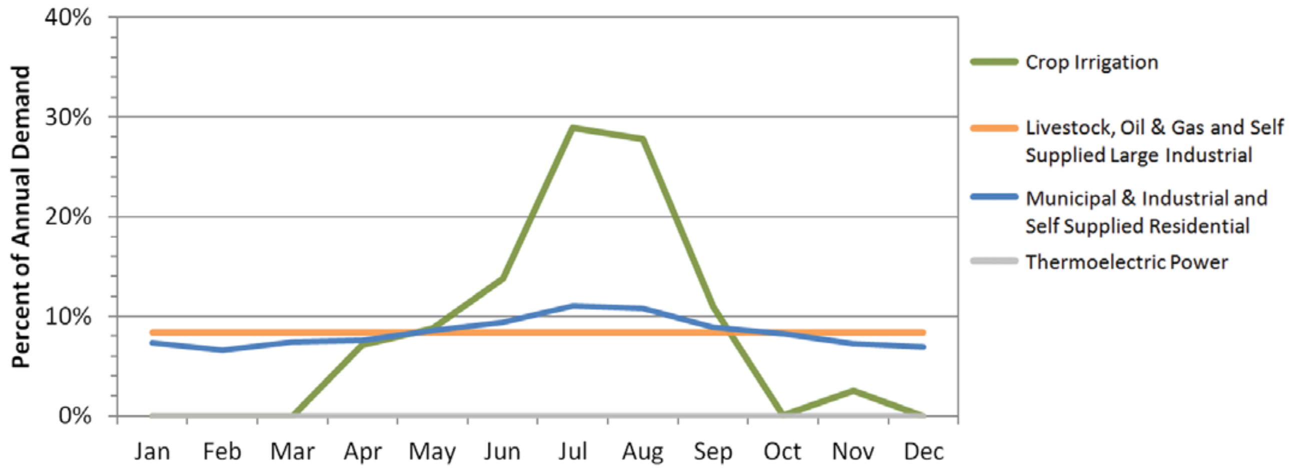
Panhandle Region, Basin 65

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	31,070	3,020	2,720	1,100	0	530	0	38,440
2020	31,740	3,050	2,770	1,560	0	540	0	39,660
2030	32,420	3,080	2,800	2,100	0	560	0	40,960
2040	33,100	3,110	2,830	2,730	0	560	0	42,330
2050	33,620	3,130	2,880	3,450	0	580	0	43,660
2060	34,450	3,160	2,930	4,250	0	590	0	45,380

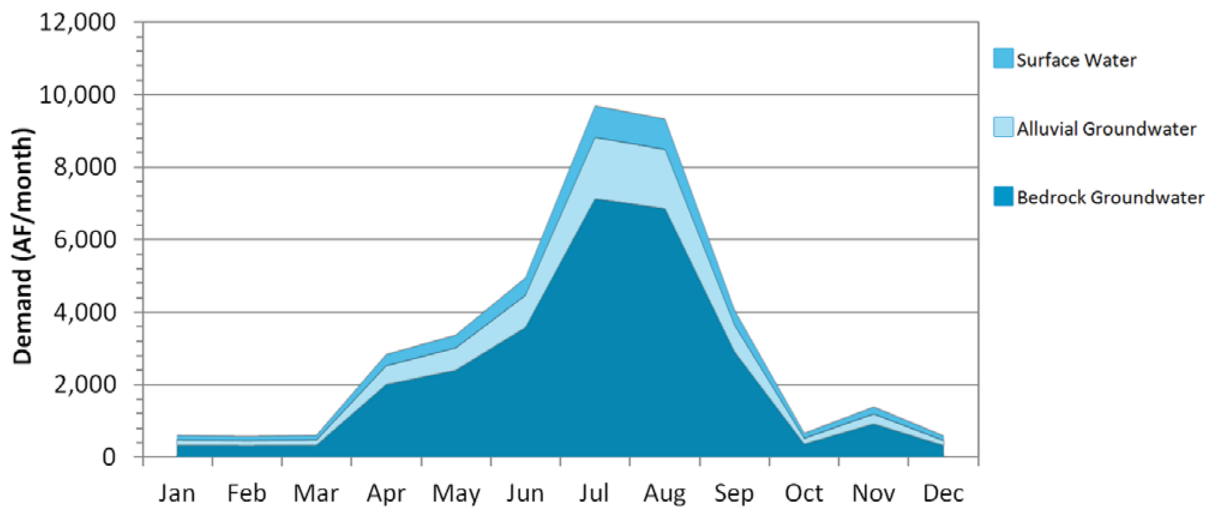
Notes & Assumptions

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

Monthly Demand Distribution by Sector (2010)
Panhandle Region, Basin 65



Monthly Demand Distribution by Source (2010)
Panhandle Region, Basin 65



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 total water demand in Basin 65 is 16.7 times the winter demand, which is more pronounced than the overall statewide pattern. The peak summer month surface water demand is 6.8 times the monthly winter use. For alluvial and bedrock groundwater, the peak summer month demand is respectively 11.9 and 22.9 times greater than the peak monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are projected to occur by 2020.
- Surface water gaps in Basin 65 may occur from spring through the fall. Surface water gaps in 2060 will be up to 16% (180 AF/month) of the surface water demand in the peak summer month, and as much as 44% (150 AF/month) of the peak fall month's surface water demand. By 2060, there will be a 66% probability of gaps occurring in at least one month of the year. Gaps are most likely to occur during the summer months.
- Alluvial groundwater storage depletions in Basin 65 may occur from spring through fall. Alluvial groundwater storage depletions in 2060 will be up to 15% (290 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 22% (180 AF/month) of the peak fall month's alluvial groundwater demand. By 2060, there will be a 66% probability of 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.
- Bedrock groundwater storage depletions in Basin 65 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 10% (800 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 16% (60 AF/month) on average of the winter months' bedrock groundwater demand.
- Projected groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Panhandle Region, Basin 65

