SECTION 4 – HAZARD IDENTIFICATION

This section of the Plan was updated to include a revised discussion of the hazards that can affect the community. This section discusses hazards in general, whereas Section 5 of the Plan will go into detail about historical occurrences of hazards within the region.

This section will cover the different hazards in a more general sense. Data for each hazard (occurrences, damages, etc.) have been updated to reflect more recent trends using data from various sources. Members of the Project Management Team and participating localities reviewed this data for accuracy.

Communities across the United States and in Virginia, including communities within Planning District 14, are vulnerable to a wide array of natural hazards that threaten life and property. These hazards include:

- **Flood**
- **Hurricanes and Tropical Storms**
- **Severe Thunderstorms and Tornadoes**
- **Wildfire**
- **Drought/Extreme Heat**
- **Winter Storms and Freezes**
- **Hail**
- **Erosion**
- **Dam/Levee Failure**
- **Earthquakes, Sinkholes and Landslides**
- **Man-made hazards**
  - **Hazardous material/chemical spills**
  - **Bio hazards**
  - **Accidents at fertilizer/other chemical facilities**
  - **Accidents at power plants/substations**
  - **Pipeline explosions**

These hazards affect the region to varying degrees.

This section of the updated Plan will include a brief discussion of man-made hazards. This narrative will not be very detailed, due to the lack of available data and the difficulties in quantifying the effects of man-made hazards on the community, but will identify man-made hazards that could impact the region.

Some hazards are interrelated (i.e., hurricanes can cause flooding and tornadoes), and some consist of hazardous elements that are not listed separately (i.e., severe thunderstorms can cause lightning; hurricanes can cause coastal erosion – or, more specific to this region, high winds, heavy rain and flooding). In addition, terrorist-related incidents or accidents involving chemical, radiological or biological agents can coincide with natural hazard events, such as flooding caused by destruction of a dam or an accidental chemical release caused by a tornado. It should also be noted that some hazards, such as severe winter storms, may impact a large area yet cause little damage, while other hazards, such as a tornado, may impact a small area yet cause extensive damage. This section provides a general description for each of the hazards listed above along with their hazardous elements, written from a national perspective. Section 5 will look at these hazards from more of a regional perspective.

Floods

Flooding is the most frequent and costly natural hazard in the United States. According to the National Weather Service, floods have caused more than 10,000 deaths since 1900. It is a common occurrence that, in many years, 75% or more of all presidential disaster declarations result – at least, in part – from flooding.

Floods are generally the result of excessive precipitation, and can be classified under two categories: general floods, precipitation over a given river basin for a long period of time; and flash floods, the product of heavy localized precipitation in a short time period over a given location. The severity of a flooding event is determined by a combination of stream and river basin topography and physiography; precipitation and weather patterns; recent soil moisture conditions; and the degree of vegetative clearing.

Flooding in Scottsville from Hurricane Agnes, 1972. Scottsville is in Albemarle County, located across the James River from Buckingham County. (Source: VDEM)

General floods are usually long-term events that may last for several days. The primary types of general flooding include riverine, coastal, and urban flooding. Riverine flooding is a function of excessive precipitation levels and water runoff volumes within the watershed of a stream or river. Coastal flooding is typically a result of storm surge, wind-driven waves, and heavy rainfall produced by hurricanes, tropical storms, nor'easters, and other large storms. Urban flooding occurs where man-made development has obstructed the natural flow of water and decreased the ability of natural groundcover to absorb and retain surface water runoff.

Torrential rains on September 23, 2011 caused flooding throughout the region. In this photo, cars parked at Longwood Landing in Farmville are partially submerged (photo courtesy Melinda Hanks via Facebook).

Flash flooding events usually occur either from a dam or levee failure, within minutes or after hours of heavy amounts of rainfall, or from a sudden release of water held by an ice jam.

Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. Although flash flooding occurs often along mountain streams, it is also common in urbanized areas where much of the ground is covered by impervious surfaces. Flash flood waters move at very high speeds – “walls” of water can reach heights of 10 to 20 feet. Flash flood waters and the accompanying debris can uproot trees, roll boulders, destroy buildings, and obliterate bridges and roads.

The periodic flooding of lands adjacent to rivers, streams, and shorelines (land known as floodplain) is a natural and inevitable occurrence that can be expected to take place based upon established recurrence intervals. The recurrence interval of a flood is defined as the average time interval, in years, expected between a flood event of a particular magnitude and an equal or larger flood. Flood magnitude increases with increasing recurrence interval.

Floodplains are designated by the frequency of the flood that is large enough to cover them. For example, the 10-year floodplain will be covered by the 10-year flood and the 100-year floodplain by the 100-year flood. Flood frequencies such as the 100-year flood are determined by plotting a graph of the size of all known floods for an area and determining how often floods of a particular size occur. Another way of expressing the flood frequency is the chance of occurrence in a given year, which is the percentage of the probability of flooding each year. For example, the 100-year flood has a 1 percent chance of occurring in any given year.

Table 4.1 shows flood damage values by fiscal year, since 1960, from a national perspective. It is important to note that these numbers should be considered approximate, since no one federal agency has specific responsibility for collecting and evaluating detailed flood loss information. The flood data presented below is from the National Weather Service (NWS), which – through its field offices – provides loss estimates for significant flooding events. However, since this is not the agency’s main focus, the quality of this data may be uneven. The Construction Cost Index, in the third column from the left, is used to adjust dollar figures for inflation. The Adjustment Factor, in the fourth column from the left, is the factor applied to unadjusted estimates to get damage estimates adjusted to 2014 dollars.

Table 4.1
National Flood Damage by Fiscal Year/Water Year*

*Fiscal Year/ Water Year **	*Unadjusted Damages*	*Adjusted Damages (2014 Dollars) ***	*U.S. Population ****	*Damage Per Capita (2014 Dollars)*
1960	$92,976,000	$1,106,459,534	180,671,158	$6.12
1961	$154,033,000	$1,783,291,143	183,691,481	$9.71
1962	$75,237,000	$846,071,126	186,537,737	$4.54
1963	$177,946,000	$1,936,668,675	189,241,798	$10.23
1964	$651,642,000	$6,826,924,628	191,888,791	$35.58
1965	$788,046,000	$7,958,371,860	194,302,963	$40.96
1966	$117,004,000	$1,125,948,208	196,560,338	$5.73
1967	$375,218,000	$3,425,873,099	198,712,056	$17.24
1968	$339,399,000	$2,881,512,203	200,706,052	$14.36
1969	$902,654,000	$6,975,118,301	202,676,947	$34.41
1970	$225,453,000	$1,600,863,228	205,052,174	$7.81

1971	$287,525,000	$1,783,346,078	207,660, 677	$8.59
1972	$4,465,135,000	$24,977,246,897	209,896,021	$119.20
1973	$1,894,493,000	$9,803,376,442	211,908,788	$46.26
1974	$576,203,000	$2,797,151,791	213,853,928	$13.08
1975	$1,373,269,000	$6,087,828,126	215,973,199	$28.19
1976	$3,000,000,000	$12,252,394,385	218,035,164	$56.19
1977	$1,300,000,000	$4,948,680,124	220,239,425	$22.47
1978	$700,000,000	$2,472,694,524	222,584,545	$11.11
1979	$3,500,000,000	$11,428,904,429	225,055,487	$50.78
1980	$1,500,000,000	$4,544,022,243	227,224,681	$20.00
1981	$1,000,000,000	$2,773,974,540	229,465,714	$12.09
1982	$2,500,000,000	$6,409,150,327	231,664,458	$27.67
1983	$4,000,000,000	$9,646,827,349	233,791,994	$41.26
1984	$3,750,000,000	$8,869,392,185	235,824,902	$37.61
1985	$500,000,000	$1,168,772,348	237,923,795	$4.91
1986	$6,000,000,000	$13,698,719,441	240,132,887	$57.05
1987	$1,444,199,000	$3,214,211,392	242,288,918	$13.27
1988	$225,298,000	$488,885,193	244,498,982	$2.00
1989	$1,080,814,000	$2,296,524,829	246,819,230	$9.30
1990	$1,636,431,000	$3,391,133,218	249,464,396	$13.59
1991	$1,698,781,000	$3,445,345,705	252,153,092	$13.70
1992	$762,762,000	$1,500,430,125	255,029,699	$5.88
1993	$16,370,010,000	$30,810,809,608	257,782,608	$119.52
1994	$1,120,309,000	$2,031,388,693	260,327,021	$7.80
1995	$5,110,829,000	$9,160,444,009	262,803,276	$34.86
1996	$6,121,884,000	$10,681,707,207	265,228,572	$40.27
1997	$8,730,407,000	$14,694,536,739	267,783,607	$54.87
1998	$2,496,960,000	$4,136,011,784	270,248,003	$15.30
1999	$5,455,263,000	$8,828,900,640	272,690,813	$32.38
2000	$1,338,735,000	$2,110,213,054	282,171,957	$7.48
2001	$7,309,308,000	$11,299,869,817	285,081,556	$39.64
2002	$1,211,339,000	$1,816,823,223	287,803,914	$6.31
2003	$2,482,230,000	$3,636,203,672	290,326,418	$12.52
2004	$13,970,646,000	$19,254,554,417	293,045,739	$65.70
2005	*$42,010,435,000*	$55,525,587,646	295,753,151	$142.045
2006	$3,744,636,000	$4,737,440,410	298,593,212	$15.87
2007	$2,529,242,000	$2,936,200,387	301,579,895	$9.74
2008	$6,987,392,000	$6,747,571,742	304,374,846	$22.17
2009	$1,000,026,000	$1,099,446,636	307,006,550	$3.58
2010	$5,041,227,000	$5,615,860,859	309,347,057	$18.15
2011	$8,410,469,500	$9,102,294,087	311,721,632	$29.20
2012	$495,583,000	$552,119,985	314,112,078	$1.78
2013	$2,152,417,080	$2,210,809,876	316,497,531	$6.99
2014	$2.861,426,089	$2,861,426,089	318,857,056	$8.97

Source: National Weather Service, U.S. Census Bureau
*The federal fiscal year/NOAA-NWS water year starts on October 1, and ends on September 30.
**The dollar figures were adjusted using the Construction Cost Index (CCI) from McGraw-Hill Construction/ the Engineering News Report.
*** Population on July 1 of each year. Damage per capita based on adjusted damages divided by population.

