CHAPTER 4

4.0 AFFECTED ENVIRONMENT

4.1. Introduction

This chapter describes the natural and socioeconomic resources that could be affected by the alternative strategies and portfolios developed in the integrated resource planning process. These resources are described at a regional scale rather than a site-specific scale.

The primary study area, hereinafter called the TVA region, is the combined TVA power service area and the Tennessee River watershed (Figure 1-1). This area comprises 202 counties and approximately 59 million acres. In addition to the Tennessee River watershed, it covers parts of the Cumberland, Mississippi, Green, and Ohio Rivers where TVA power plants are located. For some resources such as air quality and climate change, the assessment area extends beyond the TVA region. For some socioeconomic resources, the study area consists of the 170 counties where TVA is a major provider of electric power and Muhlenberg County, Kentucky, where the TVA Paradise Fossil Plant is located. The economic model used to compare the effects of the alternative strategies on general economic conditions in the TVA region includes surrounding areas to address some of TVA's major fuel sourcing areas and inter-regional trade patterns

4.2. Climate

The TVA region spans the transition between a humid continental climate to the north and a humid subtropical climate to the south. This provides the region with generally mild temperatures (i.e., a limited number of days with temperature extremes), ample rainfall for agriculture and water resources, vegetation-killing freezes from mid-autumn through early spring, occasional severe thunderstorms, infrequent snow, and infrequent impacts—primarily in the form of heavy rainfall—from tropical storms. The seasonal climate variation induces a dual-peak in annual power demand, one for winter heating and a second for summer cooling. Rainfall does not fall evenly throughout the year, but tends to peak in late winter/early spring and again in mid-summer. Winds over the region are generally strongest during winter and early spring and lightest in late summer and early autumn. Solar radiation (insolation) varies seasonally with the maximum sun elevation above the horizon and longest day length in summer. However, insolation is moderated by frequent periods of cloud cover typical of a humid climate.

The remainder of this section describes the current climate and recent climate trends of the TVA region in more detail. Identifying recent trends in regional climate parameters such as temperature and precipitation is a complex problem because year to year variation may be larger than the multi-decadal change in a climate variable. Climate is frequently described in terms of the climate "normal," the 30-year average for a climate parameter (NCDC 2008). The climate normals described in the following sections are for the 1971-2000 period. Earlier and more recent data are also presented, where available. The primary sources of these data are National Weather Service (NWS) records and records from the rain gauge network maintained by TVA in support of its reservoir operations. NWS records, unless stated otherwise, are for Memphis, Nashville, Chattanooga, Knoxville, and Tri-Cities, Tennessee, and Huntsville, Alabama.

Temperature

1971-2000 Climate Normals - Average monthly temperatures for the TVA region during 1971-2000 ranged from 38.4 ºF in January to 79.1 ºF in July (Table 4-1).

Table 4-1. Monthly, seasonal, and annual temperature averages for six NWS stations in the TVA region for 1971-2000.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ºF	38.4	42.6	50.9	59.2	67.5	75.3	79.1	78.0	71.7	60.3	50.1	41.7
ºC	3.5	5.9	10.5	15.1	19.7	24.1	26.2	25.6	22.1	15.7	10.0	53.9

	Winter	Spring	Summer	Fall	Annual
ºF	40.9	59.2	77.5	60.7	59.6
ºC	5.0	15.1	25.3	16.0	15.3

Recent Trends - There is significant year-to-year variability in temperature. As suggested by the plot in Figure 4-1, annual temperature in the TVA region appears to have increased approximately 1 ºF (0.56ºC) over the 30-year period between 1970 and 2000 (this is equivalent to a change of about 0.19ºC/decade). This increase is most prominent in the winter and summer seasons. Spring and fall experienced little change in temperature. However, the overall annual change in temperature for the longer 1958-2008 period was not statistically significant (runs test (Bendat and Piersol 1986),$r^2 = 0.0994$, $p>0.05$). This implies that average temperature during the 50-year period was within the expected range of variability and the long-term trend could not be distinguished from random variation.

There is an appearance of inconsistency with these observations when different time periods are considered. For example, the number of days during the year with temperatures at or above 90 ºF increased by about 12 days during 1971-2000. However, the number of days experiencing 90+ ºF decreased during both 1958-2004 (by 6 days) and 1979-2004 (by 10 days). For 1958-2009, the number of days essentially remained unchanged.

The US Climate Change Science Program (Lanzante et al. 2006) reports that global surface temperature through 2004 has increased at a rate of about 0.12ºC per decade since 1958, and about 0.16ºC per decade since 1979. Regional differences from the global trends are expected. In the tropics, for example, the observed surface temperature trends have increased about 0.11ºC per decade since 1958 and about 0.13ºC per decade since 1979. These rates represent an acceleration of temperature changes that, during the entire 20th century, were estimated by the Intergovernmental Panel on Climate Change (IPCC) as being in the range of 0.06 to 0.09ºC per decade (Trenberth et al. 2007).

For the southeastern U.S., Trenberth et al. (2007) found that temperature change during the 20th century (through 2005) was slightly negative with a mean cooling rate of about 0.2 to 0.3ºC per decade in the vicinity of the TVA region.

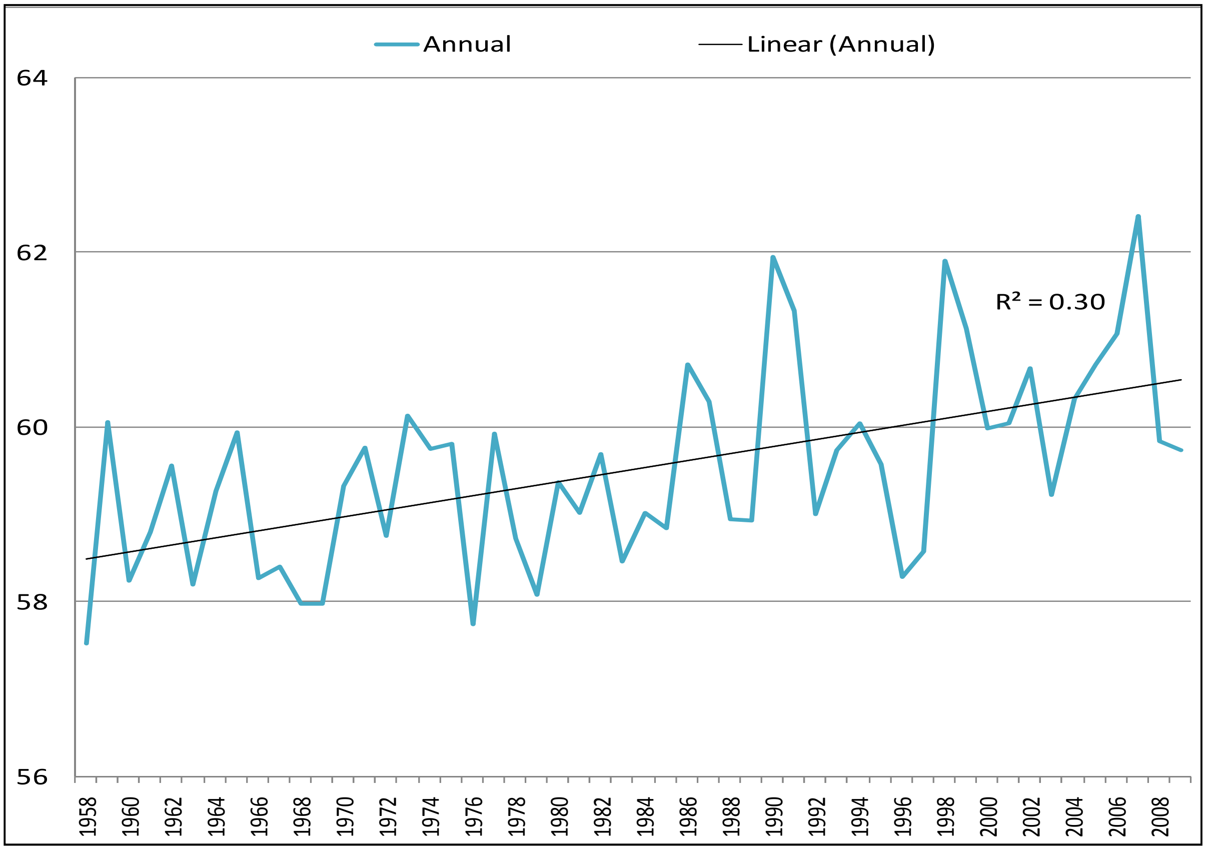


Figure 4-1. 1971-2000 TVA region annual average temperature (°F) based on data from six NWS stations.

Their data indicates a warming rate of 0.3-0.4ºC per decade for 1979-2005 for the TVA region, which is greater than the global average trend. The lack of significant temperature change (i.e., +0.19 ºC/decade) during 1958-2008 for the TVA region is consistent with these published findings.

Precipitation

<u>1971-2000 Climate Normals</u> - The average annual precipitation in the Tennessee River watershed during 1971-2000 was 49.92 inches; monthly averages ranged from 3.04 inches in October to 5.42 inches in March (Table 4-2).

<u>Recent Trends</u> - Although there is significant year-to-year variability, there appears to be a decrease in precipitation during the 30-year period (Figure 4-2). The overall annual change in precipitation over the period of 1958-2008 was not statistically significant (with 95 percent confidence) based on results from a standard statistical test (Bendat and Piersol 1986). This implies that average precipitation during the 50-year period was within the expected range of variability and the long-term change could not be assumed to be anything other than random variation in the data.

Table 4-2. Monthly, season, and annual precipitation averages in the Tennessee River watershed for 1971-2000. Source: TVA rain gage network data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inches	4.87	4.31	5.42	3.97	4.52	3.84	3.97	3.24	3.59	3.04	4.32	4.85
Centimeters	12.4	10.9	13.8	10.1	11.5	9.8	10.1	8.2	9.1	7.7	11.0	12.3

	Winter	Spring	Summer	Fall	Annual
Inches	14.03	13.91	11.04	10.95	49.92
Centimeters	35.6	35.3	28.0	27.8	126.8

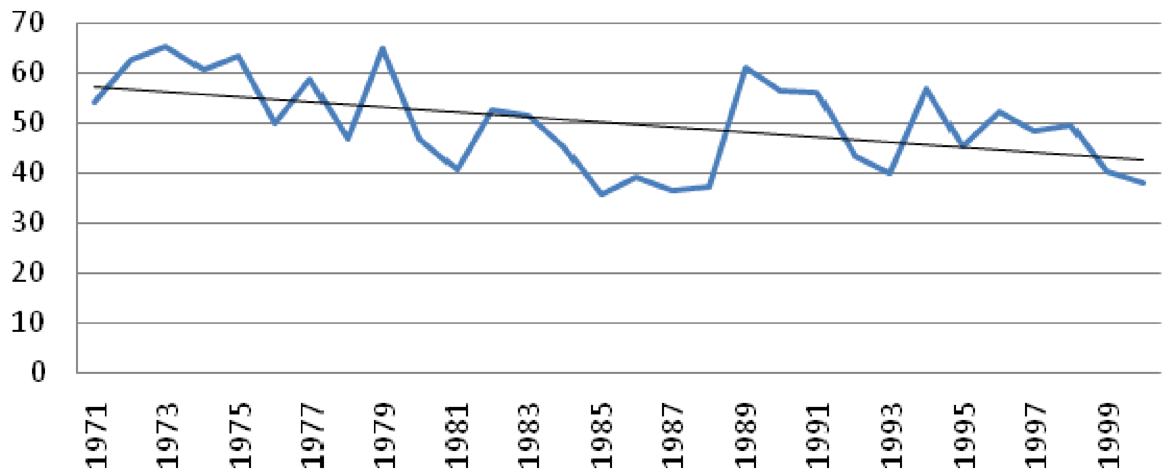


Figure 4-2. Annual average precipitation (inches) for the Tennessee River basin. The straight line represents the mean change in annual precipitation for the period. Source: TVA rain gauge network data.

Note that precipitation information is highly variable and can appear contradictory when different time periods are considered. Data for 1958-2004 indicate that annual precipitation is decreasing while data for 1979-2004 indicate that precipitation is increasing.

Recent changes in precipitation around the world are more variable than changes in temperature. Such behavior is expected as changes in atmospheric circulation (wind patterns) and temperature combine differently in different regions to influence the basic physical processes that control precipitation. The IPCC 2007 climate assessment reported that a few regions in North America, southern South America, Eurasia and Australia experienced precipitation increases during the 1901-2005 period (Trenberth et al. 2007). However, changes since 1979 have been less pronounced except in Australia. Over the southeastern U.S., precipitation since 1901 has shown a small increase of generally <10 percent overall, and since 1979, the changes have been near zero. These results are consistent with a US Global Change Research Program (USGCRP) summary of recent and projected climate change in the Southeast (Karl et al. 2009) which shows small precipitation increases across Tennessee during the 20th century offset by decreases over Alabama, Georgia, and North Carolina. Hoerling et al. (2008:47), in describing the 1951-2006 interval, state that "The spatial variations and seasonal differences in precipitation change are *unlikely* [sic] to be the result of anthropogenic greenhouse forcings alone." On a related issue they further state that (p. 48) "It is *unlikely* [sic] that a systematic change has occurred in either the frequency or area coverage of severe drought over the contiguous United States from the mid-twentieth century to the present." This does not mean that anthropogenic warming of the climate has not exacerbated the effects of drought. To the contrary, Hoerling et al. (2008) concluded that an anthropogenic link to worsening drought effects (through the enhanced drying effects of warming) is likely.

Wind

1971-2000 Climate Normals - Wind speed and direction are important indicators of weather patterns and dispersion of air pollutants. Wind speed is also a factor in determining the potential of an area for wind energy development.

Average surface wind speeds (measured 33 feet (10 m) above the ground) for nine NWS stations in the TVA region for 1973-2000[1] are relatively light with higher speeds in winter and spring and lower speeds in summer and fall (Table 4-3). In general, wind speeds at higher elevations are greater than those shown in the table. Average wind speeds in winter, spring, and fall were slightly less than the 1961-1990 seasonal norms. A similar decrease is also shown in the maximum, minimum, and annual average wind speeds. The months of occurrence for the maximum and minimum wind speed remain unchanged, with highest wind recorded in March and lowest wind in August.

Table 4-3. Monthly, seasonal, and annual wind speed averages for nine sites[2] in the TVA region for 1973-2000.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Miles/Hour	8.3	8.4	8.9	8.4	7.1	6.3	5.8	5.4	5.8	6.2	7.3	7.9
Meters/second	3.7	3.7	3.9	3.7	3.1	2.8	2.6	2.4	2.6	2.8	3.2	3.5

	Winter	Spring	Summer	Fall	Annual
Miles/Hour	8.2	8.1	5.8	6.4	7.1
Meters/Second	3.6	3.6	2.6	2.7	3.2

Surface wind directions in the TVA region for the same period are shown in the wind rose diagram (Figure 4-3). A wind rose is a diagram with spokes representing directions (e.g., N, NNE, NE). The frequency with which the measured wind blows from a given direction is illustrated by the distance between the point where a heavy line crosses a spoke and the center of the diagram. The most frequent wind directions are from the south and north sectors. This occurs at Memphis, Tupelo, Paducah, Nashville, Chattanooga, and Asheville. Prevailing wind directions at Knoxville and Tri-Cities are from northeast and/or southwest sectors, which reflect the down-valley and up-valley flow pattern seen in the area. Wind directions at Huntsville are more variable than at other sites.

[1] Data for 1971 and 1972 are not available from NCDC.
[2] The nine sites are Asheville, NC; Tri-Cities, Knoxville, Chattanooga, Nashville, and Memphis, TN; Huntsville, AL; Tupelo, MS; Paducah, KY.

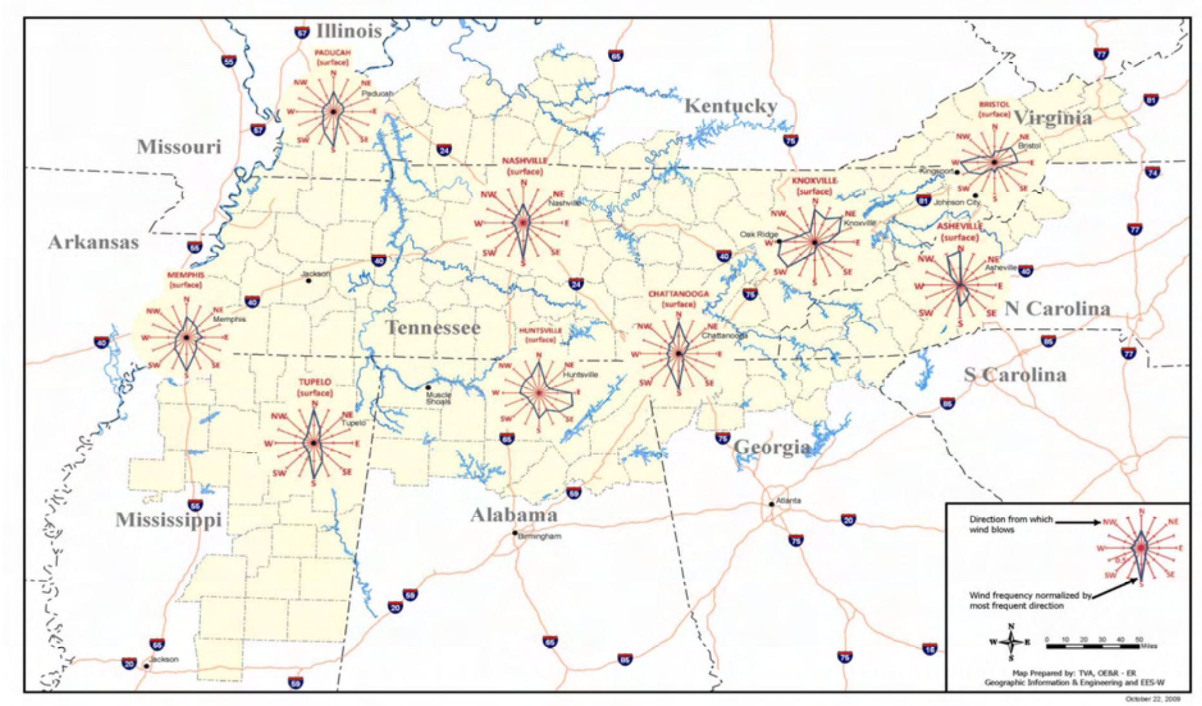


Figure 4-3. Prevailing wind direction for surface winds at nine regional airports, 1973-2000.

Overall, the prevailing wind directions in the TVA region during 1973-2000 are nearly identical to those during 1961-1990.

Recent Trends - Trends in wind direction and speed are important because of their potential to affect air quality and wind power generation. Recent trends in wind speed and direction over land have not been examined in recent climate reports (e.g., Trenberth et al. 2007, Karl et al. 2009)). Pryor et al. (2009), however, recently analyzed surface wind speed trends over the continental U.S. for the periods 1973-2000 and 1973-2005. They found that the median and 90th percentile[3] wind speeds significantly decreased at over 75 percent of the sample sites and increased at about 5 percent of the sample sites. Sites in the TVA region had either small decreases or no change in both the median and 90th percentile wind speeds. The decrease in wind speed is most prevalent at eastern U.S. sites and shows no seasonality (i.e., variation across seasons).
Data from the nine sites used to describe the wind speed normals were analyzed to quantify trends in wind speed in the TVA region (Figure 4-4). Wind speeds decreased from 1973 to 1978, slightly increased from 1979 to 1988, and decreased after 1989. The overall trend has been a significant decrease ($p < 0.05$). This trend in the TVA region is consistent with the trend identified for the continental U.S. by Pryor et al. (2009).

[3] 90th percentile is the point below which 90 percent of all observations fall. It excludes the highest 10 percent of observations.

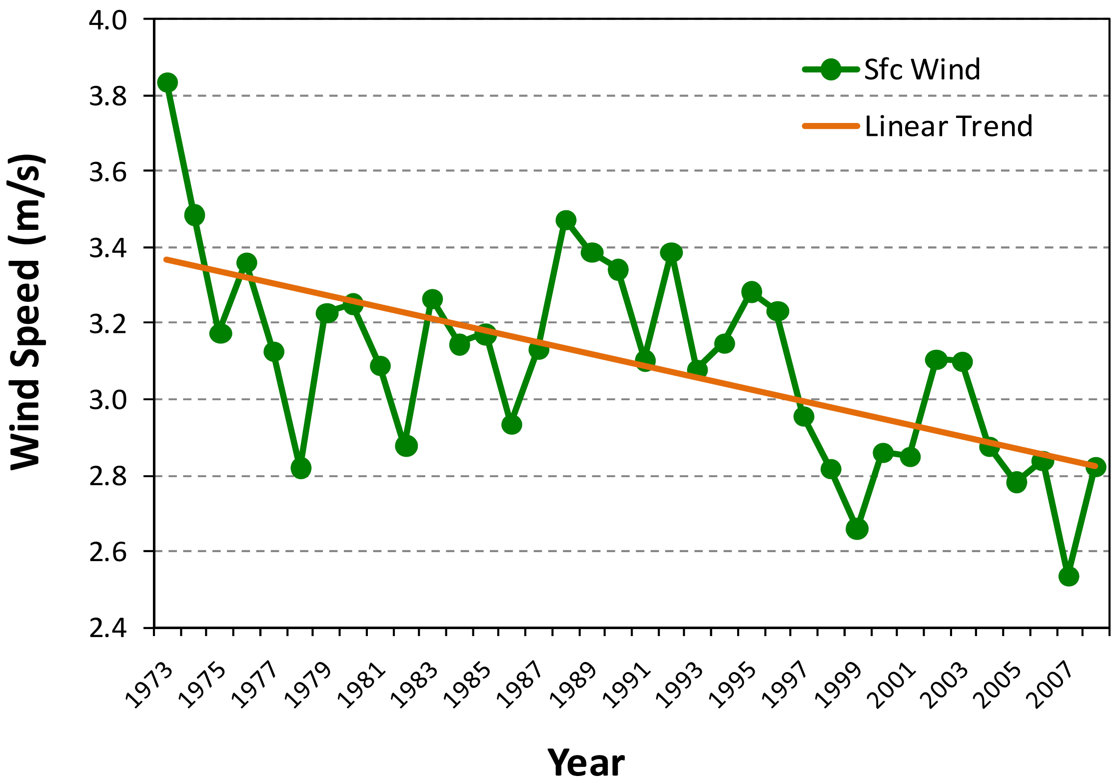


Figure 4-4. Annual median wind surface wind speeds for the TVA region, 1973-2008.

Solar Radiation

1971-2000 Climate Normals - Solar radiation (insolation) received at the earth's surface is a function of two factors, cloud cover and atmospheric particles (aerosols). Clouds generally decrease insolation by scattering and reflecting incoming solar radiation back into space. Aerosols scatter and absorb solar radiation. Absorbed radiation tends to be re-radiated by aerosols in longer wavelengths with some of the energy reaching the earth surface, some warming the atmosphere, and some going back into space.

Solar radiation is measured at few NWS weather stations and most of the data in the National Solar Radiation Database produced by the National Renewable Energy Laboratory is based on modeling rather than original measurements. Cloud cover, however, is measured at all NWS weather stations and ranges from zero (totally clear sky) to 100 percent (completely covered by clouds). Table 4-4 shows mean cloud cover for nine sites in the TVA region during 1973-2000. TVA has monitored solar radiation at Sequoyah Nuclear Plant (SQN) and Browns Ferry Nuclear Plant (BFN) since the 1970s. Figure 4-5 shows these monitoring results as well as cloud cover measurements at the Chattanooga airport (about 15 miles from SQN) and at the Huntsville airport (about 21 miles from BFN).

Cloud cover at the Chattanooga airport was negatively correlated (correlation coefficient of -0.35) with solar radiation at SQN and cloud cover at Huntsville airport was negatively correlated (correlation coefficient of -0.38) with solar radiation at BFN.

Table 4-4. Monthly, seasonal, and annual cloud cover averages for nine sites[4] in the TVA region for 1973-2000.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Percent (%)	66	64	63	57	59	56	53	51	53	49	59	63

	Winter	Spring	Summer	Fall	Annual
Percent (%)	65	60	53	53	58

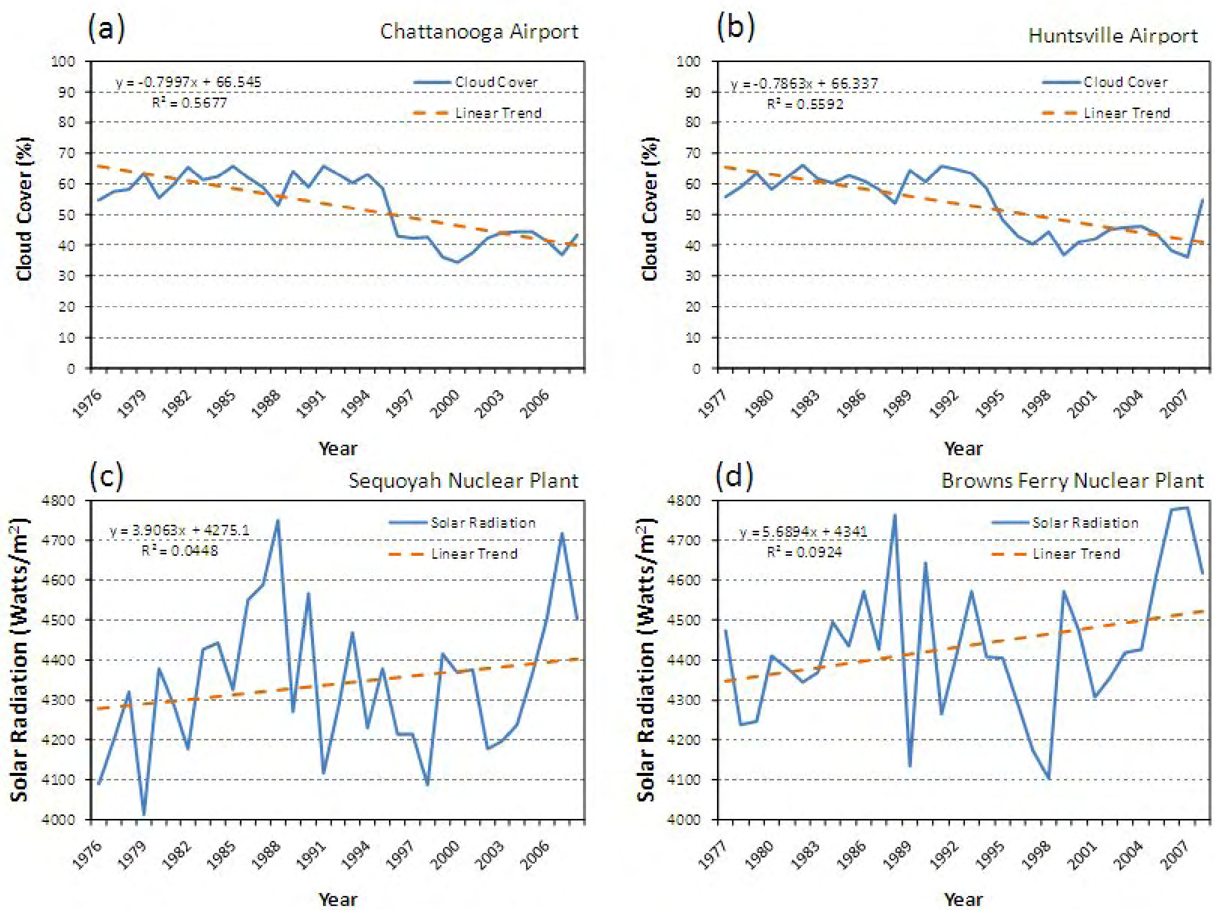


Figure 4-5. Observed annual observations and fitted trend lines for (a) cloud cover at the Chattanooga airport, (b) cloud cover at the Huntsville airport, (c) solar radiation at Sequoyah Nuclear Plant, and (d) solar radiation at the Browns Ferry Nuclear Plant for 1976/1977-2008.

[4] The nine sites are Asheville, NC; Tri-Cities, Knoxville, Chattanooga, Nashville, and Memphis, TN; Huntsville, AL; Tupelo, MS; Paducah, KY.

Recent Trends - Liepert and Tegen (2002) analyzed insolation data collected since the 1960s at 21 sites across the U.S. They focused on measurements during clear sky conditions so they could identify trends associated with aerosol scattering. They found that insolation decreased from the 1960s to the 1980s by a daily average of 7 watts/m^2 at eastern U.S. sites (including Nashville), resulting in a long-term decrease in average daily insolation of 3 percent. Although atmospheric aerosols increased during this period, Liepert and Tegen were unsuccessful in identifying the cause of the change in insolation.

The decreasing trends in cloud cover at both Chattanooga and Huntsville are significantly different ($p \leq 0.05$) from random variability. However, no trend is detected in solar radiation at SQN and BFN at the same level of significance. Due to this weak relationship between measured solar radiation and cloud cover, cloud cover is, at best, a weak proxy for solar radiation at specific sites in the TVA region.

Stanhill and Cohen (2005) examined sunshine duration (a proxy for insolation) at 106 U.S. stations with data records of at least 70 years during the period of 1891-1987. A small majority of sites in several regions, including the Southeast, had decreases in sunshine duration (with an implied decrease in insolation) since 1950. However, across all U.S. sites Stanhill and Cohen found no evidence suggesting a significant decreasing trend in insolation over the period 1891-1987.

The IPCC 2007 climate report cites three other studies that concluded finding significant increases in cloud cover, based on surface cloud observations, over the U.S. in the latter half of the 20th century (Trenberth et al. 2007). One of these, based on independent human observations at military stations, suggests an increasing trend (~1.4 percent of sky per decade) in total cloud cover. A complicating factor in identifying cloud cover trends is the change in observation methods from reliance on human observers for most of the 20th century to automated instrumentation with a concomitant increase in data uncertainty. This is the reason that human-derived military observations may carry more weight. Trenberth et al. (2007) found a lack of consensus in cloud cover changes based on satellite observations. The data are equally equivocal for surface-based solar radiation trends.

Figure 4-6 shows trends in cloud cover in the TVA region since 1973, as measured at nine sites. Between 1973 and 2008, cloud cover shows a significant ($p<0.05$) decreasing trend (Figure 4-6a). This trend, however, should be interpreted with caution. Prior to 1995, cloud cover at NWS stations was estimated by human observers, and from 1973 through 1995 there was no significant trend ($p>0.05$) in cloud cover (Figure 4-6b).

Since 1995 cloud cover has been measured with automated equipment and, because this equipment only detects clouds up to 12,000 feet above the surface, automated measurements since 1995 are noticeably lower than earlier human observations. Although the cloud cover in the TVA region appears to show a downward trend after 1995 (Figure 4-6c), this trend is not significant ($p>0.05$).

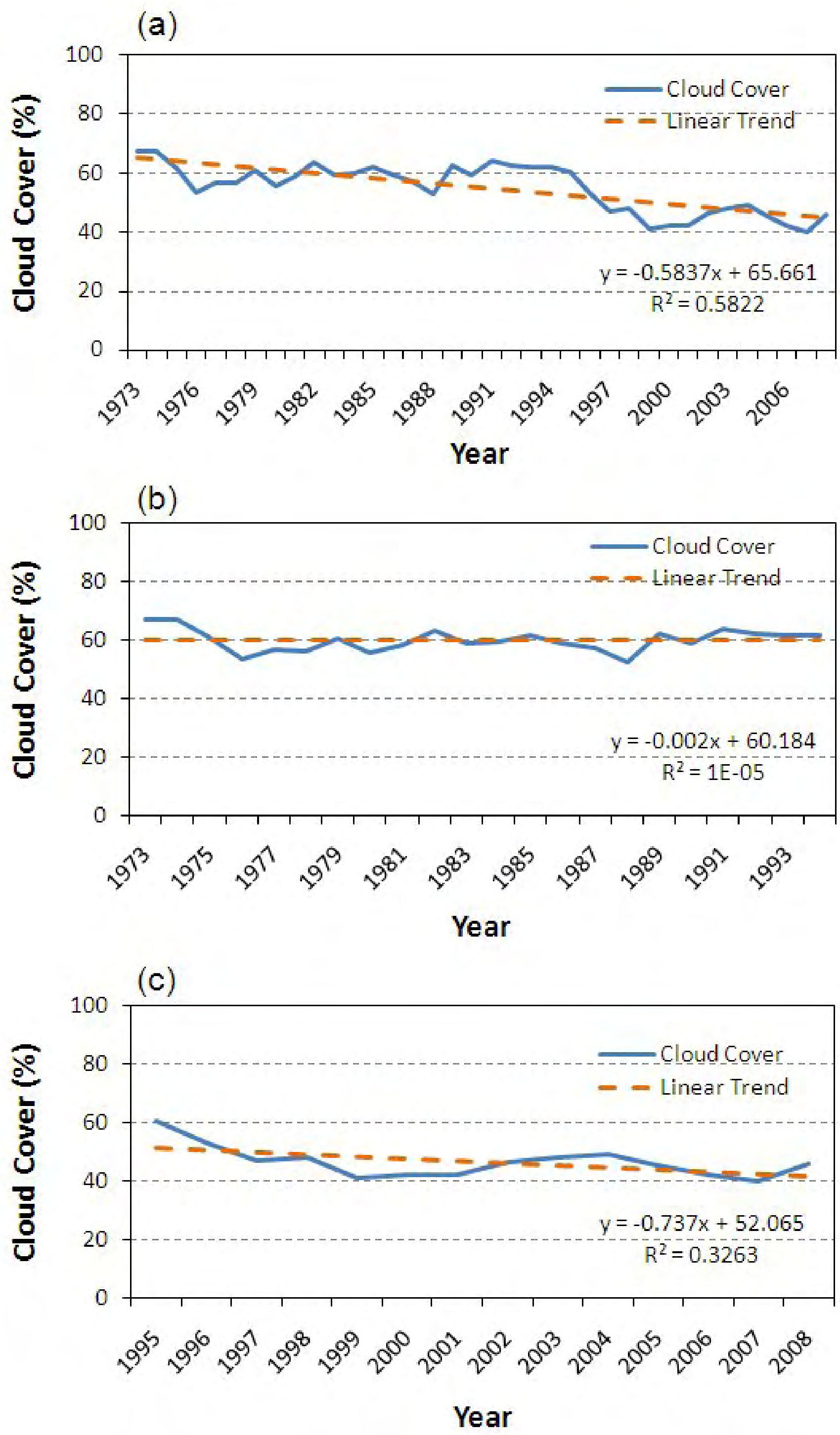


Figure 4-6. Trends in cloud cover at nine sites[5] in the TVA region for (a) 1973-2008, (b) 1973-1995, and (c) 1995-2008.

[5] The nine sites are Asheville, NC; Tri-Cities, Knoxville, Chattanooga, Nashville, and Memphis, TN; Huntsville, AL; Tupelo, MS; Paducah, KY.

