Landslides

Hazard Identification: Definition and Description

A landslide is a general term for the downslope movement of rock, soil, or both under the influence of gravity. The style of movement and resulting landform or deposit are influenced by the rock and soil type, slope location, and how fast the rock or soil moves. Landslides occur when the strength of rocks or soil is exceeded by stress applied to those hillslope materials. Common stresses are gravity, increased pore-water pressure, earthquake shaking, and slope modification.

Diverse terminology and definitions among geologists, engineers, and the public are a reflection of the complex landslide processes. Some of the most common terms are landslide, mudslide, and rockslide. Other terms such as mass wasting, slope movement, and slope failure are also commonly used to discuss landslide phenomena. Regardless of which term is used, all landslides share physical and mechanical (in rock and soil) processes that explain their occurrence. Landslides have basic parts (Fig. 2-1), including the surface of rupture, main scarp, landslide toe, tension cracks, and slide flanks. These parts play a role in the style of movement, velocity of the slide material, volume displaced, distance the slide might reach (extent), and any decisions regarding hazard mitigation and risk reduction.

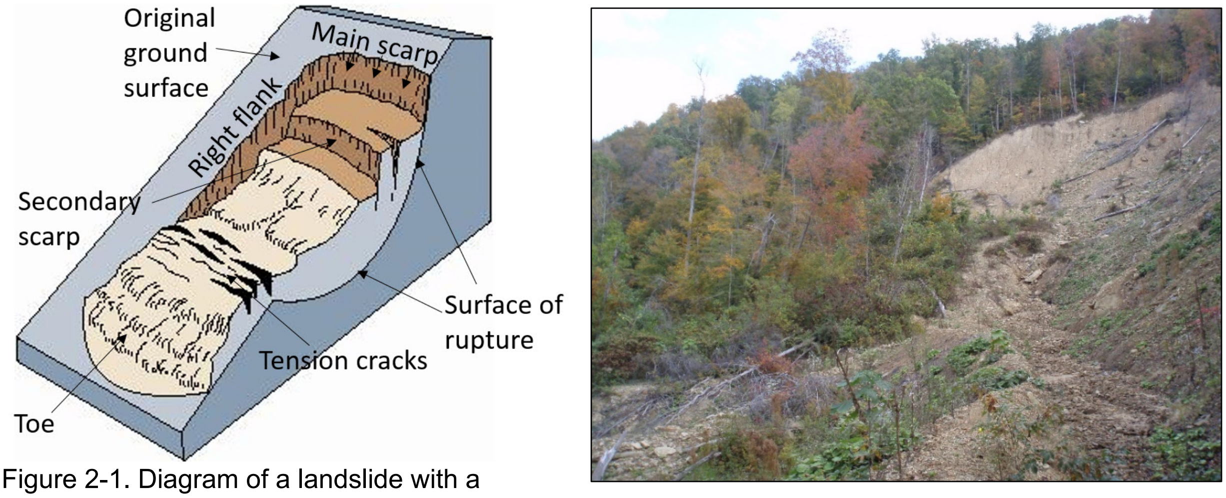

Figure 2-1. Diagram of a landslide with a curved surface of rupture and other primary landslide parts. Modified from Highland (2004). The photograph is of a large landslide in Perry County, Ky.

Landslide Types

Landslides are classified into basic types. The classifications presented here are from criteria by Varnes (1978) and Cruden and Varnes (1996) that are primarily based on the type of hillslope material and the type of movement. Material in a landslide mass is either rock, soil, or a combination of both. The type of movement describes the mechanics of how the landslide mass is displaced, which is important for determining the level of hazard. Types of movement include fall, topple, slide, spread, and flow. “Type of movement” is often synonymous with “landslide type.” Figure 2-2 is a schematic diagram of common landslide types.

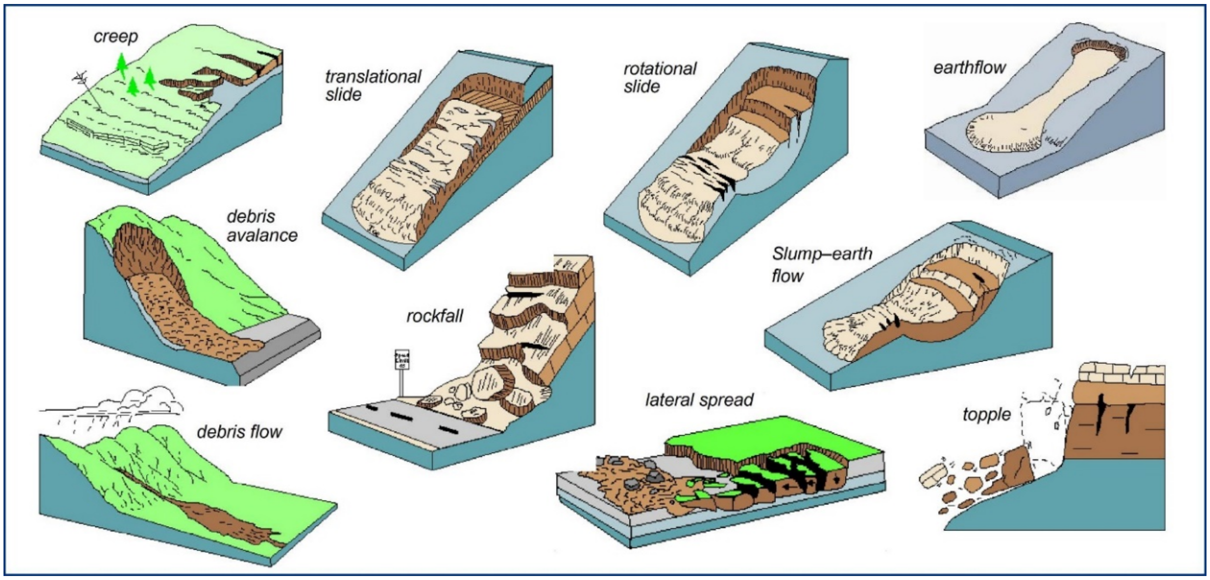

Figure 2-2. Major landslide types. Modified from Highland (2004).

