# 5.7 Landslides

## 2023 SHMP Update Changes

- The hazard profile was reorganized and significantly enhanced to include detailed descriptions of the following: hazard definition, hazard location, previous hazard occurrences, probability of future occurrences (including how future conditions may impact the hazard), and impact analysis. The profile is then followed by the vulnerability assessment, which summarizes the impacts and losses the landslide hazard can have on state and local assets and population.
- Landslide events, including rockfalls and mudslides, that occurred in the State from January 1, 2018, through December 31, 2022, were researched for the 2023 State Hazard Mitigation Plan (SHMP) Update.
- Landslide susceptibility maps, exposure tables of state buildings, critical facilities, and the population have been added and used to assess exposure in the vulnerability assessment.
- Information was updated regarding the current population affected by landslides.

## 5.7.1 Hazard Profile

### Hazard Description

In West Virginia, the most common geologic hazards are landslides and subsidence. A discussion on landslides is included in this profile. For details on land subsidence, refer to Section 5.13.

Landslides are one of the most common natural hazards in West Virginia, having the potential to damage buildings and roads, disrupt utilities, and cause injuries and deaths (West Virginia Emergency Management Division 2018).

*Figure 5.7-1. Yeager Airport Landslide of 2015*

*Source: Mistich 2015*

A landslide, such as the one shown in Figure 5.7-1, consists of mass movements of soil and/or rock down a slope due to gravity and usually water. Slips, slumps, rock falls, slides, flows, and creep are terms used by geologists to identify specific mechanisms and velocities for mass movement. Most slopes in West Virginia are vulnerable, especially after heavy rain or snow melt; the telltale signs are hummocky surfaces, leaning and bent trees or utility poles, many seeps and sag ponds (water-filled depressions), and old or recent landslides where horizontal and vertical movement has occurred (West Virginia Geological and Economic Survey 2020).

The West Virginia GIS Technical Center (WVU GISTC) identifies five different types of landslides, all of which are capable of happening in the state:

- **Slide** – Translational or rotational movement of material downslope. Slides travel at a range of rates, displacing forests and infrastructure as they move. Quite common in West Virginia, large slides are readily identified using LiDAR data.
- **Debris Flow** – Failures saturated with water, where transported material moves downslope as a slurry of rock, soil, and debris. Flows may move quickly and cause loss of property and life far downslope from their source. Debris flows are common in mountainous areas of West Virginia but can be difficult to map using LiDAR data.
- **Lateral Spread** – Lateral movement of rock blocks across relatively shallow slopes. Spreads move slowly compared to most other landslides.
- **Fall** – Free-fall of material from a steep slope or cliff face. Falls often occur with little warning. Most falls are very difficult to map using LiDAR data because they are either promptly mitigated or consist of rock fragments too small to be identified.
- **Undetermined Slope Failure** – A contingency category consisting of slope failures in which available data is insufficient to assign failure material or mode (WVU GISTC 2021).

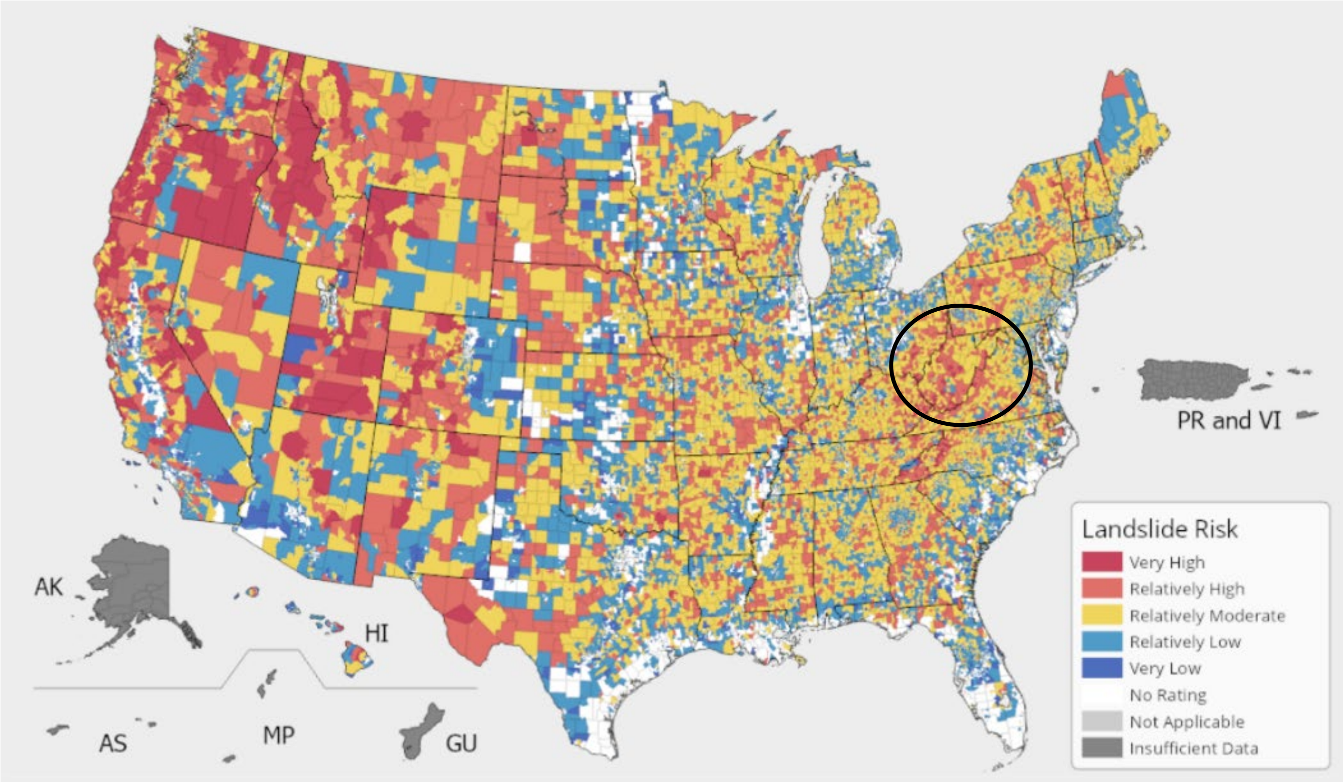
Many factors cause landslides and rockfalls, but the following are prevalent in the State: water changes, seismic activity, mining, and human activity.

- **Water** – Intense rainfall, changes in groundwater level, and water level changes along coastlines, earthen dams, and the banks of lakes, reservoirs, and rivers are the primary triggers of landslides.
- **Seismic Activity** – Earthquakes in landslide-prone areas greatly increase the likelihood that landslides will occur, either due to ground shaking alone or shaking-caused dilation of soil materials.
- **Mining** – Huge amounts of vibrations, including blasting, reach yards under the soil surface, which poses a greater threat to areas that are already at risk for sliding.
- **Human Activity** – Landslides may result directly or indirectly from human activities. Construction activity that undercuts or overloads dangerous slopes or that redirects the flow of surface or groundwater can trigger slope failures (USGS 2004).

## LOCATION

Most of West Virginia is susceptible to landslides, especially areas with steep slopes or land degradation. Eastern West Virginia is especially vulnerable due to its mountainous terrain. Landslides may also take place during flooding events, in areas subject to earthquakes, and in areas covered with thick layers of finely grained soil deposits (West Virginia Emergency Management Division 2018). Landslides tend to develop when soil moisture and pressure are at its highest and are most problematic after prolonged wet seasons, specifically in late winter and early spring when soils are saturated (Kite 2021). Figure 5.7-2 displays the Landslides Risk Index for the United States (West Virginia displayed within the black circle). According to the National Risk Index, the majority of the State has a relatively moderate to very high risk to landslides, with a very small portion in the center of the state having relatively low risk.

*Figure 5.7-2. National Risk Index, Landslides Risk Index Score*




*Source: FEMA 2023*
*Note: West Virginia is located within the black circle.*

Due to the state's mountainous terrain and the high average annual precipitation, landslides occur frequently each year. Additionally, as shown in Figure 5.7-3 through Figure 5.7-14, nearly the entire state is located in areas prone to landslides. High susceptibility landslide hazard areas were used to determine risk and impacts to the population and infrastructure. Table 5.7-1 examines the total amount of acres that are located in the high susceptibility landslide hazard area as well as the percentage of land it encompasses broken down by county. Overall, the state has over 685,000 acres (4.4 percent of the State's total land area) of land located within high susceptibility landslide hazard areas. Summers County has the largest amount of land located in the high landslide susceptibility hazard area, with over 10 percent of its total land identified as having high landslide susceptibility.

The USGS divides landslide risk into six categories. These six categories were grouped into the three broader categories to be used for the risk analysis and ranking; geographic extent is based off these groupings. These categories include:

- **High Risk**
  - High susceptibility to land sliding and moderate incidence.
  - High susceptibility to land sliding and low incidence.
  - High landslide incidence (more than 15-percent of the area is involved in land sliding).
- **Moderate Risk**
  - Moderate susceptibility to land sliding and low incidence.
  - Moderate landslide incidence (1.5 – 15-percent of the area is involved in land sliding).
- **Low Risk**
  - Low landslide incidence (less than 1.5-percent of the area is involved in land sliding) (USGS 2022).

### *Table 5.7-1: Total Acres of Land Area in the Landslide Hazard Area*

| County | Total Acres of Land Area | Total Acres of Land Area (Excluding Waterbodies) Located in the Landslide Hazard Area: Total Acres Located in the High Susceptibility Landslide Hazard Area | Percent of Total |
|---|---|---|---|
| Barbour | 218,598 | 5,708.6 | 2.6% |
| Berkeley | 205,141 | 2,461.6 | 1.2% |
| Boone | 321,687 | 17,930.8 | 5.6% |
| Braxton | 328,023 | 17,769.4 | 5.4% |
| Brooke | 59,321 | 634.4 | 1.1% |
| Cabell | 184,109 | 8,884.7 | 4.8% |
| Calhoun | 179,487 | 3,694.9 | 2.1% |
| Clay | 219,951 | 7,347.2 | 3.3% |
| Doddridge | 205,051 | 4,407.5 | 2.1% |
| Fayette | 427,276 | 29,191.4 | 6.8% |
| Gilmer | 217,274 | 6,187.6 | 2.8% |
| Grant | 305,479 | 14,309.3 | 4.7% |
| Greenbrier | 654,360 | 42,127.3 | 6.4% |
| Hampshire | 412,248 | 15,599.2 | 3.8% |
| Hancock | 56,222 | 776.5 | 1.4% |
| Hardy | 373,689 | 20,415.5 | 5.5% |
| Harrison | 266,023 | 8,024.0 | 3.0% |
| Jackson | 300,968 | 6,266.5 | 2.1% |
| Jefferson | 134,920 | 751.5 | 0.6% |
| Kanawha | 582,312 | 34,302.9 | 5.9% |
| Lewis | 246,359 | 7,262.9 | 2.9% |
| Lincoln | 280,594 | 10,174.5 | 3.6% |
| Logan | 291,325 | 22,001.0 | 7.6% |
| Marion | 199,006 | 5,042.0 | 2.5% |
| Marshall | 199,304 | 2,011.9 | 1.0% |
| Mason | 284,059 | 7,077.6 | 2.5% |
| McDowell | 342,174 | 10,160.2 | 3.0% |
| Mercer | 268,828 | 16,217.1 | 6.0% |
| Mineral | 210,134 | 9,263.2 | 4.4% |
| Mingo | 270,756 | 21,114.6 | 7.8% |
| Monongalia | 232,200 | 5,412.8 | 2.3% |
| Monroe | 302,704 | 11,494.9 | 3.8% |
| Morgan | 146,880 | 4,849.8 | 3.3% |
| Nicholas | 415,482 | 17,113.2 | 4.1% |
| Ohio | 69,666 | 599.8 | 0.9% |
| Pendleton | 446,485 | 42,013.6 | 9.4% |
| Pleasants | 85,837 | 995.6 | 1.2% |
| Pocahontas | 601,520 | 37,373.6 | 6.2% |
| Preston | 415,612 | 16,915.9 | 4.1% |
| Putnam | 223,706 | 11,274.6 | 5.0% |
| Raleigh | 388,484 | 26,841.6 | 6.9% |
| Randolph | 664,970 | 27,978.6 | 4.2% |
| Ritchie | 290,396 | 4,002.4 | 1.4% |
| Roane | 309,410 | 11,313.1 | 3.7% |
| Summers | 233,898 | 25,083.3 | 10.7% |
| Taylor | 110,892 | 3,612.1 | 3.3% |
| Tucker | 265,897 | 17,014.7 | 6.4% |
| Tyler | 166,857 | 530.8 | 0.3% |
| Upshur | 226,613 | 5,287.0 | 2.3% |

| County | Total Acres of Land Area | Total Acres of Land Area (Excluding Waterbodies) Located in the Landslide Hazard Area | |
|---|---|---|---|
| | | Total Acres Located in the High Susceptibility Landslide Hazard Area | Percent of Total |
| Wayne | 325,702 | 15,558.6 | 4.8% |
| Webster | 355,637 | 24,549.7 | 6.9% |
| Wetzel | 231,289 | 1,836.0 | 0.8% |
| Wirt | 150,356 | 2,255.3 | 1.5% |
| Wood | 241,020 | 3,969.8 | 1.6% |
| Wyoming | 320,602 | 10,613.5 | 3.3% |
| **Total** | **15,466,793** | **685,606.1** | **4.4%** |