Greenhouse Gas Emissions
Energy from the sun that reaches the earth is absorbed by oceans and land masses. Some of this energy is radiated back into the atmosphere in the form of infrared radiation (heat). A portion of infrared energy is absorbed and re-radiated back to the earth by water vapor, greenhouse gases (GHGs), and other substances. Greenhouse gas is a term used to describe natural and man-made heat-trapping gases that absorb heat radiated from the earth's surface (Thomas et al. 2009). As concentrations of GHGs increase, there are direct and indirect effects on the earth's energy balance. The direct effect is often referred to as a radiative forcing, a change in the difference between incoming and outgoing radiation energy (USCCSP 2007); an increase in incoming energy relative to outgoing energy tends to warm the system.

Water vapor is the most abundant GHG and comprises 90+ percent of the total amount of GHGs. The six most commonly discussed man-made GHGs which have recently been determined by EPA to endanger public health and welfare (EPA 2009a) are listed along with their global warming potentials (GWPs) in Table 4-5. GWP is a measure of the potential for a given amount of a greenhouse gas to contribute to global warming; it varies with the amount of infrared radiation absorbed, the wavelength of absorption, and the atmospheric lifetime of the gas (Forster et al. 2007). GWP is typically expressed in relation to CO_2, which has a GWP of 1, and for a 100-year period. A standard measure of GHGs is units of CO_2 equivalents, where the amounts of GHGs other than CO_2 are translated into equivalent amounts of CO_2 based on their GWPs (Forster et al. 2007). CO_2 equivalents are frequently abbreviated as CO_2-eq.

Table 4-5. The major man-made greenhouse gases and their global warming potentials. Source: Forster et al. (2007).

Gas	Global warming potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Hydroflourocarbons (HFCs)	140 - 11,700
Perfluorocarbons (PFCs)	6,500 - 9,200
Sulfur hexaflouride (SF_6)	23,900

The most abundant man-made GHG is CO_2; its major U.S. emission sources include combustion of fossil fuels, non-combustion uses of fossil fuels in producing chemical feedstocks, solvents, lubricants, waxes, asphalt and other materials, iron and steel production, cement production, and natural gas systems. The major U.S. emission sources of CH_4 are ruminant animals (cows and sheep), landfills, natural gas systems, and coal mining. HFCs, PFCs,and SF_6 are all industrial chemicals with no natural sources and emitted by various industrial activities (USCCSP 2007).

The major GHGs directly emitted by electric utility operations are CO_2, from burning fossil fuels and other substances containing carbon compounds, and SF_6, a flourine compound used in electrical transmission and distribution equipment. Electric utilities are also a major source of indirect emissions of methane from coal mining and natural gas extraction and transportation.

In addition to the six GHGs described above, several other naturally occurring substances whose levels have also been enhanced by human activities cause radiative forcing. These substances remain in the atmosphere for days to months, and thus, are not well mixed in the atmosphere. Their effects have both regional patterns and global consequences. These substances include water vapor, radiation-absorbing aerosols such as black carbon and other particulate matter; sulfur dioxide, the main precursor of the reflecting aerosols; and other gases such as volatile organic compounds, nitrogen dioxide, other oxides of nitrogen, and carbon monoxide (USCCSP 2007). Some of these compounds are considered criteria air pollutants and described in more detail below in Section 4.3.

Global concentrations of man-made GHGs have increased since the pre-industrial era (~1750). Increases in individual GHGs through 2008 include: CO_2 - from 278 ppmv (parts per million by volume) to 385 ppmv, a 38 percent increase; CH_4 - from 700 ppbv (parts per billion by volume) to 1745 ppbv, a 150 percent increase; and N_2O - 270 ppbv to 314 ppbv, a 16 percent increase (Thomas et al. 2009).

In 2008, global CO_2 emissions were estimated to be 30,493 million metric tons (MMT) (USEIA 2009). This is approximately 41 percent higher than 1990 levels. In 2008, CO_2 emissions for the United States were 5,833 MMT or 19.1 percent of the estimated global CO_2 emissions (Table 4-6). U.S. sources of CO_2 emissions include: industrial, commercial, and residential energy-use; transportation, and a small percentage from direct industrial emissions such as cement production, waste combustion, and natural gas flaring (USEIA 2009). In comparison, CO_2 emissions from the seven TVA region states and direct emissions from TVA power generation comprised 15.9 and 1.6 percent of U.S. CO_2 emissions (Table 4-6).

Table 4-6. 2008 global, United States, and TVA region CO_2 emissions. Source: USEIA (2009, 2010).

Area / Source	Amount (million metric tons)	Percent of Global CO_2 Emissions	Percent of U.S. CO_2 Emissions
Global	30,493	--	--
United States	5,833	19.1	--
TVA region states	928	3.0	15.8
TVA power generation	99	0.3	1.7

In 2009, direct CO_2 emissions from the generation of power marketed by TVA (from both TVA-owned facilities and facilities owned by others) totaled approximately 66.2 MMT. This is a decrease of about a third from the average of about 100 MMT/year for the previous five years, due in part to reduced demand for power in 2009 (Figure 4-7). The CO_2 emissions totals do not include the relatively small amount of CO_2 emissions from auxiliary equipment, vehicles, and infrastructure such as cooling and heating buildings. They also do not include indirect emissions from the fuel cycle (e.g., extraction, transportation, processing, spent fuel/waste management) and associated activities. TVA's emissions from power generation have increased approximately 35 percent since 1982. TVA's CO_2 emission rate (expressed in terms of tons/gigawatt-hours (GWh, 1 GWh = one million KWh) of generation) of 652 tons/GWh in 2004 was somewhat above the median but below the average of the emission rates for 28 major electrical utilities in the central and eastern United States. TVA's 2009 CO2 emission rate was approximately 485 tons/GWh.

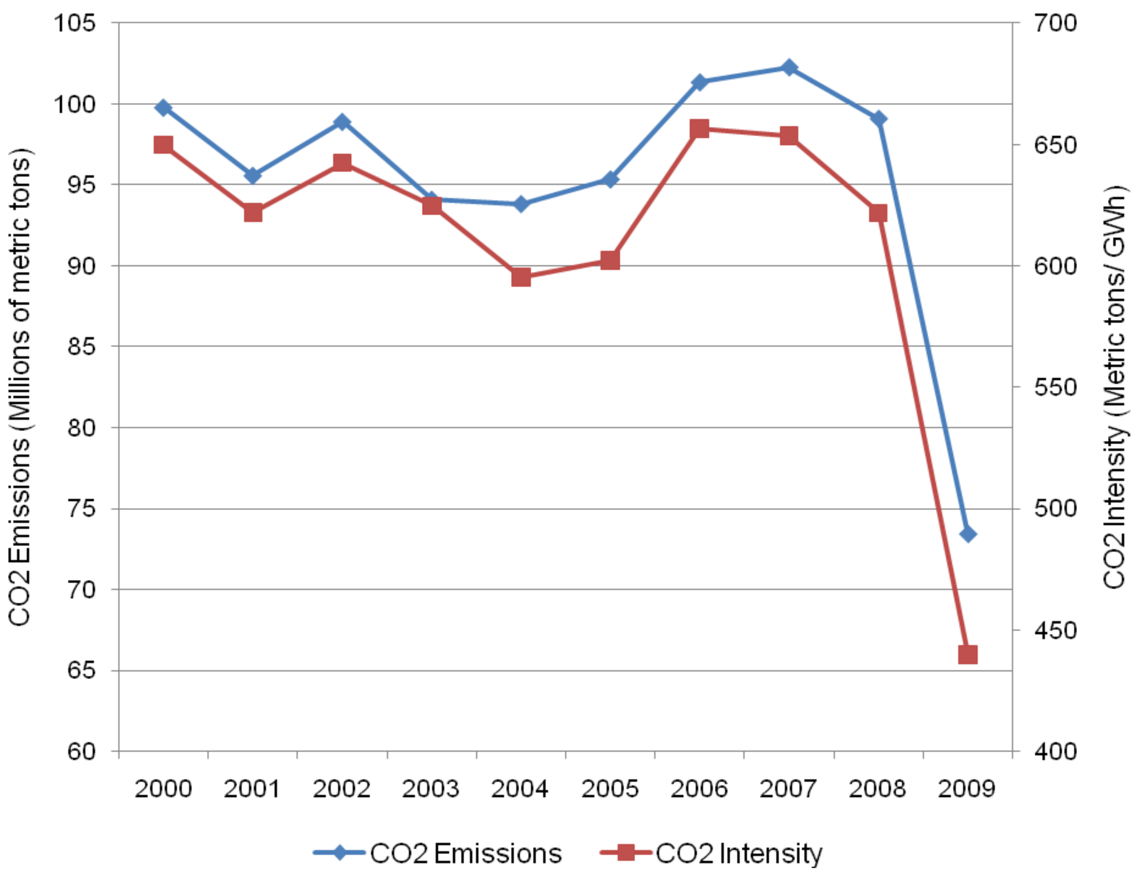


Figure 4-7. CO_2 emissions from TVA power plants and other plants with long-term TVA power purchase agreements, 2000 - 2009.

About 77 percent of SF_6 emissions are from electrical applications, and most of the remainder is from magnesium smelting and semiconductors. SF_6 is used for high voltage electrical insulation, current interruption, and arc quenching in the transmission and distribution of electricity because of its inertness and insulating properties (EPA 2008a). It is considered a long-lived GHG because it can remain in the earth's atmosphere up to 3,200 years, compared to CO_2 which has a radiative effect of about 100 years (USCCSP 2007). While global SF_6 concentrations are a small fraction of CO_2 emissions, they are 23,900 times more efficient in trapping heat and radiation (EPA 2008a). U.S. emissions of SF_6 have decreased by half since 1990 (USEIA 2000).

4.3. Air Quality

Air quality is a vital resource that impacts us in many ways. Poor air quality can affect our health, ecosystem health, forest and crop productivity, economic development, as well as our enjoyment of scenic views. This section summarizes current conditions and trends over the past 30 years for key air quality issues, including criteria pollutants, hazardous air pollutants, mercury, acid deposition, and visibility impairment. Air quality within the TVA region has steadily improved over the last 30 years.

Criteria Air Pollutants

EPA has established National Ambient Air Quality Standards (NAAQS) for six "criteria" air pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide (Table 4-7). There are two different standards for particulate matter, one for particles less than 10 microns in size (PM_{10}) and one for particles less than 2.5 microns in size ($PM_{2.5}$). Primary standards protect public health, while secondary standards protect public welfare, (e.g., visibility, crops, forests, soils and materials). Ambient air monitors measure concentrations of these pollutants to determine attainment with these standards. Areas where these measurements exceed the standards are designated as non-attainment areas. Non-attainment areas for fine particulate matter ($PM_{2.5}$) are shown in (Figure 4-8).

Table 4-7. National Ambient Air Quality Standards.

	Primary Standards		Secondary Standards	
Pollutant	Level	Averaging Time	Level	Averaging Time
Carbon Monoxide	9 ppm	8-hour	None	
	35 ppm	1-hour		
Lead	0.15 µg/m^3	Rolling 3-month average	Same as Primary	
	0.15 µg/m^3	Quarterly average	Same as Primary	
Nitrogen Dioxide	0.053 ppm	Annual (arithmetic mean)	Same as Primary	
	0.100 ppm	1-hour	None	
Particulate Matter (PM_{10})	150 µg/m^3	24-hour	Same as Primary	
Particulate Matter ($PM_{2.5}$)	35 µg/m^3	Annual (arithmetic mean)	Same as Primary	
Ozone	0.075 ppm (2008 std.)	8-hour (4th highest)	Same as Primary	
	0.08 ppm (1997 std.)	8-hour (4th highest)	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (arithmetic mean	0.5 ppm (1300 µg/m$^{3)}$	3-hour
	0.14 ppm	24-hour	None	
	0.075 ppm	1-hour	None	

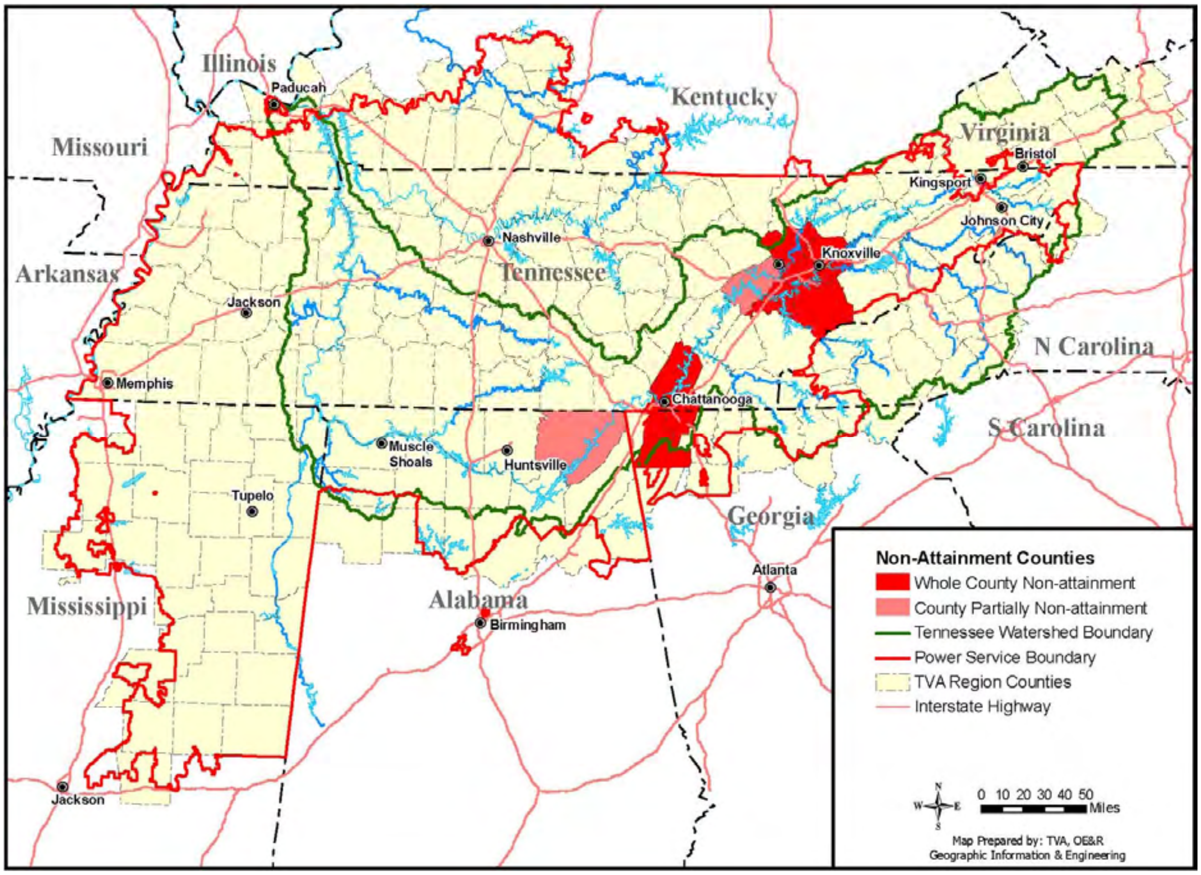


Figure 4-8. Non-attainment areas for fine particles ($PM_{2.5}$).

There are currently no non-attainment areas for carbon monoxide, nitrogen dioxide, sulfur dioxide and PM_{10} in the TVA region. However, EPA recently adopted more stringent standards for lead, nitrogen dioxide and sulfur dioxide, and one area in the region was recently designated non-attainment for lead. Additional non-attainment areas have not yet been designated for the other new standards. All or parts of seven counties in the vicinity of Knoxville have been designated non-attainment for the 1997 ozone standard. Recent monitoring data shows these counties in compliance with the ozone standard, although as of late February 2011, EPA had not finalized the redesignation of the areas attainment status . In 2008, EPA revised the ozone standard to 0.075 ppm, but this standard is under review and a more stringent ozone standard is expected to be announced very soon. Once this new standard is implemented, numerous counties in the TVA region are expected to be designated non-attainment areas for ozone.

Sulfur Dioxide

Sulfur dioxide (SO_2) is a colorless gas with a sharp odor that can cause respiratory problems at high concentrations. SO_2 also combines with other elements to form sulfate, a secondary pollutant that contributes to acid deposition, regional haze, and fine particle concentrations.

Most SO_2 is produced from the burning of fossil fuels (coal and oil), as well as petroleum refining, cement manufacturing and metals processing. In addition, geothermic activity, such as volcanoes and hot springs, can be a significant natural source of SO_2 emissions.

TVA currently emits 59 percent of the human-produced SO_2 emissions in the Tennessee Valley (Figure 4-9). While this is still a large amount of emissions, it has been substantially reduced over the past 30 years. TVA's SO_2 emissions have decreased by 85 percent since 1974 (Figure 4-10). Currently about half of TVA's coal-fired capacity is equipped with flue gas desulfurization systems ("scrubbers") to control SO_2 emissions; this percentage will likely increase in the future. The coal units without scrubbers burn low-sulfur coal.

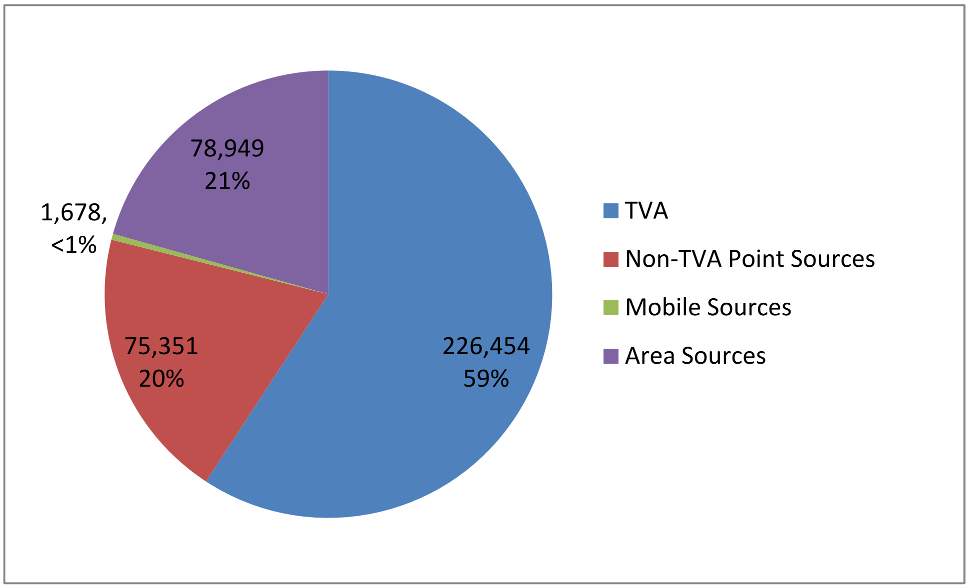


Figure 4-9. Sulfur dioxide (SO_2) emissions in the TVA region in tons and percent by source. Source: VISTAS (2009).

There are three air quality standards for SO_2: an annual standard, a daily standard and a new one-hour standard. Annual and 24-hour concentrations of SO_2 in the TVA region have been reduced by 63 percent since 1979 (Figure 4-11). Regional average concentrations are well below the annual and daily NAAQS. In 2008, annual SO_2 concentrations were 12 percent of the NAAQS and 24-hour concentrations were 18 percent of the NAAQS and there were no exceedances of the annual or daily SO_2 NAAQS in the TVA region. On June 2, 2010, EPA finalized a new one-hour SO_2 NAAQS. Non-attainment areas for this new standard have not yet been designated and some areas in the TVA region are expected to exceed this standard. Further air quality improvements are anticipated as legislative and regulatory changes will likely require additional emissions reductions.

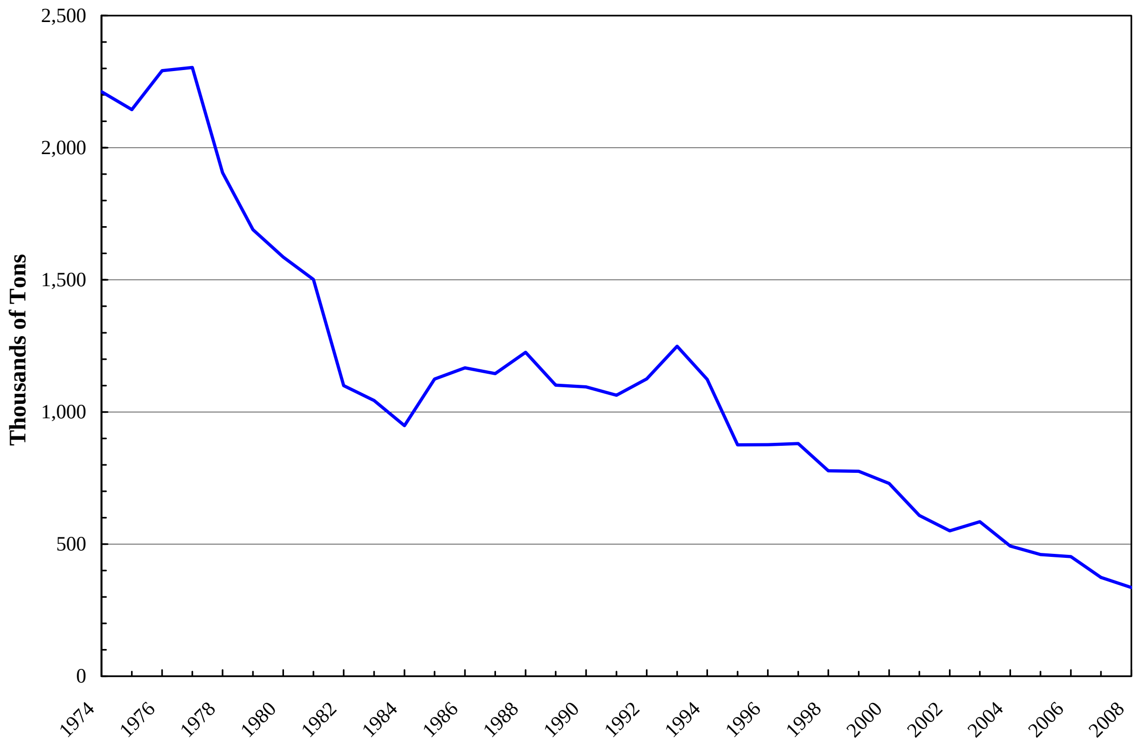


Figure 4-10. TVA sulfur dioxide (SO_2) emissions, 1974 - 2008. Source: TVA data.

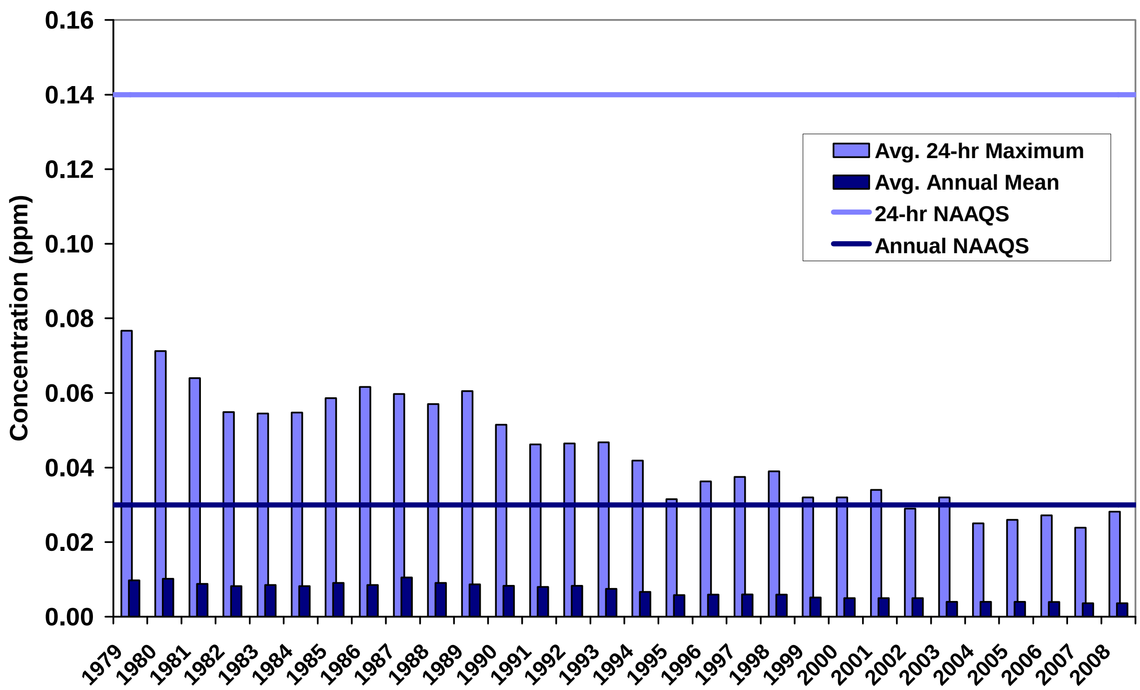


Figure 4-11. Regional average annual sulfur dioxide (SO_2) concentrations, 1979-2008. Source: EPA AQS Database.

Nitrogen Oxides

Nitrogen oxides (NOx) is a generic term for a group of highly reactive gases that contain varying amounts of nitrogen and oxygen. Nitrogen dioxide (NO_2) is one member of this group of gases. NOx emissions contribute to a variety of environmental impacts, including ground-level ozone, fine particulate matter, regional haze, acid deposition, and nitrogen saturation. Natural sources of NOx include lightning, forest fires and microbial activity; major sources of human-produced NOx emissions include motor vehicles, electric utilities, industrial boilers, nitrogen fertilizers and agricultural burning. Within the TVA region, most of the human-produced NOx emissions come from mobile sources (43 percent) and area sources (33 percent) which include off-road vehicles, agricultural activities and forest fires (Figure 4-12). Between 1993 and 2008 (Figure 4-13), TVA reduced its NOx emissions by 68 percent (and by more than 80 percent during the summer ozone season) and currently emits 11 percent of the anthropogenic NOx emissions in the TVA region. These emissions reductions have been the result of an aggressive emissions control program consisting of the installation of selective catalytic reduction (SCR) systems on 21 coal units, representing 60 percent of TVA's coal-fired capacity. The remaining coal units are equipped with selective non-catalytic reduction (SNCR) systems or utilize low NOx burners. In the fall of 2008, TVA changed the operation of SCRs and SNCRs from a seasonal to a year-round basis. This change will further reduce annual NOx emissions and will result in lower ambient NO_2 concentrations, ground-level ozone, fine particulate matter, regional haze, and acid deposition.

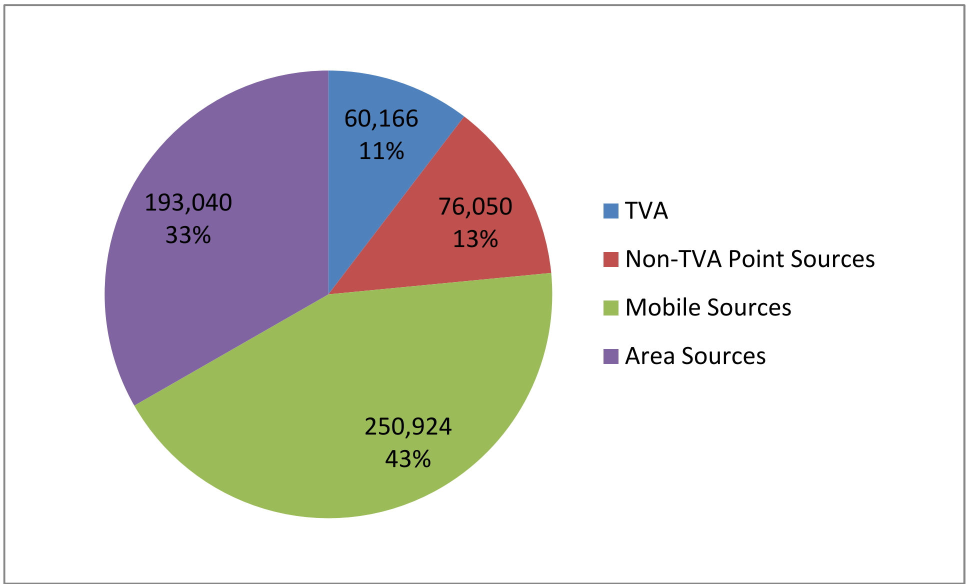


Figure 4-12. Nitrogen oxides (NOx) emissions in the TVA region in tons and percent by source. Source: VISTAS (2009).

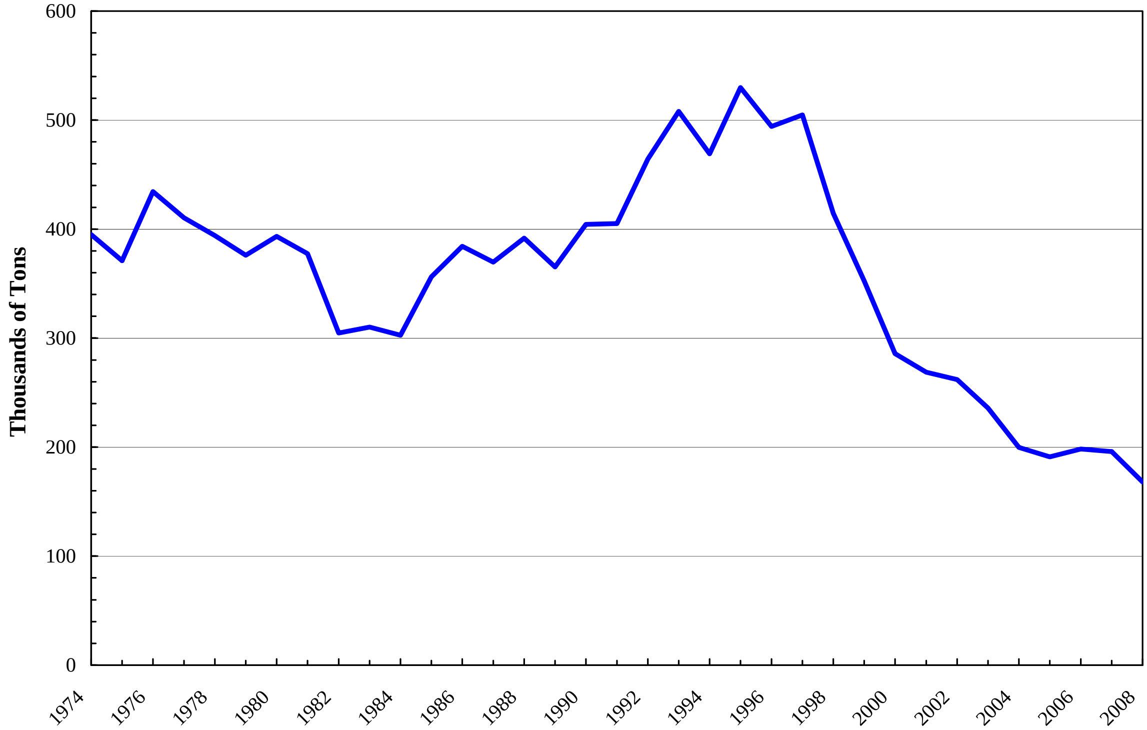


Figure 4-13. Trends in TVA nitrogen oxides (NOx) emissions, 1974 – 2008. Source: TVA data.

Regional NO_2 concentrations declined by 41 percent between 1979 and 2008 and by 54 percent since the peak concentration in 1988 (Figure 4-14). Average regional concentrations are well below the NO_2 annual NAAQS standard; the 2008 average concentration was 17 percent of the NAAQS. EPA has set a new one-hour NO_2 standard that became effective in January 2010. Non-attainment areas for this new standard have not yet been designated and some areas in the TVA region may exceed this standard.

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are compounds that have a high vapor pressure (i.e., readily evaporates at ambient temperatures) and low solubility in water. The most common sources of man-made VOCs are petrochemical storage and transport, chemical processing, motor vehicles, paints and solvents. Natural sources of volatile organic compounds include vegetation, biological decay, and forest fires. In many areas of the Southeast, natural sources contribute up to 90 percent of total volatile organic compounds. TVA VOC emissions are less than 1 percent of the regional total (Figure 4-15). While VOCs are not a criteria pollutant, they are important because they are a precursor to ground-level ozone.

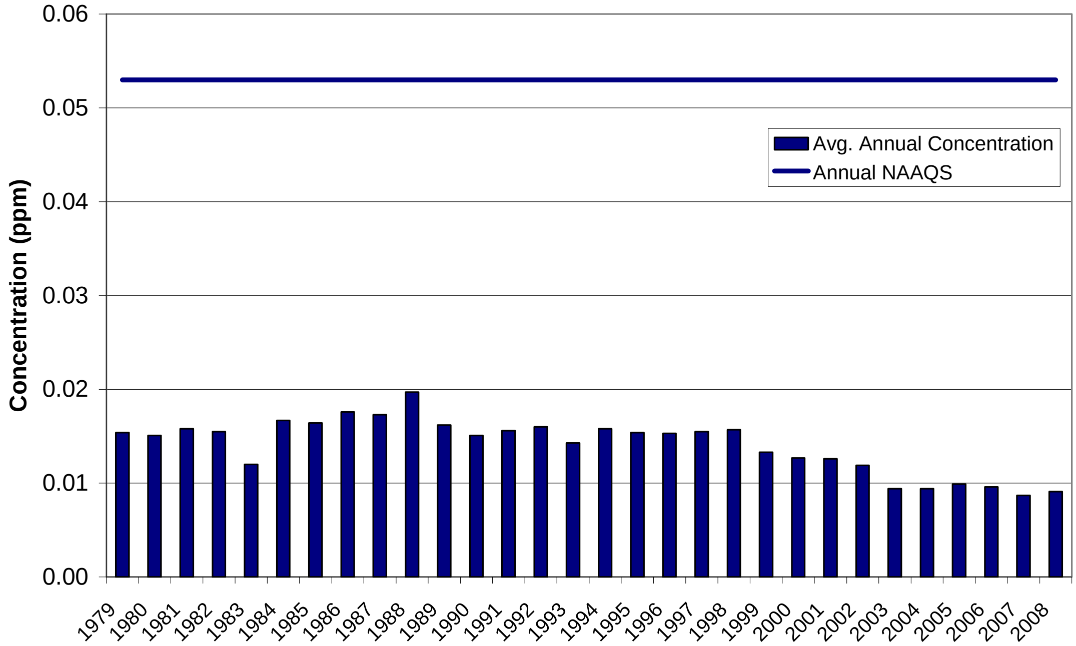


Figure 4-14. Regional average annual nitrogen dioxide (NO_2) concentrations, 1979-2008. Source: EPA AQS Database.

