MISSOURI WATER RESOURCES PLAN

UPDATE 2020

MISSOURI WATER RESOURCES PLAN

FOREWORD

As we approach the celebration of the bicentennial of Missouri's statehood, we are mindful that ours is a state born from great waters. The Mississippi and Missouri rivers are the strong roots from which the state first grew; first along the Mississippi and then up the muddy Missouri and into the West. Our rivers have been highways for American Indian migration and commerce, fur traders, explorers, Lewis and Clark, and the great riverboats of Mark Twain. Now they are commercial arteries on which we ship the fruits of our soil to the world. From the big rivers to the plains streams of the north, the clear rivers and springs of the Ozarks, and the precious water below the ground, the history of Missouri is profoundly intertwined with its water resources. So too is Missouri's future.

As Missouri enters its third century, it is more important than ever that we plan for the future of our water. The importance of water to the life of the state cannot be overstated. Water is vital for agriculture, industry, commerce, drinking water supply, transportation, recreation, and wildlife. The Missouri Water Resources Plan is an important component of Missourians' overall water planning efforts.

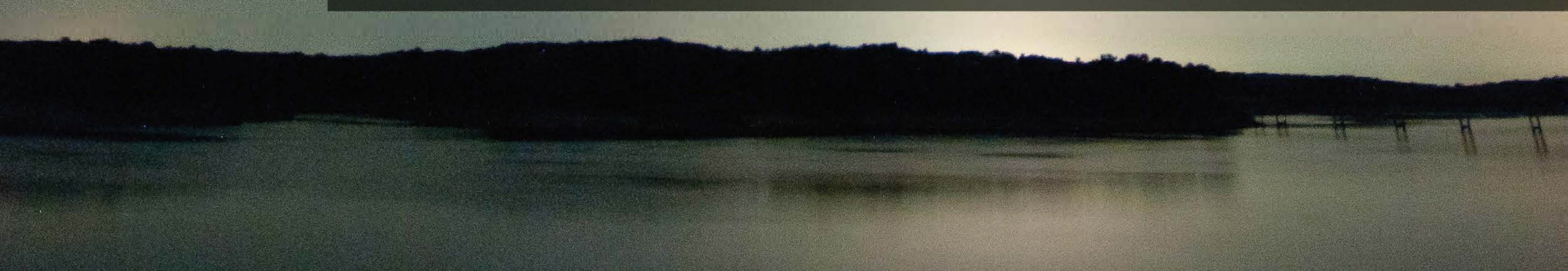
As we celebrate Missouri's water resources, we recognize that we face many challenges. It is imperative that we understand how much water we have and how much we need. Our state is fortunate to have abundant water both above and below the ground, but it is often not available when and where we need it. Additionally, approximately 1.4 million more people will call Missouri home by 2060. As our population and economy grow, so will the amount of water we need. As our cities and towns grow, much of the underlying water infrastructure will be nearing the end of its expected life. Both this aging infrastructure and the regional infrastructure needed to store and move water will require investments of more than $20 billion by 2035.

With the challenges that we face, we must continue our planning efforts at the local, state, and federal level. The Missouri Water Resources Plan explores our current and future water supplies and demands, unique subregion characteristics, infrastructure needs, available options for meeting needs, planning methods, and possible future scenarios. The plan provides key findings and recommendations for actions that the state can take to address the identified issues. We look forward to working to implement those recommendations.

We would like to thank our partners—the U.S. Army Corps of Engineers, the many Interagency Task Force members, the technical workgroup members, and other stakeholders—who provided us with their indispensable input, and the Missouri General Assembly for their support and for making the waters of our state a priority.

We hope that the Missouri Water Resources Plan will be a valuable map to guide water providers, decision-makers, and the people of Missouri as we navigate into our future.

Dru Buntin
Deputy Director
Missouri Department of Natural Resources



ACKNOWLEDGMENTS

The Missouri Department of Natural Resources (MoDNR) gratefully acknowledges the planning, technical and engineering expertise provided by CDM Smith, the University of Missouri (Rob Kallenbach and Ryan Lock), and the following agencies and specific individuals: the Missouri Water Resources Center (Jennifer Hoggatt, Michael Weller), the U.S. Army Corps of Engineers – Kansas City District (Kaely Megaro and Jennifer Henggeler), the U.S. Army Corps of Engineers – Little Rock District (Jaysson Funkhouser), and the U.S. Geological Survey (Brian Clark).

MoDNR appreciates the support from other private, state, and federal partners in the development of the Missouri Water Resources Plan (WRP) update.

Special thanks go out to Missouri agencies and citizens, who contributed their considerable time, intellect, and unique perspectives to the Missouri WRP process.

MoDNR would also like to thank those agency employees primarily responsible for the development and organization of the Missouri WRP, particularly Scott Kaden, Rob Hunt, Bryan Hopkins, John Horton, Charles DuCharme, Matthew Kirsch, Emma Schneider, Bob Bacon, Zackary Becker, and Jessica Becklenberg.

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Missouri Water Resources Plan 2020 Update
EXECUTIVE SUMMARY

The Missouri Water Resources Plan (Missouri WRP) is built upon technical analysis of water demands, supply availability, water budgets, infrastructure evaluation, funding, scenario planning, and adaptive management. The key findings and recommendations described in this section are the culmination of efforts of the Missouri Department of Natural Resources (MoDNR) and statewide technical workgroups. The technical workgroups helped to identify and prioritize water issues and options for resolving the identified gaps and stresses on water supplies in the state.

INTRODUCTION

More than any other natural resource, clean water is crucially important for Missouri. Water sustains urban and rural populations alike, and supports the state's vital agricultural industry. Water is relied upon to generate power, sustain navigation, and support numerous environmental and recreational uses. Without access to water, quality of life in Missouri would be threatened and the state's economy would cease to grow.

The Missouri and Mississippi rivers provide water supply and navigation for the eastern and central, and northwestern portions of the state. Other rivers and lakes have been developed by the U.S. Army Corps of Engineers (USACE) to provide flood control and water supply storage within Missouri, as shown in **Figure ES-1**.

Although Missouri is fortunate to have rich water resources, localized shortages do exist because of the distance from adequate supplies, insufficient infrastructure or storage, water quality constraints, and other limiting factors. In many areas, surface water supplies are subject to seasonal fluctuations; supplies are frequently at their lowest when demand is the highest. The ability to store water in reservoirs—integral to surface water availability—can help to mitigate the impacts of drought episodes and other water emergencies. Groundwater supplies, particularly bedrock aquifers, are

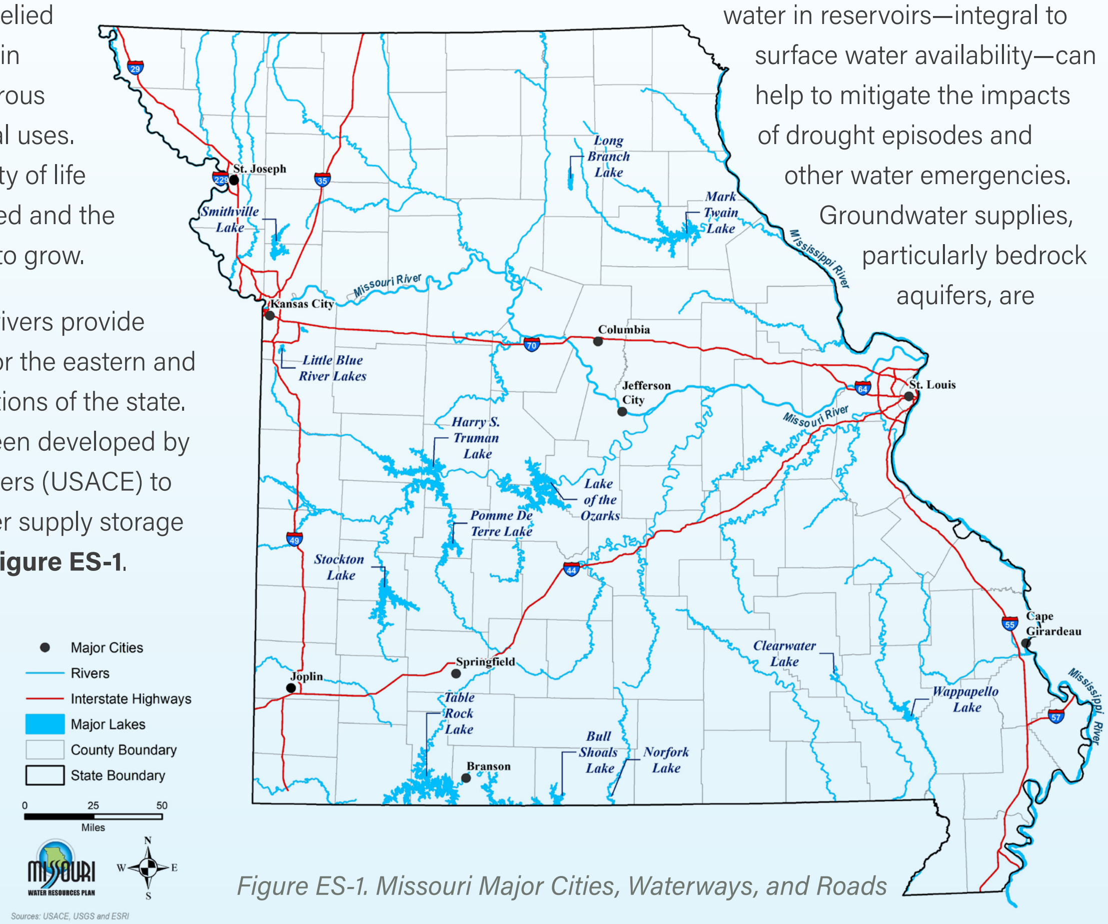


Figure ES-1. Missouri Major Cities, Waterways, and Roads less susceptible to seasonal fluctuations. In shallow alluvial aquifers, the aquifers and overlying streams can be linked hydrologically, with each resource impacting the other.

The Missouri WRP is a long-range, comprehensive strategy to provide an understanding of the existing use of and future need for Missouri's water resources. It will help ensure that the quantity of Missouri's water resources will meet future demands by identifying future shortfalls in water supplies and exploring options to address those water needs. Developing a water resources plan prepares Missouri for water delivery in the face of stresses on supply caused by future uncertainties such as climate, drought, increasing demand, and supply disruption. It is imperative to look to the future and prepare for water needs. The Missouri WRP approach is shown in **Figure ES-2**.

Figure ES-2. Missouri Water Resources Plan Approach

In 2016, the MoDNR Water Resources Center initiated this update to the Missouri WRP in partnership with USACE. The USACE partnership is achieved through their Planning Assistance to States (PAS) authority (Section 22 WRDA 1974 P.L. 93-251). This provides authority for USACE to assist states financially and technically in preparing comprehensive plans for the development and conservation of water and related land resources.

MoDNR has the statutory authority in Section 640.415 of the Revised Missouri Statutes, to develop, maintain, and periodically update a state water plan for a long-range comprehensive statewide program for surface water and groundwater uses in the state (Missouri Revisor of Statutes 2019).

WATER RESOURCES PLAN GOALS AND OBJECTIVES

The following goals and objectives are addressed in the Missouri WRP:

- Evaluate current and future groundwater and surface water availability
- Evaluate the needs of all water users, such as drinking water suppliers, agriculture, industry, navigation, and recreation
- Develop projected water supply needs through the year 2060, taking into account projected population changes, new or increasing industry demands, and hydrologic conditions
- Identify gaps in water availability based on water use projections
- Identify water and wastewater infrastructure needs, funding, and financing opportunities
- Identify impacts affecting water availability
- Outline a series of strategies to meet Missouri's water needs
- Identify gaps in water-related datasets

STAKEHOLDER PROCESS

The Missouri WRP included several key stakeholder engagement activities to promote and seek input on the plan as it was being created. These activities included regularly scheduled meetings of water resources stakeholders and agency representatives. In addition, MoDNR staff helped build awareness of the update to the plan through public presentations throughout the state of Missouri. Information on these stakeholder meetings, presentations, notes, and brochures is available on the Missouri WRP website (https://dnr.mo.gov/mowaterplan/).

INTERAGENCY TASK FORCE

Interagency Task Force Meetings:

- February 24, 2016
- November 28, 2017
- May 31, 2018
- November 29, 2018
- May 30, 2019
- November 6, 2019

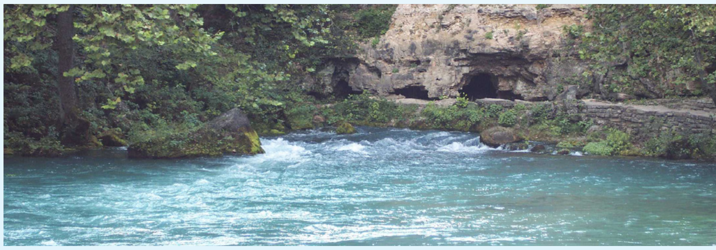
The Water Resources Law, Section 640.430, Revised Statutes of Missouri, directs MoDNR to establish an Interagency Task Force (IATF) to promote coordination among state departments and water resource stakeholders, ensure surface water and groundwater resources are maintained at the highest level practicable, and support present and future uses. The IATF serves as an advisory group for the Missouri WRP, providing guidance and direction. MoDNR coordinated with the IATF biannually throughout the duration of the Missouri WRP development.

