Table 4.3.8-4 Estimated agricultural jurisdictional losses due to Invasive Species.		
COUNTY	**TOTAL ACRES IN FARMS**	**MARKET VALUE OF ALL AGRICULTURAL PRODUCTS ($)**
Berks	222,119	$367,840,000
Chester	166,891	$553,290,000
Franklin	242,634	$304,450,000
Lancaster	425336	$1,072,151,000
Lebanon	113,486	$257,097,000
TOTAL	***1,170,466***	***$2,554,828,000***

4.3.8.9. State Facility Loss Estimation

The state critical facilities most vulnerable to invasive species threats are privately held organizations; as a result, replacement value estimates are not available. Looking more broadly, the Pennsylvania Wilds Initiative, a consortium of thirteen counties in north-central Pennsylvania with significant forest resources, recently indicated that their 2 million acres of public natural landscape represent a $126 million dollar state investment (PA Wilds, 2010). An aggressive invasive species threat to these or other state-owned lands could result in significant economic loss. Additionally, the total value of Pennsylvania's agricultural products is nearly $6 billion; an invasive species that affects agricultural products and production can cause significant losses to the Commonwealth's economy.

Aside from losses to state facilities, combatting invasive species is an expensive task. DCNR states in its Invasive Species Management Plan that in 2011, they spent $220,000 on suppressing the Hemlock Woolly Adelgid alone; other forest pest surveys cost $500,000 per year, and the gypsy moth suppression program ranges from $500,000 to $10 million annually. These programs could cause an undue burden on budgets should invasive species grow.