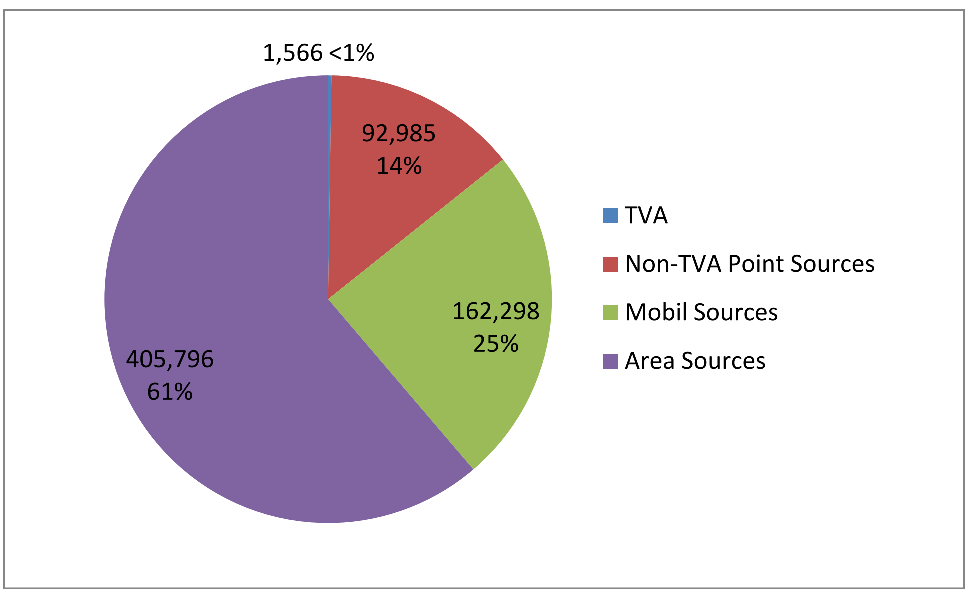


Figure 4-15. Volatile organic compounds emissions in the TVA region in tons and percent by source. Source: VISTAS (2009).

Ozone

Ozone is a gas that occurs both in the stratosphere (10 to 30 miles above the earth's surface) and at ground level where it is the main ingredient of smog. While stratospheric ozone is beneficial due to its role in absorbing ultraviolet radiation, ground-level ozone is an air pollutant that can damage lung tissue and harms vegetation. Ozone is a secondary pollutant which is not directly emitted by any source; it is formed by a chemical reaction between NOx and VOCs in the presence of sunlight. Because ozone formation is dependent on sunlight, ozone concentrations are highest during the summer and greater in areas with hot summers, such as the southeastern U.S.

On October 12, 2010, EPA published a final rule determining that that the former Knoxville non-attainment area had sufficient data to show compliance with the 1997 ozone standard, although as of late February 2011, EPA had not finalized the redesignation of the areas attainment status. In 2008 EPA lowered the ozone standard to 0.075 ppm, but it has not yet been implemented and EPA is currently reconsidering this standard. EPA is expected to promulgate a revised ozone standard between 0.060 and 0.070 ppm in the immediate future. Once the new ozone standard is implemented, many areas in the TVA region are expected to be designated as non-attainment areas for ozone.

Ozone concentrations are strongly impacted by meteorological conditions with higher ozone concentrations during hot, stagnant years and lower concentrations in wet, milder years. This causes a great deal of variability in ozone trends; despite this variability, average ozone concentrations have decreased about 11 percent over the past 30 years (Figure 4-16). However, additional reductions will be necessary in many areas to attain a NAAQS set below 0.075 ppm.

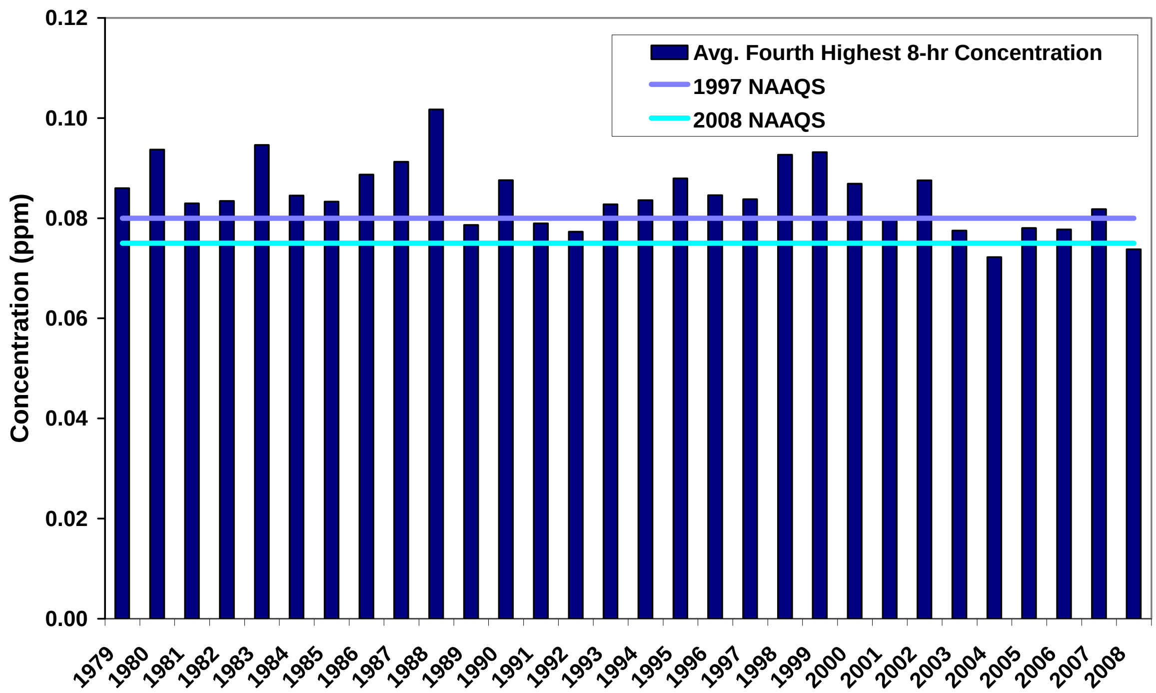


Figure 4-16. Regional average annual ozone concentrations, 1979 – 2008. Source: EPA AQS Database.

Particulate Matter

Particulate matter consists of small solid “dust” particles or liquid droplets–some just large enough to be seen with the naked eye, while others are too small to be seen without the aid of a microscope. The composition and shape of these particles varies greatly, as do their many sources. Particles emitted directly from a pollution source are called primary particles, whereas those formed after emission – by the chemical and physical conversion of gaseous pollutants – are called secondary particles. Generally speaking, primary particles tend to be larger, heavier and are deposited close to their source, while smaller, lighter, secondary particles may remain in the air for several days and can be transported long distances. Primary particle emissions are generally considered a local air quality issue, while secondary particles are a regional concern.

Fine particles have more adverse health impacts, since large particles are filtered by the nose and throat, but fine particles can be drawn deeper into the lungs (EPA 2009b). Exposure to high levels of fine particles can impact the respiratory and cardiovascular systems, particularly in elderly people and those with respiratory or cardiovascular disease. In addition to potential health effects, fine particles also contribute to acid deposition, visibility impairment, and hazardous air pollutants.

Particulate matter has many natural and human-made sources. Natural sources include wind-blown dust, forest fires, volcanoes, and ocean spray. Man-made sources include motor vehicles, fossil-fuel combustion, industrial processes, mining, agricultural activities, waste incineration, and construction. Area (non-point) sources, such as mining, agricultural and construction activities, contribute 55 percent of the primary fine particle ($PM_{2.5}$) emissions in the TVA region and non-TVA point sources, such as factories, waste incinerators, and power plants operated by other utilities, contribute 29 percent (Figure 4-17). TVA contributes 12 percent of the primary fine particles in the region, although TVA's SO_2 and NOx emissions also contribute to the formation of secondary particles.

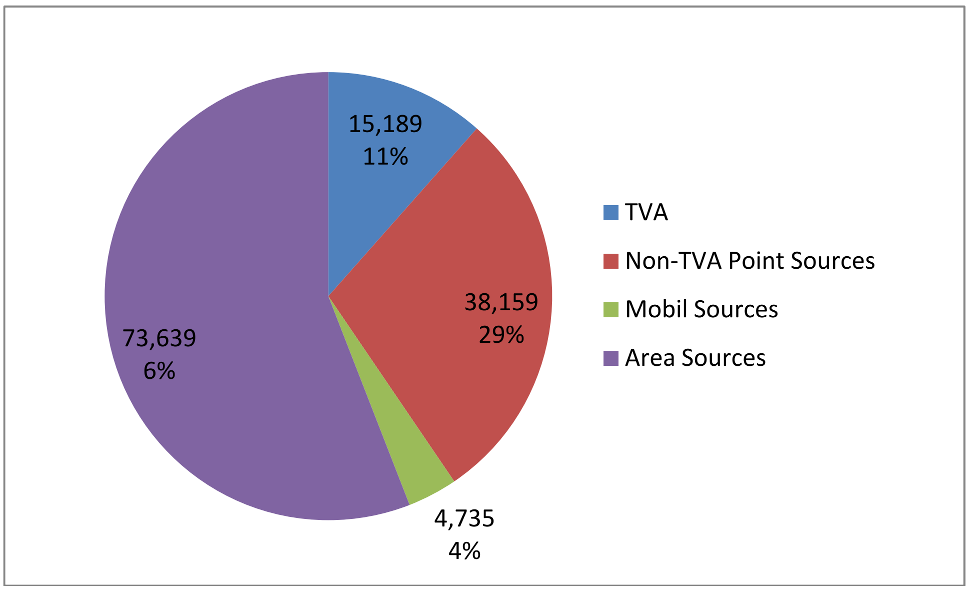
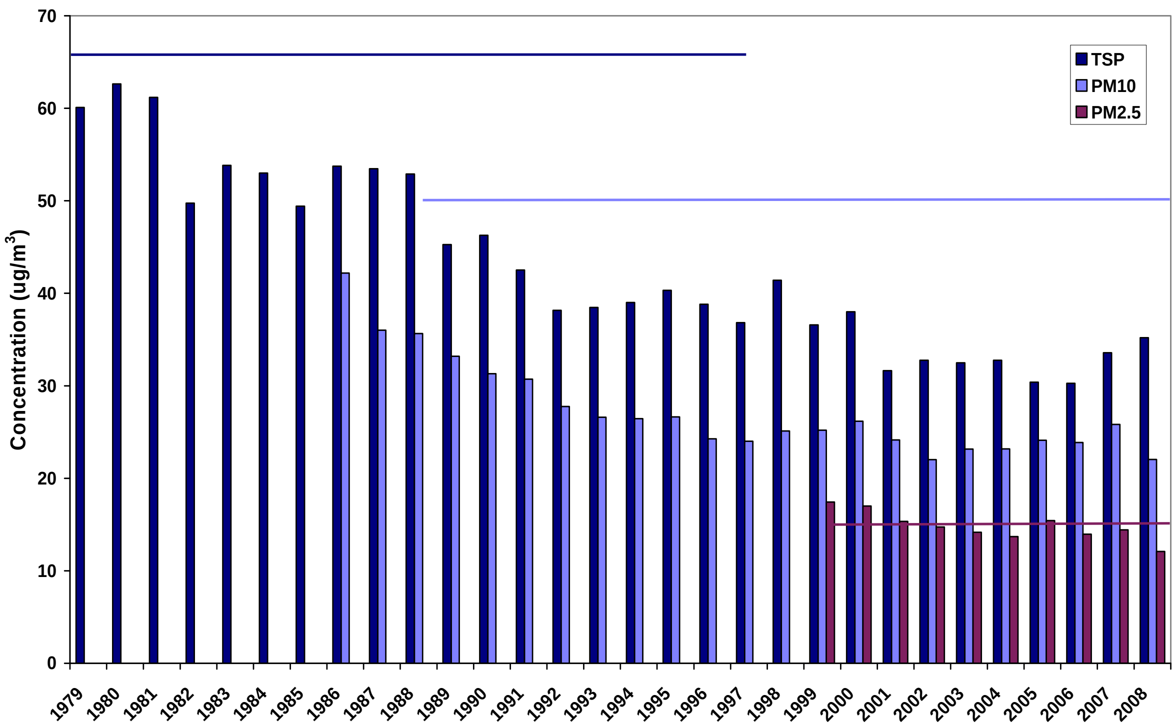


Figure 4-17. Fine particle ($PM_{2.5}$) primary emissions in the TVA region in tons and percent by source. Source: VISTAS (2009).

Particulate matter is regulated by size classes: total suspended particulates (TSP), particulate matter less than 10 micrometers in diameter (PM_{10}), and particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$). These regulations have evolved over the past 40 years to become more stringent and to place more importance on fine particles. The first NAAQS for particulate matter established in 1971 was based on total suspended particulates (TSP). In 1987 the PM_{10} NAAQS was added; in 1997 the $PM_{2.5}$, NAAQS was added and the TSP NAAQS was dropped.

Particulate levels have steadily decreased over the past 30 years. Annual average TSP concentrations decreased by more than 44 percent between 1979 and 2007 and annual average PM_{10} levels decreased by 48 percent between 1986 and 2008 (Figure 4-18).



TSP=Total suspended particles
PM_{10}=Particulates less than 10 micrometers in size
$PM_{2.5}$=Particulates less than 2.5 micrometers in size

Figure 4-18. Regional average annual particle concentrations, 1979 – 2008. Source: EPA AQS Database.

In the past decade, as the monitoring network for $PM_{2.5}$ has greatly expanded, the number of TSP and PM_{10} monitors has declined and these monitors are now primarily located near large industrial sources and are less representative of regional air quality than they once were. This accounts for the fact that TSP and PM_{10} concentrations appear not to have declined, but in some cases, have increased slightly in the past several years. Recently, the focus of regional particulate monitoring has shifted to fine particles ($PM_{2.5}$). There are two NAAQS for $PM_{2.5}$: an annual standard and a 24-hr standard. From 1999 to 2008, annual average fine particle concentrations decreased 31 percent and 24-hr average concentrations decreased 33 percent (Figure 4-19). Particulate levels are strongly influenced by weather patterns, so there is considerable fluctuation from year to year, but the trend of declining particulate levels is still apparent.

All or parts of several counties in the vicinity of Chattanooga and Knoxville are designated as non-attainment for $PM_{2.5}$ (Figure 4-8).

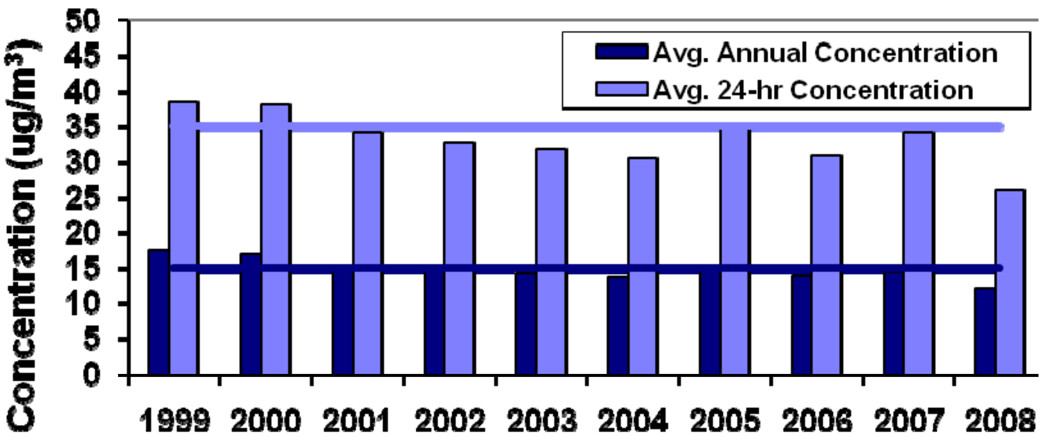


Figure 4-19. Regional average annual fine particle ($PM_{2.5}$) concentrations, 1999 – 2008. Source: EPA AQS Database.

Carbon Monoxide

Carbon monoxide (CO) is a colorless and odorless gas formed when carbon in fuel is not burned completely. At high concentrations, CO can aggravate heart disease and even cause death. Major CO sources include motor vehicles, off-road sources (i.e., construction equipment, airplanes and trains), metals processing and chemical manufacturing. The primary natural source of CO is wildfires. Electric utilities are not a major source of CO emissions and account for 1 percent of the total CO emissions in the United States.

There are two CO air quality standards: one-hour and eight-hour. From 1979 to 2008, regional average one-hour concentrations decreased by 69 percent, and eight-hour concentrations decreased by 73 percent (Figure 4-20). Regional average concentrations are well below both standards and there are no CO non-attainment areas in the TVA region, though a monitoring station in Birmingham, Alabama exceeded the level of the 8-hour standard in 2006.

Lead

Lead is a naturally occurring metal and exposure to lead can adversely affect the nervous system, kidneys and the cardiovascular system. There has been particular concern over neurological effects on children from exposure to lead-based paint in older homes. For many years, lead was added to gasoline to increase engine performance and the primary source of human-made lead emissions was motor vehicles.

Lead in gasoline was phased out during the 1980s and early 1990s, and currently, the largest sources of lead emissions are metals processors, battery manufacturers and waste incinerators. Coal contains small amounts of lead, and TVA emits about 5,000 pounds of lead per year, which is about 2 percent of lead emissions in the southeastern U.S.

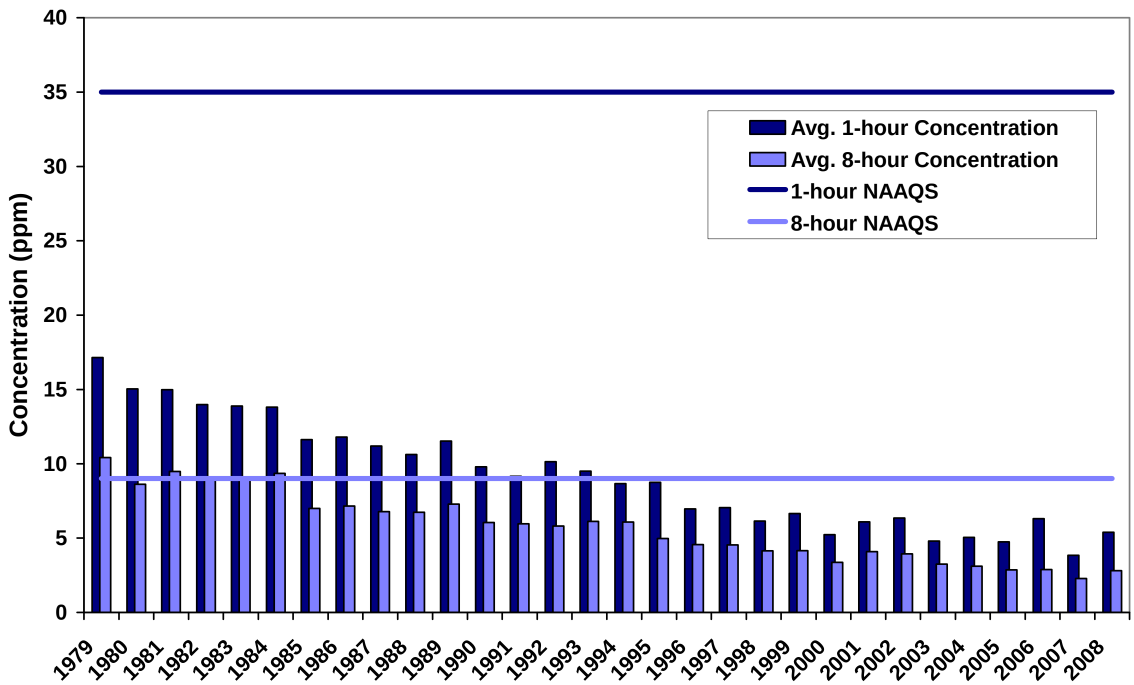


Figure 4-20. Regional average annual carbon monoxide concentrations, 1979 – 2008. Source: EPA AQS Database.

Regional lead concentrations increased through the early 1990s, primarily due to increases in the number of motor vehicles and miles driven. Following the phase-out of leaded gasoline, concentrations decreased 64 percent from the peak in 1993 to 2008 (Figure 4-21).

There are currently two non-attainment areas for lead in the vicinity of the TVA region. One, designated under an early lead standard, is associated with a lead smelting operation in Herculaneum, Missouri. Part of Sullivan County, Tennessee was designated non-attainment in November, 2010 under the more stringent lead standard based on the 3-month rolling average lead concentration established in October 2008. An EPA analysis indicated that nationwide, approximately 40 percent of the counties with a lead monitor are likely to exceed the new lead NAAQS (EPA 2008c). There are very few lead monitors currently operating in the U.S. and the new NAAQS will require additional monitors in the vicinity of large lead sources and large urban areas. Therefore, additional non-attainment areas will likely be designated after data are available from the expanded monitoring network.

Hazardous Air Pollutants (HAPs)

Hazardous air pollutants (HAPs) are toxic air pollutants, which are known or suspected to cause cancer or other serious health effects or adverse environmental effects. The Clean Air Act regulates 187 pollutants as HAPs. Most HAPs are emitted by human-activity, including motor vehicles, factories, refineries, and power plants.

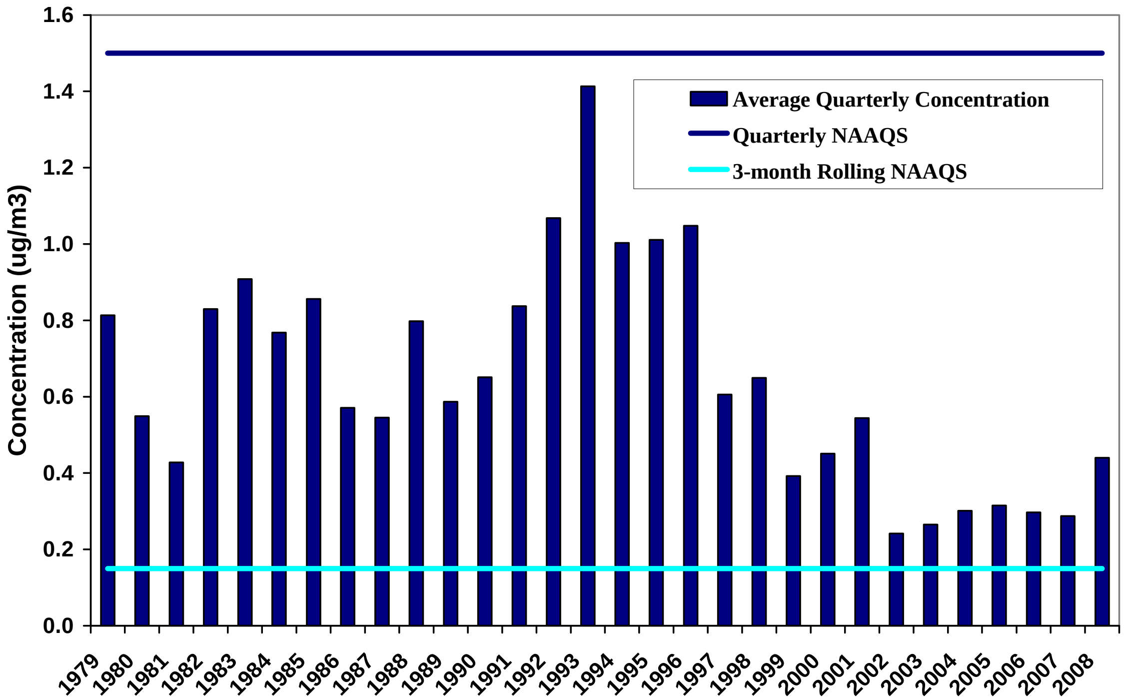


Figure 4-21. Regional average annual lead concentrations, 1979 – 2008. Source EPA AQS Database.

There are also indoor sources of HAPs which include building materials and cleaning solvents. Some HAPs are emitted by natural sources, such as volcanic eruptions and forest fires. Exposure to HAPs can result from breathing air toxics, drinking water in which HAPs have deposited, or eating food that has been exposed to HAPs deposition on soil or water. Exposure to high levels of HAPs can cause various harmful health effects including cancer, chronic and acute health effects. The level of exposure which may result in adverse health impacts varies for each pollutant.

EPA established the Toxic Release Inventory (TRI) under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded it under the Pollution Prevention Act of 1990. TRI is a database containing information on toxic chemical releases and waste management activities for nearly 650 chemicals. TRI air emissions decreased 20 percent from 2001 to 2007, when they accounted for 32 percent of all TRI emissions (EPA 2009c). In 2008, TVA emitted just over 28 million pounds of TRI pollutants to the air (Figure 4-22). Acid gases (sulfuric acid, hydrochloric acid and hydrofluoric acid) accounted for 99 percent of these emissions. The remaining one percent was made up of heavy metals, such as arsenic, barium, chromium, copper, lead, manganese, mercury, nickel, vanadium and zinc, as well as very small amounts of organic compounds, such as benzoperylene, dioxin, naphthalene and polycyclic aromatic hydrocarbons. TVA reduced its TRI air emissions by 46 percent from 1999 to 2008 (Figure 4-22).

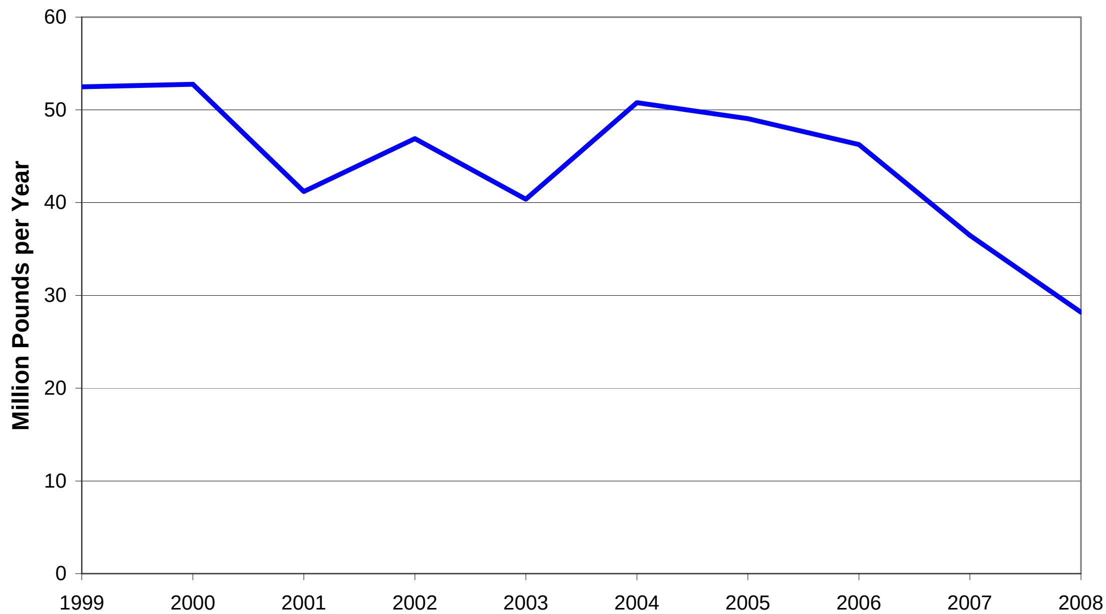


Figure 4-22. TVA Toxic Release Inventory (TRI) air emissions, 1999 – 2008. Source: TVA Form R Submittal to EPA TRI Database.

Mercury

Mercury is a naturally occurring element found in many rocks and minerals, including coal; when coal is burned, naturally occurring inorganic mercury is released into the air. Mercury emissions in the air can travel very long distances before being deposited in lakes, streams, and oceans. Once deposited, micro-organisms convert inorganic mercury to organic mercury, primarily methyl-mercury, which is a more toxic form of mercury. As fish consume these micro-organisms, they also consume increasing amounts of methyl-mercury, which is then cycled through the food chain. Large fish, birds, and mammals, including humans, can accumulate significant amounts of methyl-mercury in their bodies if they eat fish often (especially large ocean species, such as shark and swordfish). At high levels, methyl-mercury can cause neurological effects and harm the heart, lungs, liver, kidneys, and stomach. Risks to young children and developing fetuses are particularly of concern and EPA and the Food and Drug Administration have issued a joint advisory recommending that people limit their consumption of certain fish and shellfish (EPA 2004). Advisories on fish consumption due to mercury have been issued for some TVA region rivers and reservoirs (see Section 4-6).

Mercury is transported globally and about 8 percent of global mercury emissions are emitted from North America (UNEP Chemicals Branch 2008). Mercury is emitted by coal-fired power plants, municipal and medical waste incinerators, chlorine manufacturers, and mining of metals. Natural sources of atmospheric mercury include volcanoes, as well as evaporation from naturally enriched soils and water bodies. Re-emissions of previously deposited mercury can also be a significant source. TVA's mercury emissions decreased by 32 percent from nearly 4,400 pounds in 2000 to just under 3,000 pounds in 2008 (Figure 4-23).

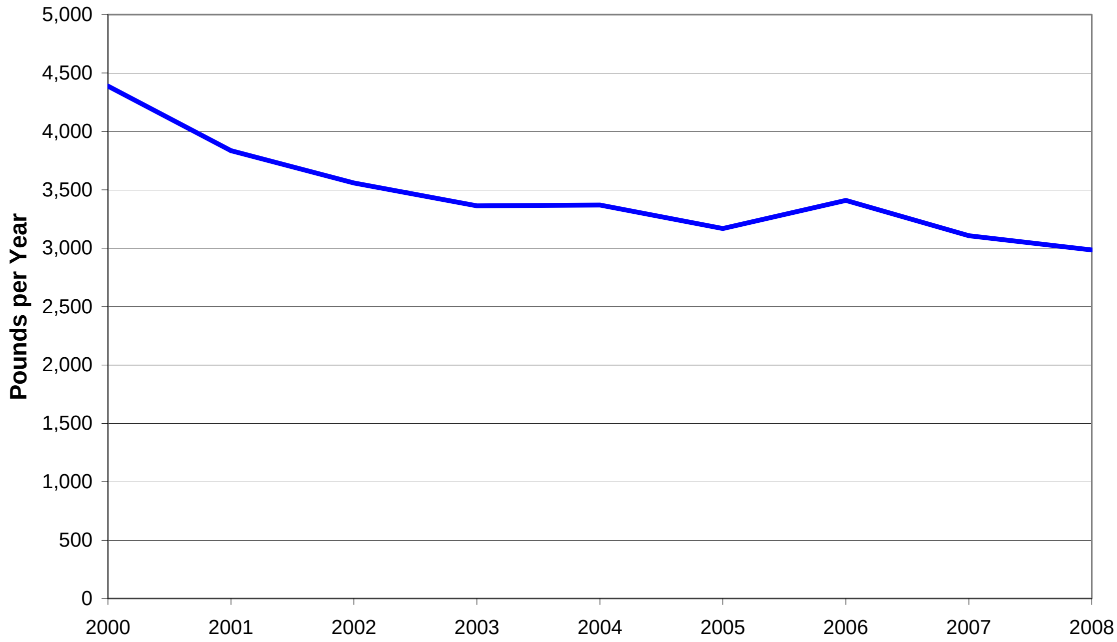


Figure 4-23. TVA mercury air emissions, 2000 – 2008. Source: TVA Form R Submittal to EPA TRI Database.

Deposition occurs in two forms: wet (dissolved in rain, snow or fog) and dry (solid and gaseous particles deposited on surfaces during periods without precipitation). Wet mercury deposition is measured at Mercury Deposition Network monitors operated by National Atmospheric Deposition Program. Dry deposition is not directly measured. The highest wet deposition of mercury in the U.S. occurs in south-central and southeastern states (Figure 4-24). Mercury deposition in the TVA region ranges from 8 to 12 micrograms per square meter, which is in the middle range for eastern North America.

The Mercury Deposition Network has operated monitors since 2001. The monitoring results for sites in the vicinity of the TVA region do not show a clear trend (Figure 4-25) and there is a large amount of variation due to the influence of seasonal variation and meteorological conditions on mercury deposition.

Acid Deposition

Acid deposition, also called acid rain, is primarily caused by SO_2 and NOx emissions which are transformed into sulfate (SO_4) and nitrate (NO_3) aerosols. Acid deposition causes acidification of lakes and streams in sensitive ecosystems which can have an adverse impact on aquatic life. Acid deposition can also reduce agricultural and forest productivity. Some ecosystems, such as high elevation spruce-fir forests in the southern Appalachians, are quite sensitive to acidification, while other ecosystems have more buffering capacity and are less sensitive to the effects of acid deposition. The acidity of precipitation (rain, snow, or fog) is typically expressed on a logarithm scale called pH which ranges from 0 to 14 with 7 being neutral. pH values less than 7 are considered acidic and values greater than 7 are considered basic or alkaline. It is thought that the average pH of pre-industrial rainfall in the eastern United States was approximately 5.0 (Charlson and Rodhe 1982).

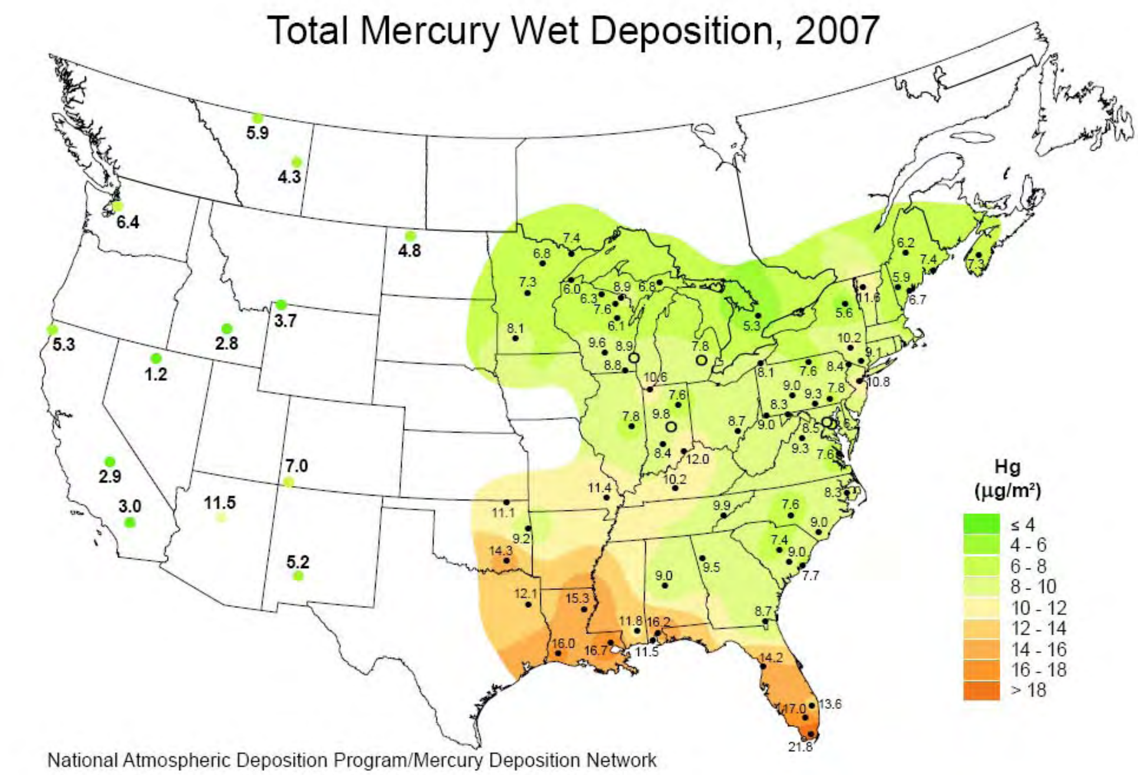


Figure 4-24. Total mercury wet deposition, 2007. Source: National Atmospheric Deposition Program / Mercury Deposition Network.

