



DIVISION OF WATER SUPPLY



Tennessee Ground Water Monitoring and Management
Drinking Water/Source Water Protection
Ground Water 305b
2006

Introduction

Tennessee has been blessed with an abundance of high quality ground water. With localized exceptions, Tennessee's ground water is of good quality as is evidenced by the number of public water systems utilizing ground water in Tennessee and the dozen or more bottled water facilities. There have been a limited number of contamination incidences of public water systems across the state. Once thought to be immune from contamination, there is increasing awareness that ground water needs to be protected as a valuable resource.

The vulnerability, quantity and quality of Tennessee's ground water sources are inextricably linked to the geology of the State. Ground water can be quite vulnerable to contamination, particularly in karst terrain (limestone characterized by caves, sinkholes and springs) and in unconfined sand aquifers. This vulnerability is particularly true for contamination from the highly mobile and widely used volatile organics (chlorinated solvents and gasoline components).

Both the availability and the quality of our drinking water are vital influences on public health and the economy. In Tennessee approximately 1.5 million people rely on public water systems that use ground water as a source for their drinking water. Approximately 300,000 people who receive their drinking water from a public water system whose source is a combination of ground water and surface water and an additional 500,000 people get their drinking water from private wells and springs. Most West Tennessee citizens rely on ground water for their drinking water. The City of Memphis has one of the largest ground water withdrawals (153 million gallons per day average production) of any municipality the southeastern United States. The communities of Bartlett, Germantown and Collierville in Shelby County withdraw an additional 18.5 million gallons per day.

Concern over the vulnerability and water yield of the Memphis Sand Aquifer that much of West Tennessee withdraws from has prompted the Department of Environment and Conservation to provide funds to the University of Memphis's Ground Water Institute and the United States Geological Survey to further study the impact of withdrawals on the Aquifer. Mississippi and Arkansas have also been involved with this study, collectively referred to as the Mississippi Arkansas Tennessee Regional Aquifer Study (MATRAS). Arkansas's concern has been the large agricultural withdrawals for rice farming out of the aquifer overlying the Memphis Sand. The eastern Arkansas counties within the vicinity of Memphis withdraw an order of magnitude more water for irrigation than Memphis does for its potable water supply. The use of the Memphis Sand Aquifer is not without controversy – there are ongoing lawsuits with the State of Mississippi and several northern Mississippi communities suing Memphis for allegedly withdrawing water rightly belonging to Mississippi and requesting resource damages on the order of billions of dollars.

Tennessee water systems have experienced water shortages during the droughts of the past decade. Somewhat surprising; however, is the fact that more ground water systems have experienced problems than systems relying on surface water (see Figure 1 below).

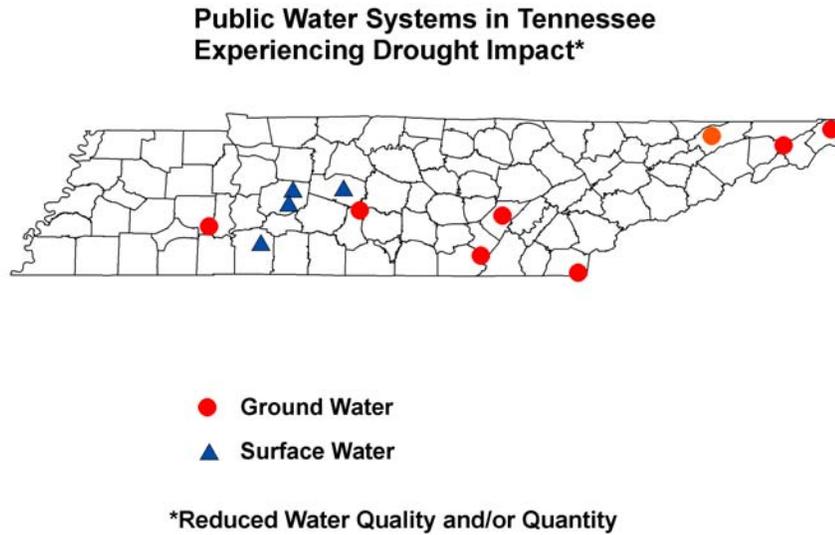


Figure 1

Long thought to be more of a western states issue, water needs in Tennessee are increasing. There are several counties in Tennessee with current or long-term issues with water supply (Figure 2). Water needs forecasting even in relatively water-rich Tennessee must reach decades into the future to provide for economic growth and the health of its citizens.