It should be noted that for 2005, those figures do NOT include most of the flooding from Hurricane Katrina since damages and deaths from that storm were largely due to storm surge (and not fresh water flooding). Likewise, for 2012, those figures do NOT include most of the flooding from Superstorm Sandy.

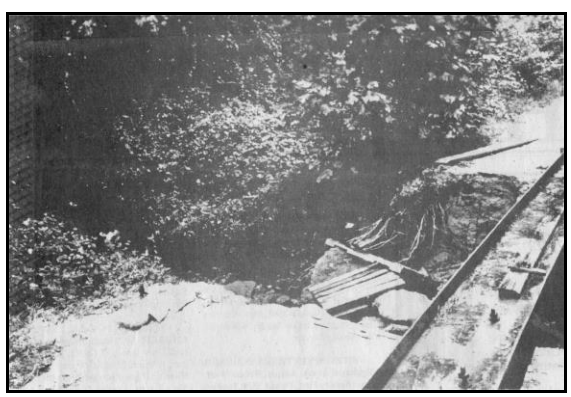
Hurricanes and Tropical Storms

Hurricanes, tropical storms, nor'easters and typhoons, also classified as cyclones, are any closed circulation developing around a low-pressure center in which the winds rotate counter-clockwise in the Northern Hemisphere (or clockwise in the Southern Hemisphere) and whose diameter averages 10 to 30 miles across. A tropical cyclone refers to any such circulation that develops over tropical waters. Tropical cyclones act as a "safety-valve," limiting the continued build-up of heat and energy in tropical regions by maintaining the atmospheric heat and moisture balance between the tropics and the pole-ward latitudes. The primary damaging forces associated with these storms are high-level sustained winds, heavy precipitation, and tornadoes. Coastal areas are also vulnerable to the additional forces of storm surge, wind-driven waves, and tidal flooding which can be more destructive than cyclone wind.

The key energy source for a tropical cyclone is the release of latent heat from the condensation of warm water. Their formation requires a low-pressure disturbance, warm sea surface temperature, rotational force from the spinning of the earth, and the absence of wind shear in the lowest 50,000 feet of the atmosphere. The majority of hurricanes and tropical storms form in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico during the official Atlantic hurricane season, which encompasses the months of June through November. The peak of the Atlantic hurricane season is in early to mid-September and, according to the National Hurricane Center, the average number of storms that reach hurricane intensity per year in the Atlantic Basin is about six (6).

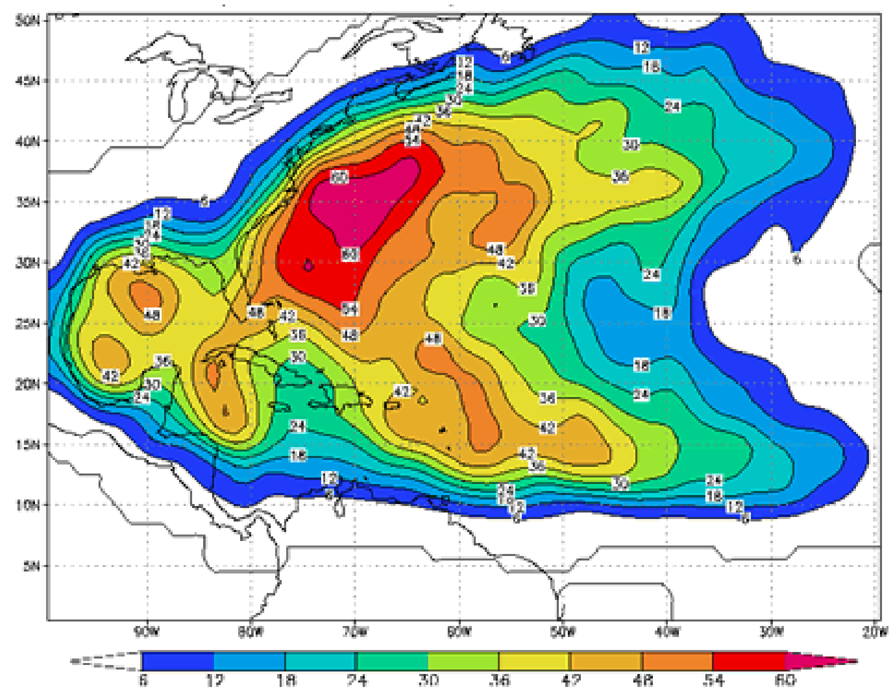
Map 4.1 shows for any particular location what the chance is that a tropical storm or hurricane will affect the area sometime during the whole Atlantic Hurricane Season (June to November). The figure was created by the National Oceanic and Atmospheric Administration's Hurricane Research Division using data from 1944 to 1999 and counting hits when a storm or hurricane was within approximately 100 miles (165 km) of each location.

Tree damage in Farmville from Hurricane Isabel in September 2003. (Photo courtesy of *The Farmville Herald*)



A section of Route 642 in Nottoway County, just south of Crewe, was washed out by heavy rains from Tropical Storm Gaston in August 2004. The steel beam in the photo was placed across the washed-out section of road so vehicles could pass until the road was repaired. (Photo courtesy of *The Crewe-Burkeville Journal*)

Map 4.1
Empirical Probability of a Named Storm



Source: National Oceanic and Atmospheric Administration, Hurricane Research Division

As an incipient hurricane develops, barometric pressure (measured in Millibars or inches) at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 miles per hour, the system is designated a tropical storm (and given a name), and is closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 miles per hour, the storm is classified a hurricane. Hurricane intensity is classified by the Saffir-Simpson Scale, which rates hurricane intensity on a scale of 1 to 5, with 5 being the most intense (see **Table 4.2**). It should be noted that the Saffir-Simpson Scale has been updated, and no longer includes surge values or minimum surface pressures.

The Saffir-Simpson Scale categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential, which are combined to estimate potential damage. Categories 3, 4, and 5 are classified as “major” hurricanes, and while hurricanes within this range comprise only 20 percent of total tropical cyclone landfalls, they account for over 70 percent of the damage in the United States. **Table 4.2** also describes the damage that could be expected for each category of hurricane.

Table 4.2
Saffir-Simpson Scale, Hurricane Damage Classification

Category	Maximum Sustained Wind Speed (MPH)	Damage Level	Damage Description
1	74 – 95	MINIMAL – MODERATE	Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96 – 110	EXTENSIVE	Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111 – 129	DEVASTATING	Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	130 – 156	CATASTROPHIC	Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5	157 and higher	CATASTROPHIC	A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Source: National Hurricane Center

A storm surge is a large dome of water often 50 to 100 miles wide and rising anywhere from four to five feet in a Category 1 hurricane up to 20 feet in a Category 5 storm. The storm surge arrives ahead of the storm's actual landfall and the more intense the hurricane is, the sooner the surge arrives. It should be noted that the Saffir-Simpson Scale has been updated, and no longer includes surge values.

Water rise can be very rapid, posing a serious threat to those who have not yet evacuated flood-prone areas. A storm surge is a wave that has outrun its generating source and become a long period swell. The surge is always highest in the right-front quadrant of the direction in which the hurricane is moving. As the storm approaches shore, the greatest storm surge will be to the north of the hurricane eye. Such a surge of high water topped by waves driven by hurricane force winds can be devastating to coastal regions, causing severe beach erosion and property damage along the immediate coast.

Storm surge heights, and associated waves, are dependent upon the shape of the continental shelf (narrow or wide) and the depth of the ocean bottom (bathymetry). A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water close to the shoreline, tends to produce a lower surge but higher and more powerful storm waves.

Hurricane Floyd brought a devastating 15 feet of storm surge that damaged or destroyed hundreds of houses along the ocean front of Long Beach on Oak Island, North Carolina in September 1999. A prime example of successful hazard mitigation can be seen in the photo above. The elevated home (right) survived while the older, ground-level block foundation of the home on the left was crushed. (Photo by Dave Gatley/FEMA News Photo)

Damage during hurricanes may also result from spawned tornadoes and inland flooding associated with heavy rainfall that usually accompanies these storms. Hurricane Floyd, as an example, was at one time a Category 4 hurricane racing towards the North Carolina coast. As far inland as Raleigh, the state capital (located more than 100 miles from the coast), communities were preparing for extremely damaging winds exceeding 100 miles per hour. However, Floyd made landfall as a Category 2 hurricane and will be remembered for causing the worst inland flooding disaster in North Carolina's history. Parts of southeastern Virginia suffered significant flooding as a result of the storm. Rainfall amounts were as high as 20 inches in certain locales and 67 counties sustained damages. A total of 57 deaths were attributed to Floyd, all but one of those occurring in the United States (which included 35 in North Carolina and three in Virginia).

Similar to hurricanes, nor'easters are ocean storms capable of causing substantial damage to coastal areas in the Eastern United States due to their associated strong winds and heavy surf. Nor'easters are named for the winds that blow in from the northeast and drive the storm up the East Coast along the Gulf Stream, a band of warm water that lies off the Atlantic coast. They are caused by the interaction of the jet stream with horizontal temperature gradients and generally occur during the fall and winter months when moisture and cold air are plentiful.

Nor'easters are known for dumping heavy amounts of rain and snow, producing hurricane-force winds, and creating high surfs that cause severe beach erosion and coastal flooding. There are two main components to a nor'easter: (1) a Gulf Stream low-pressure system (counter-clockwise winds) generated off the southeastern U.S. coast, gathering warm air and moisture from the Atlantic, and pulled up the East Coast by strong northeasterly winds at the leading edge of the storm; and (2) an Arctic high-pressure system (clockwise winds) which meets the low-pressure system with cold, arctic air blowing down from Canada. When the two systems collide, the moisture and cold air produce a mix of precipitation and have the potential for creating dangerously high winds and heavy seas. As the low-pressure system deepens, the intensity of the winds and waves will increase and cause serious damage to coastal areas as the storm moves northeast.

Table 4.4 shows an intensity scale proposed for nor'easters that is based upon levels of coastal degradation.

