Preface

Many natural phenomena occur over a wide range of magnitudes. Typically, small events occur more frequently than large ones. For example, small earthquakes occur frequently, while large earthquakes are rare. Sixty years ago, earthquake scientists developed a relationship, known as the 'magnitude–cumulative frequency' (MCF) relationship, to characterize earthquake hazards.

MCF relationships are widely used today in engineering geology to evaluate hazard and risk to people and property, specifically the likelihood or probability of earthquakes, floods, severe storms and landslides of different sizes. For example, an MCF relationship for floods can be constructed for any watershed if a continuous and lengthy record of river discharge is available. If the observed peak discharge each year over a period of N years is ranked in the order of decreasing magnitude, from the largest to the smallest, the largest flood has an annual probability of occurrence of 1/N, because only one such event was observed in N years. The cumulative frequency of the second largest event or larger is 2/N, because two such events occurred in N years. Similarly, the cumulative frequency of any given rank 'x' or larger is x/N. When such MCF data are graphed using logarithmic scales, they commonly plot on a reasonably straight line.

When compiling lists of events for MCF relationship analysis, only events of similar type, nature or process should be used. Such events are referred to as a 'population'. In the case of landslides, for example, the events in each population must be similar in type, character, materials and mechanics of failure and movement. Two populations that are not similar in these characteristics may exhibit different MCF relationships.

The construction and use of MCF relationships assume stationarity in the conditions controlling the process that is being modelled. It is reasonable to assume stationarity in earthquake occurrence over time, as long as the monitoring period is sufficiently long, typically more than two centuries. This assumption, however, is almost certainly invalid for atmospheric and hydrological phenomena, such as cyclones, debris flows and floods, because climate is continually changing.

Climate Change and Hazardous Processes

Climate change, which can be defined as long-term weather patterns that deviate from historical ranges, can have an effect on the volume and/or frequency of landslides, floods and other hydrometeorological hazards. Over the past two decades, successive reports by the Intergovernmental Panel on Climate Change (IPCC) have expressed increased confidence that climate is changing around the world and will continue to do so in the foreseeable future. The physical processes driving climate change are complex and the models on which the forecasts of climate change are based are simplifications and subject to uncertainty and error. Global climate models are downscaled to regional and local levels by comparing output from the models with historical, regional and local weather station data. By doing so, climate scientists attempt to forecast annual and seasonal climate changes at scales that are pertinent to government decision-makers, land-use planners, engineering geologists and engineers.

Even more difficult to predict are changes in (1) volumes, frequencies and even types of landslides, (2) peak discharges of floods and (3) the severity and frequencies of extreme weather events. Such changes can be regarded as second-, third- or even fourth-order effects of climate change.

Climate change affects the entire hydrologic system by changing temperature; type, amount and intensity of precipitation; evaporation; balance between water storage as ice, snow or liquid forms; and levels of soil moisture. By the end of this century, mean global temperatures at Earth's surface are likely to be 2–4 °C warmer than today, but there will be pronounced spatial and seasonal differences on our planet. For example, warming will be greater at high latitudes and in high mountains than elsewhere. Projected temperatures for an average year will be warmer than almost all of the warmest years in the recent past.

Changes in precipitation are more difficult to forecast, with many areas experiencing an overall increase in rainfall and others likely to see a reduction in precipitation. Many models suggest that extreme rainfall events will become more common with warming, although this is by no means certain. An increase in surface water runoff is expected during the winter months over large areas of North America and Northern Europe due to a greater proportion of precipitation falling as rain. An earlier spring freshet due to warmer spring temperatures is also expected. Drier conditions are expected during the summer.

Although the above-described conditions are expected to produce characteristically lower spring freshets and summer stream flows, years with severe stream floods are likely to occur in the future. For smaller watersheds with a hybrid (snowmelt and rainfall-dominated) runoff regime, a trend towards purely rain-dominated stream floods is expected. Increased temperatures are also expected to influence the intensity of summer convective rainstorms and the frequency of intense, long duration winter rainfall in areas with temperate climate. These changes have a potential bearing on the timing and magnitude of winter storms, rain-on-snow events, spring freshets, the soil–water balance and effects of antecedent moisture on landslides.

Warmer winters will raise winter freezing levels and decrease snow cover. This effect, in combination with warmer summers, will cause glaciers in high mountains to continue to thin and retreat, as they have over the past century.

As noted above, changes in landslide activity are third- or fourth-order effects of climate change; they are at least one step removed from changes in precipitation and surface water runoff. Therefore, the uncertainties associated with forecasting the effects of climate change on landslide size and frequencies on a regional, much less local, scale are large. Nevertheless, any increase in the amount and intensity of winter precipitation will likely increase the number and frequency of small and perhaps medium-sized landslides, specifically debris flows and debris floods. Although individual rainstorms are not expected to have an effect on stability of rock slopes, increased long-term saturation of the ground could reduce the stability of steep slopes, leading to major rockslides.

Because of the large uncertainties in estimates of landslides and floods in a changing climate, possible climate change effects must be dealt with by selecting suitably conservative parameters during the design of any mitigation, and by selecting solutions that have certain flexibility with respect to the magnitude of potential effects.

Incorporating Climate Change into Professional Practice?

The primary duties of professional engineers and geoscientists are to (1) hold paramount the safety, health and welfare of the public, (2) protect the environment and (3) promote health and safety within the workplace. Changing climate conditions, particularly weather patterns that deviate from historical ranges, may adversely affect engineered systems. It is the geo-scientist's responsibility to ensure that possible impacts of climate change on hazardous natural processes are articulated in the hazard or risk studies they perform. It is the engineer's duty to take all reasonable measures to ensure that engineered systems are designed and built to properly function under new climatic conditions. This understanding imposes a responsibility of due diligence on professionals to address the issue of climate change in their activities. This responsibility plays out in two ways. First, engineering geologists and engineers must consider climate change in their work to ensure public safety. Second, given the level of awareness of this issue and high visibility of impacts arising from more intense and severe weather events, engineers may ultimately be held personally or jointly liable for failures or damages arising from failure to anticipate climate impacts on engineered systems. The scientific literature indicates that significant departures from historical climate averages are happening and will continue to occur, thus planning and engineering design must take into account these departures.

Professional engineers and engineering geologists have a higher standard of care than a layperson. They have more years of training and experience with geoscience and engineering matters, and are uniquely qualified to identify and respond to issues that may compromise public health and safety through their work. This standard of care is currently poorly defined and is constantly being reviewed both by professional associations and the legal profession. The concept of 'reasonable level of care' will continue to evolve over time, and climate change imposes a new and evolving pressure on this standard.

Springer

http://www.springer.com/978-3-319-09299-7

Engineering Geology for Society and Territory - Volume 1
Climate Change and Engineering Geology
Lollino, G.; Manconi, A.; Clague, J.; Shan, W.; Chiarle, M. (Eds.)
2015, XX, 572 p. 325 illus., 273 illus. in color., Hardcover
ISBN: 978-3-319-09299-7