real-time monitoring of electronic information and processes related to crisis management and emergency preparedness, and systems can provide notifications when anomalies occur.

There are clear benefits to using e-audits, including increased efficiency, reduction of audit errors, and introduction of real-time monitoring to enhance audit methodology.

Elisa Nichols
Independent Scholar

See Also: National Fire Protection Association (NFPA) 1600, 2007, and 2010; Preparedness.

Further Readings

Bernstein, Jonathan. *Manager's Guide to Crisis Management*. New York: McGraw-Hill, 2007.

International Organization for Standardization (ISO). *ISO 9001:2008—Quality Management Systems—Requirements*. ISO, 2008.

International Organization for Standardization. *ISO 19011:2011—Guidelines for Auditing Management Systems*. Geneva: International Organization for Standardization, 2011.

Messier, W. F., Jr. *Auditing and Assurance Services: A Systematic Approach*. 3rd ed. New York: McGraw-Hill/Irwin, 2003.

National Fire Protection Association. *NFPA Standard 1600: Standard on Disaster/Emergency Management and Business Continuity Programs*. Quincy, MA: NFPA, 2010.

Russell, J. P. "Remote Control." *Quality Progress* (January 2011).

Turoff, Murray, et al. "Assuring Homeland Security: Continuous Monitoring, Control and Assurance of Emergency Preparedness." *Journal of Information Technology Theory and Application*, v.6/3 (2004).

Avalanches and Landslides

In the El Niño storms of early 1998, the U.S. Geological Survey (USGS) documented approximately $150 million in losses from 300 landslides that occurred in the California area. The 2006 landslide in the Philippines caused about 200 deaths, and about 1,000 people disappeared in the debris. Similar disasters also affect developed countries such as Japan, where approximately 3,000 people have been killed by landslides over the last century. Most landslides have occurred in Asia; however, the costly landslide damages have occurred in Europe (Table 1). Landslides and avalanches are the most destructive disasters in developing countries, particularly those with high population growth, intensive land use and deforestation, and construction and mining activities. Central America, northwestern South America, the Caucasus region, the Himalayan belt, Taiwan, the Philippines, Indonesia, Italy, and Japan are among the landslide hazard hot spots.

Mass Wasting Hazards

Landslides are external geologic processes called "mass wasting." Major causes of mass wasting are the downslope movement of rock under the force of gravity, slope angle, weakness in the structure and composition of rock (weathering), storms or heavy rain for periods of time, snow melting, human activities on slope, erosion of slope toe, deforestation loading or dredging, construction of roads, and mining.

If the mass moves along a curved surface of rupture, the movement is called slump. Usually, slumped material does not travel fast nor very far. If the material involved in rapid downslope movement is a large amount of water-saturated flow, the event has a disastrous effect on people and property. During the extremely fast mass movement, called an avalanche, rock debris along with ice and snow can move downslope at speeds of 200 kilometers (125 miles) per hour, causing a destructive event. Rock slides occur when blocks of bedrock break loose and slide downslope. Such events are among the fastest and most destructive mass movements. Rock slides tend to be most active during the spring, when heavy rains and melting snow are greatest.

Earthquakes also often trigger rockslides. The 1811 earthquake at New Madrid in Missouri caused landslides in the area of more than 13,000 square kilometers (5,000 square miles) along the Mississippi River valley. In terms of property damage, the most devastating effects of the 1964 Alaska earthquake were landslides in Anchorage, some 130 kilometers (80 miles) from the center of the quake. The earthquake triggered landslides of various types and dimensions, causing extensive damage to settlements, farmlands, and infrastructures. In addition to killing people outright, they can also have an extremely serious impact in terms of hampering rescue operations. Landslide activity can cause damage to communication and power networks, and the increased amount of sediment production and movement can also cause many problems.

Mudflow is a rapid type of mass movement that is most characteristic of canyons in semiarid mountainous regions that usually have little or no vegetation and involves a water-saturated debris flow during a large, heavy rain. The rapidly moving dense mudflow can push and carry large boulders, trees, and even houses long distances. The hot materials from the volcano cause rapid melting of great amounts of snow. Such saturated debris flow was also triggered by the volcanic activity of Mount St. Helens in 1980. "Earth flows" occur in humid areas as a result of excessive rainfall. Earth flows are quite viscous. They generally flow more slowly for a short distance downslope, unlike mudflows.

"Creep" is a type of mass movement that involves the gradual downhill movement of soil and may be initiated if the ground becomes saturated with water. Although the movement is slow, its effects are easily recognized. Creep causes fences and poles to tilt, and tree trunks are often bent with the movement.

