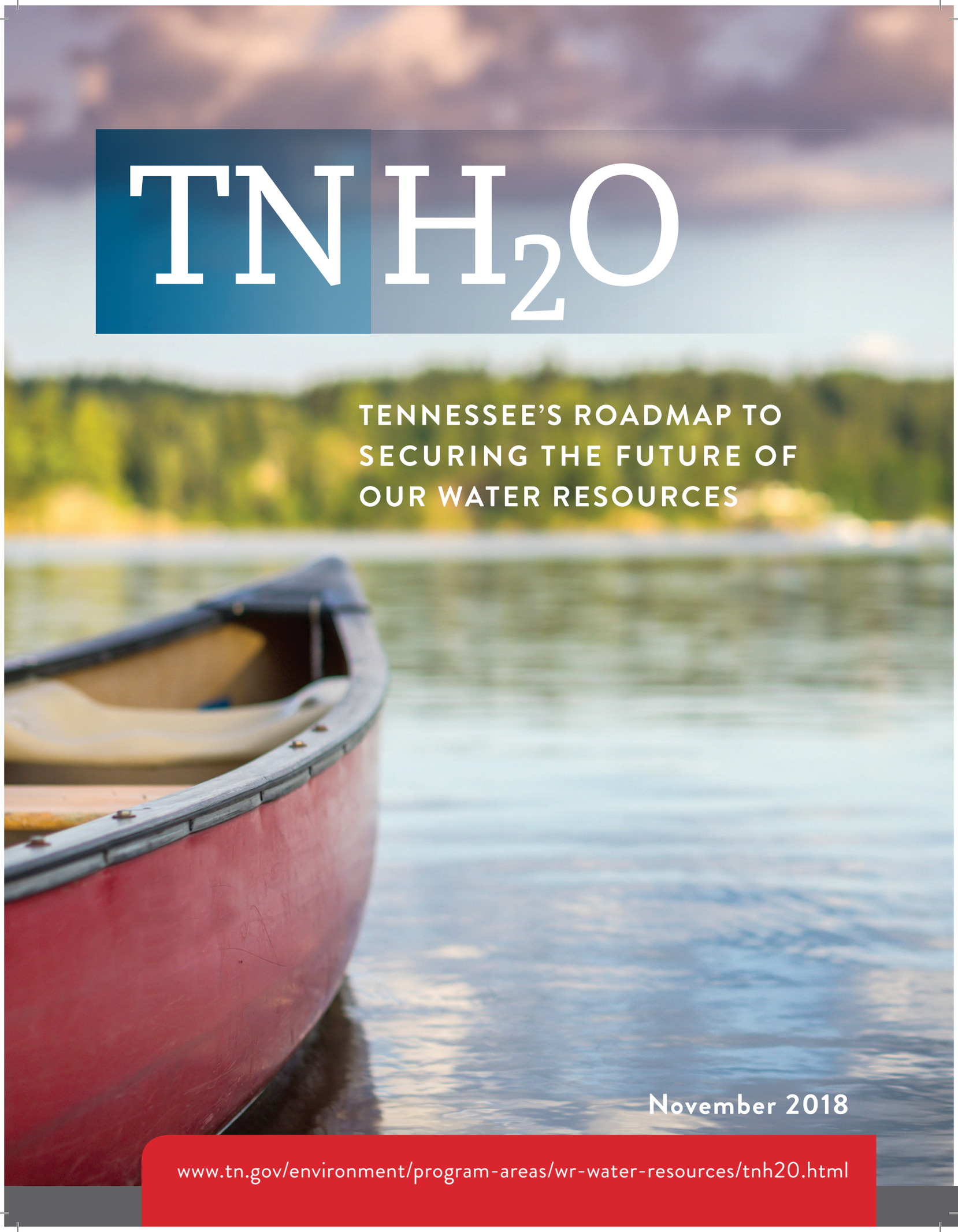
TNH2O
TENNESSEE'S ROADMAP TO SECURING THE FUTURE OF OUR WATER RESOURCES
November 2018
www.tn.gov/environment/program-areas/wr-water-resources/tnh20.html

Preface

In late 2017, Tennessee Governor Bill Haslam assembled stakeholders from federal, state, and local governments, as well as industry, academia, environmental advocacy groups, and public and private utilities, to develop a statewide plan to sustain and protect the state's water resources. This plan, called *TN H_2O*, assesses current water resources and makes recommendations to help ensure that Tennessee has abundant water resources to support future population and economic growth. This document is a roadmap to sustainable water resources, representing a statewide water plan and establishing a framework for further planning. It provides information, makes recommendations, and is intended to inform decision-making. Readers of this plan are encouraged to review the appendices for details on the status of the state's water resources and related monitoring and management programs. A copy of *TN H_2O* was given to the governor in November 2018 and made available for public input in December 2018.

Since January 2018, teams of subject matter experts in various fields have volunteered their time to study the current state of water resources and interpret and assess a wide array of data and information sources using varying models and assumptions under a limited time schedule. The resources studied include surface water, groundwater, and natural aquatic systems; related topics include water and wastewater infrastructure, water law, and tourism. From that, the volunteer teams synthesized, analyzed, and identified gaps in available data and information to arrive at recommendations for key focus areas for achieving and maintaining water availability in the future.

This plan has several limiting factors. The working group members are a diverse group of volunteers with various interests, education, and professional backgrounds. These volunteers were tasked with assessing water resources and developing recommendations to ensure the future availability of these resources, based on available data and information. Although several state and federal agencies and other organizations routinely collect water-resources data and information, no central "library" for this information exists.

Current water uses and future resource projections have been studied using varying models and assumptions, and, not surprisingly, significant data gaps have been identified. Therefore, various models and assumptions were used to determine exempt and missing data sets for water withdrawals, water levels, and flow volumes. Although projected volumes do not necessarily account for all uses of the water resource, understanding water use by sector (e.g., commercial, residential, industrial, agricultural, etc.) is critical when projecting future water demands.

Lastly, as important as water quality is to public health[1] and the environment, this plan focuses on its effect on water availability. As such, it supports the Tennessee Department of Environment and Conservation's Division of Water Resources' efforts under several water-related statutory schemes. Recommended next steps include outreach, developing a process for evaluating and prioritizing the recommendations, and initiation of a regular cycle of updates for a water plan.

[1] See Appendix for Tennessee Department of Health *TN H_2O* Overview.

Acknowledgements

TN H_2O: Tennessee's Roadmap to Securing the Future of Our Water Resources is possible because of the time, effort, and expertise of many people and organizations throughout Tennessee. ***Governor Haslam and Deputy Governor Henry would like to thank everyone who participated in the development of this document and acknowledge the invaluable assistance from the Steering Committee and various working groups.***

Below is the full list of Steering Committee members:

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- **Randy McNally**, lieutenant governor, State of Tennessee
- **Beth Harwell**, speaker of the House of Representatives, State of Tennessee
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- **Bob Rolfe**, commissioner, Department of Economic and Community Development
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- **Drexel Heidel**, co-chair, West Knox Utility District
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- **Darren Gore**, City of Murfreesboro, Utility Enterprises Division
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Executive Summary

Background of TN H_2O

In January 2018, Governor Bill Haslam appointed a steering committee of leaders from federal, state, and local governments; industry; academia; public and private utilities; and environmental advocacy groups to develop a statewide plan for future water availability in Tennessee looking out to 2040. The plan, *TN H_2O: Tennessee's Roadmap to Securing the Future of Our Water Resources,* assesses current water resources and makes recommendations to ensure that Tennessee has abundant water resources to support future population and economic growth through 2040. The *TN H_2O* Steering Committee, chaired by Tennessee Deputy Governor Jim Henry, provided high-level input and review for this effort. A copy of *TN H_2O* was given to the governor in November 2018 and made available for public input in December 2018. This aggressive schedule demonstrates Governor Haslam's commitment to the availability of sustainable Tennessee water resources. Its importance compelled Governor Haslam to pursue this effort in the last year of his term.

Teams of subject matter experts in various fields volunteered their time over several months to study the current state of various water resource areas and identify potential future concerns. These working groups focused on surface water, groundwater, water and wastewater infrastructure, legal and institutional framework, recreation and tourism, and natural resources. Some working groups used focus groups and tailored outreach to gain perspective and insight into the value of the state's water resources from the viewpoints of managers, stewards, and end users. Focus group participants consisted of members from the environmental and conservation community, academia, state government, and private industry and business sectors. Deputy Governor Henry undertook a series of meetings across the state with local officials and others to talk about *TN H_2O* and obtain their input regarding their water-related issues and challenges. Additional public outreach regarding the information and recommendations in this plan will be forthcoming. The working groups synthesized available information to arrive at recommendations to ensure water availability for future generations.

This plan is not exhaustive, but it provides recommendations, informs decision-making, and establishes a roadmap to ensure water availability for future use. Note that water availability is directly influenced by its quantity and quality. This roadmap will focus on water quantity and support the agencies addressing water quality in Tennessee. Readers of this plan are encouraged to review the appendices for details on the status of the state's resources and the programs that monitor and manage them. These documents are available online at *https://www.tn.gov/environment/program-areas/wr-water-resources/tnh20.html*.

Why is a Water Plan Necessary?

This is not the first time Tennessee has recognized the need for such a plan. Despite the abundance of water resources in Tennessee, drought has at times prompted efforts to prepare for a future in which water resources are strained by weather patterns or excessive development and use. Severe drought in the 1950s prompted creation of a Water Policy Commission and enactment of the Water Resources Act of 1957, which called for "the continued study of water resources looking toward the creation and development of a basic long-range water resource policy for the state."[2]

Consistent funding limitations, however, have prevented the Water Resources Act of 1957 from being fully implemented; notably, the planning and data-gathering imperatives of the act have not been pursued. Later, drought conditions in 1981 prompted a water report which determined that "although Tennessee is richly blessed with water resources, the patterns of use, reliance on English common law riparian rights, and urban growth in the state are placing a severe strain on these resources."[3] A Comptroller's audit in 1983 noted "the absence of an overall state plan for river basin development."[4] A 1991 report by the Comptroller's Office of Local Government again noted this deficiency and emphasized the need for a long-term strategy to provide water and sewer services in Tennessee.[5] Most recently, in March 2002, the Comptroller of the Treasury issued a water policy study, *Tennessee's Water Supply: Toward a Long-Term Water Policy for Tennessee*,[6] in response to multiple media reports over the last two years describing concerns about Tennessee's water supply.

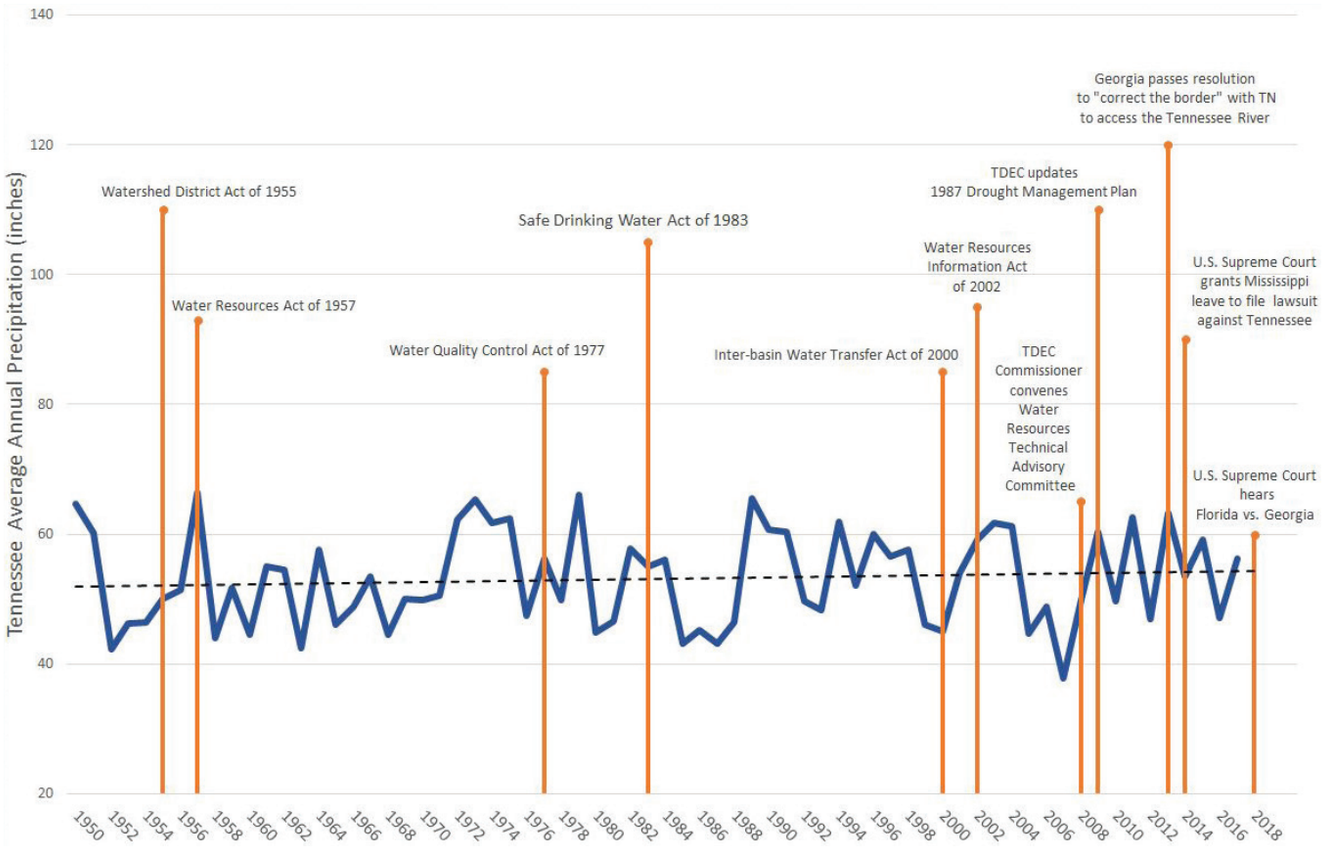

Figure 1. Timeline of significant events in Tennessee water policy and statewide trends in average annual precipitation. (Note: dashed line is the precipitation trend line).

[2] *Tennessee Code* Annotated §69-7-102.