Tennessee Counties with Potential Need for Water Supplies

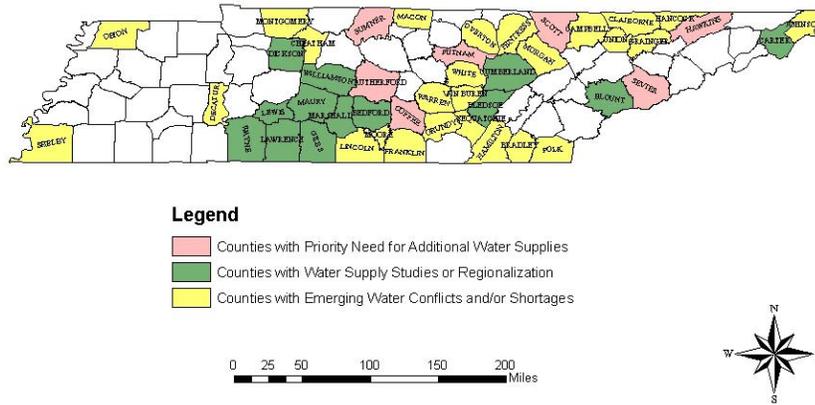


Figure 2

Public and Private Well/Spring Use

All public water systems are subject to strict testing and treatment requirements. Overall, public water systems in Tennessee have an excellent record of providing clean water to their customers. The Division of Water Supply is responsible for regulating all public water systems to protect the state’s drinking water quality. No source of water used by public water systems has been found to contain lead, copper, arsenic, radon or uranium in quantities of concern. Organic chemical contamination above drinking water standards such as from petroleum products and chlorinated solvents rarely occurs in Tennessee but can be a considerable hardship where it does occur. Prevention of contamination is a much more cost-effective method of ground water management.

Tennessee does not require persons using a private water source to test that source for contaminants. Water well **construction** is regulated in Tennessee and drillers are required to have a license and register the wells that they drill. Water well maintenance and testing are the responsibility of the individual homeowner. Springs by their very nature are not regulated since they are not constructed. Users of a private water source that have never tested the source do not know what they may be drinking. “Looks clear, tastes good” is no assurance of contaminant free water.

Chemical contamination is unusual; however, shallow wells and springs located in karst can be impacted by surface water with regard to bacteria and other naturally-occurring pathogenic organisms. Failing septic tanks (leaking directly into the ground water) are also a common cause of ground water contamination as is sinkhole dumping of garbage and other wastes. Wells and springs that become dingy after a rainfall are clearly impacted by climatic conditions and may not receive adequate natural filtration by the earth before reaching the water-bearing zone of the well or spring. If this is the case, the water may contain pathogenic organisms and should be filtered and disinfected before being used.

Abandoned wells can also be a significant hazard for contamination (illegal dumping, spills or contaminated runoff) as well as sinkhole dumps. Both the wells and sinkholes have direct connections to the ground water. There are literally thousands of abandoned wells across Tennessee. There really is no mechanism or resource available for abandoned well identification and closure or for the cleanup of sinkhole dumps.

Critical Ground Water Issues in Tennessee

Ground water in Tennessee is an extremely valuable and finite resource. Ground water contamination has had more than a quarter century of a head start over ground water protection and management. The Ground Water Classification under the Tennessee Water Quality Control Act is currently being revised to better classify the waters of the state and track those areas with ground water contamination and in managed remediation.