Table 4.3
Dolan-Davis Nor'easter Intensity Scale

Storm Class	Beach Erosion	Dune Erosion	Overwash	Property Damage
1 (Weak)	Minor changes	None	No	No
2 (Moderate)	Modest; mostly to lower beach	Minor	No	Modest
3 (Significant)	Erosion extends across beach	Can be significant	No	Loss of many structures at local level
4 (Severe)	Severe beach erosion and recession	Severe dune erosion or destruction	On low beaches	Loss of structures at community-scale
5 (Extreme)	Extreme beach erosion	Dunes destroyed over extensive areas	Massive in sheets and channels	Extensive at regional-scale; millions of dollars

Source: North Carolina Division of Emergency Management

Severe Thunderstorms and Tornadoes

According to the National Weather Service, more than 100,000 thunderstorms occur each year, though only about 10 percent of these storms are classified as "severe." Although thunderstorms generally affect a small area when they occur, they are very dangerous because of their ability to generate tornadoes, hailstorms, strong winds, flash flooding, and damaging lightning. While thunderstorms can occur in all regions of the United States, they are most common in the central and southern states because atmospheric conditions in those regions are most ideal for generating these powerful storms.

Multiple cloud-to-ground and cloud-to-cloud lightning strikes observed during a nighttime thunderstorm. (Photo courtesy of NOAA Photo Library, NOAA Central Library; OAR/ERL/ National Severe Storms Laboratory)

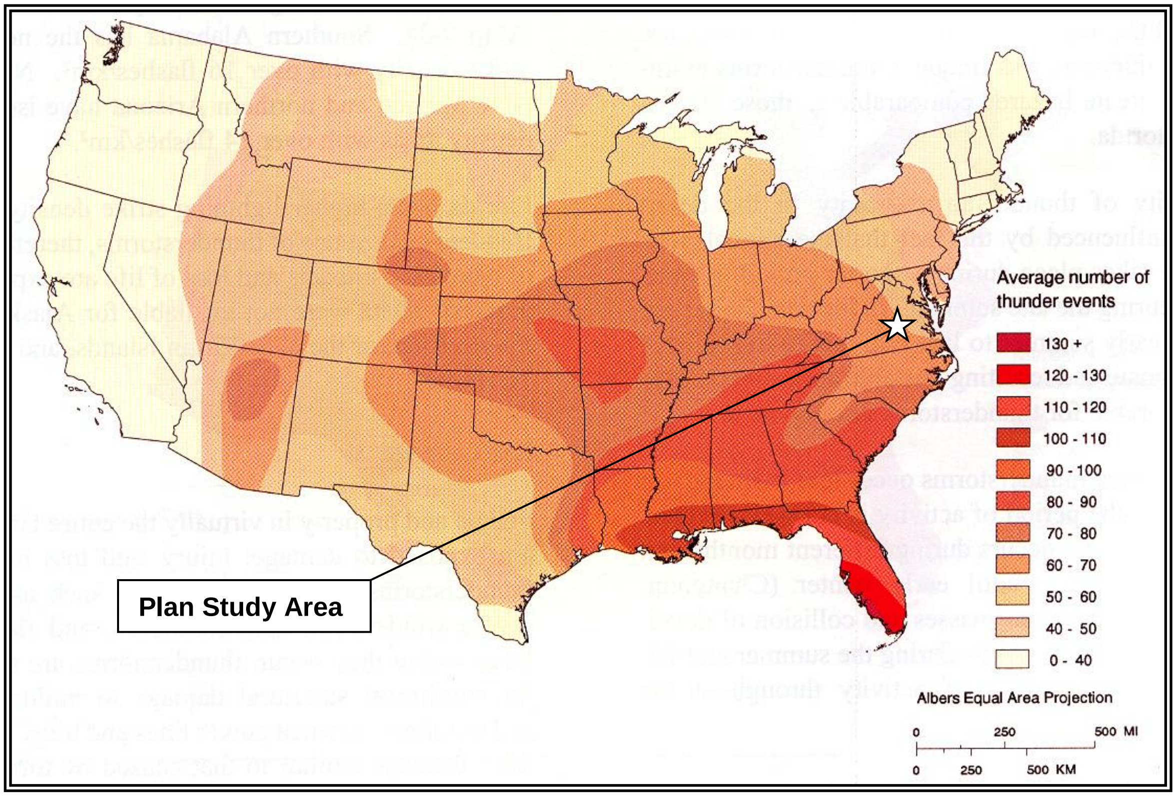
Thunderstorms are caused when air masses of varying temperatures meet. Rapidly rising warm moist air serves as the "engine" for thunderstorms. These storms can occur singularly, in lines, or in clusters. They can move through an area very quickly or linger for several hours.

Lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes thunder. According to the National Weather Service, on average, an estimated 25 million lightning strikes occur each year and over the past 30 years, lightning strikes have killed an average of 58 people per year.

The National Weather Service collected data for thunder days, number and duration of thunder events, and lightning strike density for the 30-year period from 1948 to 1977. A series of maps was generated showing the annual average thunder event duration, the annual average number of thunder events, and the mean annual density of lightning strikes.

Map 4.2 illustrates thunderstorm hazard severity based on the annual average number of thunder events from 1948 to 1977.

Map 4.2
Annual Average Number of Thunder Events



Source: Federal Emergency Management Agency

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other storms) when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. According to the National Weather Service, tornado wind speeds normally range from 40 to more than 300 miles per hour. The most violent tornadoes have rotating winds of 250 miles per hour or more and are capable of causing extreme destruction and turning normally harmless objects into deadly missiles.

At least one confirmed tornado struck Lunenburg County on April 16, 2010. Areas north of Victoria were hit, with several houses and some other buildings receiving damage. Pictured above is tornado damage in and around the Victoria Golf Club. (Photo courtesy *Kenbridge-Victoria Dispatch*)

Each year, an average of over 1,100 tornadoes is reported nationwide, resulting in an average of more than 70 deaths and 1,500 injuries per year over the last 30 years (NOAA, 2015). They are more likely to occur during the spring and early summer months of March through June and can occur at any time of day, but are likely to form in the late afternoon and early evening. Most tornadoes are a few dozen yards wide and touch down briefly, but even small short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and several miles long.

Waterspouts are weak tornadoes that form over warm water and are most common along the Gulf Coast and southeastern states. Waterspouts occasionally move inland, becoming tornadoes that cause damage and injury. However, most waterspouts dissipate over the open water causing threats only to marine and boating interests. Typically a waterspout is weak and short-lived, and because they are so common, most go unreported unless they cause damage.

The destruction caused by tornadoes ranges from light to inconceivable depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damages to structures of light construction such as residential homes (particularly mobile homes), and tend to remain localized in impact. The Fujita-Pearson Scale for Tornadoes (**Table 4.4**) was developed to measure tornado strength and associated damages. The tornado scale was enhanced in 2007. The enhanced scale is on the next page.

Table 4.4
Fujita-Pearson Scale for Tornadoes

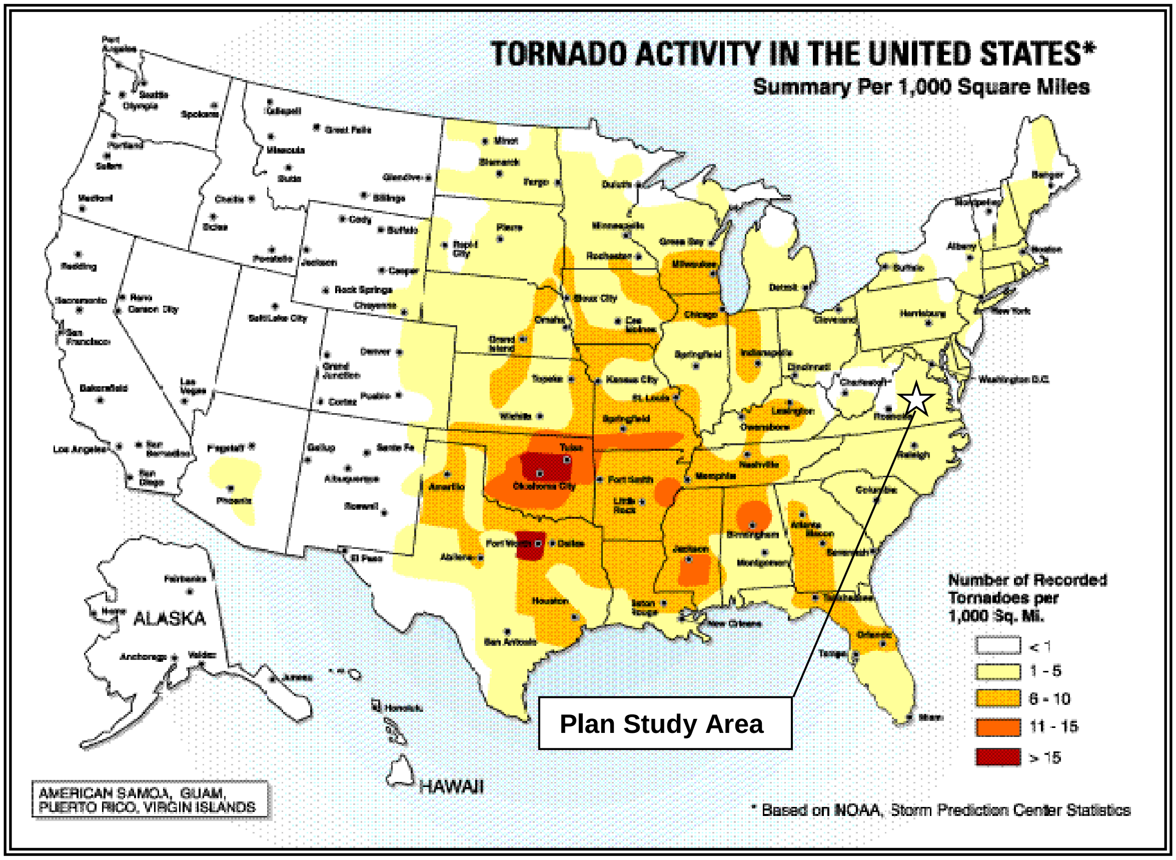
FUJITA SCALE			DERIVED EF SCALE		OPERATIONAL EF SCALE	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	**EF Number**	**3 Second Gust (mph)**
0	40-72	45-78	0	65-85	**0**	**65-85**
1	73-112	79-117	1	86-109	**1**	**86-110**
2	113-157	118-161	2	110-137	**2**	**111-135**
3	158-207	162-209	3	138-167	**3**	**136-165**
4	208-260	210-261	4	168-199	**4**	**166-200**
5	261-318	262-317	5	200-234	**5**	**Over 200**

NOTE: The Enhanced F-scale is still a set of wind estimates (not measurements) based on damage. Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed below. These estimates vary with height and exposure. The 3 second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured "one minute mile" speed.