[3] *Program Evaluation on the River Basin Agencies and Authorities* (Nashville, TN: Comptroller of the Treasury, Division of State Audit, 1983), p. 40.

[4] *Program Evaluation on the River Basin Agencies and Authorities* (Nashville, TN: Division of State Audit, 1983), p. 40.

[5] *Special Report: Planning and Service Delivery in Tennessee*, Ethel R. Detch and Scarlett J. Weakley (1991).

[6] *Special Report: Tennessee's Water Supply*, Dan Cohen-Vogel, Ph.D and Greg Spradley (March 2002).

[7] Letter from John G. Morgan, comptroller of the Treasury, to members of the Tennessee General Assembly (March 5, 2002).

Now, in 2018, rapid economic development in the state, scarcity of water resources in neighboring states, and the recognition that Tennessee remains one of few states in the nation without a long-range water plan, have prompted the *TN H_2O* study. Understanding Tennessee's water resources today—including natural resources, recreation and tourism, surface water, groundwater, water and wastewater infrastructure, and legal and institutional frameworks—is critical to planning for the future. Preparing for tomorrow and developing water-planning best practices—including criteria to determine stress areas, demand, extreme weather, interstate issues, resource conservation, infrastructure needs assessment, regionalization, water reuse, and needed data and information—are critical for Tennessee to continue to thrive. The following chapters review the working groups' assessments, projections, and recommendations.

TN H_2O Proposed Recommendations

Each working group identified recommendations focusing on their specific topic and area of expertise. These specific recommendations, listed under the associated chapter, should be examined more closely. ***Through the working groups' research and deliberations, the following overarching recommendations emerged.*** Subsequently, the Steering Committee provided substantive feedback and specific comments. Together, these will guide future decision-making and planning.

The working groups recommend addressing current and impending infrastructure needs. The sustainability of all water supply systems must be ensured to support economic development. Solutions may include the following:

- **A mechanism should be established to address unserved areas, infrastructure repair/replacement issues, and funding shortfalls faced by rural systems.**
- **Projected technical personnel needs associated with system operations and security must be acknowledged and addressed.**
- **Federal water project management, including maintenance of locks and dams, should be promoted.**

The Steering Committee unanimously recognizes the vast scope and range of this problem and the importance of this recommendation—clean, safe, reliable, and affordable water is critical to sustaining quality of life. Yet, many rural areas in Tennessee are without utility water supplies. Commenters noted that utilities and communities would need to be open to a variety of creative solutions for funding and using both public and private tools to address the gap.

Understanding the many competing demands for infrastructure resources indicates that investments should drive sustainable water and wastewater systems if we are to meet our nation's future needs and preserve our quality of life. Neither the public nor the private sector can continue to cover the cost and absorb the risk of degrading infrastructure. In particular, the working groups recommend reviewing under- and inadequately served areas in order to direct funds to assist them, especially areas with inadequate groundwater supply. Similarly, it is imperative that we develop mechanisms for attracting and retaining a workforce that continues to support a sustainable water future.

Steering Committee members also note that, although federal funding for water and wastewater infrastructure plays an important role, federal investments should be made strategically, to create the most cost-effective solutions for all customers and constituents. Our inter-waterway infrastructure is aging rapidly, not only in Tennessee but also across the United States. Tennessee should be a leader in water infrastructure investment, potentially leveraging state monies to promote and enhance federal water projects.

A related proposal called for investing in protecting and restoring natural infrastructure[8] and the processes that produce healthy and abundant water for all purposes. This recommendation emphasized the need to identify and marshal resources to protect and restore the health of Tennessee's waters and to coordinate investments in capacity across all major public and private stakeholders to ensure collaboration toward shared goals for watershed health. Local jurisdictions will need technical and financial support to meet those goals.

The working groups recommend developing a campaign to help the public and decision-makers understand the value of water and natural resources and complexity in managing them. The campaign could identify the critical role of water and natural systems in enabling and supporting quality of life and economic development in the state—from maintaining vibrant communities to industrial and population growth to recreation and tourism. The campaign could raise awareness of how individual and collective actions affect this public trust and of the importance of stewardship to protect the resource.

This recommendation was collectively recognized by the Steering Committee as important, noting the gap in the understanding of water uses, infrastructure needs, and the access and availability of water by the general public. Education would not only enable the public to get involved and understand vital and precious water resources, but also help decision makers determine our governments' priorities and funding opportunities.

Additionally, resources should be provided and research funded to help farmers, and others who work diligently to be good stewards of the environment and employ environmentally friendly and economically beneficial practices, to become even better stewards of Tennessee's natural resources.

The working groups acknowledge a need for greater collaboration and communication concerning Tennessee's water resources. The working groups recommend chartering a state water resources task force or advisory committee (group), composed of major public and private stakeholders and subject matter experts, focused on proactive water resources management. The governance structure could formalize and sustain the collaboration and coordination regarding water resources that has been initiated through the TN H_2O effort. The group could provide strategic management and oversee implementation of TN H_2O recommendations. The group could address significant water use disputes and opportunities, as well as risk management and resilience. It could leverage incentives and encourage voluntary efforts to achieve water resources goals. The group should be structured to ensure stability through administration changes.

The Steering Committee also acknowledges the need for greater collaboration and communication concerning Tennessee's water resources. The form and formality of such a governing body or other construct to proactively manage water resources needs additional discussion and vetting among major stakeholders as evidenced by various viewpoints revealed in Steering Committee discussions. Although several constructs are available for this purpose, the recommendation presented here, highlighting the need for solid science and sound legal opinions to resolve

[8] Natural infrastructure is defined as a "strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserves or enhances ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon 2006).

water rights conflicts, protect designated uses, and apply consistency and focus to understanding the status of water resources across the state, has support. Opportunities noted include collaboration among state cabinet departments and agencies to consider water health and abundance when recruiting industry, writing permits, and making grants. The proposed governing body could foster an unbiased (i.e., scientific and not political) approach to establishing water resources goals and recommendations. Moreover, whether Tennessee charters a new governing body or adopts some other construct, a need to improve monitoring and analysis of water resources was widely recognized as necessary to set Tennessee on a course to understand our water resources now and in the future and to be able to solve problems in such fashion as to ensure that they do not reoccur.

To counter the uncertainty inherent in executive branch changes, including the potential for member turnover and agenda realignment, the Steering Committee considered whether existing entities could efficiently absorb the responsibilities of a proposed governing body and continue to rely on existing water rights laws and precedents. Before establishing a new body, the General Assembly should carefully consider its membership (e.g., equal representation for rural and urban areas), duties and responsibilities, processes, and decision-making authority in managing water resources and provide direction on governance, oversight, and management. This may entail educating users, leveraging incentives, and encouraging voluntary efforts, as well as reconciling practices that hinder water resource goals. This body could also be tasked with addressing interstate and intrastate water use disputes where existing laws and regulations or common-law riparian doctrines cannot.

Evaluate existing laws for possible full implementation. State laws to address critical aspects of water supply planning already exist. Existing laws should be evaluated to assess their implementation (e.g., Water Resources Act, Watershed District Act, and Water Resources Information Act) and to determine and enable proper jurisdictions for regional water planning and programs. With these laws as a foundation, the working groups recommend maintaining currently available funding sources while seeking or creating additional funding and capacity to support the long-term sustainability of water resources across the state.

The Steering Committee notes that clarity is needed to understand who is charged with implementing existing laws, together with understanding funding for implementation. One issue that might arise concerns regional water resources organizations' jurisdictions regarding individual property owner's riparian water rights. Uncertainty also exists regarding implementing antiquated laws that are possibly no longer a priority, given that the legislature has passed subsequent laws and not funded them.

Develop a comprehensive water resources planning process and planning cycle based on good science and information (consistent monitoring, data collection, modeling, trending, and reporting) that includes all major users and stakeholders. This process could be used to both define and characterize major uses, validate models and forecasts, and establish action triggers to avoid or minimize the impacts of crises.

Stakeholder involvement and vetting will be especially important to successfully implementing this recommendation. As a modeling effort based on science and industry input should be constructive, care should be taken to define and avoid unduly burdening small users and Tennessee's farm economy. The nature of agricultural water use makes difficult the collection of water usage data on farms, and farmers would find any new reporting requirements difficult to comply with. Therefore, modeling may be a more practical and cost-effective alternative for charting agriculture's current and projected water use. The Steering Committee also considered clear responsibilities and funding critical to this recommendation.

Use the state water resources task force or advisory committee and regional water resources jurisdictions to facilitate intrastate and interstate regional cooperation. Foster cooperative arrangements among water systems (intrastate) and increase cooperative interstate water resource management as appropriate. Increase collaboration and coordination between organizations (federal, state, nongovernmental) with water resources management-related missions.

Considering the needs of both those with access to water services and those without it was a key concern of the Steering Committee, as was respecting existing riparian rights. Whether promoting or enabling cooperative arrangements among water systems, more coordination is needed between the entities listed in this recommendation. Although many water utilities in the state collaborate to ensure domestic water supply during drought, more can always be done to assist those in need. Further collaboration may also improve service to underserved areas. The Steering Committee also emphasized the importance of dedicated collaboration among regulatory agencies and with adjoining states for new water supply projects.

While not the first time Tennessee has recognized the need for water resources planning, TN H_2O is the first comprehensive look at Tennessee's water resources including surface water, groundwater, and natural resources in one effort. Severe drought in the 1950s prompted the creation of a Water Policy Commission and the enactment of the Water Resources Act of 1957, which called for the creation and development of a basic long-range water resource policy for the state. Consistent funding limitations prevented its full implementation. Ensuring that Tennessee has an abundance of water resources to support quality of life and future population and economic growth will require identifying sustainable funding for all TN H_2O recommendations.

Both working group and Steering Committee discussions revolved around funding as a critical component to this effort. The Steering Committee recognizes that infrastructure funding presents an urgent need, notwithstanding the long-term value of this planning effort and how more scientific analysis and monitoring is a fundamental role of government. State budgeting would also be necessary to *TN H_2O*'s long-term success. That said, collaboratively identifying specific agencies and/or organizations within the state responsible for implementing the recommendations and identifying specific funding levels is necessary to follow through with the recommendations now and in the future.

Water's Cultural Environment

Tennessee's great diversity in land, climate, water, and animal and plant life are reflected in its culture and economy. This long, narrow state divides naturally into three Grand Divisions: upland, often mountainous, East Tennessee, Middle Tennessee with its foothills and basin, and the low plain of West Tennessee. (See figure 2.) Each grand division developed differently through the state's early history largely because of geographic differences. And although Tennessee's mountains and rivers are no longer the barriers to movement that they once were, today's population and economic variations continue to reflect the state's geography.

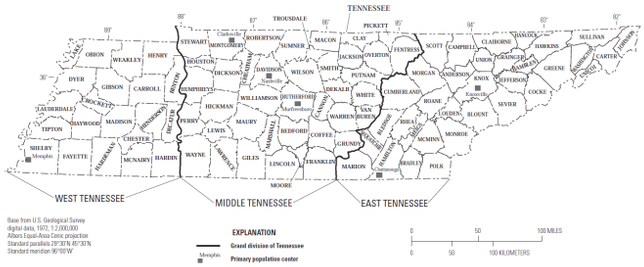

Figure 2. Tennessee counties and primary population centers by Grand Divisions. (Source: USGS, Robinson, 2018).

Population

Tennessee's population has increased by 30 percent since 1990. The U.S. Census Bureau forecasts an overall population growth of 23 percent between 2018 and 2040, reflecting a total population increase of 1,561,213. Projections indicate that 90 percent (1.4 million people) of this increase will be in urban counties, with rural counties seeing growth of 10 percent (approximately 200,000 people) in this 23 year period. (See figure 3.) Some of the increase in the state's urban population will occur in what are now rural counties near major metro areas that are expected to grow enough to be reclassified as urban counties. These future county reclassifications have been incorporated into this projected 90 percent urban county population growth. As the population continues to increase, comprehensive planning, including land use, transportation, water infrastructure, and other community needs and resources, will be imperative. Land use decisions can harness future growth for prosperity or promote unfettered expansion and inefficient use of land and increased costs for governments and citizens.[10]

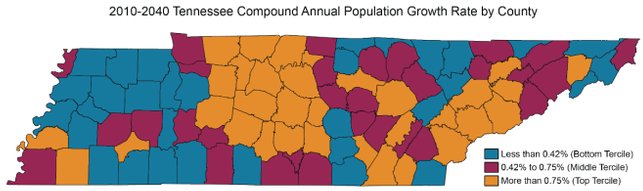

Figure 3. Tennessee compound annual population growth rate by county (2010-2040). (Source: Center for Business and Economic Research, University of Tennessee, Knoxville).

Economy

Numerous dams along the Tennessee and Cumberland rivers not only facilitate water transportation but also provide flood control; abundant, low-cost hydroelectric power; and extensive recreation areas. Manufacturing, agriculture, hunting, fishing, recreation, and tourism are all water-dependent industries contributing to the state's economy. Before the 1930s, agriculture was the leading economic sector. A shift to industrial sectors occurred with the construction of several dams to control flooding along the state's two major waterways. Availability of low-cost hydroelectric power from the multipurpose dams of the Cumberland and Tennessee Rivers and their tributaries coupled with flood control has been a stimulus to industry of all types.

[9] University of Tennessee Center for Business and Economic Research, *Study: Tennessee on Track for Steady Population Growth*. 2015. Tennessee's population is projected to reach 8.5 million by 2040. The 2040 projections at county level shown in figure 3 are available online at *https://news.utk.edu/2015/08/27/study-tennessee-track-steady-population-growth/.*

[10] TACIR, *Land Use and Planning* (2011). Retrieved on August 30, 2018 from *https://www.tn.gov/content/dam/tn/tacir/documents/LandUseAndPlanning.pdf.*

Tennessee's abundant and high-quality water resources have played a major role in the state's industrial and economic growth. Industrial users that self-supply water (do not obtain water from public utilities) used 734 million gallons of water per day in 2015. Self-supplied industrial water use has been trending down thanks to conservation and adoption of more efficient technologies. Additionally, the Mississippi, Cumberland, and Tennessee rivers are suitable for commercial traffic. In 2015, the annual commercial transport totals were roughly 35.8 million tons on the Tennessee River, 21.8 million tons on the Cumberland River, and 8.07 million tons on the Tennessee-Tombigbee.[11] Assuming the nationwide average barge shipment weight of 1,500 tons, commercial goods on the approximately 22 thousand barges, 94 percent of which is interstate in nature; 1.65 million trucks would be required to transport the same volume. Moreover, water transport is considered more efficient, cleaner, and safer for the public than other modes of cargo transport. [12]

Tennessee's principal manufacturing areas are Memphis, Nashville, Chattanooga, Knoxville, and Kingsport-Bristol. The principal types of manufacturing products are transportation equipment; food, beverage, and tobacco products; and chemical products. Although surpassed in monetary value by industrial activity, agriculture remains a vital feature of Tennessee's economic life. The wide range of climates in Tennessee—from river bottom to mountaintop—coupled with a wide range of soils, has resulted in a large number of crops that thrive in the state.