Descriptions of Landslide Types

The following descriptions are modified from Highland and Bobrowsky (2008).

- Translational slides—In a translational slide, the slide mass moves down a relatively planar surface, often the contact between soil and underlying bedrock. The sliding material can be composed of fine- to coarse-grained soils or rock. Slide-plane zones are typically shallow (less than 3 m below the surface). Size can range from small (less than 30 m long) to very large (several kilometers wide along roadways or cutbanks in streams). Movement may initially be slow (a few centimeters a month), but can become rapid (several meters per day).
- Rotational slides—Also called slumps, these slides are distinguished by an upward-curved slide plane, which causes rotational movement. Rotational slides can have multiple scarps, which create displacement that tilts back toward the head scarp and crown. Slumps often have a hummocky surface and thick toe of displaced rock or soil. These slides usually occur in thick, unconsolidated soils, loess, and artificial fills, but also may occur in weathered rock masses. Velocity of rotational slides ranges from slow (less than 0.3 m every five years) to moderately fast (1.5 m per month).
- Flows—Types of flows include debris flow, debris avalanche, and earthflow. Each type is differentiated by velocity and mixture of rock and soil, which can be relatively thin or very thick accumulations of sediment. Flow size ranges from small to very large (a few hundred meters to several kilometers). Smaller earthflows are common in soils developed on shale, weathered clay-rich rocks, and fill. Debris flows and debris avalanches are move rapidly (up to 56 km/hour). They are most common on slopes where thick soils are confined to drainages or steep channels. Excessive water commonly triggers the movement of these flows. Debris flows can be very dangerous because of the rapid onset and high velocity that mobilizes everything from large boulders to clay-size sediment.
- Creep—Creep is an extremely slow type of flow (less than 1 m per decade) that can only be noticed by its effects. Shear stresses in the soil or rock are sufficient to cause movement, but soil or rock displacement is gradual. Creep often occurs seasonally with changes in moisture content and temperature. Typical damage is tilted or curved tree trunks, broken or tilted fences, tilted telephone poles, cracked foundations, and broken underground utilities. Creep often has a complex system of rupture surfaces, and has the potential to lead to more destructive, faster-moving slides or flows.
- Spreads—Spreads usually occur on very gentle slopes where soft, clay-rich layers undergo lateral extension, which spreads apart overlying firmer rocks and soil. Spreads can occur in clayey lacustrine and other glacial deposits. Spread results in general subsidence into the weaker layer, and styles include block, liquefaction, and lateral spreads. Velocity ranges from slow (millimeters per day) to rapid (meters per day).
- Rockfalls and topples—Rock material of varying size can free-fall through the air from cliffs, roadcuts, or steep slopes. These failures are more likely if rocks are dipping in the same direction as the slope. Rocks can become detached from in-place bedrock by fracturing, weathering from freeze-thaw cycles, erosion of underlying material, and human activities such as road construction.

Facts

- Landslides occur because the strength of hillslope rocks or soil is exceeded by the stress applied to those materials. A stable slope is one that balances the stresses imposed with the strength of the soil or rock.
- Processes that can cause changes in stress and slope equilibrium include surcharges of weight (adding fill to the top of the slope), pore-water pressure changes, gravity, removal of vegetation, and removal of a landslide.
- Stresses act over time and space, and at different scales, creating various landslide types, style of movement, and levels of hazard and risk.
- Landslides can have several causes: bedrock geology, slope angle, slope morphology, groundwater dynamics, soil type, and slope modification by humans.
- Landslide triggering mechanisms work in conjunction with the causes. Triggers are the external stimuli that can initiate slides and include rainfall, earthquake shaking, volcanic eruptions, rapid groundwater change, and slope modification by humans.
- Predicting landslides is difficult, but knowing the locations of preexisting landslides and their associated rock and soil properties allows for better determination of where future landslides may occur.
- Landslides can occur on natural or engineered slopes. Increasing urbanization and development on landslide-prone slopes will increase the likelihood of slope failures. As population increases result in development of landslide-prone areas, the hazard and risk will increase.
- No systematic catalog of landslide occurrence or impact is maintained in the United States. Damage is poorly documented. Occurrence, costs, and victims are underestimated. Landslide costs rival or exceed flood and earthquake costs in Kentucky.

Impact

The societal and economic impacts of landslides are significant, and reported occurrences are underestimated globally down to the local level. Because of the wide distribution across the landscape and among different environments, landslides frequently intersect with the human-built environment (Lu and Godt, 2013). One complication is that landslides are often considered a secondary hazard associated with a primary extreme event, such as a tropical storm or an earthquake. This makes compiling statistics on landslides and their impact difficult. In the United States, landslides result in 25 to 50 fatalities annually (more than earthquakes and volcanoes) and approximately $3 billion in damage (Spiker and Gori, 2003; Highland and Bobrowsky, 2008; Lu and Godt, 2013). Landslides occur in all 50 states and U.S. territories. The deadliest landslide in the history of the conterminous United States was on March 22, 2014, near Oso, Wash., killing 43 people. In January 2018, heavy rainfall after wildfires triggered damaging landslides known as debris flows in southern California, resulting in 20 fatalities. A landslide overview map of the conterminous United States published by the U.S. Geological Survey (Radbruch-Hall and others, 1982) delineates regions in which large numbers of landslides have occurred and where slope-stability concerns should be considered, because these areas may pose engineering, environmental, and societal problems (Fig. 2-3).

