DEPARTMENT OF ENVIRONMENT & CONSERVATION

DIVISION OF WATER SUPPLY

GROUND WATER MANAGEMENT SECTION

Tennessee Ground Water Monitoring and Management

Drinking Water/Source Water Protection

Ground Water 305b

2010

Introduction

This report was prepared by the Tennessee Department of Environment and Conservation (TDEC), Division of Water Supply (DWS), to fulfill the requirements of both federal and state laws. Section 305(b) of the Federal Water Pollution Control Act, commonly called the Clean Water Act, requires a biennial analysis of water quality in the state. The Tennessee Water Quality Control Act also requires that the division produce a report on the status of water quality.

Tennessee has been blessed with an abundance of high quality and good quantity of ground water in spite of the recent drought that has affected so much of the country. With localized exceptions, Tennessee's ground water is still 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. Once thought to be immune from contamination, there is increasing awareness that ground water needs to be protected as a valuable resource. There have been a limited number of contamination incidences of public water systems across the state.

The vulnerability of Tennessee's ground water sources is 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).

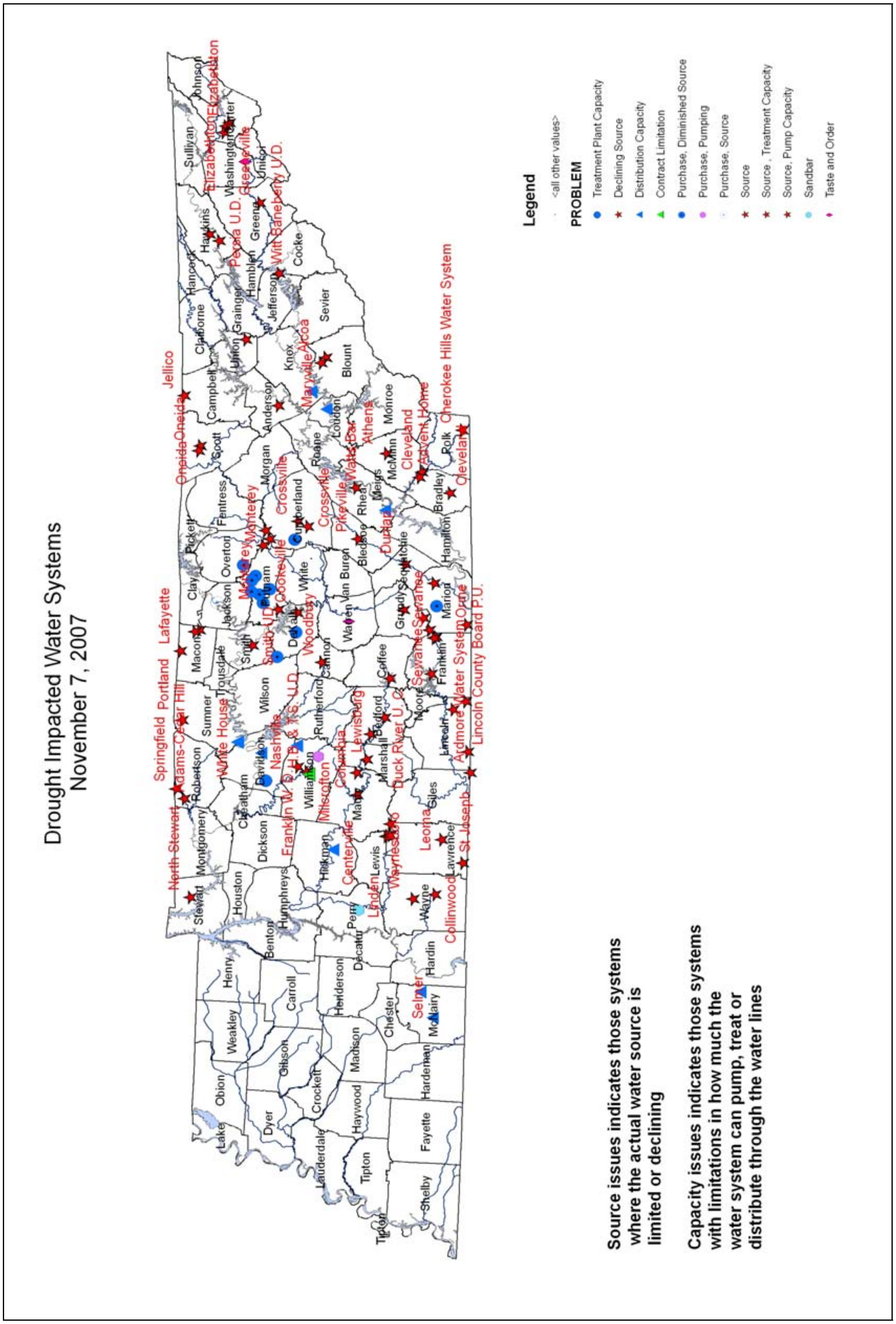
Both the availability and the quality of our drinking water are vital influences on public health and the economy. In Tennessee approximately 1.5 million people rely on public water systems that use ground water as a source for their drinking water. There are approximately 300,000 people that receive 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 (16 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 of the Memphis Sand Aquifer that much of West Tennessee withdraws from 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 withdrawing an order of magnitude more water than