TECHNICAL WORKGROUPS

Five technical workgroups were established by water plan topic area: Consumptive Needs, Nonconsumptive Needs, Infrastructure Needs, Agricultural Needs, and Water Quality. The technical workgroups met on 12 dates in various configurations over a two and a half year period. The objectives of the technical workgroups were to provide guidance on technical analyses, give feedback to the development of technical products, identify and prioritize water resource issues, and provide recommendations on how to address those issues.


IATF Meeting


Technical Workgroup Presentation



RECOMMENDATIONS

Throughout the development of the Missouri WRP, analysis and synthesis has led to several key findings. These key findings have identified both challenges and opportunities related to water resources in Missouri, which lead to the following recommendations. The recommendations are grouped by type: **planning**, **implementation**, **funding**, and **data**. The region(s) of the state are listed following each recommendation that would benefit the most if the recommendation were implemented.

Wakonda State Park near La Grange in northeast Missouri

PLANNING

Prepare for droughts by updating the state drought plan and encouraging water supply systems to develop drought contingency plans. statewide

- Update the state's drought mitigation and response plan. Include specific actions to take and resources available.
- Encourage water supply systems to develop and implement drought contingency/management plans. Effective plans are developed before drought occurs and help identify trigger points and responses to extend critical water supplies; identify alternative water sources; establish interconnections; develop education programs and demand reduction strategies; define implementation and enforcement mechanisms; and address water conservation during drought conditions.
- Continue MoDNR's program of conducting yield studies of Missouri's drinking water reservoirs based on updated bathymetric surveys. These studies and surveys give water systems an accurate and updated assessment of how long their water supplies will last during a drought, and give them an estimate of the sedimentation rate in their reservoirs.

Support regional planning groups to collaboratively address water resource challenges specific to a river basin, subregion, or watershed. statewide

To best accomplish the task of understanding and planning for water resource concerns and challenges, support regional planning groups to identify and address the unique needs and issues faced within a river basin or subregion. These regional groups should be nonregulatory and consist of local stakeholders and appropriate agency representatives. It is possible that regional planning commissions can fill this role. The goal of the regional groups will be to guide planning initiatives, collaborate on issues of mutual interest, and provide associated local and regional input directly to MoDNR and other water management agencies. MoDNR should consider assisting stakeholders in developing a framework for the regional planning groups, including delineation of the geographic boundaries, membership, organization, duties and responsibilities, funding mechanism, and extent of authority. Regional planning groups should not be constrained by state boundaries where resources are shared across multiple states.

Focus resources to pursue water-related studies where additional information is needed to address water supply availability and reliability at a watershed, regional or metropolitan level. statewide

Studies that should be considered include:

- Reliability of local water supply.
- Bathymetry of water supply reservoirs.
- Evaluation of aging water infrastructure and water loss.
- Cost-effectiveness and viability of reuse in Missouri.
- Cost-effectiveness and viability of advanced treatment techniques (i.e., reverse osmosis) to treat brackish groundwater in northern Missouri.
- Methods to maximize the use and efficiency of water needed to support Missouri's agriculture.
- Interaction between the Missouri and Mississippi rivers' alluvial aquifer and the river flow and water quality.

Track ongoing agriculture industry initiatives to anticipate future agricultural water supply needs. statewide

Recognizing Missouri's successful and vital agriculture industry, continue to work with representatives of the agriculture industry to maximize and protect water supplies. Continue to support and understand future agricultural initiatives including the expansion of agricultural-based food processing and the associated water needs.

Support integrated water resources planning in areas where water shortages exist and solutions are limited or unclear. statewide

Promote and support integrated water resource planning to identify and implement water management solutions on a local or regional scale to increase self-reliance and water security. Integrated planning identifies strategies to diversify and develop alternative water supplies, while protecting the environment and increasing resiliency to droughts and climate change. Where localized groundwater level declines and shortages exist in northwest and southwest Missouri, water providers may benefit from the coordinated conjunctive use of both surface and groundwater to meet demands. Track and monitor localized declines in the Ozark Aquifer in southwest Missouri. Grants could be provided to support planning initiatives that incorporate these principles.


Missouri River

IMPLEMENTATION

Encourage and promote water conservation as a viable option within a water supply portfolio to meet municipal and industrial (M&I) water supply needs. Effective and sustained water conservation programs help defer investment in additional sources. statewide

Potential measures that should be considered include:

- Encourage local plumbing codes for water efficiency.
- Promote conservation-focused rate structures.
- Increase awareness of the cost effectiveness of replacing aging infrastructure and implement incentives that reduce water losses through leak detection and distribution system renovation.
- Initiate and develop education programs that modify and improve consumer water use habits.
- Establish statewide conservation guidelines for drought conditions.

Optimize use of existing reservoir storage and develop additional reservoir storage where existing supplies are limited. northern and southwest Missouri

Portions of Missouri would benefit from additional storage to maintain water supplies during prolonged shortages or drought. Potential measures that should be considered include:

- Utilize storage already available for M&I use in federal reservoirs.
- Conduct bathymetric surveys.
- Evaluate when and where dredging may be feasible.
- Reallocate storage in federal reservoirs where storage is not allocated for M&I supply.
- Evaluate new reservoirs.
- Expand existing reservoirs.

Promote and support regionalization and consolidation, especially in areas where technical, managerial, and economic resources are limited and source waters are difficult to develop. statewide; northern and southwest Missouri

Regionalization, in either structural or nonstructural form, refers to the alliance of two or more water systems to improve planning, operation, and management of the systems. Regionalization has proven successful in working toward solutions to water and wastewater infrastructure and supply challenges across northern and southwest Missouri. This may also include the sizing of conveyance based on supply availability. The state could further advance regionalization by implementing a campaign targeted at the areas of need that includes dissemination of information and roundtable events, and by designating a representative to answer questions and guide water systems through the process. Projects that include regionalization as a component could be given funding priority.

Invest in improving the reliability of water supply for livestock, concentrated animal feeding operations and pasture production during periods of drought. northern Missouri

Local, state, and federal agencies should continue to work together with livestock producers to invest in restoring existing surface water impoundments and creating new impoundments and/or developing additional infrastructure such as emergency connections on farm storage tanks or new groundwater wells as a proactive approach to alleviating future shortages. Local, state, and federal agencies should work jointly to create new cost-sharing opportunities including grant programs, where gaps exist for investing in resilient livestock water supply. This is of critical importance in northern Missouri where drought threatens livestock water supplies.

Continue to work with USACE to support navigation and protect vital water supplies along the Missouri and Mississippi rivers to ensure Missouri's water needs are met. **northern and central Missouri**
Coordinate with USACE in continued monitoring of bed degradation along portions of the Missouri River and track impacts to water supply intakes for municipal needs and navigation on the River.

Continue dialogue with neighboring states and federal agencies with respect to interstate water issues. **statewide**
In addition to water from precipitation falling within the state, Missouri relies on flows entering the state. Missouri also provides flow to rivers leaving the state. State and regional water planning groups should continue to maintain a dialogue on water-related challenges and opportunities to meet current and future water needs.

Manage water resources to optimize the opportunities for nonconsumptive water needs such as navigation, power generation, recreation, aquaculture, and fish and wildlife. **statewide**
Missouri should continue to manage water resources to optimize opportunities for navigation, power generation, recreation, aquaculture, and fish and wildlife. The state should consider a program to quantify nonconsumptive needs and focus efforts on quantifying water needs that are more difficult to estimate.

Document and monitor regional projects that improve water supply reliability. **statewide**
MoDNR should continue to document and monitor regional water supply projects that improve reliability, resiliency, and sustainability. MoDNR should evaluate the effects and implications of the projects on the water resources within the state. The state should develop and maintain a list of these projects.

St. Francois State Park

Using the adaptive management approach, continue to monitor and assess key risk triggers and identify support (through funding or other means) for projects that mitigate risk to water resources. **statewide**
The Missouri WRP details a variety of possible future scenarios, identifies various risk triggers, and presents an adaptive management framework to address future water needs as they arise. Risk triggers have been developed and should continue to be refined to monitor changes in water demands, climate variability, water treatment needs and levels, supply constraints, and reservoir regulation and allocation. Local, state, and regional agencies and water managers should continue to review, follow, and update this framework to address the challenge of balancing underperformance and overinvestment of water infrastructure.

Increase coordination between MoDNR divisions and programs and across other state agencies. **statewide**
In Missouri, water issues are overseen by several agencies within the state. Recognizing the benefits of coordinated planning, state agencies should work together to share information and avoid duplication on water resources-related activities as opportunities arise.

FUNDING

Continue to leverage existing state and federal programs to finance water and wastewater infrastructure. statewide

To meet Missouri's significant drinking water and wastewater infrastructure needs, water and wastewater utilities should continue to leverage existing state and federal programs to supplement local funding and grants. MoDNR's Financial Assistance Center (FAC) offers grants and loans to utilities for planning, financing, and constructing water infrastructure projects. Projects that may need funds beyond what can be offered by FAC may consider using the Multipurpose Water Resource Fund (MPWRF). The MPWRF focuses on funding projects that provide a long-term, reliable public water supply, treatment, or transmission facility in an area that exhibits significant need. In addition to assisting utilities with current fund opportunities, MoDNR should continue to identify and track emerging federal funding opportunities. These funding opportunities should be promoted in order to raise awareness throughout the state.

Offer and promote programs to educate utilities on effective rate setting that allows for replacement and expansion of infrastructure. statewide

MoDNR and other agencies should continue to offer or promote training to utilities and communities that focuses on effective rate setting and establishment of asset management programs. Regional water infrastructure funding workshops are offered through MoDNR's FAC. Trainings should continue to address the unique needs of both small and large water and wastewater providers. Utilities need to establish rates that remain affordable but account for infrastructure replacement and expansion. Asset management provides utility managers information on capital assets, the timing of investments, and allows for more informed rate setting to ensure financial capacity for needed replacement, repair, rehabilitation and expansion of infrastructure.

Provide continued funding for Missouri WRP implementation. statewide

The state legislature has appropriated $1 million annually for Missouri WRP implementation activities. This funding will help MoDNR address water resources challenges throughout the state and help the communities that face those issues. Such reliable funding is invaluable to maintaining the momentum of the program and should be continued.


Sunset over Mark Twain Lake

DATA

Increase data and information collection to better support decision-making and to defend Missouri's rights to water. statewide

Focus resources on the following:

- Enhance and improve the data collected through MoDNR's major water users program and other programs to better establish and track Missouri's demand for water.
- Enhance data reporting with respect to agricultural groundwater use and agricultural irrigation demands. Identify opportunities to improve measurement and reporting.
- Continue to maintain the groundwater well observation network. Expand the network to fill data gaps where significant local or regional water level declines are expected or observed.
- Expand the streamflow gage network in partnership with the United States Geological Survey (USGS) to address data gaps, especially in northern Missouri where drought impacts have been observed and surface water is the primary source of supply.
- Continue efforts to expand soil moisture monitoring infrastructure in Missouri.
- Engage with USGS to review, validate, update, and enhance, where necessary, the Ozark Aquifer System groundwater model to better support local and regional water resources planning.
- Collect data to better characterize water and wastewater infrastructure across the state (e.g., size, extent, age) to identify funding needs, evaluate resiliency, and promote economic growth and development.
- Collect data to better understand existing interconnections between water systems. This may include geographic information system data of water infrastructure to identify existing and potential future interconnections.

PHYSICAL SETTING

In order to understand the water resources in Missouri, it is beneficial to understand the physical setting of the state as represented below.

LOCATION AND CLIMATE

Missouri is located in the Midwestern United States and encompasses approximately 69,707 square miles (U.S. Geological Survey [USGS] 2018). Missouri is divided into 114 counties and the City of St. Louis, which is a separate entity outside of any county.

Winter temperatures in Missouri are cool, with lows typically below freezing. Mean January minimum temperatures, which follow a northwest-to-southeast gradient, range from 12 degrees Fahrenheit (°F) in the northwest to 24°F in the southeast. Summers, conversely, include stretches of hot, humid weather that are broken up by occasional periods of dry-cool weather. Mean July maximum temperatures show little geographic variation throughout the state and range from 87 to 90°F (Decker 2018).

Mean annual precipitation varies along the same northwest-to-southeast gradient as winter temperatures, ranging from less than 34 inches in the northwest to over 46 inches in the southeast. Seasonal precipitation varies widely throughout the state. In northwestern Missouri, summer precipitation is five times greater than winter precipitation, whereas in southeastern Missouri, seasonal variation in precipitation is minimal because of the influence of subtropical air masses throughout the year (Decker 2018).

Most snow in Missouri falls in December, January, and February, although snow may fall as early as October and as late as May. North of the Missouri River, annual snowfall averages 18 to 24 inches, whereas annual snowfall averages 8 to 12 inches in the southernmost counties (National Oceanic and Atmospheric Administration 2017).