Source: NOAA (http://www.spc.noaa.gov/faq/tornado/ef-scale.html)

According to the NOAA Storm Prediction Center (SPC), the highest concentration of tornadoes in the United States has been in Oklahoma, Texas, Kansas and Florida respectively. Although the Great Plains region of the Central United States does favor the development of the largest and most dangerous tornadoes (earning the designation of “tornado alley”), Florida experiences the greatest number of tornadoes per square mile of all U.S. states (SPC, 2002). **Map 4.3** shows tornado activity in the United States based on the number of recorded tornadoes per 1,000 square miles.

Map 4.3
Tornado Activity in the United States



Source: American Society of Civil Engineers

The tornadoes associated with tropical cyclones are most frequent in September and October when the incidence of tropical storm systems is greatest. This type of tornado usually occurs around the perimeter of the storm, and most often to the right and ahead of the storm path or the storm center as it comes ashore. These tornadoes commonly occur as part of large outbreaks and generally move in an easterly direction.

Map 4.4 shows how the frequency and strength of extreme windstorms vary across the United States. The map was produced by the Federal Emergency Management Agency and is based on 40 years of tornado history and over 100 years of hurricane history. Zone IV, the darkest area on the map, has experienced both the greatest number of tornadoes and the strongest tornadoes. As shown by the map key, wind speeds in Zone IV can be as high as 250 mph.

Map 4.4
Wind Zones in the United States

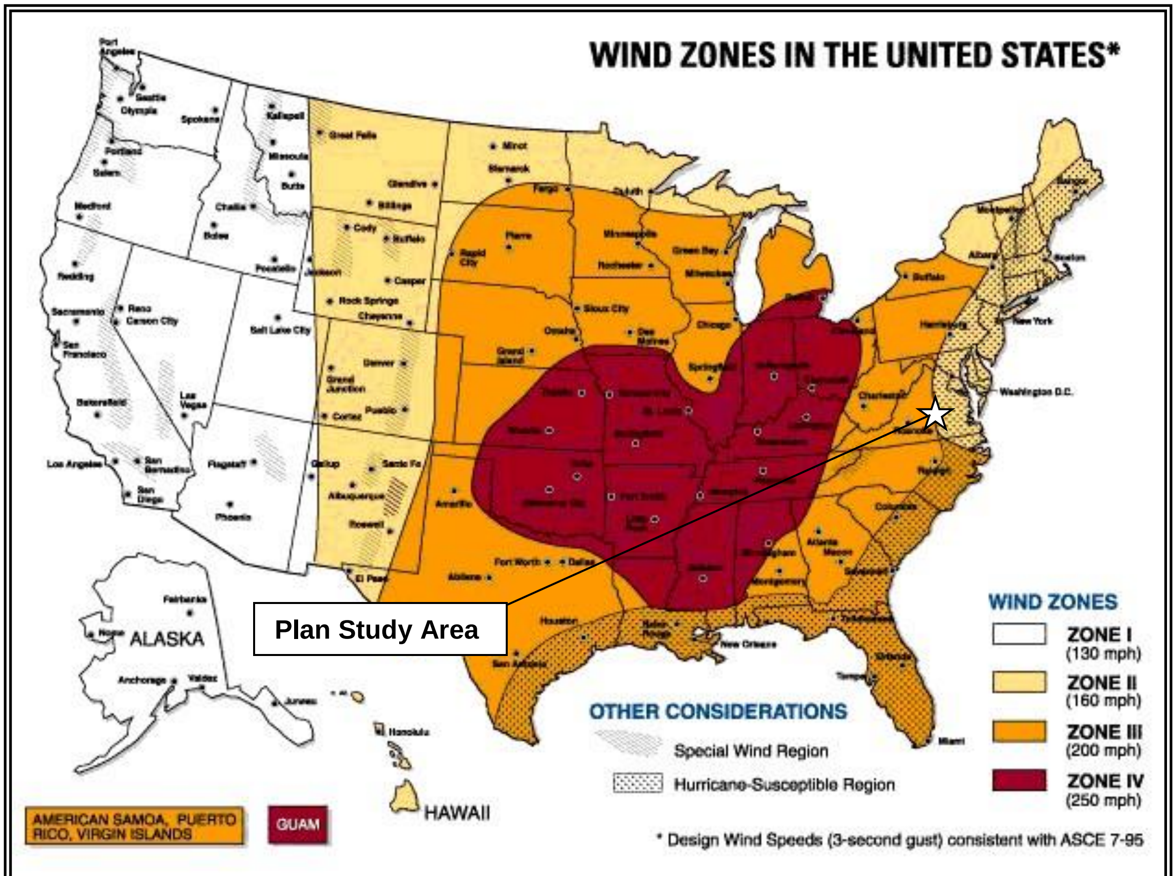


Figure I.2 Wind zones in the United States

Source: Federal Emergency Management Agency

Wildfire

A wildfire is any fire occurring in a wildland area (i.e. grassland, forest, brush land) except for fire under prescription. (Prescription burning, or "controlled burning," undertaken by land management agencies is the process of igniting fires under selected conditions, in accordance with strict parameters.) Wildfires are part of the natural management of the Earth's ecosystems, but may also be caused by natural or human factors. Over 80 percent of forest fires are started by negligent human behavior such as smoking in wooded areas or improperly extinguishing campfires. The second most common cause for wildfire is lightning.

There are three classes of wildland fires: surface fire, ground fire, and crown fire. A surface fire is the most common of these three classes and burns along the floor of a forest, moving slowly and killing or damaging trees. A ground fire (muck fire) is usually started by lightning or human carelessness and burns on or below the forest floor. Crown fires spread rapidly by wind and move quickly by jumping along the tops of trees. Wildland fires are usually signaled by dense smoke that fills the area for miles around.

State and local governments can impose fire safety regulations on home sites and developments to help curb wildfire. Land treatment measures such as fire access roads, water storage, helipads, safety zones, buffers, firebreaks, fuel breaks, and fuel management can be designed as part of an overall fire defense system to aid in fire control. Fuel management, prescribed burning, and cooperative land management planning can also be encouraged to reduce fire hazards.

Fire probability depends on local weather conditions, outdoor activities such as camping, debris burning, and construction, and the degree of public cooperation with fire prevention measures. Drought conditions and other natural disasters (tornadoes, hurricanes, etc.) increase the probability of wildfires by producing fuel in both urban and rural settings. Forest damage from hurricanes and tornadoes may block interior access roads and fire breaks, pull down overhead power lines, or damage pavement and underground utilities.

Many individual homes and cabins, subdivisions, resorts, recreational areas, organizational camps, businesses, and industries are located within high fire hazard areas. The increasing demand for outdoor recreation places more people in wildlands during holidays, weekends, and vacation periods. Unfortunately, wildland residents and visitors are rarely educated or prepared for the inferno that can sweep through the brush and timber and destroy property in minutes.

On Sunday, August 6, 2000, several forest fires converged near Sula, Montana, forming a firestorm that overran 100,000 acres and destroyed 10 homes. Temperatures in the flame front were estimated at more than 800 degrees. Nevertheless, the wildlife pictured above appeared to be taking the crisis in stride, gathering near the East Fork of the Bitterroot River where it crosses under U.S. Highway 93. (Photo by John McColgan/U.S. Forest Service Firefighter)

Drought/Extreme Heat

Drought is a natural climatic condition caused by an extended period of limited rainfall beyond that which occurs naturally in a broad geographic area. High temperatures, high winds, and low humidity can worsen drought conditions, and can make areas more susceptible to wildfire. Human demands and actions can also hasten drought-related impacts.

Droughts are frequently classified as one of following four types:

- Meteorological,
- Agricultural,
- Hydrological, and
- Socio-economic.

Meteorological droughts are typically defined by the level of "dryness" when compared to an average, or normal amount of precipitation over a given period of time. Agricultural droughts relate common characteristics of drought to their specific agricultural-related impacts. Emphasis tends to be placed on factors such as soil water deficits, water needs based on differing stages of crop development, and water reservoir levels. Hydrological drought is directly related to the effect of precipitation shortfalls on surface and groundwater supplies. Human factors, particularly changes in land use, can alter the hydrologic characteristics of a basin. Socio-economic drought is the result of water shortages that limit the ability to supply water-dependent products in the marketplace.

A USGS stream flow gauging station at the Ogeechee River near Eden, Georgia in July 2000 illustrates the drought conditions that can severely affect water supplies, agriculture, stream water quality, recreation, navigation, and forest resources. (Photo courtesy of the United States Geological Survey)