Memphis does for its potable water supply. Once the MATRAS study was completed the Mississippi Embayment Regional Groundwater Study (MERGWS) study was formed using several of the original MATRAS partners to refine the science and the study of the Mississippi aquifer over a seven state area.

Tennessee had a number of water systems impacted by the drought. The impacts caused systems to institute water restrictions, which if this continues could lead to the loss of economic growth in Tennessee. Many of these water systems have been impacted not by their sources running out but by hydraulic or treatment capacity issues due in large part to the amount of irrigation of lawns, gardens, car washing, etc. – the water systems simply could not produce enough water or pump enough water through their water lines. The map (Figure 1) shows water systems across the state that the drought has affected by showing drought impacts due to dwindling sources in Tennessee. In Appendix A there is a list of all systems affected by the drought and the measures taken by the water systems and reasons for the actions.

Most of the ground water systems in Tennessee, especially those in West Tennessee have not shown to be influenced by the drought. Those in Middle and East Tennessee that are under the direct influence of surface water have. In Tennessee there were only three ground water systems that run out of water. Orme in southeast Marion County was not able to supply water to the citizens from the existing spring. The city of Bridgeport, Alabama ran a water line to Orme in November to solve the supply issue. Orme is no longer a ground water system; they are now a distribution only system. The second city to have drought issues is the city of Mount Pleasant in Maury County. The city of Columbia (surface water system) supplied the city of Mount Pleasant during the time the springs were not producing sufficient water. The third city, St. Joseph had supply issues with the spring and had to be supplemented by the city of Loretto (also a ground water system on a spring).


Drought Impacted Water Systems
November 7, 2007
Legend
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PROBLEM
Treatment Plant Capacity
Declining Source
Distribution Capacity
Contract Limitation
Purchase, Diminished Source
Purchase, Pumping
Purchase, Source
Source
Source , Treatment Capacity
Source, Pump Capacity
Sandbar
Taste and Order
Source issues indicates those systems where the actual water source is limited or declining
Capacity issues indicates those systems with limitations in how much the water system can pump, treat or distribute through the water lines

Figure 1

There are over thirty ground water systems that are showing the effects of the drought. Note that very few West Tennessee water systems have problems – this is due to the fact that they rely on wells drilled into sand aquifers that are not showing as large an impact from the drought.

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. The Tennessee General Assembly has a Bill before them looking at the possibility of regionalization of water systems. There is also a push for a stronger Drought Management plan within the state.