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF	AF	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	70	30	9%
Jun-Aug (Summer)	180	150	45%
Sep-Nov (Fall)	150	130	43%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 65

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF	AF	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	90	40	9%
Jun-Aug (Summer)	290	240	45%
Sep-Nov (Fall)	180	100	43%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Panhandle Region, Basin 65

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AF			Percent	
2020	100	150	620	45%	45%
2030	210	320	1,260	50%	50%
2040	370	530	1,910	57%	57%
2050	590	750	2,440	57%	57%
2060	830	1,010	3,260	66%	66%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 65

Months (Season)	Average Storage Depletion[1]
	AF
Dec-Feb (Winter)	60
Mar-May (Spring)	280
Jun-Aug (Summer)	800
Sep-Nov (Fall)	340

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

Panhandle Region, Basin 65

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	830	1,010	3,260	66%	66%
Moderately Expanded Conservation in Crop Irrigation Water Use	700	810	1,890	60%	60%
Moderately Expanded Conservation in M&I Water Use	760	900	2,980	62%	62%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	630	690	1,610	59%	59%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	320	220	140	47%	47%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Panhandle Region, Basin 65

Reservoir Storage	Diversion
AF	AFY
100	200
500	1,000
1,000	1,700
2,500	3,800
5,000	7,200
Required Storage to Meet Growth in Demand (AF)	4,800
Required Storage to Meet Growth in Surface Water Demand (AF)	1,300

Water Supply Options & Effectiveness

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

Demand Management

Potentially Effective: Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and alluvial groundwater storage depletions by 24% and 32%, respectively, and bedrock groundwater storage depletions by 51%. Temporary drought management activities will likely be ineffective due to the high probability of gaps and storage depletions each year.

Out-of-Basin Supplies

Potentially Effective: Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and storage depletions. Due to the basin's available groundwater resources, distance to reliable surface water supplies, and the geographically dispersed nature of the Crop Irrigation sector, out-of-basin supplies may be less cost-effective than increased use of in-basin supplies.

Reservoir Use

Potentially Effective: Reservoir storage could mitigate surface water gaps and storage depletions. The flow in Basin 65 has been fully permitted, which is expected to severely limit the size and location of new reservoirs. However, if permittable, a river diversion and 1,300 AF of reservoir storage at the basin outlet could supply the entire increase in surface water use through 2060. 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. A detailed analysis is needed to determine the feasibility of using reservoir storage to meet future groundwater demands. The OCWP *Reservoir Viability Study* identified two potentially viable reservoir sites in Basin 65: Englewood and Forgan.

Increasing Reliance on Surface Water

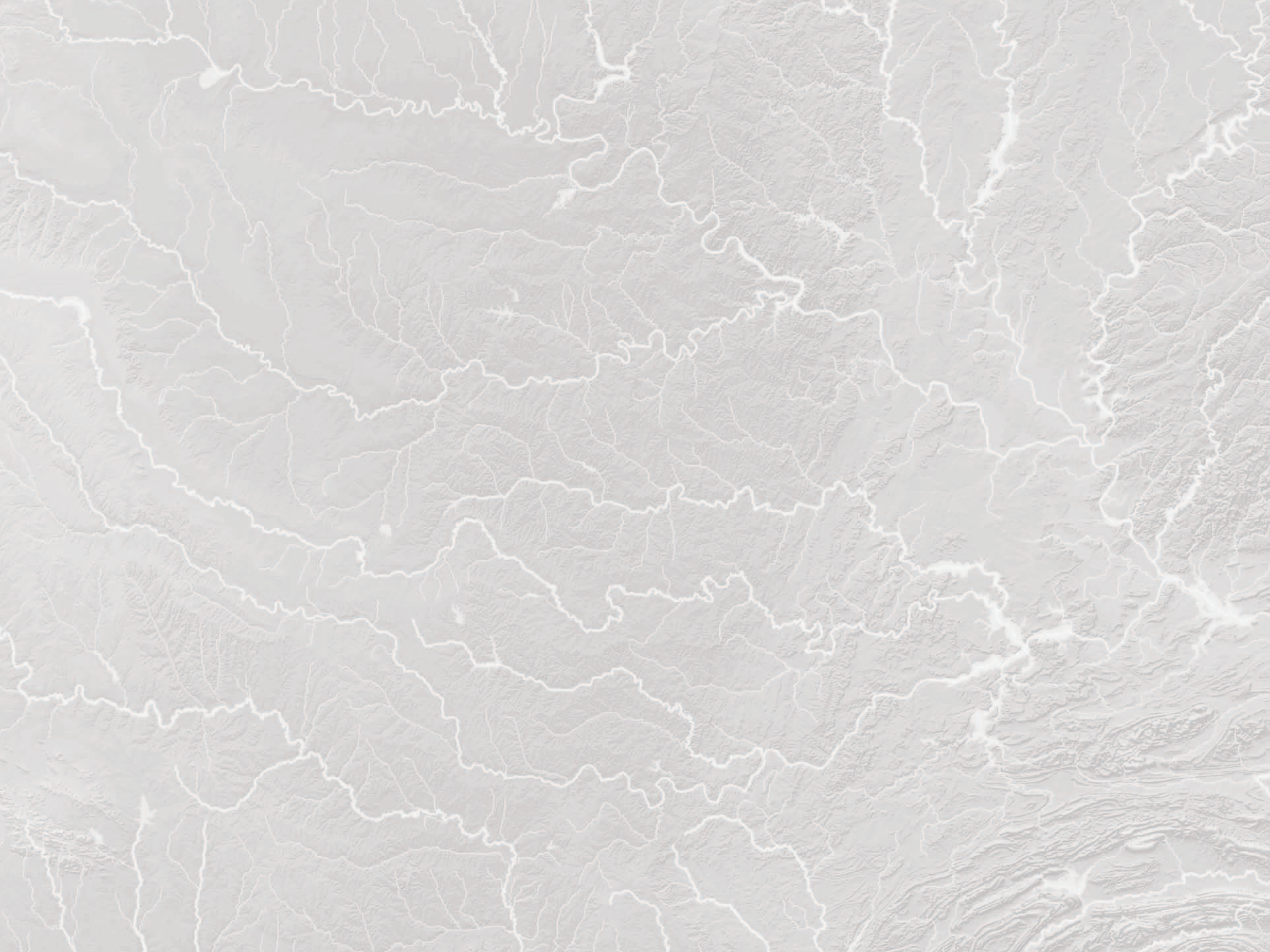
Likely Ineffective: Increased reliance on surface water through direct diversions, without reservoir storage, would increase surface water gaps in the basin and is not recommended.

