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Tennessee's Roadmap to Securing the Future of Our Water Resources

Groundwater Working Group Executive Summary

Groundwater Executive Summary

Beneath the lowlands of the Mississippi River valley in the west to under the rolling hills in middle Tennessee up into the ancestral Smoky Mountains to the east, lies a hidden treasure: a precious supply of groundwater. Characterizing our groundwater as an incredible resource is not just a Tennessean axiom, but our groundwater, most especially that in West Tennessee, is considered to be the best, high-quality groundwater in the nation. While media headlines are peppered with stories about declining water availability, water quality degradation, and drinking water contamination, Tennessee is blessed to have an abundance of water and can be considered a water-rich state.

Tennessee's Grand Divisions: West, Middle and East, divide our State into three topographies, or general configuration of the earth's surface, including its relief and the location of its natural features. Subdivided further into eight physiographic provinces representing distinct geologic regions that result in various types of aquifers. Staying general to the three Grand Divisions, the State's geology illustrates three major feature types which in turn result in key groundwater system differences. In West TN, the geology is comprised of unconsolidated sediments, thus non-cohesive sands, gravels, silts, and clay, deposited in gently sloping layers toward the Mississippi River. Moving eastward, these unconsolidated sediments thin as the deep underlying consolidate rock rises to the surface just before the Tennessee River. These rocks are comprised mostly of limestone where over millions of years, rain water dissolved solution channels or openings into the weaker limestone called karst. These limestone and other deposits comprise much of Middle and East Tennessee. In far east Tennessee, there exist metamorphic rocks that are comprised of fractures, not solution channels. Groundwater, water that is stored within the open spacing within geologic material (sand/gravel, karst, rock fractures), is a part of a larger system called aquifers.

One of Tennessee's most prolific aquifer systems underlies West Tennessee, a 21-county region, that boasts the best drinking water in the nation. West Tennessee geology is part of a much larger geologic framework called the Mississippi embayment, a geologic region crossing eight southern states with the majority of coverage occurring in Tennessee, Mississippi and Arkansas. The aquifer systems in West Tennessee follow a pancake-like geology where horizontal layers of aquifer are separated by layers of clay that, for the most part, act to protect our groundwater from contamination. Flowing through enormous quartz sand bodies, the groundwater is over 2000-3000 years old and of excellent quality.

Groundwater produced by public-water systems in Tennessee provided drinking water to more than 2.2 million Tennesseans in 2015. Twenty-one percent of the water withdrawal in the State (exclusive of thermoelectric use) is groundwater. In 2015, groundwater provided more than 298 million gallons per day (mgd) for public and rural-domestic supplies, nearly 52 mgd to self-supplied industries, and more than 60 mgd for irrigation, aquaculture and livestock uses. In West Tennessee, nearly all public supplies, industries, and rural residents use ground water – Memphis is completely dependent on groundwater for public, industrial, and agricultural needs. Groundwater is also an important resource in Middle Tennessee used primarily for domestic and agricultural water supplies. In East Tennessee, groundwater is relied on for public drinking water supplies throughout the Valley and Ridge including large water systems near Chattanooga and in the Tri-Cities area of northeast Tennessee.

Overall, Tennessee has nine principal aquifers that are relied on to supply drinking water. These aquifers vary in geologic material, spatial extent and thickness, material type, availability of groundwater, and water quality. As mentioned previously, the sand/gravel aquifers in West Tennessee are expansive and produce very high-quality groundwater at high yields (200-2,000 gallons per minute (gal/min)). The limestone aquifers of Middle and East Tennessee vary in yield based on the number and size of interconnect solution channels (50-2,000 gal/min), but due to the inherent nature of karst systems being formed by dissolution of the rock material these groundwaters contain measures of dissolved solids that influence water hardness. Unlike the layered aquifer systems in West Tennessee that have some level of protection from clay capping key sand aquifers, sinkholes in the karst region of Middle and East pose some challenges in preventing contamination from readily entering into the groundwater network. But West Tennessee has encountered challenges of its own like in Shelby County where the protective clay layer has spotty naturally occurring breaches that allow for hydraulic transfer of waters from the shallow aquifer to drain downward into the pristine Memphis aquifer.

Groundwater in Tennessee provided about 256 mgd in 2015 for public-water systems and 2.28 million people. In 2015, public-water systems in 66 Tennessee counties used groundwater for public-water supplies with 36 counties withdrawing more than 1 mgd from groundwater. Of those 36 counties, 17 were in West Tennessee, 9 in Middle Tennessee and 10 in East Tennessee. Of the five largest producing counties, 4 were in West Tennessee and 1 in East Tennessee. The Memphis Sand of the Tertiary Sand aquifer system is the most important aquifer of Tennessee and provided 159 mgd for public-water supply in West Tennessee in 2015. The carbonates aquifer in the Valley and Ridge of East Tennessee was the second most used aquifer in Tennessee providing about 36 mgd for public-water supply.