There are a number of issues for Tennessee that affect ground water pollution prevention and ground water management:

- Tennessee has variable and complex geology.
 - ◆ The limestone aquifers that are prevalent in Middle and East Tennessee have rapid movements of contaminants and more complex flow paths.
 - ◆ East Tennessee faulting and folding associated with the Appalachians is a complicating factor for that region.
 - ◆ The unconfined sand aquifers in West Tennessee are also vulnerable to contamination, particularly chlorinated solvents and degreasers.

- Contamination is not obvious or easily monitored.
 - ◆ Ground water itself and ground water contamination cannot be seen.
 - ◆ Each well is an extremely narrow “window” into the aquifer.
 - ◆ A contamination plume is commonly limited in size (hundreds to thousands of feet), irregular in shape and not evenly distributed within the aquifer.
 - ◆ Variations in the physical and chemical characteristics of contaminants can also cause the contaminants to take widely different flow paths through the aquifer.

- Sampling a well is significantly different from sampling a stream.
 - ◆ Upstream and downstream are not obvious when sampling ground water.
 - ◆ There are no aquatic indicators to reveal the health of the ground water.
 - ◆ Locating the stream is not an issue, locating the ground water can be.

- Contamination in ground water tends to be from a different suite of chemicals and of much longer duration than in surface water.
 - ◆ Surface water is subject to more natural attenuation of contamination, with both physical and biological breakdown of the contaminants.
 - ◆ Each chemical's physical and chemical properties has an effect on its movement in ground water.

- A more accurate picture of the health of Tennessee's aquifers is needed.
 - ◆ There has been not been a systematic statewide study of Tennessee's aquifers.
 - ◆ Tennessee lacks an ambient (naturally-occurring or "background" water quality) ground water quality monitoring program.
 - ◆ Public water systems sample the treated water served to their customers, not raw ground water samples.
 - ◆ Private wells and springs are not routinely sampled in Tennessee.
 - ◆ Tennessee does not have a statewide ground water contamination database or a requirement for ground water contamination to be reported.

Tennessee's Complex Geology

The geology of Tennessee makes certain aquifers {water bearing zones} more vulnerable to contamination where there is no clay confining layer or naturally filtering soil layer to deter contamination from reaching the ground water. The unconfined sand aquifers of West Tennessee (particularly the Memphis Sand Aquifer east of Memphis) are vulnerable to contamination as are the limestone (carbonates) aquifers of Middle and East Tennessee (see Figures 3 and 4). East Tennessee has the additional complicating factor of major rock deformation through faulting and folding associated with the forming of the Appalachian Mountains.

For online downloadable video produced by the Department of Environment and Conservation, the reader is referred to: www.state.tn.us/environment/videos. The video "Hollow Ground: Land of Caverns, Sinkholes and Springs" addresses karst limestone areas in Tennessee and the video "Drops of Water in Oceans of Sand: Ground Water Resources of West Tennessee" addresses the sand aquifers of West Tennessee. In addition, there is a multi-part video on source water protection (protection of the sources of public water) on the website.

Tennessee has an abundance of limestone rock types (approximately 2/3 of the state), which are highly susceptible to contamination. These limestone rock types develop a terrain that is referred to as “karst.” The term “karst” is named for a region in what was then Yugoslavia. The term refers to limestones and dolomites (magnesium-rich limestones) where the dissolution of the rocks creates solution-enlarged channels, bedding planes and microfractures for ground water flow.

Karst is characterized by sinkholes, springs, disappearing streams and caves. Karst systems have rapid, highly directional ground water flow in discrete channels or conduits. Karst aquifers have very high flow and contaminant transport rates under rapid recharge conditions such as storm events. This is a particular concern for public or private water supplies using wells or springs in karst areas where pathogenic organisms that would not be present in true ground water can survive in ground water under the influence of surface water.

Karst systems are quite easily contaminated since the waters can travel long distances through conduits with no chance for natural filtering processes of soil or bacterial action to diminish the contamination. Transport times across entire karst flow systems may be as short as hours or weeks, orders of magnitude faster than that in sand aquifers.