SUBREGION DRAINAGE BASINS

Missouri can be divided in to nine subregions based on surface hydrology. Each subregion represents a major drainage basin that corresponds to a USGS 4-digit hydrologic unit code (HUC 4), as shown in **Figure ES-3**. While only the Missouri portion of each subregion is shown in the figure, all nine of Missouri's subregions extend into one or more neighboring states. Subregions are comprised of numerous basins, subbasins, watersheds, and subwatersheds that correspond to other hydrologic unit classifications. Within each subregion, the geologic structure, landforms, climate, vegetation, and soil types all influence the availability and quality of water.

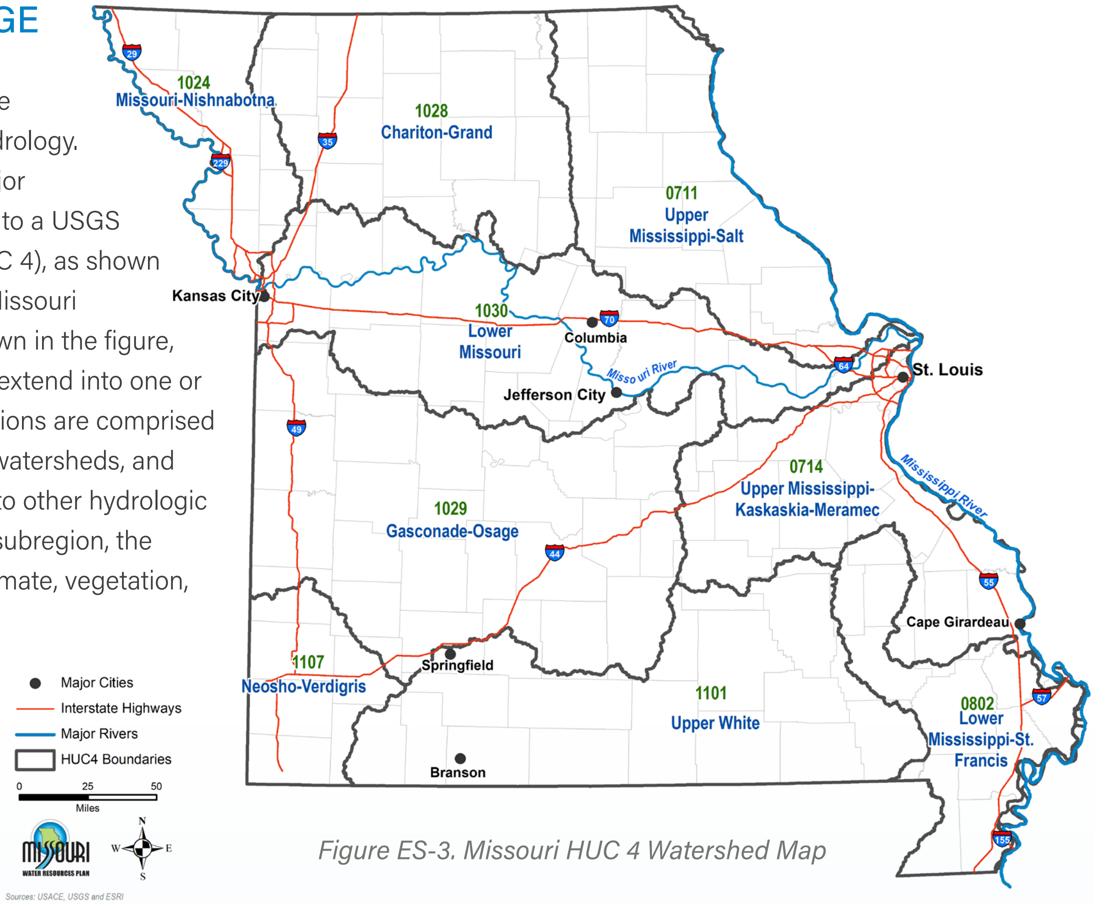


Figure ES-3. Missouri HUC 4 Watershed Map

GROUNDWATER PROVINCES

Groundwater provinces are delineated in Missouri based on aquifer boundaries, aquifer types, groundwater quality, and distinct geologic features. There are seven distinct groundwater provinces defined in Missouri, as shown in **Figure ES-4**. These seven groundwater provinces include the St. Francois Mountains, Salem Plateau, Springfield Plateau, Southeastern Lowlands, Northeastern Missouri, Northwestern Missouri, and West-Central Missouri. The alluvial valleys of the Mississippi and the Missouri rivers are distinct subprovinces located in and across the seven primary groundwater provinces found in the state.

Major aquifers are used to describe the availability of groundwater resources in Missouri within the nine subregions and seven groundwater provinces. The major aquifers are referenced throughout the Missouri WRP. Water demands are developed at the county level and then aggregated according to the major aquifers to identify potential gaps between water supply and demands.

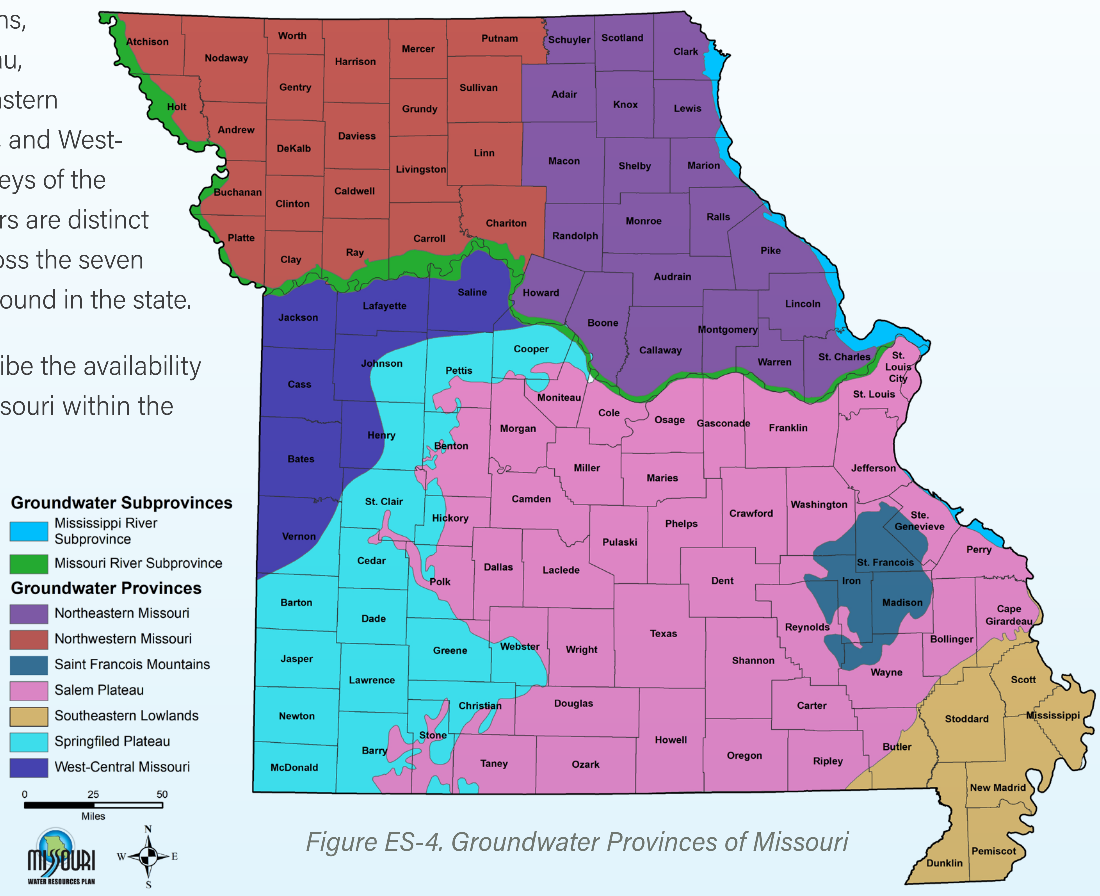


Figure ES-4. Groundwater Provinces of Missouri

DEMANDS

To manage and plan for Missouri's future water resources, it is critical to have an understanding of how water is currently used across the state now and how that might change into the future. The demand for water is driven by the people, establishments, and economic sectors that rely on it for drinking water, personal hygiene, sanitation, filling swimming pools, washing cars, keeping lawns green, producing food, creating electricity, business uses, and manufacturing processes, just to name a few. On average, the 6.1 million people and numerous businesses in Missouri consume 3.2 billion gallons of water each day. Of that demand, 78 percent is supplied by groundwater, while the remaining 22 percent is supplied by surface water as shown in **Figure ES-5**. Statewide, agriculture irrigation comprises the largest portion of consumptive water withdrawals at 65 percent, major water systems makes up an additional 25 percent, and the remaining sectors represent a combined 10 percent of annual withdrawals as shown in **Figure ES-6**. Based on growth in population, employment, and expansion of agriculture irrigation and other business sectors, statewide consumptive demand is forecasted to increase by 18 percent or 583 million gallons per day (MGD) by 2060 as shown in **Figure ES-6**. Agriculture irrigation and major water systems remain the largest consumers of water in 2060. Expressing demands as an average in MGD is useful, but these demands have a distinct seasonal pattern that peak during the summer months when outdoor water use at homes and businesses and on irrigated farmland is the greatest.

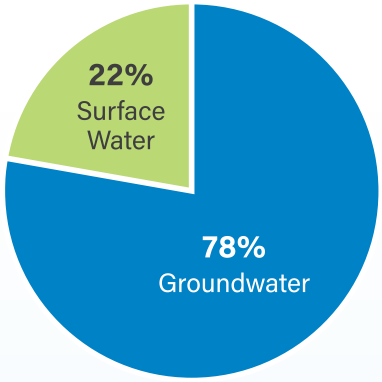


Figure ES-5. Current Water Consumption by Source of Water

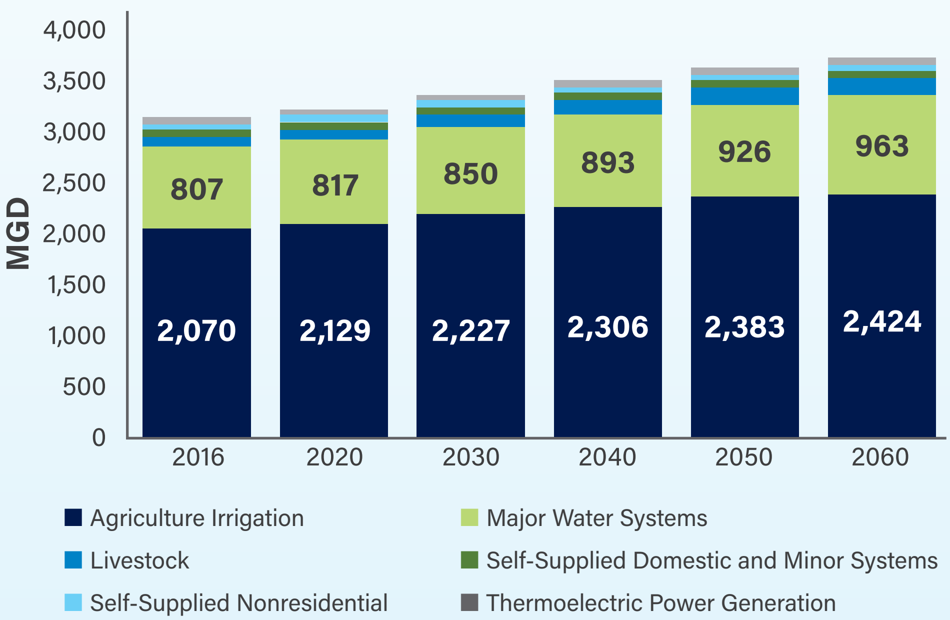
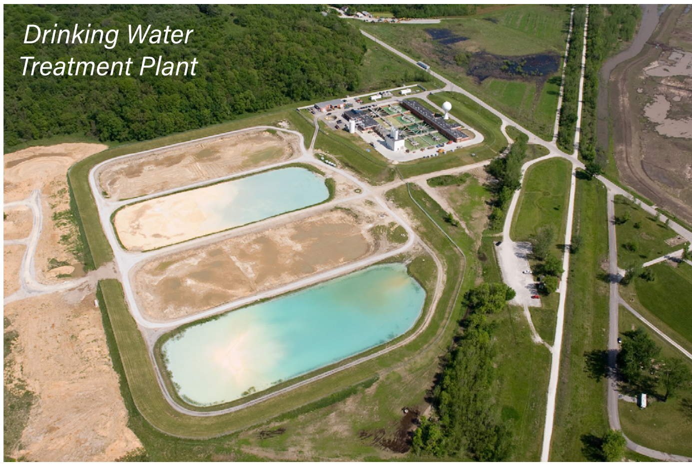


Figure ES-6. Current and Future Water Consumption by Sector

Water demands vary geographically across the state. Driven heavily by agriculture irrigation, the counties

Water Storage



Drinking Water Treatment Plant

Missouri River near Kansas City

Kansas City Water Plant Intake

estimated to have the greatest consumptive water demand are Butler, Dunkin, New Madrid, Pemiscot, and Stoddard. These same counties have the greatest growth in demand by 2060 due to projected increases in crop irrigation. Clusters of high consumptive demand are also found around urban areas and urban clusters. Population in Missouri is projected to increase from 6.12 to 7.48 million by 2060 (22 percent) (Woods & Poole Economics, Inc. 2017).