Outside of municipal and industrial use of groundwater, agriculture has a growing reliance on groundwater. According to data from the USDA census and the USDA Farm Services Agency, Tennessee had between 146,000 and 198,000 irrigated acres in the years from 2012 to 2017, respectively. The vast majority of on-farm irrigation from groundwater in Tennessee occurs in West Tennessee and is supplied by the Memphis aquifer. Given that as many as 198,000 of these acres are irrigated farm land, we can conclude that approximately 4.2% of the land above the aquifer is being irrigated. However, the effect this may have on Memphis aquifer is largely unknown. The cost of irrigation, both in financial terms and in terms of the depletion of natural resources, requires water conservation efforts, particularly within the current market conditions agriculture faces. Tennessee farmers have made significant strides in the conservation and protection of water supplies, particularly the Memphis aquifer, through their own voluntary efforts.

Groundwater withdrawals for public supply, industrial supply and irrigation will result in short-term and long-term declines in groundwater levels. The deepening of groundwater levels due to pumping can result in adverse hydrologic and economic impacts. To predict adverse impacts, groundwater monitoring wells are required to both measure water level decline and rise and to obtain samples for water quality analysis. In Tennessee, groundwater monitoring occurs primarily in Shelby County and is very sparse through the rest of the State. Statewide, observations wells used to monitor groundwater levels decreased steadily from 26 in 1970 to a low of only 7 wells across Tennessee in 2000. Since 2000, a few additional observation wells have been added. Currently in 2018, outside of Shelby County, there are 11 observation wells across Tennessee. However, 5 of the 11 wells are located in Hamilton County. The response of groundwater levels to drought, climate changes, and to groundwater withdrawals cannot be assessed in many parts of Tennessee due to the lack of observation wells. However, long-term observations in Shelby County have shown decreasing groundwater withdrawals from a high of about 218 mgd in 2000 to about 182 mgd, with water levels actually on a positive rise due to the decreased pumping rates. This is attributed to industrial reuse of water for plant operations, an increase in the use of water-efficient appliances, and education programs geared toward water conservation.

A critical factor in assess groundwater sustainability for Tennessee is recharge, the rate of natural replenishment of our groundwater. The fresh water aquifer systems of Tennessee find replenishment from the cyclic rains and melting snows year after year. A portion of the recharge to groundwater also discharges to surface water and maintains the base flow level of streams and is important for ecological flow conditions. Depending on the difference in river stage and surface water elevations in relation to shallow, near-surface groundwater elevations, these aquifers will also receive recharge from these surface features. Lastly, aquifers can actually recharge other aquifers as water moves slowly through the more resistive material (confining layers) that separates the aquifers. Of these recharge mechanisms, recharge by precipitation and surface water bodies offer the greatest means of replenishment to Tennessee's aquifers. Based on the differences in Tennessee geology, not surprisingly recharge rates and locations of direct recharge vary. In West Tennessee, recharge occurs as water slowly percolates through the small opening between the grains of sediment. In Middle and East Tennessee, recharge is highly variable and primarily occurs through rock openings and solution channel conduits such as sinkholes with additional recharge percolating down through the soil zone.

The majority of groundwater withdrawn in Tennessee occurs in West Tennessee (about 283 mgd, 66% of the State total). The key fresh water aquifers in West Tennessee are the Memphis, Fort Pillow, and McNairy aquifers. In the counties bordering the Mississippi River, these aquifers are confined; however, moving eastward these aquifers connect as they creep in the upslope direction of the Mississippi embayment. Hence, they end up forming a band across West Tennessee that forms the recharge zone where precipitation replenishes these aquifers. Yet for such a pristine, prolific and heavily relied on aquifer system, recharge rates are still a mystery. Some research by academia is shedding light on this important topic, but more is needed to fully understand the complex nature of recharge to these critical aquifers. The groundwater recharge in Middle and East Tennessee supports the baseflow of streams and the groundwater use for water supplies. Groundwater use in Middle Tennessee is about 60 mgd (14% of the State total) and in East Tennessee about 86 mgd (20%). The amount of recharge varies through time with seasonal and annual changes in precipitation, varies regionally depending on the soil, aquifer characteristics, and topography, and can vary locally in the karst areas with direct recharge through sinkholes and disappearing streams in Middle and East Tennessee. Defining recharge will afford city planners and elected officials valuable information to direct growth that won't drastically reduce natural recharge and encourage developers to employ building practices that promote recharge.