Water in karst areas is not distinctly surface water or ground water. Surface water can enter into the ground water directly through sinkholes and disappearing streams. It is not uncommon for ground water to contaminate surface water, making surface water problems into ground water problems in Middle and East Tennessee. The reverse can also occur. There are a number of water systems in Middle and East Tennessee relying on ground water sources that have been determined to be under the direct influence of surface water. These systems are required to have filtration such as that required for surface water systems.

Ground water contamination (see Figure 5) is typically chlorinated solvents or degreasers and gasoline. These are all very volatile (evaporate rapidly) and are thus not a problem in surface water, but they are a serious problem in ground water. These chemicals do not biodegrade well and can be there for decades. They also have very low drinking water standards (several are at 5 parts per billion). Another ground water problem for Middle and East Tennessee owing to the shallow bedrock associated with caves and sinkholes is contamination from septic tanks. Bacteria from septic tanks is a leading cause of private water well contamination.

Surface water contamination is typically nitrates {from fertilizer and animal waste}, bacteria, protozoa and urban runoff {runoff from yards, asphalt, etc. that has heavy metals and pesticides/herbicides, etc.}. There has been testing across the state showing atrazine (a herbicide) is getting into streams (eight across the state) after rains during growing season. Ground water in karst areas which is impacted by surface water is also subject to these same contaminants. Atrazine has also been detected at one Middle Tennessee water system where its ground water source is under the direct influence of surface water.

The protozoan cryptosporidium is a serious problem for surface water systems or ground water systems under the direct influence in that chlorine will not kill it and it is abundant in the environment. It is what gives cattle the “scours” (diarrhea). EPA’s Enhanced Surface Water Treatment Rule is predominantly the result of cryptosporidium concerns.

Naturally Occurring Radon

There are increasing concerns over naturally-occurring levels of radon, uranium and arsenic in drinking water supplies nationwide. Tennessee is fortunate that the geology is such that the naturally occurring arsenic that plagues a number of the western states is not present in this state. Neither does there appear to be a problem with uranium. Studies of public ground water supplies across the state have determined that there are locations with elevated levels of radon (Figure 6).

There was some testing for radon in public water systems across the state in 1999, which indicated that the radon in some water systems was well above the 300 pCi/liter standard. Further radon testing was needed in that some of those systems were not in the expected geologic setting for high radon levels. The 1999 testing also appeared to indicate that lower flow volume wells and springs tend to have higher levels of radon, possibly due to there being less “flushing” of the relatively volatile radon gas. This trend of smaller systems having the higher radon readings is consistently holding true in the 2001 sampling as well. The high radon readings were typically from water systems with less than 200,000 gallons per day average daily production.

It is not unexpected that there are high radon readings without corresponding uranium results in that the wells are typically going to be finished above the shales. Wells are typically not drilled into the shales that contain uranium for a ground water source because they have water quality problems from high metal and sulfur content. Radon as a gas will enter the wells drilled into the carbonate rocks overlying the shales.

Of the 92 wells and springs sampled, 34 were above the 300 pCi/liter standard and six were above 1000 pCi/l. With the exception of West Tennessee (where no radon was expected) and the Cumberland Plateau, the sample choices were intentionally made that would likely have high radon readings. Of the 92 samples, 33 of the wells/springs have been determined to be under the direct influence of surface water. Of those 33, 13 yielded radon results of 300 pCi/l or higher.

The most consistently high readings were for small community/noncommunity systems in the Highland Rim area of Middle Tennessee, although the highest reading was in East Tennessee. The majority of the high values for radon are from small community (subdivisions, trailer parks) or noncommunity (campgrounds) systems.

The Highland Rim wells/springs either side of Nashville have high readings as would be expected for Mississippian carbonates above the Chattanooga Shale.

The Chattanooga Shale is the expected source of the radioactivity in that it has low levels of uranium found in it in much of the areas where it occurs. Similarly in the Valley and Ridge (Cambrian Ordovician Carbonates) and Unaka Mountains (Crystalline Rock) of East Tennessee there are shales that are expected to be low sources of low level radioactivity. The highest radon results (3103 pCi/liter) were from a subdivision in Polk County Tennessee in the southeastern corner of the state. The second highest (2010 pCi/l) was from another subdivision in Sevier County.