Agriculture and forestry have a profound effect on Tennessee's economy, the health of our citizens, the beauty of our landscape, and the quality of our lives. In hundreds of rural communities across our state, agriculture and forestry are the primary drivers of local economic activity. Agriculture and forestry's impacts are also felt throughout the manufacturing, processing, distribution, and marketing sectors of our economy. In 2015, agriculture and forestry contributed $81.8 billion to Tennessee's economy.[13] Agriculture and forestry accounted for 12.8 percent of economic activity within the state and employed more than 351,000 people, or 9.2 percent of the workforce. Tennessee farmers earned nearly 75% percent of their cash receipts from soybeans, broilers, cattle and calves, greenhouses and nurseries, and corn and cotton.

The number of people employed in manufacturing and related industry has increased, while the number of farmers has declined proportionately. This shift supports the trend of rural populations migrating to urban areas. Tennessee's four major metropolitan areas—Memphis, Nashville, Knoxville, and Chattanooga—employ about half of all the state's industrial workers. [14]

[11] U.S. Army Corps of Engineers Waterborne Commerce Statistics Center. *Final Waterborne Commerce Statistics For Calendar Year 2016*.
[12] US Department of Transportation Maritime Administration, The American Waterways Operators "*Comparing Transportation Modes*"
[13] Menard, Jamey, Burton C. English, and Kimberly Jensen. 2015. *Economic Contributions of Agriculture and Forestry in Tennessee*. University of Tennessee Institute of Agriculture (UTIA).
[14] University of Tennessee Institute of Agriculture, Tennessee Climatological Service, *Climate Data for Tennessee*. Retrieved August 30, 2018 from *ag.tennessee.edu*, and "Tennessee." *Worldmark Encyclopedia of the States*. Retrieved August 30, 2018 from City-Data.com: *http://www.city-data.com/states/Tennessee.html*.

Fishing, boating, swimming, and camping along Tennessee's many lakes, together with the several state and national parks, have made tourism one of the state's major industries. Of the seventeen TVA lakes and seven U.S. Army Corps of Engineers' lakes, ten of these lakes span an area of 10,000 acres or more, and there are thousands of miles of creeks and mountain streams, all of which attract anglers. Recent water-based recreation and tourism data show that anglers spent $1.3 billion fishing in Tennessee that supported 17,541 jobs, with total economic output of $2.1 billion. Tennessee's recreational boating industry has an annual economic impact of more than $3 billion, supporting 15,817 jobs, and 595 businesses. Recreational visitors to the TVA lakes alone generate an average annual economic impact of $11.9 billion as well as more than 130,000 local jobs. While fishing is a major sport attraction, commercial fishing plays a relatively small role in Tennessee's economy.

Water-based recreation and tourism are as important in urban centers as it is in rural areas and contributes heavily to economic growth. A 2017 study by the University of Tennessee's Institute of Agriculture valued reservoirs at about $1 million per shoreline mile.[15] Chattanooga's redeveloped 13-mile riverfront gets a huge economic boost from the Head of the Hooch, the world's largest rowing regatta, bringing in more than 2,100 boats and an annual economic impact of more than $5.5 million for the city.[16] "Fish Dayton," a brand created in 2012 by community leaders to promote Dayton as a bass fishing destination and stimulate the local economy has resulted in $15 million in new private investments and hundreds of construction and full-time jobs for the community. Increasingly, cases like these emphasize the positive lifestyle and economic benefits afforded by Tennessee's high-quality waters.

Current and Future Water Needs

Even as Tennessee's population grew by more than a third from 1990 to 2015, total water withdrawals declined by 30% (see figure 4 and table 1). Industrial users that self-supply water (do not obtain water from public utilities) used 734 million gallons of water per day in 2015.[17] Self-supplied industrial water use have been trending down thanks to conservation, appliance upgrades, and other efficiencies, and while it is reasonable to believe that efficiencies and conservation efforts will continue to improve, the steep decline from 2005 to 2015 cannot be expected to continue even with adoption of more efficient technologies.[18] Agricultural production relied primarily on natural precipitation; however, 64 million gallons per day were used for irrigation in 2015.[19] The amount of water used for irrigation has been increasing in recent years.

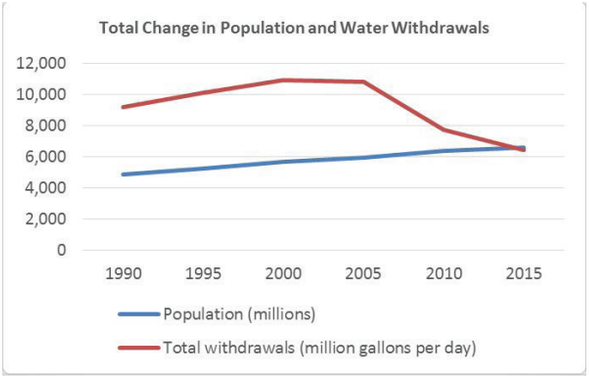

Figure 4. Total change in population and reported water withdrawal totals in Tennessee, 1990 to 2015.

[15] University of Tennessee Institute of Agriculture (UTIA), 2017.
[16] Outdoor Industry Association 2017, p. 13.
[17] Robinson, J. A. 2018, "Public-supply water use and self-supplied industrial water use in Tennessee, 2010: U.S. Geological Survey Scientific Investigation Report 2018–5009", 30 pp. *https://doi.org/10.3133/sir20185009*.
[18] Dieter, C.A., Maupin, M.A., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2018, Estimated use of water in the United States in 2015: U.S. Geological Survey Circular 1441, 65 p., *https://doi.org/10.3133/cir1441*.
[19] Dieter, C.A., Maupin, M.A., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2018, Estimated use of water in the United States in 2015: U.S. Geological Survey Circular 1441, 65 p., *https://doi.org/10.3133/cir1441*.

Table 1: Reported water use in Tennessee, 1990 to 2015[20]

Population in thousands; all withdrawals in million gallons per day

	1990	1995	2000	2005	2010	2015	Percent Change
Population	4,877	5,256	5,689	5,963	6,346	6,600	35%
Total withdrawals	9,190	10,100	10,900	10,800	7,700	6,420	-30%
Public supply	695	777	890	914	918	850	22%
Self-supplied domestic	59	54	33	37	39	43	-27%
Livestock	21	8	31	30	28	23	10%
Irrigation	38	25	22	55	72	64	68%
Thermoelectric power	7,320	8,300	9,040	8,940	5,800	4,620	-37%
Self-supplied industrial	882	863	842	783	776	734	-17%
Mining	90	6	14	22	15	31	-66%
Aquaculture	28	28	44	60	53	57	104%
Groundwater Total	503	435	456	489	470	430	-15%
Surface Water Total	8,690	9,640	10,500	10,300	7,230	5,990	-31%

Source: US Geological Survey, Robinson 2018.

Projecting future water withdrawals is a complex and difficult process, but the best estimates of water resource experts with the U.S. Geological Survey indicate that withdrawals in Tennessee will grow modestly through 2040 to around 7.9 billion gallons per day in total, including 526 million gallons per day from groundwater and 7,388 million gallons from surface water sources. Tennessee's current and future water needs are discussed more fully in the groundwater and surface water sections of the chapter, Water's Natural Environment and in the appendices that support them.

[20] Robinson 2018. Table has been modified to include percent changes from 1990 to 2015. The water-use data are available at the USGS Water Use in the United States web page (*https://water.usgs.gov/watuse/*) and published in Solley and others, 1993 and 1998; Hutson and others, 2004; Kenny and others, 2009; Maupin and others, 2014; Dieter and others, 2018. Water-use data for Tennessee have been published in Hutson 1994, 1995, and 1999; Webbers, 2003, Robinson and Brooks, 2010, and Robinson, 2018.

Water's Institutional Environment

Meeting Tennessee's water needs has produced a network of local water supply utilities supported by four state agencies, the Tennessee Valley Authority (TVA), and the U.S. Army Corps of Engineers (USACE) that provide Tennesseans with safe, dependable water. The overriding goal of Tennessee's institutional and legal structure for water supply is to safely and securely

- provide water to those who do not have it,
- meet the needs of a growing population,
- protect the state's water resources from pollution and depletion, and
- plan for the future use of waters to be used and enjoyed to the fullest extent consistent with the maintenance of unpolluted waters.

Threaded through the state's legal framework for water supply is an impressively consistent set of declarations that make clear the Tennessee General Assembly's support for a safe, healthy water supply and environment. The legislature recognizes that the waters of Tennessee are held in public trust for the benefit of its citizens and that Tennesseans are entitled to unpolluted waters as well as an adequate quantity and quality of drinking water.

Institutional Framework for Water Supply

Although many Tennesseans and some businesses supply their own water, most depend on some type of state-regulated public water system to treat and distribute water for their use.[21] Water systems in the western part of the state rely mainly on groundwater, as do some in Middle and East Tennessee, which can be made potable at lower cost than can surface water. Most of the remaining systems rely on water from the state's two major rivers or their tributaries, which include a series of impoundments created by the Tennessee Valley Authority (TVA) and the U.S. Army Corps of Engineers (USACE).

Oversight of the State's Water Utilities

Four state agencies are responsible for ensuring that the state's water utilities are both financially sound and able to provide safe and sufficient potable water:

- Tennessee Department of Environment and Conservation (TDEC)
- Utility Management Review Board (UMRB)
- Water and Wastewater Financing Board (WWFB)
- Tennessee Public Utilities Commission (TPUC)

Water quality—both the quality of drinking water and the quality of treated wastewater—is regulated by TDEC, which has broad responsibility for managing, protecting, and enhancing Tennessee's water resources through all manner of regulatory, voluntary, and educational programs. Within TDEC, the Division of Water Resources implements the water rules and regulations that the Tennessee Board of Water Quality, Oil, and Gas promulgates to implement various state laws. Although TDEC and the Board of Water Quality, Oil, and Gas have limited authority to monitor or regulate water use, all public water systems, whether governmental, investor-owned, or nonprofit, are subject to their water quality regulations.

[21] Some utilities buy treated water from other utilities for distribution to their customers.

The UMRB and WWFB are housed in the Tennessee Comptroller of the Treasury. They were established in 1987 to ensure that public water utilities operate efficiently and without repeated financial losses. The UMRB has jurisdiction over water systems established under the Utility District Law of 1937, including authority to approve or disapprove their creation, which is also subject to the approval of the mayors of the county or counties they propose to serve. The WWFB has jurisdiction over all other public water utilities. Unlike the UMRB, the WWFB does not have authority over the creation of utilities. Both boards have limited authority over utility rates, typically only when the utilities become financially distressed, although the UMRB might hear customer complaints.

Investor-owned water utilities in Tennessee are regulated by TPUC, which has broad regulatory jurisdiction over the operations of investor-owned utilities, including their creation and approval of all customer rates and charges for water service.[22] Investor-owned water utilities must also obtain a franchise from municipalities within which they seek to provide water service. Any franchise agreement between a municipality and an investor-owned water utility must be approved by TPUC. Neither water cooperatives nor water systems owned by homeowner associations are subject to oversight by any state agency, except for regulation of water quality by TDEC.

Federal Support for Water Supply

Federal water supply policy recognizes a significant federal interest in the long-term management of water supplies, but considers municipal and industrial (M&I) water supply development and management primarily the responsibility of states and local entities. In Tennessee, two federal agencies (USACE and TVA), through the operation of their dams and reservoirs, play a supporting role in managing water supply. Both agencies have stewardship responsibilities for water quality and aquatic life as well, and they coordinate closely with other federal, state, regional, and local authorities and with various stakeholders in carrying out their duties.

U.S. Army Corps of Engineers (USACE)

USACE is a direct-reporting unit under the command of the U.S. Department of the Army. Its role in developing water supplies is through construction and operation of federal multipurpose projects, which in Tennessee consist of lock-and-dam projects on the main stem and dam-and-reservoir projects on tributaries and headwaters of the Cumberland River system. The Nashville District of the USACE manages these projects for flood risk management, commercial navigation, hydropower production, municipal and industrial water supply, fish and wildlife, water quality, and recreation. USACE-provided water supply services generally involve contracting with water users to provide space to store water in reservoirs, and authorizing facilities to withdraw it.

Tennessee Valley Authority (TVA)

The TVA is a multipurpose federal corporation with authority to build and operate dams and reservoirs in the Tennessee River system to control destructive floods and promote navigation. In carrying out this mission, the agency operates a system of dams and reservoirs with associated facilities to manage the water resources of the Tennessee River and its tributaries for myriad purposes, including year-round navigation, flood-damage reduction, power production, recreational opportunities, improved water quality, economic growth, and other public benefits. Unlike USACE, because it operates under different authority, TVA does not contract with water users to provide water storage in its reservoirs.

Legal Framework for Water Supply [23]

Both public and private entities—each with their own goals and guiding authorities—combine to have a wide-reaching impact on Tennessee's water supply. This multi-faceted legal, regulatory, and planning approach has led to a complex and interrelated set of state and federal laws that supplement long-standing, court-made common law. Given this framework, it is imperative that these public and private entities coordinate and act effectively to ensure that Tennesseans have the water they need. Considerable laws have been developed to ensure water quality; therefore, the following discussion focuses on law related to ensuring that sufficient water is available to meet the needs of a growing population and sustain healthy aquatic ecosystems to support that population.