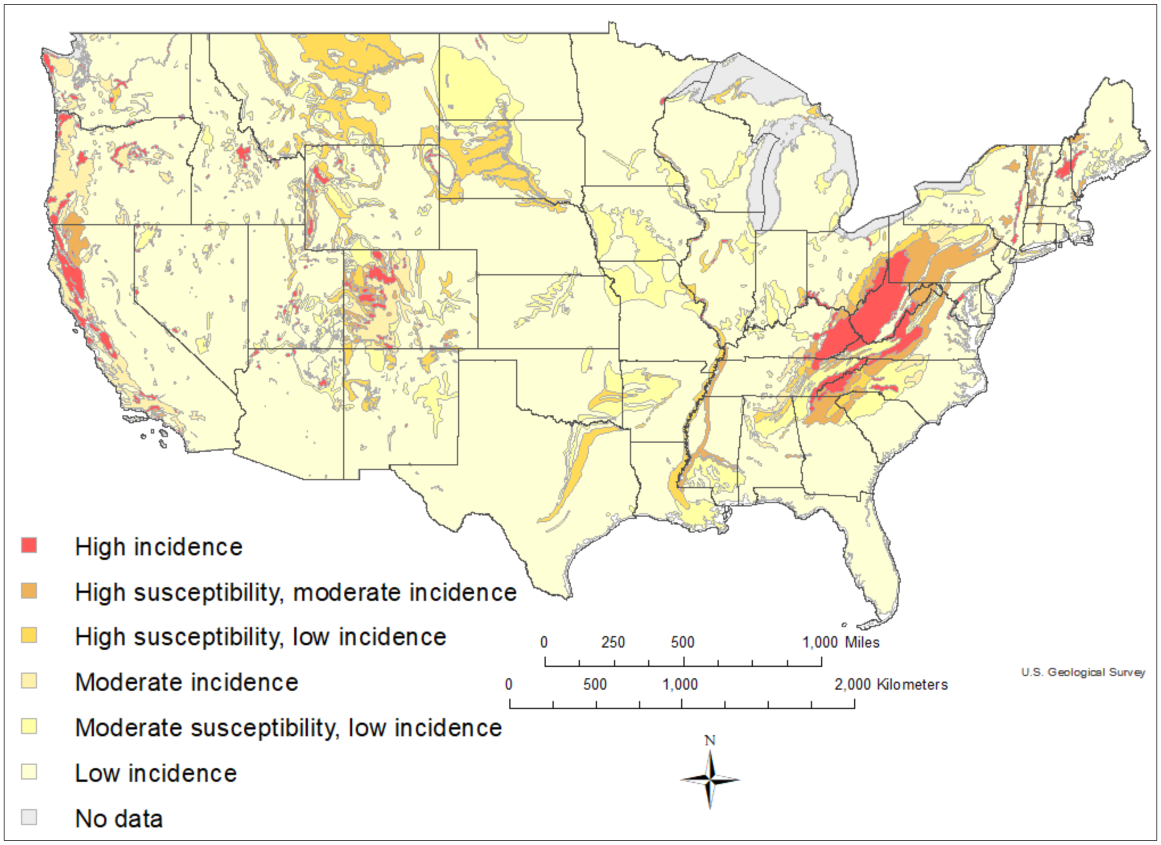

Figure 2-3. Landslide overview of the conterminous United States. Different colors represent areas of varying landslide occurrence. Polygons were digitized from the original stable-base manuscripts at 1:3,750,000 scale from Radbruch-Hall and others (1982). Digital compilation of map by Jonathan W. Godt (1997).

Landslides in Kentucky cost the state $10 to $20 million annually and cause damage to homes, commercial property, and transportation infrastructure (Fig. 2-4). These estimates are only for direct costs. Indirect costs such as road closures, decreased property values, and utility interruption are significant, but much more challenging to quantify. Table 2-1 lists documented landslides occurrences that have associated costs. The sources of the annual direct cost estimates are from the Kentucky Transportation Cabinet, Kentucky Emergency Management, and the FEMA Landslide Loss Reduction (Wold and Jochim, 1989). The state and local government agencies that respond to landslides vary in their approaches to data collection, evaluation, and mitigation. Much of the economic loss and public cost is borne by federal, state, and local agencies responsible for disaster assistance and highway repair. Private costs involve mainly damage to land and homes, often resulting in financial ruin for homeowners. Damage from landslides is typically not covered under most homeowner's insurance policies.

Table 2-1. Documented landslide costs from the Kentucky Geological Survey landslide inventory database. Sources: KYTC – Kentucky Transportation Cabinet, KGS – Kentucky Geological Survey, NRCS – National Resources Conservation Service

Source	County	Failure	Failure Location	Cost
KYTC	Casey			$2,055.00
KGS	Breathitt	5/8/2009		$4,500.00
KYTC	Spencer	5/1/1978	above roadway	$4,555.00
KGS	McCreary			$11,000.00
KYTC	Madison		road embankment	$15,000.00
KYTC	Harlan	6/18/2012		$15,632.74
KYTC	Wayne			$16,285.00
KYTC	Washington			$16,500.00
KYTC	Harlan			$20,625.00
KYTC	Owen		bridge embankment	$44,840.00
KYTC	Clay			$48,000.00
KYTC	Gallatin			$52,180.00
KYTC	Kenton		road embankment	$64,359.00
KYTC	Gallatin			$82,213.00
KYTC	Lewis		above roadway	$85,000.00
KYTC	Bell	6/19/2012		$89,175.07
KYTC	Gallatin		above roadway	$104,613.00
KYTC	Gallatin			$106,987.25
KYTC	Bell			$107,208.00
KYTC	Pulaski			$109,850.00
KYTC	Kenton	9/20/1973	roadcut	$120,000.00
KYTC	Gallatin		above roadway	$120,035.00
KYTC	Lewis		above and below roadway,	$121,500.00
NRCS	Pike	1/1/2008	above roadway	$130,000.00
KYTC	Gallatin			$135,380.80
Media	Pike	5/12/2017	road embankment, stream at	$145,000.00
KYTC	Martin			$146,150.00
KY EM	Whitley		above and below roadway,	$150,000.00
KYTC	Bath		road embankment	$167,000.00
KYTC	Rockcastle			$184,250.00
KYTC	Bell		above and below roadway	$200,000.00
KYTC	Bell			$234,000.00
KYTC	Laurel			$265,000.00
KYTC	Scott		road embankment	$272,211.00
KYTC	Knott		road embankment	$300,000.00
KYTC	Laurel			$316,200.00
KYTC	Kenton		road embankment	$325,360.00
KYTC	Leslie		above roadway	$375,000.00
KYTC	Estill		road embankment	$414,900.00
KYTC	Carroll		below roadway, stream at bottom	$481,317.00
KYTC	Morgan		bridge embankment	$500,000.00
KYTC	Magoffin			$600,000.00
Media	Bell		above roadway	$2,000,000.00
KYTC	Knott		bridge embankment	$2,160,000.00
KYTC	Kenton	1/1/1992	above and below roadway	$5,000,000.00
KGS	Fulton		below roadway	$17,000,000.00

Figure 2-4. A landslide-damaged road in Lewis County, Ky. (left), and a home torn apart by a rainfall-triggered landslide in Boyd County, Ky. (right).

