

2.7 METEOROLOGY AND AIR QUALITY

This section of the Environmental Report (ER) addresses the local and regional climatology and meteorology, as well as air quality in the vicinity of the Clinch River Nuclear (CRN) Site. The information supports independent evaluations and assessments of atmospheric diffusion characteristics and impacts of construction and operation of two or more small modular reactors (SMRs) on the environment.

2.7.1 Regional Climatology

2.7.1.1 Data Sources

Data sources for the preparation of this section include:

- Annual Local Climatological Data (LCD) presenting National Weather Service (NWS) Station data collected at Oak Ridge, Knoxville, Chattanooga, the Bristol/Johnson City/Kingsport area, and Nashville, as tabulated and published by the National Climatic Data Center (NCDC)
- Online NETSTATE Tennessee Geography information
- Air pollution data publications available from the Tennessee Department of Environment and Conservation (TDEC)
- U.S. Environmental Protection Agency (EPA) website information / documents on air quality, attainment / nonattainment areas, and mixing heights
- The NCDC's Online Storm Events Database
- U.S. Nuclear Regulatory Commission (NRC) NUREG documents and Regulatory Guides
- Onsite CRN meteorological data collected under Tennessee Valley Authority's (TVA's) meteorological data monitoring program
- Various meteorological data-related publications

2.7.1.2 Tennessee Climate Description

The State of Tennessee extends approximately 450 miles (mi) from east to west and the weather and climate across the state vary as a result of the geography of the state, air masses over the southeastern United States and their origin, and the track of low pressure systems as they move west to east or up from the Gulf of Mexico (Reference 2.7.1-1). In general, winters are moderate and summers are warm and humid over most of the state. In the eastern mountain areas, the elevated topography can have a tempering effect on summer conditions and create colder temperatures during winter. Overall, precipitation is distributed relatively evenly over the state, although there are peaks during winter and spring from synoptic scale, frontal storms, and during summer from thunderstorm activity. (Reference 2.7.1-2)

The geography of Tennessee can be described by six regions (Figure 2.3.1-16).

- Blue Ridge
- Appalachian Ridge and Valley Region
- Appalachian Plateau or Cumberland Plateau
- Highland Rim
- Nashville Basin
- Gulf Coast Plain (Reference 2.7.1-1)

The Blue Ridge region is located on the eastern side of Tennessee and borders North Carolina. This area falls to the east of the CRN Site and includes the Great Smoky Mountains. The average elevation of this region is approximately 5000 feet (ft) above mean sea level (msl), with Clingman's Dome (the highest elevation in the State of Tennessee) reaching 6643 ft msl. (Reference 2.7.1-1)

The Appalachian Ridge and Valley Region extends to the west from the Blue Ridge Region for approximately 55 mi (Reference 2.7.1-1). Elevations in this region range from approximately 1500 ft msl down to 700 ft msl (Reference 2.7.1-2). The region is characterized by valleys separated by ridges. The CRN Site is located in the western half of this region, which is commonly referred to as "The Great Valley." (Reference 2.7.1-1)

The Appalachian Plateau or Cumberland Plateau is located to the west of the Appalachian Ridge and Valley Region, and is the next region west of the CRN Site. The primary features associated with this region are flat-topped mountains with sharp valleys between. Elevations in this area extend up to 1800 ft msl. (Reference 2.7.1-1)

The next region, moving west, is referred to as the Highland Rim. Elevations in the region rise to approximately 1000 ft msl (Reference 2.7.1-2). This region is characterized as an elevated plain that surrounds the Nashville Basin region (Reference 2.7.1-1).

The Nashville Basin Region, with the Highland Rim surrounding it, includes steep slopes along its perimeter. The basin area includes fertile farming land. (Reference 2.7.1-1)

The sixth major region of Tennessee is the western most area named the Gulf Coast Plain. This area is part of the larger Gulf Coast Plain that reaches from the Gulf of Mexico up into the southern portion of Illinois. Much of this area, primarily to the east of Memphis is rolling hills. At the western side of the region is the Mississippi River. (Reference 2.7.1-1) Elevations in the Gulf Plain are generally in the range of 200 to 600 ft msl (Reference 2.7.1-2).

Tables 2.7.1-1 and 2.7.1-2 provide temperature and precipitation data, respectively, representative of the eastern portion of Tennessee in which the CRN Site is located. Figure 2.7.1-1 provides a map showing the location of the NWS Station at each of the cities included in Tables 2.7.1-1 and 2.7.1-2.

