5.13 Subsidence

2023 SHMP Update Changes

- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, and probability of future occurrence (including how future conditions may impact the hazard). New and updated figures from federal and state agencies are incorporated.
- Subsidence events that occurred in the State of West Virginia (the State) from January 1, 2018, through December 31, 2022, were researched for this 2023 State Hazard Mitigation Plan (SHMP) Update.
- Information was updated regarding the current population affected by subsidence.
- Analyzed state asset exposure to subsidence events and assessed vulnerabilities.

5.13.1 Hazard Profile

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of future conditions) and vulnerability assessment for the land subsidence hazard in West Virginia.

Hazard Description

Land subsidence is a gradual settling or sudden sinking of the earth's surface due to removal and displacement of subsurface earth materials. Subsidence is one of the most diverse forms of ground failure, ranging from small or local collapses to broad regional lowering of the earth's surface. The principal causes are mostly due to human activities and include but are not limited to:

- Aquifer-system compaction associated with groundwater withdrawals
- Drainage of organic soils
- Fracking and underground mining
- Earthquakes and erosion
- Natural compaction or collapse
- Expansive soils
- Mining activities (USGS 2019)

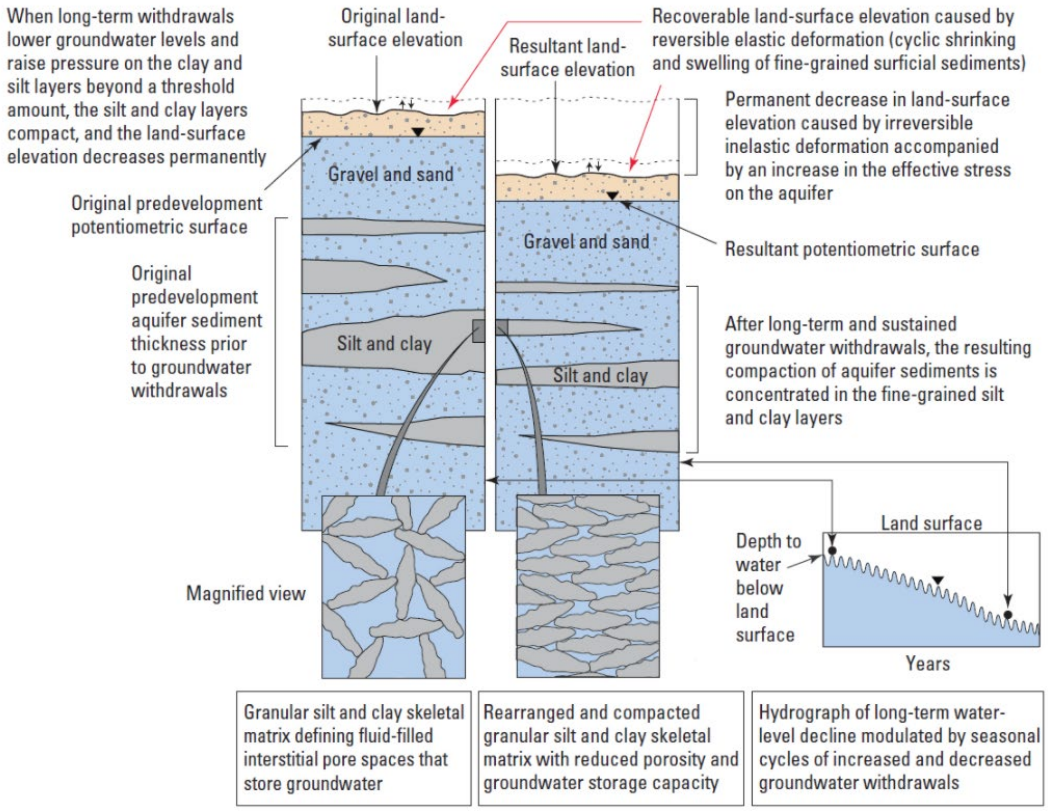
Consequences of land subsidence include:

- Reduces the ability to store water in an aquifer
- Partially or completely submerges land
- Collapses water well casings
- Disrupts collector drains and irrigation ditches
- Alters the flow of creeks and bayous, which may increase the frequency and severity of flooding
- Damages roadways, bridges, building foundations, and other infrastructure

Land subsidence occurs on karst terrain, which is generally underlain by limestone or dolomite, in which the topography is formed chiefly by the dissolving of rock which may be characterized by sinkholes, sinking streams, closed depressions, subterranean drainage, and caves (USGS 2018).

Figure 5.13-1 below illustrates the land subsidence process, wherein soil layers become compacted and unstable due to the loss of groundwater.

