CHAPTER THREE

MUDFLOW HAZARD ASSESSMENT

3.1. Need for assessment

The first step to be taken to avoid, or at least alleviate, damage from mudflows at a given location is to assess the hazards involved as realistically as possible Any such assessment, however, can at best be only approximate, in view of the considerable variations in the types and magnitudes of eventual triggering events (e.g., rainfall, earthquakes, etc.).

In general, the assessment should relate to the entire catchment area above the particular location in question, whether it be an individual structure, a village or part of a valley. In locations where there is a possibility of volcanic activity, it may be desirable to take into account areas beyond the catchment, because volcanic ash and lava flows do not necessarily originate from within the catchment. The possibility of massive mudflows overflowing the divide separating neighbouring catchments should also be considered.

3.2. Means of mudflow hazard assessment and analysis

In attempting to estimate the possible frequency and nature of future mudflows, it is very useful first to gather such evidence as may be available about the history of mudflows in the area under consideration. Potential sources of information about these past mudflows for the purpose of hazard assessment are described below.

3.2.1. Interviews with local residents

Facts about the times of occurrence and magnitudes of past mudflows can be collected through interviews with longtime local residents. The information obtained in this way can cover a period of six to seven decades Since oral information depends on the memory of the local people, details are often obscure. Anything which can be done to confirm such evidence is helpful.

3.2.2. Historical records and documentation

Historical records of past mudflows and resulting damage, where they exist, can prove most valuable One hundred years of mudflow records for a mountain range or a valley may well permit the first evaluation of the most dangerous torrents, the frequency of local debris flows and meteorological triggering events. Such records might be sought at municipal and other local offices, local churches where parish registers are kept, national archives, government offices and libraries. Back issues of local newspapers, if they exist, are often an excellent source for *informal* records, keeping in mind that the details they contain may not be the most accurate.

3.2.3. Field surveys

Information collected on the basis of the interviews and documentation recommended above should be verified by a field survey of pertinent geomorphological features.

The objectives of such a survey are to:

- Confirm the information obtained from interviews and historical records;
- Find and examine features which may initiate mudflows; and
- Place benchmarks and markers to monitor any future changes in topography.

Alluvial cones and fans can provide valuable information about past mudflows. The areal extent, slope and roughness of their surfaces largely depend on quantities of both flood and sediment. the slope of the channel and the size of the particles contained in the flood. The diameters of boulders strewn about on the surface of cones and fans can give hints as to the carrying capacity and destructive power of past mudflows. The thickness, internal structure and texture of debris layers are indicators of the mechanism of deposition. Structures such as layered deposits and parallel lamination of sandy lenses indicate a relatively tranquil process of alluvial sedimentation, while massive unsorted units of block debris indicate generally violent mudflow events.

Distribution of boulders and debris lobes is a good index to assist in the identification of the mudflow discharge in terms of volume, discharge phases, flow direction, travel distance, dynamic characteristics (such as mode of flow, velocity and impact force), and sometimes the source of debris Patches of debris above the channel often indicate the highest level attained by the moving debris. Along curved reaches of a valley the centrifugal forces tend to cause mudflows to ascend the bank on the outer side of the curve, a phenomenon known as *superelevation*.