Projected population growth varies significantly across the state. The highest growth rate is projected in the Ozark area. The seven counties surrounding Springfield (Christian, Dallas, Greene, Polk, Stone, Taney, and Webster) are projected to grow by a combined 58 percent from 2016 to 2060. The Kansas City area, which is comprised of Cass, Clay, Jackson, Platte, and Ray counties, is projected to grow by more than 350,000 people (31 percent). Boone County, where Columbia and the University of Missouri are located, is projected to grow by nearly 135,000 people (76 percent).

St. Louis County is projected to have a stable population through 2060 while St. Louis City is projected to decline in population by 26 percent over that same period. St. Charles, Lincoln, Jefferson, and Warren counties are all projected to grow significantly by 2060 (70, 62, 49, and 41 percent, respectively).

Camden County, the primary county where the Lake of the Ozarks is located, is projected to grow by 25,500 people (57 percent). Most of the northern part of the state is projected to have a slight to significant decrease in population over the next 40 years. The same is true of several counties in the southeastern most region of the Missouri Bootheel. The 2060 growth in population, employment, industry, livestock, energy production, and irrigated acres drives the demand for water up and will result in projected increases in water use.

Not all demand for water uses it in a way that makes the water unavailable for other uses (that is, consumptive demand). Nonconsumptive demand refers to water that is withdrawn from the source or required in the stream, river, or lake to support the demand but is not consumed and remains available for other uses. While the water required for these sectors is more difficult to quantify, the importance of clean, ample water to support these uses cannot be understated. Examples of nonconsumptive uses include:

- **Hydropower Generation** – Hydropower refers to the energy generated by passing water through turbine systems to generate electric power. Hydropower is Missouri's leading renewable energy source, accounting for roughly 65 percent of renewable resource electricity generation.
- **Commercial Navigation** – In-stream water for transporting barges and boats that carry grain, raw materials, and other bulk freight on Missouri's rivers is considered commercial navigation. In 2017, 38.8 million tons of commodities that originated in or were destined for Missouri were transported on Missouri's waterways.
- **Wetlands** –Missouri's wetlands are fed through natural rainfall and, for some areas, surface water diversions or groundwater pumping. Combined annual average water withdrawals to support wetland functionality in the state are estimated at 104,350 acre-feet per year.
- **Water-Based Outdoor Recreation** – In-stream water, lakes, and reservoirs support recreational activities such as fishing, swimming, motorboating, kayaking, paddle boarding, floating, and canoeing. There are 6,282 miles of rivers and streams in the state available for public use that are suitable for recreational use. Missouri has 318,939 surface acres of lake water available for recreation, 82 percent of which are available for public use.
- **Aquaculture and Fish Hatcheries** – Water withdrawals that support the farming and cultivating of cold- and warm-water organisms such as fish or crustaceans for food, and support restoration, conservation, or sport fishing is referred to as aquaculture. In 2010, Missouri aquaculture withdrawals were estimated at 181 MGD, with 94 percent supplied by surface water sources (Maupin et al. 2014).

WATER SUPPLY

Missouri has an abundant supply of water, both in the ground and on the surface. Precipitation falling within the state provides over 15 trillion gallons of runoff water to rivers, lakes, and streams during an average year. More than twice that amount of water—38 trillion gallons per year—enters the state from the Missouri and Mississippi rivers. Precipitation infiltrating the ground replenishes aquifers that provide an estimated 500 trillion gallons of potable groundwater storage within the state (Miller and Vandike 1997).

While the state generally has plentiful water sources, many supply-related challenges exist. For example, much of the groundwater originating from bedrock aquifers in northern and west-central Missouri is highly mineralized and unsuitable for most uses. In northwestern Missouri, precipitation is generally the lowest in the state, and the lack of surface water availability during prolonged droughts can result in water shortages. Timing is also important in determining the availability of water, since peak demands often coincide with the driest times of the year and multiyear droughts can lower aquifers and drain reservoirs that typically provide ample supply. Even when available, the quality of the water may not be suitable for all intended uses without treatment.

These issues highlight the need for the accurate characterization of the quantity, quality, location, and timing of water supplies that are available for use now and into the future. Once the total available supply is known, areas where water supplies may be stressed or where potential water shortages or gaps exist can be identified by comparing the total available supply to current and projected demands. The identification of water stress and water supply gaps is a core component of comprehensive water planning and a critical step leading to the development of effective water management policies and actions.

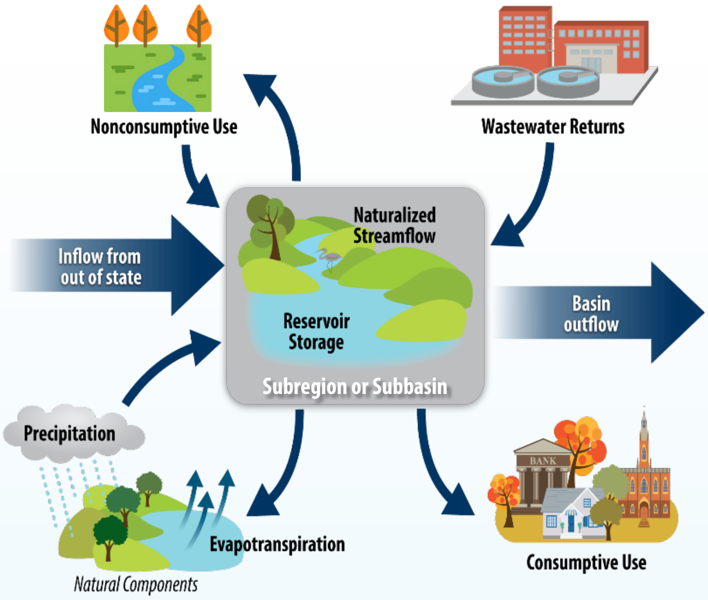


Figure ES-7. Surface Water Budget Schematic

For the Missouri WRP, the potential for water stress and gaps was investigated using a water budget approach. The water budgets account for the mostly natural movement of water within the hydrologic cycle and the movement of water resulting from human activities, as shown in **Figure ES-7**.

SURFACE WATER SUPPLY

The surface water budgets and supply analysis demonstrate that, under normal hydrologic conditions, Missouri typically has more than enough surface water to satisfy demands. On an average annual basis, projected 2060 surface water withdrawals, both consumptive and nonconsumptive, are only a small fraction of total streamflow as shown in **Table ES-1**. Even though there is generally an ample supply on an average annual basis at the subregional level, localized stress or shortages are still possible, especially during drought conditions. Additionally, a certain amount of water must remain in place to maintain flows on the state's major waterways for navigation and to preserve water temperature, water quality, and the viability of existing water supply intakes.

Table ES-1. Projected 2060 Surface Water Demands as a Percent of Average Annual Streamflow

HUC 4	Name	Total Streamflow (MGD)	Streamflow Generated in HUC 4 (MGD)	Total 2060 Withdrawals[1] as a Percent of Total Streamflow	Total 2060 Withdrawals[2] as a Percent of Streamflow Generated Only in HUC 4
0711	Upper Mississippi-Salt	83,509	4,433	0.0%	0.8%
0714	Upper Mississippi-Kaskaskia-Meramec	154,021	4,421	0.7%	1.6%
0802	Lower Mississippi-St. Francis	157,059	1,773	0.0%	1.1%
1024	Missouri-Nishnabotna	33,610	1,699	3.6%	1.9%
1028	Chariton-Grand	5,366	4,070	17.5%	23.1%
1029	Gasconade-Osage	12,214	9,390	2.1%	2.7%
1030	Lower Missouri	64,281	6,007	2.8%	2.9%
1101	Upper White	10,881	9,032	1.5%	1.8%
1107	Neosho-Verdigris	1,854	1,854	1.8%	1.8%

[1] *Includes major river and nonmajor river withdrawals*

[2] *Withdrawals on streams and rivers excluding major rivers that originate out of state*

Table Rock Lake near Branson

Time has shown that shortages can occur during periods of extended or severe drought. Analysis that incorporates monthly demands and variations in supply availability based on historical dry and drought of record years demonstrate that this problem is not going away. The results point to surface water gaps of 1 month or more during dry and/or drought of record years in the Chariton-Grand, Gasconade-Osage, Lower Missouri, Missouri-Nishnabotna, and Upper Mississippi Salt subregions. The potential for surface water stress and shortages, especially in areas that do not have access to the larger rivers or reservoirs, emphasizes the importance of reservoir storage, interconnections with other systems, conjunctive use of groundwater, or other means to bridge these potential supply gaps.

The Missouri River

The Missouri River—the longest river in the United States—is a vital natural resource to the state. The six mainstem reservoirs on the Missouri River upstream of Missouri are managed as a system to fulfill the authorized purposes of flood control, navigation, water supply, irrigation, hydropower, water quality, fish and wildlife, and recreation, with recognition that other incidental benefits are also achieved. Some of the recognized benefits in the state include:

- Upstream reservoir storage has prevented an estimated $62.5 billion in flood damages (USACE 2018)
- Over 4.6 million tons of goods and materials were transported on the river each year between 2015 and 2017 (USACE 2018)
- Approximately 50 percent of the population receives their drinking water directly from the Missouri River or from groundwater in the Missouri River Alluvial Aquifer

Ongoing trends in the Missouri River Basin present challenges to the river's use in Missouri. Recent climatic changes have affected the hydrologic cycle resulting in more frequent and/or more intense flooding and drought. Both flooding and low flows can degrade water quality, making treatment for public water supply more difficult and expensive. Bed degradation has resulted in a lowering of water surface elevations, particularly in the Kansas City reach, which threatens to expose water intakes making them more vulnerable to reduced winter flows and ice jams. Sedimentation of the upstream reservoirs and increasing consumptive use in the upper portion of the Missouri River Basin may result in a reduction of downstream flow support more quickly during drought conditions.

Confluence of the Missouri and Mississippi Rivers

GROUNDWATER SUPPLY

Statewide, there is an estimated 500 trillion gallons of usable quality groundwater stored in aquifers, although it is not evenly distributed (Miller and Vandike 1997). Where groundwater is used, analysis that accounts for future variations in supply and demand suggests there is more resiliency to drought in groundwater resources, primarily because of the large amount of groundwater in storage compared to surface water.

Table ES-2 presents components of the average annual groundwater budgets for each subregion, including the amount of potable groundwater in storage, average annual recharge from precipitation, and projected 2060 groundwater withdrawals. As can be seen by the relatively small amount of potable groundwater stored in the Missouri-Nishnabotna and Chariton-Grand subregions, groundwater resources are less available in the northern half of the state, primarily because much of the groundwater is highly mineralized, limiting its use without extensive treatment.

Table ES-2. Groundwater Budgets by Subregion

HUC 4	Basin Name	Total Potable Groundwater Storage (Billion Gallons)	Recharge to Water Table from Precipitation (MGD)	Projected 2060 Groundwater Withdrawals (MGD)	2060 Withdrawals as a Percent of Average Annual Recharge (%)
0711	Upper Mississippi-Salt	26,896	406	71	17%
0714	Upper Mississippi-Kaskaskia-Meramec	42,985	964	126	13%
0802	Lower Mississippi-St. Francis	67,277	1,257	1,889	150%
1024	Missouri-Nishnabotna	3,627	280	146	52%
1028	Chariton-Grand	6,490	514	14	3%
1029	Gasconade-Osage	140,732	1,905	96	5%
1030	Lower Missouri	68,263	581	167	29%
1101	Upper White	108,451	2,977	435	15%
1107	Neosho-Verdigris	30,974	650	68	10%

In most subregions, projected groundwater withdrawals are less than 20 percent of average annual recharge; however, in some subregions that include the Missouri and Mississippi rivers, withdrawals range from 29 percent (Lower Missouri) to 150 percent (Lower Mississippi-St. Francis) of recharge from precipitation. Significant pumping from alluvial aquifers occurs in these subregions along the two major rivers, and much of the water pumped from alluvial aquifers is expected to come from the rivers rather than recharge from precipitation. Also, in the Lower Mississippi-St. Francis, a significant amount of groundwater flows laterally into the alluvial aquifers from the Ozark Aquifer System. As such, the high percentages generally do not indicate potential stress. A more localized comparison of withdrawals to total recharge is necessary to identify stress and potential gaps.

The large amount of total potable groundwater storage in most subregions suggests that even in dry years, when recharge may be significantly lower, there is an ample supply of groundwater stored in the aquifers to mitigate drought. While this is generally the case across much of the state, local areas that rely heavily on groundwater may still be susceptible to short or prolonged droughts and experience reduced well yields or dry wells because of local conditions.