Hazard Profile

Previous Occurrences

Landslides occur in all regions of Kentucky. Documented occurrence, warnings, impact, and extent vary across the state, primarily because of the wide distribution among physiographic settings and communities, in addition to how data is compiled in local and state agencies (Table 2-2). The Kentucky Geological Survey has compiled a landslide inventory with information on 76,158 landslides to date, from various sources including published maps, reports, field investigations, media alerts, government agencies, and the public (Fig. 2-5). Data on new landslide occurrence and extent are sparse, however (Table 2-3).

Generally, more landslides occur when average statewide rainfall is higher (Fig. 2-6). Landslides also typically occur more in the late winter and early spring months, when rainfall or snowmelt is high relative to the rest of the year. In 2015, there were a record four presidential disaster declarations that included hundreds of landslides (Table 2-4). Record rain fell in March, April, and July 2015 in several counties across the state, triggering damaging debris flows, slumps, and rockfalls (Fig. 2-6). Even more landslides were not documented.

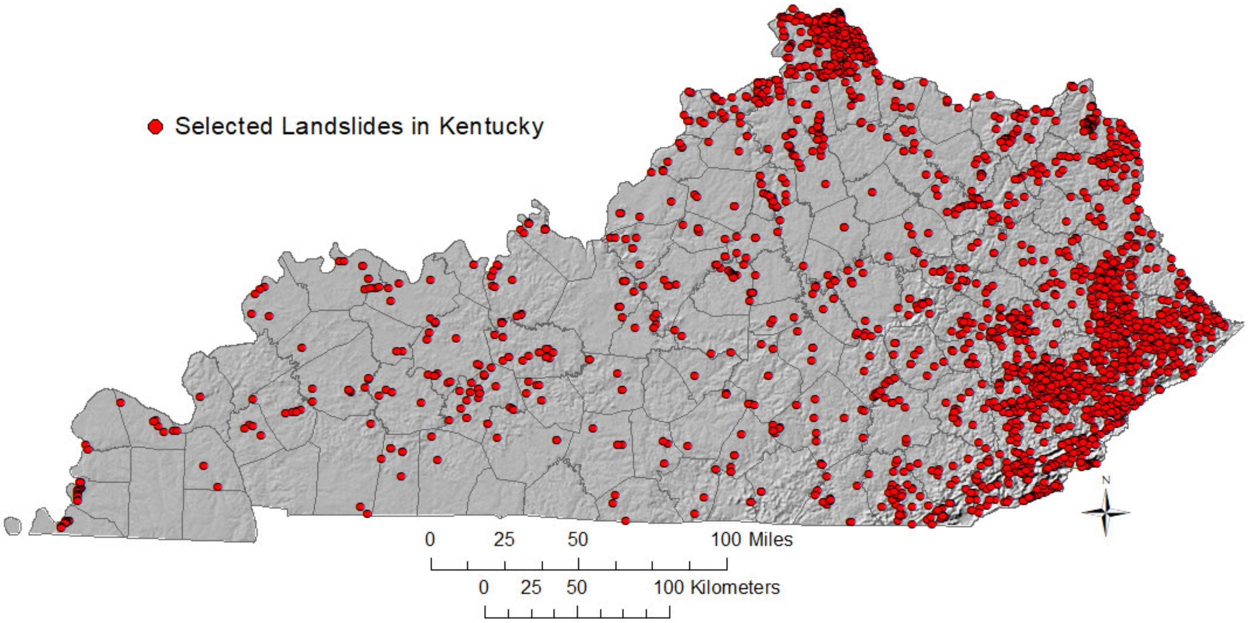

Figure 2-5. Locations of selected landslide occurrences from the Kentucky Geological Survey landslide inventory. The points represent different types, sizes, and states of activity.

Table 2-2. Profile of Landslides in Kentucky

Period of occurrence:	At any time. Landslides commonly occur during or after intense or long-duration rainfall.
Number of events:	Unknown. There are 76,158 documented landslides in the Kentucky Geological Survey landslide inventory.
Annual rate of occurrence:	Based on documented landslides in the Kentucky Geological Survey landslide inventory from 2009–17, 859 landslides/9 years = 95.4.
Warning time:	Hours to months. Depends on local geology, slope position, and triggering factor. Landslides can move instantaneously or very slowly, spanning decades.
Potential impacts:	There are direct impacts such as infrastructure damage, property damage, and loss of life, and indirect impacts decreased land value, interruption of transportation systems, and adverse environmental effects.
Recorded losses:	Estimated direct costs of $10–20 million annually.
Extent:	Landslides of all types range in extent (track length) from a few meters to several kilometers. Widths and depths to the failure zone vary significantly as well. The velocity of these landslide deposits ranges from imperceptible to extremely fast.