Figure 5.13-1. The Subsidence Process



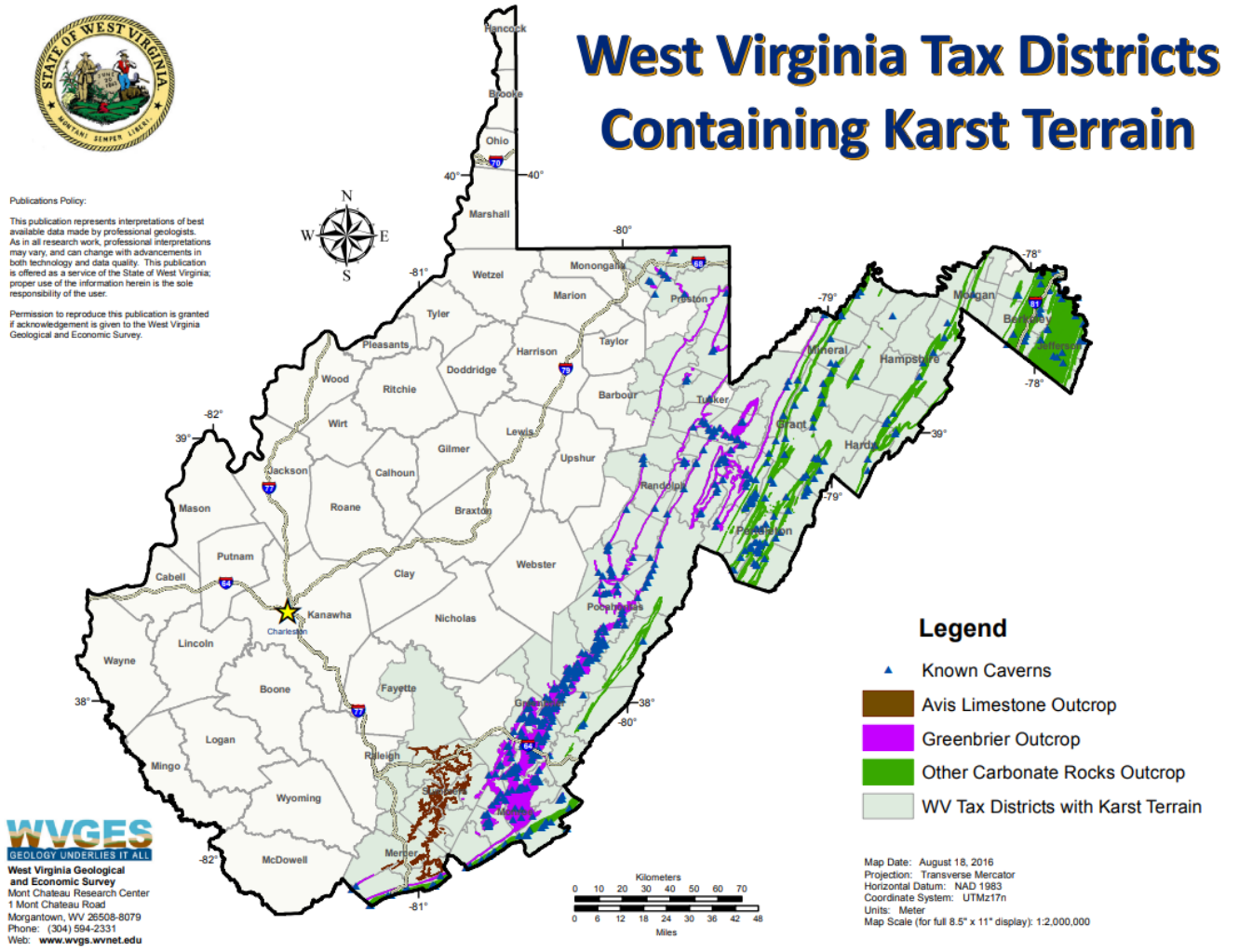
Source: USGS n.d.

LOCATION

The U.S. Geological Survey (USGS) notes that "subsidence is a global problem and, in the United States, more than 17,000 square miles in 45 states, an area roughly the size of New Hampshire and Vermont combined, have been directly affected by subsidence" (USGS 2018).

In West Virginia, karst topography exists primarily in the eastern counties. Land subsidence can also occur in developed areas as a result of subsurface erosion caused by leaking water lines or changes in groundwater flow caused by pumping associated with dewatering excavations, especially in karst areas (West Virginia Emergency Management Division 2018). Figure 5.13-2 illustrates karst terrain areas located throughout the state by tax district.

Figure 5.13-2. Karst Terrain Areas



Source: West Virginia Geological and Economic Survey (WVGES) 2016

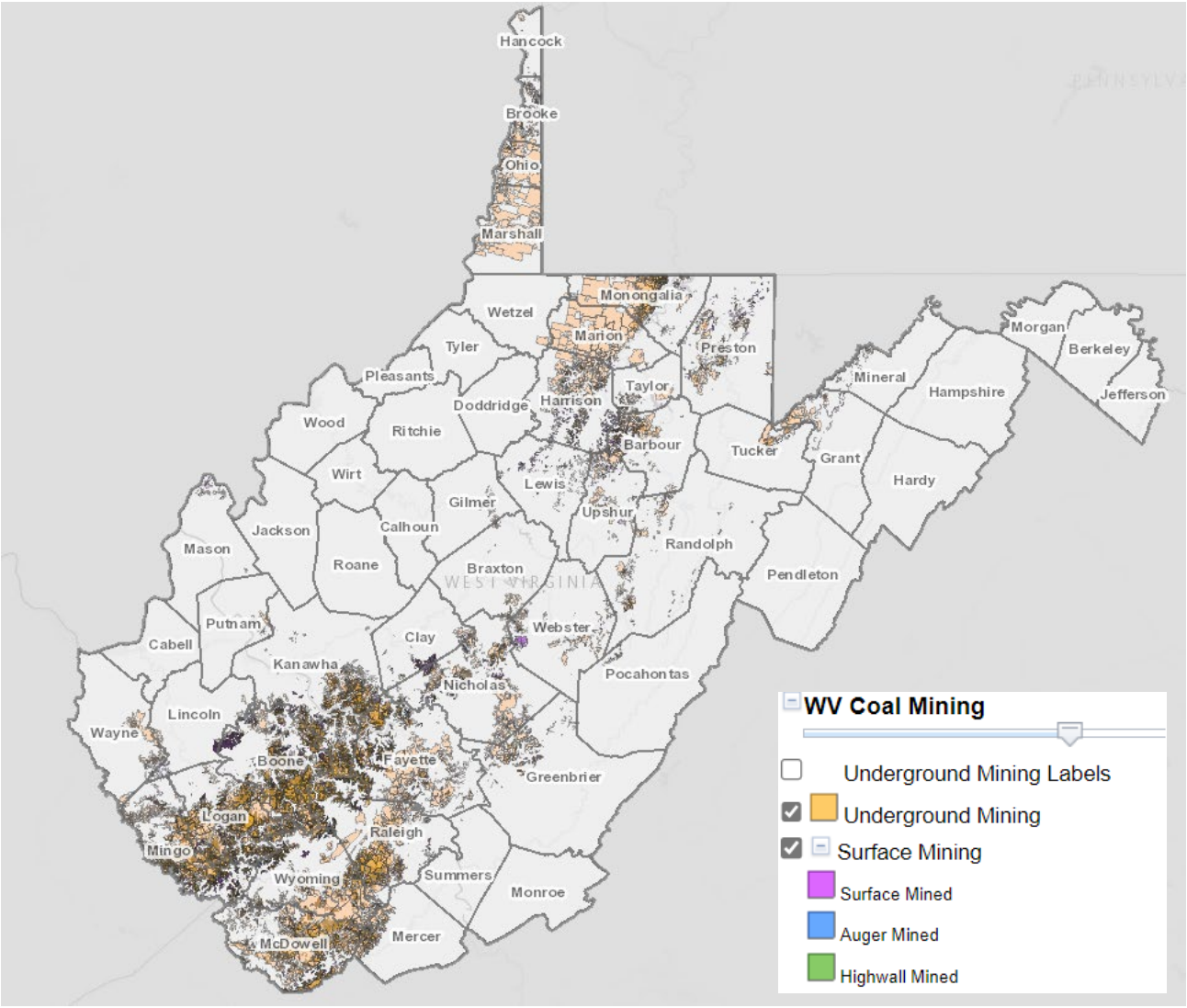
The principal karst-forming carbonate rocks in West Virginia are within the Mississippian Greenbrier Group; Devonian and Silurian Helderberg Group and Tonoloway Limestone; and Ordovician and Cambrian Black River Group, Saint Paul Group, Beekmantown Group, Conococheague Formation, Elbrook Formation, Tomstown Dolomite, and the Mississippian Avis Limestone (WVGES 2016).