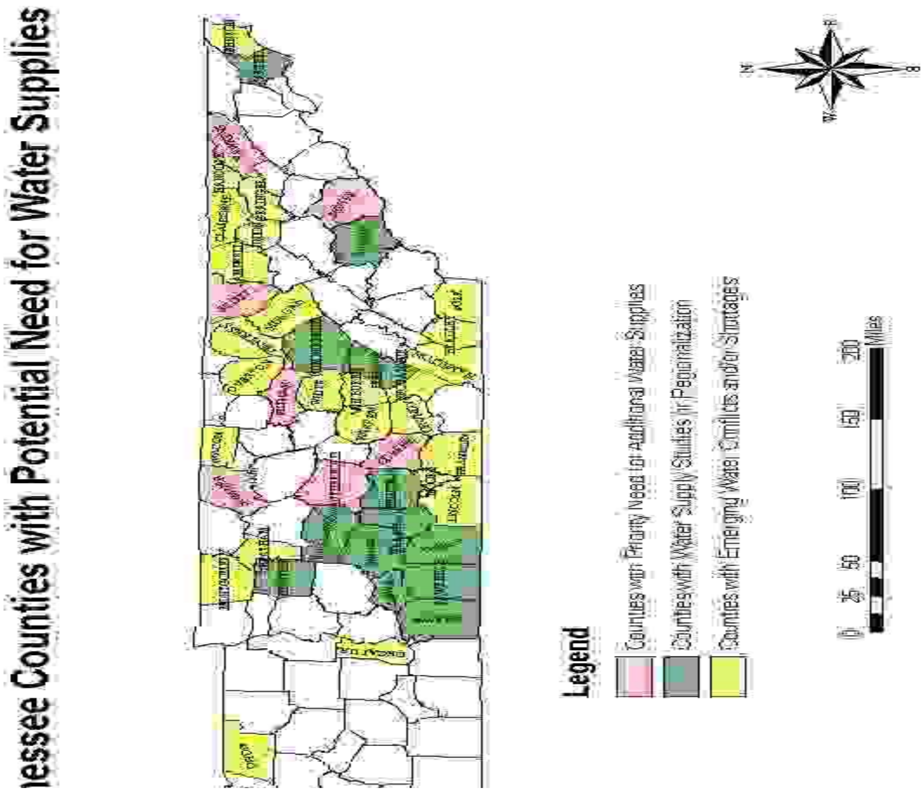


Figure 2

Statutory Requirements

The Tennessee Safe Drinking Water Act was passed in 1983 from that time the Division of Water Supply (DWS) has worked to ensure that public drinking water supplies are safe. DWS also regulates the construction of non-federal dams, enforces the Water Resources Act, monitors water withdrawals, and regulates the licensing of well drillers and pump setters. The Division contains the Ground Water management Section (GWMS) which operates the Source Water Protection Program, the Wellhead Protection Program the Underground Injection Control Program and conducts monitoring and sampling of groundwater complaints. The GWMS also houses the GIS portion of the Division.

In addition to the federal requirements, the Tennessee Water Quality Control Act of 1977 requires the Division of Water Supply to produce the ground water report to the governor and the general assembly on the status of water quality in the state. The report can include a description of the water quality plan, regulations in effect, and recommendations for improving water quality. The 2010 305(b) Report serves to fulfill the requirements of both the federal and state laws.

This report covers only ground waters in Tennessee. The department's Division of Water Pollution Control is developing a report on ground water quality as well to fulfill their requirements.

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 the well drillers are required to have a license and submit a Notice of Intent (NOI) for the proposed wells that they drill. Water well testing and maintenance are the responsibility of the individual homeowner. Springs used by private individuals 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 both drilled and hand-dug 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. These are currently addressed on an as located basis and usually require a fine placed on the current owner.

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 has been 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 in 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.
  - ♦ The state has adopted a new Ground Water Classification as it relates to the Remediation programs. This classification allows for tracking of contamination on more of a statewide basis.
  - ♦ 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.
    - ♦ In recent years, "emerging contaminants" such as human and veterinary pharmaceuticals, industrial and household wastewater products, and reproductive and steroidal hormones in water resources have become more of a focus (USGS Fact Sheet FS-027-02, Pharmaceuticals, Hormones and Other Organic Wastewater Contaminants in U. S. Streams; June 2002). Potential environmental pollutants include pharmaceutical, veterinary and illicit drugs, as well as active ingredients in personal care products (collectively referred to as PPCPs). These potential pollutants include prescription drugs and biologics, as well as diagnostic agents, fragrances, sun screen agents, ingredients in cosmetics, food supplements and numerous others. The introduction of PPCPs into the environment is not just by sewage treatment plants, but also by nonpoint runoff and failing septic systems as well as large capacity conventional and drip disposal systems.
    - ♦ 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) 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 tohttp://tn.gov/environment/videos/#water. 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 micro fractures 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 are typically nitrate {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 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).

Testing conducted for radon in public water systems across the state in 1999 indicated that the radon in some water systems was well above the EPA proposed 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 shale formations. Wells are typically not drilled into shale formations 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 shale formations.

Of the 92 wells and springs sampled, 34 were above the proposed 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 shale formations that are expected to be low sources of low level radioactivity. The highest radon result (3103 pCi/liter) was 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. Tennessee has not conducted follow-up sampling on the radon project since 2001.