*Source: WVU 2020; USGS 2022; WVU GISTC 2022*

***Figure 5.7-3: Landslide Susceptibility Hazard Area in Region 1***

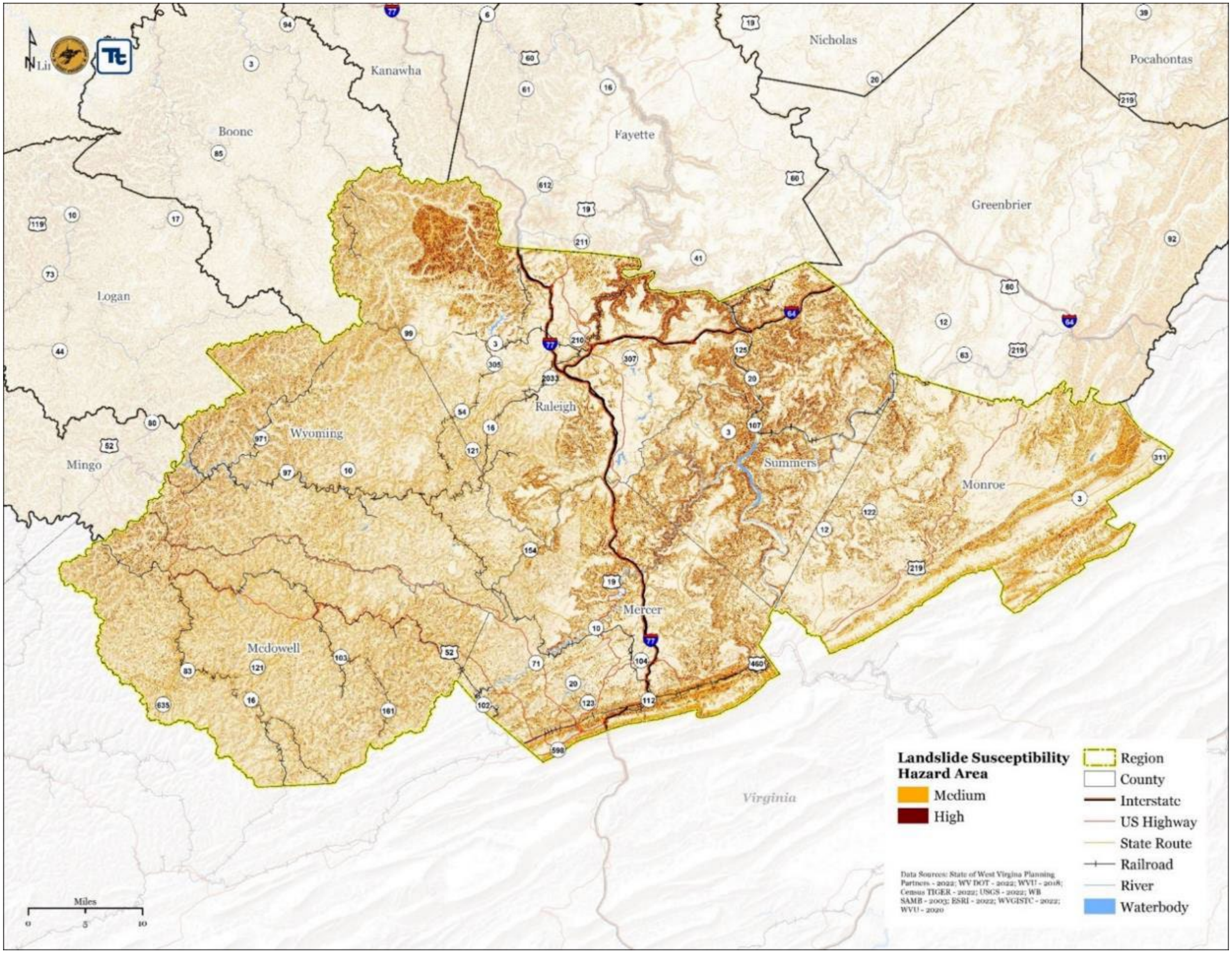


*Figure 5.7-4: Landslide Susceptibility Hazard Area in Region 2*

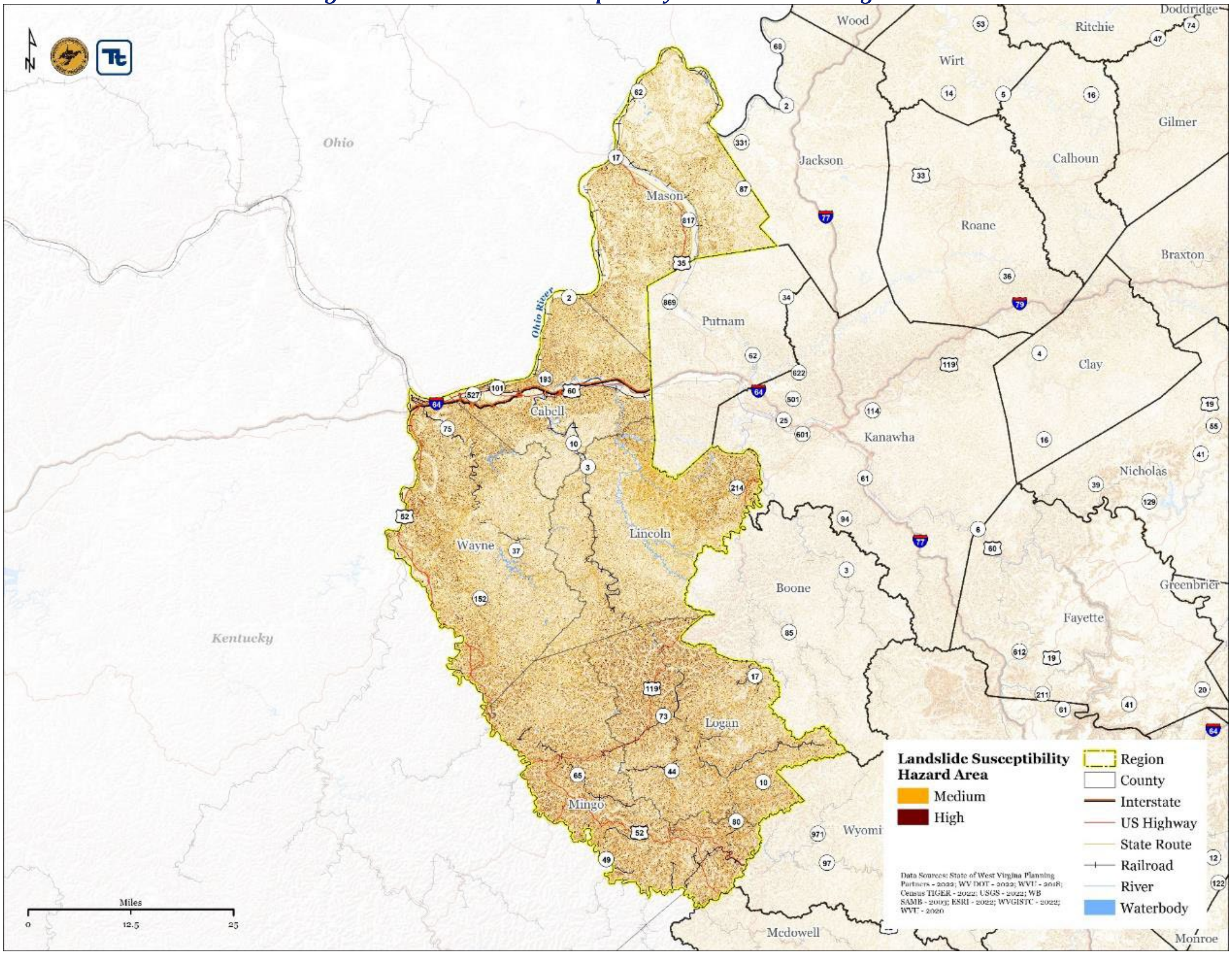


***Figure 5.7-5: Landslide Susceptibility Hazard Area in Region 3***

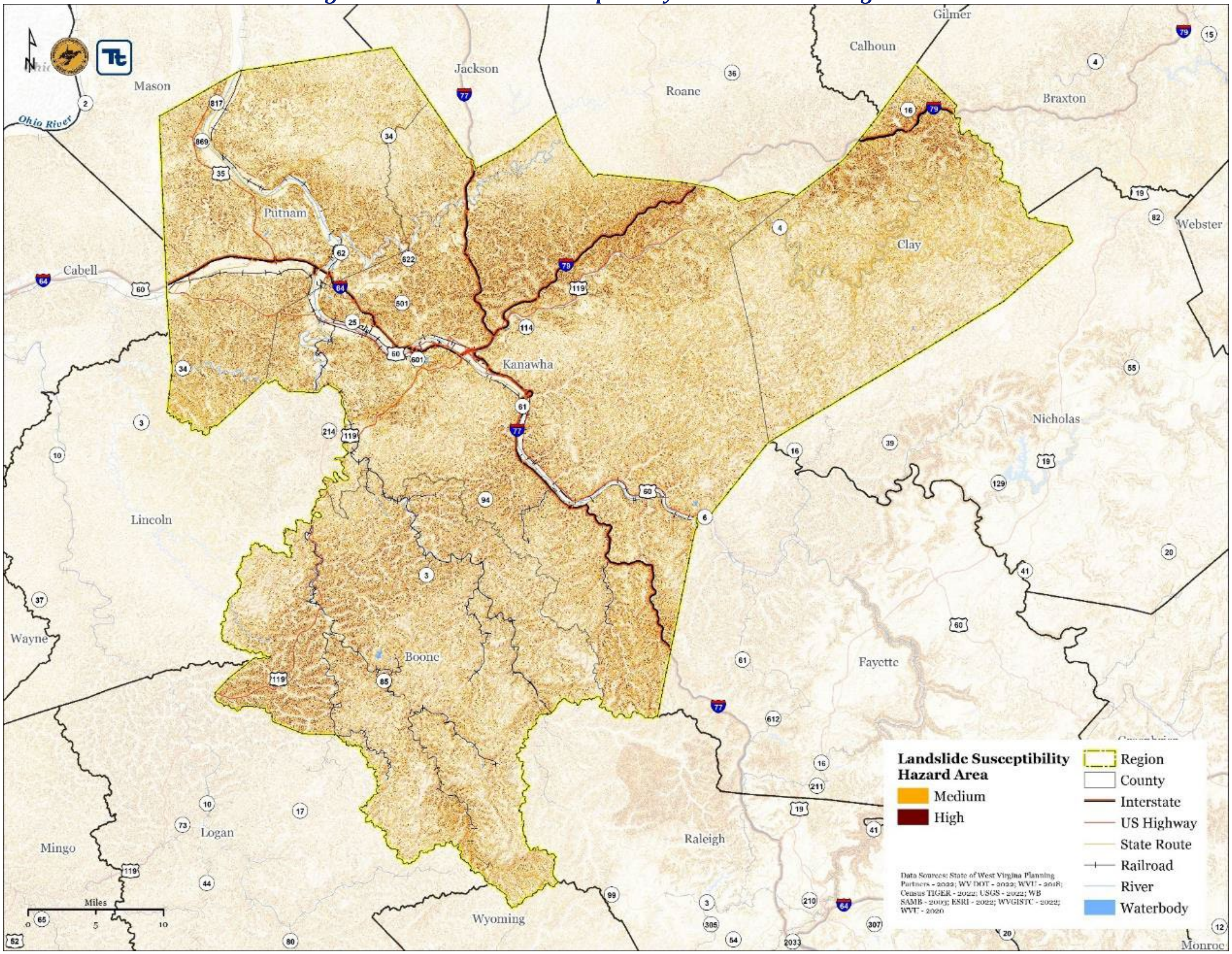


*Figure 5.7-6: Landslide Susceptibility Hazard Area in Region 4*

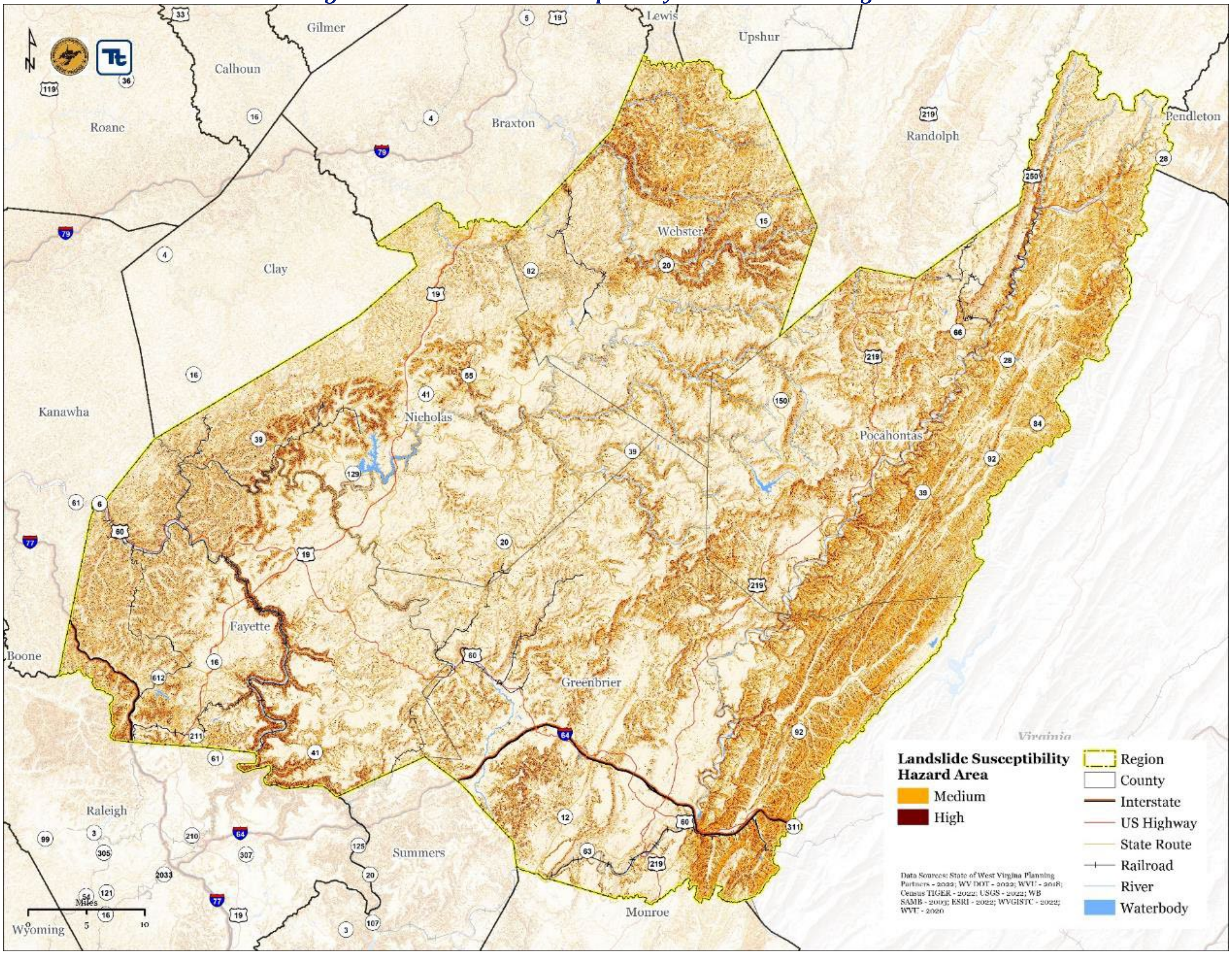


*Figure 5.7-7: Landslide Susceptibility Hazard Area in Region 5*

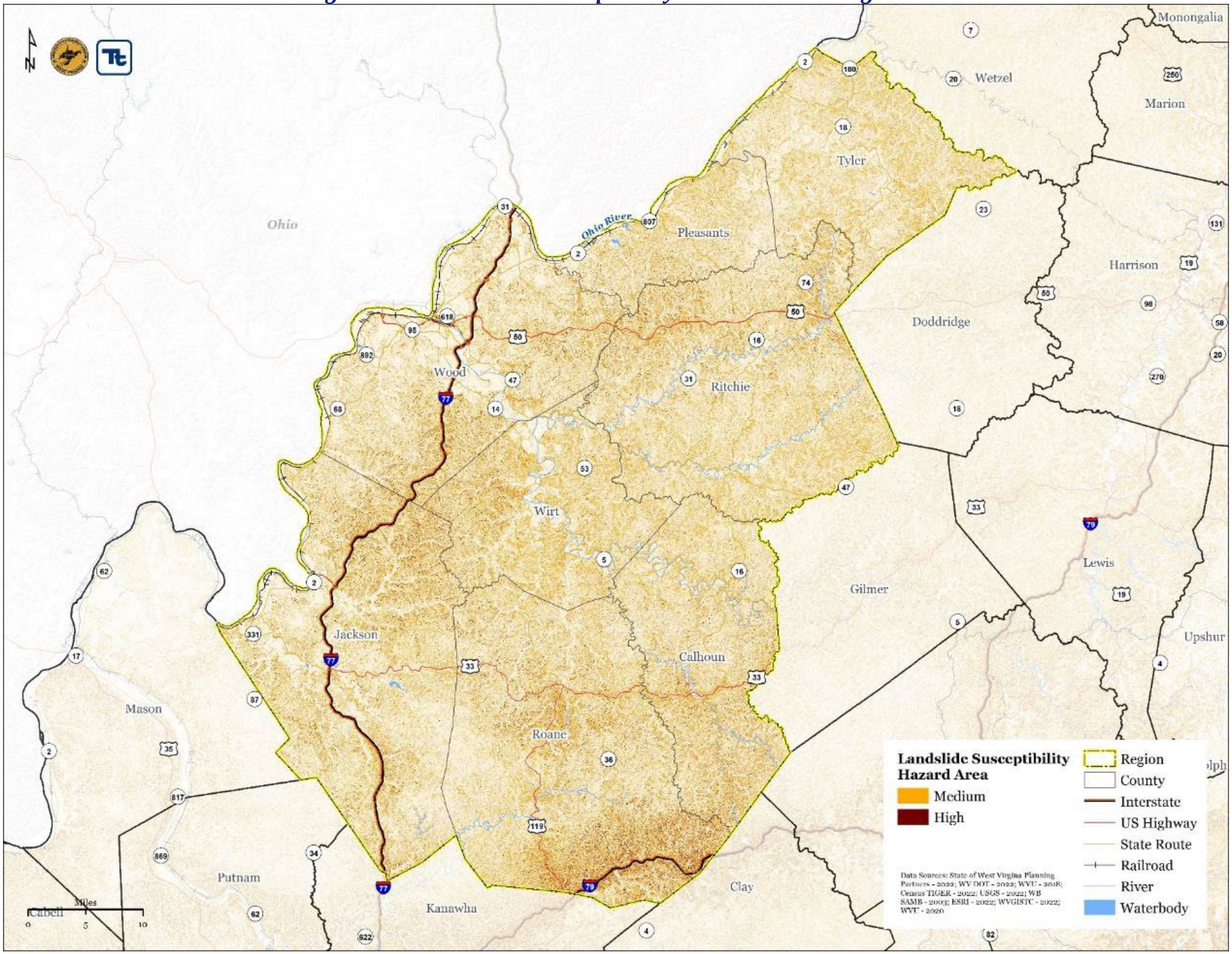


***Figure 5.7-8: Landslide Susceptibility Hazard Area in Region 6***

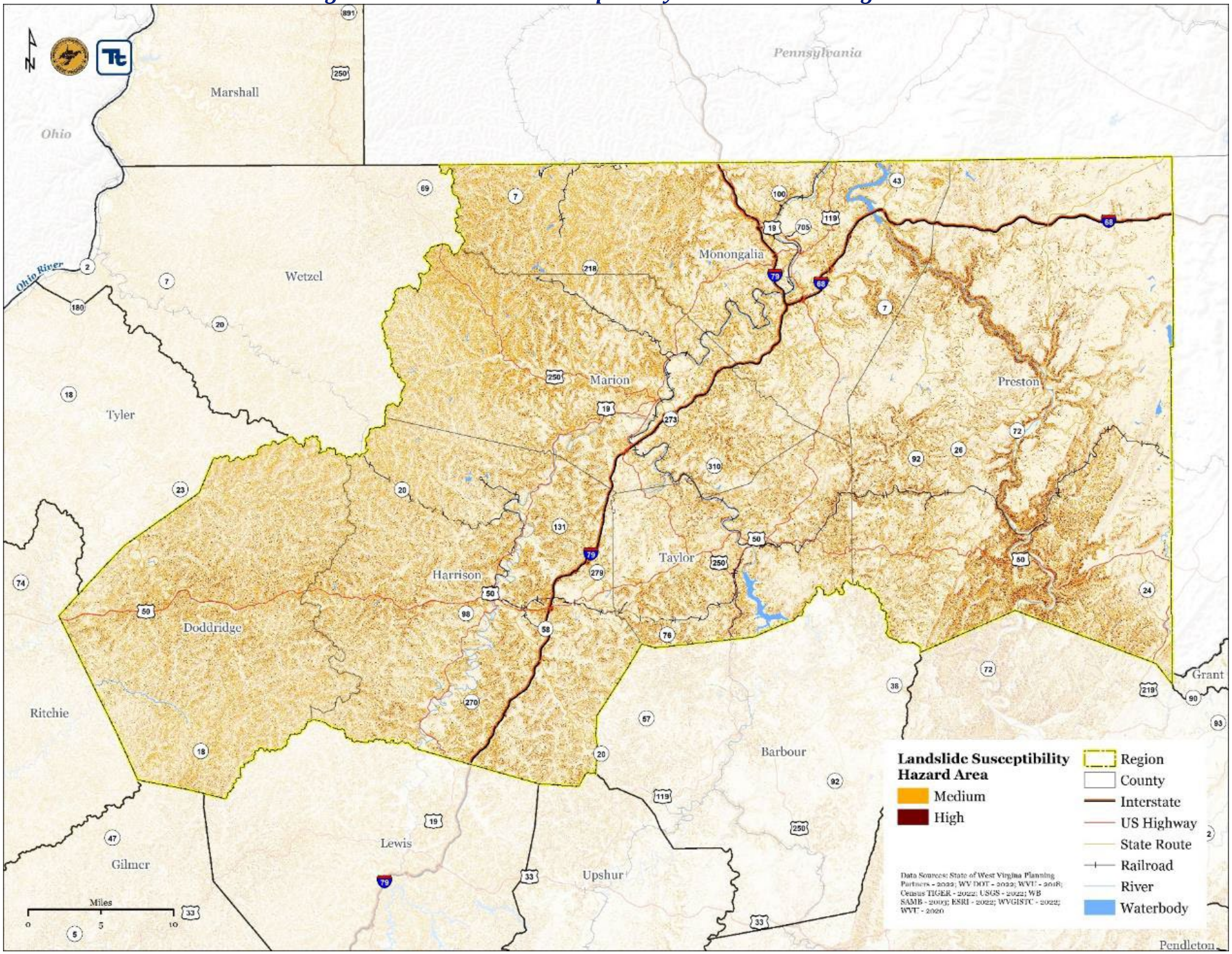


*Figure 5.7-9: Landslide Susceptibility Hazard Area in Region 7*

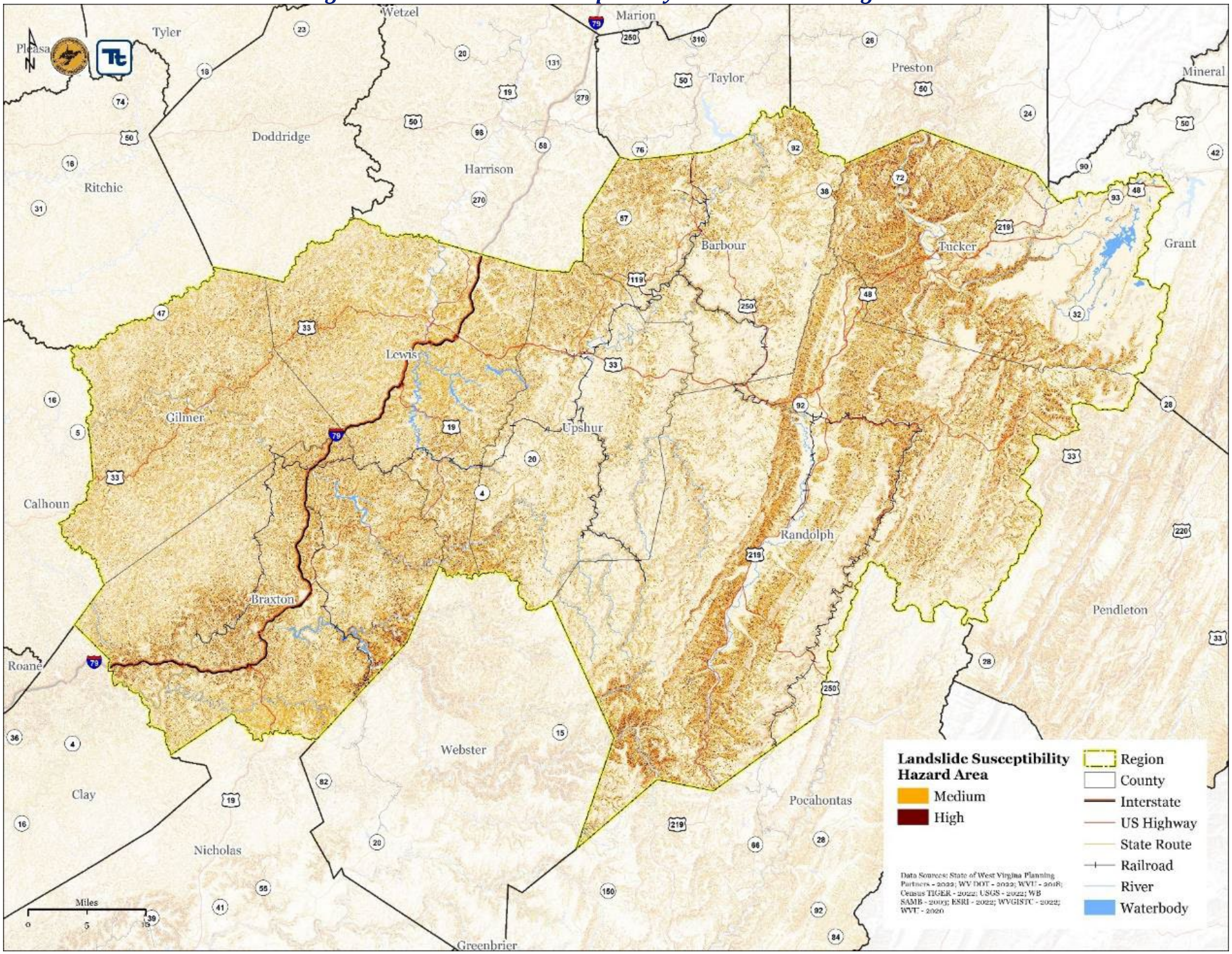


*Figure 5.7-10: Landslide Susceptibility Hazard Area in Region 8*

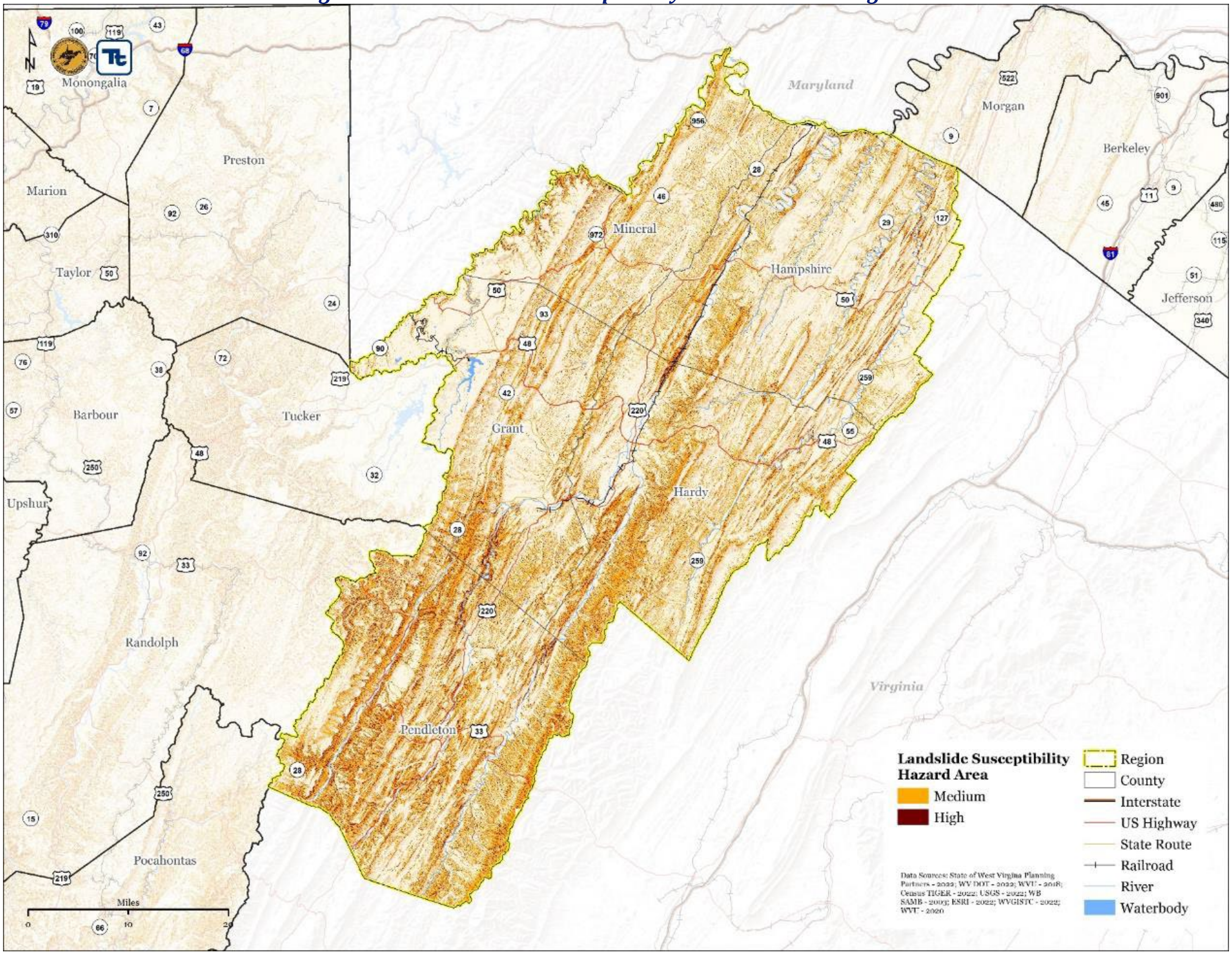


*Figure 5.7-11: Landslide Susceptibility Hazard Area in Region 9*

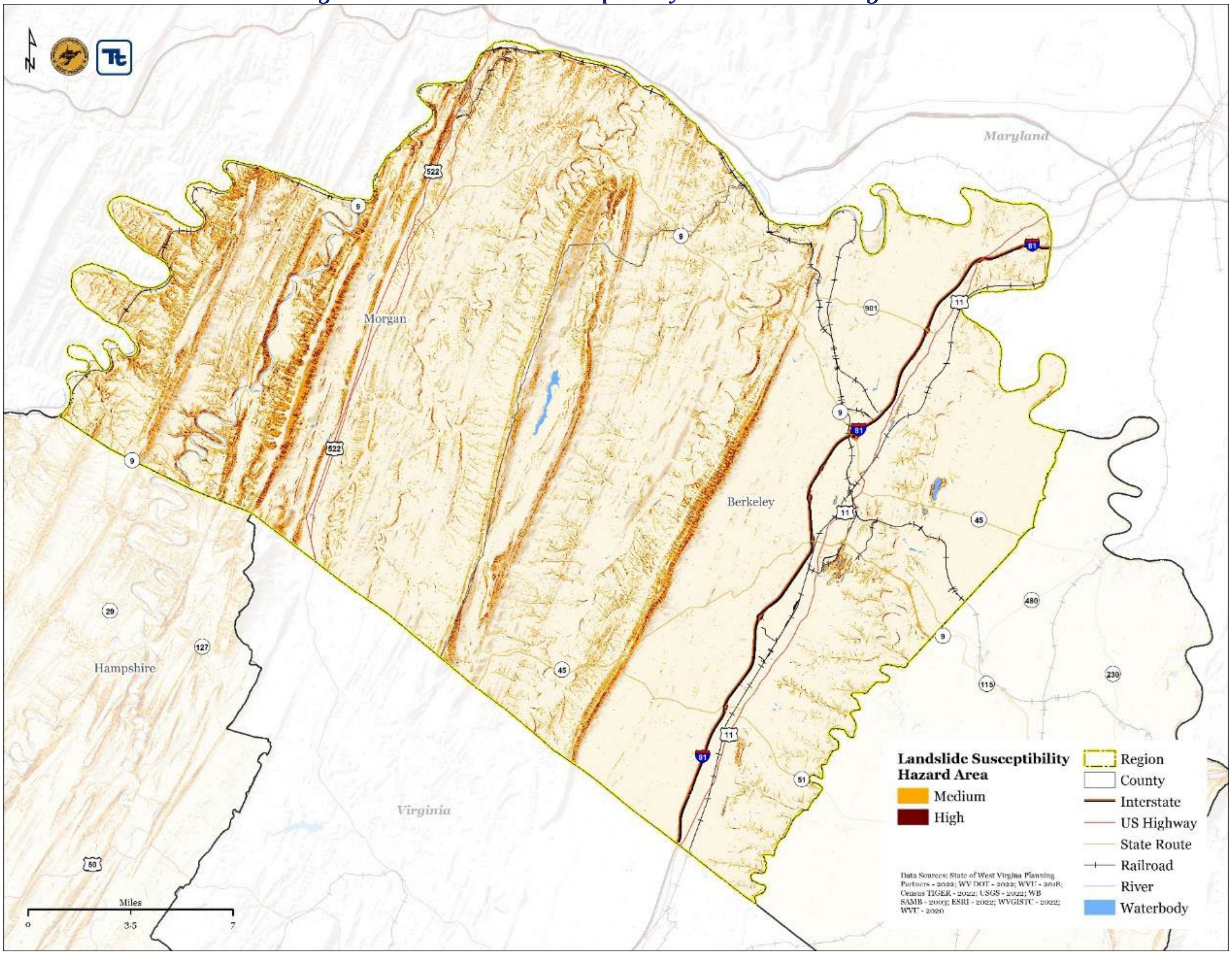


***Figure 5.7-12: Landslide Susceptibility Hazard Area in Region 10***

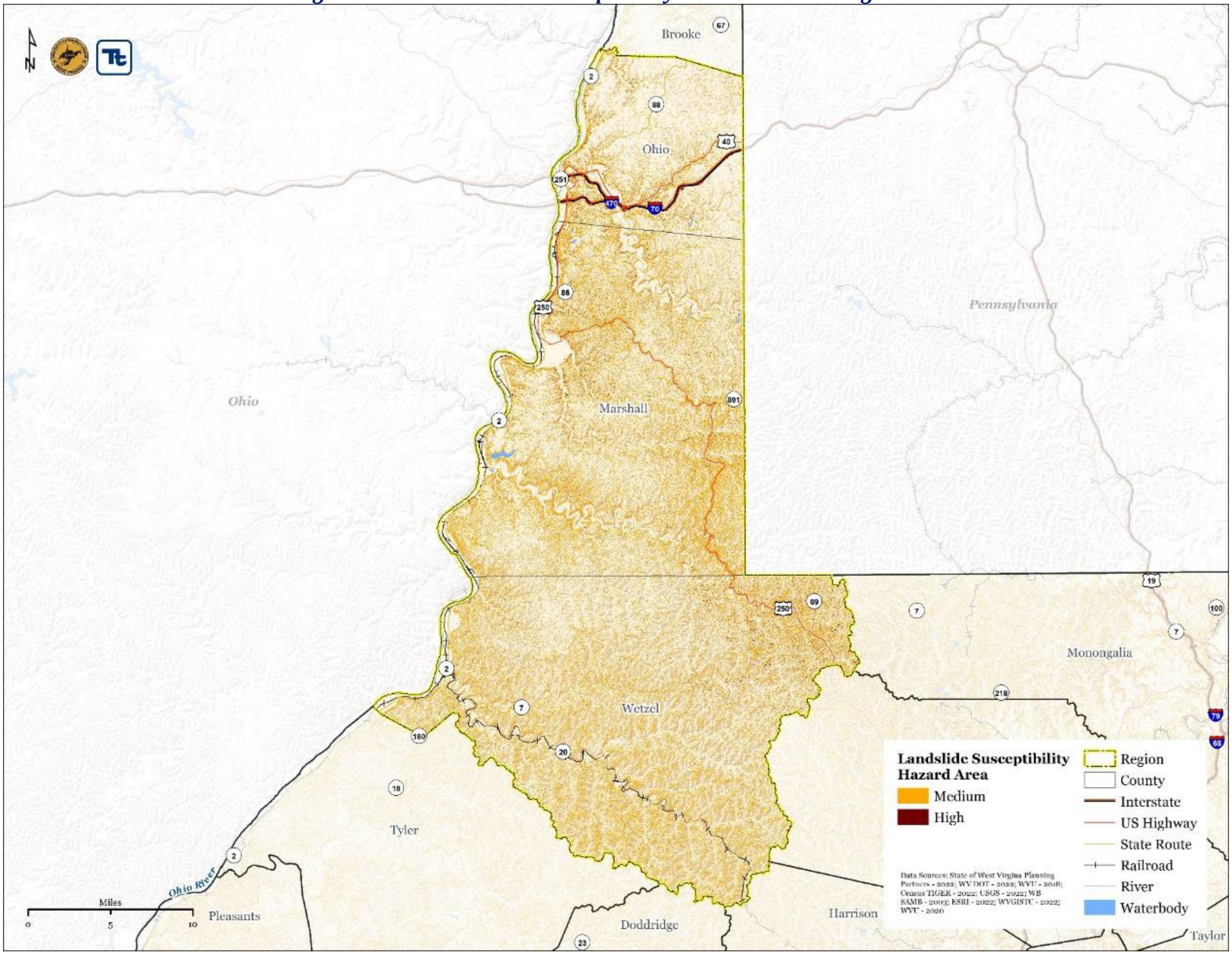


*Figure 5.7-13: Landslide Susceptibility Hazard Area in Region 11*

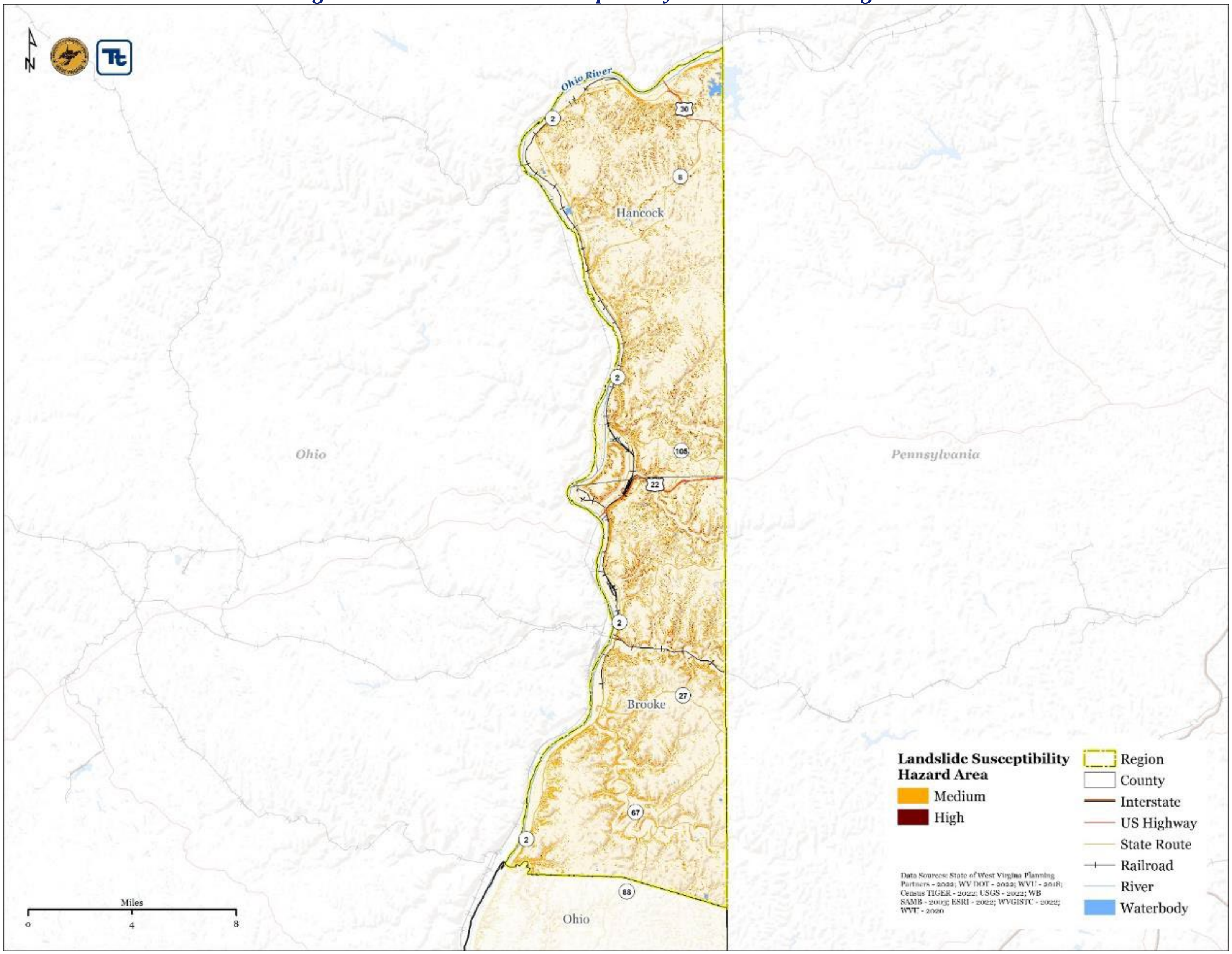
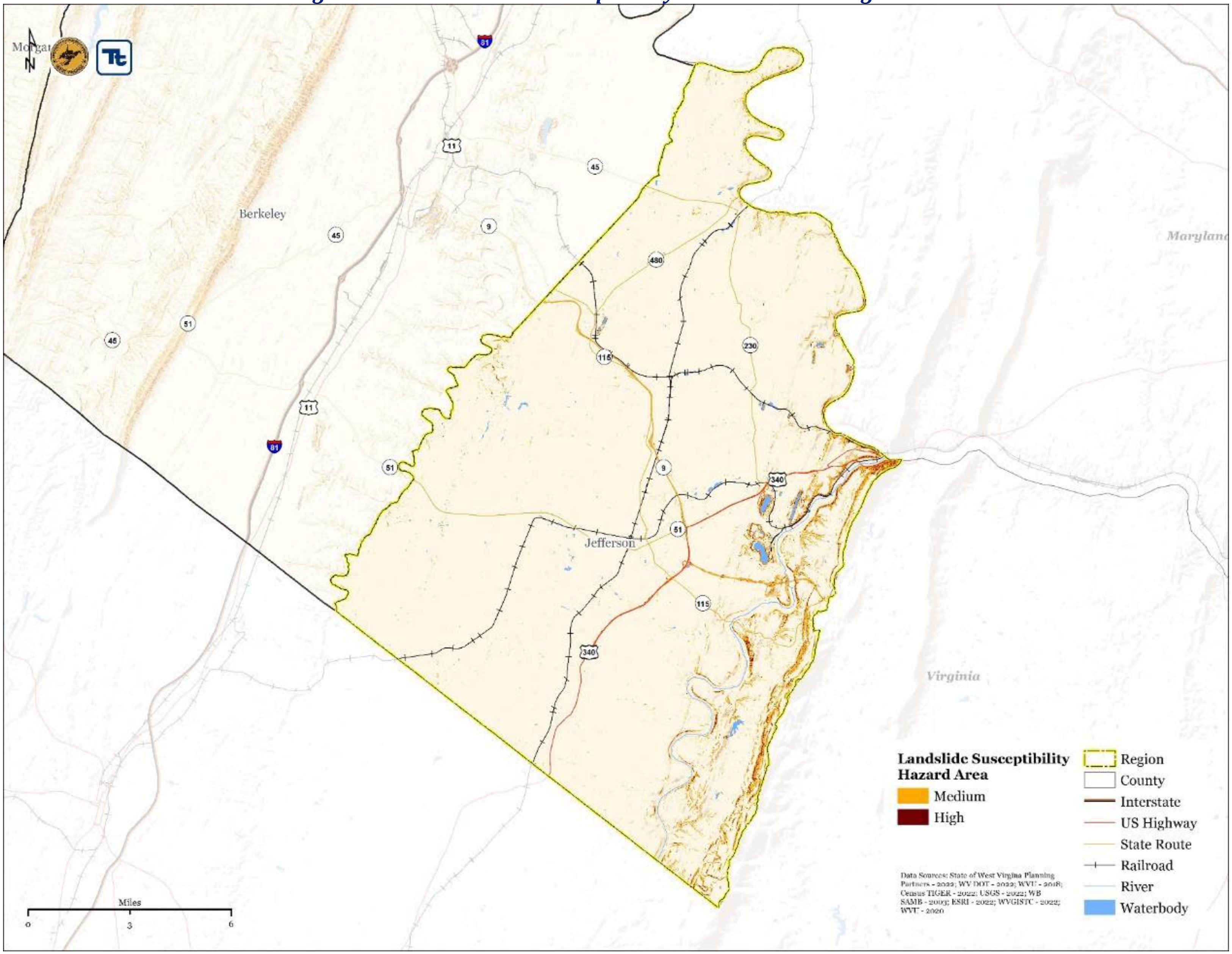


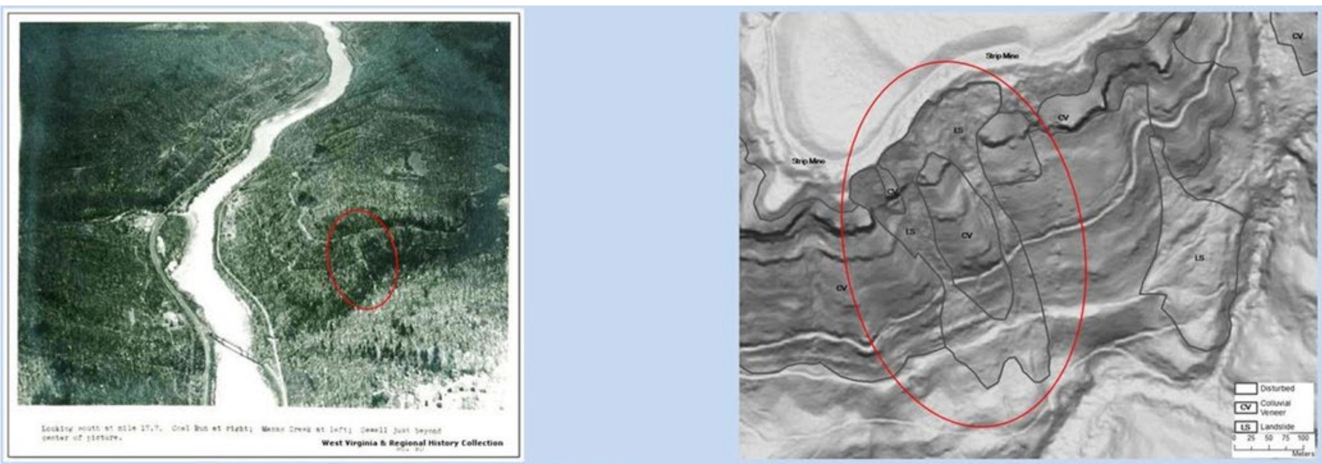
***Figure 5.7-14: Landslide Susceptibility Hazard Area in Region 12***



## EXTENT

In examining how experts and agencies measure the extent of landslides, the word "extent" can often be seen as part of the term "areal extent," referring to the geographic