Riparian Rights—The Common Law of Water Supply

Regulation of water supply in the United States is rooted in common law doctrines developed by state courts. Generally, dry western states adopted systems of "prior appropriation" (characterized by the phrase "first in time, first in right") to manage access to scarce water resources. The wetter eastern states, including Tennessee, adopted "riparian rights" systems in which water use rights are held in association with ownership of land that touches a body of surface water or groundwater. Each riparian owner is entitled to reasonable use of that water, provided the use does not interfere with the right of other riparian owners. Landowners above groundwater aquifers share a similar right to reasonable use of the water resource.

This system is more effective at resolving disputes than at preventing them. Moreover, it provides no mechanism for protecting the water environment itself or the aquatic life within it for everyone's benefit. It has been gradually supplemented in the east with statutes, rules, and programs in a system called "regulated riparianism."

Regulated Riparianism—Tennessee's Water Supply Laws

As uncertainties inherent in population growth and water-related disasters (e.g., droughts and floods) overran the narrowly drawn, reactive principles of common law, the Tennessee General Assembly adopted a series of acts to better protect and sustain the state's water resources. These protections extend to aquatic life—the flora and fauna of our springs, rivers, and streams. This "public trust doctrine," whereby wildlife is held in trust by the state for the benefit of the people of the state, predates the public trust declarations threaded through the state's water laws and has been supported by the Tennessee Constitution since 1870. Article XI, Section 13 grants the General Assembly "the power to enact laws for the protection and preservation of game and fish."

Watershed District Act of 1955

This act established a process for identifying individual watersheds for the purpose of creating boards to develop water resources within their districts. These watershed district boards are chartered by the State Soil Conservation Committee and have a variety of corporate powers, including the ability to

- conserve soil and water to retard floods and develop water resources of the district;
- construct any works or improvements for the control, retention, diversion, or use of water;
- exercise all powers conferred upon levee and drainage districts;
- acquire water rights and distribute or sell water for irrigation or for other purposes, either within or without the district; and
- provide recreation facilities. (*Tennessee Code Annotated* § 69 6 101, et seq.)

[23] All descriptions of state and federal legislation in this section are based on current law as amended through the date of this plan, regardless of the dates of the original acts.

Although more than 100 of these districts have been formed at one time or another in all parts of the state—many of which built dams or channelized streams—only 12 remain active today fulfilling some of these functions.

Water Resources Act of 1957

The Water Resources Act (WRA) created a water resources division within TDEC with a director responsible "for the general direction of all matters pertaining to conservation, protection, and development of the water resources of the state and the continued study of water resources looking toward the creation and development of a basic, long-range water resource policy for the state" (*Tennessee Code Annotated* § 69 7 102). However, as noted in a 2002 report by the Tennessee Comptroller, the "provisions of the Water Resources Act of 1957 have never been fully implemented, including the planning and data-gathering functions recommended by this and previous reports" because of consistent funding limitations.

Water Quality Control Act of 1977

Although the Water Quality Control Act (WQCA) was adopted primarily to abate and prevent pollution, one of the permitting mechanisms established to implement it, the Aquatic Resource Alteration Permits (ARAPs), applies when a proposed water withdrawal might affect the quality of a source stream by removing a significant portion of its flow. Certain withdrawals are exempt from ARAPs, including for agriculture and forestry activities.

Safe Drinking Water Act of 1983

Tennessee's Safe Drinking Water Act (SDWA) governs the construction and operation of public water supply systems, including community water systems and non-community water systems (e.g., hotels, restaurants, and industries that rely on their own surface or groundwater source). A public water system has "15 or more connections or… regularly serves 25 or more individuals daily at least 60 days out of the year." (*Tennessee Code Annotated* § 68 221 703[19]). This is the act under which the Board of Water Quality, Oil, and Gas has established standards for drinking water to protect against health risks.

Inter-Basin Water Transfer Act of 2000

The Inter-basin Water Transfer Act (IBWTA) "allow[s] regulation on the basis of the quantity of water in river basins" and established 10 water basins from which water cannot be diverted without a permit (*Tennessee Code Annotated* §§ 69 7 202 and 203). An inter-basin transfer occurs when water is withdrawn from any of Tennessee's 10 watersheds and transferred directly or through intermediaries to a point outside that watershed to provide public drinking water. TDEC makes IBTWA permit decisions based on a host of factors, including stream flow of the losing river(s); reasonable, foreseeable water needs; conservation; and whether an applicant's proposed use is reasonable and beneficial.

Water Resources Information Act of 2002

To enable more accurate monitoring of water withdrawals, the General Assembly passed the Water Resources Information Act (WRIA)—a water registration system designed to facilitate more accurate forecasts of water use and demand. Under the WRIA, "no person shall withdraw ten thousand (10,000) or more gallons of water per day from a surface water or a groundwater source unless the withdrawal is currently registered with the

commissioner" (*Tennessee Code Annotated* § 69 7 304[a]). As with ARAPs under the WQCA, certain withdrawals are exempt from registration and reporting, including those for agricultural purposes (*Tennessee Code Annotated* § 69 7 304[d]). The act also authorized creation of the Water Resources Technical Advisory Committee, which updated the state's drought management plan and framework for local utilities and developed a regional water supply planning framework.

Federal Water Supply Authority

The history of federal policy related to water supply in the eastern U.S. is one of modifying early laws and projects originally created for flood control and navigation to meet the needs of growth and development. Most federal projects in the East did not include water supply in their original authorizations, because natural flows were sufficient to meet local needs. Today, even in our water-rich state, federal reservoirs are essential in some places to meeting M&I water needs. In instances where federal laws and projects did not provide for those needs, authorized project purposes have been modified and adapted.

Tennessee Valley Authority Act of 1933

Section 26a of the TVA Act of 1933 provides for TVA's review and approval of construction, operation, and maintenance of any planned structures or activities affecting navigation, flood control, or public lands or reservations of the Tennessee River or any of its tributaries. Water withdrawals require §26a permits, as may obstructions, extractions of water for agriculture and irrigation, and temporary emergency municipal water intakes. All permits for water intake structures regulate the withdrawal rate and, in some cases, might limit approved uses and require compensation for loss of power benefits.

U.S. Army Corps of Engineers Authorizations

The Water Supply Act of 1958 (43 U.S.C. § 390b), as amended, provides general discretionary authority applicable to all USACE reservoir projects. It is the primary vehicle for USACE involvement in water supply storage. This act allows permanent municipal and industrial water supply storage space to be included in any USACE reservoir project, provided that state or local interests agree to bear the full cost of the storage provided, whether included in the reservoir's original plans or reallocated later from other authorized uses. Any modification of a planned or existing reservoir project, including any reallocation of storage for water supply, that would seriously affect the purposes for which the project was authorized, surveyed, planned, or constructed, or would involve major structural or operational changes, must be approved by Congress.

The laws through which Congress establishes the authorized purposes for reservoir projects can be grouped into three general categories: (1) laws initially authorizing project construction; (2) laws specific to the project passed subsequent to construction; and (3) laws that apply generally to all USACE reservoir projects. Specific project authorizations are found in a series of River and Harbor Acts, Flood Control Acts, and Water Resources Development Acts passed by Congress since 1870.

Other Acts Governing Federal Water Supply Projects and Actions

Water Resources Planning Act of 1965—Under the WRPA, as amended by the 2007 WRDA, "it is the policy of the United States that all water resources projects should reflect national priorities, encourage economic development, and protect the environment by

- seeking to maximize sustainable economic development;
- seeking to avoid the unwise use of floodplains and flood-prone areas, and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used; and
- protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems (42 USC § 1962 3[a]).

Principles, requirements, and guidelines established under the WRPA apply to relevant projects, programs, and activities undertaken by the U.S. Environmental Protection Agency, and the Departments of Commerce, Interior, Agriculture, and Homeland Security (Federal Emergency Management Agency), as well as USACE and TVA, consistent with statutory authorities.

National Environmental Policy Act of 1969—NEPA requires federal agencies, including USACE and TVA, to assess the environmental effects of their proposed actions and alternatives before making decisions. The range of actions covered by NEPA is broad and includes

- making decisions on projects, programs, and permit applications;
- adopting federal land management actions; and
- constructing highways and other publicly owned facilities.

Using the National Environmental Policy Act (NEPA) process, agencies evaluate the environmental and related social and economic effects of their proposed actions and provide opportunities for public review and comment on those evaluations. The NEPA process is integrated with USACE's and TVA's planning processes and TDEC, as the steward of Tennessee's natural resources, provides comments on proposed federal actions in the state.

Federal Authority to Resolve Interstate Disputes

The U.S. Constitution assigns roles to the Supreme Court and Congress to resolve disputes between or among states over interstate water resources:

- States can seek an allocation from Congress.
- States can enter into a compact subject to Congressional approval.
- States can ask to invoke the Supreme Court's "original jurisdiction" over disputes between states (U.S. Constitution, Article I, § 2), and the court will apply the federal common law of equitable apportionment to allocate the right to use an interstate water source among the competing states.

Areas of Concern for Tennessee's Institutional and Legal Framework

Tennessee is well positioned to create a more robust system of water supply planning, albeit with considerable federal support. Growing demands placed on our shared water resources are beginning to reveal concerns that might be mitigated through a more formal and coordinated planning process. These concerns include a lack of resources or formal mechanisms for

- implementing existing law, particularly Tennessee's Water Resources Act, even as its provisions become increasingly relevant and important;
- understanding the scale and frequency of water withdrawals and their potential to affect water availability and quality;
- facilitating collaboration and cooperation among water users dealing with water shortages, flood mitigation, and other challenges;
- mitigating and managing through major droughts and floods;
- integrating water supply planning with land-use planning, or with comprehensive planning generally;
- establishing the value of ecosystems and natural resources, including their economic value as well as their role in protecting and sustaining a safe and secure water supply, and factoring those values into water resource and land-use plans;
- encouraging water use conservation and demand-management, as well as leak reduction, which is estimated to have wasted more than 51 billion gallons of water and cost more than $64 million annually;[24]
- increasing water supply allocations from federal projects, which invoke a process that places enormous strain on local, state, and federal resources; and
- resolving interstate conflicts (e.g., Mississippi, Georgia), coupled with the challenging nature of current federal mechanisms for resolving interstate disputes.

Recommendations—Water's Institutional Environment

Below are the summarized recommendations from the Institutional and Legal Framework Working Group:

- Implement the planning provisions of Tennessee's Water Resources Act, including those related to maintaining an accurate inventory of the state's water resources and to estimating existing and future water use.
- Consider amending the Water Resources Act to establish a multidisciplinary and multi-stakeholder task force or similar agency for water supply planning, allocation, management of flow regimes, and conflict resolution.
- Formally recognize the inherent relationship between water quality and water availability by integrating and coordinating policies and actions under the state's Water Quality Control Act with those established under the Water Resources Act.
- Consider using the Watershed District Act, modifying it if necessary, to facilitate a system of regional water supply planning, building on the work of the commissioner's Water Resources Technical Advisory Committee, which created guidelines for regional water supply planning supported by comprehensive data collection, management, and analysis and implemented through voluntary incentives.

[24] Based on data reported by utilities and municipalities via the Comptroller's report on water loss. Estimates reflect 78 percent of audits, because 22 percent of the audits did not pass the filters recommended by American Water Works Association.

Water's Natural Environment

Located in the eastern south-central region of the United States, Tennessee, ranking 34th in size among the 50 states, has a total area of 42,144 square miles consisting of 41,155 square miles of land and 989 square miles of inland water. Tennessee borders eight states. Arkansas and Missouri are Tennessee's western neighbors, with the Mississippi River serving as the boundary. Tennessee extends east about 430 miles from the Mississippi River directly to the Appalachian Mountains, where North Carolina is its neighbor. The state's southern boundary at parallel latitude 35° north is shared with Georgia, Alabama, and Mississippi. Its northern boundary, shared with Kentucky and Virginia, is a broken line lying between parallels 36° 29′ and 36° 41′, giving it an average breadth of 110 miles.[25]

Climate and Precipitation

The National Climatic Data Center divides each state into climate divisions for climate summaries. Tennessee has four climate divisions, because of the diversity of climate conditions across the state, which are largely controlled by the state's topography, proximity to cyclone tracks, and, to a lesser extent, by latitude. Figure 5 shows the four climate divisions. Generally, Tennessee has a temperate climate, with warm summers and mild winters. However, the state's varied topography contributes to a wide range of climatic conditions.[26]

Figure 5. Tennessee Climate Divisions. (Source: University of Tennessee Institute of Agriculture, 2018).

Differences in terrain provide much cooler conditions in the east. For example, the annual average temperature at the state's highest elevation, Mount LeConte, is 42.2°F, whereas the average temperature at the state's lowest elevation, Memphis, is 63.1°F. Much of this 20.9°F variation between these two sites can be explained by the more than 6,200 feet elevation difference. Most other climate sites in northeast Tennessee in close proximity but not at a comparable elevation to Mount LeConte have annual average temperatures in the mid-to-upper 50s.[27] The annual average temperatures across Tennessee are shown in figure 6.

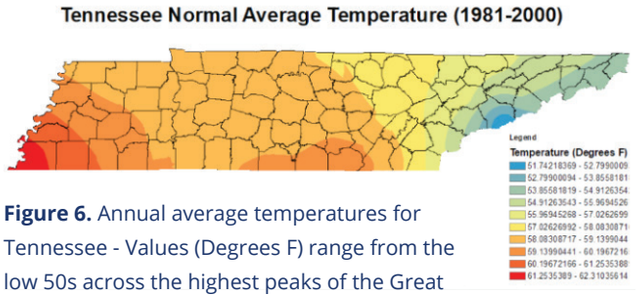

Figure 6. Annual average temperatures for Tennessee - Values (Degrees F) range from the low 50s across the highest peaks of the Great Smoky Mountains to the low 70s across portions of west Tennessee. (Source: Maye, National Weather Service, 2018).

Precipitation levels are also affected by elevation. On average, most of the state receives between 50 and 60 inches of precipitation each year. The greatest variance is in East Tennessee, because of its varied terrain. Mount LeConte has a normal annual precipitation amount of 73.5 inches; whereas the western, lowland areas of the state average between 40 and 50 inches.[28] The annual average amounts of precipitation across Tennessee are shown in figure 7.