Temperature data in Table 2.7.1-1 indicate the effect of geography and elevation; the coldest temperatures are reported on the eastern side of the state at the Bristol/Johnson City/Kingsport area, which is at the highest elevation (approximately 1500 ft msl) of the cities included in the table (Reference 2.7.1-3). The annual average temperature at the Bristol/Johnson City/Kingsport Airport is 55.6 degrees Fahrenheit (°F).

Of the cities included in the table (Table 2.7.1-1), the highest temperatures are reported at the Chattanooga Lovell Field Airport, which is located approximately 70 mi to the southwest of the CRN Site (Reference 2.7.1-4). Chattanooga has a reported annual average temperature of 60.8°F. For the remaining interior cities, the annual average temperatures are 59.3°F at Nashville, 58.8°F at Oak Ridge, and 59.1°F at Knoxville, all within one degree of each other. The maximum monthly average temperature of 80.0°F is reported at Chattanooga in July, and the minimum monthly average temperature of 35.2°F is reported at the Bristol/Johnson City/Kingsport Airport in January.

Table 2.7.1-2 provides monthly and annual average precipitation data for NWS Stations from Nashville to the Bristol/Johnson City/Kingsport area. Annual precipitation averages around 50 inches (in.) per year throughout much of the eastern portion of the state, with the exception of the Bristol/Johnson City/Kingsport area where the annual average precipitation is around 41 in.

The highest reported average annual precipitation is 52.48 in. at Chattanooga. Although precipitation is distributed relatively evenly throughout the year, the lowest monthly amounts occur during the period from August to October, depending on location. Of the five cities included in Table 2.7.1-2, the city with the lowest monthly average is the Bristol/Johnson City/Kingsport area, with 2.10 in. in October. The month with the highest average precipitation varies across the state, occurring anytime from May to November. In the Oak Ridge-Knoxville area, the maximum precipitation amounts occur in July. The city with the highest monthly precipitation is Nashville, where on average 5.50 in. of precipitation falls in May.

2.7.1.3 CRN Site Regional Climate

The CRN Site is located in Roane County in the eastern portion of Tennessee. As noted in Subsection 2.7.1.2, the CRN Site is part of a region commonly referred to as “The Great Valley.” The CRN Site in its regional setting is shown in Figure 2.1-1 of Section 2.1 (Site Location). As indicated in Section 2.1, the center point of the CRN Site is located approximately 10.7 mi southwest of the City of Oak Ridge, Tennessee business district.

On the larger, synoptic scale, weather in the region is influenced by the position of the jet stream, which is typically situated to the north of the CRN Site during the warmer times of year, allowing for higher temperatures and humid conditions. From late spring and into fall, the area is influenced by maritime tropical air masses. During winter, the jet stream typically shifts to the south and its orientation can significantly influence temperatures in the region around the CRN Site. In general, a west- to east-oriented jet stream produces more moderate conditions for the region. However, if the jet stream penetrates downward into the southern United States, polar continental air masses can affect the region producing cold temperatures (Reference 2.7.1-5).

The CRN Site is in the Appalachian Ridge and Valley Region, which is dominated much of the year by the Azores-Bermuda anti-cyclonic circulation (commonly referred to as the “Bermuda High”). This dominance is most pronounced in late summer and early fall and is accompanied by extended periods of fair weather and atmospheric stagnation. (Reference 2.7.1-6) In winter and early spring, eastward moving migratory high- or low-pressure systems bring alternately cold and warm air masses into the area. In the summer and early fall, the migratory systems are less frequent and less intense (Reference 2.7.1-2). Frequent incursions of warm, moist air from the Gulf of Mexico and occasionally from the Atlantic Ocean are experienced in the summer. The CRN Site is primarily affected by cyclones from the southwest and Gulf Coast that move toward the northeast United States by passing along either the west side or the east side of the Appalachian chain and by cyclones from the Plains or Midwest that move up the Ohio River Valley.