space a past landslide has covered or the geographic space a future landslide might be expected to cover (Highland and Bobrowsky 2008). The West Virginia Landslide Tool contains information on historical and LiDAR-identified landslides, hazard susceptibility modeling results, model inputs, and reference layers and was created as part of Hazard Mitigation Grant Program funded by FEMA and WVEMD (FEMA 2022). In this process, thousands of laser beams per second scan the earth from their position attached to fixed-wind planes or helicopters and create a map of the landscape beneath. Once processed, trees and buildings can be removed to reveal what the true ground surface looks like, down to foot trails and roads. Scientists can then analyze if there is a particular cause of a landslide and look to see if there is a landslide concern (Board 2014).

***Figure 5.7-15. Landslide in LiDAR Imagery***



Historic photo shows a landslide associated with strip mining, which can be seen in the LiDAR imagery.

*Source: Board 2014*

### Warning Time

The warning time for landslides depends on the geology, the vegetation, and the amount of predicted precipitation for an area. The current standard operating procedure is to monitor situations on a case-by-case basis and respond after the event has occurred. Generally accepted warning signs for landslide activity include:

- Tilting or cracking of concrete floors and foundations;
- Changes in the landscape, such as patterns of storm-water drainage on slopes (especially the places where runoff water converges), land movement, small slides, flows, or progressively leaning trees;