To evaluate groundwater sustainability at a more local level, the USGS Ozark Aquifer System groundwater model was used to evaluate potential impacts to projected 2060 withdrawals within the Ozark Aquifer. The model results indicate that increases in public supply, self-supplied nonresidential, and livestock demands (particularly in Christian and McDonald counties) by 2060 may result in an approximate 200-foot localized decline in Ozark Aquifer groundwater levels. Smaller, yet still significant, localized declines may occur in Dade and Taney counties based on projected increases in irrigation and self-supplied nonresidential withdrawals from the Ozark Aquifer.

WATER SUPPLY SUMMARY

Table ES-3 summarizes the results the water supply and demand analysis for the nine Missouri subregions.

Table ES-3. Subregion Water Supply Summary

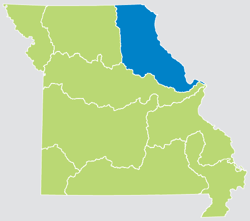
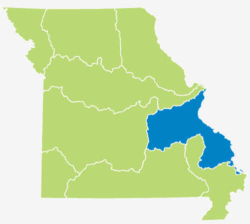
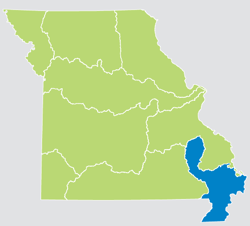
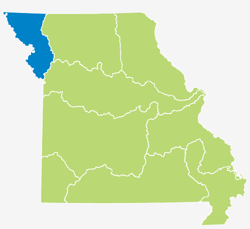
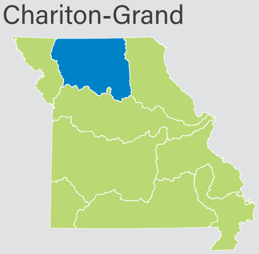
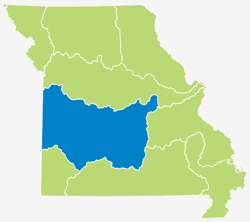
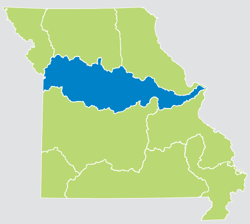
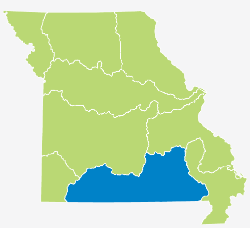
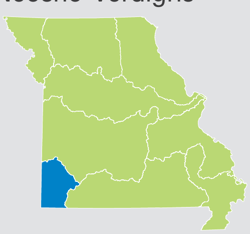
Subregion	Water Supply Summary
Upper Mississippi-Salt 	Surface water withdrawals from streams and rivers (not including the Mississippi River) approach or exceed median dry year flows in 3 months of the dry year and in 3 months of the drought of record year. The results suggest a potential for a surface water gap in areas of the subregion that do not have access to the Mississippi River. The subregion includes eight water supply reservoirs that help mitigate against the potential surface water supply gap identified in the monthly streamflow analysis. Groundwater availability, especially in the Mississippi River Alluvial and Cambrian-Ordovician aquifers, is enough to meet current and future needs through 2060.
Upper Mississippi-Kaskaskia-Meramec 	Flow in the Mississippi River exceeds total surface water withdrawals in the subregion. Surface water users in the western part of the subregion withdraw from tributaries to the Mississippi River that provide ample supply even during dry years and the drought of record year. Groundwater availability, especially in the Mississippi River Alluvial and Ozark aquifers, is enough to meet current and future needs through 2060. No stress or gaps were identified at the subregion level.
Lower Mississippi-St. Francis 	The subregion relies heavily on the groundwater stored in the northern portion of the Mississippi Embayment Aquifer System. Current groundwater withdrawals from this subregion of 1,620 MGD are approximately 70 percent greater than the combined groundwater withdrawals from all other subregions of the state. Although current groundwater withdrawals exceed average annual recharge from precipitation, observation wells in the subregion have shown no long-term declines. Recharge sources other than precipitation, namely the Mississippi, St. Francis, and Black rivers to the east and Ozark Aquifer to the northwest, likely contribute significant amounts of flow into the Southeast Lowlands Alluvial Aquifer. As a result, groundwater availability is enough to meet current and projected needs without imposing stress or resulting in supply gaps even during prolonged droughts, when recharge from precipitation is much lower.
Missouri-Nishnabotna 	The Missouri River and Missouri River Alluvial Aquifer are the major sources of water in this subregion. Eighty percent of surface water withdrawals and 95 percent of groundwater withdrawals are from the Missouri River and its alluvial aquifer, respectively. Water users in the eastern part of the subregion must rely on tributaries to the Missouri River. The combined withdrawals on tributaries to the Missouri River approach or exceed median dry year streamflow in 3 months and drought of record year streamflow in 5 months. There is the potential for a surface water gap in areas of the subregion that do not have access to the Missouri River. A potential gap is also apparent in the flow-duration curve, which suggests that streamflow generated within the subregion will be below average annual withdrawals approximately 10 percent of the time.
Chariton-Grand 	Not accounting for thermoelectric withdrawals, total water use is relatively low in this subregion and reflects the relatively low population density. Water users rely primarily on surface water resources since good-quality groundwater is limited to portions of the Glacial Drift Aquifer and the Missouri River Alluvial Aquifer in the south. A potential supply gap was identified in 1 or more months when comparing dry year and drought of record year streamflow to surface water demands in the Little Chariton, Lower Grand, Thompson, Upper Chariton, and Upper Grand, subbasins. The Chariton-Grand subregion includes 32 water supply reservoirs with a total storage of 96,707 acre-feet. Reservoirs are an important component of the subregion's overall water supply system because of the availability limitations of groundwater, lower average rainfall, and history of drought.

Table ES-3. Subregion Water Supply Summary (cont.)

Subregion	Water Supply Summary
Gasconade-Osage 	Although the monthly streamflow analysis at the subregion level does not point to the potential for stress or a surface water gap under current or future conditions, water stress and the potential for water shortages have previously been identified in more localized areas of southwest Missouri including the western portion of the Gasconade-Osage subregion. In the Little Osage subbasin, the comparison of monthly dry year and drought of record year streamflow to current withdrawals indicates the potential for a supply gap in 4 months of the year. The gap occurs due to the seasonal nature of the agriculture and aquaculture/wetlands sectors, which are largely nonconsumptive uses. The Ozark and St. Francois aquifers are estimated to store a combined 138 trillion gallons of potable groundwater. Even though groundwater recharge greatly exceeds withdrawals and large amounts of potable groundwater are available in storage, localized stress may still occur because of overpumping or poor quality, especially in the western counties of the subregion on the saline side of the freshwater-saline transition zone.
Lower Missouri 	The Missouri River and Missouri River Alluvial Aquifer are the major sources of water in this subregion. The Ozark Aquifer (south of the Missouri River) and Cambrian-Ordovician Aquifer (north of the Missouri River) are also significant groundwater sources. Although flow in the Missouri River exceeds total surface water withdrawals, surface water users in the northern and southern parts of the subregion must rely on tributaries to the Missouri. Withdrawals on the tributaries exceed median dry year flows in 5 months of the dry year and in 8 months of the drought of record year. The results suggest the potential for a surface water gap in areas of the subregion that do not have access to the Missouri River supply, and emphasize the importance of reservoir storage, adequate and dependable Missouri River flows, interconnections with other systems, and conjunctive use of groundwater, together with other means to bridge these potential supply gaps.
Upper White 	The Upper White subregion has relatively plentiful surface and groundwater resources. Surface water withdrawals remain an order of magnitude below median dry year flows in any month. The relatively consistent streamflow even during dry periods is, in part, because of the thousands of springs and outlet points in the Salem Plateau portion of the subregion, which provide consistent base flow to streams. Although results of the monthly streamflow analysis at the subregion level do not point to the potential for stress or a surface water gap under current or future conditions, the potential for shortages is a concern in growing areas such as Springfield, which sits on the drainage divide between the Upper White and Gasconade-Osage subregions. Within the subregion, the Ozark and St. Francois aquifers are estimated to store a combined 105 trillion gallons of potable groundwater.
Neosho-Verdigris 	Current surface water withdrawals approach but do not exceed median dry year and drought of record year streamflow in 2 months, indicating potential for stress. Although the groundwater budget suggests that total withdrawals are less than average annual recharge to the water table, a gradual, long-term lowering of water levels has been observed in localized portions of the Ozark Aquifer in southwestern Missouri. The declining water levels indicate that withdrawals from the Ozark Aquifer in this localized area have exceeded long-term recharge to the aquifer and continue to reduce the amount in storage. Similar localized declines, although not as severe, have been observed in observation wells in other parts of the subregion and suggest that future groundwater withdrawals in these areas may not be sustainable at current levels, given the continual decline in storage.

INFRASTRUCTURE

The following is a summary of the findings associated with water infrastructure in Missouri:

- MoDNR regulates over 2,700 drinking water systems statewide, which serve over 5 million customers or 88 percent of the state's population.
- Over half of the major drinking water systems in Missouri have infrastructure nearing or exceeding their average life spans. Proactive replacement of aging water and wastewater infrastructure in Missouri is generally only feasible for large systems that have adequate revenue to support a replacement program.

- According to the 2015 Drinking Water Infrastructure Needs Survey and Assessment (DWINSA), Missouri's 20-year need for drinking water infrastructure is $8.9 billion (EPA 2018). According to the 2012 Clean Watersheds Needs Survey, Missouri's 20-year need for wastewater infrastructure is $9.6 billion (EPA 2016).
- Many drinking water and wastewater utilities have significant need for investment in drinking water and wastewater infrastructure but must balance rate increases to support infrastructure needs with rate affordability for customers.
- There are currently several regional-scale water supply infrastructure projects in various stages of planning or development to address water supply challenges, including:
  - Construction of the East Locust Creek Reservoir in Sullivan County to provide 7 MGD of water supply
  - Construction of Little Otter Creek Lake in Caldwell County to provide 1.2 MGD of water supply
  - Construction of a 36-mile regional conveyance system in northwest Missouri to deliver 3.12 MGD of treated water from St. Joseph to the towns of Cameron, Maysville, and Stewartsville
  - A water supply reallocation from USACE reservoirs in southwest Missouri to supply approximately 39 MGD of water supply to the region
  - Construction of a reservoir in Newton County to address water supply shortages in the Joplin region

Adequate and reliable water and wastewater infrastructure is essential to human health and economic development and preservation of Missouri's waterways. While much of Missouri's water and wastewater infrastructure is in need of significant upgrades and repairs, utilities and water providers face financial challenges with updating this equipment.

DRINKING WATER INFRASTRUCTURE

More than half of the state's community public water systems became active prior to 1960, meaning that without repair or replacement original water pipes, mains, and equipment are nearing or exceeding their average expected lifespan. **Figure ES-8** provides the original build date of major water systems in Missouri by decade (MoDNR 2018). Shortfalls in investment in this infrastructure may lead to service interruption from main breaks, microbial contamination, and inadequate capacities (American Society of Civil Engineers [ASCE] 2018). Many small drinking water utilities have indicated that they lack the funding not only to proactively manage infrastructure needs, but also to meet current water quality standards and adequately address water losses. According to the *2018 ASCE Report Card for Missouri's Infrastructure*, improved planning, reduced regulatory impediments, and increased funding are critical for Missouri to maintain existing facilities and ensure a safe and reliable water supply (ASCE 2018).

The monetary needs for drinking water infrastructure are assessed at a statewide level through the DWINSA (EPA 2018). During the most recent DWINSA, of the 37 states that provided complete data, Missouri ranks 17th in total dollars needed for drinking water infrastructure improvements over the next 20 years. The estimated need for drinking water improvements over the next 20 years in Missouri is $8.92 billion. These projects include installation of new infrastructure and the rehabilitation, expansion, or replacement of existing infrastructure. This estimate does not include drinking water infrastructure needs for future growth in Missouri.

Branson Wastewater Plant

WASTEWATER INFRASTRUCTURE

Similar to drinking water infrastructure in Missouri, a significant portion of wastewater infrastructure may be approaching the end of its expected life. Additionally, extensive sewer separation projects are currently underway to separate combined stormwater and sewer systems to prevent public health risks associated with combined sewer overflows. Many providers are also challenged with controlling inflow and infiltration issues that have led to sewer backups in homes, overflows at manholes, and untreated sanitary discharges into streams and rivers. The State of Missouri's 604 (b) Statewide Water Assessment reported that 74 percent of rural wastewater treatment system respondents have documented inflow and infiltration issues (MoDNR 2011).