4.3.9. Landslide

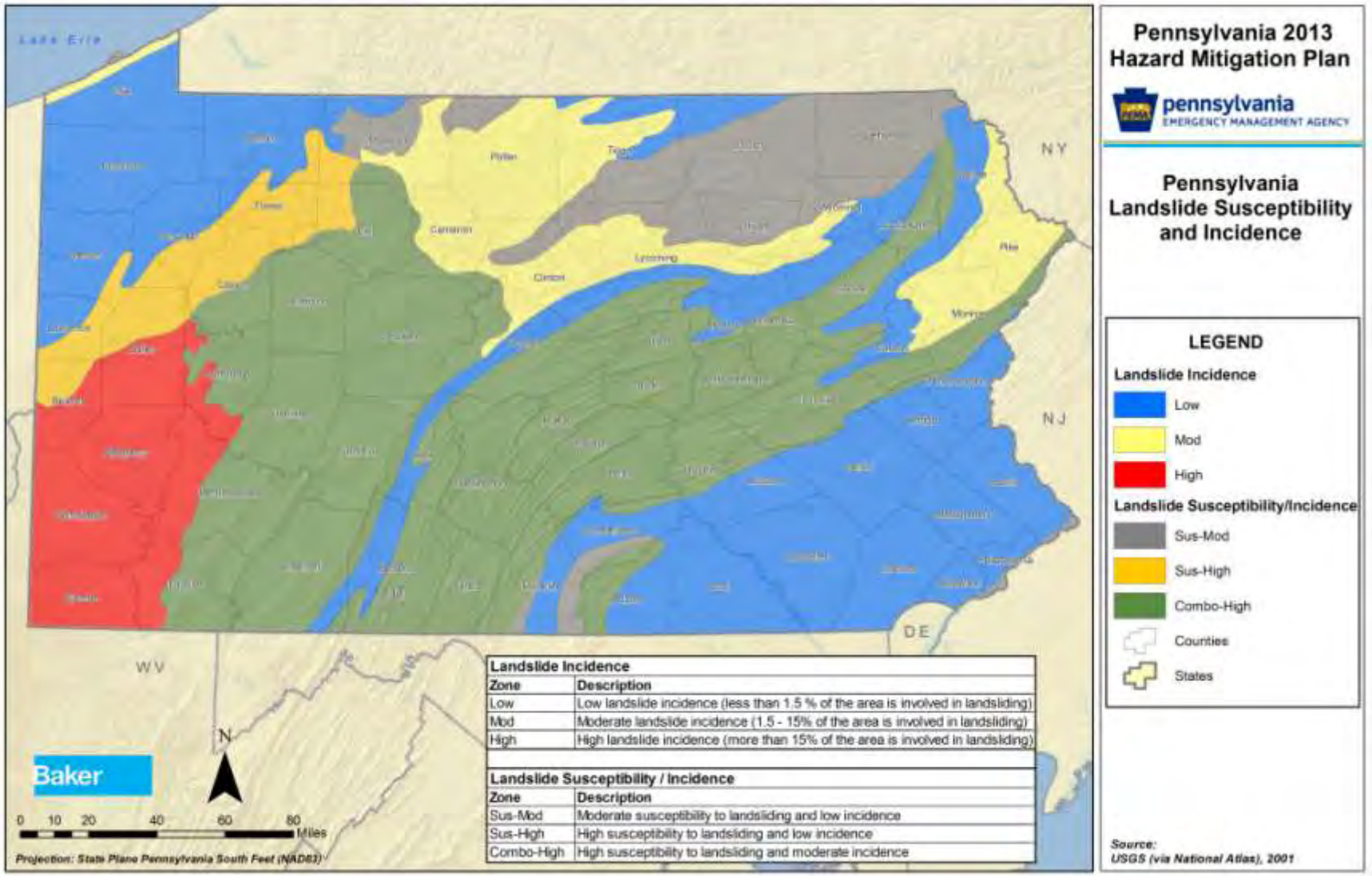
4.3.9.1. Location and Extent

Rockfalls and other slope failures occur in areas of Pennsylvania with moderate to steep slopes. Many slope failures are associated with precipitation events – periods of sustained above-average precipitation, specific rainstorms, or snowmelt events. Areas experiencing erosion, decline in vegetation cover and earthquakes are also susceptible to landslides. Landslides can also occur on manmade slopes such as along highways or through development that contributes to slope failure by altering the natural slope gradient, increasing soil water content or removing vegetation cover. Figure 4.3.9-1 shows the range of landslide susceptibility and incidence for Pennsylvania indicating which areas are most likely to experience landslide events.

Landslides have occurred in many parts of Pennsylvania, but are most abundant and most troublesome in much of the Appalachian Plateaus physiographic province of western and north-central Pennsylvania. This region is recognized as one of the major areas of landslide susceptibility and severity in the United States (Baker and Chieruzzi, 1959; Radbruch-Hall et al.,

1982). The Monongahela River Valley of northern West Virginia and southwestern Pennsylvania has a special place in landslide folklore. The name “Monongahela” is derived from an American Indian word that is translated as “river with the sliding banks” or “high banks which break off and fall down” (Espenshade, 1925). The Monongahela Valley and Pittsburgh in southwestern Pennsylvania is the most slide-prone portion of the Commonwealth.

Figure 4.3.9-1 Map showing landslide susceptibility and incidence areas across Pennsylvania.



Landslide Incidence	
Zone	**Description**
Low	Low landslide incidence (less than 1.5 % of the area is involved in landsliding)
Mod	Moderate landslide incidence (1.5 - 15% of the area is involved in landsliding)
High	High landslide incidence (more than 15% of the area is involved in landsliding)

Landslide Susceptibility / Incidence	
Zone	**Description**
Sus-Mod	Moderate susceptibility to landsliding and low incidence
Sus-High	High susceptibility to landsliding and low incidence
Combo-High	High susceptibility to landsliding and moderate incidence

4.3.9.2. Range of Magnitude

Landslides cause damage to transportation routes, utilities and buildings (Figure 4.3.9-2). They can also create travel delays and other side effects. Fortunately, deaths and injuries due to landslides are rare in Pennsylvania. Almost all of the known deaths due to landslides have occurred when rockfalls or other slides along highways have involved vehicles. Storm-induced debris flows are the only other type of landslide likely to cause death and injuries. As residential and recreational development increases on and near steep mountain slopes, the hazard from these rapid events will also increase. In addition, landslides can potentially have disastrous flood effects when they descend into water bodies, diverting or entirely blocking water flows.