Increasing Reliance on Groundwater

Potentially Effective: Increased reliance on bedrock groundwater supplies could mitigate surface water gaps and alluvial storage depletions, but will increase bedrock storage depletions. Any increases in storage depletions would be minimal relative to the storage in major aquifers in Basin 65. However, localized storage depletions may adversely affect groundwater users.

Notes & Assumptions

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



Data & Analysis

Panhandle Watershed Planning Region

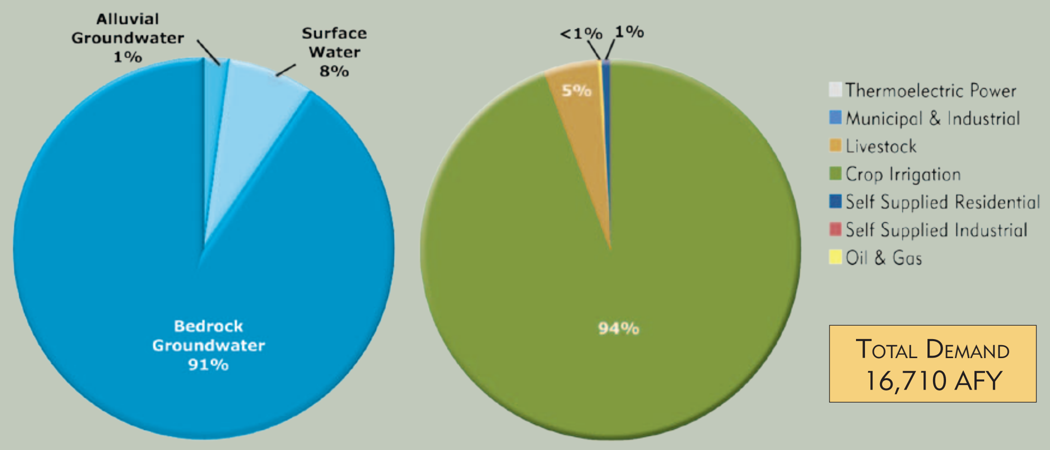
Basin 66

Basin 66 Summary

Synopsis

- Water users are expected to continue to rely primarily on the basin's alluvial and bedrock aquifers.
- By 2020, surface water gaps may occur during summer months with low streamflow conditions.
- Bedrock groundwater use is expected to exceed recharge rates by 2020 and thus draw from aquifer storage.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation activities could reduce surface water gaps and the adverse effects of localized storage depletions.
- Alternatives to direct surface water diversions, such as groundwater supplies and/or developing new small reservoirs, could eliminate gaps.
- Basin 66 has been identified as a water availability "hot spot" due to surface water and bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *OCWP Executive Report*.)