The Clean Watersheds Needs Survey is a comprehensive assessment of monetary needs for wastewater infrastructure (EPA 2016). The results of the assessment estimate

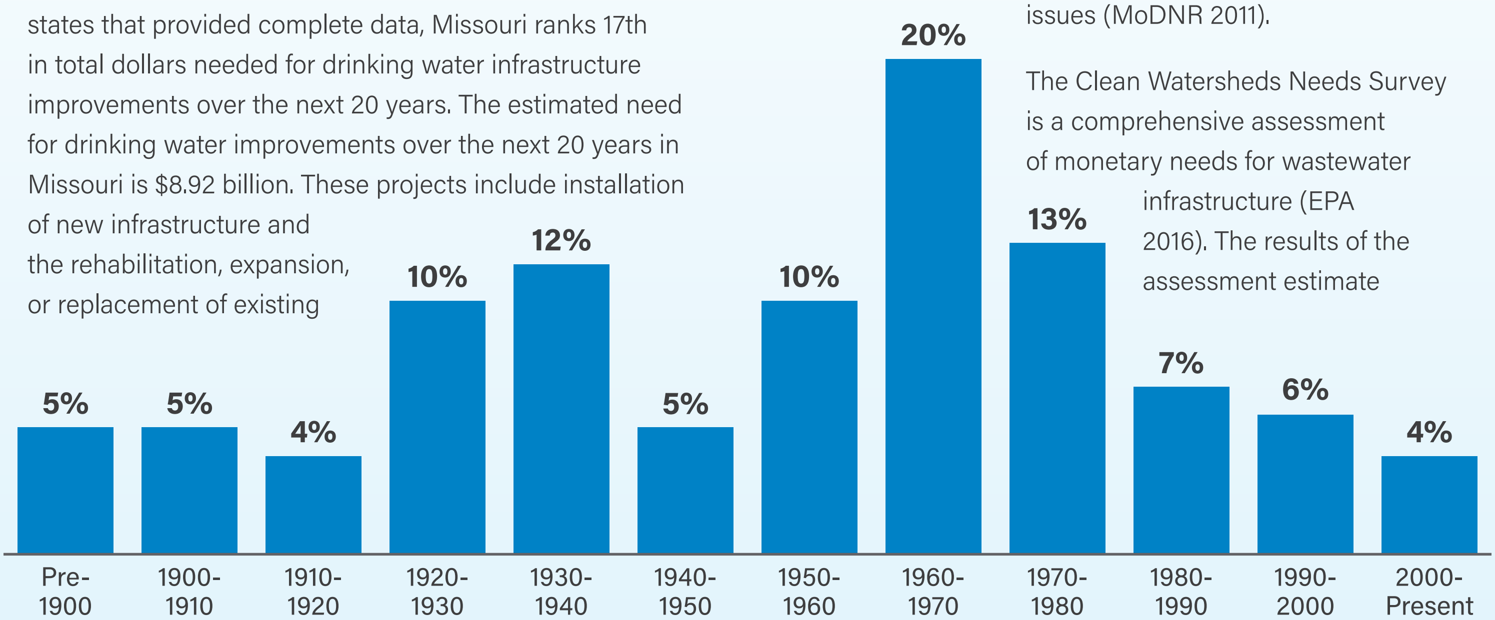
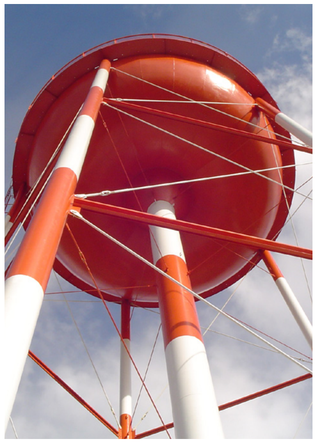


Figure ES-8 Original Build Date of Major Water Systems in Missouri (Source: Safe Drinking Water Information System [SDWIS] database)



the investment necessary to ensure that publicly owned treatment works meet the water quality objectives of the Clean Water Act. Missouri reported a 20-year need of $9.61 billion in the 2012 assessment. This need ranked Missouri in the top 10 states with the largest need per capita.

Tri-County Water Plant

DRINKING WATER AND WASTEWATER RATES

During the development of this plan, utility managers expressed concerns about not only the costs associated with managing deteriorating infrastructure, but also the rising costs of treating wastewater because of challenges associated with updated ammonia limits and reclassification of streams. Missouri utilities are challenged with balancing infrastructure improvements with affordability of rates for its customers. In many of the state's northern counties, drinking water and wastewater rates are above the U.S. Environmental Protection Agency (EPA) affordability threshold of 4.5 percent of median household income for annual water and wastewater combined.

INFRASTRUCTURE IMPROVEMENTS

Current and future infrastructure projects assist in bridging the gap between demands and supply while taking into account the aging nature of systems across the state. Large systems with adequate revenue have implemented proactive replacement schedules for drinking water and wastewater infrastructure to reduce the number of leaks and breaks resulting from aging infrastructure. Additionally, some major utilities are working towards prioritized replacement plans to meet main break replacement benchmarks established by the American Water Works Association. Some utilities have also developed integrated water resource plans to prioritize water resource projects in a manner that maximizes economic and social welfare benefits.

Several regional-scale infrastructure projects are being planned to address wastewater infrastructure and water supply shortfalls. These projects include the construction of two reservoirs in northern Missouri and a reservoir in southwest Missouri, a water supply reallocation in southwest Missouri, and a regional water conveyance system in northwest Missouri. Projects such as these continue to be necessary to overcome the obstacles associated with aging infrastructure and regional infrastructure gaps. Significant investment in water and wastewater infrastructure will be critical for the state's future water needs.

FUNDING OPPORTUNITIES

The following is a summary of the findings associated with funding opportunities in Missouri:

- Funding for developing and maintaining public drinking water and wastewater systems is available through multiple federal, state and private sources.
- MoDNR's Financial Assistance Center includes a team of engineers, project coordinators, and administrative staff dedicated to assisting Missouri communities plan and fund water, wastewater, and stormwater infrastructure projects.

Current River

Montauk State Park

Adequate and reliable water and wastewater infrastructure is vital to public health and the prosperity of Missouri's communities. The ability to effectively develop and properly maintain this critical infrastructure is often contingent on outside funding such as loans and grants. While funding for water and wastewater systems is available through multiple federal and state sources, grants are limited. Loan and grant opportunities often have cost-share or matching requirements that may be difficult to secure, especially for small utilities. Public finance sources are also available, including public bond markets, bank programs, and bond funds. Each of these programs has its own requirements, structural components, incentives, and drawbacks. Regardless of the funding method, the ability to fund needed improvements and resulting debt service is a critical element of the decision-making process for water systems' governing bodies. Balancing the demands of system maintenance and growth with the community's ability to pay is often a challenge.

A summary of federal and state assistance is provided in **Table ES-4**.

Table ES-4. Federal and State Water Infrastructure Assistance

Organization	Program	Type of Funding
Federal Municipal Bonds	Tax Exempt Municipal Bonds	Loan
U.S. Economic Development Administration	Public Works Program	Grant with cost share or matching requirement
	Economic Adjustment Assistance Program	Grant with cost share or matching requirement
EPA	Water Infrastructure Finance and Innovation Act	Loan
U.S. Department of Agriculture (USDA) Rural Development	Water and Wastewater Disposal Loans and Grants	Loans and grants with cost share or matching requirement
	Water and Wastewater Disposal Loan Guarantees	Loan guarantee
	Emergency Community Water Assistance Grants	Grant
	Special Evaluation Assistance for Rural Communities and Households	Grant
	Rural Business Development Grants	Grant
USACE	Planning Assistance to States	Cost shared on a 50% federal/50% nonfederal basis
Delta Regional Authority	States' Economic Development Assistance Program	Grant
MoDNR	Drinking Water State Revolving Fund	Loans and grants with cost share or matching requirement
	Clean Water State Revolving Fund	Loans and grants with cost share or matching requirement
	Small Borrower Loan Program	Loan
	Rural Sewer Grants	Grants with a 50% cost share or matching requirement
	Small Community Engineering Assistance Program	Grants with a 10–20% cost share or matching requirement
	Drinking Water Engineering Report Services Grants	Grants with 20% cost share; disadvantaged communities may receive up to 100% of costs
	Missouri Multipurpose Water Resource Fund	Grant with Cost Share for Planning and Feasibility Studies; Loans for Construction Projects
Environmental Improvement and Energy Resources Authority	SRF Bond Program	Loan
Missouri Development Finance Board	Missouri Infrastructure Development Opportunities Commission Program	Loan
	Public Entity Loan Program	Loan

OPTIONS TO MEET FUTURE WATER NEEDS

The following is a summary of the findings associated with water supply options in Missouri:

- A portion of Missouri's immediate water supply needs can be addressed through projects and planning processes that are currently being pursued by local and regional water providers. As new water supply needs or challenges emerge, there are numerous and diverse options available to water providers and users that can be implemented independently or in combination to meet these needs.
- M&I options include additional storage (new or expanding existing), conveyance, enhanced water treatment, wastewater reuse, expanded conservation, conjunctive use, system redundancy, and regionalization.
- Agriculture options include additional storage, conveyance, conjunctive use, system efficiencies, recycled water, expanded groundwater use, and surface impoundments.

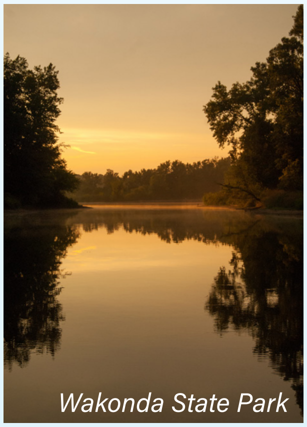
Missouri has a large supply of water overall, but it is not always found when and where it is needed, nor is it always of a usable quality. While many of Missouri's immediate water supply needs will be addressed through projects and planning processes that are currently being pursued by local and regional water providers, there are other emerging water supply needs or challenges that still must be addressed. A variety of diverse water supply options are available to water providers and users that can be implemented independently or in combination to meet these needs. The water supply options are grouped according to the two primary sectors of water demand for which they apply—M&I and agricultural. Each option has specific advantages, disadvantages, and cost and environmental implications that must be considered.

MUNICIPAL AND INDUSTRIAL OPTIONS

The options for M&I water supply have been identified as follows:

Surface water storage can be achieved by constructing new reservoirs or expanding the capacity of existing reservoirs through enlargement, removal of sediment, or repair.

Mark Twain Sunset



Wakonda State Park

Irrigation of Crops

Conveyance systems transport source water to a treatment plant and treated potable water to consumers, connects one system to another, moves municipal or industrial wastewater to treatment plants, and delivers treated wastewater to a water body.

Water treatment enhancements may be an option to help meet water supply needs. The addition of an enhanced treatment process, while more expensive than conventional methods, may be evaluated as an alternative to conveyance or developing new supply sources.

Water reuse, the process of reusing treated wastewater for beneficial purposes, can be divided into two categories: potable and nonpotable. Reusing treated wastewater can reduce the demand on a limited source of supply.

M&I **water conservation** programs improve water use efficiency and decrease water consumption. Water savings occur through the replacement of water fixtures with more efficient fittings, changes in customer behaviors, and reduction in water losses in the conveyance and distribution system.

Conjunctive use of surface water and groundwater can maximize the benefits and reliability of both surface water and groundwater sources of supply. In its simplest form, conjunctive use involves a water provider using both surface water and groundwater sources to meet demands.

Redundancy refers to secondary, backup, or duplication of the critical components of a water supply system, with the goal of increasing reliability and resiliency.

Regionalization refers to the merging or alliance of two or more water systems, either through structural or nonstructural ways or a combination of both, to improve planning, operation, and management of the systems.

AGRICULTURE OPTIONS

One pathway to improve water supply reliability for agriculture demand is the creation of **additional storage**. Water harvesting—capturing rain where it falls or as it runs off—and constructing local storage ponds is used most commonly for livestock facilities. However, new innovations are allowing the linkage of farm ponds to irrigation systems to recycle water. These systems are especially useful in allowing storage of winter and spring water for use in periods of low precipitation or drought.

Agricultural production and efficiency can be increased by transporting water to irrigate crops that otherwise are not irrigable due to supply constraints through **conveyance**.

Since agricultural demands are highly seasonal in nature, **conjunctive use** of surface water and groundwater could be used to mitigate potential future growing season shortfalls.

Water demand for agricultural irrigation is driven by the acreage and type of crop irrigated, irrigation system (e.g., flood, sprinkler, microirrigation), seasonal rainfall, water availability, economic viability, and fuel and commodity prices. The most promising measures for agricultural water-saving in Missouri include the adoption of more **efficient irrigation systems** or retrofits to existing systems, and

better irrigation management through adoption of weather-based controllers or other technology.

Drainage water recycling is the practice of capturing excess water drained from fields; storing the drained water in a pond, reservoir, or drainage ditch; and using the stored water to irrigate crops when there is a water deficit due to insufficient precipitation.

Frequently, short-term and moderate droughts affect producers' ability to provide water to livestock. Stakeholders can mitigate the effects of drought through public and private investment in **surface impoundments** for livestock water.

PLANNING METHODS

In order for a community to make change, a path must be established. Planning can be used to identify which funding options will fit the best for a community and which water supply options will best help a community combat potential water supply risk and uncertainty. There are several different planning methodologies that can be used to plan for the future. For the State of Missouri WRP Scenario Planning was used in tandem with Adaptive Management.