There exists an important bond between groundwater and surface water in Tennessee. Understanding this relationship is crucial in assessing short- and long-term effects on water quantity, water quality, ecosystem and habitat vitality, waste discharge and assimilation, and availability of clean drinking water. Simply put, what happens in one resource can directly impact the other. There are two primary ways the interaction between these two water systems occurs. The flow of surface water into the ground water system is defined as infiltration. The exchange in the opposite direction occurs from springs and base flow into the receiving lake or stream. Information about interaction is gathered from well logs, monitoring wells and surface stream gages. Yet, monitoring the interaction is complicated by our complex geology, data collection methods, the mysteries of groundwater, and no deliberate statewide baseline from which to judge the vigor of any interaction.

As Tennessee looks to the future of water availability in the State, we are acting now to protect our valuable groundwater resources from potential contamination. Through numerous means such as illegal dumping, unintentional industrial spills, leaks from aging infrastructure, underground injection, and others, aquifers can become contaminated. Once contaminated, groundwater remediation is required, costing sometimes millions of dollars and years to clean. To be proactive toward contamination prevention, the State of Tennessee wellhead protection program (WHPP) was established following Environmental Protection Agency protocols and enforcement through the Clean Water Act of 1972. Through the WHPP program, two zones of protection are delineated around each wellhead. To ascertain potential contamination of a wellhead, an annual survey of likely contaminant sources is performed, and action is taken by utilities to reduce threats.

By 2040, Tennessee is expected to have an abundance of groundwater though its population growth is expected to nearly double over this time. Water-use projections for public-water supply, domestic self-supplied, and golf course irrigation were projected based on projected population growth. Withdrawals for all water use sectors in Tennessee in 2010 totaled about 7.7 billion gallons per day and in 2015 totaled about 6.42 billion gallons per day. Water use from 2010 to 2015 declined for public-supply, self-supplied industry, thermoelectric power, and irrigation for crops. The water-use projections for 2020, 2030, and 2040, based on the assumptions and methods previously described, show a steady increase in water needs for groundwater use in Tennessee. The water-use projections are primarily driven by assumptions on the growth in population in Tennessee and conservative increases in irrigation. Specific to groundwater withdrawal for public supply, withdrawals for public-water supply in Tennessee for 2010 totaled about 890 mgd with about 321 mgd from groundwater sources and 569 mgd from surface water sources. The total state population in 2010 was about 6.35 million people. Population projections for Tennessee are 6.95 million by 2020, 7.53 million by 2030 and 8.34 million by 2040. Respectively, water withdrawals by public-water systems show similar increases of 962 mgd, 1,026 mgd and 1,114 mgd.

To meet these projected future demands, following are a list of recommendations that should be implemented by the State in order of priority:

1) Develop Tennessee Specific Educational Component on Groundwater. Focus on importance of groundwater in Tennessee, groundwater protection and conservation, hydrologic process

dependencies (e.g., recharge, surface/groundwater interactions with regional considerations), groundwater sustainability and contributing factors to include land processes, shared use, stressors, etc.

2) Promote green infrastructure and conservation techniques using incentives to encourage infiltration of unpolluted/treated rain water into aquifers.
3) Establish monitoring well networks to measure groundwater levels to proactively evaluate trends in groundwater level decline and avert impact. Additionally, conduct simultaneous data collection proximal to the intersection of surface water and groundwater systems.
4) Obtain measures of groundwater withdrawals for agricultural through a voluntary program to farmers. Regionalization should be given high priority resulting in improved data collection, greater cost efficiencies, and more reliable water supply.
5) Promote best management practices across the users of groundwater (i.e., municipal, industrial, agriculture) with an aim toward conservation and sustainability as well as economic growth and vitality.
6) Develop a funding source for scientific assessment and initiatives pertaining to the sustainability of groundwater, most especially in West Tennessee where withdrawals are highest.
7) Determine recharge mechanisms and rates to the key aquifers in West Tennessee by precipitation, surface water-groundwater exchange and inter-aquifer exchange. Derive zones of protection based on critical recharge areas and contamination potential; consider possible designation as sole source aquifer.
8) Encourage better land use planning in and around well head protection areas by integrating program outcomes into municipal planning and/or development operations. Additionally, as groundwater contamination events are from older sources, increase protection zones to 40+ years of travel. Relate source water areas to well head protection.
9) Determine implementation of regulation for using back-flow preventors in situations when flow reversal could contamination the aquifer.