At the mesoscale, topography influences the weather and climate of the region around the CRN Site. Figures 2.7.1-2 and 2.7.1-3 show the topography within a 5 mi (8 kilometer [km]) and 50 mi (80 km) radius of the CRN Site, respectively. The CRN Site is located in the Oak Ridge area, which is situated in Appalachian Ridge and Valley Region between two major mountain regions. To the northwest are the Cumberland Mountains and to the southeast are the Great Smoky Mountains. These mountainous regions orient “The Great Valley” in a southwest to northeast alignment. Prevailing winds in the region reflect the channeling of air flow caused by the orientation of the valleys and ridges. Wind speeds are low, with a mean annual wind speed of 2.9 mi per hour (mph) at Oak Ridge. During winter when the jet stream moves southward, the Cumberland Mountains also serve to retard or moderate cold outbreaks by blocking dense, cold polar continental air masses. (Reference 2.7.1-7) In summer, the topography in the region may enhance thunderstorm activity (Reference 2.7.1-2).

The following provides long-term data describing the climatology of the CRN Site based on data collected at the Oak Ridge and Knoxville NWS Stations.

Dry Bulb Temperatures

Table 2.7.1-3 provides average monthly and average annual average normal daily maximum and normal daily minimum temperatures for Oak Ridge and Knoxville for 30 years (yr; 1981 to 2010). Temperatures indicate warm summers and mild winters. In January, normal maximum temperatures are approximately 47°F and normal minimum temperatures are approximately 29°F. In July, normal maximum temperatures are approximately 88°F, and the normal minimum temperatures are approximately 69°F. The normal annual average (dry-bulb) temperature is 58.8°F at Oak Ridge and 59.1°F at Knoxville.

At Oak Ridge, the highest daily maximum temperature was 105°F in July 1952 and again in June 2012. The lowest daily minimum temperature was -17°F recorded in January 1985. (Reference 2.7.1-7)

Atmospheric Water Vapor

The long-term annual relative humidity averages 73 percent based on data from the Knoxville NWS Station (Table 2.7.1-4). Maximum relative humidity readings typically occur in the early morning and the lowest relative humidity occurs in the early to mid-afternoon hours. Average monthly relative humidity ranges from a high of 76 percent in August to a low of 65 percent in April. Table 2.7.1-4 provides monthly averages of relative humidity at the Knoxville NWS Station based on 30 yr of data (1981 to 2010).

Mean wet bulb and dew point temperatures for the Oak Ridge and Knoxville NWS Stations are also presented in Table 2.7.1-4. The mean annual wet bulb temperature is 50.2°F at the Oak Ridge NWS Station and 51.9°F at the Knoxville NWS Station. The maximum mean monthly wet bulb temperature is 69.0 to 69.9°F in July and the minimum mean monthly wet bulb temperature is 31.0 to 33.5°F in January (Oak Ridge NWS and Knoxville NWS).

The mean annual dew point temperature for the Oak Ridge and Knoxville NWS Stations is approximately 50°F. The maximum mean monthly dew point temperatures are 69.7°F and 68.7°F at Oak Ridge NWS Station and Knoxville NWS Station, respectively. The lowest mean monthly dew point temperatures are 31.8°F at Oak Ridge NWS Station and 31.1°F at Knoxville NWS Station. (Reference 2.7.1-7; Reference 2.7.1-5)

Precipitation

Precipitation in the area averages approximately 50 in. annually (Table 2.7.1-2). Winter (January through March) is usually the wettest season, with more than 14 in. at Oak Ridge NWS Station, and late summer-early autumn (August through October) is the driest time of the year, with less than 10 in. The wettest month of the year is July, with normal monthly precipitation of 5.27 in. at the Oak Ridge NWS Station and 5.08 in. at the Knoxville NWS Station (Table 2.7.1-2).

Snowfall in the area is normally light, and, if it occurs, it usually occurs during November through March. The Oak Ridge NWS Station data reports an average of 11.1 in. annually and the Knoxville NWS Station data reports a normal annual value of 6.5 in. (Reference 2.7.1-8; Reference 2.7.1-5).

Severe storms are relatively infrequent because the region is east of maximum tornado activity, south of the most significant snow storms, and inland from hurricane and tropical storm tracks (Reference 2.7.1-2).

The Oak Ridge area is not prone to drought conditions (discussed further in Subsection 2.7.3.6).