Figure 4.3.9-2 Photos showing damage to a private home (left) and PA Route 51 (right) due to landslide incidents.

(Photograph by *V.W.H. Campbell, Jr., Pittsburgh Post-Gazette. February 1983*)

The effect of landslides on the human population in Pennsylvania is substantial. However, cost data for historical landslide damages is sparse. Landslide damage estimates for Allegheny County (Pittsburgh and suburbs) from 1970-1976 estimate that annual costs ranged from $1.3 to 4.0 million over this 7-year period, averaging $2.2 million per year (PEMA, 2007). The maximum annual cost of $4.0 million occurred in 1972, the year of Tropical Storm Agnes. Data from Pennsylvania Department Transportation indicate that $6.0 million was spent to repair landslide damage along state roads in Allegheny County during the 6.5-year period from January 1971 through July 1977. Undeterminable costs to private citizens (e.g. transportation delays or detours) are not included in these estimates.

The Pennsylvania Department of Transportation and large municipalities incur substantial costs due to landslide damage and to extra construction costs for new roads in known landslide-prone areas. A 1991 estimate showed an average of $10 million per year is spent on landslide repair contracts across the Commonwealth and a similar amount is spent on mitigation costs for grading projects (PADCNR, 2009).

4.3.9.3. Past Occurrence

Pennsylvania has a long history of significant landslide activity. This has resulted from a combination of humid temperature climate, locally steep and rugged topography, and great diversity in the erosion and weathering characteristics of relatively near surface sedimentary rocks. Human activities such as commercial, industrial, and residential developments, transportation, and mining often compound landslide problems. Precipitation events which have triggered significant landslides in Pennsylvania include: Tropical Storm Agnes in June 1972, the Johnstown (Cambria County) storm in July 1977, and the East Brady (Armstrong County) storm in August 1980.

A comprehensive inventory of landslide events across the entire Commonwealth is not available, and the USGS does not maintain a formal inventory of landslides. Instead, the USGS Lanslide Hazards Program collects data as events are reported to the agency. However, landslide inventory maps were created in the late 1970s and early 1980s by the U.S. Geological Survey for areas of central and western Pennsylvania as part of an Appalachians-wide study of landslides. These maps show landslides that were identified mainly from aerial photographs for most areas of the Pennsylvania were landslides commonly occur. An example of one of these maps is shown in Figure 4.3.9-3. Additional maps are available at: http://www.dcnr.state.pa.us/topogeo/hazards/landslides/slidepubs.aspx (PADCNR, 2009).

Figure 4.3.9-3 Example of landslide inventory map for Coudersport, PA from USGS Open File Map 81-238 (G-16 by John S. Pomeroy, 1981). An index map showing the coverage of the inventory is also provided (PADCNR, 2009).

The NCDC has also begun capturing landslides as they occur in conjunction with severe storms. This inventory is quite new; as a result, there are only two landslides recorded in the events database. On July 4, 2011, isolated severe thunderstorms caused two landslides in Allegheny County. The first was a mudslide onto Forward Avenue in Pittsburgh that caused $5,000 in property damage. The second landslide reported with these thunderstorms was a rockslide on Bigelow Boulevard and Herron Avenue, also in Pittsburgh which caused $10,000 in property damage. No injuries or fatalities were reported in either event.