- Doors or windows stick or jam for the first time;
- New cracks appear in plaster, tile, brick, or foundations;
- Outside walls, walks, or stairs begin pulling away from the building;
- Slowly developing, widening cracks appear on the ground or on paved areas such as streets or driveways;
- Underground utility lines break;
- Bulging ground appears at the base of a slope;

- Water breaks through the ground surface in new locations;
- Fences, retaining walls, utility poles, or trees tilt or move;
- A faint rumbling sound that increases in volume is noticeable as the landslide nears;
- Unusual sounds, such as trees cracking or boulders knocking together, might indicate moving debris; and
- Collapsed pavement, mud, fallen rocks, and other indications of possible debris flow can be seen when driving (embankments along roadsides are particularly susceptible to landslides) (FEMA 2017).

## Previous Occurrences and Losses

### Federal Emergency Management Agency (FEMA) Disaster Declarations

Between 1953 and 2022, the State was included in 32 disaster (DR) or emergency (EM) declarations for landslide-related events. Generally, these disasters cover a wide region of the state; therefore, they can impact many counties. However, not all counties were included in the disaster declarations as determined by FEMA (FEMA 2023). Table 5.7-2 summarizes the landslide-related FEMA disaster declarations between January 1, 1953, and December 31, 2022.

*Table 5.7-2. Landslide-Related Federal Declarations (1953 to 2022)*

| Date(s) of Event | Event Type | Federal Designation | Counties Affected |