Current Demand by Source and Sector
Panhandle Region, Basin 66

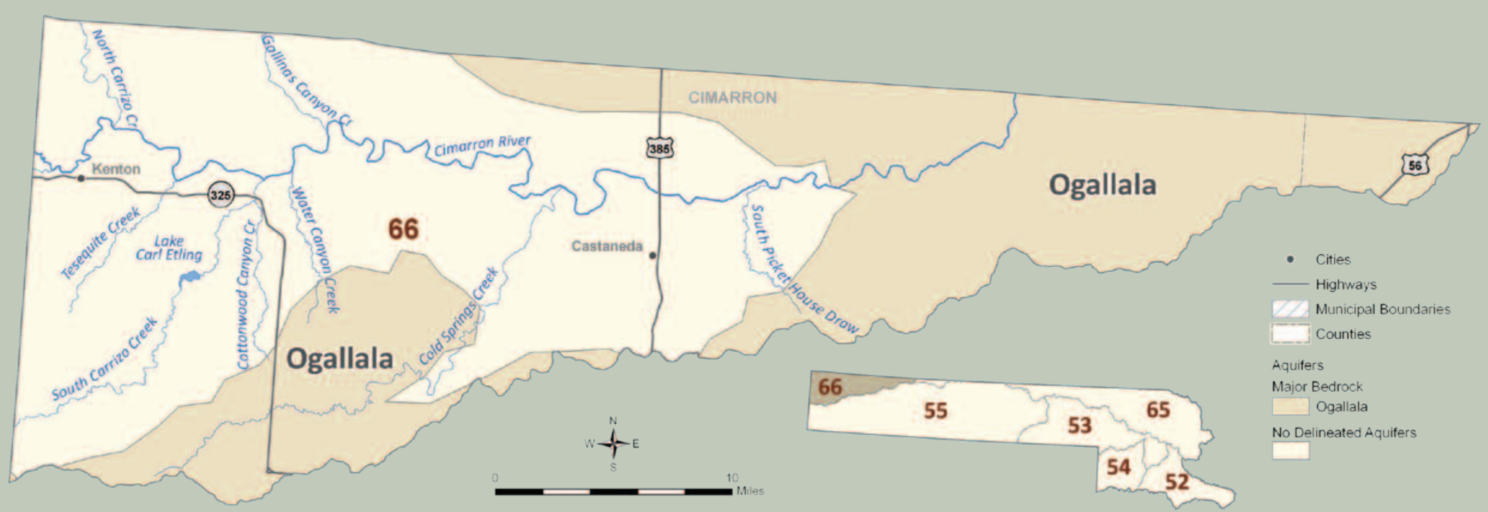


Basin 66 accounts for about 4% of the water demand in the Panhandle Watershed Planning Region. About 94% of the demand is in the Crop Irrigation demand sector. Surface water satisfies about 8% of the total basin demand and there are no major reservoirs in the basin. Future water supplies from the major river in the basin, the Cimarron River, are expected to be limited. Groundwater satisfies about 92% of the total demand (91% bedrock and 1% alluvial). The peak summer month demand in Basin 66 is 64.7 times the winter demand, which is much more pronounced than the overall statewide pattern.

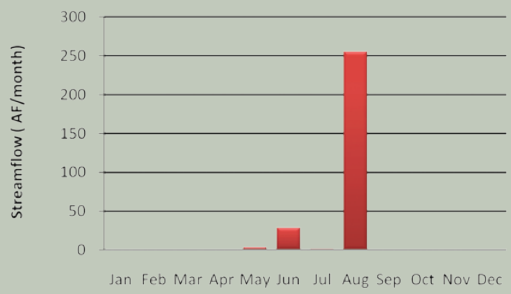
The Cimarron River near Elkhart, Kansas has historically undergone frequent periods of very low flows. Relative to other basins statewide, surface water quality in Basin 66 is fair. Surface water in the basin is currently fully allocated and has no permit availability.

The Ogallala aquifer has approximately 2.4 million acre-feet of storage and underlies the eastern part and southern portions of

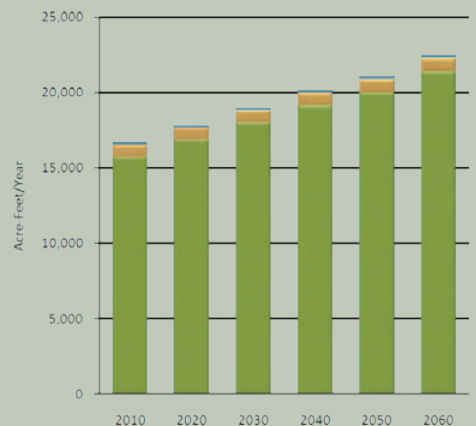
Water Resources
Panhandle Region, Basin 66



Median Historical Streamflow at the Basin Outlet
Panhandle Region, Basin 66



Projected Water Demand
Panhandle Region, Basin 66



the basin. While there are no significant basin-wide groundwater quality issues, localized areas with high levels of nitrate have been found within the extent of the Ogallala in Oklahoma and may occur in Basin 66. 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 22,480 AFY reflects a 5,770 AFY increase (35%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions are projected to occur by 2020, while alluvial groundwater storage depletions are expected by 2050. Bedrock groundwater storage depletions will be up to 5,230 AFY in 2060, whereas alluvial groundwater storage depletions will be up to 20 AFY and have a 66% probability of occurring in at least one month of the year. These rates of depletion are minimal relative to the total groundwater storage in the basin and should not constrain use over the planning horizon. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs. Surface water gaps are expected to occur in all years by 2060 and will be as large as 400 AFY.

Options

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

Since gaps and storage depletions have a high probability of occurring each year, moderately expanded permanent conservation activities can reduce gaps and storage depletions.

Out-of-basin supplies may be developed to supplement the basin's water supplies and reduce or eliminate gaps and 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 Panhandle Watershed Planning Region. However, out-of-basin supplies may not be cost-effective for all users due to the distance to reliable surface water supplies.

Due to the size of bedrock groundwater demands and limited surface water supplies, reservoir storage is not expected to be able to facilitate substantial reductions in storage depletions.

Increased reliance on surface water supplies, without reservoir storage would increase the size and probability of surface water gaps. Also, the basin is fully allocated. Therefore, this water supply option is not recommended.

Increased reliance on groundwater supplies could mitigate surface water gaps, but would increase storage depletions. Any increases in storage depletions would be minor relative to the volume of water in aquifer storage in the basin. However, localized storage depletions may adversely affect groundwater users.

Water Supply Limitations
Panhandle Region, Basin 66

Source	Limitation
Surface Water	Significant
Alluvial Groundwater	Potential
Bedrock Groundwater	Significant

Minimal · Potential · Significant

Water Supply Option Effectiveness
Panhandle Region, Basin 66

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

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

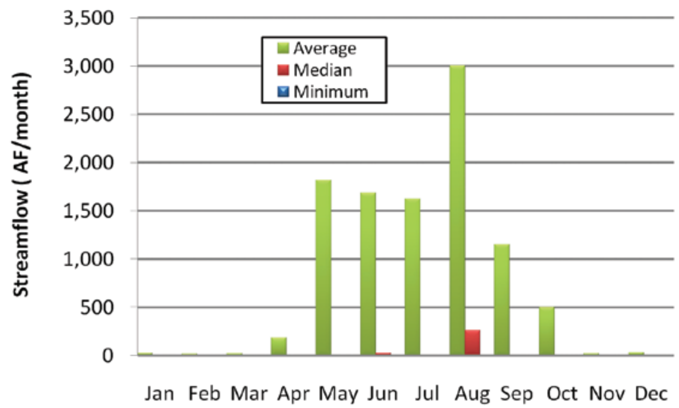
Basin 66 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Irrigation has had a significant effect on streamflow in the Cimarron River since about 1965. Streamflow has remained below the long-term average for most years since about 1980. Historically, streamflow in the Cimarron River near Elkhart, Kansas frequently has multiple months with low or no streamflow.
- The median flow in the Cimarron River near Elkhart, Kansas is less than 30 AF/month throughout the year, except in August. Additionally, the river can have prolonged periods of low flow in any month of the year. Relative to other basins statewide, the surface water quality in Basin 66 is fair.
- There are no major reservoirs in this basin.