Wind Conditions

Monthly average wind data for the Oak Ridge NWS Station and the Knoxville NWS Station are shown in Table 2.7.1-5. The mean annual wind speed at Oak Ridge NWS Station is 2.9 mph,

with a maximum monthly mean of 4.0 mph in March and minimum monthly mean wind speed of 2.1 mph in September. The mean annual wind speed at the Knoxville NWS Station is 6.0 mph, which is about twice that of the Oak Ridge NWS Station. In general, mean monthly wind speeds at Knoxville NWS Station are about twice those at Oak Ridge NWS Station. Ridges associated with the local topography are a primary factor related to the decreased wind speeds at Oak Ridge NWS Station. The peak 3-second wind speed, or wind gust, reported for Oak Ridge NWS Station is 53 mph. This occurred in February 2009.

Monthly and annual prevailing winds at the Oak Ridge NWS Station, as shown in Table 2.7.1-5, reflect the northeast-southwest-oriented topography in the region. The prevailing wind direction for the year at Oak Ridge is from the northeast. The monthly prevailing directions have either a northeasterly or southwesterly component, consistent with the orientation of the mountain ranges around the Oak Ridge area.

2.7.1.4 References

Reference 2.7.1-1. netstate.com, The Geography of Tennessee, Website:
http://www.netstate.com/states/geography/tn_geography.htm, January 5, 2014.

Reference 2.7.1-2. Chattanooga/Hamilton County Air Pollution Control Bureau, "Ambient Air Monitoring Plan 2012," Chattanooga/Hamilton County Air Pollution Control Bureau, Knox County Health Department, Memphis/Shelby County Health Department, Metropolitan Health Department, and Tennessee Department of Environment and Conservation, June 15, 2012.

Reference 2.7.1-3. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Bristol/Jhnsn Cty/Kingsprt, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.1-4. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Chattanooga, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.1-5. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Knoxville, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.1-6. Davis, Robert E., Hayden, Bruce P., Gay, David A., Phillips, William L., and Jones, Gregory V., "The North Atlantic Subtropical Anticyclone," *Journal of Climate* 10: 728-744, April, 1997.

Reference 2.7.1-7. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Oak Ridge, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

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Reference 2.7.1-8. National Oceanic and Atmospheric Administration, 1998 Local Climatological Data Annual Summary with Comparative Data - Oak Ridge, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.1-9. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Nashville, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

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Table 2.7.1-1
Normal Temperatures (°F) Across Tennessee

Month	Nashville¹	Chattanooga²	Oak Ridge²	Knoxville²	Tri-Cities^{3,4}
January	37.7	40.5	37.7	38.2	35.2
February	41.7	44.4	41.8	42.4	39.0
March	50.0	52.2	50.4	50.3	46.7
April	59.0	60.5	58.8	58.8	55.2
May	67.5	68.6	66.8	67.2	63.5
June	75.7	76.5	75.1	75.0	71.5
July	79.4	80.0	78.5	78.4	74.6
August	78.7	79.4	77.6	77.8	73.8
September	71.5	72.5	70.7	71.1	67.1
October	60.3	61.5	59.5	59.9	56.3
November	49.8	51.2	48.9	49.7	46.6
December	40.4	42.6	40.3	40.8	37.8
Annual Average	59.3	60.8	58.8	59.1	55.6

¹ Nashville Basin Region

² Appalachian Ridge and Valley Region

³ Eastern edge of Appalachian Ridge and Valley Region, near Blue Ridge Region

⁴ Tri-Cities includes Bristol/Johnson City/Kingsport, TN area

Sources:

(Reference 2.7.1-9; Reference 2.7.1-4; Reference 2.7.1-7; Reference 2.7.1-5; Reference 2.7.1-3)

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Table 2.7.1-2
Normal Precipitation (inches) Across Tennessee

Month	Nashville ¹	Chattanooga ²	Oak Ridge ²	Knoxville ²	Tri-Cities ^{3,4}
January	3.75	4.91	4.54	4.32	3.37
February	3.94	4.84	4.57	4.26	3.45
March	4.11	4.98	5.06	4.34	3.44
April	4.00	3.99	4.18	4.01	3.33
May	5.50	4.10	4.29	4.51	3.80
June	4.14	4.05	4.28	3.81	3.90
July	3.64	4.91	5.27	5.08	4.69
August	3.17	3.48	2.76	3.27	3.47
September	3.41	4.04	3.69	3.24	2.99
October	3.04	3.28	2.92	2.51	2.10
November	4.31	5.00	4.49	4.01	3.10
December	4.24	4.90	4.86	4.50	3.37
Total Annual	47.25	52.48	50.91	47.86	41.01