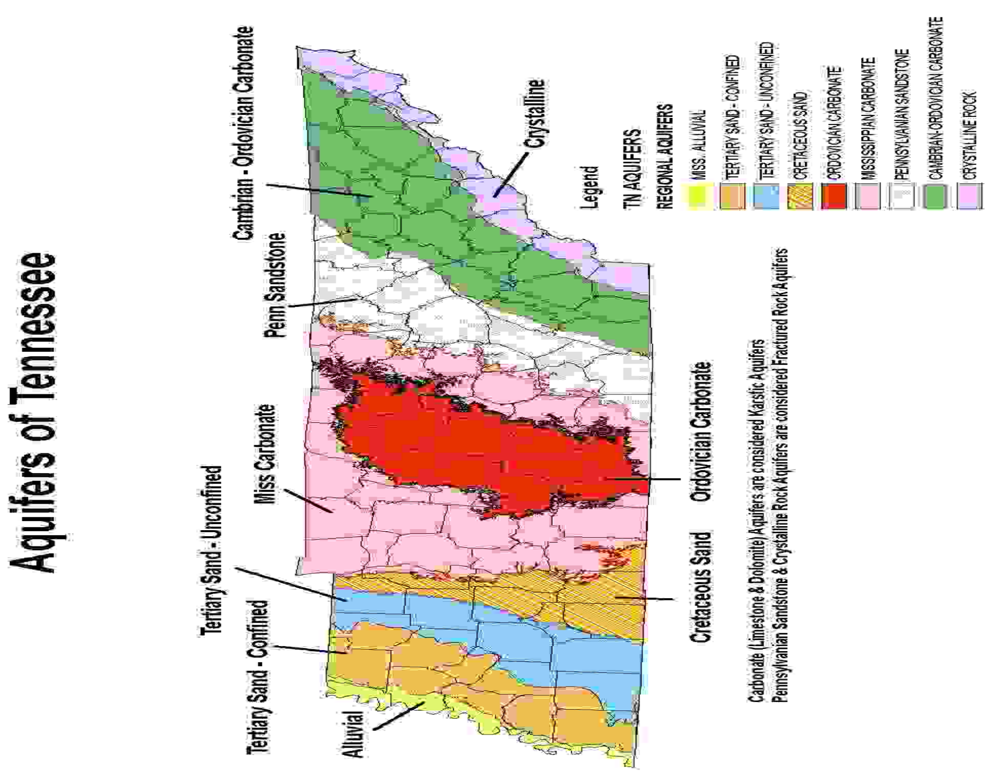


Figure 3

Figure 5

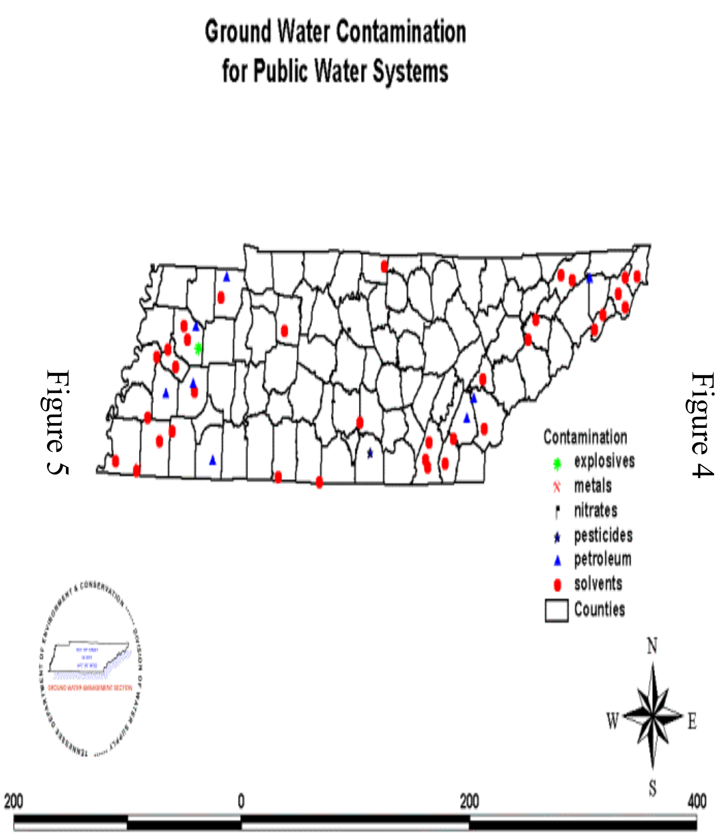
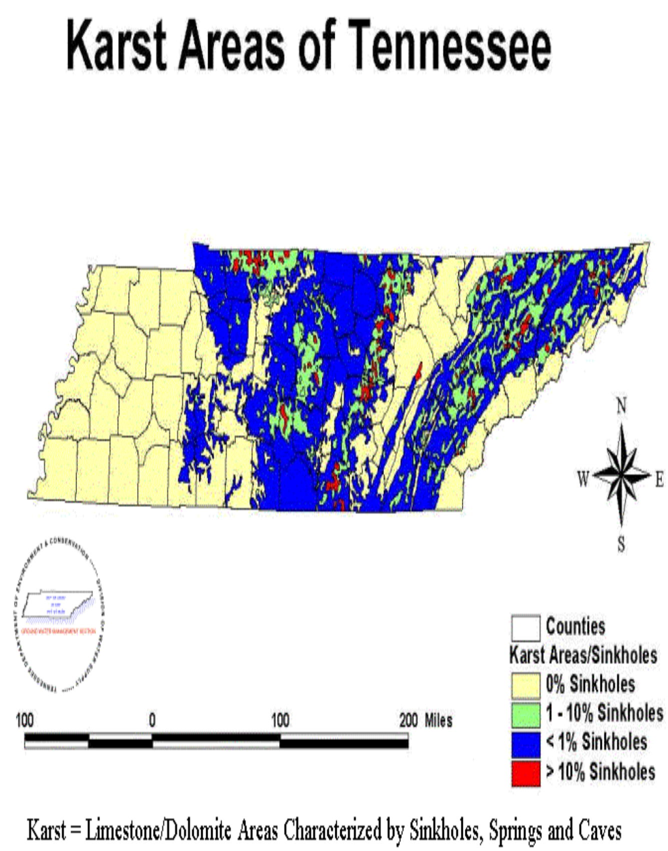