SCENARIO PLANNING

The traditional method for water supply planning is to forecast water demands based on past trends in population growth and assess water supply availability based on past hydrological conditions. This approach was adequate in the past as demographic growth and water demands were well correlated, climate was less extreme, and the cost of developing new water supplies was lower. However, in the last several decades, changes in water use patterns, more extreme climate, changes in regulations, and increased competition for fresh water supplies have been observed and are likely to cause greater uncertainties in the future. In addition, aging water infrastructure is resulting in greater risks of system failures.

As an alternative to traditional water planning, scenario planning is a technique that captures a wider range of uncertainties and risks. Scenario planning is a structured process by which future uncertainties are bundled together using scenario narratives that represent plausible future conditions. Impacts for each scenario, such as water supply shortages, are then estimated. Through scenario planning, major disruptions in the future can be addressed more adequately, as shown in **Figure ES-9**.

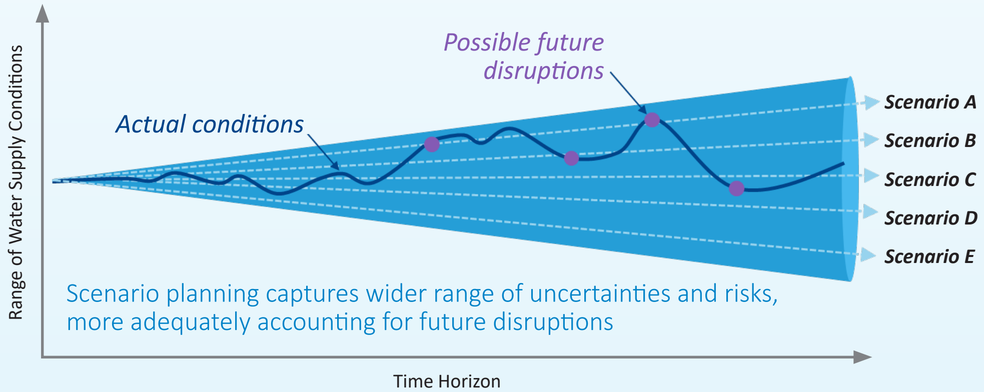


Figure ES-9. Scenario Planning with a Greater Range of Uncertainty in Forecast Conditions

Scenario planning usually has four main steps, which are listed below:

1. Identify major uncertainties that can impact the future.
2. Select the most important uncertainties to be used in the scenarios.
3. Develop scenario narratives from combinations of the most important uncertainties.
4. Assess the impacts of scenarios and identify strategies to address those impacts.

ADAPTIVE MANAGEMENT

Whereas scenario planning can be a useful planning approach to capture uncertainties and estimate a plausible range of future water needs, it alone does not provide a strategy for the timing and sizing of new projects. Adaptive management is useful as either a stand-alone planning method or in combination with scenario planning to develop implementation strategies for dealing with unknowns in a structured decision-making fashion.

As applied for water supply planning, adaptive management often looks more like a decision tree than a circular approach. In this context, adaptive management has four main elements:

1. Identify **no regret actions**, which are recommendations that are expected to provide benefits no matter what future scenario unfolds.
2. Define major **risk triggers**, which represent major uncertainties that can occur through time.
3. Assess plausible **outcomes** for each trigger.
4. Recommend **actions** for each outcome.

Adaptive management addresses the challenge of balancing underperformance (i.e., if actions are not taken quickly enough should a more stressful future scenario occur) with overinvestment (i.e., if too many actions are implemented and a less stressful future occurs). The triggers and outcomes are regularly monitored and assessed, along with any actions that have already taken place, to incrementally implement strategies as the future unfolds. An example of adaptive management, as applied to water supply planning, is shown in **Figure ES-10**.

As applied to water supply planning, a risk trigger could be future climate, where three outcomes could be assessed as being historical average temperature and precipitation; warmer temperature and more precipitation (warm/wet), and even warmer temperatures but less precipitation (hot/dry). Depending on what outcome occurs, different actions

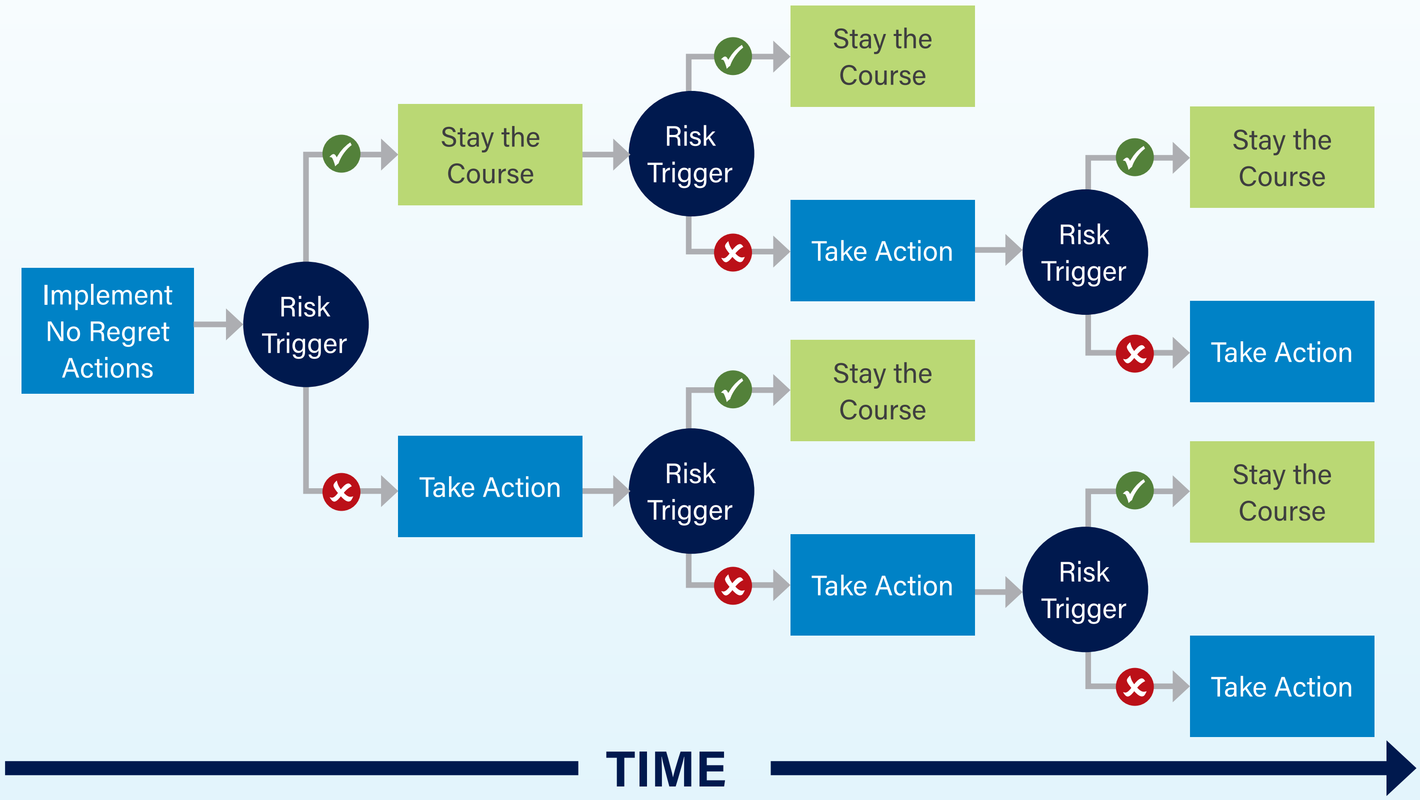


Figure ES-10. Example of Adaptive Management Using a Decision Tree Approach

Big Spring near Van Buren, part of the Ozark National Scenic Waterways

could be taken such as stay the course, construct a new regional reservoir, or implement water conservation.

ROLES IN WATER PLANNING IN MISSOURI

For adaptive management to be successful, all stakeholders need to understand and perform their respective roles in the planning and implementation process. In discussions with MoDNR, USACE, and technical workgroup members representing local municipalities, water agencies, and agricultural water users, the roles of each of the vested parties were defined. Each of the parties have a role to play in the implementation of the Missouri WRP.

LOCAL ENTITIES

Municipalities, local districts, agriculture users, private entities, and volunteer organizations are some of the local entities that identify water supply projects and implement those projects. Collectively, this group of water users provides information that, when considered in isolation, may not be meaningful at a regional or state level, but when considered holistically, can help identify trigger points that suggest action is warranted.

STATE ENTITIES

The Missouri General Assembly sets polices and laws in place to optimize Missouri's use of resources. It is under the guidance of these policies that state agencies operate. MoDNR implements state-level policies related to water, among other responsibilities, while Missouri Department of Conservation is charged with the control, management, restoration, conservation, and regulation of the bird, fish, game, forestry, and wildlife resources of the state. The state is responsible for monitoring and revising risk triggers.

FEDERAL ENTITIES

Federal entities collect data, perform studies, establish regulations and may provide technical assistance and financial support. Entities such as USACE, USGS, and Natural Resources Conservation Service (NRCS) are key for the successful implementation of solutions for water challenges. USACE provides a wide range of services related to water supply and water resources planning. In Missouri, USACE is most recognized for their operations on the Mississippi and Missouri rivers as well as several reservoirs. In addition to overseeing these operations, USACE supports and performs water studies. USGS is a vital source of high quality data about Missouri's water resources. By partnering with others, including MoDNR, USGS implements monitoring systems across Missouri. NRCS is a part of USDA and is known for assisting in the restoration of watersheds on private land. NRCS provides technical and financial assistance to landowners who practice conservation and implement management strategies in their production processes with an emphasis on improving water management and quality.

The EPA is an independent agency of the United States federal government for environmental protection. The EPA's mission is to protect and conserve the natural environment and improve the health of humans by researching the effects of and mandating limits on the use of pollutants. The Safe Drinking Water Act (SDWA) and Clean Water Act (CWA) are key environmental laws related to water resources that are overseen by the EPA.

The United States Department of Agriculture (USDA) is responsible for developing and executing federal laws related to farming, forestry, rural economic development, and food.

Big Spring near Van Buren, part of the Ozark National Scenic Waterways

FUTURE SCENARIOS ASSESSED

Following the scenario planning process and with input from the technical workgroups, the following four planning scenarios were formulated for analysis:

1. Business as Usual (also known as the baseline scenario).
2. Strong Economy/High Water Stress.
3. Substantial Agricultural Expansion.
4. Weak Economy/Low Water Stress.

The four planning scenarios are summarized in **Table ES-5**. The planning scenarios are characterized by a range of future assumptions centered around six major categories of uncertainties: M&I and rural water demands, agriculture demands, climate, water treatment levels, supply constraints, and reservoir regulations. Each scenario was evaluated through the 2060 planning period for an average hydrologic year. Scenarios were also evaluated to identify potential stress and gaps to surface water for a drought year, where a drought year represented conditions during the drought of record in the 1950s.

Bennett Spring, part of Bennett Spring State park near Lebanon

Table ES-5. Planning Scenarios

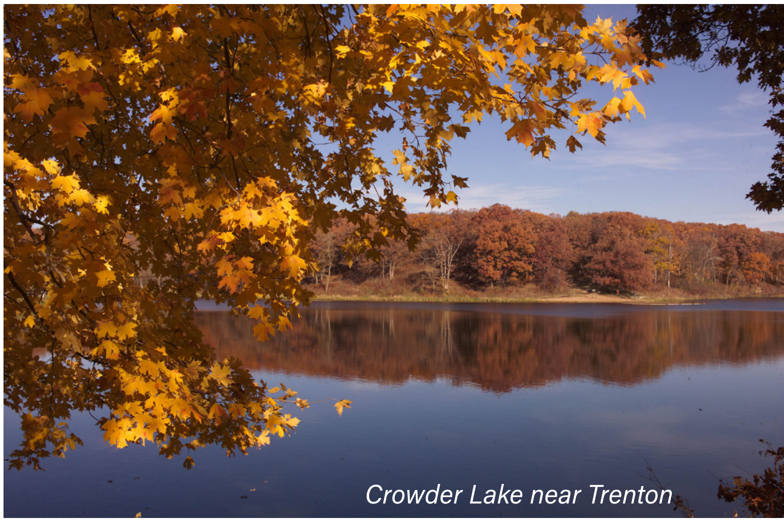
Scenario Number & Name	Uncertainty Drivers					
	M&I and Rural Water Demands	**Agriculture Demands**	**Climate**	**Water Treatment Levels**	**Supply Constraints**	**Reservoir Regulations**
1. Business as Usual	Baseline M&I Demands Baseline Rural Demands	Medium Irrigation Demands Medium Processing Demands	Historical Temperature and Precipitation	Existing Water Treatment Levels	Bed Degradation	No Reallocation of USACE Reservoirs for Supply in Missouri Existing Permitting Process for New Storage Reservoirs
2. Strong Economy/ High Water Stress	High M&I Demands Higher Rural Demands	High Irrigation Demands Medium-High Processing Demands	Hotter Temperature and Lower Precipitation	High Increase in Water Treatment Levels	Upstream Diversions out of Missouri River Limitations on Groundwater (Select Areas) Prolonged Supply Disruption on River Intakes Bed Degradation	Limited Reallocation of USACE Reservoirs for Supply in Missouri Streamlined Permitting Process for New Storage Reservoirs
3. Substantial Agricultural Expansion	Baseline M&I Demands Baseline Rural Demands	Medium Irrigation Demands High Processing Demands	Warmer Temperature and Greater Precipitation	Moderate Increase in Water Treatment Levels	Upstream Diversions out of Missouri River Limitations on Groundwater (Select Areas) Bed Degradation	Limited Reallocation of USACE Reservoirs for Supply in Missouri Existing Permitting Process for New Storage Reservoirs
4. Weak Economy/ Low Water Stress	Low M&I Demands Baseline Rural Demands	Medium Irrigation Demands Medium Processing Demands	Warmer Temperature and Greater Precipitation	Existing Water Treatment Levels	Bed Degradation	No Reallocation of USACE Reservoirs for Supply in Missouri Existing Permitting Process for New Storage Reservoirs

IMPACTS OF SCENARIOS

The four planning scenarios (Business as Usual or baseline scenario, Strong Economy/High Water Stress, Substantial Agricultural Expansion, and Weak Economy/Low Water Stress) were evaluated under years representing average hydrologic conditions and drought conditions. The average conditions are useful for summarizing the results of the scenario planning process because water stress may occur in a year with normal water availability. Issues that arise under average conditions best indicate a shift in baseline conditions, which could cause persistent struggles to meet water needs while also worsening the impact of a drought.