¹ Nashville Basin Region

² Appalachian Ridge and Valley Region

³ Eastern edge of Appalachian Ridge and Valley Region, near Blue Ridge Region

⁴ Tri-Cities includes Bristol/Johnson City/Kingsport, TN area

Sources:

(Reference 2.7.1-9; Reference 2.7.1-4; Reference 2.7.1-7; Reference 2.7.1-5; Reference 2.7.1-3)

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Table 2.7.1-3
Dry Bulb Temperatures at the Oak Ridge NWS and Knoxville NWS Stations

	Oak Ridge			Knoxville		
	Normal Daily Maximum Temperature (°F)	Normal Dry-Bulb Temperature (°F)	Normal Daily Minimum Temperature (°F)	Normal Daily Maximum Temperature (°F)	Normal Dry-Bulb Temperature (°F)	Normal Daily Minimum Temperature (°F)
Jan	46.6	37.7	28.9	47.3	38.2	29.2
Feb	51.9	41.8	31.7	52.3	42.4	32.4
Mar	61.4	50.4	39.3	61.4	50.3	39.2
Apr	70.6	58.8	46.9	70.3	58.8	47.3
May	78.3	66.8	55.2	78.1	67.2	56.2
Jun	85.7	75.1	64.5	85.4	75.0	64.7
Jul	88.4	78.5	68.6	88.2	78.4	68.7
Aug	88.0	77.6	67.2	87.8	77.8	67.8
Sep	81.7	70.7	59.7	81.8	71.1	60.4
Oct	71.1	59.5	48.0	71.2	59.9	48.5
Nov	59.6	48.9	38.3	60.4	49.7	39.0
Dec	49.6	40.3	31.1	49.8	40.8	31.7
Annual Average	69.4	58.8	48.3	69.5	59.1	48.8

Sources: (Reference 2.7.1-7; Reference 2.7.1-5)

Table 2.7.1-4
Mean Wet Bulb Temperatures, Dew Point Temperatures and Relative Humidity
at the Oak Ridge and Knoxville NWS Stations

	Oak Ridge ¹		Knoxville		
	Mean Wet Bulb Temperature (°F)	Mean Dew Point Temperature (°F)	Mean Wet Bulb Temperature (°F)	Mean Dew Point Temperature (°F)	Normal Relative Humidity (%)
Jan	31.0	31.8	33.5	31.1	74
Feb	32.8	34.0	36.0	33.6	70
Mar	40.2	40.7	43.0	39.6	66
Apr	48.8	49.8	50.4	47.6	65
May	58.3	58.8	59.6	57.8	73
Jun	65.2	65.8	66.6	65.3	75
Jul	69.0	69.7	69.9	68.7	75
Aug	68.3	68.9	69.1	67.9	76
Sep	62.0	62.3	63.2	61.5	75
Oct	51.2	51.8	52.6	50.9	75
Nov	41.0	41.7	43.0	40.9	74
Dec	34.1	34.1	36.1	33.9	75
Annual Average	50.2	50.8	51.9	49.9	73

¹ Relative humidity not reported for Oak Ridge in 2013 LCD.

Sources:

(Reference 2.7.1-7; Reference 2.7.1-5)

Table 2.7.1-5
Wind Data for the Oak Ridge and Knoxville NWS Stations

	Oak Ridge ¹			Knoxville ²		
	Mean Speed (mph)	Maximum 3-Second Speed (mph)	Prevailing Wind Direction	Mean Speed (mph)	Maximum 3-Second Speed (mph)	Prevailing Wind Direction
Jan	3.4	41	SW	6.7	54	WSW
Feb	3.6	53	NE	7.0	56	WSW
Mar	4.0	40	NE	7.3	58	WSW
Apr	3.8	39	SW	7.1	76	WSW
May	2.9	46	SW	6.2	55	WSW
Jun	2.6	51	SSW	5.6	58	WSW
Jul	2.5	40	SSW	5.4	68	WSW
Aug	2.2	43	ENE	4.8	61	WSW
Sep	2.1	38	ENE	4.9	45	NE
Oct	2.2	41	ENE	5.0	56	NE
Nov	2.5	40	NE	5.5	61	NE
Dec	2.9	44	NE	6.2	57	WSW
Annual ³	2.9	53	NE	6.0	76	WSW