[25] Safford, James M., Geology of Tennessee. Tennessee General Assembly: Nashville, 1869.
[26] University of Tennessee Institute of Agriculture, Tennessee Climatological Service, Climate Data for Tennessee. Retrieved August 30, 2018 from: *https://ag.tennessee.edu/climate/Documents/Climate%20of%20TN.pdf*.
[27] Zach Maye, National Weather Service Memphis, *Tennessee Climate Assessment*, 2018.
[28] Maye 2018.

Normal annual precipitation is distributed not only spatially across the state but also temporally throughout the year. A few similarities can be observed across the state in annual precipitation distribution throughout the year. A relative minimum precipitation occurs during August, September, and October when portions of the state are most susceptible to drought. Precipitation increases during the last two months of the year. In East Tennessee, precipitation totals remain fairly steady from November through the winter and spring months; whereas, in Nashville and Memphis, bimodal precipitation distributions occur, with the first precipitation peak in the spring and another in late fall into early winter.

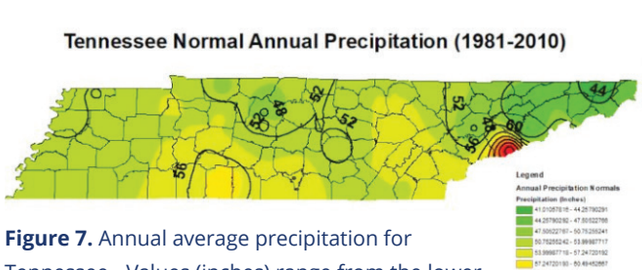

Figure 7. Annual average precipitation for Tennessee - Values (inches) range from the lower 70s across the highest peaks of the Great Smoky Mountains to the middle 40s across portions of northeast Tennessee. (Source: Maye, National Weather Service, 2018).

Widespread flooding and local flash floods can occur during the winter and early spring months when frequent migratory storms bring intense rains. In summer, heavy thunderstorms frequently cause local flash flooding. In the fall, though flooding is rare, a decadent tropical system on occasion can cause serious flooding. The numerous dams along the Tennessee and Cumberland Rivers reduce flood damage across the state. [29]

Tennessee's climate is changing; although the average temperature did not change much during the 20th century, the state has warmed in the last 20 years. Average annual rainfall is increasing, and a rising percentage of that rain is falling on the four wettest days of the year. In the coming decades, the changing climate is likely to reduce crop yields, threaten some aquatic ecosystems, and increase some risks to human health. Floods and droughts might be more frequent and severe, which would increase the difficulty of meeting the competing demands for water in the Tennessee and Cumberland Rivers.

Since the 1950s, the annual precipitation has increased by approximately five percent in Tennessee, while the amount of precipitation falling during heavy rainstorms has increased by 27 percent in the Southeast. However, rising temperatures increase evaporation, which dries the soil and decreases the amount of rain that runs off into rivers. Although rainfall during spring is likely to increase during the next 40 to 50 years, the total amount of water running off into rivers or recharging groundwater each year is likely to decline 2.5 to five percent, as increased evaporation offsets the increased rainfall. Droughts are likely to be more severe because very hot days will be more frequent, so the impact of days without rain will be more pronounced. [30]

The data clearly indicate an increasing trend in precipitation across Tennessee. This trend is expressed by more frequent heavy rainfall, and greater annual precipitation amounts, contrasted with dry spells that are more likely to be more severe because very hot days will be more frequent - even though annual precipitation is increasing. The effects of climate change result in more flash flooding when rain falls so heavily that infiltration is overwhelmed and runoff is extreme. Consequently, the instance of flash flooding is more likely, in both urban and rural areas alike.

[29] University of Tennessee Institute of Agriculture, Tennessee Climatological Service, *Climate Data for Tennessee*. Retrieved August 30, 2018 from: *https://ag.tennessee.edu/climate/Documents/Climate percent20of percent20TN.pdf*.
[30] EPA 2016.

Rural flash flooding is more likely in areas with more varied terrain, as water quickly flows down hills and mountains, flooding surrounding areas at lower elevations. As urbanization expands, with greater areas of impervious surfaces, flash flooding also increases. As a corollary, flooding is more likely as surface runoff water from these more intense rains moves to rivers and streams. This increases instances of high water on both the Mississippi and Tennessee Rivers.

Another implication of increasing rainfall and intensity is the likely increase in landslides across the mountainous portions of the state. Heavy and increased precipitation over consecutive days can make the ground soft. When precipitation begins to flow downhill, it can drag the ground surface, creating rock- and landslides. Finally, with abundant rainfall, which has increased over time, dry spells are more severe due to warmer night time low temperatures not reaching the dew point temperatures.[31]

Geology and Soils

Although Tennessee lies within a relatively narrow range in latitude, the state's elevations vary greatly, from the lowlands of the Mississippi River Bottom in the southwest to the mountain peaks in the east. The 10 physiographic provinces established by these variations and the state's complex geology are shown in figure 8. In the west, Tennessee's geology is composed of unconsolidated layers of sediments consisting of non-cohesive sands, gravels, silts, and clay. Toward the center of the state, these unconsolidated sediments thin, as the deep underlying consolidated rock, composed mostly of limestone, rises to the surface just west of the Tennessee River. These limestone and other deposits constitute much of the center and eastern portion of the state, although the east also includes metamorphic rocks. Tennessee's geology encompasses an extensive list of rock types, with a great variety of minerals.

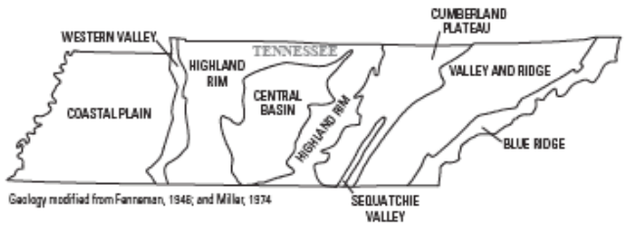

Figure 8. Tennessee physiographic provinces. (Source: USGS, Robinson, 2018).

The geology and soil types found throughout Tennessee affect the quantity and quality of groundwater and surface waters. Water can seep through porous rocks and soils, travel through fissures or cracks in subsurface rocks, and be retained or retarded by semi-permeable to non-permeable rock and soil layers. Water trapped in subsurface layers can form aquifers. Rivers and streams can lose water when it seeps through the streambed and enters the groundwater below, and they can gain water when groundwater seeps through the river and streambeds. Water movement and storage affects the quantity of water available for use.

Geology and soil type also influence water quality. When water contacts rocks and soils, minerals in these materials can be released and carried by water, affecting water chemistry. Soils can also serve as a filtration mechanism, removing some minerals and other materials as water passes through. The region's geology and soil makeup, along with climatic and other factors, also affect erosion. Eroded materials entering the waterways can remain suspended in the water column or settle out, which can impair water quality or in-stream storage and flow.

[31] Maye 2018.

Groundwater

Groundwater is a critical resource used for domestic, public, industrial, agricultural, and irrigation water supplies. In 2015, public water systems used it to serve more than 2.3 million Tennesseans for public and rural-domestic supplies, self-supplied industries, and irrigation, aquaculture and livestock uses (see figures 9 and 10). In 2015, public water systems in 66 Tennessee counties used groundwater, with 36 counties withdrawing more than one million gallons per day. Of those 36 counties, 17 were in West Tennessee, nine in Middle Tennessee and 10 in East Tennessee, as shown in figures 11 and 12.

West Tennessee is most dependent on groundwater, with nearly all public water systems, industry, domestic, and irrigation supplies using groundwater, mainly relying on the Memphis aquifer of the Tertiary sands aquifer system. The Memphis aquifer provides 159 million gallons per day for public water supplies, or about 62 percent of the total public supply withdrawals from groundwater (256 million gallons per day) in the state.[32] The Memphis aquifers in West Tennessee are composed of unconsolidated gravel, sand, silt, and clay sediments. Considered the best water in the nation, the Memphis aquifer is protected by an overlying semi-confined clay unit. However, breaches in this clay unit are providing avenues for contamination to enter the aquifer.

The limestone aquifers in East Tennessee, the second-most-used aquifer system in the state, produced more than 36 million gallons per day for public water supplies. Middle and East Tennessee aquifers are typically carbonate bedrock formations, where solution-enlarged conduits and openings allow for the storage and transport of groundwater. Groundwater availability in these carbonate bedrock aquifers varies depending on the size and intersection of conduits. The quality of groundwater from these aquifers also varies, with many waters containing calcium carbonate from rock dissolution. These aquifers are prone to contamination from their direct connection to the surface through sinkholes and surface water-bodies. Aquifers in far East Tennessee are fractured rock systems. Principal groundwater aquifers are shown in figure 13.

Tennessee currently has no comprehensive groundwater monitoring networks for assessing key groundwater uses. Natural replenishment of groundwater by precipitation is critical in determining a system's sustainability; however, recharge mechanisms and rates remain inadequately understood.

Figure 9. Groundwater withdrawal rates by use in million gallons per day during 2015.

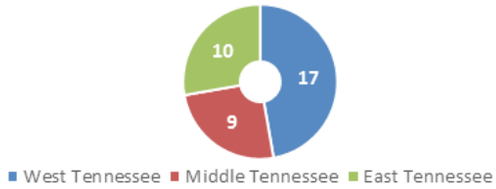

Figure 10. Number of counties by Grand Division with groundwater withdrawal rates above one million gallons per day during 2015.

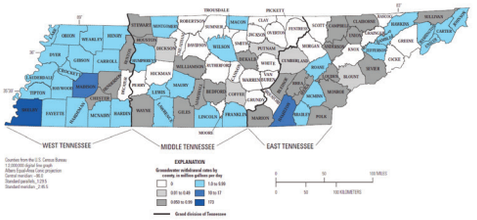

Figure 11. Public supply groundwater withdrawal rates by county in 2010. (Source: USGS, Robinson, 2018).

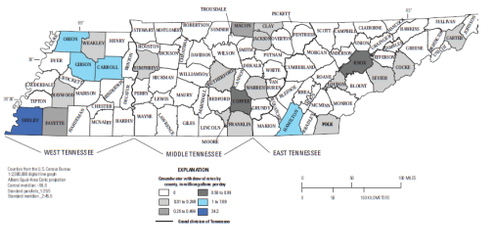

Figure 12: Self-supplied industrial groundwater withdrawal rates by county in 2010. (Source: USGS, Robinson, 2018).

[32] Robinson 2018.

Multiple agencies have mechanisms to track contaminant sources, and their efforts support improvement and security of groundwater quality.

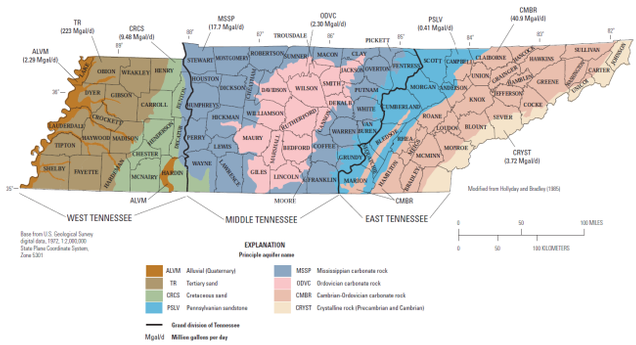

Figure 13. Principal groundwater aquifers and public-supply withdrawal rates in million gallons per day in 2010. (Source: USGS, Robinson, 2018).

Future Projections—Groundwater

The most critical component of maintaining sustainable groundwater resources is recharge. If groundwater usage exceeds the rate of recharge, the availability of the resource will diminish. Groundwater resources in Tennessee will be subject to increased withdrawals across all sectors, primarily associated with population growth and irrigation. Continued development of the landscape without recognizing the importance of groundwater recharge will diminish the availability of the resource. Continued focus toward water reuse and conservative water use practices will sustain the resource.

Areas within the state that rely on karst aquifers as a water supply are highly susceptible to drought. Additionally, continued heavy groundwater withdrawals for agricultural production in Arkansas could adversely affect the Memphis aquifer, as the aquifer in Arkansas receives no direct recharge. Direct recharge of the Memphis aquifer is only by precipitation received across West Tennessee. However, Tennessee is becoming a wetter state, and despite the lack of a comprehensive groundwater-monitoring network, it is known that groundwater levels in key counties are rising because of water-efficient appliances, industrial-water reuse initiatives, and general awareness about reducing water use. Improving recharge will also improve the availability of the resource.

Areas of Concern—Groundwater

One of the critical needs identified in this effort is to better delineate the Memphis aquifer recharge area and better understand how recharge takes place within it. Other areas of the state can benefit from an improved understanding of the exchange between surface water and groundwater. Moreover, how the state's groundwater resources can best support municipal, agricultural, and industrial users' needs to be considered. Groundwater monitoring networks are lacking to nonexistent across the state, even in areas that most rely on groundwater.

Recommendations—Groundwater

Below are the summarized recommendations from the Groundwater Working Group:

- Establish an education curriculum to improve understanding of
  - the importance of groundwater and groundwater recharge in Tennessee,
  - the importance of appropriately managing contamination and other threats to groundwater quality, and
  - effective conservation practices.
- Incentivize green infrastructure and conservation techniques.
- Establish monitoring networks and delineate recharge areas and recharge processes for the most critical aquifers.
- Develop a funding source for scientific assessments and initiatives pertaining to groundwater sustainability, especially in West Tennessee, where withdrawals are highest.
- Establish a voluntary program for reporting irrigation withdrawals from groundwater.
- Require groundwater-impact assessments in association with land-use planning.

Surface Waters

Tennessee's diverse mix of surface-water consists of more than 60,000 miles of rivers and streams, 570,000 lake and reservoir acres, and an estimated 787,000 acres of wetlands, as shown in figure 14. Water resources in Tennessee have generally been abundant, indeed, sometimes too abundant, with historical average precipitation in the Tennessee River drainage basin ranging between 59 and 63 inches per year. Tennessee's two longest rivers, the Tennessee and the Cumberland, flow into the Ohio River in Kentucky, which joins the Mississippi River at Cairo, Illinois. The Tennessee River, with a total length of 652 miles, originates in Knoxville with the convergence of the Holston and French Broad Rivers. The Tennessee River flows southwestwardly along the Alabama-Mississippi line and then flows northward across the state into Kentucky. Other tributaries of the Tennessee River are the Clinch, Duck, Elk, Hiwassee, and Sequatchie Rivers. The Cumberland River, with a total length of 687 miles, originates in southeastern Kentucky, flows across central Tennessee, and then turns northward back into Kentucky. The principal tributaries of the Cumberland River are the Harpeth, Red, Obey, Caney Fork, and Stones Rivers and Yellow Creek. In the western part of the state, the Forked Deer and Wolf Rivers are among those flowing directly into the Mississippi River, which forms the western border with Missouri and Arkansas.[33] The Mississippi, Cumberland, and Tennessee rivers are suitable for commercial traffic.