The steep, narrow continental margins are also highly affected by slope failure processes. Downslope movements of dense mass movement eroding and transporting materials with high speed along the continental slope and rise are perhaps triggered by earthquake activity. In 1929, off the coast of Newfoundland, seismic activity had caused multiple breaks and the breakage of 13 transatlantic telephone and telegraph cables. The avalanche of sediment raced downslope with a speed approaching 80 kilometers (50 miles) per hour on the steep slopes, snapping the cables in its path.

Submarine slides are common and very efficient mechanisms of sediment transfer from the shelf and upper slope to deep-sea basins. They can occur on very gentle slopes, and they have the potential for triggering a tsunami. For instance, steep submarine scarps (15 degrees) of the Marmara Sea, marked with deep basins bounding with continuous sediment transportation via submarine canyons, carry a high risk associated with a large-scale slope failure to generate tsunamis and severe damage along the coastal area of Istanbul.

The tsunami generated by the earthquake-triggered Grand Banks slide in 1929 killed 27 people in Newfoundland. The 15-meter-high tsunami that killed more than 2,000 people in Papua New Guinea in 1998 was also a result of an earthquake-triggered huge submarine slide. The enormity of the Storegga slide, which took place 8,200 years ago, makes it one of the largest submarine slides along the coasts of Norway, Scotland, and the Faeroe Islands. Large submarine slides may again generate tsunamis with the potential for severe damage along coastlines, where oil production from offshore fields is ongoing in the Norwegian margin, Gulf of Mexico, offshore Brazil, the Caspian Sea, and west Africa. Another example is the land failure along the shelf edge at the Nice airport in 1976. Nuclear power plants are often located

Table 1 Landslide damages between 1903 and 2006

	Number of events	Killed	Homeless	Affected	Total affected	Damage, $ (000s)
Africa	23	745	7,936	11,748	19,740	
Americas	144	20,651	186,752	4,480,037	4,671,598	1,226,927
Asia	244	17,554	3,784,351	2,389,151	6,177,032	1,477,893
Europe	80	17,349	8,810	41,281	50,822	2,157,389
Oceania	16	541	8,000	2,963	11,015	2,466

Source: EM-DAT.