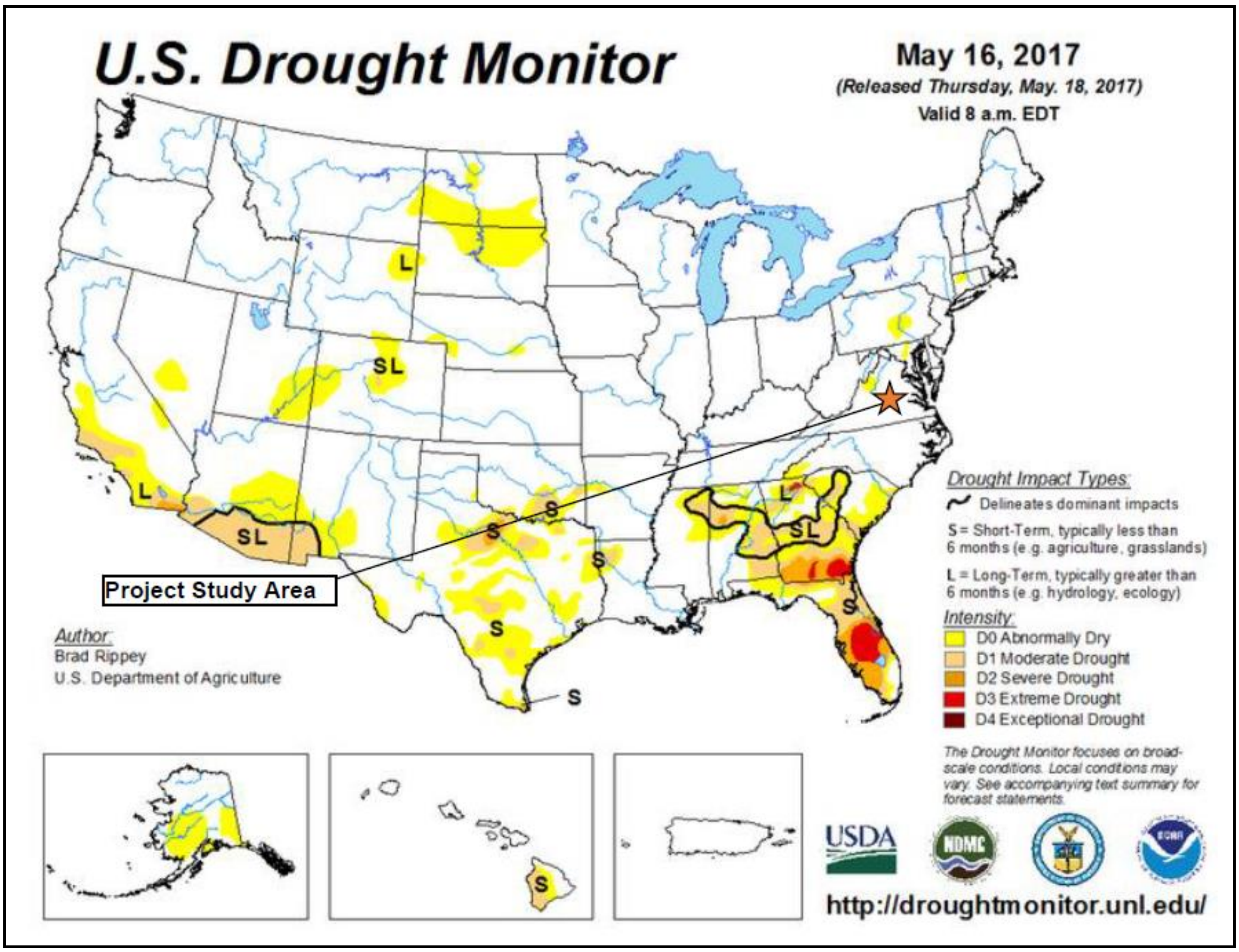
While drought mostly impacts land and water resources, extreme heat can pose a significant risk to humans. Extreme heat can be defined as temperatures that hover 10 degrees or more above the average high temperature for the region, last for prolonged periods of time, and are often accompanied by high humidity. Under normal conditions, the human body's internal thermostat produces perspiration that evaporates and cools the body. However, in extreme heat and high humidity, evaporation is slowed and the body must work much harder to maintain a normal temperature. Elderly persons, young children, persons with respiratory difficulties, and those who are sick or overweight are more likely to become victims of extreme heat. Because men sweat more than women, they are more susceptible to heat-related illness because they become more quickly dehydrated. Studies have shown that a significant rise in heat-related illness occurs when excessive heat persists for more than two days. Spending at least two hours per day in air conditioning can significantly reduce the number of heat-related illnesses.

Extreme heat in urban areas can create health concerns when stagnant atmospheric conditions trap pollutants, thus adding unhealthy air to excessively hot temperatures. In addition, the "urban heat island effect" can produce significantly higher nighttime temperatures because asphalt and concrete (which store heat longer) gradually release heat at night.

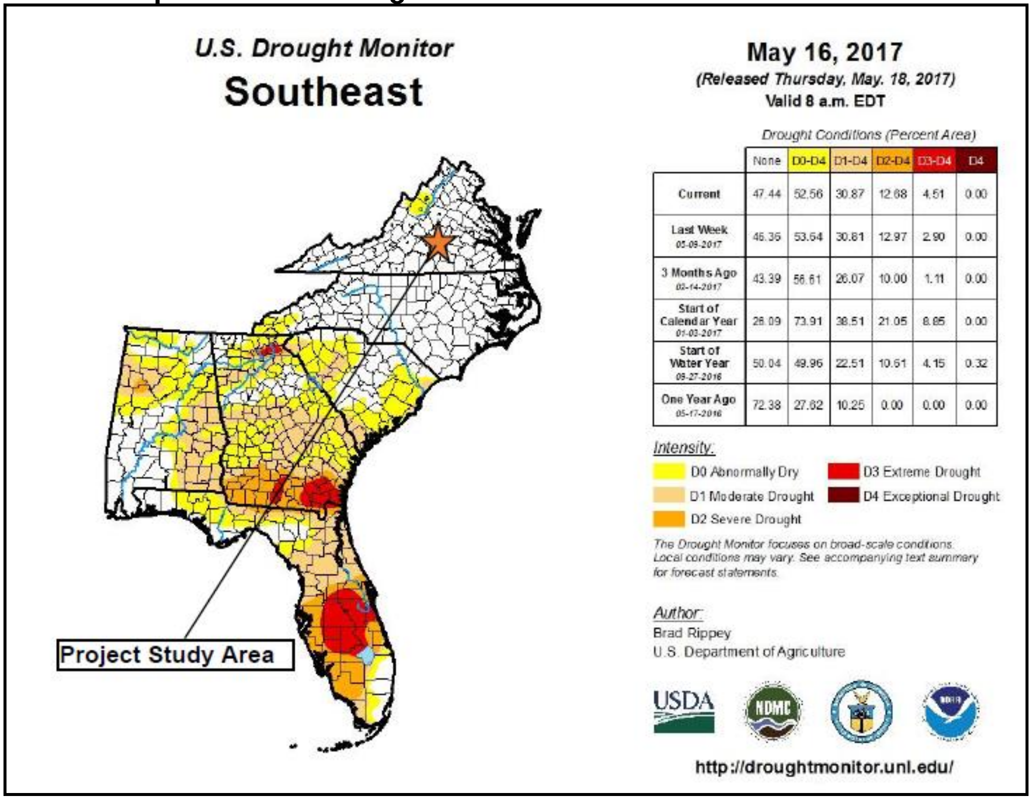
Map 4.5, **Map 4.5a**, and **Map 4.5b** show Drought Monitor summary map from the United States Department of Agriculture for March 7, 2017. Drought Monitor summary maps identify general drought areas and label droughts by intensity, with D1 being the least intense and D4 being the most intense**.** Weekly-updated maps may be obtained online from The Drought Monitor Web site, maintained by the National Drought Mitigation Center, located at the following Web address: http://drought.unl.edu/dm.

The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln (UNL), the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.

Map 4.5
U.S. Drought Monitor - Nationwide

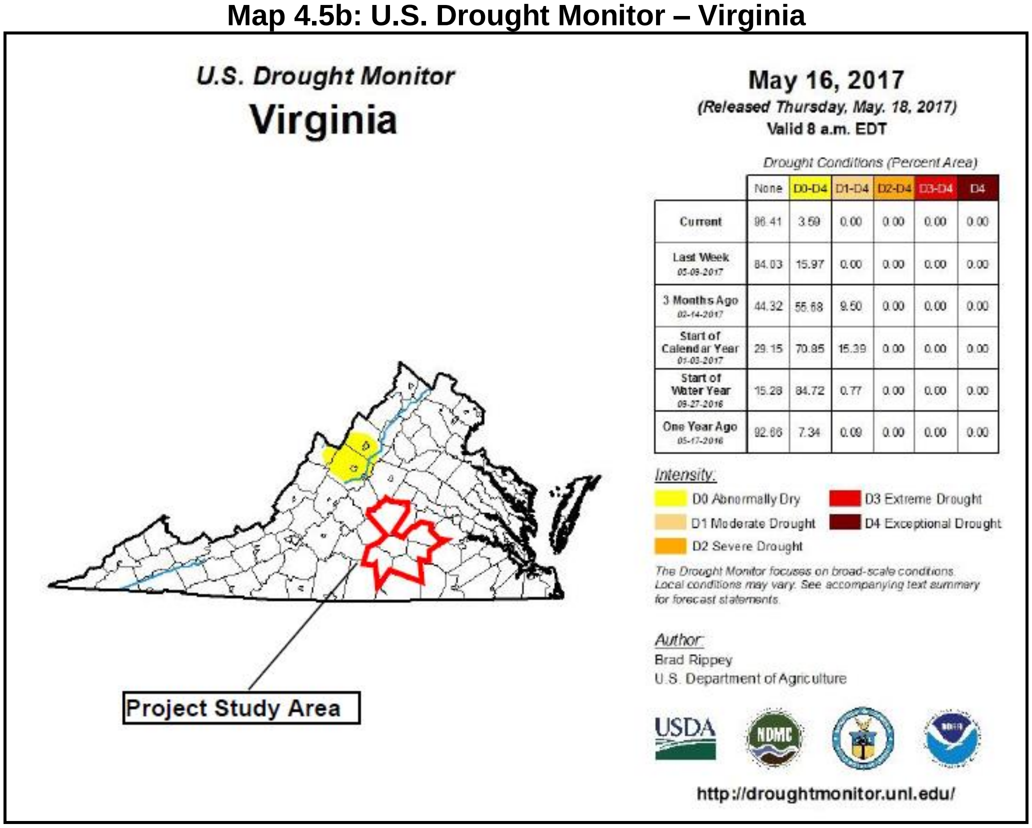


Map 4.5a: U.S. Drought Monitor – Southeast United States



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	47.44	52.56	30.87	12.68	4.51	0.00
Last Week 05-09-2017	46.36	53.64	30.81	12.97	2.90	0.00
3 Months Ago 02-14-2017	43.39	56.61	26.07	10.00	1.11	0.00
Start of Calendar Year 01-03-2017	26.09	73.91	38.51	21.05	8.85	0.00
Start of Water Year 09-27-2016	50.04	49.96	22.51	10.61	4.15	0.32
One Year Ago 05-17-2016	72.38	27.62	10.25	0.00	0.00	0.00