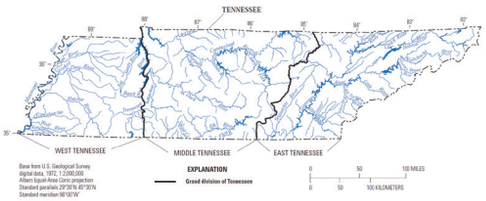

Figure 14. Surface waters in Tennessee. (Source: USGS, Robinson, 2018).

Tennessee's rivers, lakes, and wetlands provide a wide range of tangible and intangible benefits, including wildlife habitat, drinking water supply, power generation, recreation, and numerous others. These resources must continue to be protected and managed to ensure that future generations have the opportunity to benefit from them. Information about surface water quality can be found in two primary documents: Tennessee Department of Environment and Conservation (TDEC)'s *305(b) Water Quality Report* and its *303(d) List*.[34] The *305(b) Report* summarizes the general water quality of Tennessee surface waters. It contains information about water quality, the assessment process, use support, causes and sources of pollution, and water bodies posted due to human health risks. The *303(d) List* is a compilation of the lakes, rivers, and streams in Tennessee which fail to meet one or more water quality standards. It includes pollutant information and Total Maximum Daily Load (TMDL) prioritization.

The five major river basins within the state are the Middle Tennessee River Basin, the Upper Tennessee River Basin, the Lower Tennessee River Basin, the Cumberland River Basin, and the Mississippi River Basin. Regions and basins are shown in figure 15. Tennessee shares many of these basins with other states. For example, the Tennessee River Watershed includes seven states and includes three of Tennessee's five major basins. The Tennessee River system is regulated by a series of dams and reservoirs managed by the Tennessee Valley Authority (TVA).

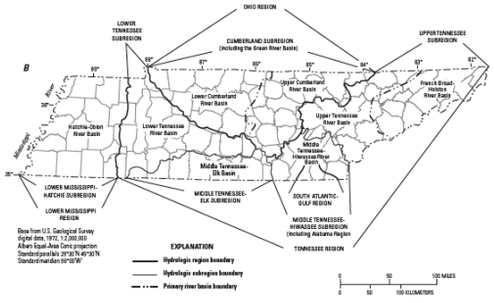

Figure 15. Regions and basins in Tennessee. (Source: USGS, Robinson, 2018).

TVA operates the Tennessee River system to provide year-round navigation, flood-damage reduction, power generation, improved water quality, water supply, recreation, and economic growth.

[33] Tennessee." *Worldmark Encyclopedia of the States*. Retrieved August 30, 2018 from City-Data.com: *http://www.city-data.com/states/Tennessee.html*. Also see Safford, James M. (Geology of Tennessee, 1869) Tennessee General Assembly, Nashville, TN, 1869.

[34] See *https://www.tn.gov/environment/program-areas/wr-water-resources/water-quality/water-quality-reports---publications.html* for latest publication of these water quality reports.

The Nashville District of USACE manages federal water-resources projects within the Cumberland River Basin to manage flood risk, commercial navigation, hydropower production, municipal and industrial water supply, fish and wildlife, water quality, and recreation. USACE operates and maintains 10 multipurpose projects within the basin, six of which are in Tennessee. Nine of these USACE projects have hydropower-production facilities. Four of them have navigable locks, of which three are in Tennessee (Cheatham, Old Hickory, and Cordell Hull). These lock and dam projects allow for a navigable waterway from the mouth of the Cumberland River to Celina, Tennessee.

Tennessee's wetlands serve as buffer zones along rivers, help filter pollutants from surface runoff, store floodwaters during times of high flows, serve as spawning areas for fish, and provide habitat for specialized plant and wildlife species. In addition to the tangible and intangible benefits of the natural water-treatment processes and enhanced habitats, wetland areas also serve as outdoor classrooms. The Conasauga River is a smaller system running through southeastern Tennessee.

Current State—Surface Water

Tennessee's surface waters have many uses: industrial, thermoelectric, public supply, and irrigation. Although these withdrawals occur primarily in Tennessee, withdrawals are also made in the neighboring states of Alabama, Kentucky, Georgia, North Carolina, and Mississippi. Surface-water usage data have been collected since the 1950s, and, since 1990, data submitted have been consistent in reporting the amounts withdrawn for various sectors. Historical information shows that some of these sectors follow population growth. For example, withdrawal for public water supply follows population estimates.

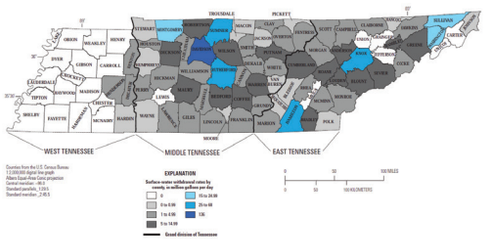

Figure 16. Public supply surface water withdrawal rates for Tennessee counties in 2010. (Source: USGS, Robinson, 2018).

In 2015, Tennessee used 5,972 million gallons per day that were withdrawn from Tennessee's surface waters for various uses (public supply, self-supplied domestic water, livestock, irrigation, thermoelectric power, self-supplied industrial, mining, and aquaculture). Withdrawals for all sectors in Tennessee in 2010 totaled about 7,209 million gallons per day. Water use from 2010 to 2015 declined for public supply, self-supplied industry, thermoelectric power, and irrigation for crops. Figures 16 and 17 indicate surface water withdrawal rates for Tennessee counties in 2010.

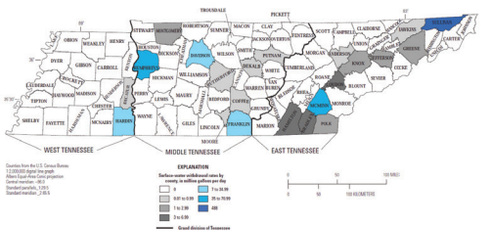

Figure 17. Self-supplied industrial surface-water withdrawal rates for Tennessee counties in 2010. (Source: USGS, Robinson, 2018).

Future Projections—Surface Water

The following projections are based on water withdrawal trends. Water use projections for 2020, 2030, and 2040 show a steady increase in water needs for off-stream use in Tennessee. Water use projections are primarily driven by assumptions about population growth in Tennessee and conservative increases in irrigation. Projected rates of water usage from surface waters for 2020, 2030, and 2040 are 7,238 million gallons per day, 7,315 million gallons per day, and 7,388 million gallons per day, respectively.[35]

[35] Water use projections prepared for the TN H_2O process currently include only withdrawals for public water systems in Tennessee. Water withdrawals by public water systems depend on the population; reported data are reported monthly, providing a data set that can be evaluated using a quality assurance/quality control (QA/QC) process. Self-supplied industrial water withdrawals are also reported to the TDEC Division of Water Resources, but projecting industrial water use is complicated by changes in economic conditions, changes in manufacturing processes, and other factors that make accurate water use projections difficult. Water uses for other sectors are also complicated by changes in economic conditions, and these estimates of water use *(continued on next page)*

Areas of Concern—Surface Water

Lacking comprehensive water budgeting, water forecasting, and local needs information, future projections are based on population projections and do not consider possible impacts on individual basins. Basin-specific projections for future surface-water withdrawal require very specific information, unique to each basin. To accurately project and analyze a river basin, a water budget must be constructed. This process uses a computer model to account for all water flowing into and out of the basin. In this manner, the potential impact of periods of excess and deficit precipitation can be identified and planned for. Creating a budget is a complex undertaking involving the collection and assimilation of a large amount of data. The local needs of each basin should be identified to help determine which model to use and the exact data that will be required before creating a budget.

Recommendations—Surface Water

Below are the summarized recommendations from the Surface Water Working Group:

- Develop statewide hydrologic planning efforts at the basin level.
- Develop water budgets for Tennessee's major basins to forecast water needs and availability with reasonable scientific accuracy. Define the purpose and objectives based on basin-specific needs.
- Planning efforts need to define objectives, basin- or watershed-level priorities, and performance measures (such as minimum base-flow requirements) to understand the effectiveness of plans.
- A model selection process should be established to understand the specific needs of each basin. When selecting a model, key factors to consider include
  - study purpose and objectives,
  - data availability and resources required to fill data gaps,
  - calibration standards, and
  - understanding the model's assumptions and limitations.
- To focus resources at the basin level and at more refined levels, a methodology and criteria for prioritizing future study must be established. Although basin-wide modeling can provide a great deal of insight, some instances could arise in which the information might be too granular, and require more refined study or modeling.
- In support of statewide water-resources management, data availability is necessary in order to make informed decisions at all levels. A centralized, broadly accessible data repository should be evaluated and developed.
- A more structured and standardized approach to data collection should be used at the local, state, and federal levels to capitalize on limited resources.
- Future predictions suggest that droughts are likely to occur at the same frequency in the Mississippi River Basin as they have in the past. Therefore, drought preparedness and planning efforts must be in place for when such events occur. Better-integrated, cross-scale, intelligent sampling and monitoring techniques are needed. A basin-wide management network should build on concepts such as "Integrated Water Resources Management"[36] and "Adaptive Water Resources Management."[37]

(continued from previous page) rely on indirect methods, such as irrigated acres for crop irrigation. Water withdrawal data by county and source for 2010 (Robinson, 2018) were used as the base year for the water use projections. The 2010 population data from the U.S. Census Bureau were used as the base population for the projections. The rate of population change for 2020, 2030, and 2040, relative to 2010, was calculated based on the population projections for those years. Water use projections for public water supply, domestic self-supplied, and golf course irrigation were projected based on projected population growth. Water use projections for the other sectors are based on trends, coordination with other agencies, or set at constant rates. (Robinson, 2018)

[36] Hooper, B., 2005. Integrated river basin governance: learning from international experiences.

[37] Holling, C. S., 1978. Adaptive Environmental Assessment and Management.

Natural Resources

Tennessee's abundant waters are among the state's most valuable natural resources and make this state a special place to live, work, and recreate. Our rivers and streams are some of the most ecologically diverse in North America. Not only are they a life-sustaining source of water for people and industry, but they also provide habitat for some of the greatest diversity of fish and other aquatic species on this continent. These special assets support a wide variety of recreational opportunities that contribute substantially to the state's economy and quality of life. With its varied terrain and soils and plentiful rainfall, Tennessee has an abundance of flora, including at least 150 species of native trees and more than 300 native plants, and is home to a wide variety of wildlife, including various species of mammals, more than 250 bird species, 56 amphibian species, 58 reptile species, and 186 fish species. Tennessee mammals more directly associated with water include the raccoon (the state animal) and muskrat. Bobwhite quail, ruffed grouse, mourning dove, and mallard duck are the most common game birds. Catfish, bream, bass, crappie, pike, and trout are the leading game fish in Tennessee's lakes and streams.

Current State—Natural Resources

Watershed health is key to protecting and conserving Tennessee's water resources and directly reflected in the health and abundance of freshwater-dependent native species and habitats. The *State Wildlife Action Plan* (SWAP) identifies 276 freshwater and another 411 subterranean and cave species of greatest conservation need, many of which depend on the stability and quality of surface and groundwater exchanges.[38] Various sport-fish species, including trout, catfish, crappie, sauger, sunfish, and three species of bass, are supported by healthy streams and reservoirs,[39] and a large variety of game species, such as migratory birds, depend on wetlands for some or all of their life stages. Across the state's physiographic regions, river bottoms, floodplains, riparian areas, and wetlands provide more than 625,000 acres of priority habitat for Tennessee's designated species of greatest conservation need, and the SWAP identifies 19 "Conservation Opportunity Areas" across the state, drawn largely around river systems.[40]

Watershed health is as important to water supply as it is to the wildlife populations that serve as indicators of watershed health. Every two years, TDEC compiles a list of the lakes, rivers, and streams in Tennessee that fail to meet one or more water quality standards and are, therefore, impaired for one or more of seven potential designated uses: fish and aquatic life, recreation, irrigation, livestock watering and wildlife, drinking water supply, navigation, and industrial water supply. According to TDEC's most current compilation, 42 percent of assessed rivers and streams are listed as impaired for fish and aquatic life, 51 percent are impaired for recreational uses, and about 33 percent of reservoirs are impaired for their designated recreational use.[41] Listing can result in restrictions on water withdrawals as well as treated-water discharges and so must be considered in water supply planning. Listing can result from a variety of land- and water-use practices, including increased pollutant loading; increased impervious surfaces; reduced groundwater recharge; stream- and river-flow alterations; wetland and headwater-stream loss; loss of upstream, downstream and floodplain connectivity; and altered biological integrity. Urbanization is a primary contributor.[42]

[38] Tennessee State Wildlife Action Plan Team (TWRA). 2015. *Tennessee State Wildlife Action Plan 2015*.
[39] Tennessee Wildlife Resources Agency (TWRA). 2014. *Tennessee Wildlife Resources Agency Strategic Plan 2014–20*.
[40] TWRA 2015.
[41] Tennessee Department of Environment and Conservation (TDEC). 2018a. State of Tennessee water quality information posted to the "Assessment, Total Maximum Daily Load (TMDL) Tracking and Implementation System (ATTAINS)."
[42] O'Driscoll et al. 2010.

The *2015 Tennessee Integrated Assessment of Watershed Health, a Report on the Status and Vulnerability of Watershed Health in Tennessee*, compiled watershed health indices for all Tennessee waters.[43] Generally, watersheds with the highest overall health scores are in areas with more natural lands, stable stream and river channels, and more natural stream-flow patterns, all of which produce and preserve better water quality and habitat conditions that support a diversity of aquatic life. Areas with lower overall watershed health scores tend to be more urbanized or have more intense agricultural uses with altered stream or river channels. Aquatic nuisance species, like Asian carp and non-native aquatic vegetation, also pose serious threats to the ecology and economy of Tennessee according to the *Tennessee Aquatic Nuisance Species Management Plan*.[44]

Future Projections

The future health of Tennessee's natural aquatic resources—including its water supply for all purposes—depends on land- and water-management decisions and investments made today. Water quality degradation, loss of habitat, changes in stream and river flows, invasive species, and changes in precipitation and temperature patterns are the major challenges.[45] Much is known about their causes, and a wide variety of cross-disciplinary innovations such green infrastructure for stormwater management, improved water quality treatment, agricultural best-management practices, and reservoir-release-improvement technologies have been developed and deployed to protect and restore our natural systems, even in the face of the growing demands on them.