|---|---|---|---|
| August 24, 1977 | Severe Storms, Landslides, & Flooding | EM-3052-WV | Boone, Logan, Mingo |
| July 18-31, 1996 | Heavy Rains, High Winds, Flooding, and Slides | DR-1132-WV | Barbour, Braxton, Cabell, Clay, Gilmer, Monongalia, Nicholas, Randolph, Upshur, Webster |
| February 28-March 15, 1997 | Heavy and Wind Driven Rain, High Winds, Flooding, Landslides, and Mudslides | DR-1168-WV | Braxton, Cabell, Calhoun, Clay, Gilmer, Jackson, Kanawha, Lincoln, Mason, Putnam, Roane, Tyler, Wayne, Wetzel, Wirt, Wood |
| February 18-22, 2000 | Flooding, Severe Storms, and Landslides | DR-1319-WV | Barbour, Braxton, Cabell, Calhoun, Doddridge, Gilmer, Harrison, Jackson, Kanawha, Lewis, Lincoln, Marion, Mason, Monongalia, Preston, Putnam, Randolph, Ritchie, Roane, Taylor, Tucker, Tyler, Upshur, Wetzel, Wirt |
| May 15-September 4, 2001 | Severe Storms, Flooding, and Landslides | DR-1378-WV | Boone, Cabell, Calhoun, Clay, Doddridge, Fayette, Greenbrier, Kanawha, Lincoln, Logan, Marion, Mason, McDowell, Mercer, Mingo, Nicholas, Preston, Putnam, Raleigh, Roane, Summers, Taylor, Wayne, Wyoming |
| May 2-20, 2002 | Severe Storms, Flooding, and Landslides | DR-1410-WV | Kanawha, Logan, McDowell, Mercer, Mingo, Raleigh, Summers, Wyoming |
| February 16-March 28, 2003 | West Virginia Severe Winter Storms | DR-1455-WV | Berkeley, Boone, Braxton, Brooke, Cabell, Calhoun, Clay, Fayette, Gilmer, Grant, Greenbrier, Hampshire, Hancock, Hardy, Harrison, Jackson, Jefferson, Kanawha, Lewis, Lincoln, Logan, Marion, Marshall, Mason, McDowell, Mercer, Mineral, |