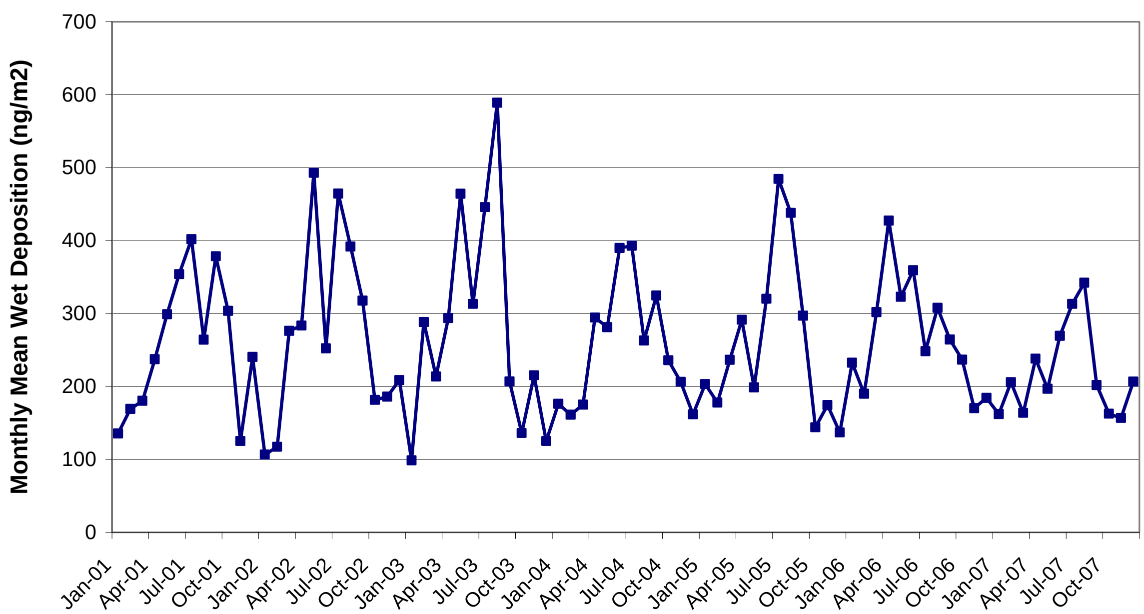


Figure 4-25. Average mercury wet deposition in the TVA region, 2001 – 2007. Source: National Atmospheric Deposition Program / Mercury Deposition Network.

A historic average pH of 5.0 is considerably lower than the pH of rainfall in the TVA region in recent years (Figure 4-26). Because pH is a logarithm, it must be converted to the hydrogen ion concentration in order to calculate percent changes. Across the region, there has been a 42 percent improvement in hydrogen ion concentration from 1979 to 2008 and a 55 percent improvement since 1985.

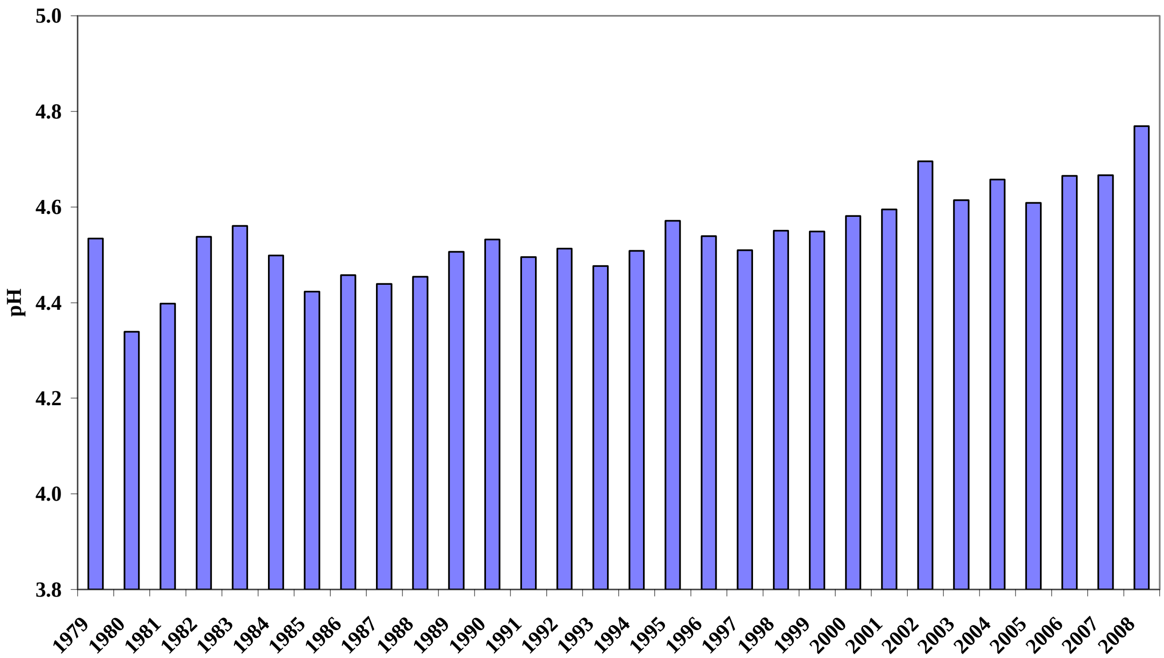
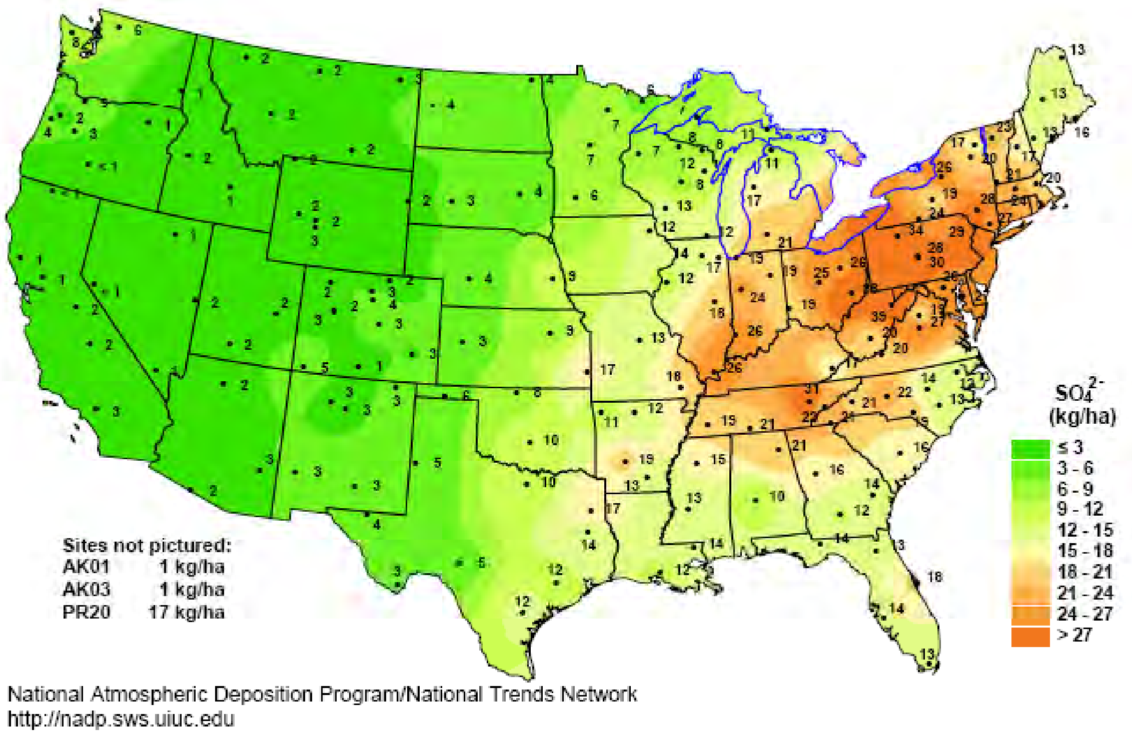


Figure 4-26. Acid deposition trends in the TVA region, 1979 – 2008. Source: National Atmospheric Deposition Program.

As previously shown in Figures 4-9, 4-10, 4-12 and 4-13, TVA currently emits 59 percent of the SO_2 emissions and 10 percent of the NOx emissions in the region and has reduced its SO_2 emissions by 85 percent since 1974 and reduced its NOx emissions by 68 percent since 1995.

The 1990 Clean Air Act Amendments established the Acid Rain Program to reduce SO_2 and NOx emissions and the resulting acid deposition. Since this program was implemented in 1995, reductions in SO_2 and NOx emissions have contributed to significant reductions in acid deposition, concentrations of $PM_{2.5}$ and ground-level ozone, and regional haze. Figure 4-27 illustrates the decrease in sulfate deposition between 1994, prior to the implementation of the Acid Rain Program, and 2007. These figures show a reduction in both the magnitude of sulfate deposition and the size of the impacted area.



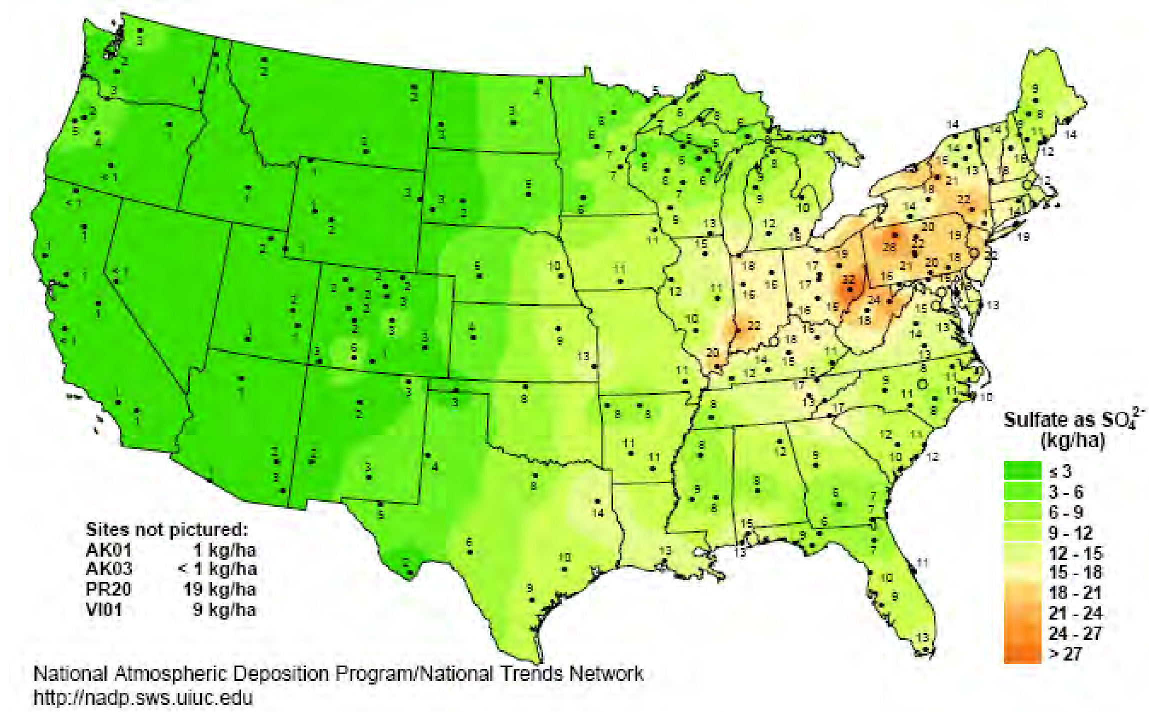


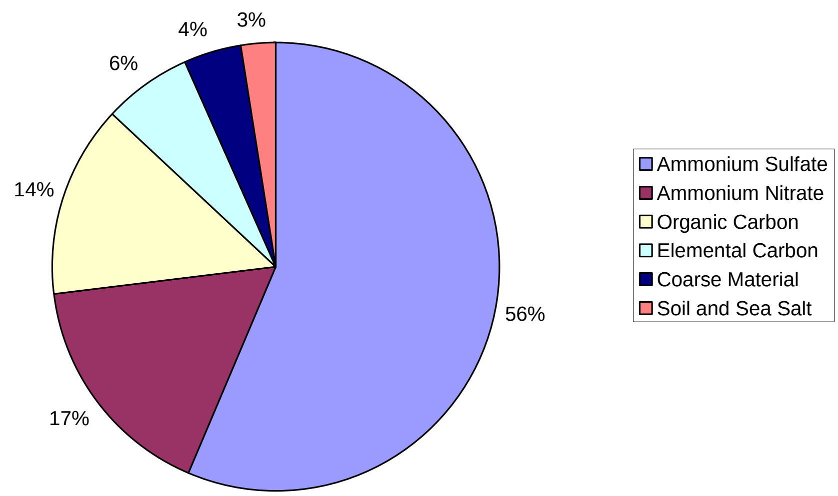
Figure 4-27. United States sulfate (SO_4) deposition in 1994 (top) and 2007 (bottom). Source: National Atmospheric Deposition Program / National Trends Network.

Visibility

Air pollution can impact visibility, which is a particularly important issue in national parks and wilderness areas where millions of visitors expect to be able to enjoy scenic views. Historically, “visibility” has been defined as the greatest distance at which an observer can see a black object viewed against the horizon sky. However, visibility is more than just a measurement of how far an object can be seen; it is a measurement of the conditions that allow appreciation of the inherent beauty of landscape features.

Visibility in the eastern United States is estimated to have declined by as much as 60 percent in the second half of the 20^{th} century (EPA 2001). Visibility impairment is caused when sunlight is scattered or absorbed by fine particles of air pollution obscuring the view. Some haze-causing particles are emitted directly to the air, while others are formed when gases are transformed into particles. In the TVA region, the largest contributor to visibility impairment is ammonium sulfate particles which are formed from SO_2 emissions (primarily from coal-fired power plants). Other particles impacting visibility include nitrates (from motor vehicles, utilities, and industry), organic carbon (predominantly from motor vehicles), elemental carbon (from diesel exhaust and wood burning), and dust (from roads, construction and agricultural activities). Visibility extinction is a measure of the ability of particles to scatter and absorb light and is expressed in units of inverse mega-meters (Mm^{-1}). The chemical composition of visibility extinction varies by season as well as degree of visibility impairment. Figure 4-28 shows the chemical composition of visibility extinction in the Great Smoky Mountains National Park on the 20 percent best days and the 20 percent worst days in 2007 (IMPROVE 2007). On the best days (Figure 4-28, top), 56 percent of the visibility extinction was due to ammonium sulfate, 17 percent due to ammonium nitrate and 14 percent due to organic carbon. On the 20 percent worst days (Figure 4-28, bottom), ammonium sulfate contributed nearly 80 percent of the visibility extinction and organic carbon was still about 14 percent, while ammonium nitrate dropped to 1.3 percent.

The Clean Air Act designated national parks greater than 6,000 acres and wilderness areas greater than 5,000 acres as Class I areas in order to protect their air quality under more stringent regulations. There are eight Class I areas in the vicinity of the TVA region: Great Smoky Mountains National Park, Mammoth Cave National Park and Joyce Kilmer, Shining Rock, Linville Gorge, Cohutta, Sipsey, and Upper Buffalo Wilderness Areas (Figure 4-29). In 1999, EPA promulgated the Regional Haze Rule to improve visibility in Class I areas. This regulation requires states to develop long-term strategies to improve visibility with the ultimate goal of restoring natural background visibility conditions by 2064. Visibility trends are evaluated using the average of the 20 percent worst days and the 20 percent best days with the goal of improving conditions on the 20 percent worst days, while preserving visibility on the 20 percent best days. From 1990 to 2007, there has been a 30 percent improvement in the visibility on the worst days and a 12 percent improvement on the best days at Class I areas in and near the TVA region (Figure 4-30).



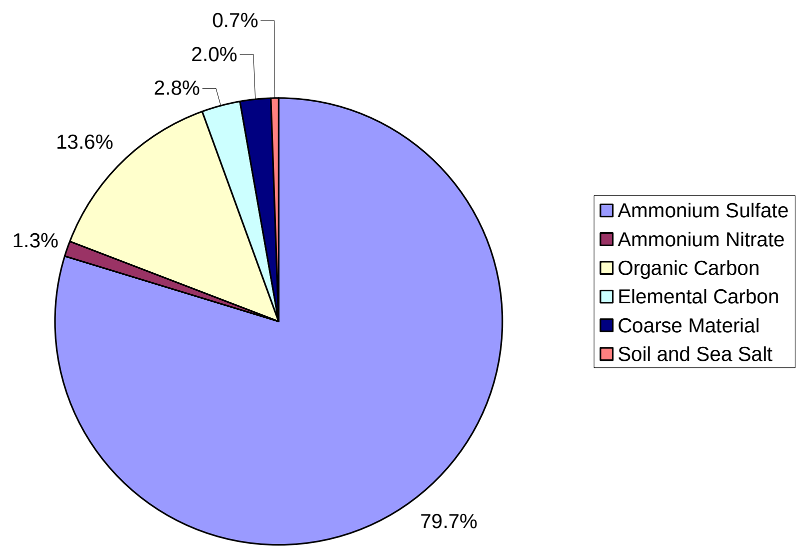


Figure 4-28. Composition of visibility extinction at Great Smoky Mountains National Park on the best 20% days (top) and the worst 20% days (bottom). Source: IMPROVE 2007.

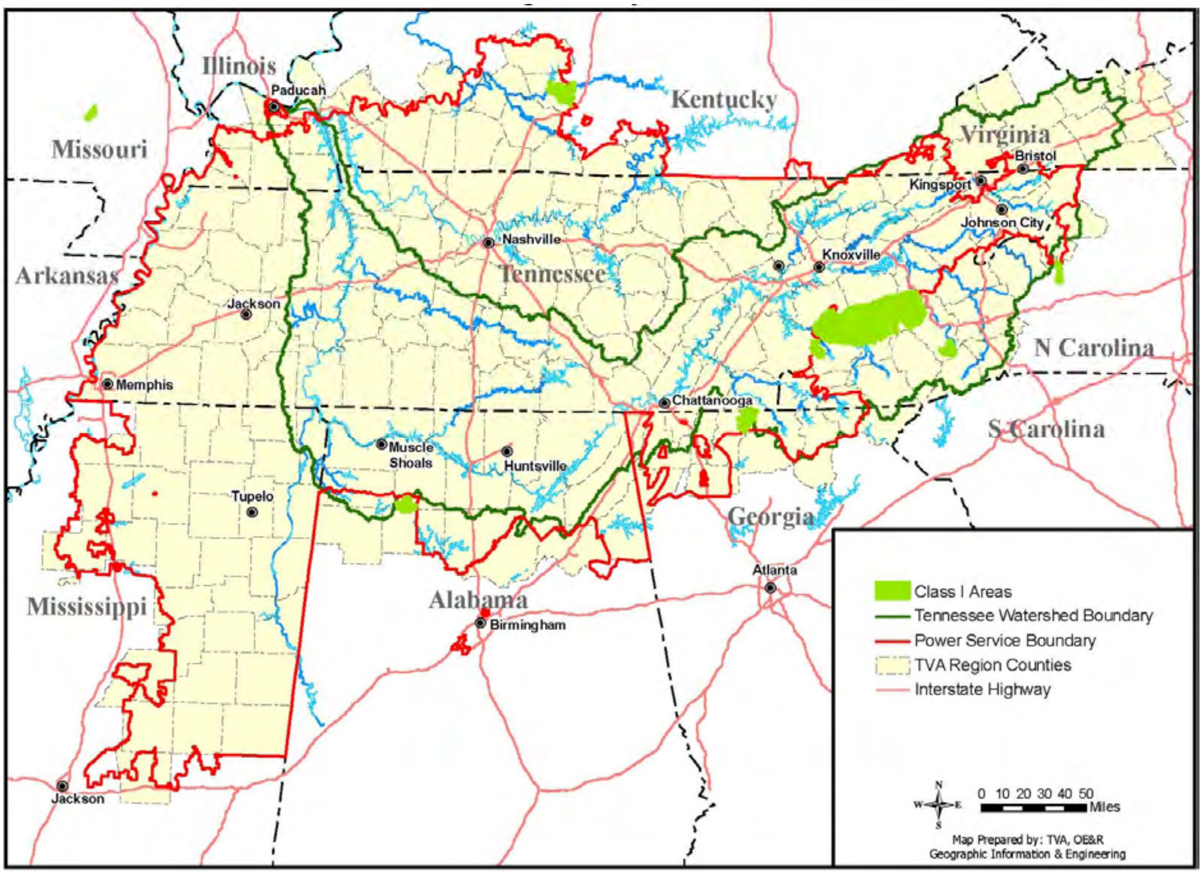


Figure 4-29. Class I areas in and near the TVA region.

4.4. Regional Geology

The TVA region encompasses portions of five major physiographic provinces and six smaller physiographic sections (Figure 4-31) (Fenneman 1938, Miller 1974). Physiographic provinces and sections are areas of similar land surfaces resulting from similar geologic history.

The easternmost part of the region is in the Blue Ridge physiographic province, an area composed of the remnants of an ancient mountain chain. This province has greater variation in terrain in the TVA region. Terrain ranges from nearly level along floodplains at elevations of about 1,000 feet to rugged mountains that reach elevations of more than 6,000 feet. The rocks of the Blue Ridge have been subjected to much folding and faulting and are mostly shales, sandstones, conglomerates, and slate (sedimentary and metamorphic rocks of Precambrian and Cambrian age – from over a billion to about 500 million years ago).

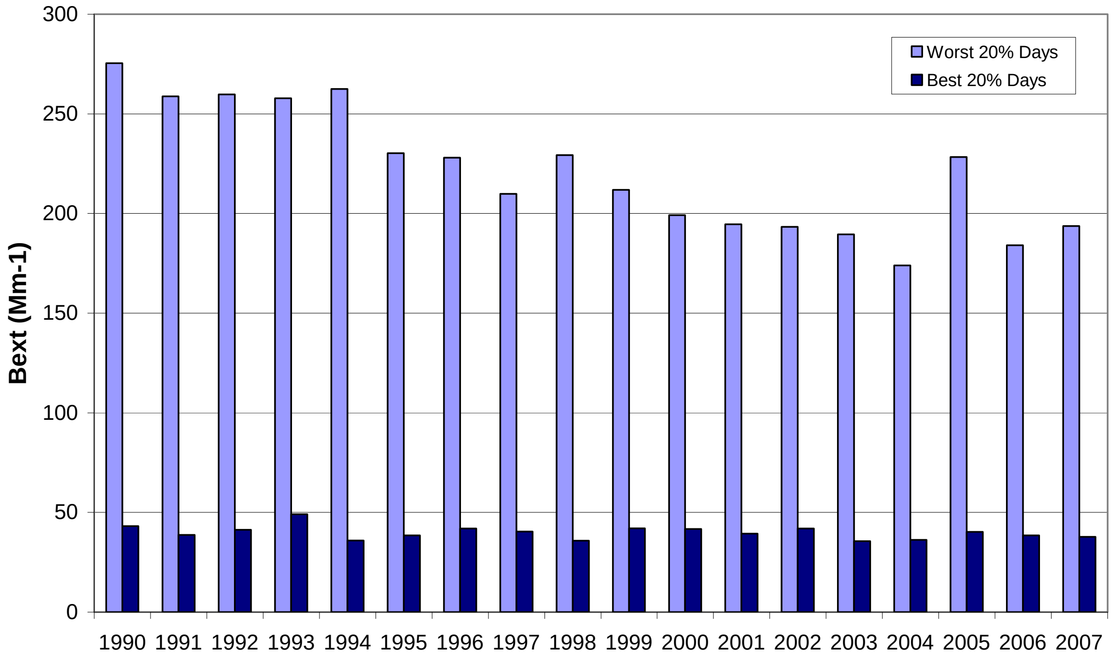


Figure 4-30. Average annual visibility extinction in and near the TVA region on the worst 20% days and the best 20% days, 1990-2007. Source: IMPROVE Program.

Located east of the Appalachian Plateaus and west of the Blue Ridge, the Valley and Ridge Province has complex folds and faults with alternating valleys and ridges trending northeast to southwest. Ridges have elevations of up to 3,000 feet and are generally capped by dolomites and resistant sandstones, while valleys have developed in more soluble limestones and dolomites. The dominant soils in this province are residual clays and silts derived from in-situ weathering. Karst features such as sinkholes and springs are numerous in the Valley and Ridge. “Karst” refers to a type of topography that is formed when rocks with a high carbonate (CO_3) content, such as limestone and dolomite, are dissolved by groundwater to form sink holes, caves, springs, and underground drainage systems.

The Appalachian Plateaus Province is an elevated area between the Valley and Ridge and Interior Low Plateaus provinces. It is comprised of two sections in the TVA region, the extensive Cumberland Plateau section and the smaller Cumberland Mountain section. The Cumberland Plateau rises about 1,000 to 1,500 feet above the adjacent provinces and is formed by layers of near horizontal Pennsylvanian sandstones, shales, conglomerates, and coals, underlain by Mississippian and older shale and limestones. The sandstones are resistant to erosion and have produced a relatively flat landscape broken by stream valleys. Towards the northeast, the Cumberland Mountain section is more rugged due to extensive faulting and several peaks exceed 3,000 feet elevation. The province has a long history of coal mining and encompasses the Appalachian coal region (USGS 1996). Coal mining has historically occurred in much of the province. The most recent Appalachian coal mining within the TVA region has been from the southern end of the province in Alabama, the northern portion of the Cumberland Plateau section in Tennessee, and the Cumberland Mountain section. Two sections of the Interior Low Plateaus Province occur in the TVA region. The Highland Rim section is a plateau that occupies much of central Tennessee

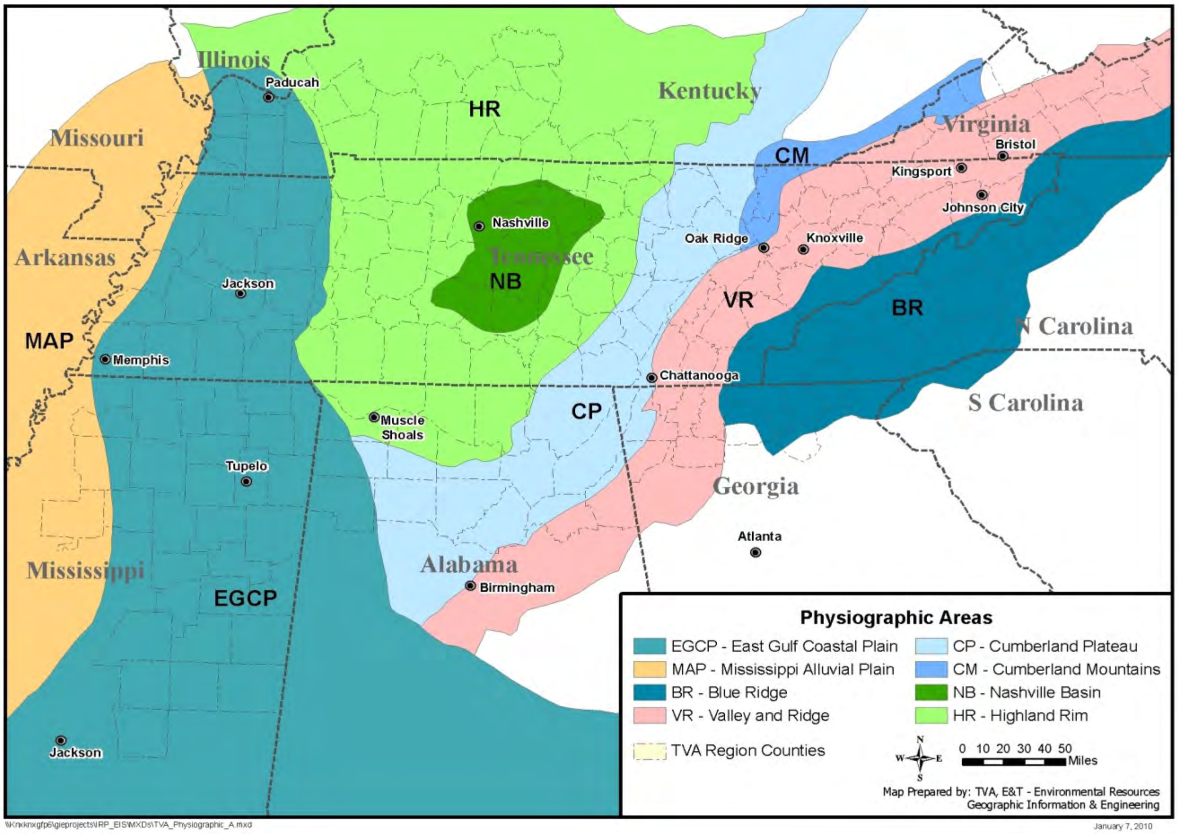


Figure 4-31. Physiographic areas of the TVA region. Adapted from Fenneman (1938).

and parts of Kentucky and northern Alabama. The bedrock of the Highland Rim is Mississippian limestones, chert, shale and sandstone. The terrain varies from hilly to rolling to extensive relatively flat areas in the northwest and southeast. The southern end of the Illinois Basin coal region (USGS 1996) overlaps the Highland Rim in northwest Kentucky and includes part of the TVA region. The Nashville Basin (also known as the Central Basin) section is an oval area in middle Tennessee lying about 200 feet below the surrounding Highland Rim. The bedrock is limestones that are generally flat-lying.

Soil cover is usually thin and surface streams cut into bedrock. Karst is well-developed in parts of both the Highland Rim and the Nashville Basin.

The Coastal Plain Province encompasses much of the western and southwestern TVA region (Figure 4-31). Most of the Coastal Plain portion of the TVA region is in the extensive East Gulf Coastal Plain section. The underlying geology is a mix of poorly consolidated gravels, sands, silts, and clays. Soils are primarily of windblown and alluvial (deposited by water) origin, low to moderate fertility, and easily eroded. The terrain varies from hilly to flat in broad river bottoms. The Mississippi Alluvial Plain section occupies the western edge of the TVA region and much of the historic floodplain of the Mississippi River. Soils are deep and often poorly drained. The New Madrid Seismic Zone, an area of large prehistoric and historic earthquakes, is in the northern portion of the section.

Geologic Carbon Dioxide Sequestration Potential

The sequestration (i.e., capture and permanent storage) of CO_2 from large stationary point sources, such as coal-fired power plants, is potentially an important component of efforts to significantly reduce anthropogenic CO_2 emissions. Successful large-scale, economical, CO_2 sequestration (also referred to as carbon capture and storage (CCS)) would enable coal to continue to be used as an energy source if the decision is made to reduce CO_2 emissions. There are, however, significant technical and legal issues associated with establishing CCS as a viable CO_2 reduction technique.

Geologic CO_2 storage involves capturing and separating the CO_2 from the power plant exhaust, drying, purifying, and compressing the CO_2, and transporting it by pipeline to the storage site where it is pumped through wells into deep geological formations. When the CO_2 capacity of the formation has been reached, or when the pressure of the formation or injection well has reached a pre-determined level, CO_2 injection is stopped and the wells are permanently sealed. The storage site would then be monitored for a period of time.

The suitability of a particular deep underground formation for CO_2 storage depends on its and the surrounding geology. In the continental and southeastern U.S., deep saline formations, unmineable coal seams, and oil and gas fields are considered to have the best potential to store CO_2 from large point sources (NETL 2008). A brief description of each of these formations is given below.

<u>Saline Formations</u>. Saline formations are layers of porous rock that are saturated with brine. They are more extensive than unmineable coal seams and oil and gas fields and have a high CO_2 storage potential. However, because they are less studied than the other two formations, less is known about their suitability and storage capacity. Potentially suitable saline formations are capped by one of more layers of non-porous rock, which would prevent the upward migration of injected CO_2. Saline formations also contain minerals that could react with injected CO_2 to form solid carbonates, further sequestering the CO_2.

<u>Unmineable Coal Seams</u>. Unmineable coal seams are typically too deep or too thin to be economically mined. When CO_2 is injected into them, it is adsorbed onto the surface of the coal. Although their storage potential is much lower than saline formations, they are attractive because the injected CO_2 can be used to displace coalbed methane, which can be recovered in adjacent wells and used as a natural gas substitute.

<u>Oil and Gas Fields</u>. Mature oil and gas fields/reservoirs are considered good storage formations because they held crude oil and natural gas for millions of years. Their storage characteristics are also well known. Like saline formations, they consist of layers of permeable rock with one or more layers of cap rock. Injected CO_2 can also enhance the recovery of oil or gas from mature fields.

Geologic Storage Potential in the TVA Region

In 2002, the Department of Energy's National Energy Technology Laboratory launched the Regional Carbon Sequestration Program to identify and evaluate carbon sequestration in different regions of the country. TVA, along with other agencies and utilities, is a participant in the program's Southeast Regional Carbon Sequestration Partnership (SECARB). This group used screening criteria for identifying potentially suitable deep, underground geologic formations for CO_2 storage (Smyth et al. 2007, NETL 2008). Using publicly available information, SECARB characterized the geologic sequestration potential in the TVA region and adjacent areas in Phase I of this program. The Midwest Geological Sequestration Consortium is conducting similar studies in the Illinois Basin area of Illinois, Indiana, and Kentucky. Following is a brief description the results of these studies. Suitable or potentially suitable geologic formations occur at or near TVA's Gallatin, Paradise, and Johnsonville Fossil Plants.

Saline Formations. Middle Tennessee is underlain by the Mt. Simon formation (Figure 4--32), a saline formation with a depth of 3,940 to 7,880 feet (1,200 to 2,400 meters) and average thickness of 100 feet (30 meters). The estimated storage capacity of the Mt. Simon is 2.5 gigatons (2.5 billion tons) of CO_2 (NETL 2008). To put this in perspective, a 1,000 MW coal-fired power plant emits about 7 million tons of CO_2 per year. The Mt. Simon formation may extend into northern Alabama and Kentucky, but its CO_2 storage potential has not been assessed in these areas. The Gallatin plant is located above the Mt. Simon formation and the potential to store CO_2 directly below or near the plant is considered good. If the Mt. Simon extends into northwest Alabama and it is still at a sufficient depth for CO_2 storage (below 800 meters), then it may be suitable for storing CO_2 from Colbert Fossil Plant. Although Cumberland Fossil Plant is underlain by the Mt. Simon, its potential to store CO_2 under or near the plant is low because of the structural complexity of the surrounding Wells Creek meteor impact crater.

The Knox formation below the Paradise plant and the Knox and Mt. Simon formations below the Johnsonville plant are considered to have good potential for CO_2 storage due to their geological characteristics (NETL 2008). Although saline formations occur in the vicinity of Allen and Shawnee Fossil Plants, their sequestration potential is considered low due to their proximity to the New Madrid Seismic Zone.

Other saline formations in or near the TVA region with the potential to store CO_2 include the Knox Group in eastern Kentucky and the extensive Tuscaloosa Group in southwest Alabama, southern Mississippi, and western Florida (NETL 2008). These formations are not close to any TVA fossil plants and pipelines would have to be built to transport the CO_2 from TVA plants to these formations.

Unmineable Coal Seams. The only TVA coal plant in the immediate vicinity of assessed coal seams is Paradise (Figure 4-33). Due to the nature of these seams, their potential to store CO_2 is considered low (NETL 2008). Potentially suitable coal seams occur elsewhere in the Illinois Basin, as well as in southeast Kentucky/southwest Virginia, west-central Alabama, and southwest Mississippi. The use of these formations to store CO_2 from TVA plants would require the construction of pipelines.