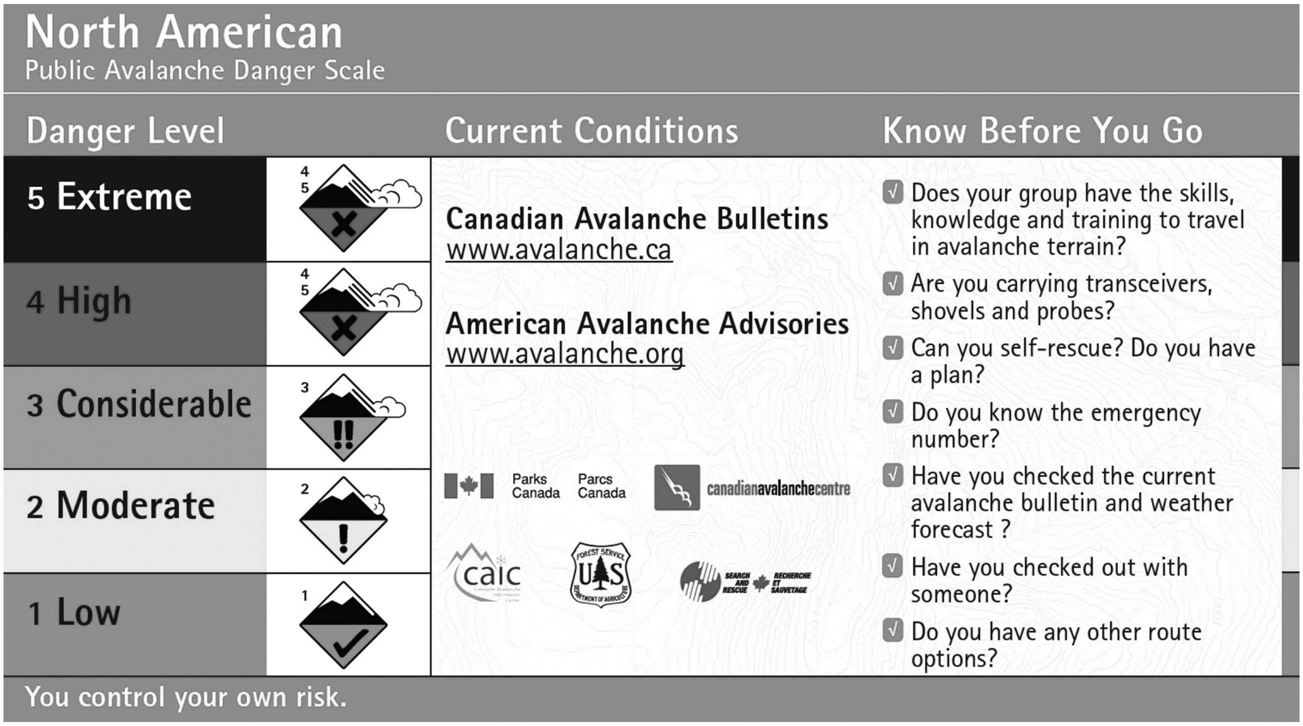

Figure 1 North American public avalanche hazard scale
Source: Canadian Avalanche Association.

in such coastal areas. Depending on the volume of deposits, submarine landslides can generate tsunami waves that can affect an entire basin.

Hazard Mapping and Monitoring

Movements such as rockslides and "rock avalanches" are the most catastrophic events of mass wasting. Since these events kill thousands, there is a need for intensive sustainable mitigation measurements, so that, through more effective and timely warnings, monitoring, forecasting, and better risk reduction, lives can be saved.

The Disaster Relief Act of 1974 delegates to the USGS the responsibility to map both flow source areas and existing landslides and to issue disaster warnings for landslides and other geologic catastrophes within the scope of this Local Hazard Mitigation Plan. The USGS has traditionally focused its landslide hazards research in specific geographic areas, such as the Pacific Northwest or southern California. The USGS and its partner, the National Weather Service, developed debris flow warning systems. The USGS has committed to assess the potential for hazard, to identify infrastructure that may be at risk, and to measure real-time precipitations aided by radar data. Warnings are broadcasts through the Advanced Weather Interactive Processing System (AWIPS) to local emergency managers and the media.

Landslides do not only kill people; they can also have an extremely serious impact in terms of hampering rescue operations and the delivery of assistance and can cause long-term damage to communication and power networks. The increased amount of sediment production and movement can also cause many structural and nonstructural problems.

It is also common that landslides do not occur as one singular event but may be induced by earthquakes and volcanic eruptions. Furthermore, landslides can also trigger other disasters such as floods, debris floods, and tsunamis. Therefore, mitigation of other disasters related to landslides should also be integrated into the local/national slope master plan.

The key factors in a comprehensive and integrated disaster management system are hazard and vulnerability identification, risk assessment, and risk mitigation. Generation of "landslide maps" is a core component of risk reduction initiatives and of great significance for assessing the landslide risk in terms of pointing out past and current landslide occurrences, identifying expected damage or losses by landslides, estimating landslide frequency, and risk reduction programs. The USGS produces basic types of landslide maps in California: landslide inventory maps, landslide hazard maps, landslide risk maps, and landslide zone maps.

The national slope master plan should provide crisis management using risk assessment, risk management, and risk communication (Figure 1), with the appropriate standard operating, early warning, evacuation, and rapid (post-disaster) information supply, and needs assessment procedures to support relief and efforts at building back better at the response stage.

Nilgün Okay
Istanbul Technical University

See Also: Earthquakes; Floods; Risk Analysis; Tsunamis; U.S. Geological Survey (USGS); Volcanic Eruptions.

Further Readings

Briand, Frederic, ed. "CIESM Workshop Monographs No 42: Marine Geo-Hazards in the Mediterranean, Nicosia, Cyprus, 2–5 February 2011." http://www.ciesm.org/online/monographs/Nicosia.html (Accessed December 2011).

EM-DAT: The OFDA/CRED International Disaster Database. http://www.em-dat.net (Accessed December 2011).

IGOS. "IGOS Geohazards Theme Report." (August 2007). http://igosg.brgm.fr (Accessed December 2011).

Nadim, F., O. Kjekstad, P. Peduzzi, C. Herold, and C. Jaedicke. "Global Landslide and Avalanche Hotspots." *Landslides*, v.3/2 (2006).

Shaw, Rajib, Yukiko Takeuchi, and Badaoui Rouhban. "Education, Capacity Building and Public Awareness for Disaster Reduction." In *Landslides: Disaster Risk Reduction*, K. Sassa and P. Canuti, eds. Berlin Heidelberg: Springer-Verlag, 2009.

U.S. Geological Survey. "National Landslide Hazards Mitigation Strategy: A Framework for Loss Reduction." Circular 1244. Washington, DC: U.S. Geological Survey, 2003.

U.S. Geological Survey. "National Landslide Hazards Program (NLHP)." http://landslides.usgs.gov (Accessed December 2011).