| Date(s) of Event | Event Type | Federal Designation | Counties Affected |
|---|---|---|---|
| | | | Mingo, Monongalia, Monroe, Morgan, Nicholas, Ohio, Pendleton, Pocahontas, Preston, Putnam, Raleigh, Roane, Summers, Taylor, Tucker, Tyler, Upshur, Wayne, Webster,Wetzel, Wirt, Wyoming |
| June 11-July 15, 2003 | Severe Storms, Flooding, and Landslides | DR-1474-WV | Berkeley, Boone, Cabell, Doddridge, Harrison, Kanawha, Lincoln, Logan, Marion, Mason, McDowell, Mingo, Monongalia, Nicholas, Preston, Putnam, Ritchie, Tucker, Wayne, Wyoming |
| November 11-30, 2003 | Severe Storms, Flooding, and Landslides | DR-1500-WV | Barbour, Boone, Braxton, Cabell, Calhoun, Clay, Doddridge, Fayette, Gilmer, Greenbrier, Harrison, Kanawha, Lewis, Logan, Marion, Marshall, McDowell, Mercer, Monongalia, Monroe, Nicholas, Pendleton, Pocahontas, Putnam, Raleigh, Ritchie, Summers, Taylor, Upshur, Wayne, Webster, Wetzel, Wyoming |
| May 27-June 28, 2004 | Severe Storms, Flooding, and Landslides | DR-1522-WV | Boone Braxton,, Cabell, Clay, Fayette, Gilmer, Jackson, Kanawha, Lewis, Lincoln, Logan, McDowell, Mason, Mercer, Mingo, Nicholas, Putnam, Raleigh, Roane, Wayne, Webster, Wirt, Wyoming |
| July 22-September 1, 2004 | Severe Storms, Flooding, and Landslides | DR-1536-WV | Fayette, Lincoln, Logan, Mingo |
| September 16-27, 2004 | Severe Storms, Flooding, and Landslides | DR-1558-WV | Berkeley, Boone, Brooke, Cabell, Clay, Hancock, Jackson, Kanawha, Lincoln, Logan, Marshall, Mason, Mingo, Morgan, Ohio, Pleasants, Putnam, Tyler, Wayne, Wetzel, Wirt, Wood |
| January 4-25, 2005 | Severe Storms, Flooding, and Landslides | DR-1574-WV | Brooke, Hancock, Marshall, Ohio, Tyler, Wetzel |
| April 14-18, 2007 | Severe Storms, Flooding, Landslides, and Mudslides | DR-1696-WV | Barbour, Boone, Cabell, Gilmer, Grant, Hardy, Lewis, Lincoln, Logan, McDowell, Mingo, Pendleton, Pocahontas, Putnam, Upshur, Wayne, Webster, Wyoming |
| June 3-7, 2008 | Severe Storms, Tornadoes, Flooding, Mudslides, and Landslides | DR-1769-WV | Barbour, Braxton, Calhoun, Clay, Doddridge, Gilmer, Harrison, Jackson, Jefferson, Lewis, Marion, Ritchie, Taylor, Tucker, Tyler, Webster, Wetzel, Wirt, |
| May 3-June 8, 2009 | Severe Storms, Flooding, Mudslides, and Landslides | DR-1838-WV | Calhoun, Gilmer, Lewis, McDowell, Mercer, Mingo, Raleigh, Roane, Upshur, Wirt, Wyoming |
| March 12-April 9, 2010 | Severe Storms, Flooding, Mudslides, and Landslides | DR-1893-WV | Fayette, Greenbrier, Kanawha, Mercer, Raleigh, Summers |

| Date(s) of Event | Event Type | Federal Designation | Counties Affected |
|---|---|---|---|
| June 12-29, 2010 | Severe Storms, Flooding, Mudslides, and Landslides | DR-1918-WV | Lewis, Logan, McDowell, Mingo, Wyoming |
| February 29-March 5, 2012 | Severe Storms, Tornadoes, Flooding, Mudslides, and Landslides | DR-4059-WV | Doddridge, Harrison, Lincoln, Marion, Mingo, Monongalia, Preston, Ritchie, Roane, Taylor, Wayne |
| March 15-31, 2012 | Severe Storms, Flooding, Mudslides, and Landslides | DR-4061-WV | Lincoln, Logan, Mingo |
| March 3-14, 2015 | Severe Winter Storm, Flooding, Landslides, and Mudslides | DR-4210-WV | Barbour, Boone, Braxton, Cabell, Doddridge, Fayette, Gilmer, Harrison, Jackson, Kanawha, Lewis, Lincoln, Logan, Marshall, McDowell, Mercer, Mingo, Monongalia, Putnam, Raleigh, Ritchie, Roane, Summers, Tucker, Taylor, Tyler, Upshur, Wayne, Webster, Wetzel, Wirt, Wood, Wyoming |
| April 3-5, 2015 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4219-WV | Boone, Cabell, Lincoln, Logan, Mingo, Wayne |
| April 8-11, 2015 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4220-WV | Braxton, Brooke, Doddridge, Gilmer, Jackson, Lewis, Marshall, Ohio, Pleasants, Ritchie, Tyler, Wetzel |
| April 13-15, 2015 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4221-WV | Cabell, Calhoun, Greenbrier, Jackson, Pleasants, Roane, Summers, Wirt |
| July 10-14, 2015 | Severe Storms, Straight-Line Winds, Flooding, Landslides, and Mudslides | DR-4236-WV | Braxton, Clay, Jackson, Lincoln, Logan, Nicholas, Roane, Webster, Wood |
| June 22-29, 2016 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4273-WV | Clay, Fayette, Greenbrier, Jackson, Kanawha, Lincoln, Monroe, Nicholas, Pocahontas, Roane, Summers, Webster |
| July 28-29, 2017 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4331-WV | Doddridge, Harrison, Marion, Marshall, Monongalia, Ohio, Preston, Randolph, Taylor, Tucker, Tyler, Wetzel |
| February 14-20, 2018 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4359-WV | Brooke, Cabell, Calhoun, Doddridge, Hancock, Harrison, Lincoln, Logan, Marshall, Mason, Monongalia, Ohio, Pleasants, Preston, Ritchie, Taylor, Tyler, Wayne, Wetzel, Wirt, Wood |
| May 28-June 3, 2018 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4378-WV | Grant, Hampshire, Hardy, Jefferson, Mineral, Morgan, Pendleton |
| June 29-30, 2019 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4455-WV | Grant, Pendleton, Preston, Randolph, Tucker |
| July 12-13, 2022 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4678-WV | McDowell |
| August 14-15, 2022 | Severe Storms, Flooding, Landslides, and Mudslides | DR-4679-WV | Fayette |

*Source: FEMA 2023*

## U.S. Department of Agriculture (USDA) Disaster Declarations

The Secretary of Agriculture from USDA is authorized to designate counties as disaster areas to make emergency loans to producers suffering losses in those counties and in counties that are contiguous to a designated county. Between 2012 and 2022, West Virginia was included in two landslide-related agricultural disaster declarations, as shown in Table 5.7-3 (USDA 2023).

*Table 5.7-3. Landslide-Related USDA Declarations (2012 to 2022)*

| Date(s) of Event | Designation Number | Description of Disaster | Counties Declared |
|---|---|---|---|
| March 1-August 25, 2015 | USDA-S3934 | Mudslides, Debris Flows, Landslides | Cabell, Hancock, Jackson, Marshall, Mason, Ohio, Pleasants, Tyler, Wayne, Wetzel, Wood |
| July 26-29, 2022 | USDA-S5322 | Mudslides, Debris Flows, Landslides | Mingo, Wayne |

*Source: USDA 2023*

## Previous Events

Many sources provided landslide information regarding previous occurrences and losses associated with landslide events throughout the State. The 2018 SHMP discussed specific landslide events that occurred in the State through 2018. For this 2023 SHMP, landslide events were summarized between January 1, 1977, and December 31, 2022.

Table 5.7-4 includes details of major landslide events that occurred in the state between 2018 and 2022. Major events include those that resulted in losses or fatalities, as reported by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI), events that led to a FEMA disaster declaration, and/or event that led to a USDA declaration. Associated precursor hazards to landslides, including heavy rain, flood, flash flood, heavy snow, and wildfire are presented to provide an indication of the potential for landslide events, as the NOAA NCEI Storm Events Database does not report landslide events.

### *Table 5.7-4. Landslide Events in the State of West Virginia (2018 to 2022)*

| Date(s) of Event | Event Type | Disaster Declaration (if applicable) | Counties Affected | Description |
|---|---|---|---|---|
| February 16-21, 2018 | Severe Storm, Flooding, Landslide, Mudslide | DR-4359-WV | Barbour, Cabell, Doddridge, Gilmer, Harrison, Jackson, Kanawha, Lewis, Lincoln, Logan, Mason, Pleasants, Putnam, Randolph, Ritchie, Roane, Taylor, Tyler, Upshur, Wayne, Wood | A wave of low pressure and surface front crossed West Virginia, producing heavy rainfall on the 16th. Generally, one to two inches of rain fell on already saturated soil. This resulted in creek and stream flooding on the 16th and into the 17th. As the rain drained through the river system, smaller main stem rivers flooded. This eventually led to flooding along the Ohio River. $168,500 of property damages were incurred from this event. |
| April 15-16, 2018 | Flood, Flash Flood, Heavy Rain, Landslide | N/A | Barbour, Berkeley, Braxton, Fayette, Gilmer, Grant, Greenbrier, Hampshire, Hardy, Harrison, Jefferson, Lewis, Marion, Mason,McDowell, Monongalia, Monroe, Morgan, Nicholas, Pendleton, Pocahontas, Preston, Randolph, Taylor, Tyler, Upshur, Webster | A strong upper-level system combined with a lot of low-level moisture led to a period of heavy rainfall on the 15th into the 16th. Widespread rainfall amounts of 2 to 3 inches fell in 24 to 36 hours from north central West Virginia into the mountainous counties. This led to flooding on many rivers and streams. Low pressure and its associated cold front passed through during the early morning hours of April 16th. Heavy rain of two to four inches fell in portions of the state, causing flooding mainly in Grant, Pendleton, and Hardy Counties. This water then moved downstream, causing flooding of larger rivers on the 17th and 18th. A period of moderate to heavy rain in advance of a passing cold front led to some isolated flooding across the upper Ohio Valley on the 16th. Over-saturated ground because of several rounds of rain across the area also led to several landslides, which did cause some problems in western Pennsylvania and northern West Virginia. $136,000 of property damages were incurred from this event. |
| May 28 - June 3, 2018 | Flood, Heavy Rain, Landslide | DR-4378-WV | Grant, Hampshire, Hardy, Jefferson, Mineral, Morgan, Pendleton | Heavy rain of one to four inches fell on June 1st across the eastern West Virginia panhandle, causing flooding and a few instances of flash flooding in Hampshire County. Flooding continued into the overnight hours. Then, persistent rain on the 2nd renewed the flooding, along with isolated flash flooding in and near Pendleton County, where over three inches of rain was observed. A landslide triggered by heavy rain, along with associated floodwaters, caused the closure of U.S.-220 just south of Moorefield near the Valley View Golf Club. No monetary damages were incurred from this event. |
| February 20-25, 2019 | Flood, Heavy Rain, Landslide | N/A | Doddridge, Fayette, Harrison, Jackson, Kanawha, Lincoln, Logan, Mason, McDowell, Mercer, | From February 20th to 25th, multiple rounds of precipitation passed across southeast West Virginia, resulting in liquid accumulations ranging from around 1.5 to 3 inches. The storm started out on the 20th as a combination of snow, sleet, and freezing rain across the mountains with liquid equivalents of 0.50 up to 2 inches. The next storm arrived early late on February 21st, with warmer air arriving with the system allowing the |

| Date(s) of Event | Event Type | Disaster Declaration (if applicable) | Counties Affected | Description |
|---|---|---|---|---|
| | | | Mineral, Mingo, Monroe, Ritchie, Tyler | precipitation to fall mainly as rain, which helped to quickly melt the frozen precipitation which fell during the 24-36 hours prior. With soils already saturated from previous precipitation, runoff from this storm caused mainly minor stream flooding and at least one significant landslide. $120,000 of property damages were incurred from this event, of which $70,000 were attributed to flooding. |
| June 29-30, 2019 | Flood, Flash Flood, Mudslide | DR-4455-WV | Grant, Pendleton, Preston, Randolph, Tucker | Showers and thunderstorms with heavy rain developed in the warm sector along the Mason-Dixon line in the afternoon on the 29th. These showers continued to train over parts of Marion, Monongalia, and Preston counties in West Virginia as well as Garrett County in Maryland. Two to three inches of rain were reported within only a few hours in addition to the rain from earlier in the day with the passage of the warm front. Roads were made impassable by fast-moving floodwaters and mudslides. Approximately 260 homes and businesses were impacted in Marion, Monongalia, and Preston counties combined. Estimated damage to public property, Marion $557,000, Monongalia $518,00, and Preston $855,000. |
| July 12-13, 2022 | Severe Storm, Flood, Landslide, Mudslide | FEMA-DR-4678 | Kanawha, McDowell, Putnam, Raleigh | Showers and storms with strong winds, large hail, and heavy downpours led to high water issues across the state. Roughly $1.008 million of property damages were incurred from this event. |
| August 15-16, 2022 | Severe Storms Flood, Landslide, Mudslide | FEMA-DR-4679 | Fayette, Greenbrier, Kanawha | A narrow band of heavy rain fell across the I-64 corridor during the early morning hours of August 15th. The Charleston airport reported 4.33 inches of rain had fallen since the previous evening, with radar estimates ranging from two to five inches from Putnam to Fayette Counties. The Campbells Creek area of Kanawha County observed significant damage from flash flooding, with damage costs extending close to one million dollars. Flash flooding was also observed in the Scrabble Creek area of Fayette County. The Governor of West Virginia declared a State of Emergency for Kanawha and Fayette Counties due to the flooding, and recovery and clean-up efforts spanned weeks after the event occurred. Another round of showers and storms transpired on the afternoon of August 16th, which once again caused high water issues within Fayette County. Roughly $10 million of property damages were incurred from this event. |

*Sources: FEMA 2023; USDA 2023; NOAA NCEI 2023*
*Notes: DLNR Department of Land and Natural Resources*
*FEMA Federal Emergency Management Agency*

## PROBABILITY OF FUTURE HAZARD EVENTS

### Overall Probability

The stability of natural and engineered slopes will likely lead to more landslides due to the increased frequency and intensity of future rain events. In most cases, this will be directly connected to flooding events. What is less clear, however, are the details of those consequences: the type, extent, magnitude, and direction of the changes in the stability conditions and on the location, abundance, activity, and frequency of landslides in response to the projected future conditions. Conditions that increase the risk of a landslide include heavy rain, snowmelt, and changes in groundwater level which may trigger landslides. Erosion may remove the toe and lateral support of certain areas, triggering potential landslides (West Virginia Emergency Management Division 2018).