Oil and Gas Fields. No suitable or potentially suitable oil and gas fields occur in the immediate vicinity of TVA's fossil plants (Figure 4-34). The use of oil and gas fields to store CO_2 from TVA plants would require the construction of pipelines.

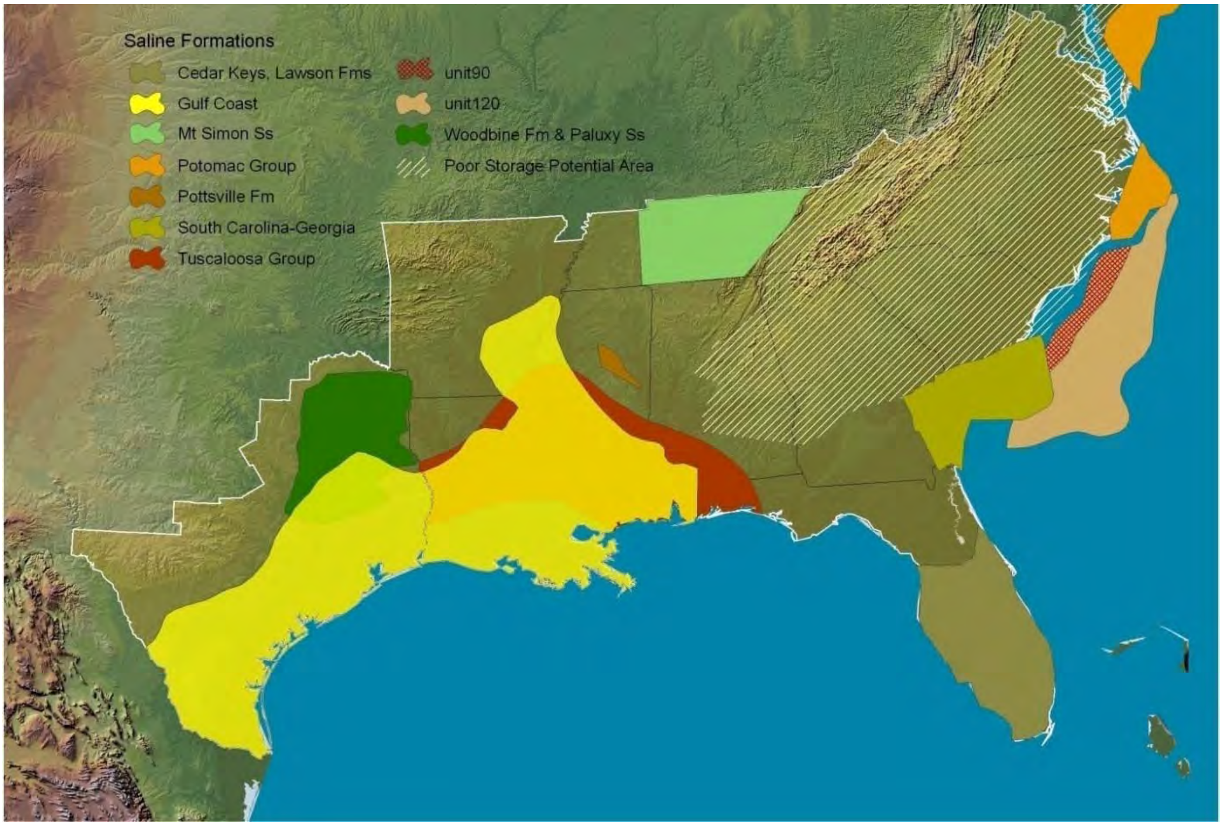


Figure 4-32. Saline formations in the southeastern United States potentially suitable for CO_2 storage. Source: NETL (2008).

The screening results described above are based on the results of Phase I characterization studies conducted through the southeast and midwest regional programs. Both of these programs are conducting Phase II (Validation) and Phase III (Deployment) tests which will better refine the potential and costs of storing regional CO_2 emissions.

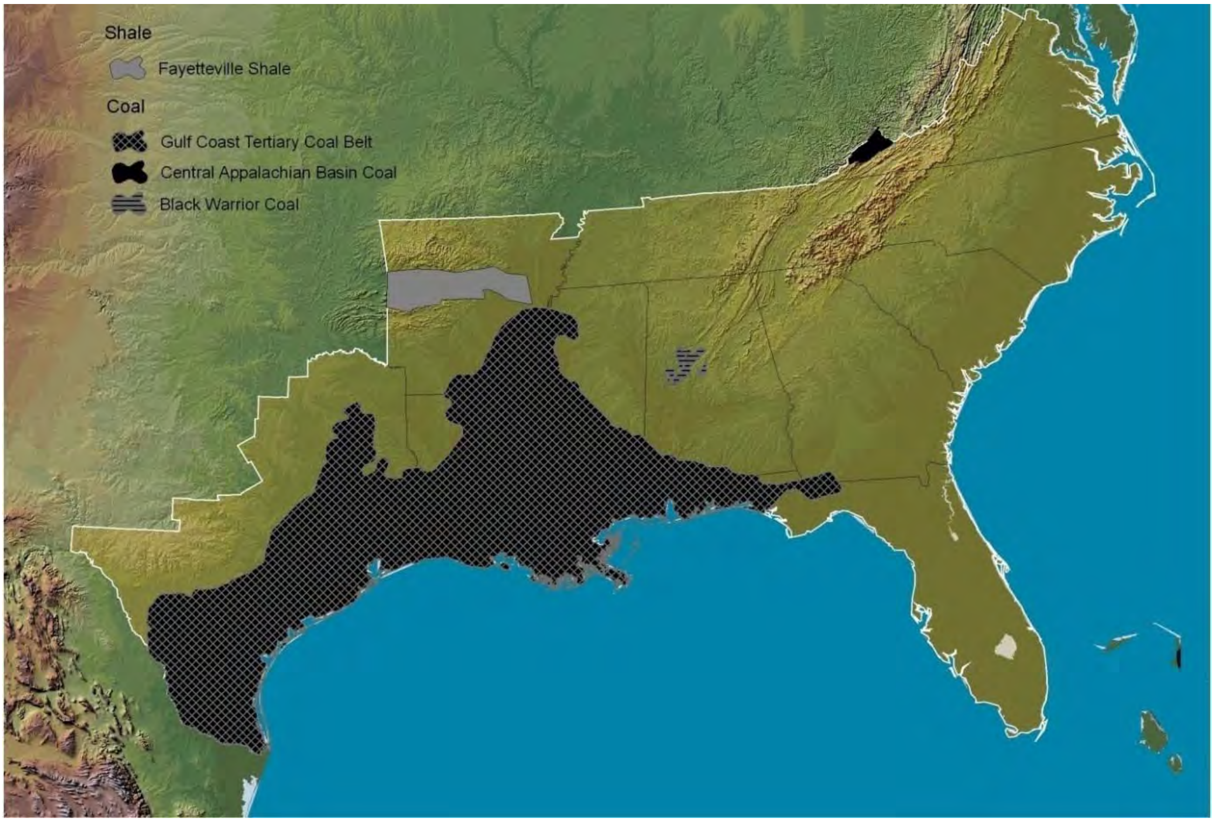


Figure 4-33. Unmineable coal seams in the southeastern United States potentially suitable for CO_2 storage. Source: NETL (2008).

4.5. Groundwater

Three basic types of aquifers (water-bearing geologic formations) occur in the TVA region: unconsolidated sedimentary sand, carbonate rocks, and fractured noncarbonate rocks. Unconsolidated sedimentary sand formations, composed primarily of sand with lesser amounts of gravel, clay and silt, constitute some of the most productive aquifers. Groundwater movement in sand aquifers occurs through the pore spaces between sediment particles. Carbonate rocks are another important class of aquifers. Carbonate rocks, such as limestone and dolomite, contain a high percentage of carbonate minerals (e.g., calcite) in the rock matrix. Carbonate rocks in some parts of the region readily transmit groundwater through enlarged fractures and cavities created by dissolution of carbonate minerals by acidic groundwater. Fractured noncarbonate rocks represent the third type of aquifer found in the region. These aquifers include sedimentary and metamorphic rocks, e.g., sandstone, conglomerate, and granite gneiss, which transmit groundwater through fractures, joints, and beddings planes. Eight major aquifers occur in the TVA (Table 4-8). These aquifers generally align with the major physiographic divisions of the region (Figure 4-31).

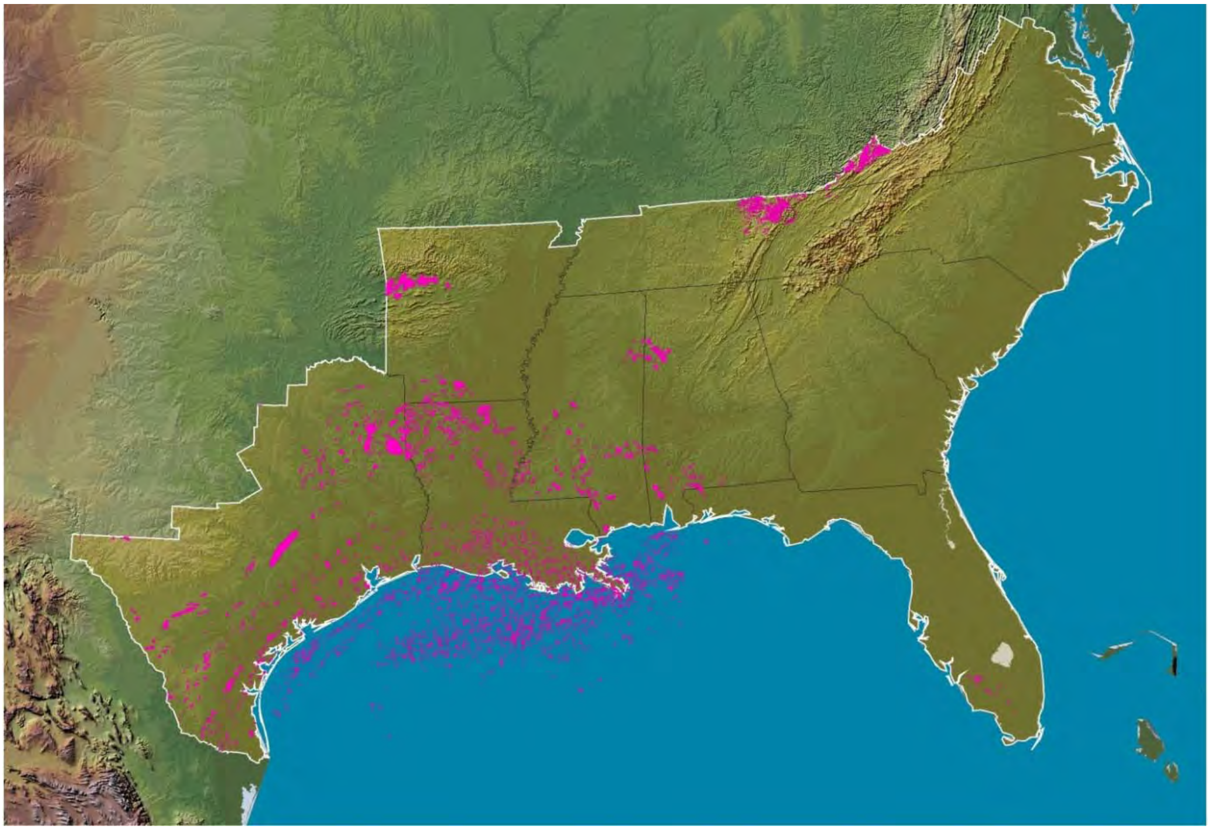


Figure 4-34. Oil and gas fields in the southeastern United States potentially suitable for CO_2 storage. Source: NETL (2008).

The aquifers include (in order of increasing geologic age): Quaternary age alluvium occupying the floodplains of major rivers, notably the Mississippi River; Tertiary and Cretaceous age sand aquifers of the Coastal Plain Province; Pennsylvanian sandstone units found mainly in the Cumberland Plateau section; carbonate rocks of Mississippian, Silurian and Devonian age of the Highland Rim section; Ordovician age carbonate rocks of the Nashville Basin section; Cambrian-Ordovician age carbonate rocks within the Valley and Ridge Province; and Cambrian-Precambrian metamorphic and igneous crystalline rocks of the Blue Ridge Province.

The largest withdrawals of groundwater for public water supply are from the Tertiary and Cretaceous sand aquifers in the Mississippi Alluvial Plain and Coastal Plain physiographic areas. These withdrawals account for about two-thirds of all groundwater withdrawals for public water supply in the TVA region. The Pennsylvanian sandstone and Orodovician carbonate aquifers have the lowest groundwater use (less than 1 percent of withdrawals) and lowest potential for groundwater use. Groundwater use is described in more detail in Section 4-7. The quality of groundwater in the TVA region is largely dependent on the chemical composition of the aquifer in which the water occurs (Table 4-8). Precipitation entering the aquifer is generally low in dissolved solids and slightly acidic. As it seeps through the aquifer it reacts with the aquifer matrix and the concentration of dissolved solids increases.

Table 4-8. Aquifer, well, and water quality characteristics in the TVA region. Source: Webbers (2003).

Aquifer Description	Well Characteristics (common range, maximum)		Water Quality Characteristics
	Depth (feet)	Yield (gpm*)	
Quaternary alluvium: Sand, gravel, and clay. Unconfined.	10 - 75, 100	20 - 50, 1,500	High iron concentrations in some areas.
Tertiary sand: Multi-aquifer unit of sand, clay, silt, and some gravel and lignite. Confined; unconfined in the outcrop area.	100 - 1,300, 1,500	200 - 1,000, 2,000	Problems with high iron concentrations in some places
Cretaceous sand: Multi-aquifer unit of interbedded sand, marl, and gravel. Confined; unconfined in the outcrop area.	100 - 1,500, 2,500	50 - 500, 1,000	High iron concentrations in some areas.
Pennsylvanian sandstone: Multi-aquifer unit, primarily sandstone and conglomerate, interbedded shale and some coal. Unconfined near land surface; confined at depth.	100 - 200, 250	5 - 50, 200	High iron concentrations are a problem; high dissolved solids, sulfide or sulfate are problems in some areas.
Mississippian carbonate rock: Multi-aquifer unit of limestone, dolomite, and some shale. Water occurs in solution and bedding-plane openings. Unconfined or partly confined near land surface; may be confined at depth.	50 - 200, 250	5 - 50, 400	Generally hard; high iron, sulfide, or sulfate concentrations are a problem in some areas
Ordovician carbonate rock: Multi-aquifer unit of limestone, dolomite, and shale. Partly confined to unconfined near land surface; confined at depth.	50 - 150, 200	5 - 20, 300	Generally hard; some high sulfide or sulfate concentrations in places.
Cambrian-Ordovician carbonate rock: Highly faulted multi-aquifer unit of limestone, dolomite, sandstone, and shale; structurally complex. Unconfined; confined at depth.	100 - 300, 400	5 - 200, 2,000	Generally hard, brine below 3,000 feet
Cambrian-Precambrian crystalline rock: Multi-aquifer unit of dolomite, granite gneiss, phyllite, and metasedimentary rocks overlain by thick regolith. High yields occur in dolomite or deep colluvium and alluvium. Generally unconfined.	50 - 150, 200	5 - 50, 1,000	Low pH and high iron concentrations may be problems in some areas.

*gpm = gallons per minute

Acidic precipitation percolating through carbonate aquifers tends to dissolve carbonate minerals present in limestone and dolomite, resulting in reduced groundwater acidity and elevated concentrations of calcium, magnesium, and bicarbonate. Consequently, groundwater derived from carbonate rocks of the Valley and Ridge, Highland Rim, and Nashville Basin is generally slightly alkaline and high in dissolved solids and hardness. Groundwater from mainly noncarbonated rocks of the Blue Ridge, Appalachian Plateaus, and Coastal Plain typically exhibits lower concentrations of dissolved solids compared to carbonate rocks. However, sandstones interbedded with pyritic shales often produce acidic groundwater high in dissolved solids, iron, and hydrogen sulfide. These conditions are commonly found on the Appalachian Plateaus and in some parts of the Highland Rim and Valley and Ridge (Zurawski 1978).

The chemical quality of most groundwater in the region is within health-based limits established by the EPA for drinking water. Pathogenic microorganisms are generally absent, except in areas underlain by shallow carbonate aquifers susceptible to contamination by direct recharge through open sinkholes (Zurawski 1978).

4.6. Water Quality

The quality of the region's water is critical to protection of human health and aquatic life. Water resources provide habitat for aquatic life, recreation opportunities, domestic and industrial water supplies, and other benefits. Major watersheds in the TVA region include the entire Tennessee River basin, most of the Cumberland River basin, and portions of the lower Ohio, lower Mississippi, Green, Pearl, Tombigbee, and Coosa River basins. Fresh water abounds in much of this area and generally supports most beneficial uses, including fish and aquatic life, public and industrial water supply, waste assimilation, agriculture, and water-contact recreation, such as swimming. Water quality in the TVA region is generally good.

Causes of degraded water quality include:

- Wastewater discharges – Sewage treatment systems, industries, and other sources discharge waste into streams and reservoirs. These discharges are controlled through state-issued National Pollutant Discharge Elimination System (NPDES) permits issued under the authority of the federal Clean Water Act. NPDES permits regulate the concentrations of various pollutants in the discharges and establish monitoring and reporting requirements.
- Non-point source discharges – Runoff from agriculture, urban uses, and mined land can transport sediment and other pollutants into streams and reservoirs. Non-point runoff from some commercial and industrial facilities and some construction sites is regulated through state NPDES storm water permitting systems.
- Heated water discharges – Electrical generating plants and other industrial facilities may withdraw water from streams or reservoirs, use it to cool facility operations, and discharge heated water into streams or reservoirs. State regulations, under the authority of the Clean Water Act, limit the water temperature increases in the receiving waters and the resulting effects on the aquatic community.
- Air pollution – Airborne pollutants can affect surface waters through rainout and deposition.

Following is an overview of how power generation can affect water quality.

<u>Fossil Plant Wastewater.</u> Fossil plant sites have systems to control storm water runoff. These typically consist of retention ponds to capture sediment, and may include oil/water separators. Coal-fired power plants have several liquid waste streams that are treated and released to surface waters. These releases are permitted by each state under the NPDES program. Many of these waste streams receive extensive treatment before they are released and periodic toxicity testing ensures that there are no acute or chronic toxic effects to aquatic life. Coal mining and processing operations, as well as coal combustion waste processing operations, also discharge wastewater which can impact the receiving water body. Combined-cycle combustion turbine plants typically require an NPDES permit for the discharge of treated water from the cooling system ("cooling tower blowdown") and other plant processes. These discharges are typically to surface waters.

<u>Nuclear Plant Wastewater</u>. Nuclear plant sites have systems to control storm water runoff. These typically consist of retention ponds to capture sediment, and may include oil/water separators. Nuclear plants have noncomplex wastewaters from plant processes that are subjected to various levels of treatment and are usually discharged to surface waters. Periodic toxicity testing is performed on this discharge as part of the NPDES permit to ensure that plant wastes do not contain chemicals at deleterious levels that could affect aquatic life.

<u>Fossil and Nuclear Plant Heat Releases</u>**.** TVA's coal-fired and nuclear plants withdraw water from reservoirs or rivers for cooling and discharge the heated water back into the water body (see Section 4.7). TVA conducts extensive monitoring programs to help ensure compliance and to provide information about potential adverse effects. Recent programs have focused primarily on spawning and development of cool-water fish species such as sauger, the attraction of fish to heated discharges from power plants, and changes in undesirable aquatic micro-organisms such as blue-green algae. In general, these monitoring programs have not detected significant negative effects resulting from release of heated water from TVA facilities in the Tennessee River drainage.

<u>Runoff and Air Pollution</u>. Many non-point sources of pollution are not subject to government regulations or control. Principal causes of non-point source pollution are agriculture, including runoff from fertilizer, pesticide and herbicide applications, erosion, and animal wastes; mining, including erosion and acid drainage; and urban runoff. Pollutants reach the ground from the atmosphere as dust fall or are carried to the ground by precipitation.

<u>Low Dissolved Oxygen Levels and Low Flow Downstream of Dams.</u> A major water quality concern in the Tennessee River is low dissolved oxygen levels in reservoirs and in the tailwaters downstream of dams. Long stretches of river can be affected, especially in areas where pollution further depletes dissolved oxygen. In addition, flow in these tailwaters is heavily influenced by the amount of water released from the upstream dams; in the past, some of the tailwaters were subject to periods of little or no flow. Since the early 1990s, TVA has addressed these issues by installing equipment and making operational changes to increase dissolved oxygen concentrations below 16 dams and to maintain minimum flows in tailwaters (TVA 2004: 4.4-3).

The Tennessee River System

The Tennessee River basin contains all except one of TVA's dams and covers a large part of the TVA region (Figure 3-12). A series of nine locks and dams built mostly in the 1930s and 1940s regulates the entire length of the Tennessee River and allows navigation to Knoxville (TVA 2004). Virtually all the major tributaries have at least one dam, creating 14 multi-purpose storage reservoirs and seven single-purpose power reservoirs. The construction of the TVA dam and reservoir system fundamentally altered both the water quality and physical environment of the Tennessee River and its tributaries. While dams promote navigation, flood control, power generation, and river-based recreation by moderating the flow effects of floods and droughts throughout the year, they also disrupt the daily, seasonal, and annual flow patterns that are characteristic of a river. This system of dams and their operation is the most significant factor affecting water quality and aquatic habitats in the Tennessee River and its major tributaries.

Major water quality concerns within the Tennessee River drainage basin include point and non-point sources of pollution that degrade water quality at several locations on mainstream reservoirs and tributary rivers and reservoirs. TVA regularly evaluates several water quality indicators as well as the overall ecological health of reservoirs through its Vital Signs monitoring program. This program evaluates five metrics: chlorophyll concentration, fish community health, bottom life, sediment contamination, and dissolved oxygen (DO) (TVA 2004: 4.4-3, -4). Scores for each metric from monitoring sites in the deep area near the dam (forebay), mid-reservoir, and at the upstream end of the reservoir (inflow) are combined for a summary score and rating. Vital Signs ratings, major areas of concern, and fish consumption advisories are listed in Table 4-9.

Six of TVA's nine coal-fired power plants and all of TVA's nuclear plants are in the Tennessee River watershed. All of these facilities are dependent on the river system for cooling water. Three of TVA's gas-fired generating plants are along or close to the Tennessee River; they are not dependent on it for cooling water.

Other Major River Systems

The Ohio, Green, and Mississippi Rivers each host a TVA coal-fired plant. TVA operates two coal-fired plants on the main stem of the Cumberland River and a small hydroelectric plant on a Cumberland River tributary. Combustion turbine plants are located in the Hatchie and Obion (both tributaries to the Mississippi River) drainages and the Tombigbee River drainage. Because of recent low summer flows in the Cumberland River due to repairs on Wolf Creek Dam by the U.S. Army Corps of Engineers and drought conditions, thermal discharges from the Cumberland Fossil Plant have led to the state of Tennessee placing a portion of the Cumberland River on the Clean Water Act Section 303(d) list of impaired waters (TDEC 2008). Fish consumption advisories are in effect for waters in the vicinity of Shawnee and Allen fossil plants, Otherwise, water resources conditions and characteristics in these river systems are generally similar to those in the Tennessee system.

4.7. Water Supply

In 2005, estimated average daily water withdrawals in the TVA region totaled 20,176 million gallons per day (mgd) (Kenny et al. 2009). About five percent of these water withdrawals were groundwater and the remainder was surface water. The largest water use (79 percent of all withdrawals) was for thermoelectric generation; this water use is described in more detail below.

Table 4-9. TVA reservoir ecological health ratings, major water quality concerns, and fish consumption advisories. Source: TVA Data at http://www.tva.com/environment/ecohealth/index.htm and state water quality reports.

Reservoir	Ecological Health Rating - Score	Latest Survey Date	Concerns	Fish Consumption Advisories
Apalachia	Good - 84	2008	--	Mercury (NC statewide)
Bear Creek	Fair - 64	2007	DO	Mercury
Beech	Poor - 51	2008	DO, chlorophyll	None
Blue Ridge	Good - 83	2007	DO	Mercury
Boone	Poor - 50	2007	DO, chlorophyll, bottom life	PCBs, chlordane
Cedar Creek	Fair - 69	2007	DO	Mercury
Chatuge	Fair - 59	2008	DO, bottom life, sediment quality	Mercury
Cherokee	Fair - 63	2008	DO, chlorophyll, bottom life	Mercury (upstream of Poor Valley Creek)
Chickamauga	Fair - 69	2007	Chlorophyll, bottom life	Mercury (Hiwssee River embayment)
Douglas	Poor - 55	2007	DO, chlorophyll	None
Fontana	Fair - 69	2008	Bottom life	Mercury (NC statewide)
Fort Loudoun	Poor - 50	2007	DO, chlorophyll, bottom life	PCBs, mercury (above US 129)
Fort Patrick Henry	Fair - 60	2007	Chlorophyll, bottom life	None
Guntersville	Fair - 68	2008	Chlorophyll	Mercury (Long Island to AL/TN state line)
Hiwassee	Fair - 67	2008	DO, chlorophyll	None
Kentucky	Good - 76	2007	DO, chlorophyll	Mercury (KY statewide)
Little Bear Creek	Fair - 60	2007	DO, bottom life	Mercury
Melton Hill	Fair - 65	2008	Bottom life	PCBs, mercury (Poplar Creek

Table 4-9. Continued.

Reservoir	Ecological Health Rating - Score	Latest Survey Date	Concerns	Fish Consumption Advisories
				embayment)
Nickajack	Good - 75	2007	Chlorophyll	PCBs
Normandy	Poor - 52	2008	DO, chlorophyll	None
Norris	Fair - 60	2007	DO, chlorophyll, bottom life	Mercury (Clinch River portion)
Nottely	Poor - 46	2007	DO, chlorophyll, bottom life	Mercury
Parksville	Fair - 71	2007	Sediment quality	None
Pickwick	Good - 78	2006	Chlorophyll	None
South Holston	Fair - 60	2006	DO, bottom life	Mercury (Tennessee portion)
Tellico	Fair - 59	2007	DO, chlorophyll, bottom life	PCBs, mercury
Tims Ford	Poor - 52	2008	DO, bottom life	None
Upper Bear Creek				Mercury
Watauga	Good - 75	2008	DO	Mercury
Watts Bar	Fair - 59	2008	DO, chlorophyll, bottom life	PCBs
Wheeler	Poor - 57	2007	DO, chlorophyll, bottom life	DDT, mercury (Limestone Creek embayment)
Wilson	Poor - 54	2008	DO, chlorophyll, bottom life	Mercury (Big Nance Creek embayment)

Groundwater Use

Groundwater use data is compiled by the U.S. Geological Survey (USGS) and cooperating state agencies in connection with the national public water use inventory conducted every five years (Bohac and McCall 2008, Bradley and Robinson 2009, Burt 2009, Fannin 2009, Kenny et al. 2009, Littlepage 2009, Pope 2009, Yeary 2009). The largest use of groundwater is for public water supply (Figure 4-35). About 60 percent of water used for irrigation and almost all water used for domestic supply in the TVA region is groundwater. Groundwater is also widely used for industrial and mining purposes. The extent of monitoring and reporting for these two uses, as well as for irrigation, is somewhat inconsistent among states. Public water supply is typically the largest category of groundwater use and is therefore a useful indicator of overall trends.

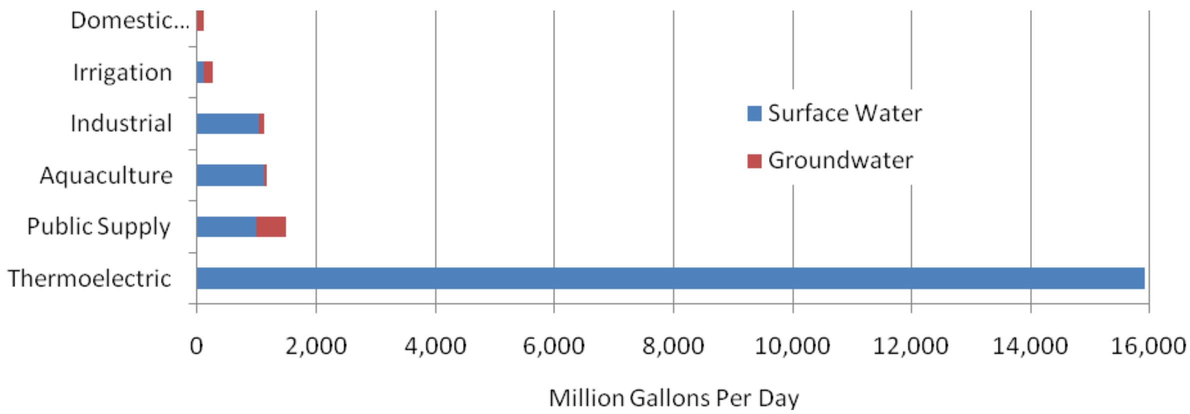


Figure 4-35. 2005 water withdrawals in the TVA region by source and type of use. Source: Kenny (2009).

The use of groundwater to meet public water supply needs varies across the TVA region and is greatest in West Tennessee and northern Mississippi. This variation is the result of several factors including (1) groundwater availability, (2) surface water availability, (3) where both surface and groundwater are present in adequate quantity and quality, which water source can be developed most economically, and (4) public water demand which is largely a function of population. For example, there are numerous sparsely-populated rural counties in the region with no public water systems. Residents in these areas are self-served, most often by individual wells or springs.

Total groundwater use for public water supply in 2005 averaged 492 mgd in the TVA region. Approximately 56 percent of all groundwater withdrawals were supplied by Tertiary sand aquifers in West Tennessee and North Mississippi. Shelby County, Tennessee alone pumped 187 MGD from Tertiary aquifers, accounting for 38 percent of total 2005 regional pumpage. The dominance of groundwater use over surface water use in the western portion of the TVA region is due to the availability of prolific aquifers and the absence of adequate surface water resources in some areas.

Since 1950, groundwater and surface water withdrawals by public supply systems in Tennessee have greatly increased (Figure 4-36). Since 1950, the magnitude and rate of growth of withdrawals of surface water has exceeded groundwater. The annual increase in groundwater withdrawals for public supply in Tennessee averaged about 2.5 percent and the increase in surface water withdrawals averaged about 3.8 percent. Although these data are for Tennessee public water supplies, they are representative of the overall growth in groundwater use for the TVA region.

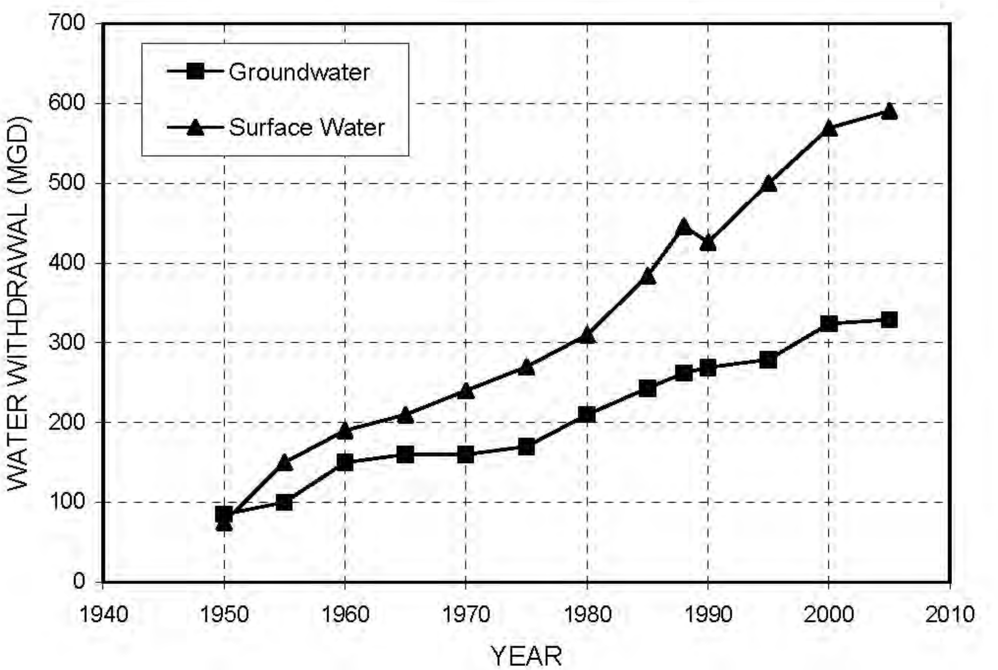


Figure 4-36. Groundwater and surface water withdrawals by public supply systems in Tennessee, 1950 to 2005. Source: Adapted from Webbers (2003).

Surface Water Use

The majority of water used for thermoelectric, public supply, aquaculture, and industrial uses is surface water (Figure 4-35). Most of this water is returned to streams or reservoirs; in the Tennessee River drainage, 96.5 percent of the withdrawn surface water was returned to the watershed (Bohac and McCall 2008). The water use categories with the greatest consumptive use (i.e., not returned to the watershed) were irrigation (~100 percent consumed), public supply (40 percent consumed), and industrial (7 percent consumed).

The trend in surface water use by public water supply systems is described above. Trends in some other use categories are more variable and irrigation and aquaculture are very sensitive to weather and market conditions.

Water Use for Thermoelectric Power Generation

Thermoelectric power generation uses steam produced from the combustion of fossil fuels or from a nuclear reaction. A significant volume of cooling water is required to condense steam into water. All TVA coal-fired plants and nuclear plants are cooled by water withdrawn from adjacent rivers or reservoirs. The amount of water required is highly dependent on the type of cooling system employed. While the volume of water used to cool the plants is large, most of this water is returned to the adjacent rivers or reservoirs.

In 2005, TVA coal-fired plants and nuclear plants withdrew an average of 15,539 mgd (Table 4-10). The amount of water used to generate electricity is often described as the water use factor, the total plant water withdrawal divided by the net generation. All TVA coal-fired plants except Paradise employ open-cycle (once-through) cooling all the time. In open cycle (once-through) systems, water is withdrawn from a water body, circulated through the plant cooling condensers, discharged back to the water body. Plant water use factors for the coal plants, except for Paradise, range from about 29,000 to 61,000 gal/MWh

Table 4-10. 2005 water use for TVA coal-fired and nuclear generating plants. Source: Bohac and McCall (2008).