Even prior to 2011, Allegheny County has had a long history of landslide hazards. However, a few catastrophic landslide events have occurred in Pittsburgh in the past, include a rockslide in 1942 that buried a bus near Aliquippa, killing 22 people on board. In 1951, excavators for a new office building made an 8-foot deep cut at the base of a hill along Island Avenue in Stowe, triggering a 500-foot wide landslide that destroyed 6 houses and disrupted a streetcar line and utilities. In 1983, a rockslide killed 2 people who were sitting in their cars at a traffic light on Saw Mill Run Boulevard.

Historically, there were two significant landslide events which resulted in fatalities. In December 1942, a 150-cubic-yard rock fall from a highway cut along the Oho River opposite Ambridge, Beaver County, crushing a bus. Twenty-two people were killed and four were injured (Ackenheil, 1954; Gray and others, 1979). In February 1983, a 300-cubic yard rock fall occurred in Pittsburgh in during remedial excavation of a highway slope having a long history of rock falls. This rock fall crushed three vehicles. Two persons were killed and one was injured. These events can be considered the worst-case event for Pennsylvania. However, typically, every year one or more construction workers are killed or injured in cave-ins of trenches and other excavations in Pennsylvania.

4.3.9.4. Future Occurrence

Using Figure 4.3.9-1, it is evident that the probability of future occurrence of landslide events varies depending on location. Additionally, of the events that do occur, the size and impact of those events also varies. The occurrence of landslide events ranges from low in southeastern and northwestern Pennsylvania to high in southwestern Pennsylvania. Studies investigating the probability of future occurrence of landslide events have not been identified. Based on historical events, knowledge of the topography of the Commonwealth, and input from the SPT, the annual occurrence of a landslide event of any magnitude is considered *highly likely* as defined by the Risk Factor Methodology (see Section 4.1). While landslides will continue to occur across Pennsylvania, the damage and magnitude of the events will continue to be widely varied.

4.3.9.5. Environmental Impacts

The impact of landslides on the environment depends on the size and specific location of the event. In general, impacts include:

- Changes to topography
- Damage or destruction of vegetation
- Potential diversion or blockage of water in the vicinity of streams, rivers, etc…
- Increased sediment runoff both during and after event

Beyond the environmental impacts, landslides can have serious impacts on transportation routes, utilities, and buildings depending on their location.

4.3.9.6. Jurisdictional Vulnerability Assessment

Much of Pennsylvania has landslide susceptible areas in the form of loose soil and both natural and human-made steep slopes. Most highways have sections cut in rock or soil that can fail. Vulnerable areas are primarily located in the Ridge and Valley Physiographic Province spanning central Pennsylvania and encroaching into the northeastern section of the state and in far southwestern Pennsylvania (Butler, Beaver, Allegheny, and Greene Counties). These landslide susceptibility areas, characterized as High (more than 15% of the land involved in landsliding) and Combo-High landslide hazard zone (high susceptibility and moderate instance of landslides) by the USGS, were used to identify vulnerable jurisdictions and critical facilities. The exact vulnerability of a jurisdiction will depend on the geology and topography. GIS analysis shows that 48 of the 67 counties are vulnerable to landslide events.

Additionally, 50 counties profiled landslide hazards in their most recent hazard mitigation plan or plan update. The complete list of counties profiling landslides is found in Table 4.3.9-1. As

stated in Section 4.1, the decision by a county to profile a hazard is one indicator of the presence of risk from that hazard. This indicator should be viewed complementary to other analysis in this section. Together this analysis from reputable sources addresses different aspects of risk for a full risk profile.

Of the 33 counties which currently have calculated risk factor values for landslide, the average value is 1.6; this average does not include Lebanon, Montour, Perry, and Philadelphia, who use an alternate Risk Factor/Ranking system. The State Risk Factor for landslide is 2.2, while the Pennsylvania THIRA scored landslide as a 4 out of 10. For more details on the State Risk Factor and THIRA rankings, please see Section 4.1.

Table 4.3.9-1 Counties profiling landslides with hazard ranking and risk factor (if available).