Map 4.5b: U.S. Drought Monitor – Virginia



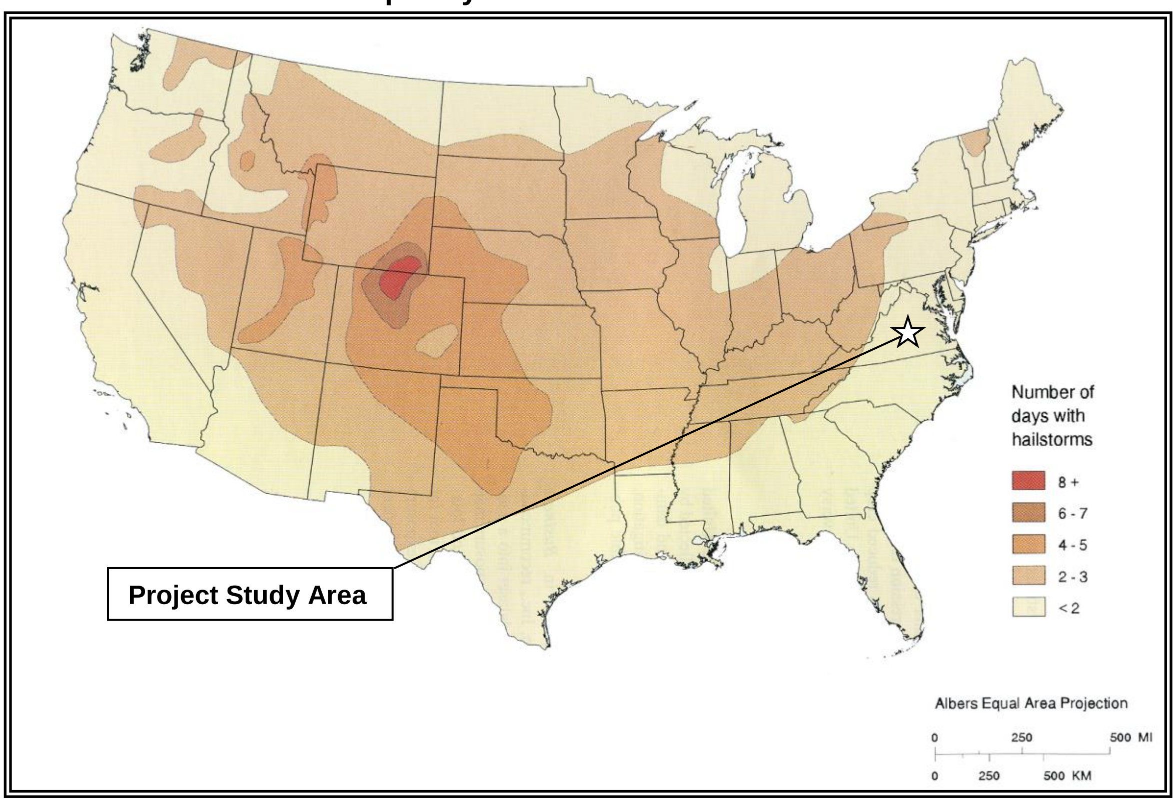
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	96.41	3.59	0.00	0.00	0.00	0.00
Last Week 05-09-2017	84.03	15.97	0.00	0.00	0.00	0.00
3 Months Ago 02-14-2017	44.32	55.68	9.50	0.00	0.00	0.00
Start of Calendar Year 01-03-2017	29.15	70.85	15.39	0.00	0.00	0.00
Start of Water Year 09-27-2016	15.28	84.72	0.77	0.00	0.00	0.00
One Year Ago 05-17-2016	92.66	7.34	0.09	0.00	0.00	0.00

Hail

Hailstorms are an outgrowth of severe thunderstorms. Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until, having developed sufficient weight, they fall as precipitation — as balls or irregularly shaped masses of ice greater than 0.75 in. (1.91 cm) in diameter. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size. **Map 4.6** shows the annual frequency of hailstorms in the United States.

Large hail collects on streets and grass during a severe thunderstorm. Larger stones appear to be nearly two to three inches in diameter. (NOAA Photo Library, NOAA Central Library; OAR/ERL/National Severe Storms Laboratory)

Map 4.6
Annual Frequency of Hailstorms in the United States



Source: Federal Emergency Management Agency

Winter Storms and Freezes

A winter storm can range from a moderate snow over a period of a few hours to blizzard conditions with blinding wind-driven snow that lasts for several days. Some winter storms may be large enough to affect several states, while others may affect only a single community. Many winter storms are accompanied by low temperatures and heavy and/or blowing snow, which can severely impair visibility.

Winter storms may include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation. Sleet – raindrops that freeze into ice pellets before reaching the ground – usually bounce when hitting a surface and do not stick to objects; however, sleet can accumulate like snow and cause a hazard to motorists. Freezing rain is rain that falls onto a surface with a temperature below freezing, forming a glaze of ice. Even small accumulations of ice can cause a significant hazard, especially on power lines and trees. An ice storm occurs when freezing rain falls and freezes immediately upon impact. Communications and power can be disrupted for days, and even small accumulations of ice may cause extreme hazards to motorists and pedestrians.

A freeze is weather marked by low temperatures, especially when below the freezing point (zero degrees Celsius or 32 degrees Fahrenheit). Agricultural production is seriously affected when temperatures remain below the freezing point.

In 2004, staff from the National Weather Service developed the Northeast Snowfall Impact Scale (NESIS). It characterizes and ranks high-impact snowstorms (have had large areas of snowfall accumulations that total 10 inches or more), using snowfall and population information from the eastern two-thirds of the United States. NESIS has five categories: Extreme, Crippling, Major, Significant, and Notable. The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements, thereby giving an indication of a storm's societal impacts. This scale was developed because of the impact Northeast snowstorms can have on the rest of the country in terms of transportation and economic impact.

A heavy layer of ice was more weight than this tree in Kansas City, Missouri could withstand during a January 2002 ice storm that swept through the region bringing down trees, power lines and telephone lines. (Photo by Heather Oliver/FEMA News Photo)

NESIS scores are a function of the area affected by the snowstorm, the amout of snow, and the number of people living in the path of the storm. **Table 4.5** shows NESIS categories. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score which varies from around one for smaller storms to over ten for extreme storms. The raw score is then converted into one of the five NESIS categories. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers.

Table 4.5
NESIS Classifications

Category	NESIS Value	Description
1	1 – 2.499	Notable
2	2.5 – 3.99	Significant
3	4 – 5.99	Major
4	6 – 9.99	Crippling
5	10.0 +	Extreme

Source: NOAA, NCDC (http://www.ncdc.noaa.gov/snow-and-ice/nesis.php)

Erosion

Erosion is the gradual breakdown and movement of land due to both physical and chemical processes of water, wind, and general meteorological conditions. Natural, or geologic, erosion has occurred since the Earth's formation and continues at a very slow and uniform rate each year.

There are two types of soil erosion: wind erosion and water erosion. Wind erosion can cause significant soil loss. Winds blowing across sparsely vegetated or disturbed land can pick up soil particles and carry them through the air, thus displacing them. Water erosion can occur over land or in streams and channels. Water erosion that takes place over land may result from raindrops, shallow sheets of water flowing off the land, or shallow surface flow, which is concentrated in low spots. Stream channel erosion may occur as the volume and velocity of water flow increases enough to cause movement of the streambed and bank soils. Major storms such as hurricanes may cause significant erosion by combining high winds with heavy surf and storm surge to significantly impact the shoreline.

An area's potential for erosion is determined by four factors: soil characteristics, vegetative cover, topography climate or rainfall, and topography. Soils composed of a large percentage of silt and fine sand are most susceptible to erosion. As the content of these soils increases in the level of clay and organic material, the potential for erosion decreases. Well-drained and well-graded gravels and gravel-sand mixtures are the least likely to erode. Coarse gravel soils are highly permeable and have a good capacity for absorption, which can prevent or delay the amount of surface runoff. Vegetative cover can be very helpful in controlling erosion by shielding the soil surface from falling rain, absorbing water from the soil, and slowing the velocity of runoff. Runoff is also affected by the topography of the area including size, shape and slope. The greater the slope length and gradient, the more potential an area has for erosion. Climate can affect the amount of runoff, especially the frequency, intensity and duration of rainfall and storms. When rainstorms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature and rainfall amounts define the period of highest erosion risk of the year.

During the past 25 to 30 years, the importance of erosion control has gained the increased attention of the public. Implementation of erosion control measures consistent with sound agricultural and construction operations is needed to minimize the adverse effects associated with increasing settling out of the soil particles due to water or wind. The increase in government regulatory programs and public concern has resulted in a wide range of erosion control products, techniques, and analytical methodologies in the United States. The preferred method of erosion control in recent years has been the restoration of vegetation.

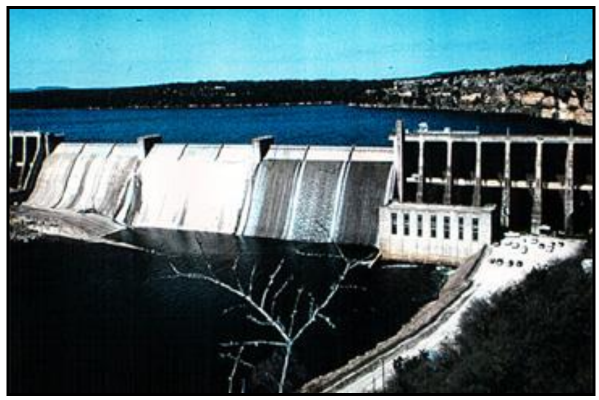
Dam/Levee Failure

Worldwide interest in dam and levee safety has risen significantly in recent years. Aging infrastructure, new hydrologic information, and population growth in floodplain areas downstream from dams and near levees have resulted in an increased emphasis on safety, operation and maintenance.

There are more than 80,000 dams in the United States today, according to data from the Army Corps of Engineers National Inventory of Dams. A large majority of those (approximately 70 percent) are privately owned. The rest are owned by state and local authorities, public utilities, federal agencies, and other entities.

The benefits of dams are numerous: they provide water for drinking, navigation, and agricultural irrigation. Dams also provide hydroelectric power, create lakes for fishing and recreation, and save lives by preventing or reducing floods.

Though dams have many benefits, they also can pose a risk to communities if not designed, operated, and maintained properly. In the event of a dam failure, the energy of the water stored behind even a small dam is capable of causing loss of life and great property damage if development exists downstream of the dam. If a levee breaks, scores of properties are quickly submerged in floodwaters and residents may become trapped by this rapidly rising water. The failure of dams and levees has the potential to place large numbers of people and great amounts of property in harm’s way.



Dam failure can result from natural events, human-induced events, or a combination of the two. Failures due to natural events such as hurricanes, earthquakes or landslides are significant because there is generally little or no advance warning. The most common cause of dam failure is prolonged rainfall that produces flooding. (Photo: Michael Baker Corporation)

Earthquakes, Sinkholes and Landslides

Earthquakes

An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Earthquakes result from crustal strain, volcanism, the collapse of caverns, or landslides (though not likely). Earthquakes can affect hundreds of thousands of square miles; cause damage to property measured in the tens of billions of dollars; result in loss of life and injury to hundreds of thousands of persons; and disrupt the social and economic functioning of the affected area.