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. Human activities triggering landslides are usually associated with construction and changes in slope and surface water and groundwater levels. Changes in irrigation, runoff, and drainage can increase erosion and change groundwater levels and ground saturation. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of a site and by making inquiries to planning and engineering departments of local governments. They can also obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazard potential of a site, built or unbuilt (USGS 2022).

Impacts from landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increases when groundwater is prevented from rising in the landslide mass by (1) covering the landslide with an impermeable membrane, (2) directing surface water away from the landslide, (3) draining groundwater away from the landslide, and (4) minimizing surface irrigation. Slope stability is also increased when a retaining structure and/ or the weight of a soil/rock berm are placed at the toe of the landslide or when mass is removed from the top of the slope (USGS 2022).

According to FEMA, USDA, NOAA-NCEI, and the 2018 SHMP, the State experienced 35 landslide events between 1976 and 2022, as summarized in Table 5.7-5.

***Table 5.7-5: Probability of Future Landslide Events in West Virginia***

| Hazard Type | Number of Occurrences Between 1976 and 2022 | Percent Chance of Occurrence in Any Given Year |
|---|---|---|
| Landslide | 35 | 48.6 |

*Sources: FEMA 2023; USDA 2023; NOAA NCEI 2023; West Virginia Emergency Management Division 2018*

### Projected Future Conditions

Heavy rains and floods, as described in the Hazard Profile, are precursors to the landslide hazard. In the future, rain events are expected to become more frequent and more intense across the United States. Moderate flooding events are expected to become more frequent in most of the Northeast during the 21st century because of more intense precipitation (U.S. Global Change Research Program 2018). Annual precipitation is projected to increase for West Virginia over this century, with the largest increases occurring during winter and spring.

Projections indicate that future conditions may include an increase in temperatures across the State of Virginia. Temperatures in West Virginia have risen 1°F since the beginning of the 20th century. Drier conditions in the future may increase the likelihood of wildfires. Wildfires destroy landscapes by decimating trees, shrubs, and other vegetation. Similar to issues presented by logging actives (refer to Impacts to the Environment), the elimination of vegetation in forested areas results in loose soil and increases the amount of water that remains on top of the soil since it can no longer be absorbed by vegetation; these conditions may exacerbate the possibility of a landslide event (Geertsema, Highland and Vaugeouis 2009).

## 5.7.2 Vulnerability Assessment

A statewide assessment was conducted based on landslide susceptibility data provided by West Virginia Department of Transportation, U.S. Geological Survey, and West Virginia University. Landslide susceptibility mapping describes the relative likelihood of future landslides based solely on prior failure (from a landslide inventory), rock or soil strength, and steepness of slope. This analysis used the areas mapped having high or very high susceptibility to landslides (U.S. Geological Survey 2023).

### State Assets

Table 5.7-6 and Table 5.7-7 summarize the number and replacement cost value of state assets located in high landslide susceptibility areas; both tables reflect only the counties with state facilities. All other counties do not have state facilities within high susceptibility landslide hazard areas. Pocahontas and Fayette County both have one state facility within the landslide hazard area. Pocahontas County contains the Miner's Health Safety, Division of Training, which has a total replacement cost value (RCV) of $3.4 million. The Department of Health & Human Resources is located in Fayette County and has a total RCV of $130,000.

***Table 5.7-6. State Facilities Located within the High Susceptibility Landslide Hazard Area***

| State Facilities located Within the High Susceptibility Landslide Hazard Area | | Replacement Cost Value for State Facilities Within the High Susceptibility Landslide Hazard Area by County | | |
|---|---|---|---|---|
| County | Number of Structures | Replacement Cost Value (Structure Only) | Replacement Cost Value (Contents Only) | Total Replacement Cost Value (Structure & Contents) |
| Fayette | 1 | $1,900,000 | $1,500,000 | $3,400,000 |
| Pocahontas | 1 | $0 | $130,000 | $130,000 |
| **Total** | **2** | **$1,900,000** | **$1,630,000** | **$3,530,000** |

*Source WVEMD 2023; WVU 2020*

***Table 5.7-7: State Facilities Located within the High Susceptibility Landslide Hazard Area by Agency***

| State Facilities located within the High Susceptibility Landslide Hazard Area | | Replacement Cost Value for State Facilities within the High Susceptibility Landslide Hazard Area by Agency | | |
|---|---|---|---|---|
| Agency | Number of Structures | Replacement Cost Value (Structure Only) | Replacement Cost Value (Contents Only) | Total Replacement Cost Value (Structure & Contents) |
| Health & Human Resources, Department of State of West Virginia | 1 | $0 | $130,000 | $130,000 |
| Miner's Health Safety, Division of Training, State of West Virginia | 1 | $1,900,000 | $1,500,000 | $3,400,000 |

| State Facilities located within the High Susceptibility Landslide Hazard Area | | Replacement Cost Value for State Facilities within the High Susceptibility Landslide Hazard Area by Agency | | |
|---|---|---|---|---|
| Agency | Number of Structures | Replacement Cost Value (Structure Only) | Replacement Cost Value (Contents Only) | Total Replacement Cost Value (Structure & Contents) |
| **Total (WV State)** | **2** | **$1,900,000** | **$1,630,000** | **$3,530,000** |

*Source WVEMD 2023; WVU 2020*

## Critical Facilities and Community Lifelines

One critical facility and lifeline is located in the high susceptibility landslide hazard area in the state. This facility is located in Fayette County, under the Safety and Security lifeline, shown in Table 5.7-8.

***Table 5.7-8: Critical Facilities Located within the High Susceptibility Landslide Hazard Area***

| County | Communications | Energy | Food, Water, Shelter | Hazardous Material | Health & Medical | Safety & Security | Transportation | Total |
|---|---|---|---|---|---|---|---|---|
| Fayette | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| **Total** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **1** |

*Source WVEMD 2023; WVU 2020*

In addition to critical facilities, a significant amount of infrastructure can be exposed to landslides:

- Roads—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation.
- Bridges—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- Power Lines—Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines.
- Rail Lines—Similar to roads, rail lines are important for response and recovery operations after a disaster. Landslides can block travel along the rail lines, which would become especially troublesome, because it would not be as easy to detour a rail line as it is on a local road or highway.

## Population

Generally, a landslide event would be an isolated incidence and impact the populations within the immediate area of the incident. Populations downslope of a landslide hazard area are particularly vulnerable to this hazard. Health threats from landslides include: 1) trauma caused by rapidly moving water and debris; 2) broken electrical, water, gas and sewage lines that can lead to injury or illness; and 3) disrupted roadways that can endanger motorists and disrupt transport and access to health care (Centers for Disease Control and Prevention [CDC] 2018).

To understand the risk to populations residing in high landslide susceptibility areas, a spatial analysis was conducted using the 2020 U.S. Census data. Table 5.7-9 evaluates the population located in the high susceptibility areas. Overall, 49,465 people in West Virginia are living in the high susceptibility landslide hazard areas.

***Table 5.7-9: Population Located in High Susceptibility Landslide Hazard Areas***

| County | Total County Population | Total Population | % Total Population | Highly Vulnerable Population | % Highly Vulnerable Population |
|---|---|---|---|---|---|
| Barbour | 16,543 | 382 | 2.31% | 47 | 12.23% |
| Berkeley | 117,615 | 766 | 0.65% | 32 | 4.15% |
| Boone | 21,897 | 1,683 | 7.69% | 324 | 19.28% |
| Braxton | 14,032 | 724 | 5.16% | 180 | 24.87% |
| Brooke | 22,162 | 218 | 0.98% | 51 | 23.56% |
| Cabell | 93,328 | 2,592 | 2.78% | 254 | 9.80% |
| Calhoun | 7,185 | 130 | 1.81% | 0 | 0.00% |
| Clay | 8,599 | 302 | 3.51% | 33 | 10.82% |
| Doddridge | 8,499 | 150 | 1.76% | 0 | 0.00% |
| Fayette | 43,087 | 1,176 | 2.73% | 566 | 48.13% |
| Gilmer | 7,970 | 248 | 3.11% | 102 | 41.16% |
| Grant | 11,565 | 576 | 4.98% | 279 | 48.38% |
| Greenbrier | 34,893 | 1,295 | 3.71% | 499 | 38.49% |
| Hampshire | 23,304 | 773 | 3.32% | 250 | 32.36% |
| Hancock | 29,118 | 394 | 1.35% | 83 | 21.11% |
| Hardy | 13,789 | 701 | 5.08% | 0 | 0.00% |
| Harrison | 67,620 | 1,115 | 1.65% | 119 | 10.64% |
| Jackson | 28,793 | 420 | 1.46% | 0 | 0.00% |
| Jefferson | 56,922 | 226 | 0.40% | 0 | 0.01% |
| Kanawha | 181,014 | 8,834 | 4.88% | 1,661 | 18.80% |
| Lewis | 16,024 | 366 | 2.28% | 45 | 12.36% |
| Lincoln | 20,617 | 862 | 4.18% | 156 | 18.12% |
| Logan | 32,593 | 2,513 | 7.71% | 1,671 | 66.50% |
| Marion | 56,233 | 987 | 1.76% | 45 | 4.58% |
| Marshall | 30,900 | 311 | 1.01% | 0 | 0.00% |
| Mason | 26,700 | 345 | 1.29% | 0 | 0.00% |
| McDowell | 18,083 | 441 | 2.44% | 195 | 44.23% |
| Mercer | 59,370 | 2,142 | 3.61% | 800 | 37.37% |
| Mineral | 27,047 | 979 | 3.62% | 51 | 5.25% |
| Mingo | 23,808 | 1,510 | 6.34% | 840 | 55.63% |
| Monongalia | 106,196 | 1,429 | 1.35% | 149 | 10.41% |
| Monroe | 13,344 | 447 | 3.35% | 0 | 0.00% |
| Morgan | 17,800 | 400 | 2.25% | 0 | 0.00% |
| Nicholas | 24,857 | 660 | 2.66% | 0 | 0.00% |
| Ohio | 41,875 | 573 | 1.37% | 67 | 11.65% |
| Pendleton | 6,968 | 659 | 9.46% | 0 | 0.00% |
| Pleasants | 7,457 | 87 | 1.17% | 0 | 0.00% |
| Pocahontas | 8,382 | 443 | 5.29% | 0 | 0.00% |
| Preston | 33,610 | 929 | 2.76% | 4 | 0.41% |
| Putnam | 56,604 | 2,074 | 3.66% | 0 | 0.00% |
| Raleigh | 74,452 | 1,172 | 1.57% | 730 | 62.25% |
| Randolph | 28,763 | 876 | 3.05% | 222 | 25.33% |

| County | Total County Population | Total Population | % Total Population | Highly Vulnerable Population | % Highly Vulnerable Population |
|---|---|---|---|---|---|
| Ritchie | 9,747 | 144 | 1.48% | 0 | 0.00% |
| Roane | 13,831 | 527 | 3.81% | 99 | 18.78% |
| Summers | 12,710 | 1,171 | 9.21% | 408 | 34.84% |
| Taylor | 16,817 | 218 | 1.30% | 63 | 28.83% |
| Tucker | 6,943 | 464 | 6.68% | 0 | 0.00% |
| Tyler | 8,736 | 17 | 0.19% | 0 | 0.00% |
| Upshur | 24,451 | 400 | 1.64% | 0 | 0.00% |
| Wayne | 39,952 | 1,944 | 4.87% | 0 | 0.00% |
| Webster | 8,289 | 369 | 4.45% | 0 | 0.00% |
| Wetzel | 15,291 | 88 | 0.58% | 0 | 0.00% |
| Wirt | 5,764 | 82 | 1.42% | 0 | 0.00% |
| Wood | 84,387 | 515 | 0.61% | 18 | 3.40% |
| Wyoming | 20,890 | 616 | 2.95% | 68 | 11.06% |
| Total | **1,807,426** | **49,465** | **2.74%** | **10,111** | **20.44%** |