Facility	Units	Withdrawal (mgd)	Return (mgd)	Consumption (Withdrawal - Return, mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh)
			Fossil Plants			
Allen	1-3	405.7	405.5	0.2	5,160,139	28,697
Bull Run	1	563.2	563.2	0.0	6,587,608	31,205
Colbert	1-5	1294.1	1292.8	1.3	7,776,803	60,740
Cumberland	1-2	2291.6	2285.0	6.6	16,371,958	51,089
Gallatin	1-4	943.0	943.0	0.0	7,494,267	45,928
John Sevier	1-4	693.7	692.4	1.3	4,960,616	51,042
Johnsonville	1-10	1226.9	1226.8	0.1	7,639,746	58,617
Kingston	1-9	1280.0	1279.2	0.8	9,479,726	49,284
Paradise	1-3	354.7	305.7	49.0	13,974,044	9,265
Shawnee	1-10	1292.0	1292.0	0.0	9,293,226	50,744
Widows Creek	1-8	1476.3	1476.3	0.0	9,851,670	54,696
			Nuclear Plants			
Browns Ferry	2-3	1990.2	1987.5	2.7	17,931,672	40,511
Sequoyah	1-2	1539.3	1539.2	0.1	18,999,153	29,572
Watts Bar	1	188.2	173.9	14.3	8,803,955	7,803

of net generation. Differences in river temperature, plant design, atmospheric conditions, and plant operation account for the variability in water use factors. Year-to-year variation in water use factors is typically less than 10 percent.

Paradise employs substantial use of cooling towers (closed-cycle cooling) resulting in a relatively low plant water use factor and less water returned to the river (Table 4-10). In closed-cycle systems, water from the steam turbine condensers is circulated through cooling tower where the condenser water is cooled by transfer of heat to the air by evaporation, conduction, and convection. The proportion of cooling water discharged to the river or reservoir is lower than for open-cycle systems, as are the overall volume of water required and the plant water use factor. Browns Ferry and Sequoyah nuclear plants operate primarily in the open-cycle mode, with infrequent use of cooling towers except during the warmer summer months. Watts Bar uses a combination of open-cycle and closed-cycle cooling.

Power plant water use factors averaged about 50,000 gal/MWh nationally in 1960 and declined to about 38,000 gal/MWH in 1995 (EPRI 2002). The reduction was due to increasing use of closed-cycle cooling, particularly in the western United States where water is relatively scarce. For 2000, the national average water use factor was 21,450 gal/MWh (King and Webber 2008), which is lower than the TVA average of 39,300 gal/MWh. This is also due to a higher percentage of closed-cycle cooling systems in the national average compared to the TVA system, which was designed and located to specifically take advantage of open-cycle cooling. Although the individual plant water use factors vary, the TVA average water use factor appears to be fairly constant as the TVA average for 2005 was also 39,300 gal/MWh.

Browns Ferry Unit 1 returned to service in 2007 and Watts Bar Unit 2 is expected to begin commercial operation in 2013; the projected water use by all units at these plants is shown in Table 4-11. The addition of Browns Ferry Unit 1 is expected to slightly decrease the water returned to the river due to increased cooling tower operation. However, the plant water use factor for three unit operation is expected to be about the same as with two units operating. Because Watts Bar Unit 2 will primarily operate in closed-cycle, the plant water use factor is low but water consumption (withdrawal - return) will increase from that of Unit 1 operation.

Natural gas-fueled combined cycle generating plants require water to generate the steam used in powering the steam generator and to cool (condense) the steam. Water use requirements for TVA's Southaven plant is shown in Table 4-12. The Caledonia plant has contracted to use reclaimed wastewater, and Southaven uses groundwater. The Lagoon Creek combined-cycle plant, which began operations in September, 2010, uses groundwater and the John Sevier plant will use surface water and closed-cycle cooling. All of these facilities return or will return their process water to surface waters.

Table 4-11. Projected Browns Ferry and Watts Bar Nuclear Plant water use. Source: TVA data.

Facility	Units	Withdrawal (mgd)	Return (mgd)	Withdrawal - Return (mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh)
Browns Ferry*	1-3	3099.0	3094.3	4.7	27,921,676	40,511
Watts Bar**	1-2	274.0	234.0	40.0	20,297,000	4,927

*Browns Ferry Notes:

1. Withdrawal based on flow test data.
2. Withdrawal less Return based on a 2.6 percent increase in cooling tower operation with three units compared to two units (TVA 2002).
3. Net Generation is shown as an example assuming that the water use factor for two unit operation is the same for three unit operation.

**Watts Bar Notes:

1. Withdrawal and Return are based on total two-unit generation of 2317 MW (Hopping 2010).
2. Net Generation is shown as an example based on 2317 MW with capacity factor = 1.0 applied.

Table 4-12. TVA combined-cycle generating plant water use.

Facility	Units	Withdrawal (mgd)	Return (mgd)	Withdrawal - Return (mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh)
Southaven, MS*	3	3.3	0.3	3	1,646,268	732

*2005 data, prior to TVA's acquisition of the facility

Although TVA generates the preponderance of electrical energy in the region, there are non-TVA power plants that used significant volumes of water in 2005 (Table 4-13). Four of these plants, Red Hills, Caledonia, Decatur, and Morgan, sell all or a large amount of their electricity to TVA.

Table 4-13. Regional non-TVA power generation and thermoelectric water use.

Facility	Units	Withdrawal (mgd)	Return (mgd)	Withdrawal - Return (mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh
			Coal			
Asheville, NC*	4	262.6	262.5	0.1	2,333,900	41,068
Clinch River, VA*	3	15.16	3.2	11.96	3,931,000	1,408
Red Hills, MS**	3	5.9	0	5.9	3,239,873	664
			Combined-Cycle			
Batesville, MS*	3	2.13	0.5	1.63	1,785,447	435
Caledonia, MS*	2	4	0.8	3.2	1,076,577	1,356
Decatur Energy Center, AL*	3	1.2	0.4	0.8	1,214,000	361
Morgan Energy Center, AL	3					
Magnolia, MS	3		0.04		1,525,750	NA

*2005 data, reported in Bohac and McCall (2008)
**TVA (1998)

The Asheville, Clinch River, Batesville, and Decatur plants use surface water and return their process water to surface waters. The Red Hills plant uses groundwater and does not discharge process water. The Magnolia plant uses groundwater and discharges to surface waters. The Caledonia plant uses reclaimed wastewater.

Current environmental regulations make it very difficult for new thermoelectric plants to use open-cycle cooling. A 2004 U.S. Second Circuit Court of Appeals decision effectively requires all new power plants to install closed-cycle cooling technology.

4.8. Aquatic Life

The TVA region encompasses portions of several major river systems including all of the Tennessee River drainage and portions of the Cumberland River drainage, Mobile River drainage (primarily the Coosa and Tombigbee Rivers), and larger eastern tributaries to the Mississippi River in Tennessee and Mississippi. These river systems support a large variety of freshwater fishes and invertebrates (including freshwater mussels, snails, crayfish, and insects). Due to the presence of several major river systems, the region's high geologic diversity (see Section 4.4), and the lack of glaciation, the region is recognized as a globally important area for freshwater biodiversity (Stein et al. 2000).

The Tennessee River Basin

The Tennessee River drainage is the dominant aquatic system within the TVA region and the most TVA generating facilities are within the watershed. The construction of the TVA dam and reservoir system fundamentally altered both the water quality and physical environment of the Tennessee River and its tributaries. While dams promote navigation, flood control, power benefits, and river-based recreation by moderating the flow effects of floods and droughts throughout the year, they also disrupt the daily, seasonal, and annual flow patterns that are characteristic of a river. Damming of the most of the rivers was done at a time when there was little regard for aquatic resources (Voigtlander and Poppe 1989). Beyond changes in water quality, flood control activities and hydropower generation have purposefully altered the flow regime (the main variable in aquatic systems) to suit human demands (Cushman 1985).

TVA has undertaken several major efforts (e.g., TVA's Lake Improvement Plan, Reservoir Release Improvements Plan, and Reservoir Operations Study (ROS; (TVA 2004)) to mitigate some of these impacts on aquatic habitats and organisms. While these actions have resulted in improvements to water quality and habitat conditions in the Tennessee River drainage, the Tennessee River and its tributaries remain substantially altered by human activity.

<u>Mainstem Reservoirs</u> - The nine mainstem reservoirs on the Tennessee River differ from tributary reservoirs primarily in that they are shallower, have greater flows, and thus, retain the water in the reservoir for a shorter period of time. Although dissolved oxygen in the lower lake levels is often reduced, it is seldom depleted. Winter drawdowns on mainstem reservoirs are much less severe than tributaries, so bottom habitats generally remain wetted all year. This benefits benthic organisms, but promotes the growth of aquatic plants in the extensive shallow overbank areas of some reservoirs. Tennessee River mainstem reservoirs generally support healthy fish communities, ranging from about 50 to 90 species per reservoir. Good to excellent sport fisheries exist, primarily for black bass, crappie, sauger, white and striped bass, sunfish, and catfish. The primary commercial species are channel and blue catfish and buffalo.

<u>Tributary Reservoirs and Tailwaters</u> - Tributary reservoirs are typically deep and retain water for long periods of time. This results in thermal stratification, the formation of an upper layer that is warmer and well oxygenated, an intermediate layer of variable thickness, and a lower layer that is colder and poorly oxygenated. These aquatic habitats are simplified compared to undammed streams, and fewer species are found. Aquatic habitats in the tailwater can also be impaired due to a lack of minimum flows and low dissolved oxygen levels. This may restrict the movement, migration, reproduction, and available food supply of fish and other organisms. Dams on tributary rivers affect the habitat of benthic invertebrates (benthos), which are a vital part of the food chain of aquatic ecosystems. Benthic life includes worms, snails and crayfish, which spend all of their lives in or on the stream beds, and aquatic insects, mussels and clams, which live there during all or part of their life-cycles. Many benthic organisms have narrow habitat requirements that are not always met in reservoirs or tailwaters below dams. Further downstream from dams, the

number of benthic species increases as natural reaeration occurs and dissolved oxygen and temperatures rise.

Other Drainages in the TVA Region

The other major drainages within the TVA region (the Cumberland, Mobile, and Mississippi River drainages) share a diversity of aquatic life equal to or greater than that found in the Tennessee River drainage. As with the Tennessee River, these river systems have seen extensive human alteration including construction of reservoirs, navigation channels and locks. Despite these changes (as with the Tennessee River drainage), remarkably diverse aquatic communities are present in each of these river systems.

Major TVA generating facilities located in these watersheds include Allen Fossil Plant (Mississippi River), Cumberland and Gallatin Fossil Plants (Cumberland River), Paradise Fossil Plant (Green River/Ohio River), and Shawnee Fossil Plant (Ohio River). With the exception of the Marshall County facility, TVA's free-standing natural gas-fueled generating facilities are located in the Mississippi and Mobile River drainages.

4.9. Vegetation and Wildlife

The TVA region encompasses nine ecoregions (Omernik 1987) which generally correspond with physiographic provinces and sections (see Section 4.4 and Figure 4-31). The terrain, plant communities, and associated wildlife habitats in these ecoregions vary from bottomland hardwood and cypress swamps in the floodplains of the Mississippi Alluvial Plain to high elevation balds and spruce-fir and northern hardwood forests in the Blue Ridge. About 3,500 species of herbs, shrubs and trees, 55 species of reptiles, 72 species of amphibians, 182 species of breeding birds, and 76 species of mammals occur in the TVA region (Ricketts et al. 1999, Stein 2002, TWRA 2005, TOS 2007). Although many plants and animals are widespread across the region, others are restricted to one or a few ecoregions. For example, high elevation communities in the Blue Ridge support several plants and animals found nowhere else in the world (Ricketts et al. 1999), as well as isolated populations of species typically found in more northern latitudes.

Regional Vegetation

The southern Blue Ridge Ecoregion, which corresponds to the Blue Ridge physiographic province, is one of the richest centers of biodiversity in the eastern United States and one of the most floristically diverse (Griffith et al. 1998). The most prevalent land cover (80 percent) is forest, which is dominated by the diverse, hardwood-rich mesophytic forest and its Appalachian oak sub-type (Dyer 2006; USGS 2008). About 14 percent of the land cover is agricultural and most of the remaining area is developed. Relative to the other eight ecoregions, the Blue Ridge Ecoregion has shown the least change in land cover since the 1970s (USGS 2008).

Over half (56 percent) of the Ridge and Valley Ecoregion, which corresponds to the Valley and Ridge physiographic province, is forested. Dominant forest types are the mesophytic forest and Appalachian oak sub-type, and, in the southern portion of the region, the southern mixed forest and oak-pine sub-type (Dyer 2006, USGS 2008). About 30 percent of the area is agricultural and 9 percent is developed (USGS 2008).

The Cumberland Mountains physiographic section comprises the southern portion of the Central Appalachian Ecoregion. This ecoregion is heavily forested (83 percent), primarily with mesophytic forests including large areas of Appalachian oak (Dyer 2006, USGS 2008). The remaining land cover is mostly agriculture (7 percent), developed areas (3 percent), and mined areas (3 percent). The dominant source of land cover change since the 1970s has been mining (USGS 2008), and this ecoregion, together with the Southwestern Appalachian Ecoregion, comprises much of the Appalachian coalfield.

The Southwestern Appalachian Ecoregion corresponds to the Cumberland Plateau physiographic section. About 75 percent of the land cover is forest, predominantly mesophytic forest; about 16 percent is agricultural and 3 percent is developed (USGS 2008). The rate of land cover change since the 1970s is relatively high, mostly due to forest management activities.

The Interior Plateau Ecoregion consists of the Highland Rim and Nashville Basin physiographic sections. The limestone cedar glades and barrens communities associated with thin soils and limestone outcrops in the Nashville Basin support rare, diverse plant communities with a high proportion of endemic species (Baskin and Baskin 2003). About 38 percent of the ecoregion is forested, 50 percent in agriculture, and 9 percent developed (USGS 2008). Forests are predominantly mesophytic, with a higher proportion of American beech, American basswood, and sugar maple than in the Appalachian oak subtype (Dyer 2006). Eastern red cedar is also common.

A small area in the northwest of the TVA region is in the Interior River Valley and Hills Ecoregion, which overlaps part of the Highland Rim physiographic section. This ecoregion is relatively flat lowland dominated by agriculture and forested hills. It contains much of the Illinois Basin coalfield. Drainage conditions and terrain strongly affect land use. Bottomland deciduous forests and swamp forests were common on wet lowland sites, with mixed oak and oak-hickory forests on uplands. A large portion of the lowlands have been cleared for agriculture. About 20 percent of the ecoregion is forested and almost two-thirds is agricultural (USGS 2008). About 7 percent is developed and 5 percent is wetlands. The rate of land cover change since the 1970s is moderate and primarily from forest to agricultural and from agriculture and forest to developed.

The Southeastern Plains and Mississippi Valley Loess Plain Ecoregions correspond to, respectively, eastern and western portions of the East Gulf Coastal Plain physiographic section. They are characterized by a mosaic of forests (52 percent of the land area), agriculture (22 percent), wetlands (10 percent) and developed areas (10 percent). Forest cover decreases and agricultural land increases from east to west. Natural forests of pine, hickory, and oak once covered most of the ecoregions, but much of the natural forest cover has been replaced by heavily managed timberlands, particularly in the Southeastern Plains (USGS 2008). The Southeastern Plains in Alabama and Mississippi include the Black Belt, an area of rich dark soils and prairies. Much of this area has been cleared for agricultural purposes and only remnant prairies remain. Of the nine ecoregions in the TVA region, the rate of land cover change in the Southeastern Plains Ecoregion is the highest, with intensive forest management practices the leading cause. The rate of land cover change in the Mississippi Valley Loess Plain Ecoregion is moderate relative to the other ecoregions.

The Mississippi Alluvial Plain is a flat floodplain area originally covered by bottomland deciduous forests. A large portion has been cleared for agriculture and subjected to drainage activities including stream channelization and extensive levee construction. Most of the land cover is agricultural and the remaining forests are southern floodplain forest dominated by oak, tupelo, and bald cypress. The rate of land cover change since the 1970s has been moderate (USGS 2008).

The major forest regions in the TVA region include mesophytic forest, southern-mixed forest, and Mississippi alluvial plain (Dyer 2006). The mesophytic forest is the most diverse with 162 tree species. While canopy dominance is shared by several species, red maple and white oak have the highest average importance values. A distinct section of the mesophytic forest, the Appalachian oak section, is dominated by several species of oak including black, chestnut, northern red, scarlet, and white oak. The Nashville Basin mesophytic forest has close affinities with the beech-maple-basswood forest that dominates much of the Midwest. The oak-pine section of the southern mixed forest region is found in portions of Alabama, Georgia, and Mississippi, where the dominant species are loblolly pine, sweetgum, red maple and southern red oak (Dyer 2006). The Mississippi Alluvial Plain forest region is restricted to its namesake physiographic region. The bottomland forests in this region are dominated by American elm, bald cypress, green ash, sugarberry, and sweetgum.

Numerous plant communities (recognizable assemblages of plant species) occur in the TVA region. Several of these are rare, restricted to very small geographic areas, and/or threatened by human activities. A disproportionate number of these imperiled communities occur in the Blue Ridge region; smaller numbers are found in the other ecoregions (NatureServe 2009). Many of these imperiled communities occur in the Southern Appalachian spruce-fir forest; cedar glades; grasslands, prairies and barrens; Appalachian bogs, fens and seeps; and bottomland hardwood forest ecosystems. Major threats to the Southern Appalachian spruce-fir forest ecosystem include invasive species such as the balsam wooly adelgid, acid deposition, ozone exposure, and climate change (TWRA 2009). The greatest concentration of cedar glades is in the Nashville Basin; a few also occur in the Highland Rim and the Valley and Ridge. Cedar glades contain many endemic plant species, including a few listed as endangered (Baskin and Baskin 2003); threats include urban development, highway construction, agricultural activities, reservoir impoundment, and incompatible recreational use. The category of grasslands, prairies and barrens includes remnant native prairies; they are scattered across the TVA region but most common on the Highland Rim. This category also includes the high elevation grassy balds in the Blue Ridge and the Black Belt prairie in the East Gulf Coastal Plain. Threats to these areas include agricultural and other development, invasive plants, and altered fire regimes. Appalachian bogs, fens and seeps are often small, isolated, and support several rare plants and animals. Threats include drainage for development and altered fire regimes. Bottomland hardwood forests are most common in the Mississippi Alluvial Plain and East Gulf Coastal Plain; they also occur in the physiographic regions. About 60 percent of their original area is estimated to have been lost, largely by conversion to croplands (EPA 2008b).

Wildlife Population Trends

Many animals are wide-ranging throughout the TVA region; most species that are tolerant of humans have stable or increasing populations. The populations of many animals have been greatly altered by changes in habitats from agriculture, mining, forestry, urban and suburban development, and the construction of reservoirs. While some species flourish under these changes, others have shown marked declines. For example, populations of some birds dependent on grassland and woodland dependent birds have shown dramatic decreases in their numbers (SAMAB 1996). Across North America, 48 percent of grassland-breeding birds are of conservation concern because of declining populations, as are 22 percent of forest-breeding birds (NABCI 2009). A large number of the declining birds are Neotropical migrants, species that nest in the United States and Canada and winter south of the United States. Over 30 species of birds breeding in the TVA region are considered to be of conservation concern (USFWS 2008). The primary causes for their declines are the loss and fragmentation of habitats from urban and suburban development and agricultural and forest management practices.

In general gulls, wading birds, waterfowl, raptors, upland game birds (with the exception of the northern bobwhite), and game mammals are stable or increasing in the TVA region. Population trends of much non-game wildlife other than birds (e.g., reptiles, amphibians, and small mammals) are poorly known. The construction of the TVA and Corps of Engineers reservoir systems created large areas of habitat for waterfowl, herons and egrets, ospreys, gulls, and shorebirds, especially in the central and eastern portions of the TVA region where this habitat was limited. Ash and gypsum settling and storage ponds at TVA fossil plants also provide regionally important habitat for these birds and other wetland species. These increases in habitat, as well as the ban on the use of the pesticide DDT, have resulted in large increases in the local populations of several birds. Both long-term and short-term changes in the operation of the reservoir system affect the quality of habitat for these species (TVA 2004) as do pond management practices at fossil plants.

Invasive Species

Invasive species are species that are not native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (NISC 2008). Invasive species include terrestrial and aquatic plants and animals as well as other organisms such as microbes. Human actions, both intentional and unintentional, are the primary means of their introductions.

Four plants designated by the U.S. Department of Agriculture as noxious weeds under the Plant Protection Act occur in the TVA region: hydrilla, giant salvinia, cogongrass, and tropical soda apple. Hydrilla is a submersed aquatic plants present in several TVA reservoirs. Giant salvinia, also an aquatic plant, occurs in ponds, reservoirs, and slow-moving streams. It primarily occurs south of the TVA region and has not yet been reported from the Tennessee River drainage. Cogongrass is an upland plant present in several TVA region counties in Alabama and Mississippi. It occurs on and in the vicinity of several TVA transmission line right-of-ways and can be spread by line construction and maintenance activities. Tropical soda apple has been reported from a few counties in the TVA region and primarily occurs in agricultural areas.

Several additional invasive plants that are considered to be of severe threat or significant threat (TEPPC 2001) occur on or in the immediate vicinity of TVA generating facilities and transmission line right-of-ways. These include tree-of-heaven, Asian bittersweet, autumn olive, Chinese privet, kudzu, phragmites, Eurasian water-milfoil, multiflora rose, and tall fescue. Phragmites occurs in ash ponds at several TVA coal-fired plants and is otherwise uncommon in the TVA region.

Invasive aquatic animals in the TVA region that harm or potentially harm aquatic communities include the common, grass, bighead and silver carp, alewife, blueback herring, rusty crayfish, Asiatic clam, and zebra mussel. Because of their potential to affect water intake systems, TVA uses chemical and warm-water treatments to control Asiatic clams and zebra mussels at its generating facilities.

Invasive terrestrial animals at TVA generating facilities which occasionally require management include the rock pigeon, European starling, house sparrow, and fire ant. These species have little effect on the operation of TVA's power system.

4.10. Endangered and Threatened Species

In recognition of the declining populations of fish, wildlife and plant species, the Endangered Species Act of 1973 (ESA; 16 U.S.C. §§ 1531-1543) was passed to conserve the ecosystems upon which endangered and threatened species depend. Endangered species are defined by the ESA as any species in danger of extinction throughout all or a significant portion of its range. A threatened species is likely to become endangered within the foreseeable future throughout all or a significant part of its range. The ESA establishes programs to conserve and recover these species and makes their conservation a priority for federal agencies.

Thirty-seven species of plants, one lichen, and 109 species of animals in the TVA region area are listed under the ESA as endangered or threatened species or formally proposed for such listing by the U.S. Fish and Wildlife Service. An additional 31 species in the TVA region have been identified by the U.S. Fish and Wildlife Service as candidates for listing under the ESA. Several areas across the TVA region are also designated under the ESA as critical habitat essential to the conservation of listed species.

All of the seven states in the TVA region have passed laws protecting endangered and threatened species. The number of species on these state lists and the degree of protection they receive varies among the states. In addition to the species listed under the ESA, about 750 plant species and 1,500 animal species are formally listed by one or more of the states or considered as sensitive species.

The highest concentrations of terrestrial species listed under the ESA occur in the Blue Ridge, Appalachian Plateaus, and Interior Low Plateau regions. The highest concentrations of listed aquatic species occur in these same regions. Relatively few listed species occur in the Coastal Plain and Mississippi Alluvial Plain regions. The taxonomic groups with the highest proportion of species listed under the ESA are fish and mollusks. Factors contributing to the high proportions of vulnerable species in these groups include the high number of endemic species in the TVA region and the alteration of their habitats by reservoir construction and water pollution. River systems with the highest numbers of listed aquatic species include the Tennessee, Cumberland, Coosa, and Mobile rivers.

Populations of a few listed species have increased to the point where they are no longer listed under the ESA (e.g., bald eagle, peregrine falcon, Eggert's sunflower) or their listing status has been downgraded from endangered to threatened (e.g., snail darter, large flowered skullcap, small whorled pogonia). Other listed species with increasing populations include the gray bat. Among the listed species with populations that continue to decline are the Indiana bat and the American hart's tongue fern. Population trends of many listed species in the TVA region are poorly known.

Thirty-seven species listed under the ESA occur in the immediate vicinity of the TVA reservoir system and are potentially affected by its operation (TVA 2004, USFWS 2006). The major reservoir system habitats supporting listed species are flowing (unimpounded) mainstem reaches and warm tributary tailwaters. Other habitats in the TVA region less associated with the TVA reservoir system and supporting high concentrations of listed species include free-flowing rivers, caves, and limestone cedar glades. TVA has recently taken several actions to minimize the adverse effects of its operation of the reservoir system on endangered and threatened species (TVA 2004, USFWS 2006).

At least 11 species listed or candidates for listing under the ESA occur on or in the immediate vicinity of TVA generating facility reservations. These include the following:

- Large-flowered skullcap, *Scutellaria montana* - Threatened
- Gray bat, *Myotis grisescens* - Endangered
- Dromedary pearlymussel, *Dromus dromas* - Endangered
- Fanshell, *Cyprogenia stegaria* - Endangered
- Pink mucket, Lampsilis abrupta - Endangered
- Ring pink, *Obovaria retusa* - Endangered
- Rough pigtoe, *Pleurobema plenum* - Endangered
- White wartyback, *Plethobasis cicatricosus* - Endangered
- Slabside pearlymussel, *Lexingtonia dolabelloides* - Candidate for listing
- Spectaclecase, *Cumberlandia monodonta* - Candidate for listing
- Anthony's river snail, *Athernia anthonyi* - Endangered

Species listed or candidates for listing under the ESA that occur on or in the immediate vicinity of TVA transmission line right-of-ways include the following:

- Braun's rock-cress, *Arabis perstellata* - Endangered
- Cumberland sandwort, *Minuartia cumberlandensis* - Endangered
- Fleshy-fruit gladecress, *Leavenworthia crassa* - Candidate for listing
- Green pitcher plant, *Sarracenia oreophila* - Endangered
- Large-flowered skullcap, *Scutellaria montana* - Threatened
- Leafy prairie-clover, *Dalea foliosa* - Endangered
- Monkey-face orchid, *Platanthera integrilabia* - Candidate for listing
- Price's potato-bean, *Apios priceana* - Threatened
- Pyne's ground plum, *Astragalus bibullatus* - Endangered
- Shorts bladderpod, *Lesquerella globosa* - Candidate for listing
- Spring Creek bladderpod, *Lesquerella perforata* - Endangered
- Tennessee coneflower, *Echinacea tennesseensis* - Endangered
- Gray bat, *Myotis grisescens* - Endangered

TVA transmission lines also cross many streams supporting listed aquatic species.

4.11. Wetlands

Wetlands are areas that are inundated or saturated by water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (EPA regulations at 40 C.F.R § 230.3(t)). Wetlands generally include swamps, marshes, bogs and similar areas. Wetlands are highly productive and biologically diverse ecosystems that provide multiple public benefits such as flood control, reservoir shoreline stabilization, improved water quality, and habitat for fish and wildlife resources.

Wetlands occur across the TVA region and are most extensive in the south and west where they comprise 5 percent or more of the landscape (USGS 2008). Wetlands in the TVA region consist of two main systems: palustrine wetlands such as marshes, swamps and bottomland forests dominated by trees, shrubs, and persistent emergent vegetation, and lacustrine wetlands associated with lakes such as aquatic bed wetlands (Cowardin et al. 1979). Riverine wetlands associated with moving water within a stream channel are also present but relatively uncommon. Almost 200,000 acres of wetlands are associated with the TVA reservoir system, where they are more prevalent on mainstem reservoirs and tailwaters than tributary reservoirs and tailwaters (TVA 2004). Almost half of this area is forested wetlands; other types include aquatic beds and flats, ponds, scrub/shrub wetlands, and emergent wetlands. Emergent wetlands occur on many TVA generating facility sites, often in association with ash disposal ponds and water treatment ponds. Scrub-shrub and emergent wetlands occur within the right-of-ways of many TVA transmission lines. A large proportion of these wetlands were forested before the transmission lines were constructed.

National and regional trends studies have shown a large, long-term decline in wetland area both nationally and in the southeast (Dahl 2000, Dahl 2006, Hefner et al. 1994). Wetland losses have been greatest for forested and emergent wetlands, and have resulted from drainage for agriculture, forest management activities, urban and suburban development, and other factors. The rate of loss has significantly slowed over the past 10 years due to regulatory mechanisms for wetland protection. These include the Clean Water Act and state water quality legislation. Executive Order 11990—Protection of Wetlands requires federal agencies to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance their natural and beneficial values.

4.12. Parks, Managed Areas, and Ecologically Significant Sites

Numerous areas across the TVA region are recognized and, in many cases, managed for their recreational, biological, historic, and scenic resources. These areas are owned by federal and state agencies, local governments, and private corporations and individuals. They are typically managed for one or more of the following objectives:

- Recreation—areas managed for outdoor recreation or open space. Examples include national, state, and local parks and recreation areas; reservoirs (TVA and other); picnic and camping areas; trails and greenways; and TVA small wild areas.
- Species/Habitat Protection—places with endangered or threatened plants or animals, unique natural habitats, or habitats for valued fish or wildlife populations. Examples include national and state wildlife refuges, mussel sanctuaries, TVA habitat protection areas, and nature preserves.
- Resource Production/Harvest—lands managed for production of forest products, hunting, and fishing. Examples include national and state forests, state game lands and wildlife management areas, and national and state fish hatcheries.
- Scientific/Educational Resources—lands protected for scientific research and education. Examples include biosphere reserves, research natural areas, environmental education areas, TVA ecological study areas, and federal research parks.
- Historic Resources—lands with significant historic resources. Examples include national battlefields and military parks, state historic sites, and state archeological areas.
- Scenic Resources—areas with exceptional scenic qualities or views. Examples include national and state scenic trails, scenic areas, wild and scenic rivers, and wilderness areas.

Numerous parks, managed areas, and ecologically significant sites occur in the TVA region. These areas occur throughout the TVA region in all physiographic areas; they are most concentrated in the Blue Ridge and Mississippi Alluvial Plain physiographic areas. Individual areas vary in size from a few acres to thousands of acres. Many cross state boundaries or are managed cooperatively by several agencies.

Parks, managed areas, and ecologically significant sites occur on or immediately adjacent to many TVA generating facility reservations, including Allen, Colbert, Gallatin, Kingston, Paradise and Shawnee fossil plants, Watts Bar Nuclear Plant, and the Bellefonte site. This is especially the case at hydroelectric plants, where portions of the original reservation lands have been developed into state and local parks. TVA transmission line right-of-ways cross six National Park Service units, eight National Forests, five National Wildlife Refuges, and numerous state wildlife management areas, state parks, and local parks.

4.13. Land Use

Major land uses in the TVA region include forestry, agriculture, and urban/ suburban/industrial (USDA 2009). About three percent of the area of the TVA region is water, primarily lakes and rivers. This proportion has increased slightly since 1982, primarily due to the construction of small lakes and ponds. About 5.5 percent of the land area is Federal land; this proportion has also increased slightly since 1982. Of the remaining non-Federal land area, about 12 percent is classified as developed and 88 percent as rural. Rural undeveloped lands include farmlands (28 percent of the land area) and forestland (about 60 percent of the land area). The greatest change since 1982 has been in developed land, which almost doubled in area due to high rates of urban and suburban growth in much of the TVA region. Forestland increased in area through much of the 20th century; this rate of increase has slowed and/or reversed in parts of the TVA region in recent years (Conner and Hartsell 2002, USDA 2009). Both cropland and pastureland have decreased in area since 1982 (USDA 2009).

<u>Agriculture</u> - Agriculture is a major land use and industry in the TVA region. In 2007, 27.8 percent of the land area in the TVA region was farmland and part of 147,349 individual farms (USDA 2007). Average farm size was 158 acres. Almost half (48.5 percent) of the farmland was classified as cropland in 2007; this classification includes hay and short rotation woody crops. A quarter (26.3 percent) of the farmland was pasture and the remainder was woodland or devoted to other uses such as buildings and other farm infrastructure. Farm size in the TVA region varies considerably with numerous small farms and a smaller number of large farms. The median farm size in most counties is generally less than 100 acres, and increases from east to west (USDA 2007).

Farms in the TVA region produce a large variety of products that varies across the region. While the proportion of land in farms is greatest in southern Kentucky and central and western Tennessee, the highest farm income occurs in northern Alabama and Georgia (EPRI and TVA 2009). Compared to farms in the southern and western portions of the TVA region, farms in the eastern and northern portions tend to be smaller and receive a higher proportion of their income from livestock sales than from crop sales. Region-wide, the major crop items by land area are forage crops (hay and crops grown for silage), soy, corn, and cotton. The major farm commodities by sales are cattle and calves, poultry and eggs, grains and beans, cotton, and nursery products (USDA 2007).

Although the area of irrigated farmland is small (1.2 percent of farmland), it increased by 143 percent between 1987 and 2007 to 281,741 acres (Bureau of Census 1989, USDA 2007). The area of irrigated farmland is likely to increase in the future as temperature and precipitation patterns become less predictable or drought conditions become more prevalent (EPRI and TVA 2009).

Crops grown specifically to produce biomass for use as fuels (dedicated energy crops) are a potentially important commodity in the TVA region. In 2002, the Census of Agriculture began recording information on short rotation woody crops, which grow from seed to a mature tree in 10 years or less. These have traditionally been used by the forest products industry for producing paper or engineered wood products. They are also a potential source of biomass for power generation. In 2007, there were 286 farms in the TVA region growing at least 12,433 acres of short rotation woody crops and 109 farms harvested over 1,326 acres of short rotation woody crops (USDA 2007).

Prime Farmland - The Farmland Protection Policy Act recognized the importance of prime farmland and the role that federal agencies can have in converting it to nonagricultural uses. The act requires federal agencies to consider the potential effects of their proposed actions on prime farmland and consider alternatives to actions that would adversely affect prime farmland.

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and that is available for these uses (NRCS 2009a). It has the combination of soil properties, growing season, and moisture supply needed to produce sustained high yields of crops in an economic manner if it is treated and managed according to acceptable farming methods. Prime farmland is designated independently of current land use, but it cannot be areas of water, urban, or built-up land.

Approximately 22 percent[6] of the TVA region is classified as prime farmland (NRCS 2009b). An additional 4 percent of the TVA region would be classified as prime farmland if drained or protected from flooding.

Forestry - About 97 percent of the forestland in the TVA region is classified as timberland (USFS 2010), forestland that is producing or capable of producing more than 20 cubic feet of merchantable wood per acre per year and is not withdrawn from timber harvesting by law. About 14 percent of timberland is in public ownership, primarily national forests. About 20 percent is owned by corporations and the remainder in non-corporate private ownership. While the majority of corporate timberlands have historically been owned by forest industries, this proportion has decreased in recent years as many forest industries have sold timberlands due to changing market conditions.

4.14. Cultural Resources

Cultural resources include archaeological sites, historic sites, and historic structures. Because of their importance to the Nation's heritage, they are protected by several laws and Federal agencies, including TVA, are to facilitate their preservation. The primary law governing the role of federal agencies in their management and preservation is the National Historic Preservation Act (NHPA; 16 U.S.C. §§ 470 et seq.). Other relevant laws include the Archaeological and Historic Preservation Act (16 U.S.C. §§ 469-469c), Archaeological Resources Protection Act (16 U.S.C. §§ 470aa-470mm), and the Native American Graves Protection and Repatriation Act (25 U.S.C. §§ 3001-3013).