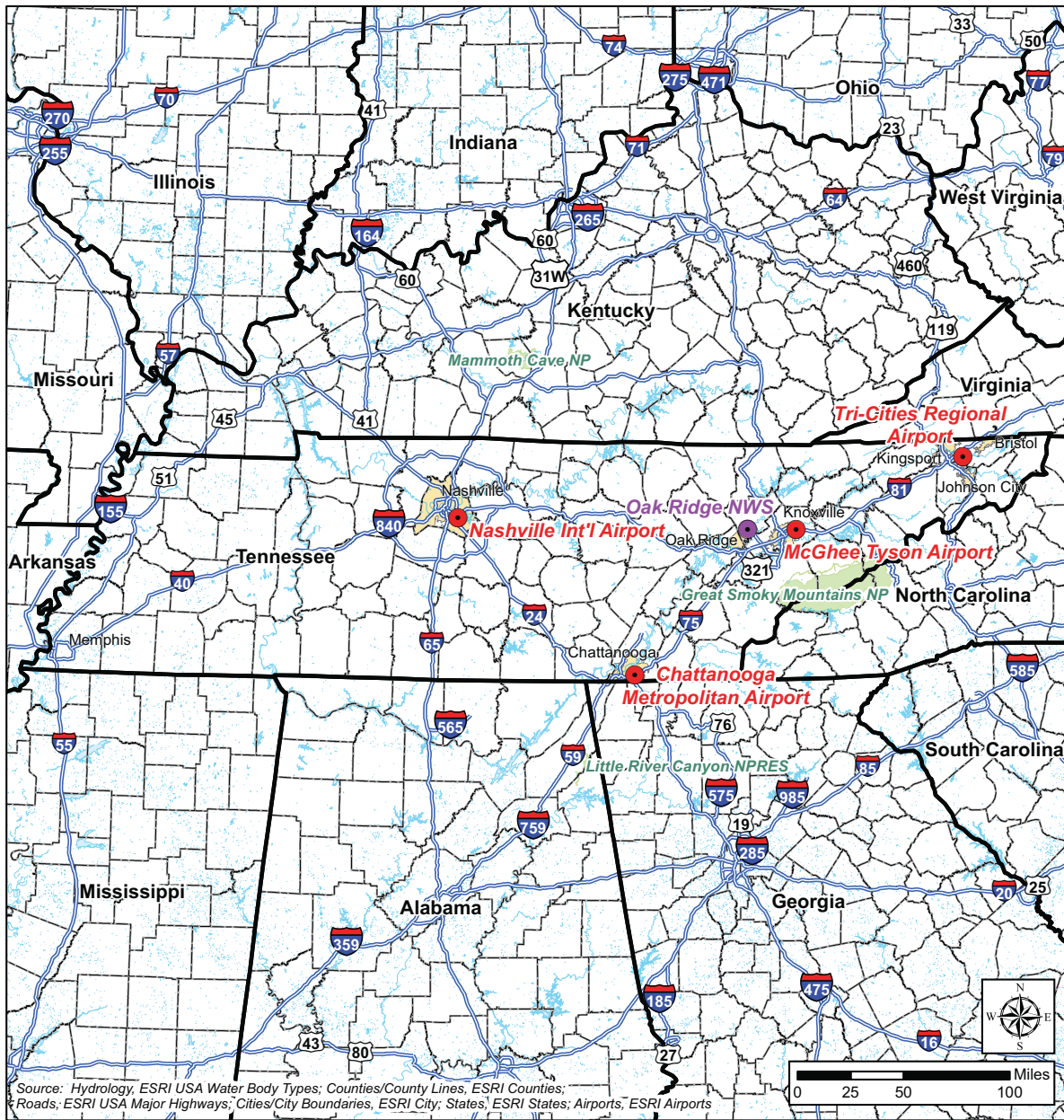
¹ Oak Ridge wind speeds based on 14 years, wind direction based on 15 years data.

² Knoxville mean wind speed based on 30 years, 3-second gust speed based on 18 years, and wind direction on 40 years of data.

³ Wind speed is annual average, 3-second speed is maxima over period of record, and wind direction is prevailing direction over period of record.