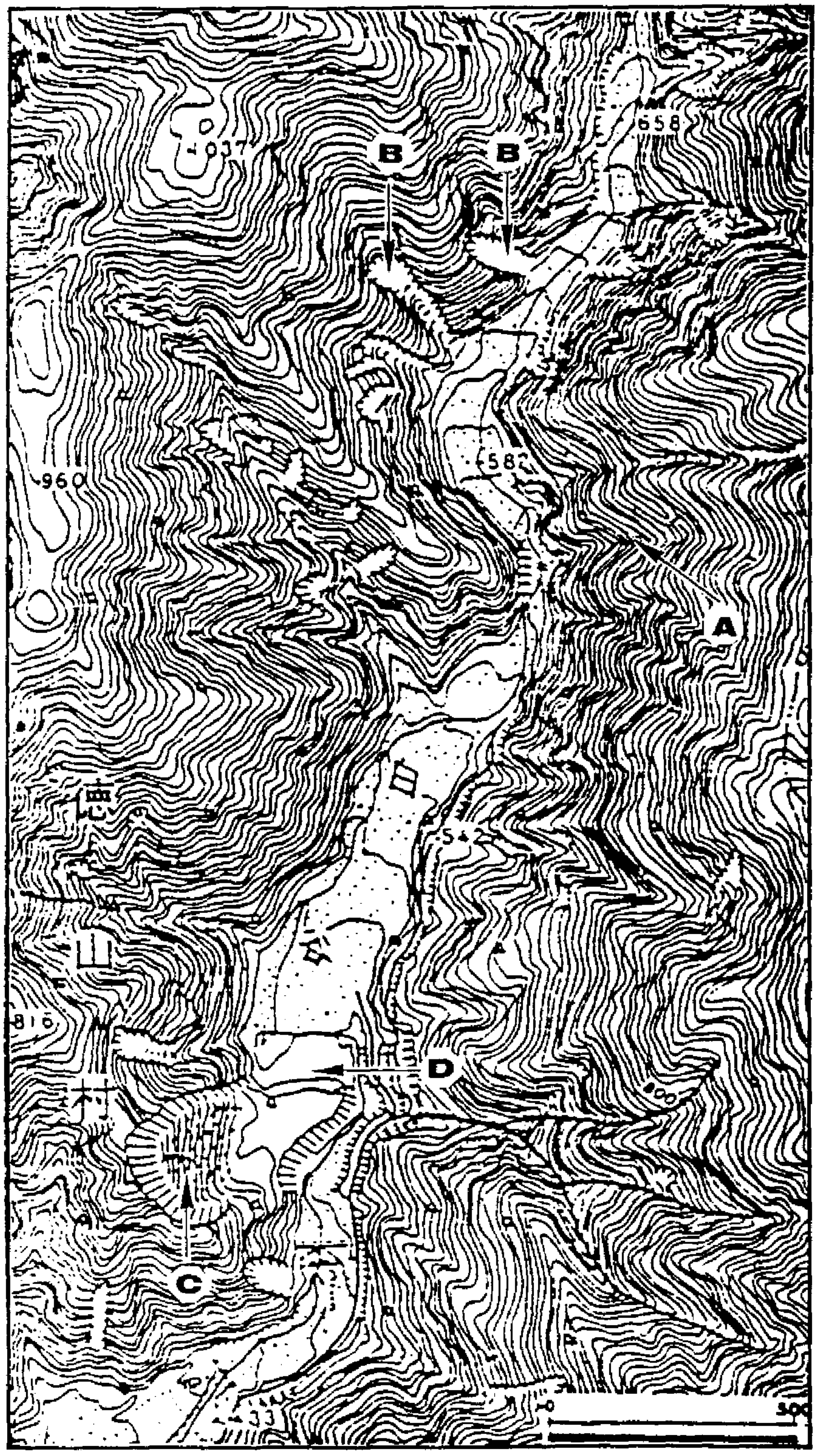

FIGURE 3.1 Topographical features of a source area (Oishi *et al.*, 1985).

3.2.4. Topographical and geological maps and aerial photographs

Some hazard indicators or "silent witnesses" in an alluvial fan, a gorge or a catchment can be identified on a topographic map of adequate scale. A study of contour lines may provide information about landslides, rockfalls, slope failures, terraces and gullies (*Fig. 3.1*). For instance, a marked local deviation from the parallelism of adjacent contour lines may indicate the presence of a debris lobe.

Studying geological maps of the area may be very useful because they can provide a clear picture of geological formations and mass movements, as well as providing suggestions on the dynamics of the displacements. For this purpose, the most appropriate maps are large-scale geological maps. Aerial photographs and photographs from space are useful and efficient tools for both reconnaissance and detailed surveys. Stereoscopic images derived from a pair of photographs may give clear views of the geological, morphological and other essential properties of the torrent system. Sets of aerial or space photographs taken at regular intervals provide qualitative and quantitative information on any changes which may have taken place in the topography, vegetation or other features of the area.

Studying topographical maps and aerial photographs prior to a field survey can permit major savings of time, energy and cost. There is, however, no substitute for a first hand on-site examination of the topographical features of the area under consideration.

3.2.5. Observation of vegetation

The age, distribution and some abnormal features of vegetation can provide useful information about the time of occurrence and magnitude of past mudflows.