Section 106 of the NHPA requires Federal agencies to consider the effect of their actions on historic properties and to allow the Advisory Council on Historic Preservation an opportunity to comment on the action. Section 106 involves four steps: 1) initiate the process; 2) identify historic properties; 3) assess adverse effects; and 4) resolve adverse

[6] This estimate does not include about 20 counties for which soil survey information is incomplete or not available.

effects. This process is carried out in consultation with the State Historic Preservation Officer of the state in which the undertaking takes place and with any other interested consulting parties, including federally recognized Indian tribes.

Historic properties are defined as buildings, structures, sites, objects, and districts that meet the Criteria for Eligibility for the National Register of Historic Places (NRHP). Sites can be considered eligible for the NRHP if they meet one or more criteria related to significant historical events, important historical persons, distinctive construction or artistic value, and potential to yield important information. In addition to these criteria, the property must possess integrity of location, design, setting, materials, workmanship, feeling, and association.

Section 110 of the NHPA sets out the broad historic preservation responsibilities of Federal agencies and is intended to ensure that historic preservation is fully integrated into their ongoing programs. Federal agencies are responsible for identifying and protecting historic properties and avoiding unnecessary damage to them. Section 110 also charges each Federal agency with the affirmative responsibility for considering projects and programs that further the purposes of the NHPA, and it declares that the costs of preservation activities are eligible project costs in all undertakings conducted or assisted by a Federal agency.

Archaeological Resources

The TVA region has been occupied by humans for over 15,000 years. The earliest documentation of archaeological research in the region dates back to the 19th Century when entities such as the Smithsonian Institute and individuals such as Cyrus Thomas undertook some of the first archaeological excavations in America to document the history of Native Americans (Guthe 1952).

Archaeological survey coverage and documentation in the region varies by state. Each state keeps records of archaeological resources in different formats. While digitization of this data is underway, no consistent database is available for determining the number of archaeological sites within the TVA region. Survey coverage on private land has been inconsistent and is largely project-based rather than focusing on high-probability areas so data is likely skewed. Based on the knowledge of the seven states located in the TVA region, TVA estimates that over 67,000 archaeological sites have been recorded. Significant archaeological excavations have occurred as a result of TVA and other Federal projects and have yielded impressive information regarding the prehistoric and historic occupation of the Southeastern United States. Notable recent excavations and related projects in the region include those associated with the Townsend, Tennessee highway expansion, Shiloh Mound mitigation on the Tennessee River in Hardin County, Tennessee, the Ravensford in Swain County, North Carolina, and documentation of prehistoric cave art in Alabama and Tennessee.

TVA was a pioneer in carrying out archaeological investigations during the construction of its dams and reservoirs in the 1930s and early 1940s (Olinger and Howard 2009). Since then, TVA has conducted numerous archaeological surveys associated with permitting and power generation and transmission system activities. These surveys, as well as other off-reservoir projects, have identified more than 2000 sites, including over 250 associated with transmission system activities, within the TVA region. A large proportion of these sites have not been evaluated for NRHP eligibility and the number eligible or potentially eligible for listing on the NRHP is unknown.

Historic Structures

Numerous historic structures, buildings, sites and districts occur across the TVA region. Over 5,000 historic structures have been recorded in the vicinity of TVA reservoirs and power system facilities. Of those evaluated for NRHP eligibility, at least 85 are listed in the NRHP and about 250 are considered eligible or potentially eligible for listing. TVA power system facilities listed in the NRHP include the Ocoee 1, Ocoee 2, Great Falls, and Wilson Dams, and hydroelectric plants. Wilson Dam is also listed as a National Historic Landmark. Power system facilities determined to be eligible or potentially eligible for the NRHP are associated with Blue Ridge, Chatuge, Hiwassee, Nottely, Ocoee 3, Apalachia, Fontana, Norris, Watts Bar, Pickwick, and Guntersville Dams and the decommissioned Watts Bar Steam Plant. The switch houses at several TVA substations are also likely eligible for listing, and some of the oldest transmission lines are potentially eligible for listing. Given their age and historical significance, some of TVA's operating coal-fired fossil plants are potentially eligible for listing.

4.15. Socioeconomics

This section describes socioeconomic conditions in the TVA region with the focus on the power service area consisting of the 170 counties where TVA is a major provider of electric power (Figure 1-1). In addition to population, economy, employment, and income, it describes the relative size and location of minority and low income populations.

Population

The population of the TVA power service area was about 8.4 million in 2000 (Bureau of Census 2000a). By 2009, it had increased to about 9.2 million (Bureau of Census 2010). If trends over recent decades continue, the total population will be about 10.9 million by 2030 (TVA data).

Population varies greatly among the counties in the region (Figure 4-37). The larger population concentrations tend to be located along river corridors: the Tennessee River and its tributaries from northeast Tennessee through Knoxville and Chattanooga into north Alabama; the Nashville area around the Cumberland River; and the Memphis area on the Mississippi River. Low population counties are scattered around the region, but most are in Mississippi, the Cumberland Plateau of Tennessee, and the Highland Rim of Tennessee and Kentucky.

About 65 percent of the region's total population lives in metropolitan areas[7] (Table 4-14). Two of these have populations greater than one million: Nashville, almost 1.6 million, and Memphis, almost 1.1 million in the region. The Knoxville and Chattanooga metropolitan areas have populations greater than 500,000. These four metropolitan areas account for about 42 percent of the region's population.

Although the proportion of the region's population living in metropolitan areas is lower than the national average of 84 percent, it is has been increasing and this trend is likely to continue in the future (TVA data). A substantial part of this increase is likely to follow the pattern of increases in the geographic size of metropolitan areas as growth spreads out from the central core of these areas. Increases in the cost of energy and transportation may dampen this trend, however, resulting in more concentrated growth patterns.

[7] The Chattanooga MSA has one county outside the TVA region, Dade County, GA; the Memphis MSA has three counties outside the TVA region, Crittenden County in Arkansas and DeSoto and Tunica counties in Mississippi.

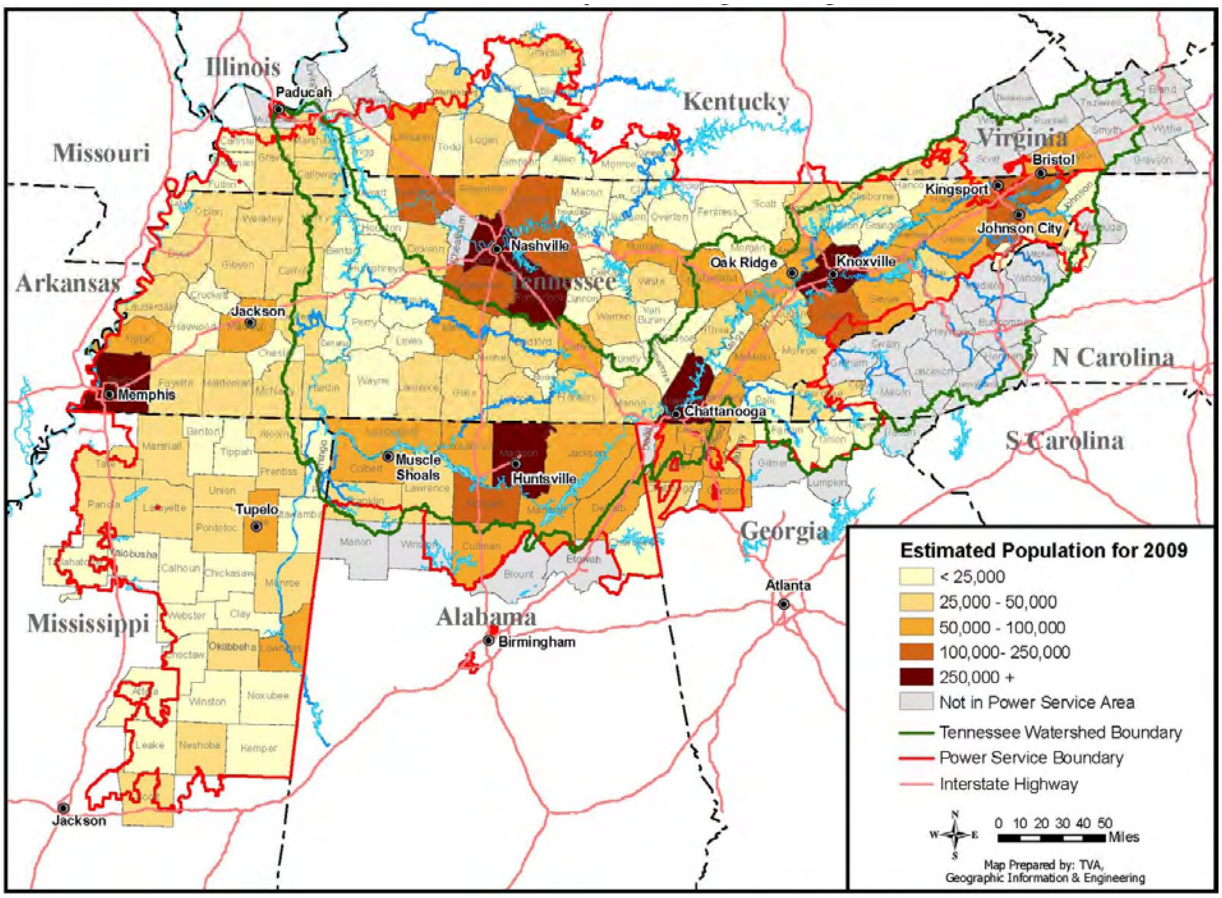


Figure 4-37. TVA region estimated 2009 population by county. Source: Bureau of Census (2010).

Economy and Employment

In 2008, the TVA region had an economy of about $361 billion in gross product and total personal income of about $286 billion, about 2.5 percent of the national total (USBEA 2010). Total nonfarm employment was slightly more than 4 million. While income levels in the region have increased relative to the nation over the past several decades, average income is still below the national level. 2008 per capita personal income averaged about $33,250, about 83 percent of the national average (USBEA 2010). The area is more rural and the economy depends more on manufacturing than does the nation as a whole. The area also has a larger proportion of agricultural workers than the nation as a whole.

Manufacturing — The manufacturing sector is relatively more important in the region than in the nation overall, providing about 12 percent of regional employment and 17 percent of regional earnings (Figure 4-38), compared to the national rates of 8 percent and 11 percent respectively. The relative importance of manufacturing has been declining for a number of years, both nationally and regionally. The estimated manufacturing employment in the TVA region is about 631,000 at the present time, a sharp decrease from its level of almost 852,000 ten years ago. Manufacturing in the TVA region accounts for about 2.5 percent of all manufacturing earnings in the nation, and is expected to maintain this share. Factors contributing to the high proportion of manufacturing include location with good access to 852,000 ten years ago. Manufacturing in the TVA region accounts for about 2.5 percent of all manufacturing earnings in the nation, and is expected to maintain this share. Factors

Table 4-14. TVA region metropolitan areas (Source: Bureau of Census 2000a, 2010).

Metropolitan Area	2000 (Census of Population)	2009 (Census Estimate)	2030 (Projection based on trend, 1970 to 2009)	2030 (Projection based on trend, 1980 to 2009)
Bowling Green, KY	104,166	120,595	143,901	144,821
Chattanooga, TN-GA	461,377	508,176	569,980	563,540
Clarksville, TN-KY	232,000	268,546	329,982	333,762
Cleveland, TN	104,015	113,358	140,995	137,536
Dalton, GA	120,031	134,319	171,322	172,717
Decatur, AL	145,867	151,399	179,790	176,345
Florence-Muscle Shoals, AL	142,950	144,238	159,582	152,547
Huntsville, AL	342,376	406,316	482,141	509,431
Jackson, TN	107,377	113,629	134,366	134,614
Johnson City, TN	181,607	197,381	229,429	226,895
Kingsport-Bristol-Bristol, TN-VA	275,081	273,044	320,109	306,493
Knoxville, TN	616,079	699,247	818,292	826,277
Memphis, TN-AR	1,037,912	1,082,749	1,227,188	1,228,318
Morristown, TN	123,081	137,612	166,680	166,139
Nashville- Davidson-Murfreesboro, TN	1,311,789	1,582,264	1,952,115	2,023,164
Total	5,305,708	5,942,873	7,025,872	7,102,600

contributing to the high proportion of manufacturing include location with good access to markets in the Northeast, Midwest, and Southwest, as well as the rest of the Southeast, good transportation, relatively low wages and cost of living, right-to-work laws, and abundant, relatively low-cost resources including land and electricity.

While the mix of manufacturing industries varies considerably across the region, there has been a continuing shift from non-durable goods, such as apparel, to durable goods, such as automobiles. In 1990, about 48 percent of manufacturing jobs were in durables. That share has increased to about 53 percent, and this increase is expected to continue (TVA data). Nondurable goods manufacturing peaked about 1993; the most notable decline has been in apparel and other textile products, which declined from about 13 percent of regional manufacturing in 1990 to about 2 percent in 2009 (TVA data). Nationally, there has been a slight increase in the share of non-durables, from about 40 percent in the year 2000 to a little more than 41 percent currently.

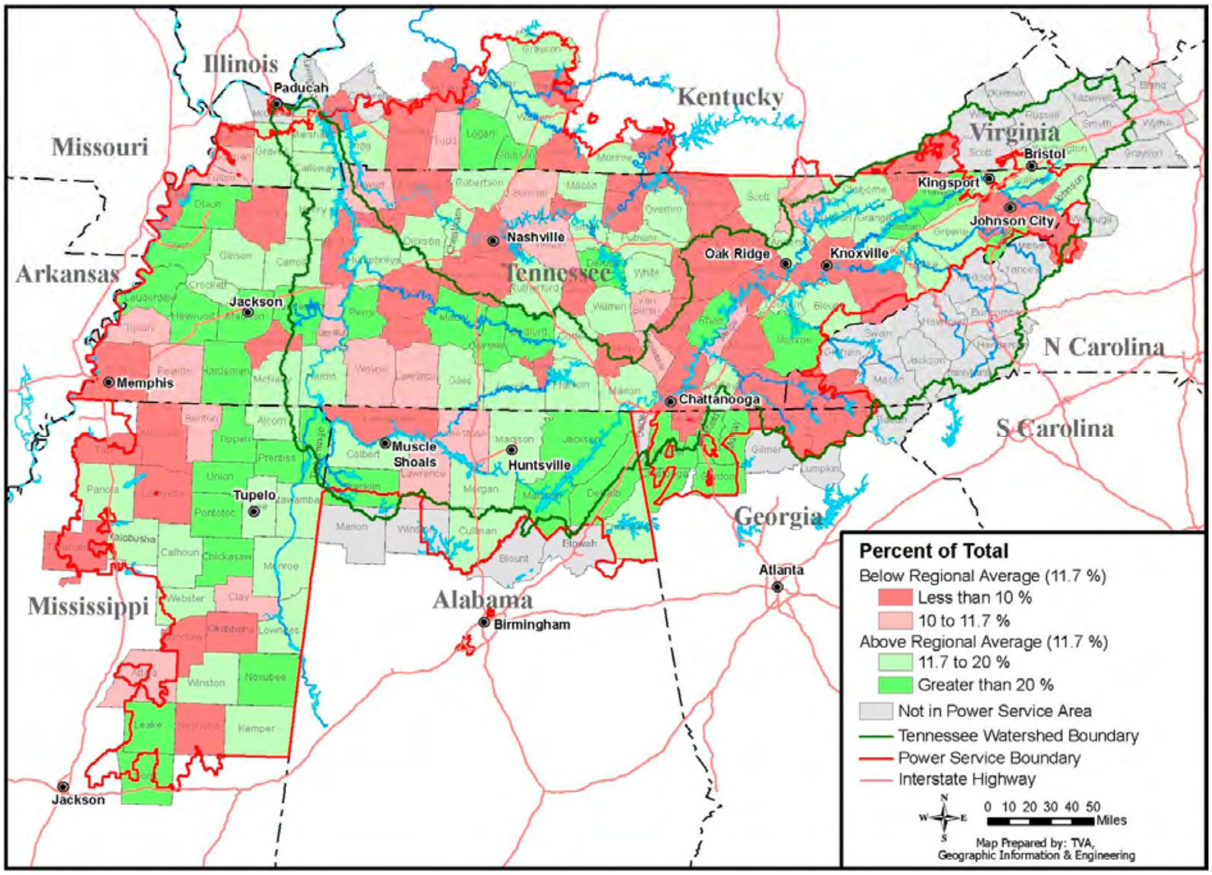


Figure 4-38. Manufacturing employment as proportion of total employment in 2008. Source: USBEA (2010).

Agriculture — The total market value of farm products produced in the TVA region in 2007 was $8.6 billion; 63 percent of this total ($6.2 billion) was from the sale of livestock, poultry, and their products and 27 percent ($2.3 billion) was from the sale of crops (USDA 2007). The regional farm sector provides approximately 141,000 jobs, about 2.6 percent of all jobs in the region (Figure 4-39). This is greater than the national average of 1.5 percent of workers employed in farming, and, like the national average, has decreased in recent decades. Part of this decrease is due to efficiency increases.

Much of the farming in the region is done on a part-time basis, and only 38.9 percent of principal farm operators in Tennessee reported farming as their primary occupation. Net cash farm income averaged $3,075 per farm, much less than the nationwide average of $33,827 (USDA 2007).

There is a large amount of diversity among farms in the region. For example, cotton is an important crop in parts of Mississippi and the western part of Tennessee. Soybeans are common through much of the region, and fruit and vegetable farming is widespread but generally in small operations. Pork and beef production are also widespread. Wholesale production of trees and shrubs for the commercial nursery industry is important in the southeastern Highland Rim of Tennessee.

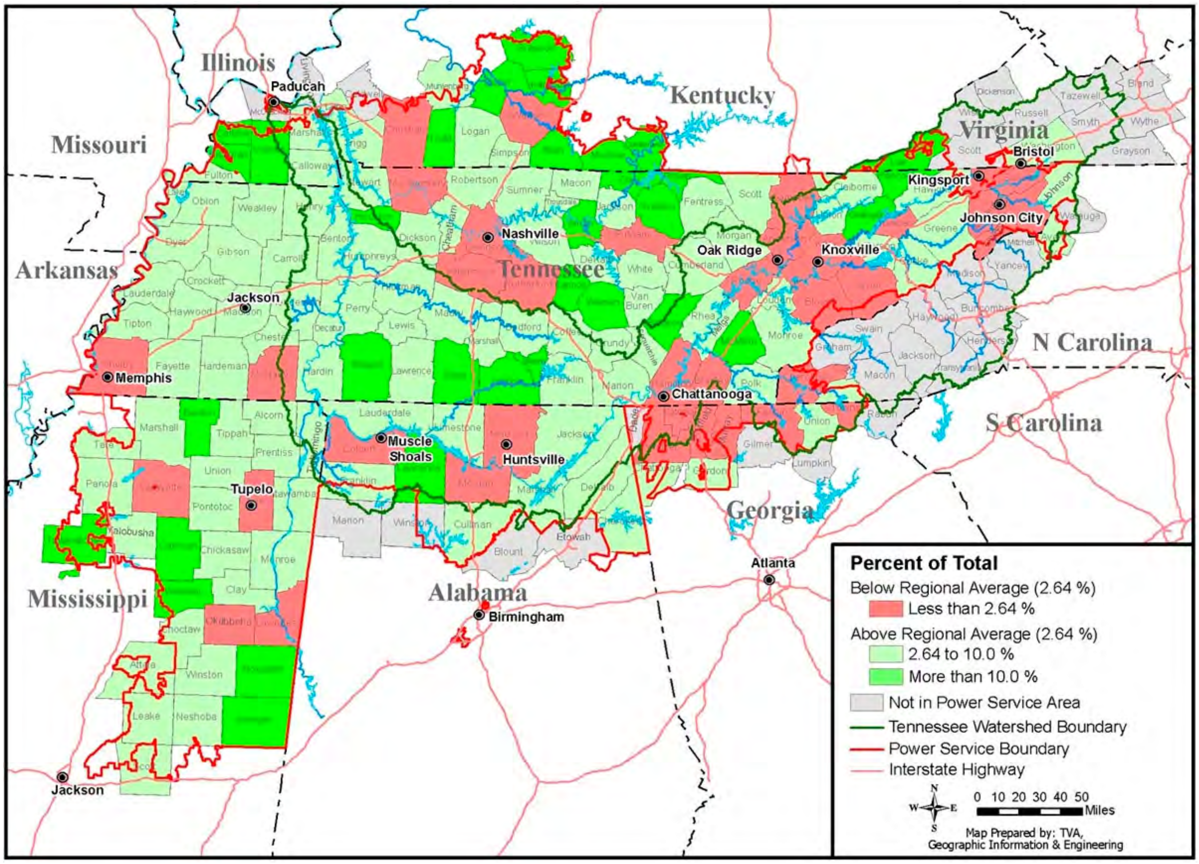


Figure 4-39. Agricultural employment as proportion of total employment in 2008. Source: USBEA (2010).

<u>Services and Other</u> — The service sector is a significant share of the regional economy, accounting for about 31 percent of nonfarm workers, slightly lower than the national proportion of 35 percent. The service sector and other non-farming, non-manufacturing sectors of the regional economy have continued to grow, increasing by about 21 percent and 9 percent, respectively, in the region since 2000. This growth was due to increases in services employment and, to a lesser extent, in civilian government. Employment in the region has declined or remained essentially level in other sectors. Nationally, services grew somewhat more slowly than in the region, about 13 percent, while civilian government grew only slightly faster, at almost 9.5 percent.

Income

Per capita personal income in the region in 2008 was $33,251, about 83 percent of the national average of $40,166. However, there was wide variation within the region (Figure 4-40). Most counties above the regional level are located in metropolitan areas. Williamson County, Tennessee, located in the Nashville metropolitan area, had the highest average, $55,717, almost 139 percent of the national average. Two other counties exceeded the national average, Davidson, TN, where Nashville is located, with $44,228, about 110 percent of the national average, and Shelby, TN, where Memphis is located, with $41,598, about 104 percent of the national average. At the other extreme only one county had per capita income less than half the national average, Hancock County, Tennessee, with about 46 percent of the national average.

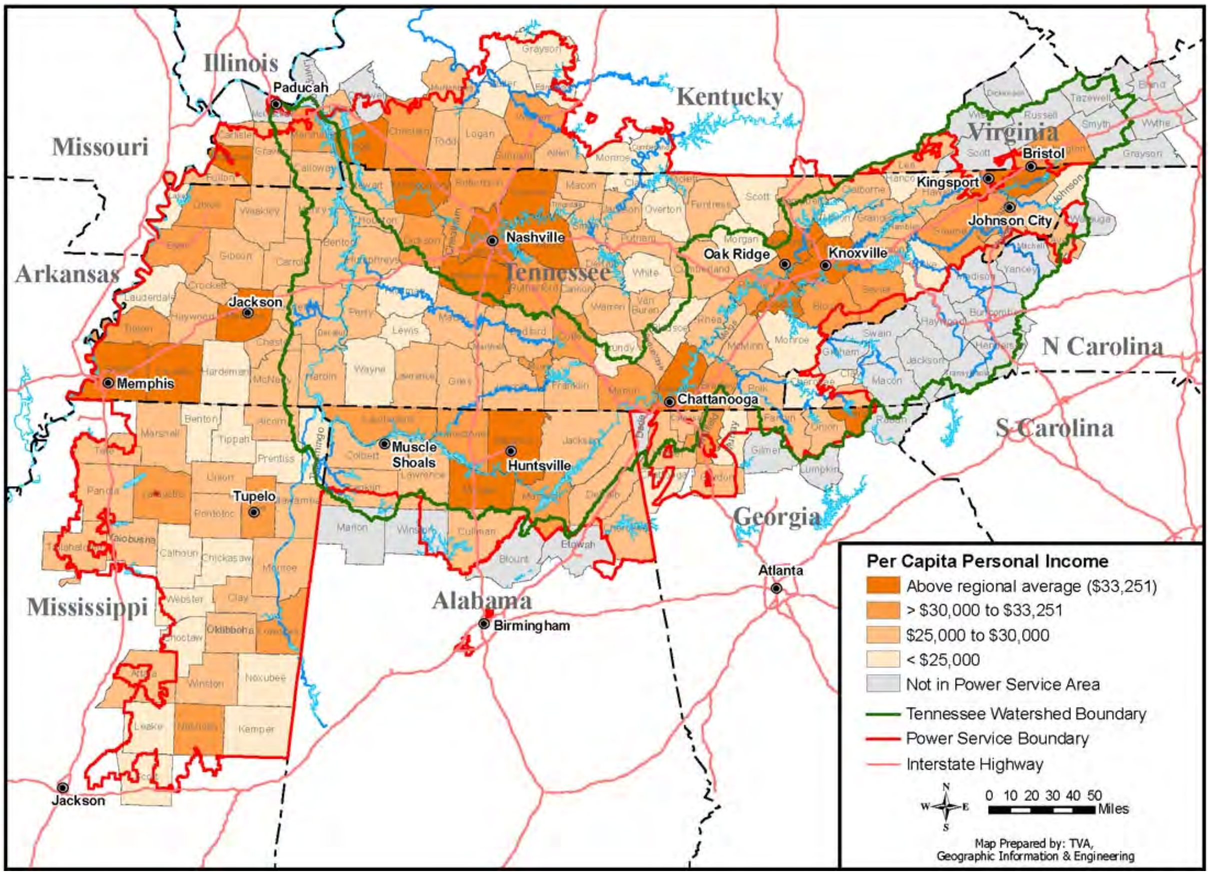


Figure 4-40. Per capita personal income in 2008. Source: USBEA (2010).

The Future of the Economy

The regional and national economies have recently shown signs of slowly recovering from the 2008-2010 recession. Total employment in the region is expected to increase from its current level of slightly less than 5.1 million, reaching about 5.5 million by 2014 and 6.3 million over the next 20 years (TVA data). Some small increase in manufacturing employment is expected in the nearer term as the economy recovers from the current recession. In the longer term, however, manufacturing employment will continue to decline, reflecting, at least in part, greater efficiencies in production. Employment, both regionally and nationally, will continue to grow in service sectors as they become an even larger component of the economy. Overall, it is likely that the region will surpass national growth rates once the effects of the current recession are over. The region has an advantage in manufacturing, especially in automobiles, distribution services, and tourism. It also has excellent opportunities for manufacturing and services related to energy, including alternative energy. It is expected, however, that growth, nationally as well as regionally, will be somewhat subdued by historical standards, given the severity of the current recession. Investment decisions will be likely to undergo greater scrutiny than in recent years, not only as a reaction to the recession, but also because greater financial market regulation and tighter credit conditions, along with large federal budget deficits due in part to the recession, will dampen growth expectations.

Minority and Low Income Populations

The minority population of the region, as of 2008, is estimated to be a little less than 2.1 million, about 22.6 percent of the region's total population of about 9.1 million (Bureau of 2009). This is well below the national average minority population share of 34.4 percent. About 12 percent of minorities in the region are white Hispanic and the rest are nonwhite. Minority populations are largely concentrated in the metropolitan areas in the western half of the region and in rural counties in Mississippi and western Tennessee (Figure 4-41).

The estimated poverty level in the region, as of 2008, is 15.8 percent, somewhat higher than the national poverty level of 13.2 percent (Bureau of Census 2009). Counties with the higher poverty levels are generally outside the metropolitan areas and most concentrated in Mississippi (Figure 4-42).

4.16. Solid and Hazardous Waste

This section focuses on the solid and hazardous wastes produced by the construction and operation of generating plants and transmission facilities. Wastes typically produced by construction activities include trees cleared from the facility site, demolition debris, packing materials, scrap lumber and metals, and domestic wastes (garbage). Non-hazardous wastes typically produced by common facility operations include sludge from water treatment plant filters and demineralizers, used oil and lubricants, spent resin, desiccants, batteries, and domestic wastes. Between 2006 and 2009, TVA power facilities produced an annual average of about 18,500 tons of solid waste. The amount of waste produced at a facility can vary from year to year due to maintenance and asset improvement activities.

Hazardous, non-radiological wastes typically produced by common facility operations include paint, paint thinners, paint solids, discarded laboratory chemicals, parts washer liquid, hydrazine, chemical waste from demineralizer beds and makeup water treatment, and broken fluorescent bulbs (TVA 2010c). The amount of these wastes generated varies with the size and type of facility. Standard TVA procedures for handling non-hazardous wastes include minimizing their production, reuse and recycling, and, where these are not feasible, offsite disposal in a permitted landfill.

Hazardous wastes and wastes requiring special handling (Table 4-15) are shipped to TVA's hazardous waste storage facility in Muscle Shoals, Alabama, for interim storage prior to disposal in permitted hazardous waste disposal facilities.

Hazardous wastes are defined by the Resource Conservation and Recovery Act to include those that meet criteria of ignitability, corrosivity, reactivity, or toxicity, or are listed in regulations or by the Toxic Substances Control Act. They can include paints, solvents, corrosive liquids, and discarded chemicals. TSCA wastes are regulated under the Toxic Substances Control Act, primarily chemicals (both hazardous and non-hazardous) and polychlorinated biphenyl compounds (PCBs), which have historically been used as insulating fluids in transformers. Universal wastes are a class of hazardous wastes that generally pose a relatively low threat, but contain materials that cannot be freely released into the environment. This classification includes batteries, pesticides, and equipment containing mercury.

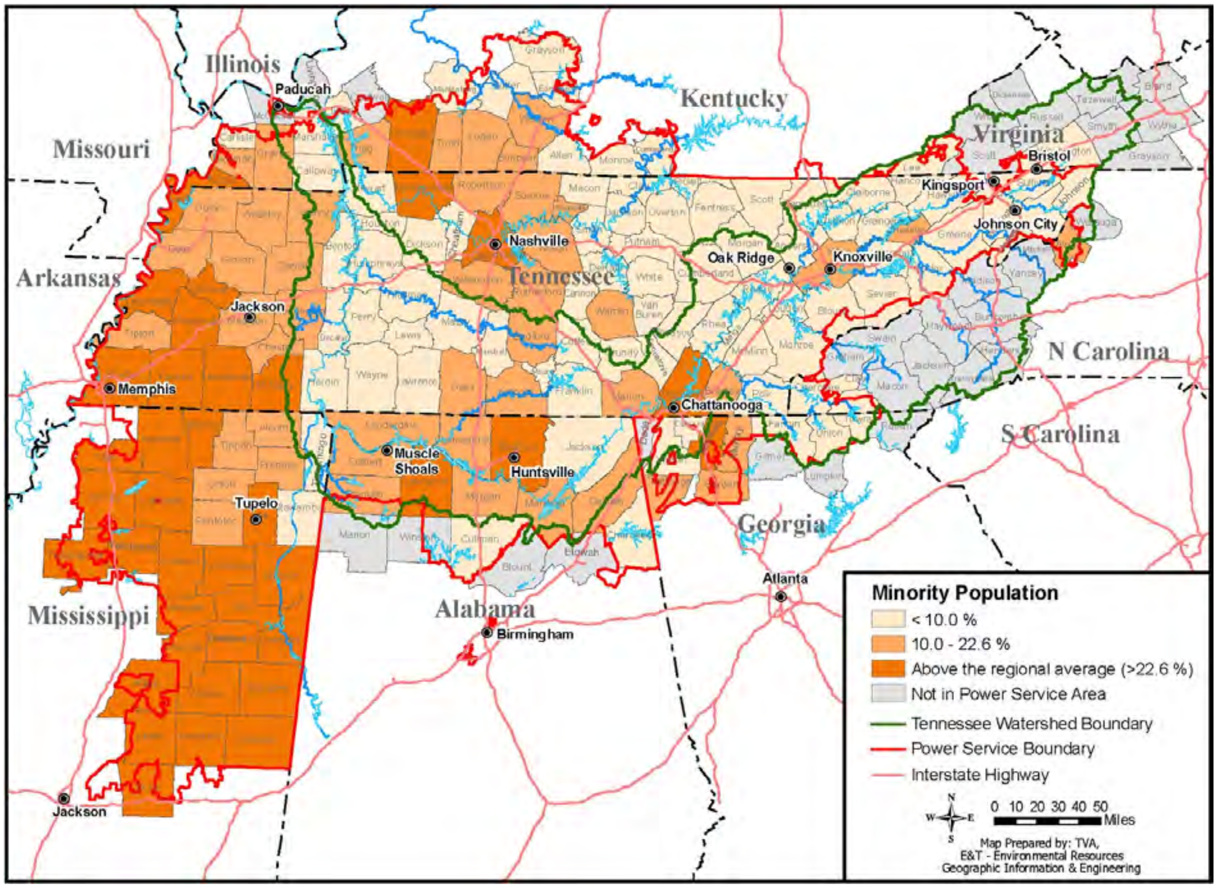


Figure 4-41. Percent minority population of TVA region counties in 2008. Source: Bureau of Census (2009).

Table 4-15. Quantities (in kilograms) of hazardous wastes and other wastes requiring special handling produced by TVA generating facilities, 2006-2009. See text for descriptions of the waste classifications.

Waste Classification	Type of Generating Facility							
	Coal		Nuclear		Hydro		Natural Gas	
	2006-08 average	2009	2006-08 average	2009	2006-08 average	2009	2006-08 average	2009
Hazardous	21,723	10,988	4,834	8,511	7,037	2,503	80	38
Universal	348	204	134	22	78	9	0	0
TSCA	19,807*	22,435	1,554	2,654	8,063	5,536	0	0
Used Oil	6,137	11,324	8,501	5,907	11,324	11,980	747	6,343

*All quantities in kilograms.

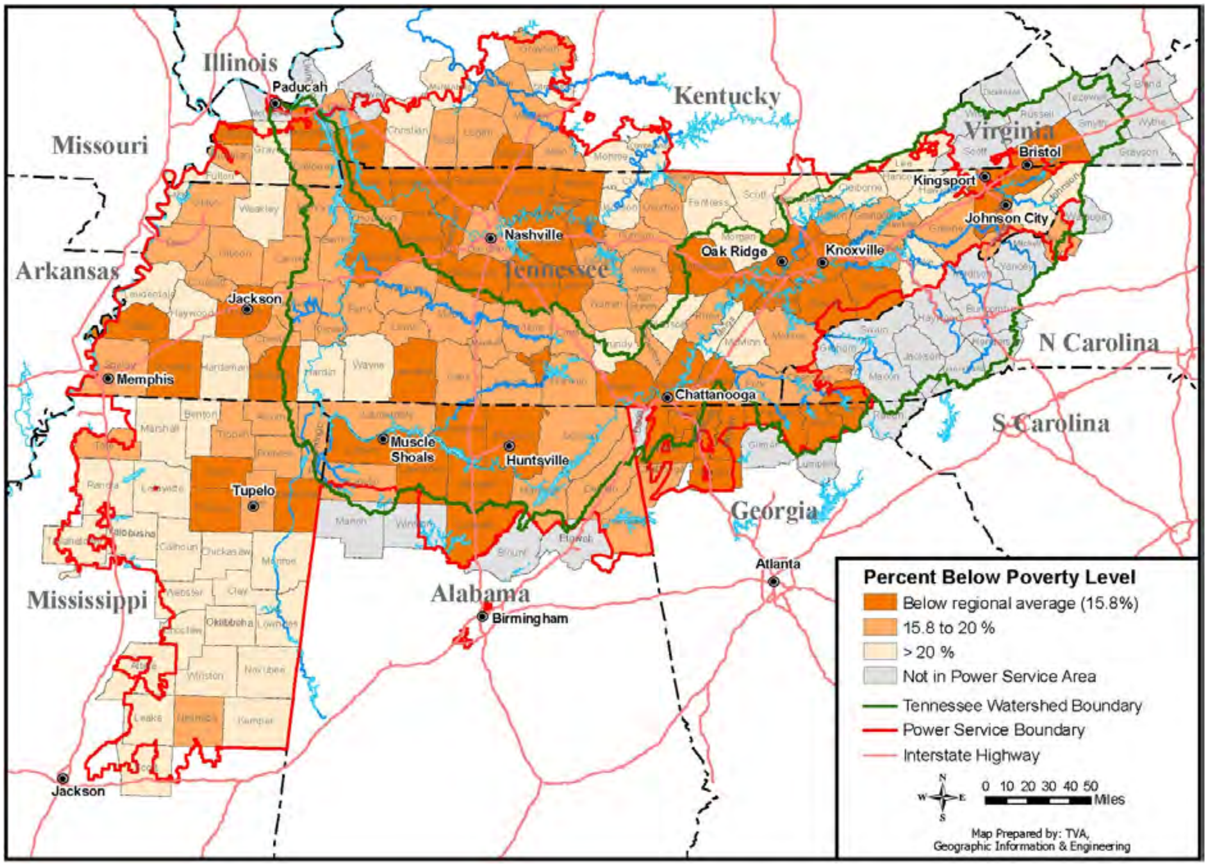


Figure 4-42. Percent of population below the poverty level in 2008. Source: Bureau of Census (2009).