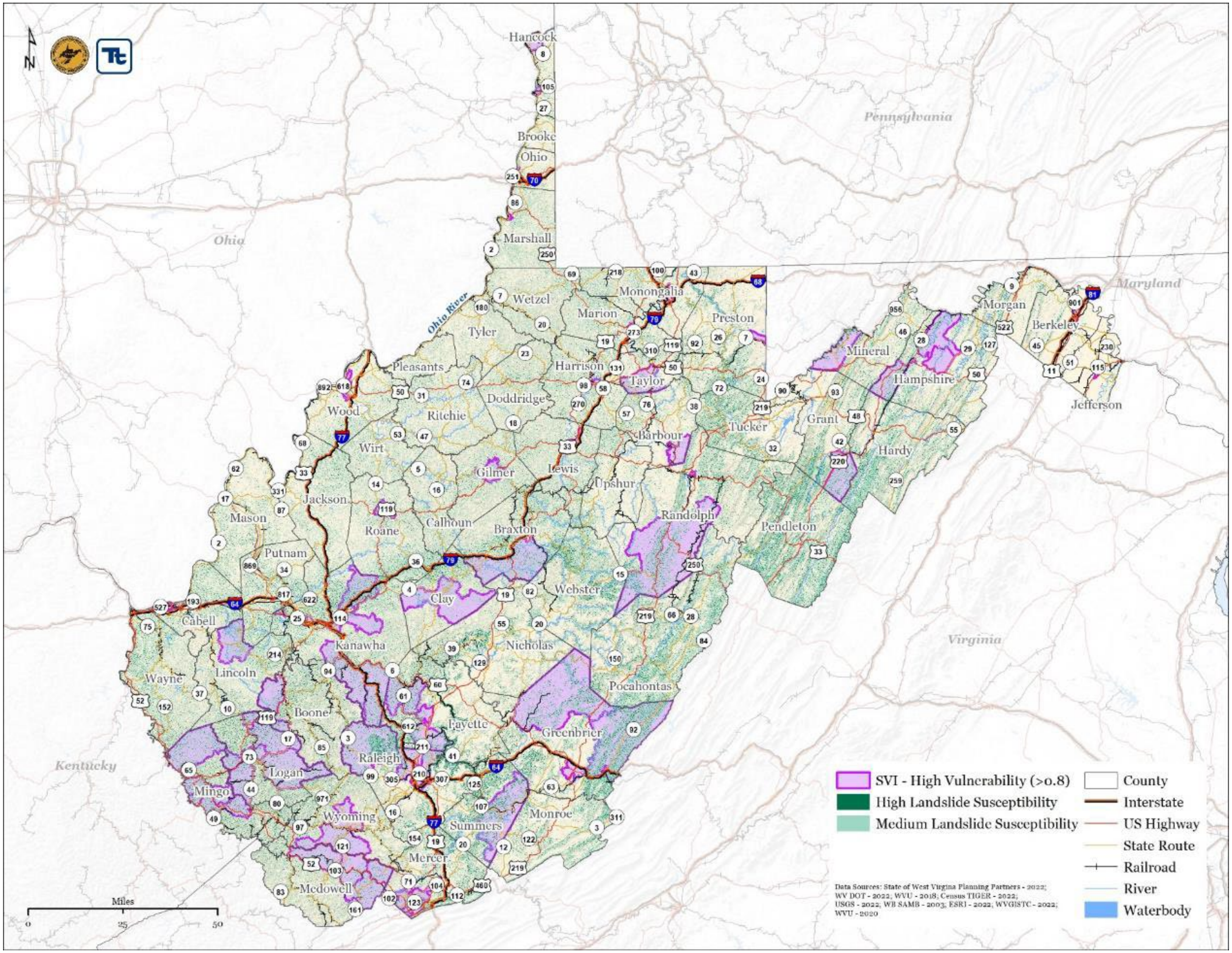
*Source* *CDC 2020; WVU 2020*

### Impacts on Socially Vulnerable Populations

Socially vulnerable populations are most susceptible to the landslide hazard on many factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. Power and communication failures due to landslides can also create problems for vulnerable populations and businesses.

Figure 5.7-16 illustrates the location of the socially vulnerable populations within the landslide susceptibility hazard areas. Of the total population located within the high susceptibility landslide hazard area (49,465) 20.4 percent are identified as being socially vulnerable. These residents may be displaced by the destruction of their homes, requiring them to seek temporary shelter with friends and family or in emergency shelters. These populations may also lack access to vehicles for any necessary evacuations. Logan County has the greatest percentage (66.5 percent) of its socially vulnerable population located in the high susceptibility landslide hazard areas, followed by Raleigh County, at 62.25 percent. Of the total population exposed, 10,111 persons are identified as socially vulnerable and may be impacted more severely by landslide events.

*Figure 5.7-16: Social Vulnerability Index for Landslides*



### Future Changes That May Impact State Vulnerability

Understanding future changes that may impact vulnerability in the state can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The State considered the following factors in examining potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including impacts of future conditions.

#### Potential or Projected Development

It is anticipated that any new development in the high susceptibility landslide hazard area will be exposed to the hazard. Further development in the hazard area would expose the population and structures to the landslide hazard.

#### Projected Changes in Population

West Virginia is losing population faster than recent forecasts, which do not account for county-by-county increases. According to population projections in 2022 from the WVU Bureau of Business and Economic Research, West Virginia's population was projected to fall from 1,793,716 in 2020 to 1,705,509 in 2040 (West Virginia University 2022). As of July 1, 2019, according to estimates by the U.S. Census Bureau, West Virginia's total population is 1,792,147, representing a 3.3 percent decline since 2010 (approximately 60,487 fewer residents). West Virginia lost population both naturally, with 19,000 more deaths than births, and through migration, with 27,000 more people leaving the state than moving in (WVDOT 2020). Refer to Section 2 (County Profile), which includes a discussion on population trends for the County. As population in the state continues to decrease there is the potential that less people will reside or work within the state's high susceptibility landslide hazard area.

#### Other Factors of Change

Projections may alter the stability of land in the high susceptibility landslide hazard area. More frequent and intense rain and storms can increase the likelihood of soil erosion and movement. Similarly, due to projected increases in temperatures, there may be an escalated risk of wildfires, which can also be a precursor to soil erosion and movement.

Current land uses may be exacerbating the possibility of landslides occurring. As discussed in Impacts to the Environment, forested areas may be seeing an increase in landslides due to deforestation caused by logging activities.

## 5.7.3 Consequence Analysis

### Impacts to the Public

Residents, buildings, and infrastructure located within the high susceptibility landslide hazard areas of the state are the most at risk to landslides. Generally, a landslide event would be an isolated incident and impact the populations within the immediate area of the incident, particularly if the population is located downslope. Loss of property can also leave individuals homeless, which can be detrimental for vulnerable populations, particularly those who rely on medical equipment or home-health care.

An analysis performed on the population of the State revealed that an estimated 49,465 West Virginian residents are located in the high susceptibility landslide hazard area and 20.44 percent are highly vulnerable. Please reference Table 5.7-9 for more information regarding populations in the high susceptibility landslide hazard area.

### Impacts to Responders

Significant landslide events may hinder the delivery of emergency services. Landslides can cause delays or impair rail and road transportation, halt supply chains, and disrupt medical and emergency services that provide lifesaving support. Landslide events can collapse buildings and knock down trees and power lines, making it difficult for responders to get to reach an impacted area and maintain communications with one another; communications may also be impacted for the public if any communication towers are impacted by the subsidence event.

Responders, especially those in search and rescue or recovery operations, should maintain situational awareness when entering a structure with damage from a landslide. Unstable ground may cause the structure to collapse, as land movements have been known to cause the support and stability of a structure's foundation to collapse or sink. Responders should listen and watch for any additional rushing water or mud, as it will signal another landslide is underway. Unusual sounds such as trees cracking or boulders knocking together, might indicate moving debris. A faint rumbling sound that increases in volume is noticeable as the landslide nears (U.S. DHS 2022).

### Impacts to Continuity of Operations

Landslide events have the potential to bring down trees, electrical wires, telephone poles and lines, and communication towers. Communication and power can be disrupted for extended periods of time while utility companies repair damages, impacting day-to-day operations. Larger events may interrupt transportation flow in communities as damages could include downed trees, utility line, and structural collapses near major roadways. If damages are along major throughways, the roads may be impacted for an undetermined amount of time, stopping the flow of supplies and disrupting emergency and medical services. Although there are only two state facilities in the high susceptibility landslide hazard area, one is identified as a critical facility.

### Impacts to Property, Facilities, and Infrastructure

Landslides have the potential to cause extensive amounts of property damage. Recognizing signs of slope instability can help avoid future costly repairs. Signs of slope instability include:

- Cracks or fissures in the ground,
- Cracks in or displacement of paved surfaces,
- Cracked or bent walls, foundations, and chimneys,
- Tilted, warped, or cracked retaining walls,
- Tilted fence posts, utility poles, signs, etc.,
- Curved tree trunks, indicating soil creep, and
- Irregular topography indicating the occurrence of past landslides (WVU 2020).

Infrastructure may also incur damages from landslides. Roadways, bridge, and rail lines may have soil and debris strewn across the easements, making it dangerous for drivers and operators to attempt to utilize the structures. Damages to these structures could interrupt public and private methods of transportation, including public buses and trains, commercial vehicles and trains, and emergency response vehicles.

Power lines, although generally elevated above steep slopes, may be impacted as sediment and debris tumble downslope, knocking down the towers supporting them. The loss of power would impact methods of communication, making it difficult or nearly impossible for individuals to connect one another.

Table 5.7-10 details state roads that are located in the high susceptibility landslide area; counties without any vulnerable state roads are not shown in the table. In total, the state has 7.98 miles of roadway that is located in the high susceptibility landslide hazard area, with Pocahontas County having the most miles of state roadways in the hazard area (1.02 miles).

**Table 5.7-10: State Roads in the High Susceptibility Landslide Area**

| State Roads located within the High Susceptibility Landslide Hazard Area | | State Roads located within the High Susceptibility Landslide Hazard Area | |
|---|---|---|---|
| County | Mileage of Roadway | County | Mileage of Roadway |
| Barbour | 0.19 | Mingo | 0.02 |
| Berkeley | 0.03 | Monongalia | 0.02 |
| Braxton | 0.27 | Monroe | 0.01 |
| Calhoun | 0.05 | Morgan | 0.01 |
| Doddridge | 0.01 | Nicholas | 0.06 |
| Fayette | 0.06 | Pocahontas | 1.02 |
| Gilmer | 0.16 | Preston | 0.02 |
| Grant | 0.01 | Raleigh | 0.66 |
| Hampshire | 0.02 | Randolph | 0.28 |
| Jefferson | 0.12 | Ritchie | 0.02 |
| Kanawha | 0.03 | Summers | 0.52 |
| Lewis | 0.02 | Taylor | 0.02 |
| Logan | 0.63 | Tucker | 0.06 |
| Marion | 0.01 | Upshur | 0.15 |
| Marshall | 0.01 | Webster | 0.90 |
| McDowell | 0.93 | Wetzel | 0.08 |
| Mercer | 0.56 | Wood | 0.04 |
| Mineral | 0.19 | Wyoming | 0.75 |
| | | **Total** | **7.98** |

*Source WVU 2020; WVDOT 2021*

## Impacts to the Environment

Landslides change and modify the landscape it interrupts. The hazard can overwhelm and pollute bodies of water with excess sediment deposits; in some cases, the amount of sediment may be enough to dam streams and rivers, impacting water quality and habitats (Geertsema, Highland and Vaugeouis 2009).

West Virginia is a largely forested state, of which landslides can also impact. Forest destruction caused by landslides is a result of heavy rains and soil movement. Areas which participate in logging, which is the process of cutting, processing, and moving trees to a location or transport, may have an increased likelihood to be impacted by landslides. Each of the state's 55 counties participate in the wood industry; the forest products sector is the largest employer in many of the counties (West Virginia Division of Forestry 2021). The removal of trees in forested areas adversely impacts forested areas and increases vulnerability to the landslide hazard as the soil which was once held in place by the roots of the trees, and the water which was absorbed by the trees, become loose and susceptible to becoming eroded or cause landslides (Geertsema, Highland and Vaugeouis 2009).

## Impacts to the Economic Condition of the State

Landslides can impose direct and indirect impacts on the state's economy. Direct costs include actual damage sustained to buildings, property, and infrastructure. Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity, are difficult to measure. There are 1,117 State-owned or leased facilities located throughout West Virginia. While landslides can cause significant damage to state assets, there are no standard formulas for estimating associated losses. In the event of complete losses, the two state facilities located the high susceptibility landslide hazard area have a replacement cost value of over $2.1 million.

## Impacts to Public Confidence in State Governance

The public confidence in state governance would mainly depend on how effective the State has been in the past at preparing for and responding to landslides. Public confidence also depends on the size of the event and the preparation the State takes for each potential event. In general, if the State is transparent in sharing relevant information with the public regarding landslides and demonstrates its reliability to the public through availability of programs and services relevant to landslides, then the public will remain confident in the State's governance (Chew, et al. 2021).

The West Virginia Geological and Economic Survey's website offers information on how homeowners can prepare for various geologic hazards, including landslides.

West Virginia's Division of Emergency Management partnered with FEMA and the WVU GISTC to create guidance for homeowners on how to recognize landslide risk on their property and how to mitigate that risk. Similarly, these organizations partnered to create a landslide risk assessment for the State and its Major Land Resource Areas.