Based on Figure 5.13-2, 17 of the state's 55 counties are susceptible to subsidence risk in karst areas:

- Barbour
- Berkeley
- Fayette
- Grant
- Greenbrier
- Hampshire
- Hardy
- Jefferson
- Mercer
- Mineral
- Monongalia
- Monroe
- Morgan
- Pendleton
- Pocahontas
- Preston
- Raleigh

As previously mentioned, subsidence events may also occur from mining activities, especially in areas where the cover of a mine is thin or in areas where bedrock is not necessarily conducive to their formation. Figure 5.13-3 below displays the underground and surface coal mines in the State.

Figure 5.13-3. Underground and Surface Coal Mines in West Virginia



Source: WVGES 2023

Based on Figure 5.13-3, 38 of the state's 55 counites are susceptible to mine subsidence:

- Barbour
- Boone
- Braxton
- Brooke
- Clay
- Harrison
- Kanawha
- Lewis
- Lincoln
- Logan
- Mineral
- Mingo
- Monongalia
- Nicholas
- Ohio
- Summers
- Taylor
- Tucker
- Upshur
- Wayne

- Fayette
- Gilmer
- Grant
- Greenbrier
- Hancock
- Marion
- Marshall
- Mason
- McDowell
- Mercer
- Preston
- Putnam
- Pocahontas
- Raleigh
- Randolph
- Webster
- Wetzel
- Wyoming

Table 5.13-1 details the number of acres and percentage of lands located in the subsidence karst hazard areas and subsidence abandoned mine hazard areas by county. 4.6 percent of West Virginia's total land is located in karst subsidence areas and 0.4 percent of land is located in mine subsidence areas. Jefferson County has the highest percentage (79.4 percent) of land in the karst subsidence area, followed by Berkeley County at 40.8 percent. Logan and McDowell Counties both have the largest percentage of land in mine subsidence areas at 2.4 percent.

Table 5.13-1: Total Acres of Land Area Located in the Subsidence Hazard Areas

County	Total Acres of Land Area	Total Acres of Land Area (Excluding Waterbodies) Located in the Subsidence Hazard Areas			
		Total Acres Located in the Subsidence Karst Hazard Area	Percent of Total	Total Acres Located in the Subsidence Abandoned Mine Lands hazard area	Percent of Total
Barbour	218,598	161	0.1%	572	0.3%
Berkeley	205,141	83,765	40.8%	0	0.0%
Boone	321,687	0	0.0%	2,791	0.9%
Braxton	328,023	0	0.0%	184	0.1%
Brooke	59,321	0	0.0%	1,202	2.0%
Cabell	184,109	0	0.0%	0	0.0%
Calhoun	179,487	0	0.0%	0	0.0%
Clay	219,951	0	0.0%	1,257	0.6%
Doddridge	205,051	0	0.0%	0	0.0%
Fayette	427,276	0	0.0%	4,775	1.1%
Gilmer	217,274	0	0.0%	383	0.2%
Grant	305,479	38,933	12.7%	226	0.1%
Greenbrier	654,360	98,135	15.0%	116	0.0%
Hampshire	412,248	29,843	7.2%	0	0.0%
Hancock	56,222	0	0.0%	2	0.0%
Hardy	373,689	37,139	9.9%	0	0.0%
Harrison	266,023	0	0.0%	2,808	1.1%
Jackson	300,968	0	0.0%	0	0.0%
Jefferson	134,920	107,101	79.4%	0	0.0%
Kanawha	582,312	0	0.0%	1,924	0.3%
Lewis	246,359	0	0.0%	257	0.1%
Lincoln	280,594	0	0.0%	432	0.2%
Logan	291,325	0	0.0%	6,946	2.4%
Marion	199,006	0	0.0%	1,712	0.9%
Marshall	199,304	0	0.0%	270	0.1%
Mason	284,059	0	0.0%	1,910	0.7%
McDowell	342,174	0	0.0%	8,180	2.4%
Mercer	268,828	14,596	5.4%	348	0.1%
Mineral	210,134	19,479	9.3%	51	0.0%
Mingo	270,756	0	0.0%	4,062	1.5%
Monongalia	232,200	1,434	0.6%	1,220	0.5%
Monroe	302,704	91,122	30.1%	0	0.0%