These results show that, in general, the highest risk observed comes from the Strong Economy/High Water Stress scenario, which has higher demands from a strong economy but reduced supply because of climate. The Substantial Agricultural Expansion scenario also indicates future vulnerability to a strong economy even with an increased water supply from increases in precipitation. A strong economy is a benefit to Missouri; however, the results of the scenario planning process indicate that it poses an increased likelihood of causing water stress and potential water shortages. Careful tracking and planning of increases in water demands due to economic growth will be key to maintaining a sustainable and resilient supply of water in Missouri as the economy grows.

Identifying and assessing potential impacts of Missouri River supply constraints, reservoir reallocation and permitting, groundwater limitations, and water treatment levels provide further evidence of potential outcomes under each scenario. For example, a high degree of reallocation of USACE reservoirs to meet existing water demands in the southwest portion of the state is important to maintaining



Crowder Lake near Trenton

an adequate water supply, minimizing shortages, and eliminating potential gaps. Should reservoir reallocations not occur, as assumed in the Business as Usual and Weak Economy/Low Water Stress scenarios, the Neosho-Verdigris, western portion of the Upper White, and southern portion of the Gasconade-Osage subregions are likely to experience higher risk of future water supply stress.

Figure ES-11 shows the relative level of surface water and groundwater stress for each scenario by subregion for both average and drought conditions. The subregions in the central and northern part of Missouri are expected to have the highest likelihood for water supply gaps under the Strong Economy/High Water Stress scenario. In the Lower-Mississippi-St. Francis subregion, the most stress and highest potential for gaps are expected under the Substantial Agricultural Expansion scenario; however, the assumptions behind the supply source (groundwater versus surface water) to meet the increased demands of this scenario play a large role in determining that potential. In the Neosho-Verdigris subregion, the highest potential

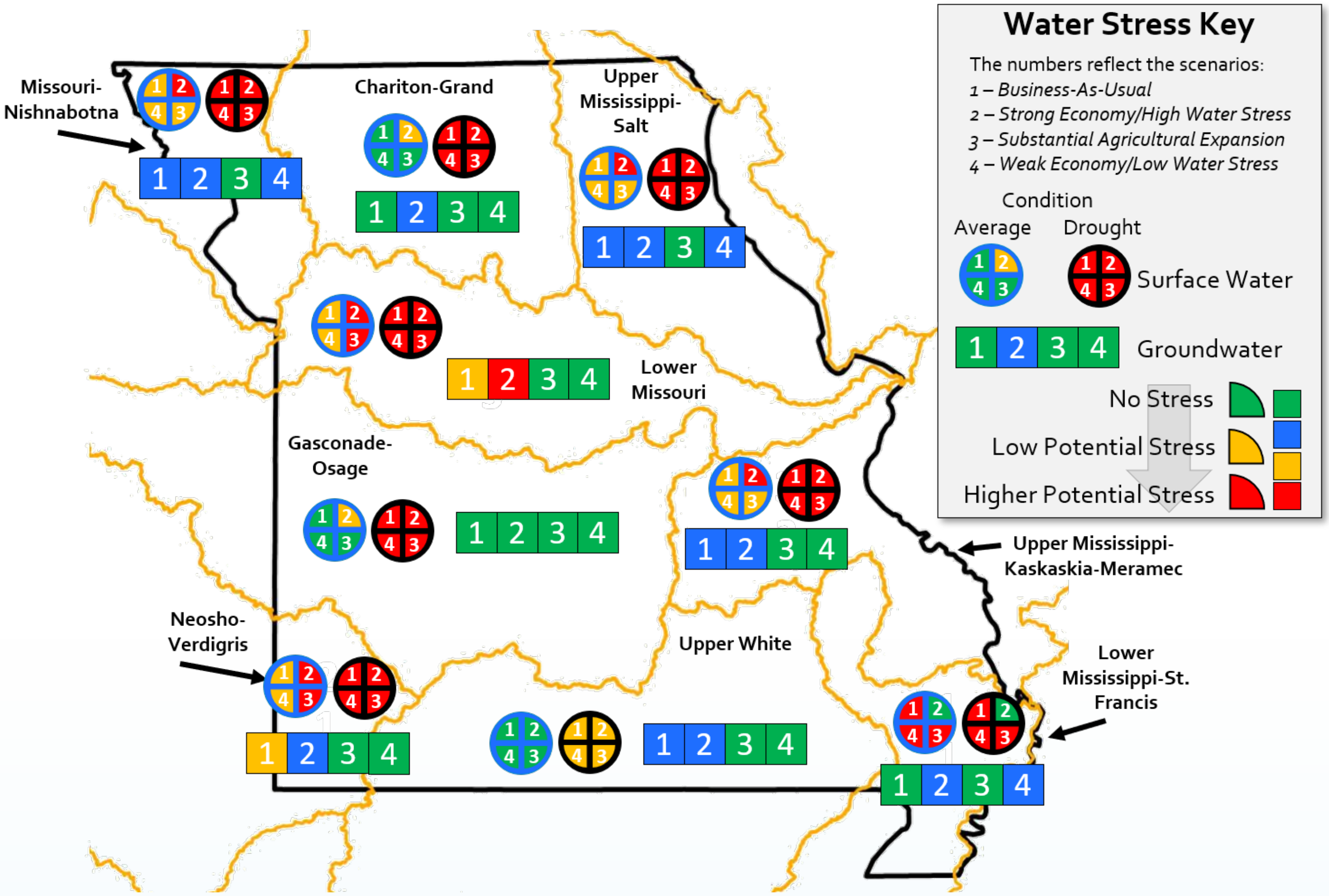


Figure ES-11. Scenario Results Showing Stress Level in Each Subregion for Average and Drought Conditions

for stress and gaps occurs under average conditions with the Strong Economy/High Water Stress and Substantial Agricultural Expansion scenarios. Under drought conditions, the Business as Usual and Weak Economy/Low Water Stress scenarios would be expected to show the highest level of stress because of no reservoir reallocations and the assumption that no new reservoirs are constructed.

This result suggests the increasing need for effective water conservation plans; surface storage, especially in areas where groundwater availability is limited; adequate infrastructure; interconnections to distribute water effectively from system to system; and regionalization of systems where economically and technically feasible.

The analyses suggest that most groundwater users are generally less likely to experience increasing stress than surface water users. Exceptions to this may be groundwater users with shallow wells in a surficial, nonalluvial aquifer. These wells may experience reduced yield or become dry from increased competition for water and/or drought.

Driving this result is the expected slight to moderate increase in recharge rates across the state as a result of the warmer temperatures and greater rainfall conditions used for the Substantial Agricultural Expansion and Weak Economy/Low Water Stress scenarios. Since most of the recharge occurs in the cooler months, the increase in precipitation during these months is expected to result in an overall increase in average annual recharge. Even during the hotter temperature/lower precipitation (relative to the other scenarios) condition of the Strong Economy/High Water Stress scenario, groundwater recharge is expected to increase over current conditions due to the timing of precipitation. The increase in recharge under all scenarios will continue to replenish the relatively large amount of potable water stored in Missouri's aquifers. However, as noted elsewhere, localized areas (such as those in the southwestern part of the state) may continue to experience declining aquifer levels from localized overuse, ultimately experiencing shortages.

USING ADAPTIVE MANAGEMENT WITH SCENARIO PLANNING

Adaptive management is a useful tool to continually assess and implement the results of scenario planning or similar tools. A combination of scenario planning with adaptive management was used to evaluate Missouri's water resources needs.

Figure ES-12 shows an overview of the adaptive management framework for Missouri. Identified projects have been incorporated in the present time frame. The figure shows that a different set of strategies may be needed between now and 2060, depending on which scenario (or combination of scenarios) occurs.

For example, to develop a detailed adaptive management framework to meet M&I water needs, risk triggers from each scenario were used to represent future outcomes. The risk triggers are:

- Identified projects implementation
- Reservoir regulation/reallocation
- M&I water demand growth
- Changing climate
- Supply and water quality constraints

A range of possible outcomes are identified for each risk trigger with a level assigned for each. Options are then identified to meet those outcomes. For Example, M&I options to address future water needs, further described in detail in **Section 7**, are represented as:

- Additional surface water storage, reallocation of existing storage, and expansion of existing storage facilities
- Conveyance
- Enhanced water treatment
- Wastewater reuse
- Expanded water use conservation
- Conjunctive use (groundwater/surface water)
- System redundancy (intakes and conveyance)
- Regionalization of water systems

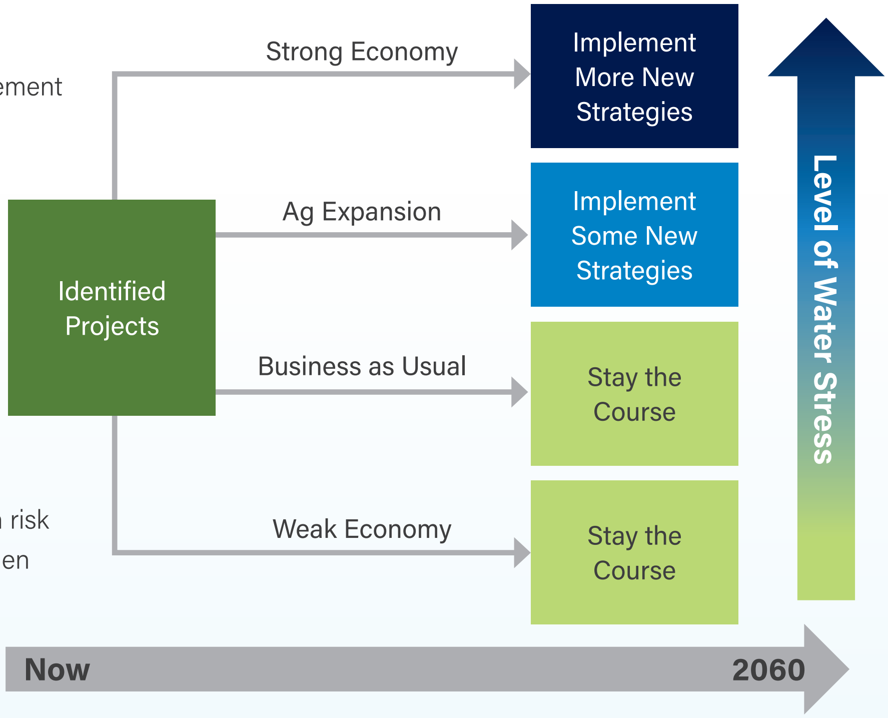


Figure ES-12. Overview of Adaptive Management Framework for Missouri

OUTLINE OF THE PLAN

This Plan is organized into ten sections which contain additional detail on the data and analysis undertaken with this update. **Section 2** discusses the physical setting in which the water resources of Missouri are being assessed in the Missouri WRP. **Section 3** explores the demographics and associated water use within Missouri to quantify demands, followed by a review and assessment of available surface water and groundwater supplies in **Section 4**. **Section 5** characterizes water and wastewater infrastructure throughout Missouri and identifies the major water resources projects currently in various stages of planning. **Section 6** summarizes the drinking and wastewater funding options available in Missouri. Options for meeting future water needs are identified in **Section 7**, and the framework for evaluating water resources strategies is described in **Section 8**. In **Section 9**, four hypothetical water resource scenarios representing a range of future conditions are evaluated to identify potential shortages, and the results are used to develop an adaptive management strategy to assess planning decisions at future milestones. Finally, in **Section 10**, the plan uses the information and analyses performed in **Sections 3** through **9** to develop a list of key findings and recommendations to maintain a long-term, comprehensive strategy to meet Missouri's water resources needs into the future.

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