Table 2-3. Selected landslides and attributes from the KGS landslide inventory. showing attributes related to extent. Note all attributes have been documented. Sources: KYTC – Kentucky Transportation Cabinet, KGS – Kentucky Geological Survey, NRCS – Natural Resources Conservation Service, DNR-DMRE – Division of Natural Resources-Mine Reclamation and Enforcement, KYEM – Kentucky Emergency Management

Source	County	Failure Type	Track Length (ft)	Width (ft)	Scarp Height (ft)	Failure Zone Depth (ft)
KGS	Jessamine	composite	15	50		
KYTC	Kenton		20	250		
KYTC	Nelson		25			
KYTC	Kenton		30	90		
KGS	Breathitt		30	10		
KYTC	Garrard		35	350	4	
KYTC	Kenton	rotational	35	75	3-5	
KGS	Trimble	translational	35	25		
KGS	Rowan	rockslide	35	50		
KYTC	Boone		35	100		
KYTC	Franklin		40	60	6-8	
KYTC	Spencer		40	225		
KGS	Franklin	earthflow	40			
KYTC	Pendleton		40	50	2-3	
KGS	Trimble	translational	40	20		
KGS	Ballard		40	85		
KGS	Breathitt		50		3-5	
KGS	Kenton	rotational	50			
KGS	Rowan	rotational	50	100	20	
Public	Grayson		60	70	2	
KYTC	Campbell		70	50		8-10
NRCS	Pike	translational	75	100	5	
Public	Campbell		75	150		
KYTC	Leslie		80			
KYTC	Knox		80			
KGS	Knott		85			
KYTC	Kenton		90	110	5	
NRCS	Lawrence	rotational	95	257	5	
KGS	Caldwell		100			
KGS	Lawrence		100	205	5	
KY EM	Floyd		100			
Public	Casey		100	60		
KGS	Kenton		115	107	10	
Public	Perry	translational	120		4	
KGS	Boyd		140	330	10	
KGS	Madison		150			
KGS	Kenton	translational	150			
KYTC	Leslie		150			
KGS	Caldwell		150			
Public	Pike	landslide	150	175		
KGS	Grayson		150			
KGS	Whitley		150	30		
KGS	Ohio		175	525		
KGS	Lewis		195			
KYTC	Carroll	rotational	200	400		0-35
KGS	Kenton	translational	200			
KGS	Caldwell		215	1100		

Source	County	Failure Type	Track Length (ft)	Width (ft)	Scarp Height (ft)	Failure Zone Depth (ft)
KGS	Campbell		225			
KGS	Lawrence		230	360	1	
KGS	Pike		250			
KYTC	Whitley		250	150		12-20
KGS	Boyd	rotational	270	200	5	
Public	Pike		280	371	10	
DNR-DMRE	Knott		280	75		
KGS	Kenton		300			
KYTC	Bracken		317	240		
KGS	McCreary		320			
KGS	Madison	translational	320	80		
KY EM	Powell	composite	350			
KGS	Johnson		380	450		
KGS	Lewis		430	930		
KYTC	Pendleton		440			
KYTC	Leslie		450			
KYTC	Kenton		460			
KGS	Pike		500			
DNR-DMRE	Floyd		525			
KGS	Harlan	rotational	600	500		50
KGS	Carter		630	580		
KGS	Fulton		750			
KGS	Lewis		780	3280		
KYTC	Clinton		800	400		
KGS	Lawrence		885	160		
KY EM	Floyd	debris flow	1000			
KY EM	Floyd	debris flow	1400			
KY EM	Floyd	debris flow	1500			

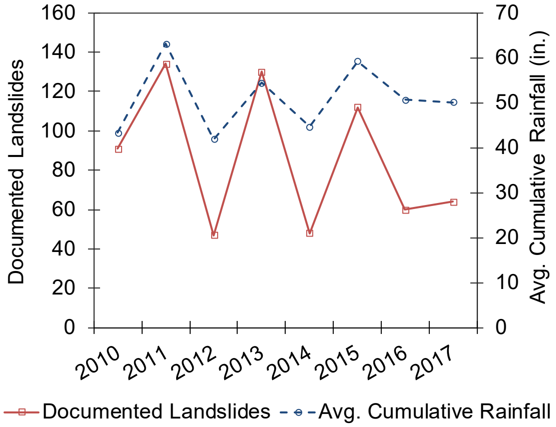

Figure 2-6. Number of documented landslides in Kentucky compared with statewide average annual rainfall (left) and a debris flow that covered a road and damaged a home in Floyd County, Ky. (right). The landslide pictured at right was the result of heavy rainfall in the late winter and spring of 2015.

Table 2-4. Landslide-related FEMA disaster declarations in Kentucky.

FEMA Disaster Declarations	*Title*	*Incident Period*	*Individual Assistance Applications*	*Total Individual & Household Dollars Approved*	*Total Public Assistance Grants Obligated*
DR-1912	KY Severe Storms, Flooding, **Mudslides**, and Tornadoes	5/1/2010–6/1/2010	4,258		$22,243,260.54
DR-1925	KY Severe Storms, Flooding, and **Mudslides**	7/17/2010–7/30/2010	1,624	$10,602,928.54	$6,010,738.74
DR-4196	KY Severe Storms, Flooding, **Landslides**, and **Mudslides**	8/14/2014–8/24/2014			$5,773,235.99
DR-4216	KY Severe Storms, Snowstorms, Flooding, **Landslides**, and **Mudslides**	2/15/2015–2/23/2015			$4,440,912.99
DR-4217	KY Severe Storms, Tornadoes, Flooding, **Landslides**, and **Mudslides**	4/2/2015–4/17/2015	1,086	$4,083,332.11	$12,960,691.50
DR-4218	KY Severe Storms, Snowstorms, Flooding, **Landslides**, and **Mudslides**	3/3/2015–3/9/2015			$20,514,774.22
DR-4239	KY Severe Storms, Tornadoes, Straight-Line Winds, Flooding, **Landslides**, and **Mudslides**	7/1/2015–7/20/2015	924	$5,577,558.88	$10,453,950.37
DR-4278	KY Severe Storms, Tornadoes, Flooding, **Landslides**, and **Mudslides**	7/2/2016–7/9/2016			$4,633,989.42

Landslide Hazard Mitigation

Approximately $11.2 million was spent on Kentucky Emergency Management and FEMA landslide mitigation projects for private residences from 2003 to 2015 (Federal Emergency Management Agency, 2018). The Kentucky Transportation Cabinet incurs direct costs of approximately $20 million annually for landslides that damage roads (Fig. 2-7). One of the most expensive mitigation projects was in in Hickman, Kentucky between 1996 and 2000. A landslide along the bluff of the Mississippi River was threatening several buildings and streets and more than $17 million was needed to stabilize the slope (Fig. 2-7).