Coal-fueled generating plants produce large quantities of ash and other coal combustion solid wastes, and nuclear plants produce radiological wastes. These wastes are described in more detail below.

Coal Combustion Solid Wastes

The primary solid wastes produced by coal combustion are fly ash, bottom ash, boiler slag, char, spent bed material, and synthetic gypsum. The properties of these wastes (also known as coal combustion products or CCPs) vary with the type of coal plant, the chemical composition of the coal, and other factors. Ash and slag are formed from the non-combustible matter in coal and small amounts of unburned carbon. Fly ash is composed of small, silt- and clay-sized, mostly spherical particles that are carried out of the boiler by the exhaust gas. Bottom ash is heavier and coarser with a grain size of fine sand to fine gravel. It falls to the bottom of the boiler where it is typically collected by a water-filled hopper. Boiler slag, a coarse, black, granular material, is produced in cyclone furnaces when molten ash is cooled in water. Ash and slag are primarily composed of silica (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). Spent bed material is produced in fluidized bed combustion boilers (e.g., Shawnee Fossil Plant Unit 10). Synthetic gypsum is formed in flue gas desulfurization systems (scrubbers) by the interaction of sulfur in the flue gas with finely ground limestone. It is primarily hydrated calcium sulfate ($CaSO_4 2H_2O$).

During 2009, TVA produced approximately 5.3 million tons of CCPs, with almost half being gypsum and 35 percent being fly ash (Table 4-16). Of the 5.3 million tons, 1.5 million tons, or 29 percent, were utilized or marketed. Coal combustion solid wastes are sold for reuse in the manufacture of wallboard, roofing, cement, concrete, and other products.

Table 4-16. 2006 - 2009 coal combustion solid waste production and utilization.

	Production (tons)		Utilization (percent)	
Type	2006-2008 Average	2009	2006-2008 Average	2009
Fly Ash	2,947,925	1,849,911	41.7	25.2
Bottom Ash	581,970	357,116	51.4	1.3
Boiler Slag	543,179	525,320	89.4	110.3*
Char	109,269	55,641	0	0
Spent Bed	34,429	17,261	0	0
Gypsum	2,308,609	2,487,950	34.3	19.9
Total	6,525,381	5,293,199	43.0	29.2

*More sold than produced during the year.

The 1.5 million tons sold during 2009 decreased from the 2.8 million ton annual average for 2006-2008; much of this decrease is due to reduced demand resulting from the recent recession. The CCPs that are not sold for reuse are stored in landfills and impoundments at or near coal plant sites. Five TVA plants use dry ash collection/storage systems, and six plants use wet ash collection/storage system. In response to the December 2008 collapse of a wet ash storage pond dike at Kingston Fossil Plant, TVA has committed to converting all wet ash and gypsum storage facilities, present at six of its plants, to dry storage and disposal facilities. These projects are expected to be completed in eight to ten years.

Nuclear Waste

The nuclear fuel used for power generation produces liquid, gaseous, and solid radioactive wastes (radwaste) that require storage and disposal. These wastes are categorized as high-level waste and low-level waste. These categories are based on the type of radioactive material, the intensity of its radiation, and the time required for decay of the radiation intensity to natural levels.

<u>High-Level Waste</u> **-** About 99 percent of high-level waste generated by nuclear plants is spent fuel, including the fuel rod assemblies. Nuclear fuel is made up of small uranium pellets placed inside long tubular metal fuel rods. These fuel rods are grouped into fuel assemblies, which are placed in the reactor core. In the fission process, uranium atoms split in a chain reaction which yields heat. Radioactive fission products - the nuclei left over after the atom has split, are trapped and gradually reduce the efficiency of the chain reaction. Consequently, the oldest fuel assemblies are removed and replaced with fresh fuel at about 18-month intervals. Because nuclear plants normally operate continuously at full load, spent fuel production varies little from year to year. The six operating nuclear units produce about 650 tons of high-level waste per year.

After it is removed from the reactor, spent fuel is stored at the nuclear plants in pools (steel-lined, concrete vaults filled with water). The spent fuel pools were originally intended to store spent fuel onsite until a monitored retrievable storage facility and a permanent repository were built by the Department of Energy as directed by the Nuclear Waste Policy Act of 1982. Because these facilities have not yet been built, the storage capacity of the spent fuel pools at Sequoyah and Browns Ferry nuclear plants has been exceeded, TVA, like other utilities, has begun storing spent fuel in above-ground dry storage casks constructed of concrete and metal storage casks. The Watts Bar plant is forecasted to start using dry storage casks in 2015 (TVA 2007c).

Low-Level Waste **-** Low-level waste consists of items that have come into contact with radioactive materials. At nuclear plants, these wastes consist of solids such as filters, spent resins (primarily from water filtration systems), sludge from tanks and sumps, cloth and paper wipes, plastic shoe covers, tools and materials, and liquids such as tritiated waste (i.e., containing radioactive tritium), chemical waste, and detergent waste, and gases such as radioactive isotopes created as fission products and released to the reactor coolant. Nuclear plants have systems for collecting these radioactive wastes, reducing their volume, and packaging them for interim onsite storage and eventual shipment to approved processing and storage facilities. Dry active waste, which typically have low radioactivity, are presently shipped to a processor in Oak Ridge, Tennessee for compaction and then to a processor in Clive, Utah for disposal. Wet active wastes with low radioactivity are shipped to the Clive processor. Other radioactive wastes are currently shipped to and stored at the Sequoyah plant. Table 4-17 lists the amounts of low level waste produced at TVA nuclear plants in recent years.

Table 4-17. Quantity (in lbs.) and rate (in lbs/GWh) of low level waste generated at TVA nuclear plants, 2006-2009. Source: TVA data.

	2006		2007		2008		2009	
Plant	Amount	Rate	Amount	Rate	Amount	Rate	Amount	Rate
Browns Ferry	517,576	29.0	1,182,591	55.8	1.386,551	55.5	702.830	27.3
Sequoyah	216,911	12.0	174,869	9.4	136,297	7.2	173,461	9.8
Watts Bar	63,516	9.5	91,465	9.1	101,413	12.5	126.922	13.8
Total	798,003	18.8	1,488,925	29.0	1,624,261	31.2	1,003,213	19.0

4.17. Availability of Renewable Resources

Most of the alternative strategies being evaluated include the increased reliance on renewable generating resources. TVA includes all renewable resources in its definition, including hydro generation. This assessment of potential renewable resources does not include TVA's existing hydro facilities and considers renewable resources in this context of recently proposed federal climate and renewable portfolio standard legislation and in many state renewable portfolio standards to include solar, wind, small hydro (see Section 5.4.3) and upgrades to existing large hydro plants, biomass, landfill gas, and geothermal energy.

Following is an assessment of the availability of potential renewable resources for generating electricity in and near the TVA region. Geothermal generation is not considered because of the lack of a developable resource in the TVA region (Augustine and Young 2010).

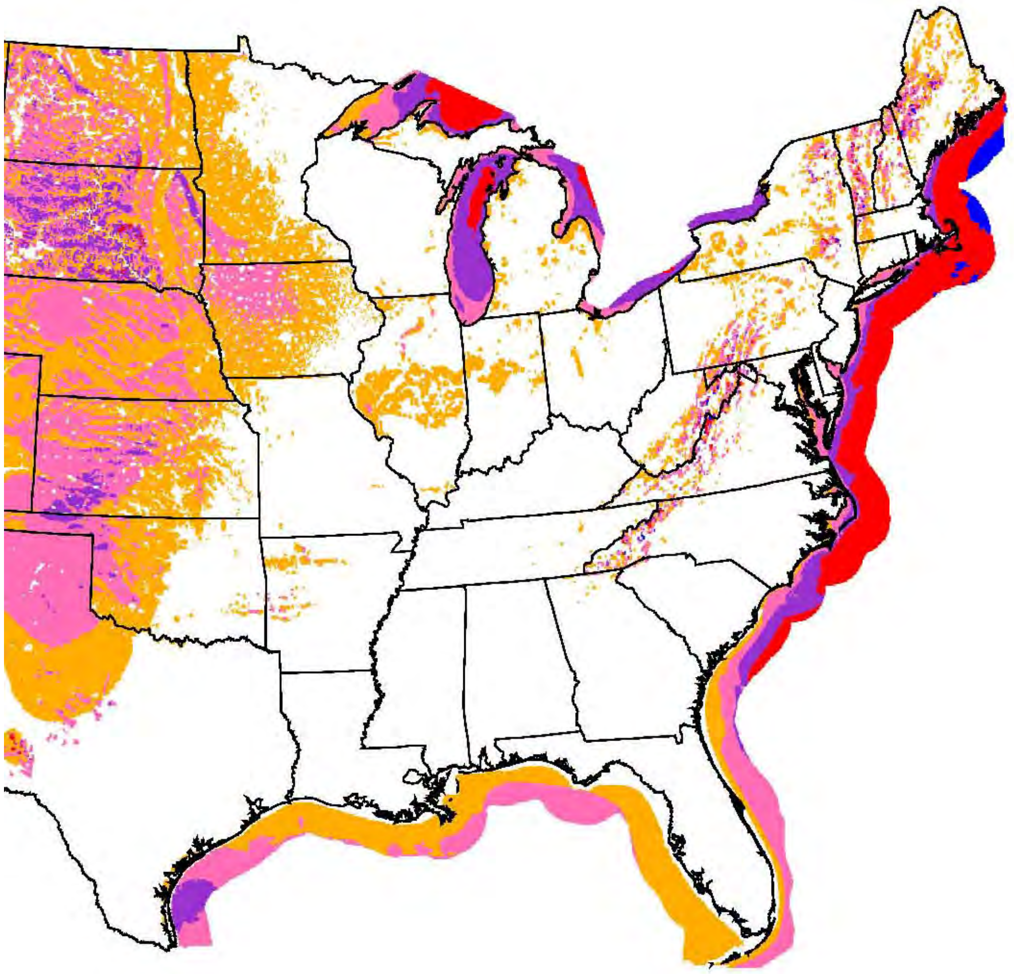
4.17.1. Wind Energy Potential

The suitability of the wind resource in an area for generating electricity is typically described in terms of wind power classes ranging from Class 1, the lowest, to Class 7, the highest (Elliott et al. 1986). The seven classes are defined by their average wind power density (in units of watts/m^2) or equivalent average wind speed for a specified height above ground. Areas designated Class 3 or greater at a height of 50 m above ground usually have adequate wind for most commercial wind energy developments. Based on wind resource assessments at the 50-m height, relatively little of the TVA region is suitable for commercial wind energy development (Figure 4-43).

Raichle and Carson (2009) presented the results of a detailed wind resource assessment in the southern Appalachian Mountains. Measured annual wind speeds at nine representative privately owned sites ranged from 4.4 m/s on the Cumberland Plateau in northwest Georgia to 7.3-7.4 m/s on sites in the Blue Ridge Mountains near the Tennessee/North Carolina/Virginia border. Two sites in the Cumberland Mountains and one site in the Blue Ridge Mountains were categorized as Class 3 and two sites in the Blue Ridge Mountains were categorized as Class 4. The Class 3 and Class 4 sites had capacity factors of 28 to 36 percent and an estimated energy output of 2.8-3.5 GWh per MW of installed capacity. Capacity factor is the ratio (in percent) of energy a facility actually produced over a given period of time (typically a year) to the amount of the energy that would have been produced if the facility had run at full capacity during the same time period. All sites had significantly less wind during the summer than during the winter and significantly less wind during the day than at night during all seasons. Due to the configuration of ridge tops within this area in relation to prevailing wind directions, potential wind projects would likely be linear in extent and relatively small.

More recent wind assessments have shifted from a power class rating to a capacity factor value and to higher elevations of 80 m and 100 m above ground, a tower height more representative of current wind turbines (NREL 2010). This re-evaluation showed an increased potential for wind generation in the western portion of the TVA region, especially at a height of 100 m. Due to the spatial resolution of this data, the ridgetop potential in the TVA region appears to have been devalued from previous National Renewable Energy Laboratory (NREL) estimates. Therefore, the total maximum wind resource potential for the TVA region may not be fully represented in this assessment.

Based on a 30 percent gross capacity factor (not adjusted for losses) and excluding undevelopable areas such as national and state parks, wilderness areas, wildlife refuges, and recreation areas, the potential installed wind capacity in the TVA region is 450 to 1,300 MW depending on elevation. The corresponding generation values are 1,200 and 3,400 GWh, respectively. The NREL Eastern Wind Integration and Transmission Study (NREL 2010b) further supplements this data by estimating a wind potential of 1,247 MW in the TVA region, with an expected annual energy generation value between 3,500-4,000 GWh. Additional wind speed data collection from high elevation towers (minimum of 50 m) is necessary to develop a more precise wind resource estimate for the TVA region.



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

Figure 4-43. Wind resource potential of the eastern and central U.S. at 50 m above ground. Areas unlikely to be available for wind power development due to land use or environmental issues are not mapped. Source: Adapted from NREL (2009b).

4.17.2. Solar Energy Potential

Solar energy resource potential is a function of average daily solar insolation (see Section 4-2) and is expressed kWh/m^2/day (available energy (kWh) per unit area (square meters) per day). Solar resource measurements are reported as either direct normal radiation (no diffuse light) or total radiation (a combination of direct and diffuse light). Diffuse or scattered light is caused by cloud cover, humidity, or particulates in the air. These measurements do not incorporate losses from converting photovoltaic (PV)-generated energy (direct current) to alternating current or the reduced efficiency of some PV panels at high temperatures. PV panels are capable of generating with both direct and diffuse light sources while concentrating solar generators require direct normal radiation. Figure 4-44 shows the solar generation potential for both flat plate PV panels and concentrated solar technologies in the TVA region. The PV potential assumes flat-plate panels are oriented to the south and installed at an angle from horizontal equal to the latitude of the location.

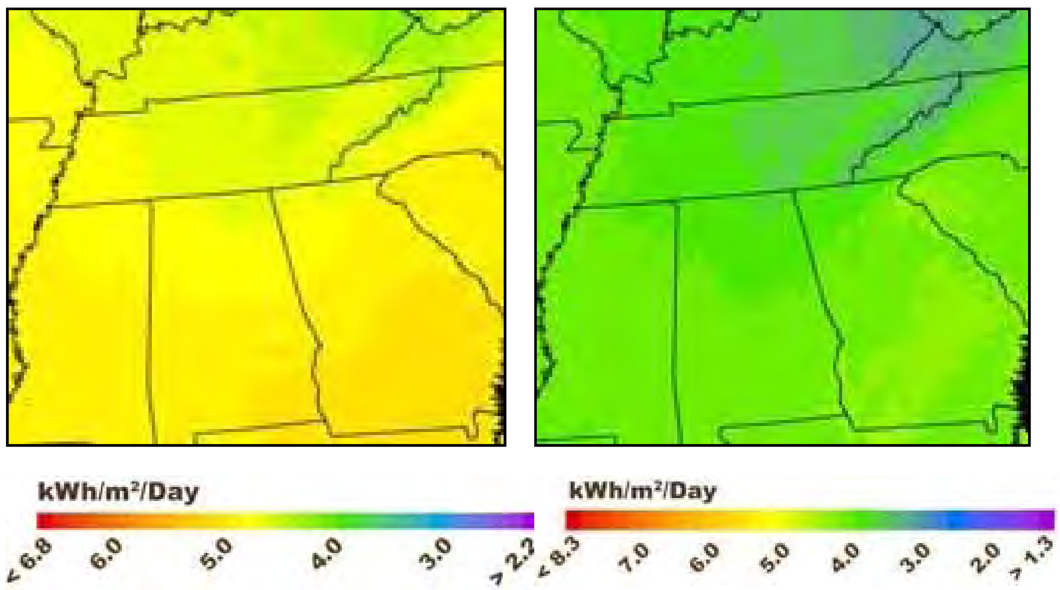


Figure 4-44. Solar photovoltaic generation potential (left) and concentrating solar generating potential (right) in the TVA region. Source: Adapted from NREL (2009a).

Most of the TVA region has between 4-5 kWh/m^2/day of available solar insolation for flat-plate PV collectors and 3.5-4.5 kWh/m^2/day for concentrated solar collectors. Because of the high proportion of diffuse sunlight, performance of concentrating solar generation is reduced in the TVA region and there has, to date, been no commercial development of this generation in or near the TVA region.

Because PV is the most abundant and easily deployable renewable resource, it is difficult to accurately assess a feasible potential value for the TVA region. Following are two distinct evaluation cases developed by the NREL. The first case examines the land area required to meet all of the 2005 TVA electrical load for each state in the TVA region. The second case explores the rooftop PV potential for states in the TVA region.

<u>Land Area Relative to Electrical Load</u> - Denholm and Margolis (2007) studied the land area of each state necessary to meet the state's entire electrical load by PV generation. To determine the annual PV generation per unit of module power, hourly insolation values were used for 2003-2005 from 216 sites in the lower 48 U.S. states. Net PV energy density (the annual energy produced per unit of land area) for each state was calculated using the weighted average of three distinctive PV technologies (polycrystalline silicon, monocrystalline silicon, and thin film) which vary in their generating efficiency. Various panel orientations including fixed positions and 1- and 2-axis tracking were included. Tracking panels (i.e., on mounts that pivot to follow the sun) produce more energy per unit area than fixed panels although their initial installation costs are higher.

The resulting state-level solar electric footprint shows that achieving all of the electricity is theoretically possible (Figure 4-45). Because PV generation is not a base load resource (only generates during the day), a scaling factor of 1.23 was applied to compensate for losses associated with back-up battery storage. Generating all of the region's electricity by PV it is not a practical goal unless very inexpensive and very high capacity energy storage devices become available. Therefore, the conclusion of this analysis is not to assign a specific theoretical solar potential but to point out that the solar resource in the TVA region is plentiful. Relative to other states, the seven TVA region states ranked between 14th (Alabama) and 29th (Kentucky) in PV energy density (Denholm and Margolis 2007).

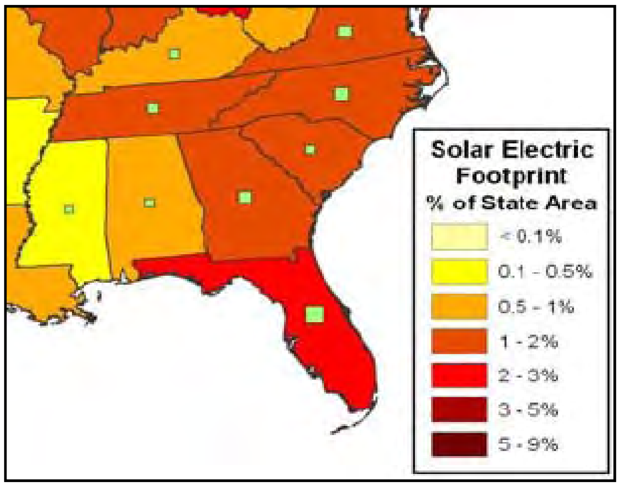


Figure 4-45. Solar electric footprint of southeastern states (2003-2005) Source: Adapted from Denholm and Margolis (2007).

Available Rooftop Area - Paidipati et al. (2008) examined the technical potential of rooftop area available for solar by considering both the PV system power density and available roof space. PV power density is defined as the deployable peak power per unit of land area (expressed in MW peak direct current per million square feet). The power density is based on a weighted-average module efficiency using the market share values for the three most prevalent solar technologies. An additional packing factor of 1.25 was applied to account for space needed for the PV array (e.g., access between modules, wiring, and inverters). The analysis assumed both rooftop areas and solar panel system efficiencies grow over time. The TVA power service area PV rooftop potential in 2010 is roughly 23,000 MW of solar capacity and 27,000 GWh of annual generation. The expected potential in 2015 is roughly 30,000 MW of capacity and 35,500 GWh of annual generation (Figure 4-46).

4.17.3. Hydroelectric Energy Potential

Hydroelectric generation (excluding the Raccoon Mountain pumped storage facility) presently accounts for about 10 percent of TVA's generating capacity (see Section 3-3). TVA has been gradually increasing this capacity by upgrading the hydro turbines and associated equipment. To date, this program has increased TVA's hydro generating capacity by about 15 percent. TVA anticipates upgrading about 34 turbines during the IRP planning period, resulting in a capacity increase of about 88 MW. This capacity increase would qualify as renewable energy under most recently proposed renewable portfolio standard legislation.

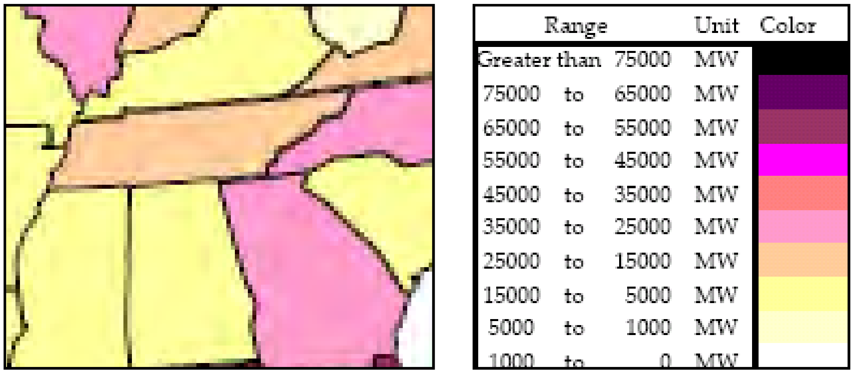


Figure 4-46. 2015 region rooftop PV technical potential for states in the TVA region. Source: Adapted from Paidipati et al. (2008).

A 1998 Department of Energy study identified approximately 547 MW of potentially developable conventional (dam and turbine) hydroelectric capacity at 54 sites in the TVA power service area and outside the power service area but in the Tennessee River drainage (Connor et al. 1998). The sites included previously identified undeveloped sites as well as existing dams without operating turbines, including 4 TVA dams and several Corps of Engineers dams. Most of the sites were potentially developable by adding turbines to existing dams or constructing new run-of-river dams and turbines. Twenty-nine of the sites were in the Tennessee River watershed. After considering environmental, legal, and institutional constraints, the adjusted potential for new capacity was 287 MW.

A more recent Department of Energy study (Hall et al. 2006) focused on the hydropower potential of sites developed as low power (<2 MW) and small hydro (between 2 and 60 MW) projects. Feasibility criteria, in addition to the water energy resource, included site accessibility, load or transmission proximity, and land use or environmental constraints that would inhibit development. Potential sites were assumed to be developed in ways that would not require the stream to be obstructed by a dam such as partial stream diversion through a penstock to a conventional turbine, as well as unconventional ultra-low head and kinetic energy (in-stream, see Section 5-4.2) turbines. The study identified numerous small hydro and low power sites with an estimated total feasible capacity of 1,770 MW. The study did not evaluate the hydrokinetic potential of sites with little or no elevation difference and thus likely underestimates this potential resource.

4.17.4. Biomass Fuels Potential

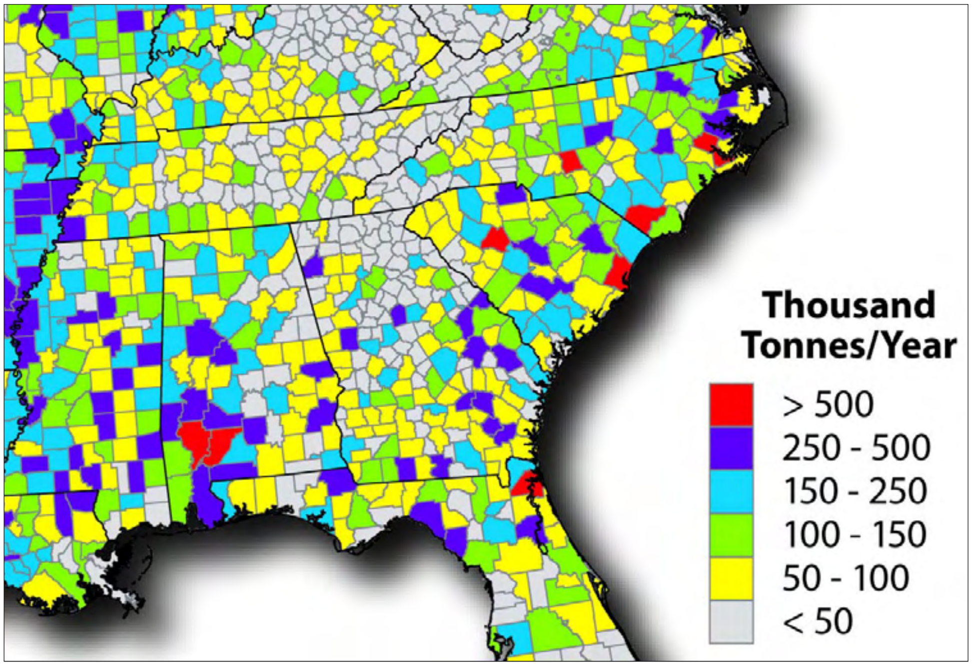
Milbrandt (2005; see also NREL 2009c) analyzed geographic patterns in the availability of biomass suitable for power generation. Her analysis included crop residues; forest residues; primary and secondary mill residues; urban wood waste; dedicated energy crops; and methane emissions from landfills, livestock and poultry manure management, and domestic wastewater treatment. Many TVA region counties had a total biomass resource potential of over 100,000 tons/year; these counties are concentrated in Kentucky, western Tennessee, Mississippi, and Alabama (Figure 4-47). The total potential biomass resource for the TVA region is approximately 36 million tons/year. This equates to a potential of up to 47,000 GWh[8] of annual biomass energy generation. The TVA region biomass resource potential for each resource type is shown in Figure 4-48.

Dedicated energy crops are crops grown specifically for use as fuels, either by burning them or converting them to a liquid fuel, such as ethanol, or a solid fuel, such as wood pellets or charcoal. They can include traditional agricultural crops, non-traditional perennial grasses, and short rotation woody crops. Traditional agricultural crops grown for fuels include corn, whose kernels are fermented to produce ethanol, and soybeans, whose extracted oil can be converted to biodiesel. Sorghum is also a potential fuel feedstock. Non-traditional perennial grasses suitable for use as fuel feedstocks include switchgrass (*Panicum virgatum*) and miscanthus, also known as E-grass (*Miscanthus x giganteum*, a sterile hybrid of *M. sinensis* and *M. sacchariflorus*) (Dale et al. 2010). Short rotation woody crops are woody crops that are harvested at an age of 10 years or less. Trees grown or potentially grown for short rotation woody crops in the TVA region include eastern cottonwood, hybrid poplars, willows, American sycamore, sweetgum, and loblolly pine (UT 2008; Dale et al. 2010). Plantations of these trees are typically established from stem cuttings or seedlings. With the exception of loblolly pine, these trees readily resprout from the stump after harvesting. As described in Section 4.13, the area of short rotation woody crops in the TVA region is small. Milbrandt (2005) analyzed the potential production of dedicated energy crops on Conservation Reserve Program lands, a voluntary program that encourages farmers to address natural resource concerns by removing land from traditional crop production. Growing dedicated energy crops on conservation reserve lands reduces their impact on food production.

Forest residues consist of logging residues and other removable material left after forest management operations and site conversions, including unused portions of trees cut or killed by logging and left in the woods. Mill residues consist of the coarse and fine wood materials produced by mills processing round wood into primary wood products (primary mill residues) and residues produced by woodworking shops, furniture factories, wood container and pallet mills, and wholesale lumberyards (secondary mill residues) (Milbrandt 2005). Crop residues are plant parts that remain after harvest of traditional agricultural crops; the amount available was adjusted to account for the amount left in fields for erosion control and other purposes. Methane sources include landfills, domestic wastewater treatment plants, and emissions from farm animal manure management systems.

This estimate of 36 million potential tons/year does not consider several important factors and may be optimistic. The analysis assumes that all of the biomass is available for use without regard to current ownership and competing markets. Growth in use of biomass will likely result in increased competition for biomass feedstock and reduce the feasibility of some biomass. Some biomass may also not meet environmental and operational standards for electrical generation. The distance between sourcing areas and the generating facility is also important; feasible sourcing areas for solid biomass fuels are typically considered to be within a 50- or 75-mile radius of the generating facility. Finally, there is currently no established infrastructure in the TVA region to transport, process, and utilize biomass for generating electricity. As biomass fuel markets develop in and near the TVA region, better resource estimates should become available.

[8] Based on assumed heating values for agricultural crops and wood residues of 7,200 to 8,570 Btu/lb and for methane of 6,400 to 11,000 Btu.lb, depending on feedstock type. Assumed generating unit heat rates are 13,500 Btu/kWh for crop and wood residues and 12,500 Btu/kWh for methane.



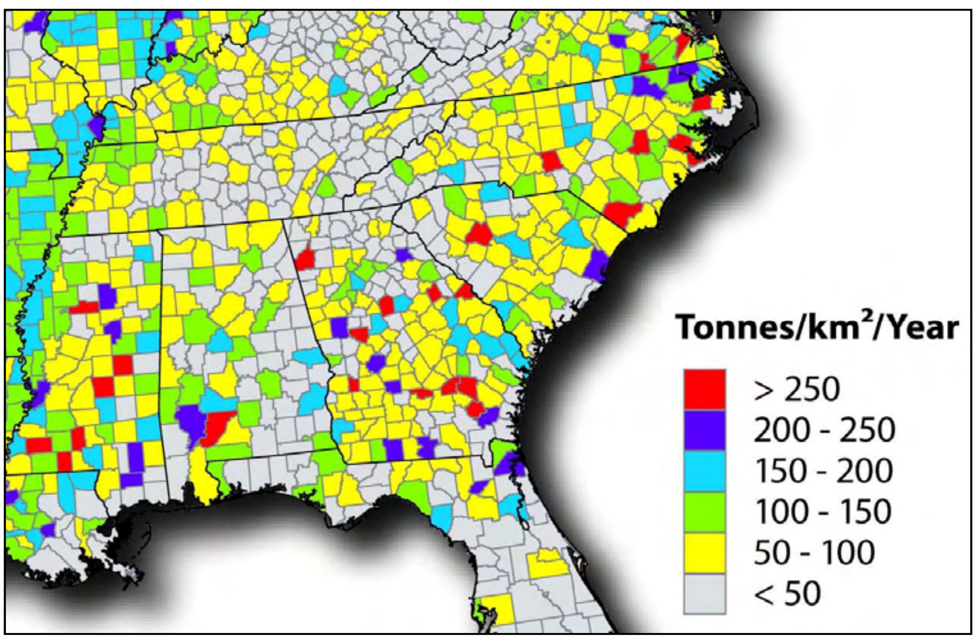


Figure 4-47. Total biomass resources potentially available in the TVA region by county (top) and per square kilometer by county (bottom). Source: Adapted from Milbrandt (2005).

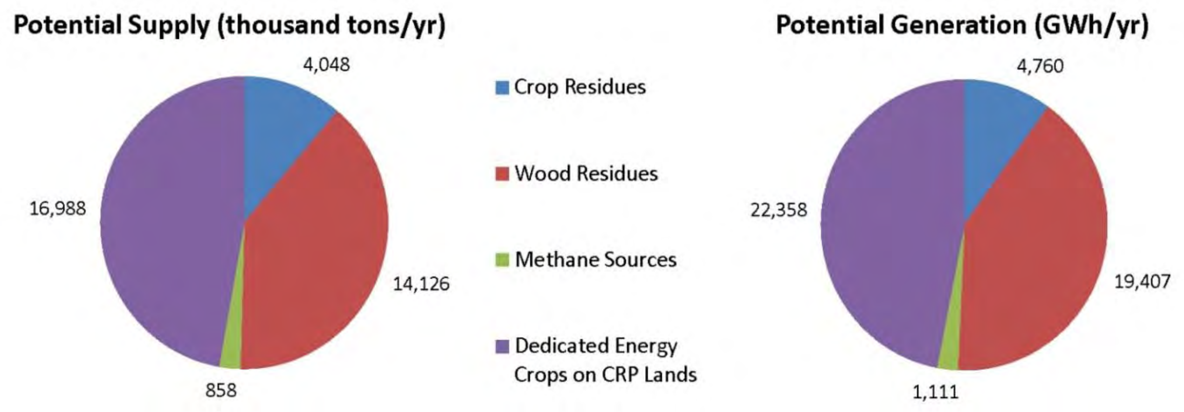


Figure 4-48. TVA region potential biomass resource supply (left) and generation (right). Source: Adapted from Milbrandt (2005 and NREL (2009c).

TVA has commissioned studies of the biomass potentially available for fueling its coal-fired generating plants. A 1996 study (ORNL 1996) addressed the potential supply of short-rotation woody crop and switchgrass biomass grown on crop and pasture lands. The potential supply is greatly influenced by the price paid for biomass, which influences its profitability relative to the profitability of conventional crops. With higher prices, larger amounts of more productive farmland would likely be converted from food production to biomass production, and the western portion of the TVA region has the greatest potential for producing large energy crop supplies.

In a more recent study, Tillman (2004) surveyed the availability of woody biomass for cofiring at eight TVA coal-fired plants (all except Bull Run, Cumberland, and Gallatin). Potential sources included producers of primary and secondary mill residues as described above. These sources produced about 433,000 dry tons/year (approximately 7,153,000 MBtu/yr) of potential biomass fuels within economical haul distances of TVA coal-fired plants. The most abundant material type was sawdust (about 57 percent of the total) and only about two percent of the biomass was not already marketed. At a 2004 price of $1.25-1.50/MBtu, sufficient biomass would be available to support 75-80 MWe of generating capacity and the annual generation of 300,000-450,000 MWh of electricity.