County	Total Acres of Land Area	Total Acres of Land Area (Excluding Waterbodies) Located in the Subsidence Hazard Areas			
		Total Acres Located in the Subsidence Karst Hazard Area	Percent of Total	Total Acres Located in the Subsidence Abandoned Mine Lands hazard area	Percent of Total
Morgan	146,880	6,573	4.5%	0	0.0%
Nicholas	415,482	0	0.0%	585	0.1%
Ohio	69,666	0	0.0%	159	0.2%
Pendleton	446,485	76,296	17.1%	0	0.0%
Pleasants	85,837	0	0.0%	0	0.0%
Pocahontas	601,520	54,664	9.1%	0	0.0%
Preston	415,612	8,342	2.0%	1,612	0.4%
Putnam	223,706	0	0.0%	2,164	1.0%
Raleigh	388,484	0	0.0%	2,365	0.6%
Randolph	664,970	26,872	4.0%	413	0.1%
Ritchie	290,396	0	0.0%	0	0.0%
Roane	309,410	0	0.0%	0	0.0%
Summers	233,898	1,566	0.7%	21	0.0%
Taylor	110,892	0	0.0%	307	0.3%
Tucker	265,897	18,470	6.9%	378	0.1%
Tyler	166,857	0	0.0%	0	0.0%
Upshur	226,613	0	0.0%	452	0.2%
Wayne	325,702	0	0.0%	833	0.3%
Webster	355,637	84	0.0%	292	0.1%
Wetzel	231,289	0	0.0%	2	0.0%
Wirt	150,356	0	0.0%	0	0.0%
Wood	241,020	0	0.0%	0	0.0%
Wyoming	320,602	0	0.0%	3,126	1.0%
Total	**15,466,796**	**714,575**	**4.6%**	**54,337**	**0.4%**

Source: WVDEP 1996; USGS 2022; West Virginia GIS Technical Center (WVU GISTC) 2022

EXTENT

Human activity can often be the cause of a subsidence area. Leaking water pipes or structures that convey stormwater runoff may also result in areas of subsidence as the water dissolves substantial amounts of rock over time. In some cases, construction, land grading, or earth-moving activities that cause changes in stormwater flow can trigger subsidence events. Subsidence events may occur during mining activities, especially in areas where the cover of a mine is thin or in areas where bedrock is not necessarily conducive to their formation. Subsurface (i.e., underground) extraction of materials such as oil, gas, coal, metal ores (i.e., copper, iron, and zinc), clay, shale, limestone, or water may result in slow-moving or abrupt shifts in the ground surface (Whittaker and Reddish 1989).

The occurrence of subsidence is not as obvious as other geologic hazards. The detection of subsidence is gradual and is typically from the identified movement of key benchmarks or landmarks, such as a statue or tree appearing to have moved or sunk into the ground. Scientists will use radar images from Earth-orbiting satellites to monitor subsidence by mapping the land-surface deformation. This tool is called InSAR or interferometric synthetic aperture radar. Once subsidence is identified and mapped, assessments of the InSAR data can be done to improve our understanding of the subsidence processes (USGS 2019).

Warning Time

Signs that subsidence is occurring include slumping or falling fence posts, trees, or foundations; sudden formation of small ponds; wilting vegetation; discolored well water; and/or structural cracks in walls and floors. These signs tend to appear over time, and may not be noticed. The ground giving way due to the collapse of the roof of a sinkhole or underground mine shaft may occur suddenly without any warning.

Previous Occurrences and Losses

Federal Emergency Management Agency (FEMA) Disaster Declarations

Between 1954 and 2022, the State was not included in any disaster (DR) or emergency (EM) declarations for land subsidence-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).

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

The Secretary of Agriculture from the 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, the State was not included in any land subsidence-related agricultural disaster declarations (USDA 2023).

Previous Events

For the 2023 SHMP update, known land subsidence events that impacted the State between 2018 and 2022 were researched. While numerous sources, including 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 were researched during this plan update, information regarding occurrences and losses associated with land subsidence hazard events in the state was limited.

For events prior to 2018, refer to the 2018 SHMP.

Probability of Future Hazard Events

Overall Probability

Although subsidence events will continue to be a possibility in West Virginia, the probability of an occurrence is difficult to predict due to the low number of recorded previous events. Future development and mining activities in the state can lead to a higher probability of subsidence occurring in the hazard area.

Projected Future Conditions

Periods of drought and flooding are likely to increase in frequently in severity. Impacts from drought and flood events may exacerbate the likelihood of a subsidence event due to soil expansion and contraction. As drought levels increase, the need to pump water from aquifers also increases, which increase the likelihood of subsidence (Shirzaei and Bürgmann 2018).

5.13.2 Vulnerability Assessment

A statewide assessment was conducted based on areas underlain by karst geology and areas of abandoned mines, with data provided by West Virginia Department of Environmental Protection, U.S. Geological Survey, and West Virginia GIS Technical Center (WVU GISTC). For this plan, subsidence hazard areas are identified as karst areas and areas of abandoned mines.

State Assets

Table 5.13-2 and Table 5.13-3 summarize the number and replacement cost value of state assets located in the subsidence karst hazard area. Table 5.13-2 reflects only the counties with state facilities. All other counties not shown in the table do not have state facilities within the subsidence karst hazard area. Table 5.13-3 reflects only the agencies with structures located in the subsidence karst hazard area.

The spatial analysis for the subsidence hazard determined there are 95 state facilities located in the subsidence karst hazard area with the greatest number of state buildings located in Berkeley County (37 buildings) while Jefferson County has the highest replacement cost value ($279 million). Out of all State agencies, the Division of Natural Resources – Parks, Department of Health and Human Resources, and Department of Military Affairs and Public Safety – State Police have the most facilities (9 each) located in the subsidence karst hazard area, while Shepherd University has the highest replacement cost value ($273.6 million).