Sources:

(Reference 2.7.1-7; Reference 2.7.1-5)



Legend

- | | | | |
|--|--|---|---|
| ● Airport | — Interstate | Counties | National Parks |
| ● Roane State Community College (Oak Ridge Campus) | — Highway | State Line | |
| | City/Town Boundaries | Rivers and Lakes | |

Figure 2.7.1-1. Tennessee Meteorological Data Monitoring City Locations

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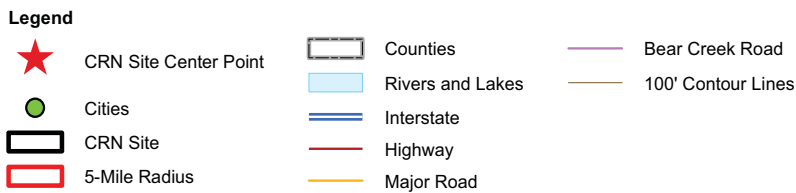
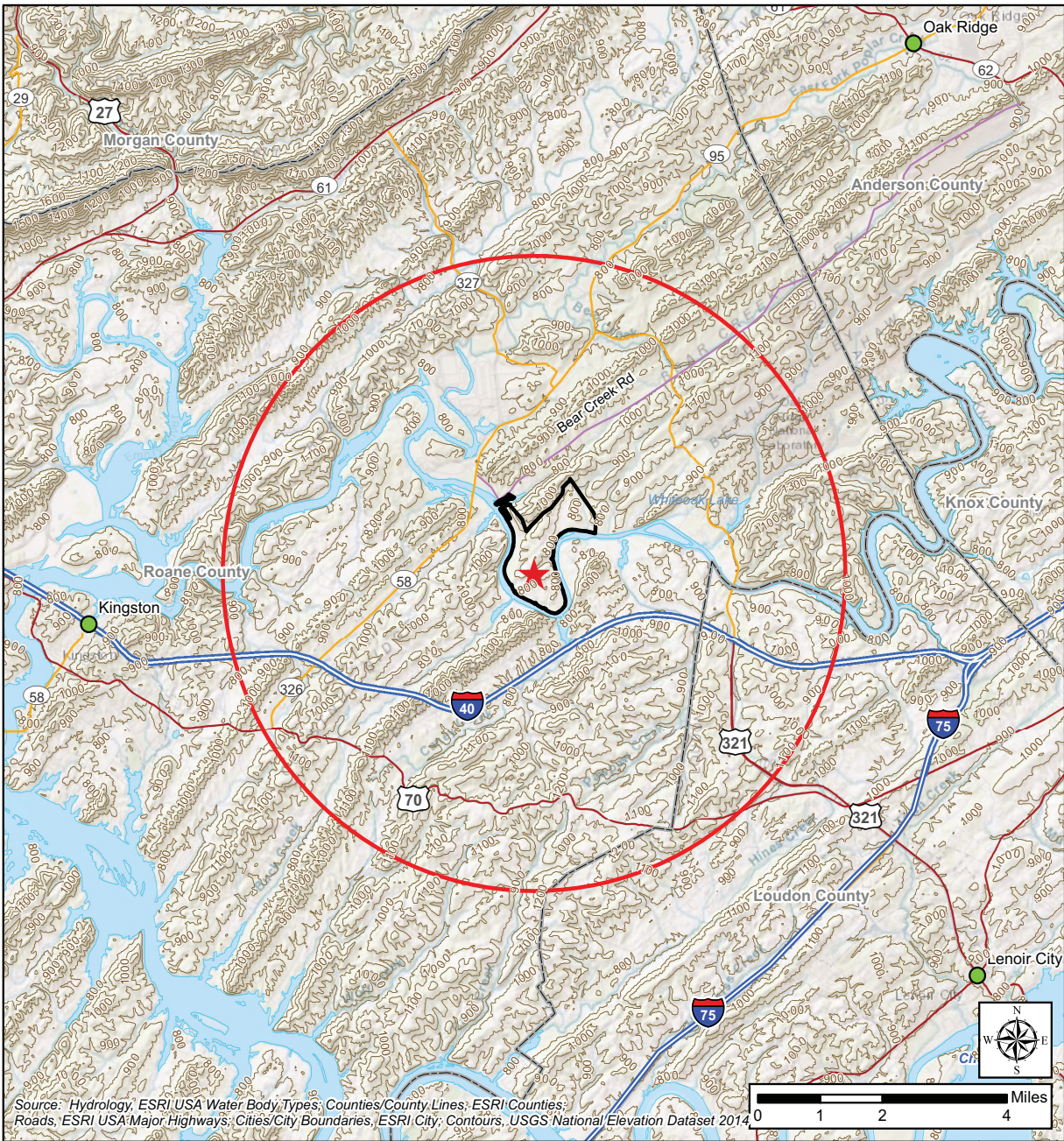