Figure 4



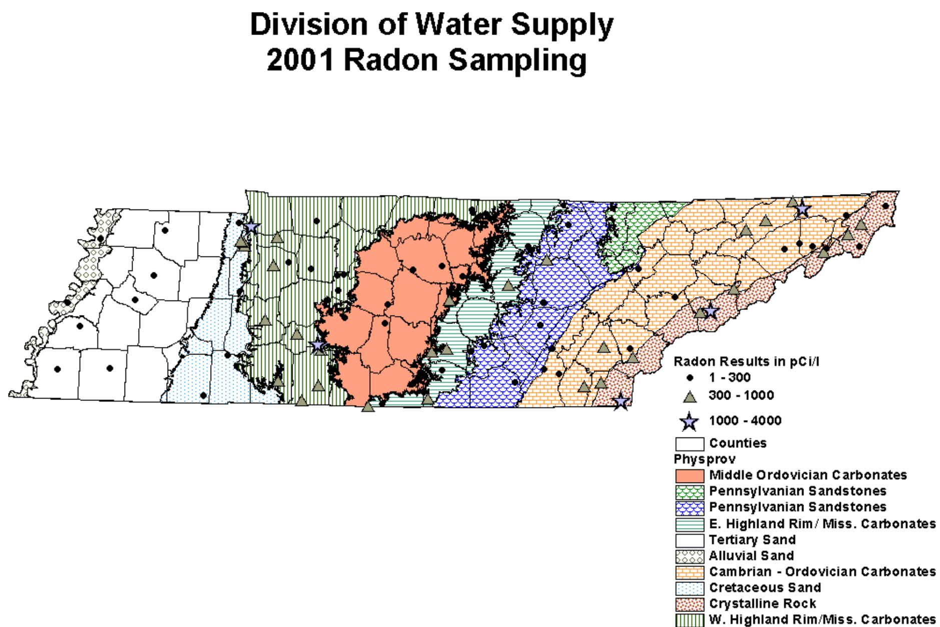


Figure 6

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. These monies have been used in the Mississippi Arkansas Tennessee Regional Aquifer Study (MATRAS) through the U. S. Geological Survey, and as a basis for the Mississippi Embayment Regional Ground Water Study (MERGWS). Karst ground water studies with the University of Tennessee's Center for Environmental Biotechnology have been completed with the report submitted to the State and work with the University of Memphis's Ground Water Institute on Geographic Information System (GIS) work with the Wellhead Protection Areas and Source Water Protection Areas, the "adopt a spring" educational pilot project with Austin Peay State University was produced and has had a good response from the education community. Wellhead/Source Water Protection Tools for Local Government with the Tennessee Valley Authority is an ongoing project providing a tool box by the end of 2008, as well as a new contract with the Tennessee Association of Utility Districts to provide an outlet for working with individual water systems.