COUNTY	Profiled Hazard	Did Not Profile Hazard	Ranking (if available)	Risk Factor (If available)
Adams		X		
Allegheny	X		Medium	2.0
Armstrong	X		Not Ranked	No RF
Beaver	X		Low	1.6
Bedford	X		Low	1.3
Berks	X		Not Ranked	No RF
Blair	X		Not Ranked	No RF
Bradford	X		Not Ranked	No RF
Bucks	X		Low	1.3
Butler	X		Low	1.3
Cambria	X		Medium	2.2
Cameron	X		Low	1.3
Carbon	X		Low	1.9
Centre	X		Low	1.6
Chester		X		
Clarion	X		Not Ranked	No RF
Clearfield	X		Low	1.6
Clinton	X		Medium	2.3
Columbia	X		Low	1.9
Crawford	X		Low	1.1
Cumberland	X		Low	1.3
Dauphin	X		Not Ranked	No RF
Delaware	X		Low	1.3
Elk	X		Low	1.6

Table 4.3.9-1 Counties profiling landslides with hazard ranking and risk factor (if available).

COUNTY	Profiled Hazard	Did Not Profile Hazard	Ranking (if available)	Risk Factor (If available)
Erie	X		Low	1.3
Fayette	X		High	2.5
Forest	X		Not Ranked	No RF
Franklin		X		
Fulton		X		
Greene	X		High	2.6
Huntingdon		X		
Indiana	X		Low	1.6
Jefferson	X		Low	1.8
Juniata		X		
Lackawanna	X		Not Ranked	No RF
Lancaster		X		
Lawrence	X		Low	1.3
Lebanon*		X		
Lehigh	X		Low	1.3
Luzerne	X		Not Ranked	No RF
Lycoming		X		
McKean	X		Low	1.7
Mercer	X		Medium	2.2
Mifflin		X		
Monroe		X		
Montgomery	X		Low	1.6
Montour*	X		Not Ranked	2.0
Northampton	X		Low	1.3
Northumberland	X		Low	1.6
Perry*	X		Not Ranked	2.0
Philadelphia**		X		
Pike		X		
Potter	X		Not Ranked	No RF
Schuylkill		X		
Snyder	X		Low	1.5
Somerset		X		
Sullivan		X		

Table 4.3.9-1 Counties profiling landslides with hazard ranking and risk factor (if available).

COUNTY	Profiled Hazard	Did Not Profile Hazard	Ranking (if available)	Risk Factor (If available)
Susquehanna	X		Low	1.8
Tioga	X		Medium	2.1
Union	X		Not Ranked	No RF
Venango	X		Low	1.3
Warren	X		Low	1.3
Washington	X		Not Ranked	No RF
Wayne		X		
Westmoreland	X		Not Ranked	No RF
Wyoming	X		Not Ranked	No RF
York	X		Low	1.5

* Lebanon, Montour, and Perry use an alternate weighted ranking where Risk Factor = Frequency x [(0.25 x Critical facilities) + (0.40 x Social) + (0.25 x Economic) + (0.10 x Environmental)]. While this risk factor was used to comparatively rank hazards, the number does not correspond to a high-medium-low rating.

**Philadelphia uses an A, B, C rating system where A is high, B is medium, and C is low.

The vulnerable counties are home to 3,211 state critical facilities. Allegheny, Cambria, Luzerne, Washington, and Westmoreland Counties have the most critical facilities located within landslide hazard zones. Table 4.3.9-2 illustrates the number of critical facilities in each county vulnerable to landslide hazards.