Moreover, as Tennessee's water-based recreational economy continues to thrive and grow, maintaining high-quality waters in sufficient quantity to satisfy multiple uses remains a critical need. As paddling and angling increase, for example, so will impacts on surface waters. Tennessee needs to identify the rivers that are under extreme pressure from overuse and associated water quality issues to protect natural systems for water supply. Problems associated with exotic invasive species must be proactively addressed to maintain ecological balance and ensure safe and high-quality user experiences. An integrated management approach is needed to maintain the health and integrity of our streams, rivers, wetlands, lakes, and reservoirs and support broad-based economic growth.

Areas of Concern—Natural Resources

Five major themes emerged from the working group's assessment and were offered for consideration in designing and implementing the recommendations of the *TN H_2O* Plan:

- A need for greater transparency, collaboration, and support for science at all levels in both the public and private sectors in support of the regulatory framework and more effective and inclusive decision-making.
- A need to reduce pollution and to maintain and restore the ecological functions and health of Tennessee's streams and watersheds, including floodplains and riparian conditions, to support aquatic habitat; clean water for domestic, agricultural, and industrial use; flood control; and recreation. Clean and plentiful waters that are fishable, swimmable, and provide adequate and reliable sources of drinking water are key to equitable and sustainable communities.

[43] RTI. (2015). Tennessee Integrated Assessment of Watershed Health, A Report on the Status and Vulnerability of Watershed Health in Tennessee.
[44] Tennessee Aquatic Nuisance Species Task Force (TANSTF), 2008. *Tennessee Aquatic Nuisance Species Management Plan.*
[45] Environmental Protection Agency (EPA). *Identifying and Protecting Healthy Watersheds Concepts, Assessments, and Management Approaches*. 2012; RTI 2015; and TWRA 2015.

- A need to prioritize streams based on their potential for restoration and community benefit and to help growing communities slow the increase in impervious surfaces and the loss of pervious surface benefits to better manage the health of their local watersheds.
- A need to substantially reduce threats posed by invasive and exotic aquatic species that negatively affect water supplies.
- A need to improve awareness and stewardship to directly and proactively address major impacts to Tennessee's water resources. Specific topics of concern include littering, the value of water, water resource protection, and recreation etiquette on the waterways.

Recommendations—Natural Resources

The Natural Resources Working Group produced a number of recommendations designed to elevate the significance of natural resources in decision-making at all levels and in all sectors to protect and restore Tennessee's unique and diverse freshwater resources and species. Some pertain particularly to the regulation, administration, and management of water resources, as well as the inextricable link between water availability and healthy waters and sustainable economic growth and development. Below are the summarized recommendations from the Natural Resources Working Group:

- Promote water conservation best practices and behaviors to support and sustain healthy and abundant Tennessee waters by building on existing public and private education and outreach efforts and increasing incentives to conserve water and protect watersheds.
- Make water health and abundance a prime consideration when recruiting industry, issuing permits, and awarding grants.
- Promote and use existing laws and regulations to protect water health and abundance, particularly as it relates to the key natural processes that support abundant, clean water.
- Establish an approach for adaptive management of river flows and minimum flows that utilizes the best available science to protect ecological health and recreational uses of Tennessee rivers and streams for the long-term, recognizing that climate-related temperature and precipitation changes will exacerbate flow-related stressors.
- Develop a program similar to the *Tennessee Healthy Watershed Initiative*[46] to directly address water health and abundance:
  - Collaborate with all levels of government and with non-government partners to develop shared goals for watershed health.
  - Work with the Tennessee Department of Economic and Community Development to encourage water stewardship and provide incentives for industries expanding or relocating in Tennessee to restore Tennessee waters.
- Prepare and update every five years a comprehensive Tennessee water resource assessment similar to the *Lower Mississippi River Resource Assessment* describing the information needed for river-related management, the needs of natural habitats and the species they support, and the need for more river-related recreation and public access[47] as a foundation for

[46] Information on the Tennessee Healthy Watershed Initiative can be viewed online at *https://www.tn.gov/environmetn/program-areas/wr-water-resources/watershed-stewardship/tennessee-healthy-watershed-iniative.html*.

- improving understanding of the importance of headwaters to protecting biodiversity and healthy water supplies;
- updating and supporting water-related natural resource plans and assessments (e.g., state wetlands strategy, Tennessee Drought Management Plan, State Wildlife Action Plan, habitat assessments, flood studies, drought studies, recreation studies, economic assessments, and regional supply plans);
- establishing goals for watershed protection and restoration efforts in collaboration with local jurisdictions, including identification of priority watersheds for remediation; and
- addressing complex issues such as invasive aquatic plant and animal management that require multi-disciplined and multi-agency collaboration.

Recommendations—Water-based Recreation and Tourism

The following recommendations were developed by the Natural Resources Working Group with input from the Recreation and Tourism focus group participants to leverage Tennessee's outstanding natural water resources and the recreation and tourism opportunities they afford while protecting, conserving and in some cases, enhancing and restoring the state's high-quality natural assets:

- Inform Tennessee executive branch agencies and governor's staff about the impact Asian carp are having in the Mississippi, Tennessee, and Cumberland river systems, and establish a collaborative approach to securing sufficient federal funding for a multi-state (i.e., Tennessee, Alabama, Kentucky, and Mississippi) solution.
- Establish a multi-agency—Tennessee Department of Tourist Development (TDTD), TWRA, TDEC, U.S. Coast Guard, USACE, and TVA—approach to improve and enhance recreational opportunities on Tennessee's waters, by assessing the need for:
  - improved access to Tennessee waters, and
  - a common set of guidelines and standards for marina facilities to enhance public use and safety.
- Provide sufficient funds and a strategic and coordinated approach to promote and manage high-quality experiences on Tennessee waters:
  - improve access to Tourism Enhancement and related grants,
  - address the limited resources of law enforcement and the associated jurisdictional challenges this presents,
  - understand the impacts from new and increased numbers of recreational users, and
  - educate end users about responsible resource use.

[47] Lower Mississippi River Resource Assessment can be viewed online at *http://www.lmrcc.org/programs/lower-mississippi-river-resource-assessment/.*

Water's Built Environment

Tennessee's water infrastructure includes piping networks to collect, treat, and distribute drinking water, stormwater, and wastewater. This report does not consider the dam systems, both hydroelectric and non-hydroelectric, as part of the water infrastructures of Tennessee. Historically, stormwater-collection systems were combined with wastewater systems, as is the case in most Tennessee urban areas. These systems are included in the discussion of wastewater systems in this report. Clear differences exist in the level of service for water and wastewater within Tennessee. These differences have been identified by Grand Division as well as by counties and communities. Making broad generalizations about the adequacy of the system is difficult, because, for the most part, water and wastewater service are provided in so many ways by so many entities.

A number of approaches were used to determine infrastructure stress in evaluating the condition of Tennessee's water and wastewater infrastructure systems. This section of the plan summarizes the data considered as well as the methodology used to quantify the level of stress and forecast infrastructure needs. Tennessee is fortunate to have extensive documentation of its water and wastewater infrastructure systems through TDEC. These data, coupled with system-specific information, provided the working group the means to determine infrastructure stress, both in 2018 and through the forecast period of 2040. Generally, data were evaluated for (a) water treatment capacity; (b) water-system sanitary-survey scores; (c) water system notices of violation; (d) water-distribution system water-loss; (e) wastewater treatment plant capacity; (f) wastewater-system notices of violation; and (g) wastewater-system overflows. Other non-state resources were also incorporated into assessing the status of Tennessee's water and wastewater infrastructure, including the 2016 American Society of Civil Engineer's (ASCE) *Infrastructure Report Card for Tennessee* and supporting documentation collected by ASCE.

The Infrastructure Working Group acknowledges additional differences between current and future needs for areas or counties designated as "urban" service areas, versus those currently classified as "rural." Note that many areas designated "urban" were originally classified as "rural," because historically many of these area expansions required upgrades. Therefore, we can reasonably anticipate that this transition trend will continue across the state as the overall population increases.

Current State—Drinking Water Infrastructure

Potable water is provided within most Tennessee urban counties by municipal entities, utility districts, authorities, or other public entities. See figure 18. However, many Tennesseans still have private wells within areas designated as both "urban" and "rural." By far, most public water systems are owned and operated by local governments or by utility districts. Although their boards are appointed by the mayors of their respective counties, utility districts are otherwise entirely independent governmental entities, though they do not have taxing authority. Regardless of whether they are operated by cities, counties, or utility districts, all public water systems must support themselves solely with revenue from their customers, and so must have water rates sufficient to cover their expenses. No public

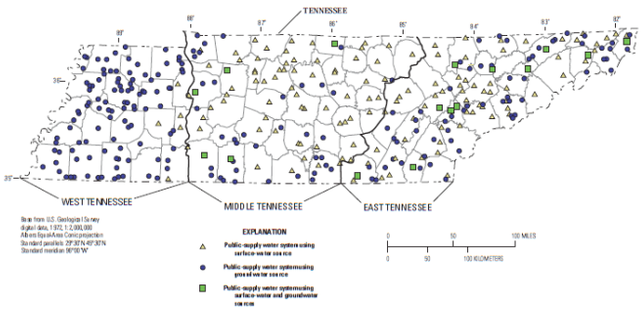

Figure 18. Distribution of public-supply water systems using surface water or groundwater in Tennessee in 2010. (Source: USGS, Robinson, 2018).

utility in Tennessee can rely on tax revenues, nor can they rely on revenue from other utility services. They must be financially independent.

Only seven water utilities in Tennessee are investor-owned, and all of them are very small, except for the Tennessee American Water Company. A few nonprofit water systems exist, including approximately five water cooperatives and a handful of homeowner associations that operate very small water-distribution systems, as well as some that operate on-site wastewater systems. The per capita percentage of Tennesseans getting their water from private wells is greater than those served by a public source.

Tennessee's drinking water infrastructure treats raw water from various sources using a variety of methods and then distributes it through underground networks of pipelines routed under streets, in public rights of way, or through easements across private properties throughout service areas. The pipes, pumps, valves, and other fittings that make up these networks vary in size, length, and age. TDEC currently requires systems to maintain 24 hours of average daily demand in water storage. Storage is generally provided in water tanks, at appropriate points throughout the systems, either to buffer flow variations or to provide volume for firefighting. Urban systems, particularly in larger population centers, have many components that have far exceeded their intended design life.

The number and size of interconnections to nearby water systems varies considerably throughout the state. Generally, utilities in the more densely populated urban counties are better connected to neighboring utilities than are those in the more rural counties. Concerns about water quality degradation in long, stagnant waterlines, coupled with the high cost of running long pipelines, hinder most rural water systems from connecting with their neighbors. Public utilities in urban areas are increasingly being asked to provide water for nearby rural utilities. Some rural systems include smaller lines, though many are increasing line sizes and establishing water storage facilities to extend service to additional customers.

A greater ratio of private sources (e.g., private wells) is found in the rural counties of the West Grand Division, which are characterized by sand aquifers within reasonable depths, and, to a lesser degree, in the southeastern quadrant of the East Grand Division. Individual wells are sporadically placed in the Middle Grand Division; however, the underlying geology does not favor their use in most cases. Continued growth in the number of private wells has also coincided with rural community growth, due to prohibitive "costs to serve" considerations in many areas. We understand that the expansion of private wells is becoming more challenging, due to aquifer quantity and quality at depths that are economically accessible. Adding to this challenge is the increased use of irrigation from private wells in agricultural-based businesses.

Current State—Wastewater Infrastructure

Approximately 60 percent of Tennesseans are served by centralized wastewater collection and treatment systems, which vary considerably across the state in the means of collection and treatment. Most use a combination of gravity collection mains and pumping stations to convey flow to a treatment works of some sort. Pressurized systems with individual pumping facilities are increasingly being used instead of gravity systems, due to terrain and topographic constraints in population growth areas, because of both cost and dependability. Treatment works can vary from simple lagoons to membrane filtration systems, depending on the level of treatment necessary to comply with TDEC discharge permits.

The remaining 40 percent of Tennesseans are served by decentralized collection and treatment systems. These generally involve either household septic tanks and leachate fields or community wastewater collection and treatment at a small decentralized, unstaffed, packaged treatment unit. Disposal for these systems usually involves drip dispersal of the treated water into a dedicated plot of land.

Tennesseans in urban counties have access to wastewater collection systems that convey flow to publicly owned treatment works (POTWs); however, a large number of urban public customers, primarily in older and more rural areas, remain on privately owned wastewater systems like septic tanks. Decentralized wastewater collection and treatment systems have increased markedly in rural counties, where ownership and operational responsibilities might fall under municipalities or utility districts. Infiltration and in flow are significant challenges for most wastewater collection systems across the state. Both EPA and TDEC have taken enforcement action against numerous Tennessee municipalities and utility districts for excessive, chronic, sanitary-sewer overflows (SSOs) or combined-sewer overflows (CSOs) from their collection systems.

Infrastructure Financing

Funding opportunities for public systems are available through a multitude of federal and state sources. Public-finance sources are also available, including public bond markets, bank programs, and bond funds. Each of these programs has its own requirements and structural components, as well as incentives and concerns. Regardless of the funding method, except for direct grants from federal and state agencies, 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 the most difficult charge for a governing body.

Future Projections—Infrastructure Needs

With Tennessee's rapid growth comes a reasonable obligation to make public water and wastewater services available to the growing public. Forecasting future infrastructure needs first comes down to the dollars that must be invested to meet these needs, regardless of the funding source. Meeting those needs and the need to repair or replace existing infrastructure will require an estimated investment of $15.6 billion between now and 2040. Even with this investment, growth and development in some areas of the state will continue to be limited because of the excessive cost of extending public serves in those areas.