Tennessee has completed the latest round of Wellhead Protection updates on all Noncommunity and Community Water Systems. The updates are completed every three years. The update includes the observation and documentation of any new contaminant source. Then every sixth year a new wellhead protection plan is submitted with new photographs and maps showing any new protection strategies that have been employed by the water system. The next new plan for community water systems is due to the Division by 2010. The Noncommunity water systems have a new plan every three years based on the grand division that they are located in, the 2008 series starts with West Tennessee, 2009 is Middle Tennessee and 2010 is East Tennessee.

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: http://tn.gov/environment/dws/dwassess.shtml.

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 has available resources to assist individual water systems with contaminant source issues as well. The Division has completed the contract with the University of Memphis to produce a multi-part video on source water protection, which is available for download online at: http://tn.gov/environment/videos/#water

The Division of Water Supply is participating in the Department of Environment and Conservation's recently formed Water Resources Technical Advisory Committee. The broad based committee was established based on requirements in the Tennessee Water Resources Information Act and is being asked to supply input on drought management, regionalization for stressed areas and other water supply issues. Source Water protection is essential to the development of new water supplies and is an ongoing consideration. There is a link to the Technical Advisory Committee at
http://www.tn.gov/environment/boards/wrtac/

With input from the WRTAC, The Department finalized a Drought Management Plan in February 2009, and held workshops in March of 2010 which are posted on the TDEC website at
http://www.tn.gov/environment/dws/pdf/droughtmgtplan.pdf.

The Department also finalized a guidance document for local communities in developing their drought management plans, which is located at:
http://www.tn.gov/environment/boards/wrtac/pdf/LocalDroughtMgtPlanningGuidelines.pdf

More information about WRTAC is available on the TDEC website at http://www.tn.gov/environment/boards/wrtac/*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

TDEC began a study of karst terrain in the Red River Watershed. The EPA-funded study, in partnership with the United States Geological Survey (USGS) and the Red River Watershed Association, will examine the relationship between surface water and ground water in five subwatersheds in the Montgomery, Robertson, and Stewart County portions of the Red River Watershed.

The GWMS also completed a contract with the Tennessee Association of Utility Districts (TAUD) in order to update the potential contaminate inventory for all community wellhead protection areas.

The GWMS is entering into a contract with the University of Tennessee to provide TDEC with information on the prevalence and concentration of pharmaceutical compounds in select wastewater treatments in Tennessee. The specific goals will be to:

1) Analyze wastewater treatment samples for select pharmaceutical compounds using analytical chemistry methods

2) Analyze wastewater treatment samples for endocrine disrupting potential using recombinant yeast (*Saccharomyces cerevisiae*) bioreporter strains.

This project we will begin surveying waters in Tennessee (wastewater, surface water and ground water) for the presence of both pharmaceutical compounds and endocrine disrupting compounds. Initially select pharmaceutical compounds including: caffeine, carbamazepine, DEET, 17α-ethinyl estradiol, fluoxetine and ibuprofen will be analyzed using GC/MS or LCMS analytical methods. In order to supplement analytical testing for endocrine disrupting compounds, bioluminescent-based yeast (*Saccharomyces cerevisiae)* reporters for the detection and quantification of estrogenic and androgenic chemicals will also be used on each sample (Sanseverino et al. 2008). The combined use of these two strains allows testing of chemicals for estrogenic and androgenic activity and may provide rapid assessment of the prevalence of endocrine disrupting chemicals in water samples.

