

b) Glacial outburst floods

A glacial outburst flood is also known by the Icelandic term *jökulhlaup*. It is a powerful flood caused by the sudden discharge of a subglacial or ice-dammed lake. The catastrophic flooding from glacial Lake Missoula described in Chapter 5 provides an example of a glacial outburst flood on the largest scale. There is potential for an outburst flood wherever meltwater collects behind an ice obstruction, and sudden release of water can be triggered in a variety of ways. These include:

- increased flotation of ice as water levels rise
- overflow and melting of an ice dam
- break down of an ice dam because of tectonic activity
- enlargement of pre-existing tunnels beneath an ice dam because of increased water pressure.

Outburst floods can also be cyclic in nature. Following a flood, the ice dam may reform and the ice-dammed lake will gradually fill over several years until it reaches the critical level necessary to burst through the obstruction again.

Glacial outburst floods present a hazard in many glacial environments where settlements or structures are located down-valley of glaciers. They are particularly frequent in Iceland because of volcanic activity that both generates meltwater beneath glaciers and acts as a trigger for ice instability and subsequent release of meltwater. The Vatnajökull ice cap located in south-east Iceland covers about 8% of the country and averages 400 m thick, and it is the source of large outburst floods that occur fairly regularly over time. Heat from the Grimsvötn volcano beneath the ice cap melts ice and creates a subglacial lake within its caldera. When the subglacial lake reaches a critical size it forces its way through subglacial tunnels and the lake drains catastrophically in a matter of hours. This process produces outbursts on average every 5–6 years, with total discharges usually ranging between 0.5 and 3.5 km³. In 1922 an outburst flood occurred that discharged approximately 7 km³ of water and, for a short time, had a maximum flow about a quarter of the flow of the Amazon River. More recently, on 30 September 1996, an eruption of Grimsvötn broke through the ice sending up a column of ash 10 km high and melting a large quantity of ice. The meltwater remained obstructed by ice until 5 November when it burst through the glacier. This was the largest flood from Grimsvötn since 1938 with a massive peak discharge of 55 000 m³ s⁻¹, and it severely damaged bridges, roads and power lines causing an estimated US\$15 million of economic loss.

Besides Iceland, glacial outburst floods pose a high risk in several other parts of the world. In Washington State, USA there is a high potential for outburst floods from Mount Rainier, and this presents a serious threat to the area around Seattle. Mount Rainier has 25 glaciers radiating from its summit, containing more ice than any other mountain in the USA outside Alaska. Outburst floods from the mountain have occurred many times in the past century because of periods of relatively high temperature and rainfall that generated excess meltwater. Human-induced climatic change (global warming) could cause more and, perhaps, larger outburst floods of this type in the future. Mount Rainier is also a volcano, and an eruption would melt far more snow and ice causing immense flooding downstream. By mixing with sediment and soil, the flood waters from an eruption would produce a **lahar** (mudflow) capable of travelling a distance over 50 miles from the volcano. Studies of lahar deposits around Mount Rainier have shown that past lahars have extended well into areas near Puget Sound that are now heavily populated.

There is also growing concern about glacial outburst floods in the Himalayas. In 1985 the Dig Tsho glacial lake in Nepal burst through its confines destroying 14 bridges and causing about US\$1.5 million of damage to a hydroelectric power plant downstream. However, this disaster was relatively small scale compared with predictions for future glacial outburst floods in the region. Recent climatic warming is believed to have significantly increased melting and retreat of Himalayan glaciers, and many glacial lakes in Nepal and Bhutan have become dangerously full. One of these lakes, Tsho Rolpa lake in the Dolakha district of Nepal, has grown to six times its size in the late 1950s. An outburst from this lake would damage a large amount of infrastructure and agricultural land downstream and would threaten the lives of over 10 000 people. Engineers are developing and installing sensors and sirens in the hazardous zone in the hope that in the event of an outburst flood people will have early enough warning to evacuate. Scientists from the United Nations Environment Programme (UNEP) have estimated that more than 40 other lakes in Nepal and Bhutan have become similarly unstable and could experience outbursts in the next several years.

Along the Andes in the tropics, muddy floods and ice/rock avalanches from high-altitude glaciers are sometimes referred to as **alluviones**. Similar to *jökulhlaups*, they can be caused by sudden release of meltwater from a formerly blocked glacial lake. They can also be caused by earthquakes that trigger avalanching of ice and rock. The Cordillera Blanca mountains of Peru have been the source of some devastating alluviones. In 1970, for example, an earthquake-induced ice and rock avalanche from Mount Huascarán travelled 11 miles from its source, burying the towns of Yungay and Ranrahirca, and killing about 18 000 people.