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault, site and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction, in which ground soil loses the ability to resist shear and flows much like quick sand. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse.

Most earthquakes are caused by the release of stresses accumulated as a result of the rupture of rocks along opposing fault planes in the Earth's outer crust. These fault planes are typically found along borders of the Earth's seven major tectonic plates (there are also many minor plates). These plate borders generally follow the outlines of the continents, with the North American plate following the continental border with the Pacific Ocean in the west, but following the mid-Atlantic trench in the east. As earthquakes occurring in the mid-Atlantic trench usually pose little danger to humans, the greatest earthquake threat in North America is along the Pacific Coast.

Many structures in Louisa County, including the house pictured above in Cuckoo (near the Town of Mineral), were damaged by the 5.8 magnitude earthquake that struck near Mineral on August 23, 2011. Other buildings damaged in Louisa County include the High School (pictured below) and a number of businesses in Mineral and the surrounding areas. (Photos courtesy *Richmond Times-Dispatch*)

The areas of greatest tectonic instability occur at the perimeters of the slowly moving plates, as these locations are subjected to the greatest strains from plates traveling in opposite directions and at different speeds. Deformation along plate boundaries causes strain in the rock and the consequent buildup of stored energy. When the built-up stress exceeds the rocks' strength, a rupture occurs. The rock on both sides of the fracture is snapped, releasing the stored energy and producing seismic waves, generating an earthquake. It should be noted that some earthquakes occur in areas that are far from tectonic plate boundaries.

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude (see **Table 4.6**). Each unit increase in magnitude on the Richter Scale corresponds to a ten-fold increase in wave amplitude, or a 32-fold increase in energy.

Table 4.6
Richter Scale

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally not felt, but recorded.
3.5-5.4	Often felt, but rarely causes damage.
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0-7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

Source: North Carolina Division of Emergency Management

Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using roman numerals, with a I corresponding to imperceptible (instrumental) events, IV corresponding to moderate (felt by people awake), to XII for catastrophic (total destruction). A detailed description of the Modified Mercalli Intensity Scale of earthquake intensity and its correspondence to the Richter Scale is given in **Table 4.7**.

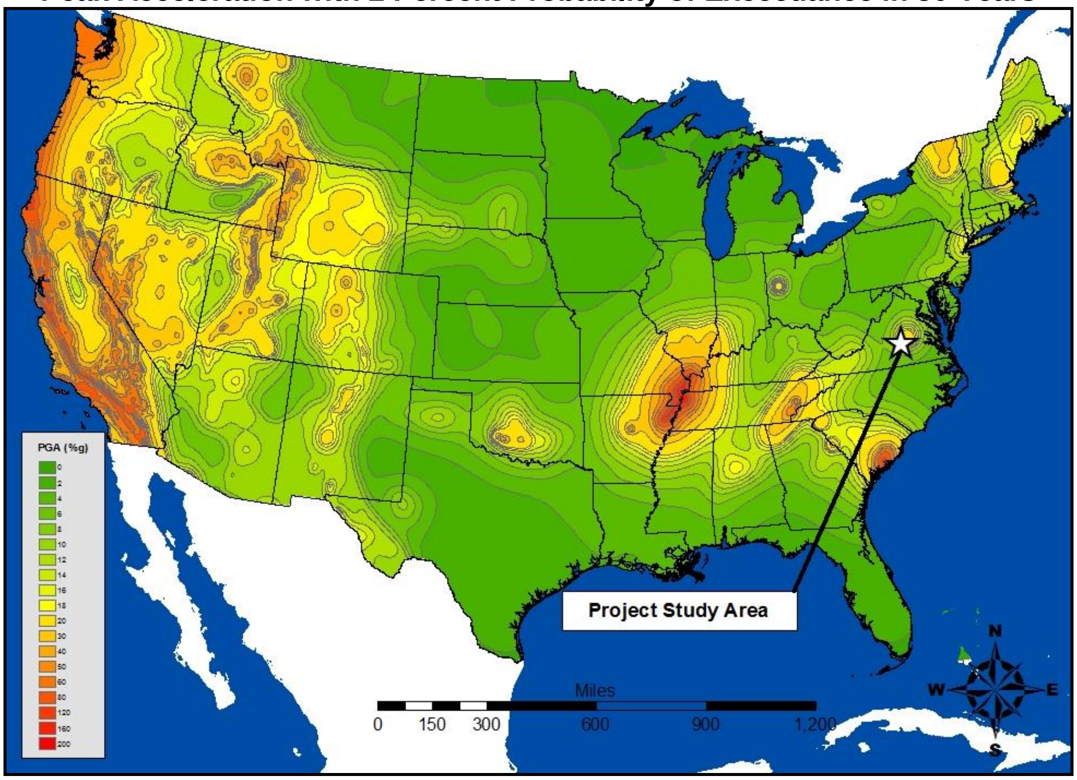
Table 4.7
Modified Mercalli Intensity Scale for Earthquakes

Scale	Intensity	Description of Effects	Corresponding Richter Magnitude
I	Instrumental	Detected mainly on seismographs, felt by very few people	1.0 – 2.0
II	Feeble	Some people feel it, especially on upper floors	2.0 – 3.0
III	Slight	Felt by people resting, especially on upper floors; May not be recognized as an earthquake	3.0 – 4.0
IV	Moderate	Felt by many people indoors, a few outdoors; may feel like a large truck rumbling by	4.0
V	Slightly Strong	Felt by almost everyone, some people awakened; small objects moved, trees and poles may shake.	4.0 – 5.0
VI	Strong	Felt by everyone; difficult to stand, some heavy furniture moved, some plaster falls; chimneys may be slightly damaged.	5.0 – 6.0
VII	Very Strong	Slight to moderate damage in well built, ordinary structures, considerable damage to poorly built structures; some walls may fall.	6.0
VIII	Destructive	Little damage in specially built structures, considerable damage to ordinary buildings, severe damage to poorly built structures; some walls collapse.	6.0 – 7.0
IX	Ruinous	Considerable damage to specially built structures, buildings shifted off foundations; ground cracked noticeably; wholesale destruction, landslides.	7.0
X	Disastrous	Most masonry and frame structures and their foundations destroyed; ground badly cracked; landslides, wholesale destruction.	7.0 – 8.0
XI	Very Disastrous	Total damage; few, if any, structures standing; bridges destroyed, wide cracks in ground, waves seen on ground.	8.0
XII	Catastrophic	Total damage; waves seen on ground; objects thrown up into air.	8.0 or greater

Source: Michigan Tech

Map 4.7 shows the probability that ground motion will reach a certain level during an earthquake. The data show peak horizontal ground acceleration (the fastest measured change in speed, for a particle at ground level that is moving horizontally due to an earthquake) with a two (2) percent probability of exceedance in 50 years. The map was compiled by the U.S. Geological Survey (USGS) Geologic Hazards Team, which conducts global investigations of earthquake, geomagnetic, and landslide hazards.

Map 4.7
Peak Acceleration with 2 Percent Probability of Exceedance in 50 Years



Map created by CRC – October 2015
Source: United States Geological Survey, ESRI, Great Lakes Information Network

Sinkholes

Sinkholes are a natural and common geologic feature in areas with underlying limestone and other rock types that are soluble in natural water. Most limestone is porous, allowing the acidic water of rain to percolate through their strata, dissolving some limestone and carrying it away in solution. Over time, this persistent erosional process can create extensive underground voids and drainage systems in much of the carbonate rocks. Collapse of overlying sediments into the underground cavities produces sinkholes.

The three general types of sinkholes are: subsidence, solution, and collapse. Collapse sinkholes are most common in areas where the overburden (the sediments and water contained in the unsaturated zone, surficial aquifer system, and the confining layer above an aquifer) is thick, but the confining layer is breached or absent. Collapse sinkholes can form with little warning and leave behind a deep, steep sided hole. Subsidence sinkholes form gradually where the overburden is thin and only a veneer of sediments is overlying the limestone. Solution sinkholes form where no overburden is present and the limestone is exposed at land surface.

Sinkholes occur in many shapes, from steep-walled holes to bowl or cone shaped depressions. Sinkholes are dramatic because the land generally stays intact for a while until the underground spaces get too big. If there is not enough support for the land above the spaces, then a sudden collapse of the land surface can occur. Under natural conditions, sinkholes form slowly and expand gradually. However, human activities such as dredging, constructing reservoirs, diverting surface water, and pumping groundwater can accelerate the rate of sinkhole expansions, resulting in the abrupt formation of collapse sinkholes.

Although a sinkhole can form without warning, specific signs can signal potential development:

- Slumping or falling fenceposts, trees, or foundations;
- Sudden formation of small ponds;
- Wilting vegetation;
- Discolored well water; and/or
- Structural cracks in walls, floors.

Collapses, such as the sudden formation of sinkholes, may destroy buildings, roads, and utilities. (Photo: Bettmann)

Sinkhole formation is aggravated and accelerated by urbanization. Development increases water usage, alters drainage pathways, overloads the ground surface, and redistributes soil. According to the Federal Emergency Management Agency (FEMA), the number of human-induced sinkholes has doubled since 1930. Insurance claims for damages as a result of sinkholes increased 1,200 percent from 1987 to 1991, costing nearly $100 million.

Landslides

A landslide is the downward and outward movement of slope-forming soil, rock, and vegetation, which is driven by gravity. Landslides may be triggered by both natural and human-caused changes in the environment, including heavy rain, rapid snow melt, steepening of slopes due to construction or erosion, earthquakes, volcanic eruptions, and changes in groundwater levels.

There are several types of landslides: rock falls, rock topple, slides, and flows. Rock falls are rapid movements of bedrock, which result in bouncing or rolling. A topple is a section or block of rock that rotates or tilts before falling to the slope below. Slides are movements of soil or rock along a distinct surface of rupture, which separates the slide material from the more stable underlying material. Mudflows, sometimes referred to as mudslides, mudflows, lahars or debris avalanches, are fast-moving rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, such as heavy rainfall or rapid snowmelt, changing the soil into a flowing river of mud or "slurry." Slurry can flow rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. Slurry can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way. As the flows reach flatter ground, the mudflow spreads over a broad area where it can accumulate in thick deposits.