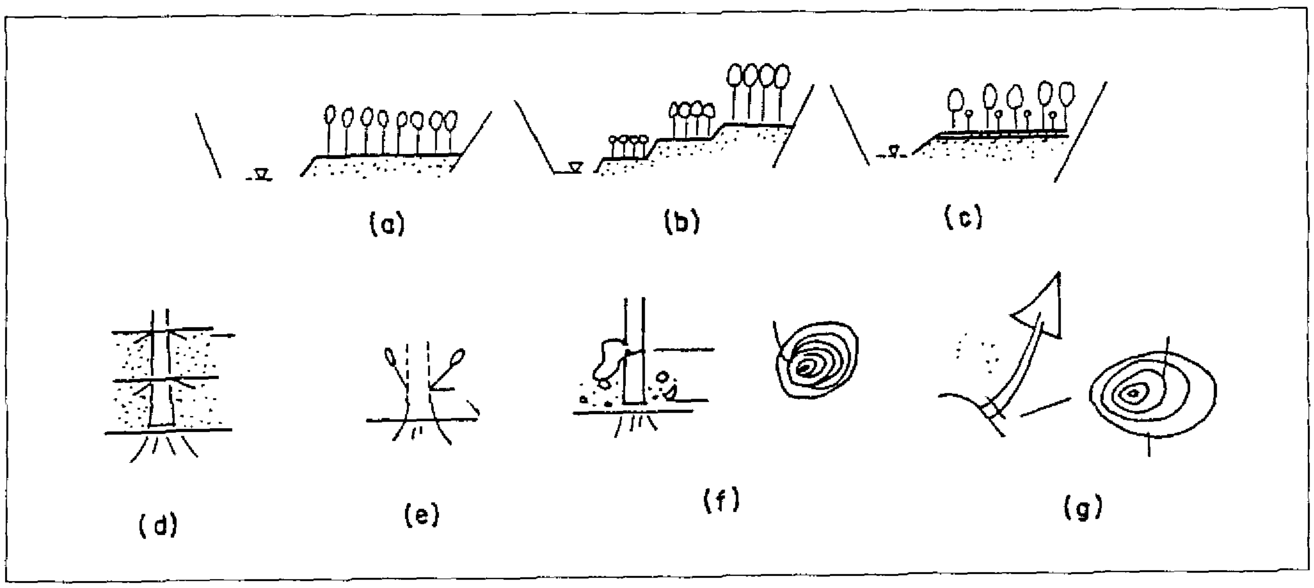

FIGURE 3.2 Use of vegetation and the analysis of the annual ring of trees to assess the age and characteristics of mudflow: (*a*) Natural forest of equal age; (*b*) Terraced forest; (*c*) Dual-phased forest; (*d*) Adventitious roots; (*e*) Germination; (*f*) Bark wrapping; and (*g*) Ate. (Araya, 1972).

Natural forests of equal age, that is, those in which all the trees are equally old and generally of the same height (*Fig. 3.2* (a)), are formed when trees take seed on the soil formed as a result of a mudflow. A terraced forest (*Fig. 3.2* (b)) may be formed on the terraced deposits on a valley floor. The age of such a forest may give a clue to the age of the terrace. A dual-phased forest (*Fig. 3.2* (c)) may be formed when a fresh layer of sediment is deposited on an existing terrace and, in turn, becomes seeded with trees.

"Adventitious" roots (i.e., roots which sprout from the trunk of a tree above the base), may grow when the lower portion of a tree is buried by sediment (*Fig. 3.2* (d)). They can serve to determine the height of a past mudflow and to make a crude estimate of its volume.

If a tree trunk is broken by a mudflow, sprouts may germinate from the stump soon after (*Fig. 3.2* (e)), in which case the annual ring corresponding to the sprouts may indicate the year of the event. Bark wrapping may take place if a tree has been hit by a mudflow boulder and if the annual rings are damaged. Rings formed subsequently wrap the damaged portion, as shown in *Figure 3.2* (f). An asymmetric annual ring, or "Ate" (*Fig. 3.2* (g)), is formed after a tree has been uprooted or tilted (after being hit by boulders or by erosion), followed by continued growth.

3.3. Quantitative methods

It would be ideal if a simple rule existed to predict the timing and magnitude of a future mudflow. Many kinds of formulas have been proposed towards this end but most are site-specific, and others give only rough estimates. There is, however, no guarantee of the reliability of any such formula. Two examples of quantitative methods to assess mudflow hazard are described here.

3.3.1. Kronfellner-Kraus formula

The Kronfellner-Kraus formula takes into account the basic parameters of a torrent system. It was proposed on the basis of an analysis of historical documents on debris flows in various catchment basins in the eastern European Alps (Kronfellner-Kraus, 1982):

$$V = K \times A \times J$$

where V is the volume of extreme sediment yields (sum of bed load and suspended load) from a torrential drainage basin in m^3, K is a regional parameter which varies greatly with the geological characteristics and the size of the source area, A is the area of the catchment basin in km^2, and J is the average gradient of the torrent in question from the source area to the apex of the fan, in percentage. The value of the parameter K ranges from 500 for large, low-gradient and well-forested basins to 1,500 for small, high-gradient and poorly-forested basins. Kronfellner-Kraus (1982) presents K in the form:

$$K = 1750 / e^{0.018A}$$

3.3.2. PWRI formula

The Public Works Research Institute (PWRI) of Japan proposes an analytical method, based on a review of past mudflow cases, which takes into account multiple factors in an attempt to assess the level of danger at a specified time prior to the next mudflow discharge.

The level of danger of mudflow occurrence in the torrent in question can be expressed by:

$$L = a_1x_1 + a_2x_2 + a_3x_3 + \dots\dots\dots + a_nx_n$$

where L is the level of danger, $a_1, a_2, a_3, \dots\dots, a_n$ are coefficients, and $x_1, x_2, x_3, \dots\dots, x_n$ are quantities related to torrent bed deposit, vegetation cover on the slopes, bed gradient, etc. (see *PWRI, 1977* for details). When L exceeds a certain level, the torrent is deemed to be able to generate mudflows. The principal parameters which contribute to high levels of L are:

(*a*) Potentially mobile bed material on the valley floor;

(*b*) Gradient of the valley floor;

(*c*) Particle size and distribution;

(*d*) Water supply sufficient to inundate the potentially mobile material on the valley floor.