Figure 2-7. Slope stabilization project in Hickman, Ky. (left), and generations of steel piles stabilizing a road in Kenton County, Ky. (right).

Landslide Hazard Assessment

Landslide Susceptibility

A statewide landslide susceptibility model was developed in ArcGIS using two map layers: geology and slope. The geology and slope maps (raster images) were reclassified based on a matrix of weighted scores that were assigned to particular geologic formations and ranges of slope values (Table 2-5). The weighted score for slope doubled with each increasing slope range. The weighted score for the geology ranged from 10 to 40 depending on the rock type. Using the ArcGIS Weighted Sum tool, the newly reclassified values of both raster map layers were multiplied by an assigned weight and then values for both layers were added together (Eq. 2-1). In order to have slope be a greater influence on the susceptibility model, a 70 percent weight was assigned for slope and a 30 percent weight was assigned for geology.

Eq. 2-1

(geology reclass value × 0.30) + (slope reclass value × 0.70) = landslide susceptibility value

Using the summed cell values from the two layers, landslide susceptibility was manually classified into low, moderate, and high categories (Fig. 2-8). Classification was made by visually inspecting the map and by determining the distribution of existing landslides cataloged in the Kentucky Geological Survey inventory.

Table 2-5. Landslide susceptibility model matrix. Reclassification values for geology and ranges of slope values are in bold italic. A weighted value of 70 percent was assigned to slope and 30 percent to geology. The calculated cell values and classification breaks are in red, yellow, and green, which indicate low, moderate, and high susceptibility, respectively.

Geologic Classification		**Slope Range (°)**						
		0–5	5–10	10–15	15–20	20–30	30–40	> 40
		1	***4***	***8***	***16***	***32***	***64***	***128***
Alluvium	***10***	**3.7**	**5.8**	**8.6**	**14.2**	**25.4**	**47.8**	**92.6**
Resistant rocks, thick sandstones, and limestones	***20***	**6.7**	**8.8**	**11.6**	**17.2**	**28.4**	**50.8**	**95.6**
Less resistant rocks and soils; weaker limestones, shales, and sandstones	***30***	**9.7**	**11.8**	**14.6**	**20.2**	**31.4**	**53.8**	**98.6**
Argillaceous rocks and selected unconsolidated deposits; shales, loess, and glacial deposits	***40***	**12.7**	**14.8**	**17.6**	**23.2**	**34.4**	**56.8**	**101.6**

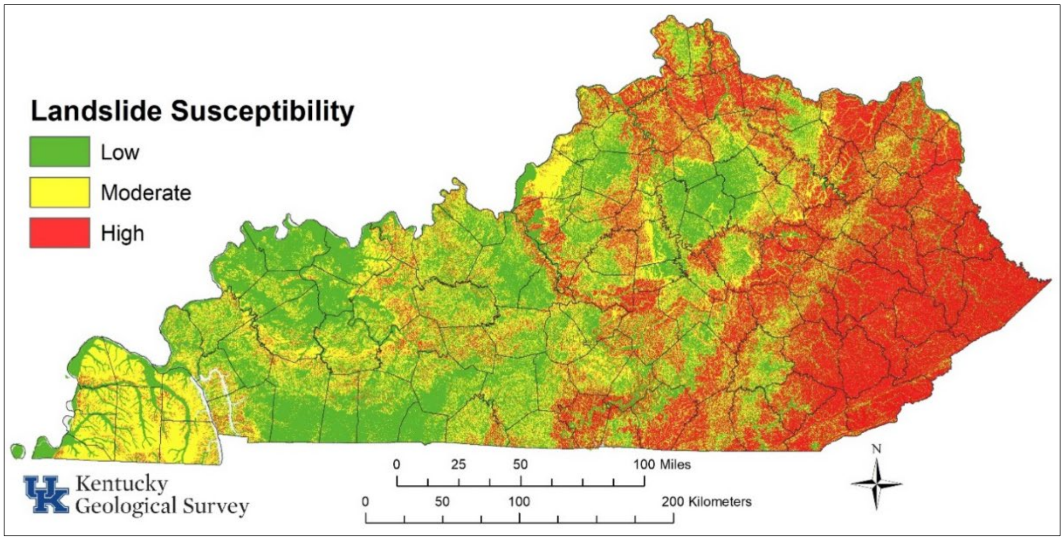

Figure 2-8. Landslide susceptibility of Kentucky. County outlines are in gray.

Landslide Vulnerability

A landslide vulnerability map was created to identify specific areas where impact from landslide activity may be significant because of exposure (Fig. 2-9). U.S. Census Bureau census tract population data and the landslide susceptibility values were used to create the map. Using the ArcGIS Raster Calculator, the vulnerability values were calculated by multiplying population by the weighted landslide susceptibility score. Vulnerability was classified as low, moderate, high, or very high based on population, topography, and the distribution of landslides listed in the inventory.