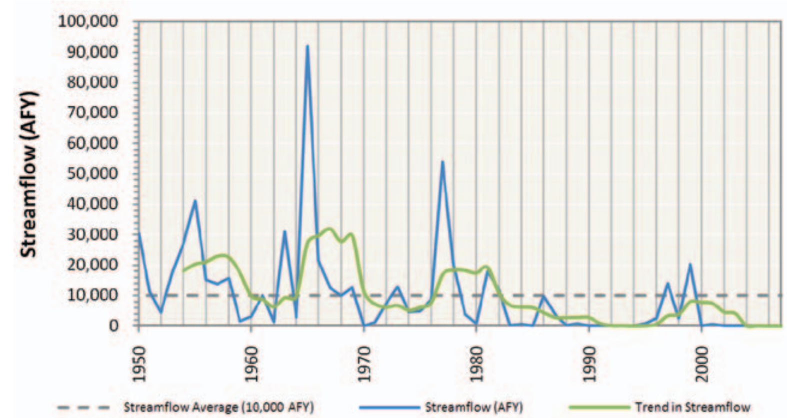
Monthly Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 66



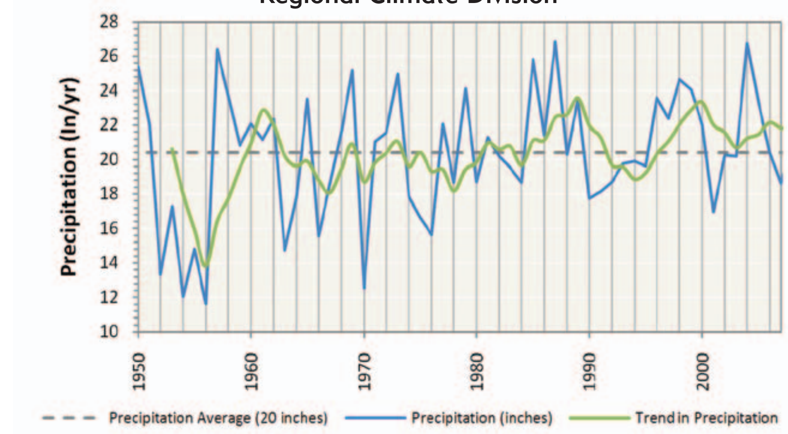
Historical Streamflow at the Basin Outlet

Panhandle Region, Basin 66



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)

Panhandle Region, Basin 66

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
Ogallala	Bedrock	Major	42%	45,400	2,433,000	2	285,700
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	400	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	100	N/A	temporary 2.0	N/A

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

Groundwater Resources

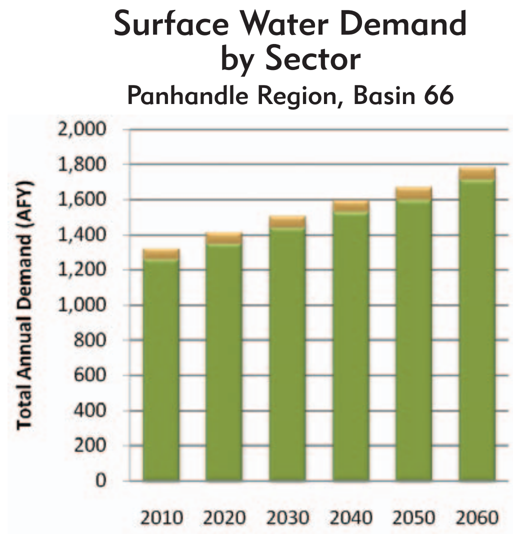
- Allocated withdrawals from the Ogallala bedrock aquifer, underlying the south and east portions of the basin, represent the vast majority of water rights in the basin. There are also water rights from bedrock and alluvial non-delineated groundwater sources. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. Estimated Ogallala aquifer recharge in the basin is 3,000 AFY.
- There are no significant basin-wide groundwater quality issues in the basin.

