Pre-Event Management Strategies for Geophysical Hazards

Geophysical hazards, such as volcanic eruptions, earthquakes, tsunamis, and landslides, cannot be prevented; however, their impacts on people, buildings, and infrastructure can be mitigated through effective pre-event management strategies. These strategies aim to monitor hazards, reduce vulnerability and limit potential damage before an event occurs. The effectiveness of such measures varies between countries, often depending on levels of wealth, technology and governance.

1. Volcanoes: Monitoring and Lava Diversion

One of the most important pre-event strategies for volcanoes is monitoring. Modern volcano observatories use a range of technologies to detect early warning signs of an eruption. GPS sensors are placed around the crater and on the flanks of volcanoes to measure ground deformation. As magma rises, it causes the volcano to swell slightly. These tiny movements, sometimes only a few millimetres, can indicate increasing pressure beneath the surface and help scientists predict when an eruption may occur. This type of monitoring is used at volcanoes such as Mount Etna in Italy and Kīlauea in Hawaii.

Gas monitoring is also important. Increases in sulphur dioxide and carbon dioxide emissions can signal that magma is approaching the surface. Thermal cameras and satellite imagery are used to detect rising temperatures around vents and lava domes. Together, these methods enable authorities to issue evacuation warnings and restrict access to hazardous areas.

In some cases, physical attempts are made to control lava flows. Lava diversion involves constructing barriers, channels or earth banks to redirect lava away from settlements and critical infrastructure. A well-known example is the 1973 eruption on the island of Heimaey in Iceland, where seawater was sprayed onto advancing lava to cool and solidify it, successfully protecting the harbour. On Mount Etna, artificial channels and embankments have been built to steer lava away from towns and farmland. However, lava diversion is difficult and expensive, and the exact path of lava is often unpredictable. While such methods can protect small areas, they are not always effective for large, fast-moving flows.

Land-use planning is therefore essential. Hazard maps identify high-risk zones near vents or along likely lava flow pathways. In these areas, development may be restricted, and emergency plans prepared. Buildings in ash-fall zones are often designed with steeply sloping roofs to prevent ash from accumulating and causing collapse.

2. Earthquakes: Building Design and Ground Stability

Earthquakes pose a major threat because they strike with little warning and can cause widespread structural failure. The most effective pre-event strategy is the design of earthquake-resistant buildings. In high-risk areas, such as Japan, Chile and California, strict building codes require structures to be flexible rather than rigid. Flexible materials, such as steel frames and reinforced concrete, allow buildings to sway during shaking without collapsing.

Base isolation is a key technique used in major cities like Tokyo. Buildings are constructed on rubber bearings or springs that absorb seismic energy and reduce the amount of movement transferred from the ground to the structure. Cross-bracing, shear walls and deep foundations anchored into solid bedrock also increase stability.

The height and shape of buildings are important. Tall, narrow structures are more vulnerable to resonance, where seismic waves match the building's natural frequency, increasing shaking. For this reason, some cities limit building heights in high-risk zones.

Ground conditions also affect earthquake damage. Soft sediments, such as clay and reclaimed land, can undergo liquefaction, where the ground behaves like a liquid during shaking. Pre-event planning therefore involves avoiding construction on unstable soils or improving ground strength through compaction and drainage.

Tsunamis are often triggered by undersea earthquakes and can cause devastating coastal flooding. Pre-event management focuses on early warning systems, physical defences and evacuation planning. In the Pacific, networks of ocean-floor pressure sensors and surface buoys detect sudden changes in sea level and transmit data to warning centres. When a tsunami is detected, alerts are sent to coastal communities, allowing time for evacuation. Coastal defences, including seawalls, breakwaters and raised embankments, are designed to reduce wave energy. Japan has built some of the world's largest tsunami walls, particularly along the Tōhoku coast. These structures can reflect or absorb wave energy and reduce inland flooding, although extremely large tsunamis can overtop or разруш them, as seen in 2011.

Evacuation planning is equally important. Clearly marked routes to high ground, vertical evacuation towers, and regular drills help communities respond quickly. Coastal zoning prevents dense settlement in the most exposed areas, reducing potential loss of life.

3. Mass Movement: Slope Stabilisation and Hazard Mapping

Mass movement, including landslides, rockfalls and mudflows, is common in mountainous and high-rainfall regions. Pre-event management aims to stabilise slopes and control water movement.

Slope stabilisation involves a combination of engineering and environmental techniques. Retaining walls and gabions (wire cages filled with rocks) support unstable slopes and prevent material from collapsing. Rock bolts and mesh are used on steep cliffs to hold fractured rock in place and reduce rockfall risk.

Drainage is crucial because water increases pore pressure and reduces friction between particles, making slopes more likely to fail. Surface drains, tunnels and pipes are installed to remove excess groundwater and redirect runoff safely. In some areas, rivers and streams are channelled away from unstable slopes to prevent undercutting.

Vegetation plays a natural stabilising role. Tree roots bind soil together, while forest canopies reduce the impact of heavy rainfall on the ground. Reforestation programmes in places such as Hong Kong and Nepal have helped reduce landslide frequency.

Terracing is widely used in mountainous agricultural regions. By cutting slopes into steps, the angle is reduced, lowering the force of gravity acting on the soil and decreasing the likelihood of slumping.

Hazard mapping is another key strategy. Landslide hazard maps identify areas of high, medium and low risk based on slope angle, geology, rainfall and past events. These maps guide land-use planning, helping authorities restrict construction in the most dangerous zones and plan evacuation routes.

Conclusion

Pre-event management strategies for geophysical hazards focus on monitoring, engineering design, land-use planning and community preparedness. GPS and gas monitoring improve volcanic prediction, while lava diversion can protect specific sites. Earthquake-resistant buildings and base isolation reduce collapse risk. Tsunami defences and warning systems provide time to evacuate, and slope stabilisation techniques limit mass movement in vulnerable terrain.

Although such measures cannot eliminate risk entirely, they can greatly reduce vulnerability and save lives, especially where investment in technology, infrastructure and planning is high. The contrast between well-prepared countries such as Japan and more vulnerable regions with limited resources highlights the importance of development in effective hazard management.