Table 5.13-2. State Facilities Located in the Subsidence Karst Hazard Area by County

State Facilities Located Within the Subsidence Karst Hazard Area		Replacement Cost Value for State Facilities Within the Subsidence Karst Hazard Area by County		
County	Number of Structures	Replacement Cost Value (Structure Only)	Replacement Cost Value (Contents Only)	Total Replacement Cost Value (Structure & Contents)
Berkeley	37	$46,485,286	$14,542,092	$61,027,378
Greenbrier	23	$74,124,458	$15,055,143	$89,179,601
Jefferson	13	$250,331,187	$28,709,213	$279,040,400
Mercer	2	$0	$130,400	$130,400
Monroe	6	$944,818	$519,027	$1,463,845
Morgan	7	$73,264,366	$11,120,000	$84,384,366
Pendleton	1	$0	$125,000	$125,000
Pocahontas	1	$0	$25,000	$25,000
Preston	1	$760,000	$40,000	$800,000
Tucker	1	$0	$0	$0
Webster	3	$0	$275,000	$275,000
Total	95	$445,910,115	$70,540,875	$516,450,990

Source: WVEMD; WV Geological and Economic Survey 1968

Table 5.13-3: State Facilities Located in the Subsidence Karst Hazard Area by Agency

State Facilities Located Within the Subsidence Karst Hazard Area		Replacement Cost Value for State Facilities Within the Subsidence Karst Hazard Area by Agency		
Agency	Number of Structures	Replacement Cost Value (Structure Only)	Replacement Cost Value (Contents Only)	Total Replacement Cost Value (Structure & Contents)
Armory Board State of West Virginia	5	$7,848,637	$3,017,500	$10,866,137

State Facilities Located Within the Subsidence Karst Hazard Area		Replacement Cost Value for State Facilities Within the Subsidence Karst Hazard Area by Agency		
Agency	Number of Structures	Replacement Cost Value (Structure Only)	Replacement Cost Value (Contents Only)	Total Replacement Cost Value (Structure & Contents)
Attorney General, Office of The State of West Virginia	1	$0	$40,000	$40,000
Blue Ridge Community & Technical College	3	$17,395,660	$8,206,792	$25,602,452
Conservation Agency, West Virginia State of West Virginia	3	$0	$184,645	$184,645
Corrections, Division of State of West Virginia	3	$12,065,260	$1,052,500	$13,117,760
Department of Transportation	1	$0	$0	$0
Eastern Panhandle Instructional COOP	8	$800,000	$1,655,000	$2,455,000
Education, Department of State of West Virginia	4	$5,403,548	$1,006,500	$6,410,048
Environmental Protection, Division of State of West Virginia	1	$14,000	$23,000	$37,000
Forestry, Division of State of West Virginia	1	$15,000	$8,000	$23,000
Health & Human Resources, Department of State of West Virginia	9	$7,571,000	$2,245,000	$9,816,000
Highways, Division of State of West Virginia	5	$1,510,500	$325,000	$1,835,500
Insurance Commissioner, Office of The State of West Virginia	1	$0	$20,000	$20,000
Juvenile Services, Division of	3	$0	$180,000	$180,000
Motor Vehicles, Division of State of West Virginia	4	$0	$645,000	$645,000
New River Community & Technical College	1	$1,058,000	$530,000	$1,588,000
Osteopathic Medicine, WV Board of State of West Virginia	2	$66,788,139	$8,193,198	$74,981,337
Parks, West Virginia State C\O Division of Natural Resources	9	$73,556,281	$11,199,600	$84,755,881
Rehabilitation Services Division of Commerce	2	$0	$773,100	$773,100
Shepherd University	1	$246,443,250	$27,131,195	$273,574,445
State Police, West Virginia Dept of Military Affairs & Public Safety	9	$1,400,000	$550,000	$1,950,000
Supreme Court of Appeals State of West Virginia	7	$0	$461,100	$461,100
Tax Department State of West Virginia	1	$0	$100,000	$100,000
Unknown	4	$0	$0	$0
Veterans Assistance, Department of State of West Virginia	2	$0	$18,000	$18,000
West Virginia University Kearneysville	1	$3,587,937	$539,318	$4,127,255
West Virginia University Union	1	$452,903	$53,427	$506,330
Workforce West Virginia	2	$0	$133,000	$133,000
WVsom Clinic Inc Dba Robert C Byrd Clinic	1	$0	$2,250,000	$2,250,000
Total (WV State)	95	$445,910,115	$70,540,875	$516,450,990

Source WVEMD; WV Geological and Economic Survey 1968

Table 5.13-4 and Table 5.13-5 summarize the number and replacement cost value of state assets located in the abandoned mind lands hazard area. Table 5.13-4 reflects only the counties with state facilities; all other counties not shown in the table do not have state facilities within the abandoned mind lands hazard area. Table 5.13-5 reflects only the agencies with structures located in abandoned mind lands hazard areas.

The spatial analysis for the subsidence hazard determined there are 10 state facilities located in the abandoned mine lands hazard area with the greatest number of state buildings located in Marion County (5 buildings with a

replacement cost value of $2.5 million). Out of the state agencies, the Department of Health and Human Resources has the most facilities (3) located in the abandoned mine lands hazard area with a replacement cost value of approximately $2.5 million).

Table 5.13-4: State Facilities Located in the Abandoned Mine Lands Hazard Area by County

State Facilities Located Within the Abandoned Mine Lands Hazard Area		Replacement Cost Value for State Facilities Within the Abandoned Mine Lands Hazard Area by County		
County	Number of Structures	Replacement Cost Value (Structure Only)	Replacement Cost Value (Contents Only)	Total Replacement Cost Value (Structure & Contents)
Barbour	1	$0	$255,000	$255,000
Clay	2	$0	$243,100	$243,100
Marion	5	$2,055,000	$460,000	$2,515,000
Ohio	1	$680,000	$10,000	$690,000
Tucker	1	$129,600	$4,300	$133,900
Total	10	$2,864,600	$972,400	$3,837,000

Source: WVEMD; WVDEP 1996

Table 5.13-5: State Facilities Located in the Abandoned Mine Lands Hazard Area by Agency

State Facilities Located Within the Abandoned Mine Lands Hazard Area		Replacement Cost Value for State Facilities Within the Abandoned Mine Lands Hazard Area by County		
Agency	Number of Structures	Replacement Cost Value (Structure Only)	Replacement Cost Value (Contents Only)	Total Replacement Cost Value (Structure & Contents)
Education, Department of State of West Virginia	2	$0	$20,000	$20,000
Health & Human Resources, Department of State of West Virginia	3	$680,000	$475,000	$1,155,000
Highways, Division of State of West Virginia	2	$2,055,000	$440,000	$2,495,000
Parks, West Virginia State C\O Division of Natural Resources	1	$129,600	$4,300	$133,900
State Police, West Virginia Dept of Military Affairs & Public Safety	1	$0	$0	$0
Supreme Court of Appeals State of West Virginia	1	$0	$33,100	$33,100
Total (WV State)	10	$2,864,600	$972,400	$3,837,000

Source: WVEMD; WVDEP 1996

Critical Facilities and Community Lifelines

Transportation routes are vulnerable to subsidence and have the potential to be inaccessible, creating isolation issues. Those that are in poor condition are the most vulnerable; however, roads and bridges in good condition could fault as well. Utility infrastructure is also vulnerable; the interruption of services may impact vulnerable populations and facilities that need to be in operation during a disaster. Full functionality of critical facilities such as police, fire, and medical services is essential for response during and after a subsidence event.