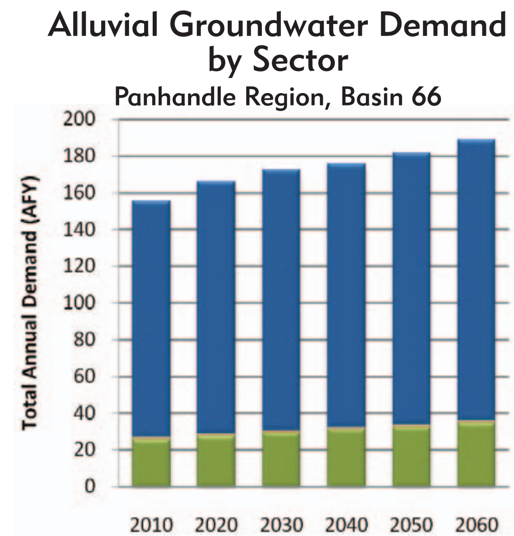
Notes & Assumptions

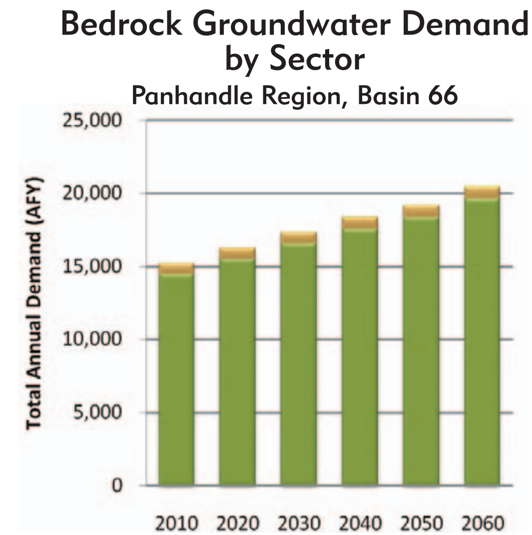
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater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

- Basin 66's water needs are about 4% of the demand in the Panhandle Watershed Planning Region and will increase by 35% (5,770 AFY) from 2010 to 2060. The majority of demand and growth in demand over this period will be in the Crop Irrigation demand sector. Unlike most basins in the state, Basin 66 has no Municipal and Industrial demand.
- Surface water is used to meet 8% of the demand in Basin 66 and is expected to increase by 34% (450 AFY) from 2010 to 2060. The majority of surface water use and growth in the surface water use over this period will be in the Crop Irrigation demand sector.
- Alluvial groundwater supplies about 1% of total demand in the basin, consisting mostly of the Self Supplied Residential demand sector. Alluvial groundwater demand will increase 21% (30 AFY) from 2010 to 2060.
- Bedrock groundwater is used to meet about 91% of the demand in Basin 66 and its use will increase by 35% (5,290 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector.