Table 4.3.9-2 Number of State Critical Facilities impacted by landslides in each county

COUNTY	NUMBER OF CRITICAL FACILITIES	COUNTY	NUMBER OF CRITICAL FACILITIES
Adams	16	Juniata	15
Allegheny	705	Lackawanna	119
Armstrong	93	Lawrence	1
Beaver	108	Lebanon	7
Bedford	31	Lehigh	1
Blair	36	Luzerne	195
Butler	81	Lycoming	14
Cambria	144	Mifflin	28
Carbon	48	Monroe	15
Centre	65	Montour	13
Clarion	16	Northampton	1
Clearfield	88	Northumberland	91

Table 4.3.9-2 Number of State Critical Facilities impacted by landslides in each county			
COUNTY	**NUMBER OF CRITICAL FACILITIES**	**COUNTY**	**NUMBER OF CRITICAL FACILITIES**
Clinton	4	Perry	22
Columbia	65	Pike	10
Cumberland	6	Schuylkill	204
Dauphin	44	Snyder	23
Elk	20	Somerset	85
Fayette	121	Susquehanna	5
Franklin	8	Union	16
Fulton	14	Washington	148
Greene	38	Wayne	11
Huntingdon	47	Westmoreland	273
Indiana	68	York	2
Jefferson	46		

Some municipalities in Pennsylvania have grading codes and ordinances intended to ensure appropriate geological and engineering investigation, design, and construction of excavated slopes and fill slopes. In many cases, the objectives of these codes are not met because of limited or non-existent capability for knowledgeable review and follow-up inspection and enforcement of their provisions.

4.3.9.7. State Facility Vulnerability Assessment

The vulnerability of state critical facilities was evaluated as facilities that are located in the landslide susceptibility areas rated High or Combo-High. Using this criterion, a total of 3,211 vulnerable critical facilities have been identified. Due to the large number of schools, fire departments, and police stations in the Commonwealth, it is unsurprising that those categories of facility have the highest number of critical facilities. The vulnerability of each individual critical facility will differ based on the topographic position of the facility as well as underlying geology. Table 4.3.9-3 shows the vulnerability of state critical facilities by facility type.

Table 4.3.9-3 State Critical Facilities vulnerable to landslides by Critical Facility Type	
STATE CRITICAL FACILITY TYPE	**NUMBER OF IMPACTED FACILITIES**
Agriculture	33
Banking	6
Chemical	1
Commercial Facilities	24
Communications	1
Critical Manufacturing	2
Dams	20
Defense Industrial Base	7

Table 4.3.9-3 State Critical Facilities vulnerable to landslides by Critical Facility Type	
STATE CRITICAL FACILITY TYPE	**NUMBER OF IMPACTED FACILITIES**
Education	46
Emergency Services	40
Energy	14
Fire Departments (Non-HSIP)	1,233
Government Facilities	11
Healthcare & Public Health	7
Hospital (Non-HSIP)	93
National Monuments & Icons	1
Nuclear Reactors, Materials & Waste	4
Police (Non-HSIP)	588
Postal & Shipping	4
School (Non-HSIP)	1,032
Transportation	30
Water	14
Agriculture	33
Banking	6
TOTAL VULNERABLE CRITICAL FACILITIES	***3,211***

4.3.9.8. Jurisdictional Loss Estimation

As stated in Section 4.3.9.6, loss estimates were prepared based on the sum of the number and value of buildings in Census tracts located in landslide combo-high areas, aggregated to the county level. The Commonwealth has a total of 3,291,555 potentially impacted buildings with over $746 billion in exposure in 50 counties. Allegheny County is the most threatened jurisdiction with 706,960 vulnerable buildings and over $180 billion in possible losses stemming from landslide events. Luzerne, Washington, and Westmoreland Counties are also highly threatened by landslide hazards with over $31 billion each in possible building and contents losses. Table 4.3.9-4 illustrates the number of impacted buildings and their associated dollar value of exposure by county.

Table 4.3.9-4 Estimated jurisdictional losses due to landslides.		
COUNTY	**NUMBER OF IMPACTED BUILDINGS**	**DOLLAR VALUE OF EXPOSURE, BUILDING AND CONTENTS (THOUSANDS $)**
Adams	28,542	$6,512,907
Allegheny	706,960	$180,606,811
Armstrong	70,067	$14,115,273
Beaver	86,154	$22,023,606
Bedford	34,395	$6,276,009

Table 4.3.9-4 Estimated jurisdictional losses due to landslides.