Critical facilities are crucial to continuity of operations statewide and are sorted into lifeline categories. Table 5.13-6 summarizes the critical facilities located in the subsidence karst hazard area and reflects only the counties with state facilities. All other counties not shown in the table do not have state facilities within the subsidence karst hazard area. There are no critical facilities located in the abandoned mind lands hazard area.

Table 5.13-6: Critical Facilities Located in the Subsidence Karst Hazard Area by County

County	Communications	Energy	Food, Water, Shelter	Hazardous Material	Health & Medical	Safety & Security	Transportation	Total
Berkeley	0	0	0	0	0	3	0	3
Greenbrier	0	0	0	0	0	2	0	2
Jefferson	0	0	1	0	0	1	0	2
Pendleton	0	0	0	0	0	1	0	1
Webster	0	0	0	0	1	0	0	1
Total	**0**	**0**	**1**	**0**	**1**	**7**	**0**	**9**

Source: WV Emergency Management Division; WV Geological and Economic Survey 1968

POPULATION

Subsidence has the potential to impact human health and life of residents and responders, structures, infrastructure, and natural resources. Based on the analysis, an estimated 131,102 West Virginian residents are located in the subsidence karst hazard area, and 22.9 percent are highly vulnerable. Berkely County accounts for nearly half of the population, with 57,798 people being located within the karst hazard area. In addition, an estimated 15,528 West Virginian residents are located in the abandoned mine hazard area, with 40.3 percent being highly vulnerable. Marion County has nearly a third of the population, with 5,131 people being located within the abandoned mine hazard area. Table 5.13-7 and Table 5.13-8 list the estimated total population and highly vulnerable population living in both karst and abandoned mine subsidence hazard, respectively; only counties with populations in the two hazards areas are shown.

Table 5.13-7: Population Located in the Subsidence Karst Hazard Area by County

County	Total Population Located in the Subsidence Karst Hazard Area	Highly Vulnerable Population Located in the Subsidence Karst Hazard Area	% Population Highly Vulnerable Located in the Subsidence Karst Hazard Area
Barbour	7	0	0.0%
Berkeley	57,798	17,110	29.6%
Grant	1,475	673	45.7%
Greenbrier	7,886	3,348	42.5%
Hampshire	1,775	446	25.1%
Jefferson	45,663	2,389	5.2%
Mercer	6,556	5,649	86.2%
Mineral	2,281	4	0.2%
Monongalia	76	0	0.0%
Monroe	2,861	0	0.0%
Morgan	953	0	0.0%
Pendleton	1,209	0	0.0%
Pocahontas	1,023	0	0.0%
Preston	307	45	14.5%
Randolph	599	304	50.7%
Summers	55	55	100.0%
Tucker	563	0	0.0%
Webster	15	0	0.0%
Total	**131,102**	**30,024**	**22.9%**

Source: Centers for Disease Control and Prevention (CDC) 2020; WV Geologic and Economic Survey 1968

Table 5.13-8: Population Located in the Subsidence Abandoned Mine Lands Hazard Area by County

County	Total Population Located in the Subsidence Abandoned Mine Lands Hazard Area	Highly Vulnerable Population Located in the Subsidence Abandoned Mine Lands Hazard Area	% Population Highly Vulnerable Located in the Subsidence Abandoned Mine Lands Hazard Area
Barbour	74	23	30.7%
Boone	205	15	7.5%
Braxton	14	0	0.0%
Brooke	239	0	0.0%
Clay	24	21	86.9%
Doddridge	0	0	0.0%
Fayette	754	444	58.9%
Gilmer	39	0	0.5%
Grant	5	0	0.0%
Greenbrier	6	1	23.5%
Harrison	2,538	928	36.6%
Kanawha	351	141	40.2%
Lewis	61	1	2.2%
Lincoln	46	0	0.0%
Logan	1,075	908	84.4%
Marion	5,131	1,414	27.6%
Marshall	435	356	81.8%
Mason	243	0	0.0%
McDowell	754	611	81.0%
Mercer	16	2	13.1%
Mineral	7	7	100.0%
Mingo	753	683	90.7%
Monongalia	523	0	0.0%
Nicholas	8	0	0.0%
Ohio	216	58	26.8%
Preston	185	0	0.0%
Putnam	711	0	0.0%
Raleigh	859	624	72.6%
Randolph	21	0	0.4%
Taylor	7	7	100.0%
Tucker	2	0	0.0%
Upshur	92	0	0.0%
Wayne	76	0	0.0%
Webster	5	0	0.0%
Wyoming	53	8	14.4%
Total	**15,528**	**6,253**	**40.3%**