Appendix A

WATER SYSTEMS IMPACTED BY THE DROUGHT

2007 December 19

SYSTEM NAME	COUNTY	WATER SOURCE	Prob-lem	Mea-sures	Population Served
Bedford Co UDs	Bedford	Duck River, Shelbyville WS	D	V, FN1	18,008
Shelbyville WS	Bedford	Duck River	D	V, FN1	21,932
Pikeville WS	Bledsoe	Wells	FN4	M	3,358
Alcoa WS	Blount	Little River	S	M, FN7	25,001
Maryville DWQ	Blount	Little River	S	M, FN7	34,064
Cleveland Utilities	Bradley	Waterville Spg and other sources	S	M	71,348
Ocoee UD	Bradley	Spring (Nearby sinkhole development)	FN4	N	14,863
Jellico WD	Campbell	Well and Strip Mine Impoundment	D	M	4,458
Woodbury WS	Cannon	East Fork Stones River	S	V	8,612
Elizabethton WD	Carter	Springs	D	V	24,910
Duck River UC	Coffee	Normandy Lake	D	V, FN1	47,946
Crab Orchard Utility District	Cumberland	Otter Creek Impoundment	D	V	14,646
Crossville WD	Cumberland	Holiday Hills and Meadow Park Lakes	D	M	25,961
West Cumberland UD	Cumberland	Bon De Croft UD	D	V	3,674
Harpeth Valley UD	Davidson	Cumberland River	C	N	44,275
Nashville WD	Davidson	Cumberland River	N	N	406,245
Alexandria WS	DeKalb	Smithville WS and Smith Co UD #1	D	FN5	2,233
DeKalb UD #1	DeKalb	Smithville WS	D	FN5	10,920
DeKalb UD #2	DeKalb	Smithville WS	D	FN5	1,420
DeKalb UD #3	DeKalb	Smithville WS	D	FN5	598
DeKalb UD #4	DeKalb	Smithville WS	D	FN5	465
Smithville WS	DeKalb	Center Hill Lake	D	FN5	5,387
Sewanee UD	Franklin	Small lakes	D	V	4,708
Winchester WS	Franklin	Tims Ford Lake	H	V, FN3	18,862
Ardmore WS	Giles	Wells	S, P	V	1,519
Greeneville WS	Greene	Nolichucky River	T, D	T	22,967
Big Creek UD	Grundy	Ranger Lake	S,C	V	8,001
Monteagle PUB	Grundy	Laurel Lake	S	M	3,399
Tracy City WS	Grundy	Fiery Gizzard Impoundment	S	M	3,680
Persia UD	Hawkins	Rogersville, Wells	D	N	3,985
Rogersville WD	Hawkins	Big Cr, Old Towne Spring and Wells (2)	D	N	8,134
Centerville WS	Hickman	Big Swan Cr	H	M	7,845
Jackson Co UD #4	Jackson	Red Boiling Spg	D	M	1,703
Baneberry UD	Jefferson	Wells (4), Witt UD	D	N	692

		(Morristown WS)			
1st UD of Knox Co	Knox	Sinking Cr and Walker Spg	H	N	72,897
Leoma UD	Lawrence	Well, Lawrenceburg, Loretto	D	V	2,842
St. Joseph WS	Lawrence	Spring and Loretto	D	V	1,303
Summertown UD	Lawrence	Wells (5) and Lawrenceburg	D	M	3,144
Lincoln Co. BPU	Lincoln	Wells and Fayetteville	D, H	V	18,673
Lenoir City UB	Loudon	Watts Bar Lake and First UD of Knox Co	H	V	19,191
Lafayette WS	Macon	Adams Spring	D	M	14,657
Red Boiling Spgs WS	Macon	McClellan and Sabin Spgs	S	M	4,894
Foster Falls UD	Marion	Tracy City	D	M	650
Jasper WS	Marion	Spring and Sequatchie River	S	V	8,805
Orme WS	Marion	Springs	S	M	87
Whitwell WS	Marion	Sequatchie River	S	V	6,728
Lewisburg WS	Marshall	Duck River	D	V, FN1	14,953
Columbia WS	Maury	Duck River	D	V, FN1	56,739
Mt. Pleasant WS	Maury	Springs	D	V, FN3	6,339
Spring Hill WD	Maury	Duck River	S	V, FN1	18,718
Advent Home WS	McMinn	Wells	S	M	65
Athens UB	McMinn	Spgs, wells, Hiwassee	D	V	18,515
Adamsville WS	McNairy	Wells	H		8,063
Selmer WS	McNairy	Wells	H	V	17,276
West Overton UD	Overton	Livingston and Cookeville (via Algood)	D	FN5	7,006
Linden WD	Perry	Buffalo River	Sandbar	V	4,950
Cherokee Hills WS	Polk	Springs	S	M	295
Algood WS	Putnam	Cookeville WS	D	FN5	6,457
Bangham UD	Putnam	Cookeville WS	D	FN5	6,672
Baxter WD	Putnam	Cookeville WS	D	FN5	4,588
Cookeville Boat Dock Road UD	Putnam	Cookeville WS	D	FN5	5,880
Cookeville WD	Putnam	Center Hill Lake	D	FN5	32,446
Double Springs UD	Putnam	Cookeville WS	D	FN5	6,779
Heritage Academy	Putnam	Wells	D	M	100
Monterey WD	Putnam	City Lake, Meadow Creek Lake	S	M	4,397
Old Gainesboro Road UD	Putnam	Cookeville WS	D	FN5	5,491
Dayton WS	Rhea	Tennessee River	H	V	18,974
Watts Bar UD	Rhea	Wells and Hiwassee Utilities	S	V	9,574
Oliver Springs WB	Roane	Spg, Anderson Co UD, and Oak Ridge PW	D	V	5,138
Adams-Cedar Hill WS	Robertson	Red River	S	V	4,774
Springfield	Robertson	Red River	S	V	31,022
Oneida W&S	Scott	Huntsville, Well, Baker		V	11,182