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

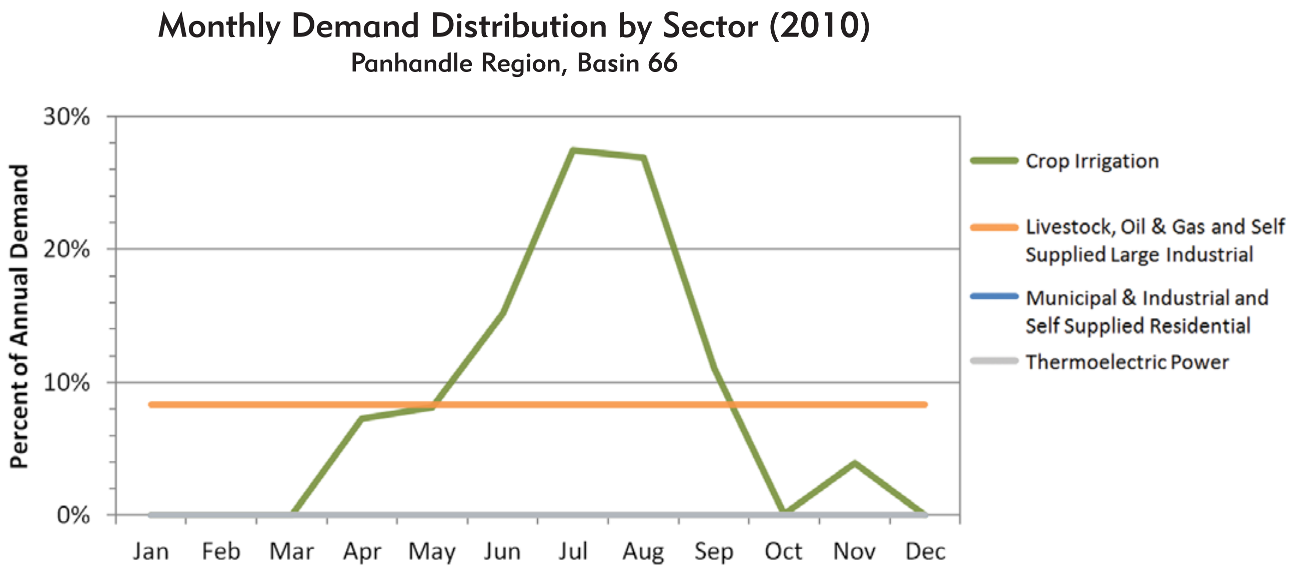
Total Demand by Sector

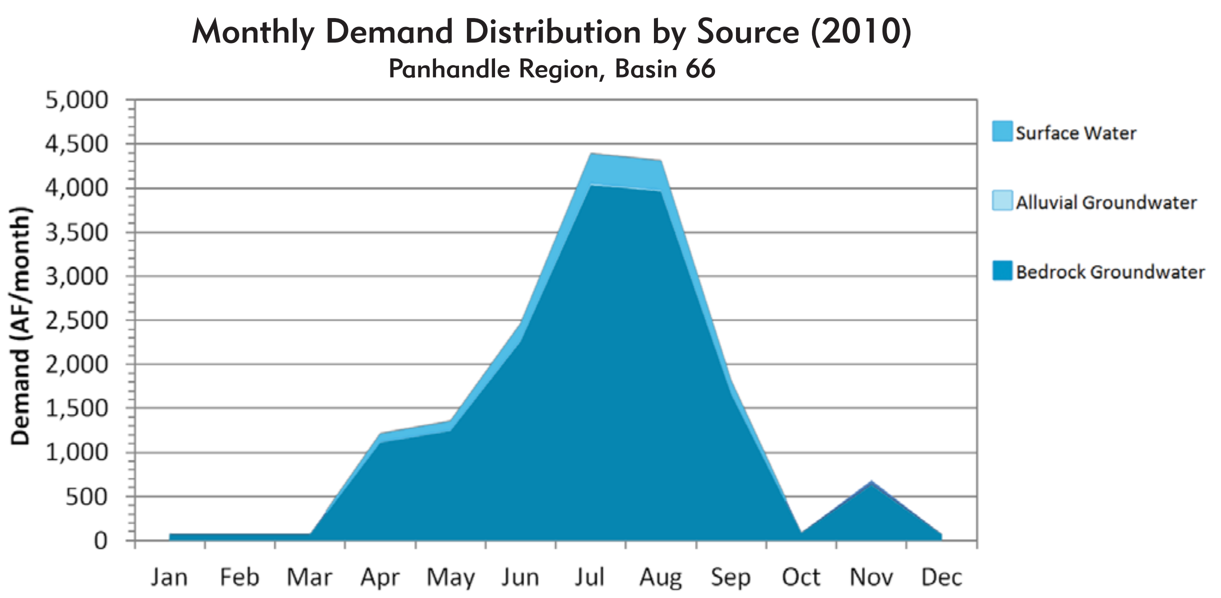
Panhandle Region, Basin 66

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	15,760	800	0	20	0	130	0	16,710
2020	16,890	810	0	30	0	140	0	17,870
2030	18,010	820	0	30	0	140	0	19,000
2040	19,140	840	0	40	0	140	0	20,160
2050	20,010	850	0	60	0	150	0	21,070
2060	21,400	860	0	70	0	150	0	22,480

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Self Supplied Residential demand sector uses 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 total water demand in Basin 66 is 64.7 times the monthly winter demand, which is much more pronounced than the overall statewide pattern. The peak summer month demand for all sources of water is much higher than the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater storage depletions are projected to occur by 2020, while alluvial groundwater storage depletions are expected by 2050.
- Surface water gaps in Basin 66 may occur during the spring, summer, and fall, peaking in size during the summer. Surface water gaps in 2060 will be up to 23% (110 AF/month) of the surface water demand in the peak summer month, and up to 23% (30 AF/month) of the peak spring month's surface water demand. By 2060, surface water gaps will occur in at least one month of every year.
- Alluvial groundwater storage depletions in Basin 66 may occur in the summer. By 2060, there will be a 66% probability of storage depletions occurring in at least one month of the summer.
- Bedrock groundwater storage depletions in Basin 66 may occur in the spring, summer, and fall. Bedrock groundwater storage depletions in 2060 will be up to 26% (430 AF/month) of the bedrock groundwater demand on average in the peak spring month, and 26% (1,430 AF/month) on average of the peak summer month's demand.
- Projected groundwater storage depletions are minimal relative to the amount of water in storage in the aquifers. However, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Panhandle Region, Basin 66

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	30	30	88%
Jun-Aug (Summer)	110	110	74%
Sep-Nov (Fall)	40	20	95%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 66

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	66%
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

Panhandle Region, Basin 66

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
2020	60	0	1,050	98%	0%
2030	150	0	2,080	100%	0%
2040	260	0	3,150	100%	0%
2050	290	10	3,960	100%	53%
2060	400	20	5,230	100%	66%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Panhandle Region, Basin 66

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	430
Jun-Aug (Summer)	1,430
Sep-Nov (Fall)	580

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

Panhandle Region, Basin 66

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	400	20	5,230	100%	66%
Moderately Expanded Conservation in Crop Irrigation Water Use	330	20	4,170	100%	60%
Moderately Expanded Conservation in M&I Water Use	400	20	5,230	100%	66%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	330	20	4,170	100%	59%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	30	0	600	83%	0%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Panhandle Region, Basin 66

Reservoir Storage	Diversion
AF	AFY
100	0
500	0
1,000	100
2,500	100
5,000	200
Required Storage to Meet Growth in Demand (AF)	Insufficient Surface Water Supplies
Required Storage to Meet Growth in Surface Water Demand (AF)	Detailed analysis required

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 gaps by 18% and bedrock groundwater storage depletions by about 20%. Temporary drought management activities will likely be ineffective due to the high probability of gaps and storage depletions each year.

Out-of-Basin Supplies

New out-of-basin supplies could be used to augment in-basin supplies and meet demand. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Panhandle Watershed Planning Region: Englewood and Forgan, both in Basin 65. However, due to the availability of groundwater resources in Basin 66 and distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for some water users in the basin.

Reservoir Use

Reservoir storage is not recommended as a water supply option. A detailed analysis must be conducted to determine the viability of any reservoir in Basin 66. The flow in Basin 66 has been fully permitted, which is expected to severely limit the size and location of new reservoirs. Additionally, the basin is not expected to generate a significant water supply yield. The basin does have small agricultural lakes, but the yields are unknown.

Increasing Reliance on Surface Water

Increased reliance on surface water supplies, without reservoir storage, is not recommended.

Increasing Reliance on Groundwater

Increased reliance on bedrock groundwater supplies may mitigate surface water gaps and alluvial groundwater storage depletions but bedrock storage depletions will be increased. There is more than 2.4 million AF of storage in Basin 66's portion of the Ogallala aquifer. Any increases in storage depletions would be minimal relative to the volume of water in stored in the portion of the Ogallala aquifer underlying the basin. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs. Increasing the use of alluvial groundwater beyond the current proportion is not recommended without detailed analysis since there are no delineated alluvial aquifers in the basin.

Notes & Assumptions

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

Glossary

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

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

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

Alluvial groundwater: water found in an alluvial aquifer.

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

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

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

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

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

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

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

Basin: see Surface water basin.

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

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

Bedrock groundwater: water found in a bedrock aquifer.

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

Board: Oklahoma Water Resources Board.

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

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

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

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

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

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

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

CWSRF: see State Revolving Fund (SRF).