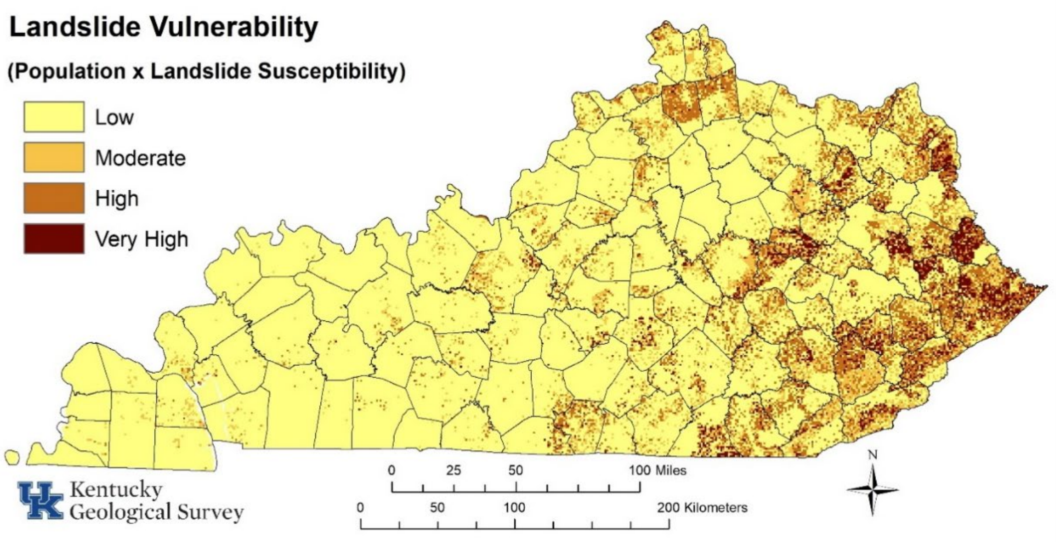

Figure 2-9. Landslide vulnerability in Kentucky. County outlines are in gray. Darker colors indicate areas of high population and high landslide susceptibility; lighter colors indicate low population and low to moderate susceptibility.

Both the landslide susceptibility model and landslide vulnerability map are best viewed in a GIS. These maps should be used for planning purposes only and are not intended for site-specific investigations. If warranted, maps in greater detail could be created using higher-resolution elevation/slope data, detailed geology, and more exposure data.

A Note by the Commonwealth on the Probability of Landslide Occurrence[1]

Given the unsystematic, ad-hoc, and individual nature of landslide record, there is not a basis by which to determine an frequency or rate of occurrence of landslide. However, using the number of events recorded in Kentucky Geological Survey's (KGS's) landslide inventory and acknowledging that landslide events often are tied with other hazard events, e.g., flooding and seismic events, the Commonwealth of Kentucky guarantees – i.e., that there is a 100% probability – that a landslide event will occur somewhere within the Commonwealth in any given year.

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[1] The below statement is made by the University of Kentucky Hazard Mitigation Grants Program Office (UK-HMGP) and by Kentucky Emergency Management (KYEM) and does not necessarily reflect the views of the Kentucky Geological Survey (KGS).

Summary of Loss Estimates from Local Hazard Mitigation Plans[2]

Given the unsystematic nature of collecting information on landslide events, estimating potential losses currently can be a lesson in futility. Consequently, most local hazard mitigation plans – even ones for regions and counties where landslide events are highly probable and especially deleterious – will convey potential losses to identified assets as an assumption that all identified assets are equally vulnerable to landslide events.

Below is a table summarizing all of Kentucky's local hazard mitigation plans' loss estimates as they pertain to the landslide hazard. With the exception of Lexington-Fayette Urban County Government (LFUCG) and Louisville/Jefferson County Metropolitan Government, all of Kentucky's local multi-hazard mitigation plans are multi-jurisdictional and developed by Kentucky's Area Development Districts (ADDs). Unless otherwise stated (in footnotes), the values in the list reflect values for residential, commercial, industrial, agricultural, religious, educational, and governmental building stock.

Table 2-6. Local Hazard Mitigation Plan Potential Loss Estimate Summaries for Landslides

Area Development District	County	Estimated Losses
Barren River ADD	Allen	$ 9,670,842,041.00
	Barren	$ 3,958,251,841.00
	Butler	$ 1,024,039,685.00
	Edmonson	$ 1,167,896,164.00
	Hart	$ 3,747,649,200.00
	Logan	$ 3,980,216,871.00
	Metcalfe	$ 485,802,500.00
	Monroe	$ 1,248,315,078.00
	Simpson	$ 535,815,020.00
	Warren	$ 2,867,998,265.00
Big Sandy ADD	Floyd	$ 1,690,321,000.00
	Pike	$ 2,673,441,700.00
	Johnson	$ 845,535,200.00
	Magoffin	$ 389,568,200.00
	Martin	$ 425,073,100.00

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[2] The below section is written by the University of Kentucky Hazard Mitigation Grants Program Office (UK-HMGP).

Area Development District	County	Estimated Losses
Bluegrass ADD[3]	Anderson	High
	Bourbon	Low
	Boyle	Low
	Clark	Moderate
	Estill	High
	Fayette[4]	$ 2,146,738,559.00
	Franklin	Moderate
	Garrard	Moderate
	Harrison	Moderate
	Jessamine	Low
	Lincoln	Moderate
	Madison	Moderate
	Mercer	High
	Nicholas	Moderate
	Powell	Moderate
	Scott	Low
	Woodford	Low
Buffalo Trace ADD	Bracken	$ 1,500,857,120.00
	Fleming	$ 1,870,756,500.00
	Lewis	$ 2,125,877,600.00
	Mason	$ 2,732,050,100.00
	Robertson	$ 650,269,400.00
Cumberland Valley ADD[5]	Bell	$ 172,215,000.00
	Clay	$ 648,626,000.00
	Harlan	$ 551,164,345.00
	Jackson	$ 42,510,000.00
	Knox	$ 263,155,074.00
	Laurel	$ 1,286,433,946.00
	Rockcastle	$ 334,440,764.00
	Whitley	$ 426,394,400.00
FIVCO	Boyd	$ 20,326,082.00
	Carter	$ 165,424,000.00
	Elliott	$ 68,306,000.00
	Greenup	$ 12,652,731.00
	Lawrence	$ 2,561,362.00

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[3] Bluegrass ADD uniquely considered estimated potential losses in purely subjective terms. Its regional hazard risk assessment admits the weaknesses apparent in most local hazard mitigation plans that estimating potential losses for most hazard types usually require the unhelpful assumption that all assets are equally vulnerable. Bluegrass ADD defined a Calculated Vulnerability Risk methodology: Past occurrences for each hazard type were recorded regionally and then averaged with local rankings of potential for future events to occur, the overall vulnerability ranking of each hazard, and, relevant to this section, total potential impact. A “LOW” score for potential impact was defined as total cost of impact would be less than $50,000. A “MODERATE” score for potential impact was defined as total cost of impact would be greater than or equal to $50,000 and less than or equal to $500,000. A “HIGH” score for potential impact was defined as total cost of impact would be greater than $500,000.