		and City Lakes			
Dunlap WS	Sequatchie	Sequatchie River	S	N	5,645
Smith UD	Smith	Caney FK and Baxter WS	D	FN5	6,204
Smith UD #2	Smith	Baxter WS	D	FN5	170
North Stewart UD	Stewart	Wells and Spring	D	N	4,270
Hendersonville UD	Sumner	Old Hickory Lake	N	V	37,786
Portland WS	Sumner	City Lake, Sportsman Lake	D	M	17,944
White House UD	Sumner	Old Hickory Lake	H	V	73,867
Luttrell-Blain-Corryton UD	Union	Spgs, Wells, Pond and Northeast Knox UD	D	M	7,504
McMinnville WS	Warren	Barren Fork River	T	T	14,835
Jonesborough WD	Washington	Nolichucky River	T	T	22,617
Collinwood WD	Wayne	Well	D	V	1,902
Waynesboro WS	Wayne	Green River	D	M	3,549
Bon De Croft UD	White	Billy's Branch	D	V	3,234
Franklin WD	Williamson	Harpeth River and Harpeth Valley UD	S	FN3	51,061
H.B. & T.S. UD	Williamson	Spring Hill and Harpeth Valley UD	L	V	14,977
Mallory Valley UD	Williamson	Franklin WD, Harpeth Valley and Milcrofton	N	N	18,184
Milcrofton UD	Williamson	Harpeth Valley UD	P	M	11,395
Nolensville/College Grove UD	Williamson	Wells, Smyrna WS, Metro WS and Brentwood WS	H	V	12,810
Gladeville UD	Wilson	Wells	N	V	19,899

Problem:
C – Treatment Plant Capacity
D – Declining Source
H – Distribution Hydraulic Capacity
L – Contract Limitation
N – None reported
P – Pump Capacity
S – Source
T – Taste and Odor

Measures Taken:
N – None (No measures have been requested by the water system)
V – Voluntary Conservation (Water system has requested that customers restrict unnecessary use and may request specific uses be deferred during specified timeframes)
M – Mandated Conservation (Specified water uses are banned or restricted and a program of surveillance, warnings, fines and cut-offs is in place to enforce the restrictions)
R – Rationing (Specified water uses are banned or restricted and overall water use is rationed based on a pre-established level of use. Surcharges for use above a ration, fines and cut-offs are in effect.)
T – Additional treatment
* - Required by the DWS to meet psi requirements
FN1 – Duck River Utilities Commission (DRUC) obtains water from Normandy Lake and sells water to Manchester (13,978) Tullahoma (25,595) and Hillsville Utility District (8,348).
FN2 – TN-American was removed from the list because they no longer require measures in the GA portion of their system.
FN3 – Reductions in demand have allowed the system to replace Mandatory Restrictions with Voluntary Conservation.
FN4 – Reportedly no source problem has resulted due to the sink hole. Monitoring the situation.

FN5 – Lake levels due to repairs to Center Hill Lake Dam and lack of rainfall to sustain water supply levels may impact Alexandria WS, DeKalb UD #1-4, Smithville WS, West Overton UD, Algood WS, Bangham UD, Baxter WD, Cookeville WD, Cookeville Boat Dock Road UD, Double Springs UD, Old Gainesboro Road, Smith UD and Smith UD #2.

FN6 – Water systems depending on Duck River include: Bedford County UD, Shelbyville WS, Lewisburg WS, Columbia WS and Spring Hill WD. Duck River flows are being maintained by releases from Normandy Lake. Currently, releases are being made to protect aquatic life and maintain water quality for assimilation of waste discharges. Mandatory restrictions will be triggered when Normandy Reservoir reaches 850 feet MSL. It is presently at 853 feet MSL.

FN7 – Water conservation, utilization of other sources and other measures are being taken to protect aquatic life and/or maintain water quality for assimilation of waste discharges.