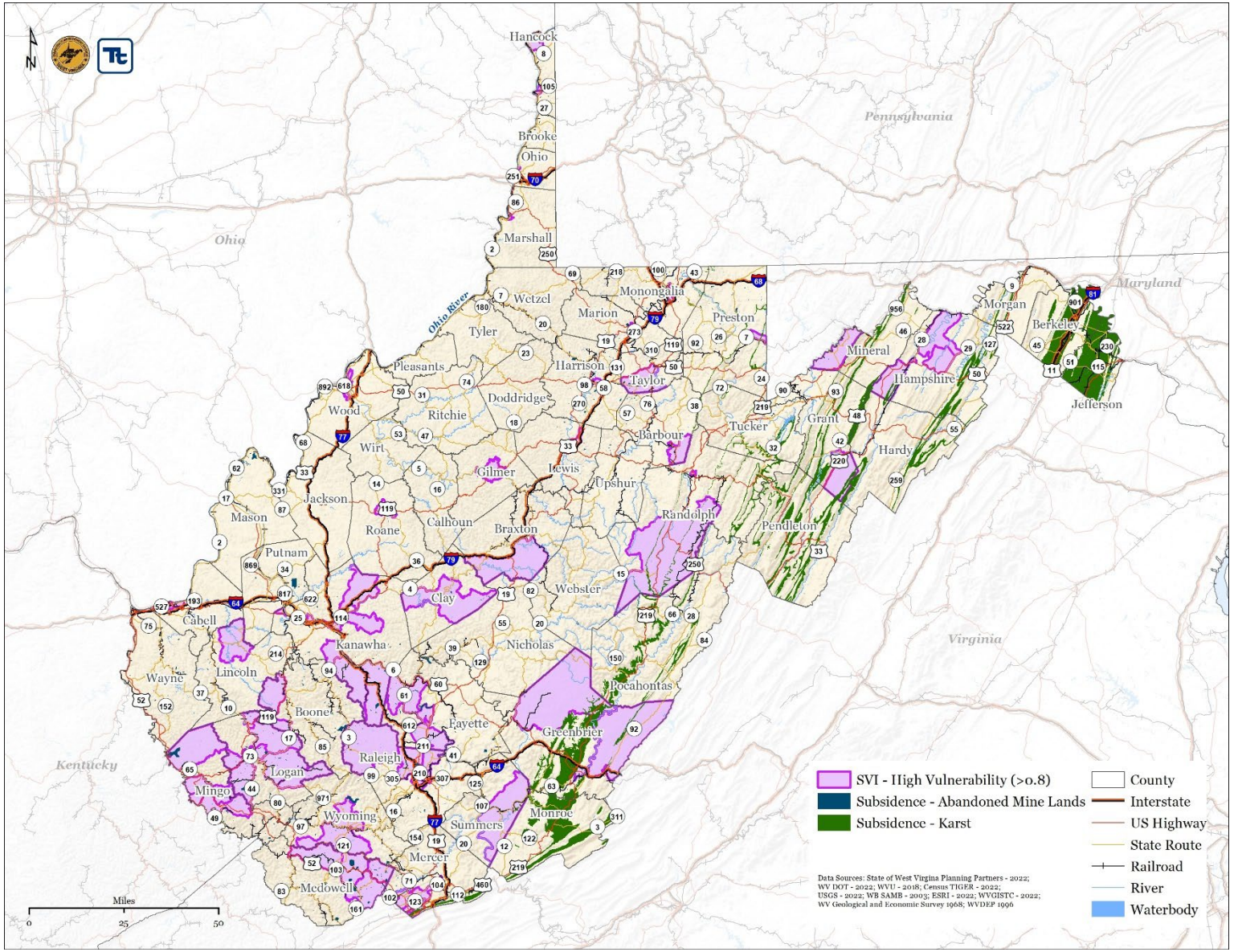
Source CDC 2020; WVDEP 1996

Impacts on Socially Vulnerable Populations

The risk assessment for subsidence found that 22.9 percent of people in the karst subsidence hazard areas are identified as being in the highly vulnerable population (30,024), and 40.3 percent of people in the subsidence abandoned mine hazard areas are identified as being in the highly vulnerable population (6,253) (refer to Table 5.13-7 and Table 5.13-8, respectively). Figure 5.13-4 depicts the social vulnerability index overlayed with the hazard areas.

A subsidence event would be an isolated incidence and impact the populations within the immediate area of the incident. Socially vulnerable populations in those areas who are economically disadvantaged may face the brunt of the impacts as subsidence can damage or destroy structures and property.

Figure 5.13-4. Social Vulnerability Index for Subsidence



Future Changes That May Impact State Vulnerability

Understanding future changes that 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 to examine potential conditions that may affect hazard vulnerability:

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

Potential or Projected Development

It is anticipated that any new development in the subsidence hazard areas will be exposed to the hazard. Table 5.13-1 identifies that 768,914 acres of land are located within the total subsidence hazard area. Further development in the hazard area would expose the population and structures to the subsidence hazard.

Chapter 33, Article 30, Section 6 of the State of West Virginia Code identifies that every insurance policy issued or renewed must include, at a separately stated premium, insurance for loss occurring on or after October 1, 1982, caused by mine subsidence unless waived by the insured. However, in the counties listed below, the coverage may only be provided if it is requested by the insured (State of West Virginia 2022).

- Berkeley
- Cabell
- Calhoun
- Hampshire
- Hardy
- Jackson
- Jefferson
- Monroe
- Morgan
- Pendleton
- Pleasants
- Ritchie
- Roane
- Wirt
- Wood

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 West Virginia University (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 (State Profile), which includes a discussion on population trends for the state.

Increased abandoned mines and potential subsidence areas that are more vulnerable to the elements are more likely to experience subsidence events. However, as population in the state continues to decrease, there is the potential that fewer people will reside or work within the state's land subsidence hazard areas.

Other Factors of Change

Impacts from drought and flood events may exacerbate the likelihood of a subsidence event due to soil expansion and contraction. As drought levels increase, the need to pump water from aquifers also increases, which increases the likelihood of subsidence (Shirzaei and Bürgmann 2018).

Projections may alter the stability of land in the subsidence hazards areas. Karst soils are easily erodible by rains as the water seeps into the rock, which can alter the landscape (National Geographic 2022). Eroded landscapes can lead to unstable ground above, making the area at increased risk. The alteration of these landscapes should be factored into future land use regulations to avoid an increased risk to population and property.

More frequent and intense rain and storms can increase chemical leaching from degraded lands and increase the risk of mine blowouts and landslides, which can be devastating and deadly for people and wildlife. Reclaiming these abandoned mines could produce an increase in jobs and revenue in the state; the RECLAIM (Revitalizing the Economy of Coal Communities by Leveraging Local Activities and Investing More) Act has been introduced on the federal level and encourages reclamation of abandoned mine lands for recreation, community development, and wildlife habitat, all while creating good jobs (NWF 2021). Performing these actions could improve and address environmental, health, and economic issues.