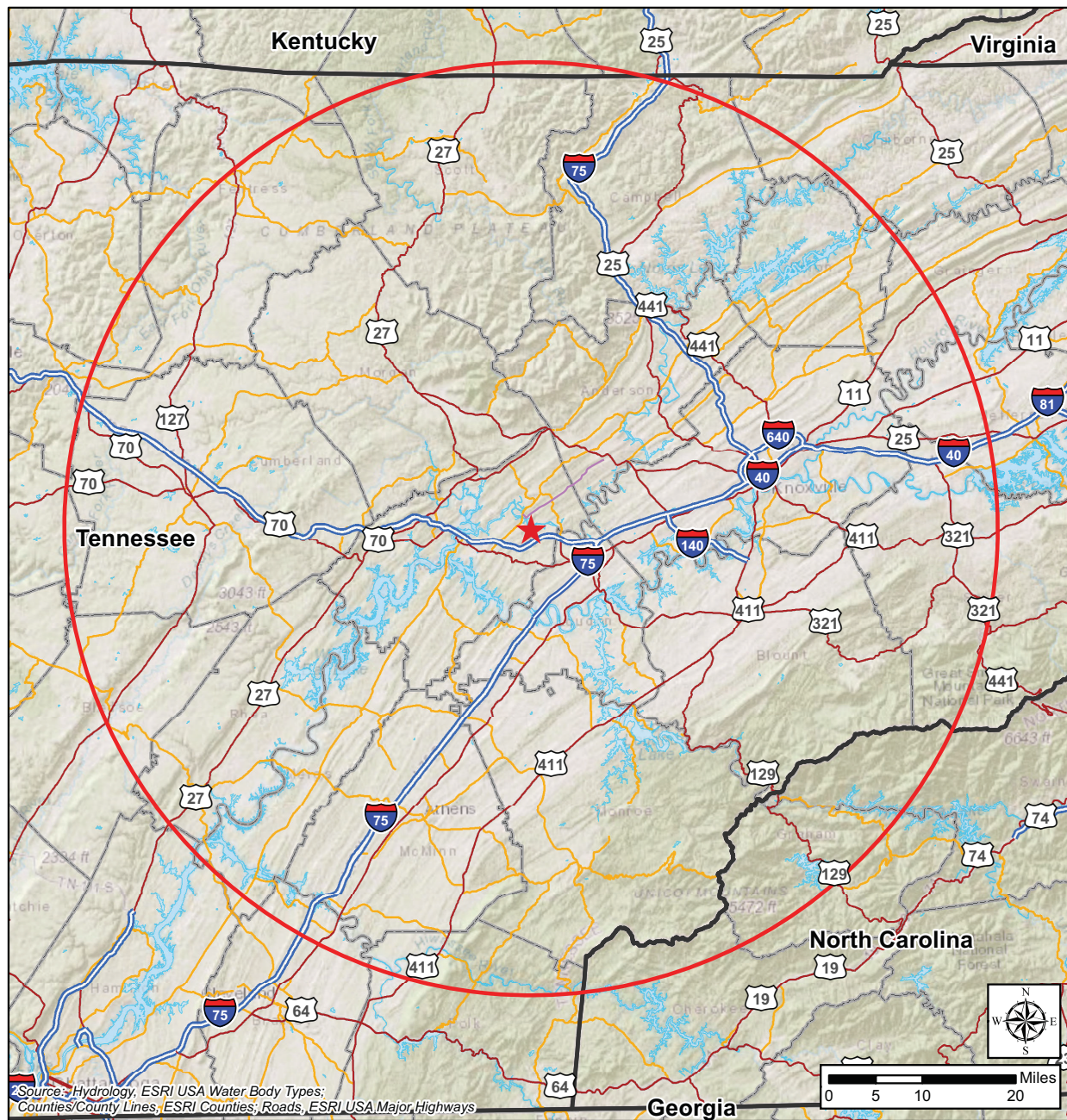


Figure 2.7.1-2. Topographical Features Within 5 Miles of the CRN Site

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Legend

- | | | |
|-------------------------|------------------|-----------------|
| ★ CRN Site Center Point | State Line | Highway |
| 50-Mile Radius | Rivers and Lakes | Major Road |
| Counties | Interstate | Bear Creek Road |

Figure 2.7.1-3. Topographical Features Within 50 Miles of the CRN Site