It is in some ways fortunate that radon is the issue in Tennessee and not arsenic and uranium as with several other states including some in the Southeast. Radon can be removed from water relatively easily in that it is a volatile gas. Treatment for uranium and arsenic is much more complex.

Aquifers of Tennessee

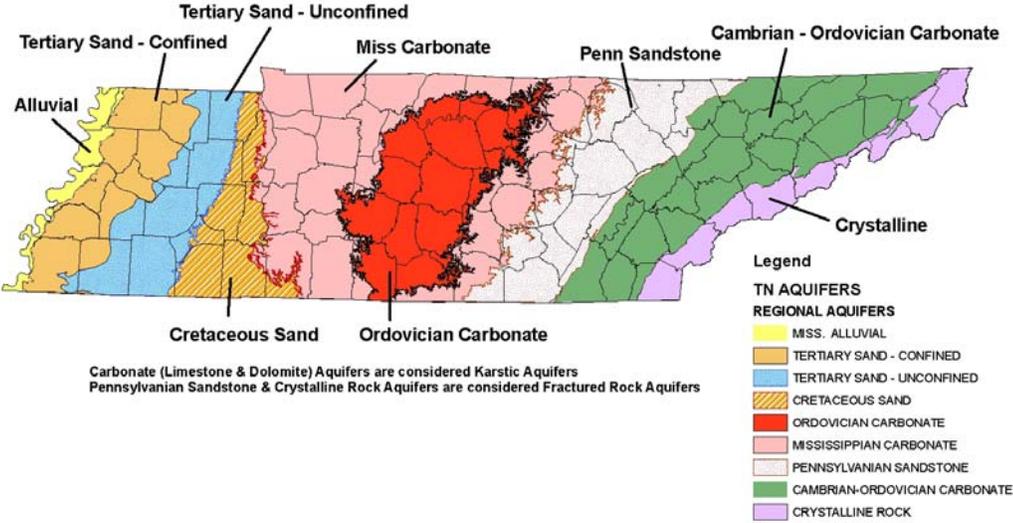


Figure 3

Karst Areas of Tennessee

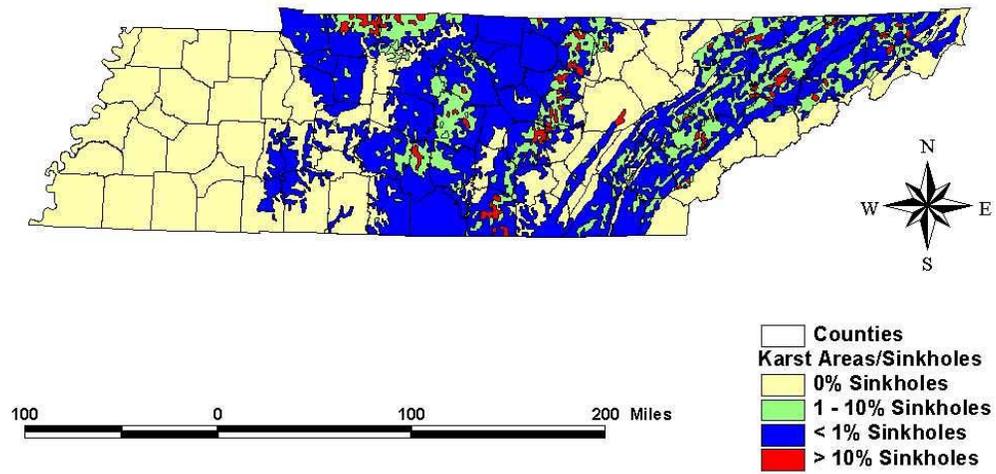


Figure 4

Ground Water Contamination at Public Water Systems

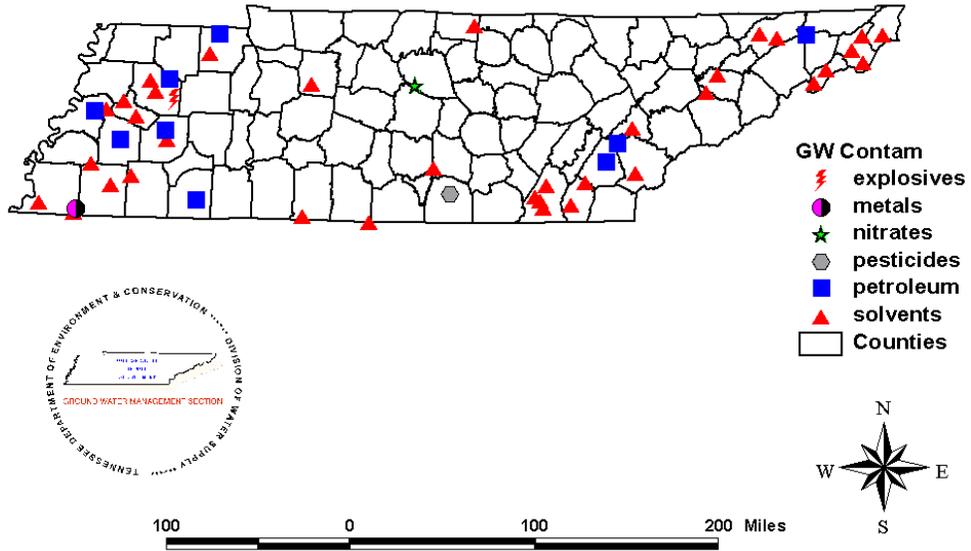


Figure 5

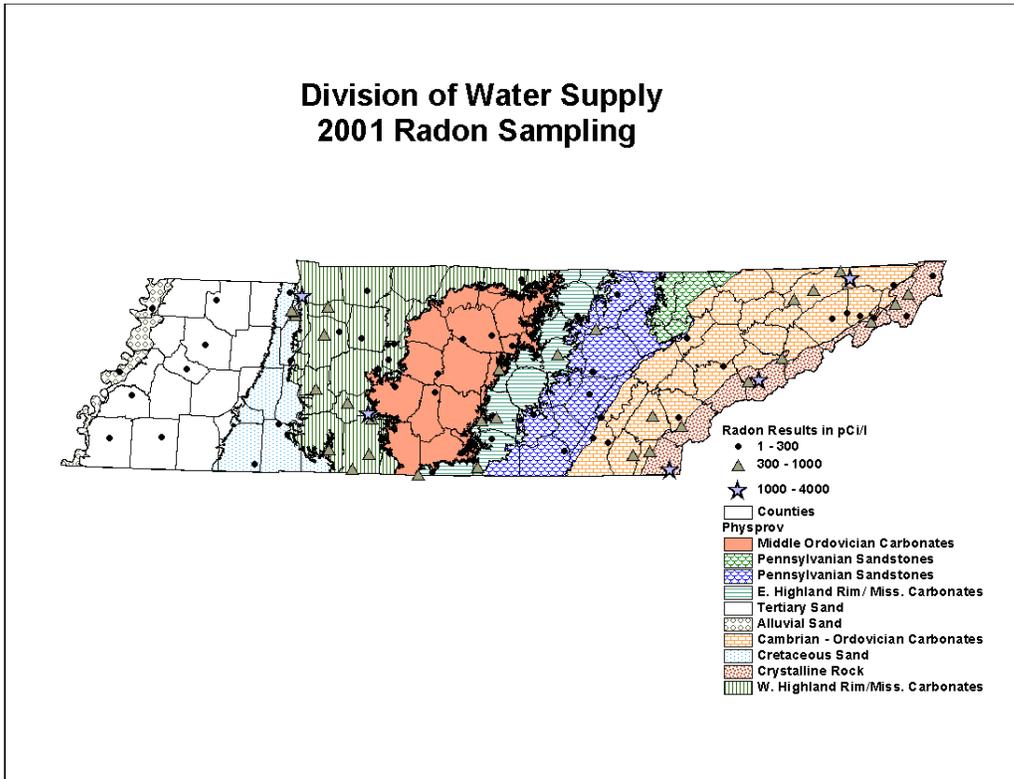


Figure 6

Ongoing Activities

The Division of Water Supply has been using Wellhead Protection set aside monies from the Drinking Water State Revolving Fund and EPA 106 Ground Water Grant monies to further ground water investigation and management activities, including the Mississippi Arkansas Tennessee Regional Aquifer Study (MATRAS) through the U. S. Geological Survey, karst ground water studies with the University of Tennessee's Center for Environmental Biotechnology and work with the University of Memphis's Ground Water Institute, an "adopt a spring" educational pilot project with Austin Peay State University and Wellhead/Source Water Protection Tools for Local Government with the Tennessee Valley Authority.

Source Water Protection: Protecting Public Drinking Water Supply Sources

There have been significant developments at the State level since EPA's approval of Tennessee's Source Water Assessment Program in 1999 and the submittal of the assessments to EPA in 2003. Most significant for Source Water Protection are the changes made in the Tennessee Safe Drinking Water Act in 2002 at the request of the Division of Water Supply. Prior to the amendment, TCA 68-221-711 (5) prohibited the discharge of sewage above an intake.