COUNTY	NUMBER OF IMPACTED BUILDINGS	DOLLAR VALUE OF EXPOSURE, BUILDING AND CONTENTS (THOUSANDS $)
Berks	12,240	$2,643,201
Blair	50,987	$10,666,665
Butler	95,301	$25,002,688
Cambria	102,381	$21,746,588
Cameron	5,214	$1,048,498
Carbon	40,581	$9,301,732
Centre	88,141	$20,029,636
Clarion	21,913	$4,155,500
Clearfield	76,155	$14,298,037
Clinton	14,661	$2,871,184
Columbia	46,682	$10,293,284
Cumberland	32,316	$7,615,040
Dauphin	53,901	$13,315,786
Elk	32,620	$6,564,209
Fayette	108,993	$21,491,644
Forest	2,499	$425,414
Franklin	34,151	$6,609,908
Fulton	25,440	$4,642,568
Greene	32,453	$6,253,362
Huntingdon	59,376	$11,664,374
Indiana	80,594	$16,313,646
Jefferson	57,165	$11,041,035
Juniata	41,698	$7,704,686
Lackawanna	89,223	$20,107,209
Lebanon	11,804	$2,612,339
Lehigh	5,965	$1,230,258
Luzerne	145,086	$31,746,439
Lycoming	16,378	$3,218,802
McKean	1,205	$221,841
Mifflin	44,344	$8,490,432
Monroe	53,403	$14,321,925
Montour	15,459	$3,743,907
Northampton	11,165	$2,670,134
Northumberland	68,366	$14,689,258
Perry	66,093	$14,659,509
Pike	10,715	$2,714,783
Schuylkill	110,405	$24,135,616
Snyder	37,714	$8,069,002

Table 4.3.9-4 Estimated jurisdictional losses due to landslides.		
COUNTY	**NUMBER OF IMPACTED BUILDINGS**	**DOLLAR VALUE OF EXPOSURE, BUILDING AND CONTENTS (THOUSANDS $)**
Somerset	76,466	$15,327,784
Susquehanna	2,188	$432,042
Union	52,167	$11,273,059
Washington	143,661	$34,783,249
Wayne	16,325	$3,447,079
Westmoreland	265,845	$61,884,497
York	5,998	$1,344,791
TOTAL	***3,291,555***	**$746,357,246**

4.3.9.9. State Facility Loss Estimation

The specific state facility losses will depend on the slope and soil type a given facility is constructed on. For example, facilities located on steep slopes or built on loose soils are more likely to experience landslides of the land beneath them. Additionally, facilities located in valleys are more likely to be buried as a result of debris flow from higher slopes. In total, though, the estimated replacement cost of all State Critical Facilities located in landslide combo-high hazard zones with available replacement values is $24,789,223,523.

4.3.10. Lightning Strike

4.3.10.1. Location and Extent

Lightning events occur across the entire Commonwealth. Different areas experience varying event frequencies, but in all cases lightning strikes occur primarily during the summer months. Figure 4.3.10-1 below shows the average annual lightning flash density for 2000-2009 from the Cooperative for Applied Meteorological Studies (2013). This image indicates that relatively more lightning flashes occur in southwestern Pennsylvania and in the Lehigh Valley. While the impact of flash events is highly localized, strong storms can result in numerous widespread events over a broad area. In addition, the impacts of an event can be serious or widespread if lightning strikes a particularly significant location such as a power station or large public venue. While the most lightning flashes occur in southwestern Pennsylvania, eastern and southeastern Pennsylvania is at greater risk for death, injury, or damage to lightning than central and north-central sections of the Commonwealth due to higher population density.