Landslides are typically associated with periods of heavy rainfall or rapid snow melt and tend to worsen the effects of flooding that often accompanies these events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly.

Aerial view of the June 1995 landslide near Graves Mill in Madison County, Virginia. This landslide was caused by heavy rains, which resulted in flooding throughout Central Virginia (photo from *The debris flows of Madison County, Virginia: 34th Annual Virginia Geological Field Conference Guidebook).*

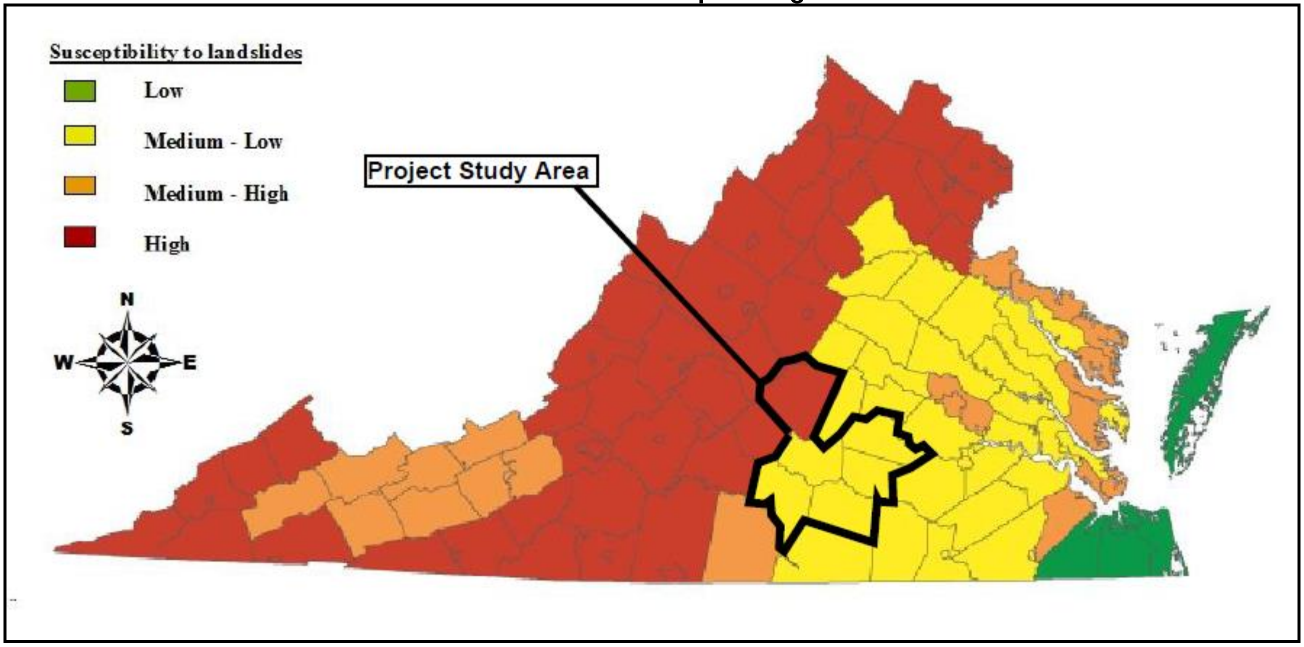
Among the most destructive types of debris flows are those that accompany volcanic eruptions. A spectacular example in the United States was a massive debris flow resulting from the 1980 eruptions of Mount St. Helens, Washington. Areas near the bases of many volcanoes in the Cascade Mountain Range of California, Oregon and Washington are at risk from the same types of flows during future volcanic eruptions.

Areas that are generally prone to landslide hazards include previous landslide areas; the bases of steep slopes; the bases of drainage channels; and developed hillsides where leach-field septic systems are used. Areas that are typically considered safe from landslides include areas that have not moved in the past; relatively flat-lying areas away from sudden changes in slope; and areas at the top or along ridges, set back from the tops of slopes.

In the United States, it is estimated that landslides cause up to $2 billion in damages and from 25 to 50 deaths annually. Globally, landslides cause billions of dollars in damage and thousands of deaths and injuries each year.

Map 4.8 delineates susceptibility to landslides throughout Virginia, based on the USGS Landslide Overview Map of the Conterminous United States. As can be seen in the map, at least half of the Commonwealth falls into zones of high potential.

Map 4.8
Landslide Overview Map of Virginia



Source: Virginia Department of Mines, Minerals and Energy, Division of Geology and Mineral Resources

Man-made Hazards

Hazardous materials (hazmat) spills

Hazmat substances, because of their chemical nature, can pose a danger to life, health or property if released. Hazmat spills can happen during production, storage, transportation, use or disposal of these substances. Virginia's hazardous materials officers typically receive 2,000 notifications of hazmat incidents a year, according to the Virginia Department of Emergency Management. Of these, spills or releases of flammable liquids are the most common. Most of these incidents occur in "fixed facilities" such as industrial plants, highways and waterways. Homes, businesses and schools located near the site of a hazmat spill or release are not likely to be affected unless the substance is airborne and poses a threat to areas outside the accident site. In that case, local emergency officials would evacuate areas that could potentially be affected. The length of the evacuation would depend on the type of substance, and could range from hours to days. In some cases, special equipment might be used to decontaminate people, objects or buildings affected.

Accidents at fertilizer/chemical facilities

Fertilizer and chemical plants and storage facilities are prone to accidents that can have a significant impact on the facility as well as the surrounding community. Accidents at these facilities can be caused by inadequate process hazards analysis, use of inappropriate or poorly-designed equipment, inadequate indications of process condition, and other factors. For significant accidents tracked by the U.S. Environmental Protection Agency and Occupational Safety and Health Administration, issues of note include installation of emissions or pollution control equipment (occurred prior to a number of accidents, which highlight the need for stronger systems for management of change) and similar accidents, near-misses, or low-level failures occurring just before a major accident (indicating the need for more attention to lessons-learned implementation and more thorough company investigation of near-misses and low-level failures). Such accidents can cause serious injury or death, as well as property damage to the facility. In some cases, residents in nearby communities need to be evacuated due to the release of toxins into the air.

Biological (Bio)-hazards

Bio hazards can pose a threat to people, animals, and the environment when biological agents are accidentally or intentionally released into the air or water. Samples of bio-hazards include medical waste, samples of a microorganism, virus or toxin (from a biological source), or substances that are harmful to animals. Biohazard severity ranges from Level 1 (not considered dangerous, precautions required are minimal) to Level 4 (can cause severe to fatal disease in humans, and for which vaccines or other treatments are not available).

Accidents at power plants

Reactors in nuclear power plants use a process called fission, or atom splitting, to produce energy. Nuclear reactors control the fission process by slowing it down, cooling it off, and controlling the number of splitting atoms in the reactor. Nuclear reactors cannot explode like a nuclear bomb, since they use different materials and structures, and nuclear power plants are designed to prevent the release of radioactive materials and include multiple protective barriers placed around reactors, making the accidental release of radiological materials extremely unlikely. However, accidents do sometimes occur at nuclear power plants that result in the release of radioactive materials into the atmosphere or nearby water sources. Other types of power plants (coal fired, gas fired) and electric substations can sometimes experience accidents or malfunctions that can cause injury or death to plant workers and disrupt the flow of electricity for homes and businesses in the area.

Pipeline explosions/Accidents at above-ground storage facilities

While pipelines are considered the safest way to move gas, petroleum, and other hazardous materials, they can sometimes malfunction and even explode. If corrosion controls fail to properly function, and/or corrosion is not repaired in a timely manner, then the pipeline could explode. An explosion can cause serious injury, even death, and significant damage to property. Storage tanks for gas, oil, and other chemicals can sometimes experience “catastrophic failure” and explode. This can occur when flammable vapors are ignited, causing a break in either the shell-to-bottom or side seam of the tank. Sometimes, workers performing maintenance or other operations can introduce an ignition source. This type of accident can cause injury or death to workers, and release harmful chemicals into the atmosphere. Such accidents can happen anywhere, but are more of a concern in cases where the tanks were built before 1950 or tanks are poorly maintained, rarely inspected, or repaired without attention to the tank’s design.

Data Sources

American Society of Civil Engineers (ASCE), "Facts About Windstorms."
Web site: www.windhazards.org/facts.cfm

Bureau of Reclamation, U.S. Department of the Interior
Web site: www.usbr.gov

Federal Emergency Management Agency (FEMA)
Web site: www.fema.gov

National Climatic Data Center (NCDC), U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)
Web site: http://lwf.ncdc.noaa.gov/oa/ncdc.html

National Drought Mitigation Center, University of Nebraska-Lincoln
Web site: www.drought.unl.edu/index.htm

National Severe Storms Laboratory (NSSL), U.S. Department of Commerce, NOAA
Web site: www.nssl.noaa.gov

National Weather Service (NWS), U.S. Department of Commerce, NOAA
Web site: www.nws.noaa.gov (flood data: http://www.nws.noaa.gov/hic/summaries/)

Storm Prediction Center (SPC), U.S. Department of Commerce, NOAA, NWS
Web site: www.spc.noaa.gov

The Tornado Project, St. Johnsbury, Vermont
Web site: www.tornadoproject.com

United States Geological Survey (USGS), U.S. Department of the Interior
Web site: www.usgs.gov

U.S. Army Corps of Engineers, National Inventory of Dams
Web site: http://geo.usace.army.mil/pgis/f?p=397:1:1684077269977742

North Carolina Division of Emergency Management
Web site: http://www.nccrimecontrol.org/Index2.cfm?a=000003%2C000010

Michigan Tech
Web site: http://www.mtu.edu/

Construction Cost Index, McGraw Hill Construction/the Engineering News Report
Web site: http://enr.construction.com/economics/current_costs/default.asp

Virginia Department of Mines, Minerals and Energy: Division of Geology and Mineral Resources
Web site: https://www.dmme.virginia.gov/dgmr/divisiongeologymineralresources.shtml

The Richmond Times-Dispatch
Web site: http://www2.timesdispatch.com/

The Farmville Herald
Web site: http://www.farmvilleherald.com/

The Kenbridge-Victoria Dispatch
Web site: http://kvdispatch.com/

The Crewe-Burkeville Journal