After some difficulties in addressing a specific problem where it was difficult to ascertain which agency should/could respond, language was successfully added (bolded in italics) that prohibits:

“The discharge by any person of sewage ***or any other waste or contaminant*** at such a proximity to the intake, ***well or spring*** serving a public water system in such a manner or quantity that it will or will likely endanger the health or safety of customers of the system or cause damage to the system.”

Tennessee considers this a significant achievement toward Source Water Protection that is not available at the federal level. In addition, another amendment was proposed and successfully added to the Tennessee Safe Drinking Water Act that is more geared toward water quantity issues but that can easily become a water quality issue as well. Prior to amendment, TCA 68-221-711(8) prohibited heavy withdrawal from a water supply (water supply lines).

After concerns over addressing a major commercial water withdrawal in vicinity to a water supply spring, at the request of the Division of Water Supply an additional prohibition was added (bolded in italics):

“The heavy pumping or other heavy withdrawal of water from a public water system ***or its water supply source*** in a manner that would interfere with existing customers' normal and reasonable needs or threaten existing customers' health and safety.”

With this new authority to protect water supply sources within the Act, the Division of Water Supply promulgated regulations in October of 2005 to add complimentary language to the former Wellhead Protection Rule 1200-5-1-.34. There has been language added to the Rule that gives the Division authority to address certain high risk activities in the vicinity of water supply intakes, wells and springs that might otherwise be unregulated. The Rule is now titled “Drinking Water Source Protection” and also includes contaminant inventory and emergency operation requirements for water systems using surface water intakes in addition to the wellhead protection requirements for ground water systems that were present previously.

Every community public water system is also required to address their source water assessment in the Consumer Confidence Report that is required to be made available to its customers annually and advise customers of the location of the Division's website: www.state.tn.us/environment/dws/dwassess.php.

The Tennessee Division of Water Supply in conjunction with the Tennessee Association of Utility Districts is working with other state and local agencies, water systems and local governments to develop localized source water protection plans within counties and watersheds. The Division of Water Supply is working with its available resources to assist individual water systems with contaminant source issues as well. The Division also contracted with the University of Memphis to produce a multi-part video on source water protection, which is available for download online at: www.state.tn.us/environment/videos.

Source Water Protection is a dynamic process. The states and EPA will never truly be "finished." Tennessee's Source Water Protection Program has adopted a motto: "Everybody Lives Downstream of Somebody." Source Water Protection is a complex matter of integrating the protection of the countries drinking water resources into the myriad of other environmental protection activities at the state and federal levels. This will require the long-range commitment of resources that have not yet materialized.

As we encroach more and more on the environment and our natural resources, we must be even more diligent in protecting them. Our health, safety, economy and quality of life depend on a clean, reliable source of drinking water.