5.13.3 Consequence Analysis

Impacts to the Public

Subsidence events caused by karst terrain or abandoned mines are isolated and impact the population within the immediate area. In some cases, subsidence can damage or destroy homes, which forces the homeowners or renters to find temporary or permanent shelters. 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. Subsidence may also affect the amount of water in which an aquifer can hold, which would adversely affect those dependent on the aquifer for potable water (USGS 2019).

An analysis performed on the population of the State revealed that an estimated 131,102 West Virginian residents are located in the subsidence karst hazard area, and 22.9 percent are highly vulnerable. In addition, an estimated 15,525 West Virginian residents are located in the abandoned mine hazard area, with 40.3 percent being highly vulnerable. Please reference Table 5.13-7 and Table 5.13-8 for more information regarding populations in the subsidence hazard areas.

Impacts to Responders

Significant subsidence events may hinder the delivery of emergency services. Subsidence can cause delays or impair rail transportation, halt supply chains, and disrupt medical and emergency services that provide lifesaving support. Intense subsidence 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 subsidence. Unstable ground may cause the structure to collapse, as subsidence has been known to cause the support and stability of a structure’s foundation to collapse or sink.

Impacts to Continuity of Operations

Subsidence 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, airports and roadways may be impacted for an undetermined amount of time, stopping the flow of supplies and disrupting emergency and medical services.

Impacts to Property, Facilities, and Infrastructure

Roads provide a vital transportation link between populated areas through West Virginia. Subsidence incidents can result in damages to roadways and road closures, leading to traffic congestion, longer commuting times, and prevention of emergency personnel from responding to incidents. More specifically, the state's network of roadways provide access to local and federal roadways. The state roadways located in hazard areas are more susceptible to damages and closures. West Virginia has over 215 miles of state roads that run through karst terrain and over 49 miles of state roads running through abandoned mining areas. Jefferson County has the greatest number of road miles (65.87 miles) exposed in the subsidence karst hazard area and McDowell County has the greatest number of road miles (12.82 miles) exposed in the subsidence abandoned mine lands hazard area. Table 5.13-9 displays the state roads in both karst and abandoned mine subsidence hazard areas; only counties with populations in the two hazard areas are shown.

Table 5.13-9: State Roads Located Within the Subsidence Karst and Abandoned Mine Lands Hazard Areas by County

County	State Roads Located Within the Subsidence Karst Hazard Area	State Roads Located Within the Subsidence Abandoned Mine Lands hazard area
	Mileage of Roadway	Mileage of Roadway
Barbour	0.00	0.12
Berkeley	33.58	0.00
Boone	0.00	1.42
Brooke	0.00	0.28
Clay	0.00	9.11
Fayette	0.00	1.71
Gilmer	0.00	0.49
Grant	7.17	0.48
Greenbrier	18.12	0.91
Hampshire	4.49	0.00
Hardy	0.49	0.00
Harrison	0.00	0.47
Jefferson	65.87	0.00
Kanawha	0.00	0.08
Lincoln	0.00	0.95
Logan	0.00	7.17
Marion	0.00	0.67
Marshall	0.00	0.55
Mason	0.00	2.14
McDowell	0.00	12.82
Mercer	6.56	0.09
Mineral	8.80	0.00

County	State Roads Located Within the Subsidence Karst Hazard Area Mileage of Roadway	State Roads Located Within the Subsidence Abandoned Mine Lands hazard area Mileage of Roadway
Mingo	0.00	0.82
Monongalia	3.41	0.51
Monroe	37.41	0.00
Morgan	0.55	0.00
Nicholas	0.00	2.71
Ohio	0.00	0.54
Pendleton	5.11	0.00
Pocahontas	6.88	0.00
Preston	1.01	1.08
Raleigh	0.00	0.87
Randolph	2.12	0.00
Summers	3.64	0.00
Taylor	0.00	0.02
Tucker	9.97	0.25
Upshur	0.00	0.41
Wayne	0.00	0.18
Webster	0.29	0.00
Wyoming	0.00	3.01
Total	**215.47**	**49.86**

Source: WVDEP 1996; WVDOT – 2021

Impacts to the Environment

As displayed in Table 5.13-1, there are just under 769,000 acres of land within the subsidence hazard areas in West Virginia. 54,338 acres of the subsidence area are located above or near abandoned mines. Subsidence caused by abandoned mines poses threats to water quality and wildlife. Nearby bodies of water can experience loss of riparian habitat, biodiversity, and groundwater contamination. Wildlife suffer losses by being forced out of their habitat and losing a safe source of drinking water (NWF 2021). 714,576 acres of the subsidence area is located on karst soils. Karst landscapes may feature caves, underground streams, and sinkholes on the surface. One primary concern with karst is that due to its geologic makeup, the porous nature of the rock allows water to flow through it without much filtration, which could allow contaminants to enter a karst aquifer and cause water quality problems (NPS 2022).

Impacts to the Economic Condition of the State

Subsidence events 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 cleanup costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity, are difficult to measure. Despite only having 104 state facilities located throughout West Virginia, the total replacement value for these structures and the contents within them is over $177 million (refer to Table 5.13-2 through Table 5.13-5). While subsidence can cause significant damage to state assets, there are no standard formulas for estimating associated losses.

Impacts to Public Confidence in State Governance

The public confidence in state governance primarily depends on how effective the State has been in the past at preparing for and responding to subsidence events. 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, proves that it has the capability to support the residents of West Virginia if subsidence events occur, and demonstrates its reliability to the public through availability of programs and services relevant to subsidence, then the public will remain confident in the State's governance (Chew, et al. 2021).

The State has governmental offices dedicated to abandoned mine lands and the reclamation of those lands. The Office of Abandoned Mine Lands and Reclamation oversees and facilitates the resolving of public safety issues as mine fires and subsidence, hazardous highwalls, mining-impacted water supplies, open shafts and portals, and other dangers resulting from mining before 1977. This office oversees the Abandoned Mine Lands Economic Revitalization (AMLER) Program, which administers federal funding for economic development projects on abandoned mine lands (WVDEP 2023).