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

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

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

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

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

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

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

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

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

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

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

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

DWSRF: see State Revolving Fund (SRF).

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

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

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

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

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

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

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

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

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

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

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

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

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

Groundwater recharge: see Recharge.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Potable: describing water suitable for drinking.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Withdrawal: water removed from a supply source.

AF: acre-foot or acre-feet

AFD: acre-feet per day

AFY: acre-feet per year

BMPs: best management practices

BOD: biochemical oxygen demand

cfs: cubic feet per second

CWAC: Cool Water Aquatic Community

CWSRF: Clean Water State Revolving Fund

DO: dissolved oxygen

DWSRF: Drinking Water State Revolving Fund

EPS: equal proportionate share

FACT: Funding Agency Coordinating Team

gpm: gallons per minute

HLAC: Habitat Limited Aquatic Community

HQW: High Quality Waters

HUC: hydrologic unit code

M&I: municipal and industrial

MAY: maximum annual yield

mgd: million gallons per day

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

mg/L: milligrams per liter

NLW: nutrient-limited watershed

NPS: nonpoint source

NPDES: National Pollutant Discharge Elimination System

NRCS: Natural Resources Conservation Service

NTU: Nephelometric Turbidity Unit (see "Turbidity")

OCWP: Oklahoma Comprehensive Water Plan

ODEQ: Oklahoma Department of Environmental Quality

O&G: Oil and Gas

ORW: Outstanding Resource Water

OWQS: Oklahoma Water Quality Standards

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

pH: hydrogen ion activity

ppm: parts per million

RD: Rural Development

REAP: Rural Economic Action Plan

SBCR: Secondary Body Contact Recreation

SDWIS: Safe Drinking Water Information System

SRF: State Revolving Fund

SSI: Self-Supplied Industrial

SSR: Self-Supplied Residential

SWS: Sensitive Water Supply

TDS: total dissolved solids

TMDL: total maximum daily load

TSI: Trophic State Index

TSS: total suspended solids

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WLA: wasteload allocation

WWAC: Warm Water Aquatic Community

Water Quantity Conversion Factors

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

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

CFS: cubic feet per second
GPM: gallons per minute
MGD: millions gallons per day

AFY: acre-feet per year
AFD: acre-feet per day

1 acre-foot: 325,851 gallons

Sources

AMEC Earth & Environmental. (2011). *Climate Impacts to Streamflow*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2009). *Programmatic Work Plan*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2009). *Provider Survey Summary Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2010). *Artificial Aquifer Recharge Issues and Recommendations*. Data and technical input provided by the OCWP Artificial Aquifer Recharge Workgroup. Commissioned by the Oklahoma State Legislature in 2008 and published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2010). *Conjunctive Water Management in Oklahoma and Other States*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2010). *Marginal Quality Water Issues and Recommendations*. Data and technical input provided by the OCWP Marginal Quality Water Workgroup. Commissioned by the Oklahoma State Legislature in 2008 and published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Conservation and Climate Change (Water Demand Addendum)*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Drinking Water Infrastructure Needs Assessment by Region*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Physical Water Supply Availability Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Public Water Supply Planning Guide*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Water Demand Forecast Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Water Supply Hot Spot Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Water Supply Permit Availability Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

C.H. Guernsey & Company. (2010). *Reservoir Viability Study*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

C.H. Guernsey & Company. (2011). *Water Conveyance Study*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

FirstSouthwest Bank. (2011). *Infrastructure Financing Needs and Opportunities*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

INTERA. (2011). *Instream Flow Issues and Recommendations*. Data and technical input provided by the OCWP Instream Flow Workgroup. Published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Climatological Survey. (2010). *Climate Issues and Recommendations*. Published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Department of Environmental Quality. (2008). *Integrated Water Quality Assessment Report*. Published by the Oklahoma Department of Environmental Quality. Available online at http://www.deq.state.ok.us/wqdnew/305b_303d/ (October 2011).

Oklahoma State University Division of Agriculture Sciences and Natural Resources (DASNR). (2011). *Agricultural Water Issues and Recommendations*. Commissioned by the Oklahoma Water Resources Board and the Oklahoma Department of Agriculture Food and Forestry as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (1980). *1980 Update of the Oklahoma Comprehensive Water Plan*. Published by the Oklahoma Water Resources Board. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (1995). *1995 Update of the Oklahoma Comprehensive Water Plan*. Published by the Oklahoma Water Resources Board. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2007). *Oklahoma Water Atlas*. Published by the Oklahoma Water Resources Board.

Oklahoma Water Resources Board. (2011). *2012 OCWP Executive Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as the principal report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Beaver-Cache Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2009). *Beneficial Use Monitoring Program Report*. Published by the Oklahoma Water Resources Board. Available online at http://www.owrb.ok.gov/quality/monitoring/bump.php (October 2011).

Oklahoma Water Resources Board. (2011). *Blue-Boggy Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Central Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Eufaula Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Grand Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Lower Arkansas Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Lower Washita Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Middle Arkansas Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Oklahoma Statewide Water Quality Trends Analysis*. Published by the Oklahoma Water Resources Board as a supplement to the 2012 Update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Panhandle Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Southeast Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Southwest Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Upper Arkansas Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Water Policy and Related Recommendations for Oklahoma*. Published by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Water Quality Issues and Recommendations*. Analysis provided by the OCWP Water Quality Workgroup. Published by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *West Central Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Robertson, Lindsay. *Tribal Water Issues and Recommendations*. (2011). Commissioned through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Wahl, Kenneth L.; Tortorelli, Robert L. *Changes in Flow in the Beaver-North Canadian River Basin Upstream from Canton Lake, Western Oklahoma*. (1997). WRI; 96-4304 Published by the United States Geological Survey. Available online at http://pubs.usgs.gov/wri/wri964304/.