Historically, contributed capital, such as, private party contributions (often the development community) and grants, have been available to most communities and have helped offset their total investment needs. We can reasonably assume that some level of contributed capital would continue to be made available. Considering this factor, the total funding needed to address both repair and replacement costs and extending new service in Tennessee for the projected growth period is $13.9 billion.

Recommendations—Infrastructure

Although Tennessee's public providers are to be commended for their proactive approach to maintaining current systems, we must also pay attention to additional maintenance, repair, and replacement of the existing aging infrastructure. Doing so today on a comprehensive level would likely create prohibitive rate structures that most of the public could not bear. Even with contributed capital as a funding source, some public entities will not be able to fund the $13.9 billion "local share" without burdensome rate increases for their customers. Therefore, and in keeping with legislative action establishing the Water Resource Act, we urge that this act be implemented in a way that creates additional funding sources for Tennesseans to meet these needs while offsetting excessive rate adjustments.

The following six other factors must be addressed concurrently with infrastructure funding for Tennessee's plan to be successfully implemented:

- Although acknowledging that this was not within the realm of the working group in developing a plan, attention must be given to maintaining and improving the quality of raw water that is used to serve the public. A secure water future requires sufficient water quality and quantity. This includes both surface and groundwater sources.
- We encourage consistent monitoring, data collecting, and reporting to provide usable modeling and trending data. This should be implemented (a) to include all major water users and stakeholders; (b) based on the most current and accepted science-based practices; and (c) with the goal of establishing a means of comprehensive planning and information sharing.
- Tennessee must continue to embrace new and creative technologies, such as water reuse. This must be done with a focused pursuit of identifying unintended consequences while also creating incentives for successful implementation of such practices.
- This roadmap should be used as a tool to facilitate intrastate and interstate regional cooperation. Such cooperation, particularly as it relates to infrastructure, must enable continued cooperative arrangements among water utilities, as well as increase agency collaboration and coordination at all levels.
- While proactively seeking to avert the potential crisis that Tennessee could face in available water, equal attention must be given to the critical need associated with a diminishing workforce charged with the maintenance, security, and growth of our infrastructure investment. The state is quickly reaching the disturbing point of not having a sufficient number of operators to protect, manage, and maintain these systems in the future.
- Educating the public will ultimately be the foundation of this plan's successful implementation. Water truly has a value that has been taken for granted in many sectors of our state. This plan provides an opportunity to serve as the springboard for educational outreach to all age groups in our state.

Conclusion

As a call to action, this roadmap to securing the future of our water resources represents Tennessee's first attempt to establish a framework for further planning. Next steps include outreach, developing a process for evaluating and prioritizing these recommendations, and the initiation of a regular cycle of updates to help ensure that Tennessee has abundant water resources to support future population and economic growth. It will be important to Tennessee's future to be water wise and to work together to ensure we have adequate infrastructure and appropriate planning and requisite action to meet our needs.

TN H_2O's diverse and enthusiastic participants provided these key insights to help facilitate and guide the effort. We look forward to making progress together to ensure the resiliency and sustainability of Tennessee's water resources so they are available for generations to come.

Terms and Abbreviations

ANS: Aquatic nuisance species

ARAP: Aquatic Resource Alteration Permit

ASCE: American Society of Civil Engineers

CSO: Combined sewer overflow

EPA: U.S. Environmental Protection Agency

IBWTA: Inter-Basin Water Transfer Act

M&I: Municipal and industrial

NEPA: National Environmental Policy Act

POTW: Publicly owned treatment works

SDWA: (Federal) Safe Drinking Water Act

SGCN: Species of greatest conservation need

SSO: Sanitary sewer overflow

SWAP: State Wildlife Action Plan

TDEC: Tennessee Department of Environment and Conservation

TPUC: Tennessee Public Utility Commission

TVA: Tennessee Valley Authority

TWRA: Tennessee Wildlife Resources Agency

UMRB: Utility Management Review Board

USACE: U.S. Army Corps of Engineers

USGS: U.S. Geological Survey

WQCA: (TN) Water Quality Control Act

WRA: (TN) Water Resources Act

WRDA: (TN) Water Resources Development Act

WRIA: (TN) Water Resources Information Act

WRPA: (TN) Water Resources Planning Act

WWFB: Water and Wastewater Financing Board

Units

AF: acre feet (measurement of volume equal to an area of one acre with a depth of one foot)

cfs: cubic feet per second (measurement of water flow)

GPD: gallon(s) per day (measurement of water flow)

Mgal/d: million gallon(s) per day (measurement of water flow)

Understanding the explicit meaning of the following terms in the context of this report is important:

The **303(d) List** is a compilation of the lakes, rivers, and streams in Tennessee that fail to meet one or more water quality standards, to include pollutant information and TMDL prioritization.

The **305(b) Report** summarizes the general water quality of surface waters in Tennessee. The report contains information about water quality, the assessment process, use support, causes, and sources of pollution, and water bodies posted due to human health risks. There is also a version of the 303(b) report directed towards groundwater resources in Tennessee.

aquifer: Geologic formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. The formation could be sand, gravel, limestone, sandstone, or fractured igneous rocks.

available water: Water that can be put to consumptive and/or non-consumptive uses within a river basin, whether it originates from streams, reservoirs, or groundwater.

challenges: Realities in Tennessee's natural, regulatory, or economic environment that may hinder or restrict the way particular options are able to satisfy the goals of the plan. In other words, the challenges are conditions that might inhibit or prevent the implementation of various options.

consumptive water use: Any water use that requires the removal of water from a stream or aquifer, even if some or all of it is returned at a downstream location.

conjunctive use: The combined use of groundwater and surface water sources that optimizes the beneficial characteristics of each source.

drainage basin: The area drained by a river and all its tributaries; also called catchment area, drainage area, or watershed.

goals: The overarching statements about what the stakeholders wish the plan to accomplish.

groundwater recharge: A hydrologic process where water moves downward from surface water to groundwater. This process occurs both naturally and through artificial process where rainwater and/or reclaimed water is routed to the subsurface. Groundwater is recharged naturally by the infiltration of rain and snow melt and to a smaller extent by surface water. Recharge may be impeded by human activities such as paving, land development, or logging, which can result in loss of topsoil and reduce water infiltration.

incentive/incentivize: Add advantages that might be monetary, and/or otherwise, beneficial to users, the environment, or recreation. Similar terms include "promoted," "initiated," and "sponsored," that might help change initiatives and decisions.

natural infrastructure: A "strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserves or enhances ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon 2006).

public: Any citizen of Tennessee—all are invited to public meetings and workshops, and will be given opportunity to comment, ask questions, voice concerns, and have direct dialogue with state officials and project consultants. public supply water use: Public supply water use refers to water use by public and private utilities for delivery to domestic, commercial, and industrial users, and for municipal services such as firefighting. Water lost by leaky pipes in the distribution system (conveyance losses) and system maintenance is included in this category.

stakeholders: People representing various water interests, and who will participate in facilitated discussion during the workshops in order to make consensus recommendations. By designation, the stakeholders for this plan are the members of the TN H_2O SC (Steering Committee), which includes the chairs of the various subcommittees, and by extension, the individuals and organizations represented by those groups.

water budget: Accounting of the flow of water into and out of a system. The water budget of a place or system, whether it is an agricultural field, a watershed, or a continent, can be determined by calculating the input, output, and storage changes of water at the earth's surface over a period of time.

watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

water management options: Alternative ways that water can be managed in the future, including both supply management and demand management.

water reuse: The use of reclaimed water for a direct beneficial use, and indirect potable reuse, and indirect non-potable reuse, or a controlled use.

water use: In this report, the quantity of water use for a specific category is the combination of water supply withdrawals and public supply deliveries. In a restrictive sense, the term refers to water that is actually used for a specific purpose, such as for domestic use, irrigation, or industrial processing. More broadly, water use pertains to human interaction with the hydrologic cycle, and includes dimensions such as water withdrawal, delivery, consumptive use, wastewater release, reclaimed wastewater, return flow, and in-stream use.

Appendices

- Tennessee Department of Health: TN H_2O Overview
- Institutional Working Group
- Surface Water Working Group
- Groundwater Working Group
- Natural Resources Working Group
  - Tennessee's Water-Based Natural Resources
  - Tennessee's Water-Based Recreation and Tourism
- Infrastructure Working Group

The above appendices are available online at: www.tn.gov/environment/program-areas/wr-water-resources/tnh20.html.

Further Reading

Infrastructure Reports

Refer to the ASCE website, *https://www.infrastructurereportcard.org/* for the American Society of Civil Engineers' Report Card for America's infrastructure with scores based on the physical condition and needed investments for improvement. The ASCE Infrastructure Report Card for Tennessee's Infrastructure is available online, *https://www.infrastructurereportcard.org/state-item/tennessee/*, and provides additional information on Tennessee's infrastructure needs and estimated costs.

Water Quality Reports

Refer to TDEC Division of Water Resources' website, *https://www.tn.gov/environment/program-areas/wr-water-resources/water-quality/water-quality-reports---publications.html* for the latest information on water quality laws; rules; general information and planning documents; water quality assessment publications; and technical / engineering documents.

The **303(d) List** is a compilation of the lakes, rivers, and streams in Tennessee that fail to meet one or more water quality standards, to include pollutant information and TMDL prioritization. The latest version of the 303(d) List is available for viewing online at *https://www.tn.gov/content/dam/tn/environment/water/planning-and-standards/wr_wq_303d_2018-final-epa-decision-doc.pdf*.

The **305(b) Report** summarizes the general water quality of surface waters in Tennessee. The report contains information about water quality, the assessment process, use support, causes, and sources of pollution, and water bodies posted due to human health risks. There is also a version of the 303(b) report directed towards groundwater resources in Tennessee. The latest edition of the 305(b) report is available for viewing online at *https://www.tn.gov/content/dam/tn/environment/water/documents/wr_wq_report-305b-2014.pdf.*

Source Water Assessment Reports

All states were required by Congress in the 1996 Safe Drinking Water Act Amendments to develop a Source Water Assessment Program for the assessment of the potential contamination of public water system groundwater and surface water sources. Tennessee's Source Water Assessment Program was approved by EPA in November of 1999.

Refer to TDEC Division of Water Resources' website for information on source water protection and assessments: *https://www.tn.gov/environment/program-areas/wr-water-resources/water-quality/source-water-assessment.html*

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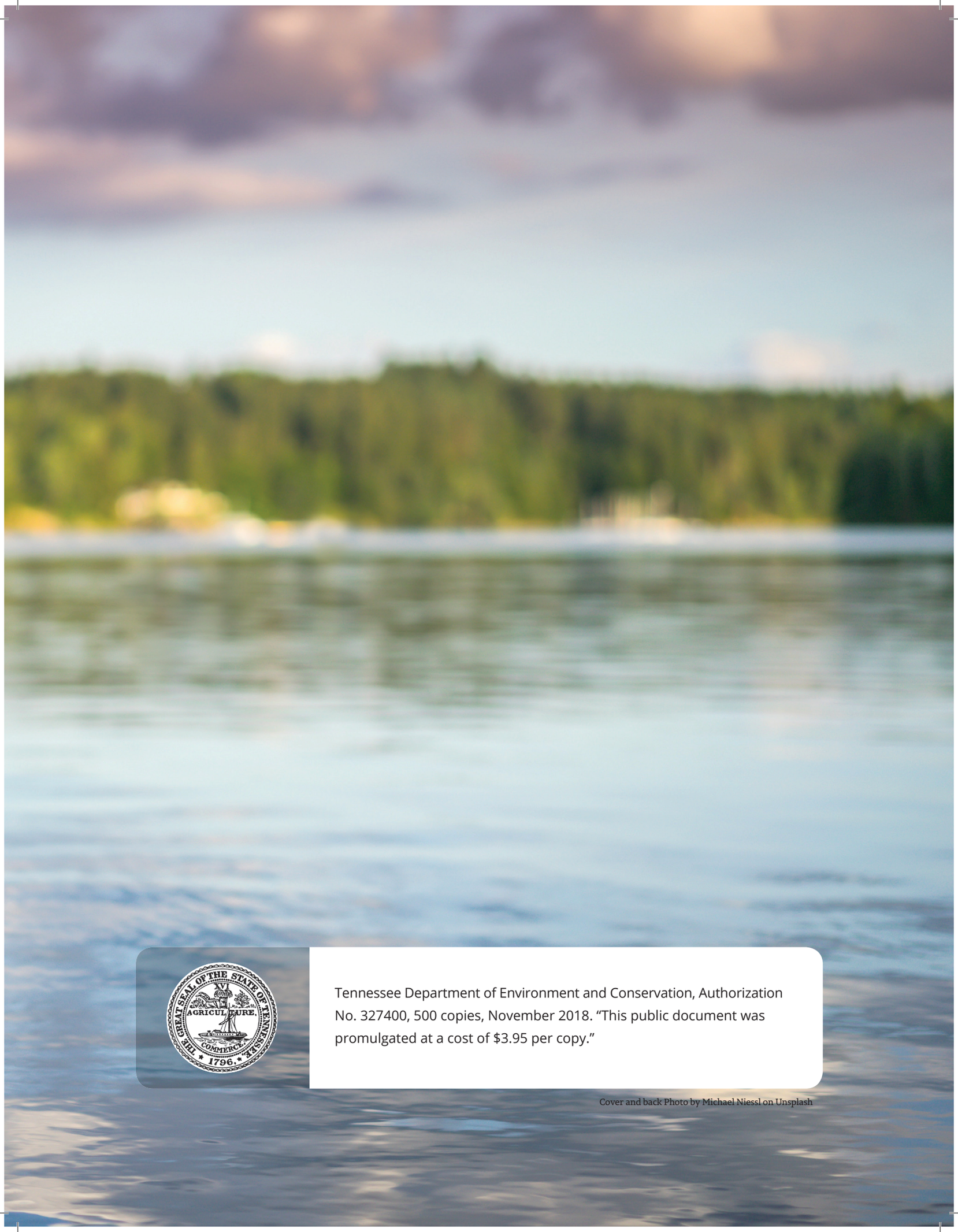

Tennessee Department of Environment and Conservation, Authorization No. 327400, 500 copies, November 2018. “This public document was promulgated at a cost of $3.95 per copy.”

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