[4] Fayette County writes its own multi-hazard mitigation plan independently of the Area Development District to which it belongs.

[5] Cumberland Valley ADD estimated potential losses only for critical facilities.

Area Development District	County	Estimated Losses
Gateway ADD	Bath	$ 838,500,000.00
	Menifee	$ 522,656,000.00
	Montgomery	$ 2,469,931,000.00
	Morgan	$ 953,904,000.00
	Rowan	$ 2,215,489,000.00
Green River ADD	Daviess	$ 15,426,498,674.00
	Hancock	$ 4,019,132,528.00
	Henderson	$ 4,711,473,338.00
	McLean	$ 2,090,997,652.00
	Ohio	$ 1,733,482,044.00
	Union	$ 2,990,835,384.00
	Webster	$ 3,861,742,416.00
Kentucky River ADD	Breathitt	$ 61,129,983.00
	Knott	$ 216,264,573.00
	Lee	$ 267,336,625.00
	Leslie	$ 294,032,069.00
	Letcher	$ 362,509,742.00
	Owsley	$ 186,156,853.00
	Perry	$ 452,788,163.00
	Wolfe	$ 187,500,384.00
Kentuckiana Regional[6] Planning and Development Agency (KIPDA)	Bullitt	$ 4,062,975.00
	Henry	$ -
	Jefferson	$ 1,808,080,870.00
	Oldham	$ -
	Shelby	$ -
	Spencer	$ -
	Trimble	$ -
Lake Cumberland ADD	Adair	$ 2,448,567,780.00
	Casey	$ 1,697,424,332.00
	Clinton	$ 1,316,116,762.00
	Cumberland	$ 967,288,669.00
	Green	$ 1,348,920,110.00
	McCreary	$ 1,139,879,571.00
	Pulaski	$ 5,049,274,348.00
	Russell	$ 1,613,920,706.00
	Taylor	$ 2,694,903,118.00
	Wayne	$ 1,668,379,353.00

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[6] KIPDA estimated potential losses only for government buildings.

Area Development District	County	Estimated Losses
Lincoln Trail ADD	Breckinridge	$ 999,237,848.00
	Grayson	$ 1,328,407,122.00
	Hardin	$ 6,457,655,731.00
	LaRue	$ 804,637,734.00
	Marion	$ 971,747,221.00
	Meade	$ 1,612,379,352.00
	Nelson	$ 2,546,410,178.00
	Washington	$ 622,977,057.00
Northern Kentucky ADD	Boone	$ 15,011,357,000.00
	Campbell	$ 11,032,354,000.00
	Carroll	$ 1,122,982,000.00
	Gallatin	$ 662,632,000.00
	Grant	$ 2,231,669,280.00
	Kenton	$ 29,879,599,815.00
	Owen	$ 958,574,982.00
	Pendleton	$ 1,212,853,158.00
Pennyrile ADD	Caldwell	$ 596,494,200.00
	Christian	$ 2,942,126,400.00
	Crittenden	$ 321,089,600.00
	Hopkins	$ 1,872,620,000.00
	Livingston	$ 430,254,000.00
	Lyon	$ 532,324,000.00
	Muhlenberg	$ 1,063,050,000.00
	Todd	$ 440,922,000.00
	Trigg	$ 953,316,000.00
Purchase ADD	Ballard	$ 545,949,576.00
	Calloway	$ 2,355,178,011.00
	Carlisle	$ 234,857,047.00
	Fulton	$ 277,810,192.00
	Graves	$ 1,886,576,304.00
	Hickman	$ 265,028,387.00
	Marshall	$ 2,457,186,169.00
	McCracken	$ 5,111,587,459.00
	Region CF[7]	$ 3,187,950,000.00

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[7] The Purchase ADD did not disaggregate by county the estimated potential losses to its Critical Facilities (CF). So, the $3.187 million dollar number reflects the additional losses for the whole region from vulnerable critical facilities.

A Note on Future Conditions[8]

The Commonwealth of Kentucky Enhanced Hazard Mitigation Plan for 2018 (CK-EHMP 2018) has relied on a recent study on climate conditions from modeling specific to Kentucky that was conducted by the United States Army Corps of Engineers (USACE) and the Ohio River Basin Alliance (ORB Alliance). This study is called *Ohio River Basin: Formulating Climate Change Mitigation/Adaptation Strategies through Regional Collaboration with the ORB Alliance*.

From this study, the Commonwealth of Kentucky assumes the following:

- There has been a gradual warming trend throughout the Ohio River Basin since the late 1970s.
- Precipitation has increased during the latter summer and early fall months since the late 1970s.
- Summer highs and winter lows between 2011 and 2040 will remain generally within what has been observed over that historic period. (But, record temperatures, rainfall, or drought cannot be ruled out.)
- The influence of the jet stream across the Ohio River Basin latitudes increases the *variability* of the weather (and further complicates forecasting future climatic conditions).
- Significant changes in river flow discharges and mean annual air temperatures will not be occurring before 2040. The climate will not vary substantially from what has been experienced between 1952 and 2001.

In other words, there has been gradual warming since the late 1970s. This gradual warming will continue without much significant change until 2040. (After 2040, the modeling in the study predicts temperatures may rise one (1) degree every decade through 2099.) Further, part of this gradual warming since the late 1970s involves precipitation increases. Precipitation increases affects nearly every hazard identified in this hazard mitigation plan: Landslides are triggered by precipitation; sinkholes flood with increased precipitation; flash flooding increases from severe storms; and winter storms either increase or become more severe.

The variability interpretation also is interesting and applicable to expected future conditions for Kentucky's identified hazards:

With gradual warming and its effects on summer highs and winter lows, with increased precipitation, and with increased variability of the weather, it is expected that the probability (or, rather, the frequency and/or severity) of landslide events will increase.

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[8] The below statement is made by the University of Kentucky Hazard Mitigation Grants Program Office (UK-HMGP) and by Kentucky Emergency Management (KYEM) and does not necessarily reflect the views of the Kentucky Geological Survey (KGS).

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