CHAPTER FOUR

MUDFLOW PREVENTION

4.1. Prevention

The objectives of a strategy to prevent and mitigate mudflow disasters should be to:

- Restrain debris at the source from moving;
- Reduce the frequency of mudflows;
- Minimize the volume of debris transported;
- Ensure the hazardless passage of mudflows;
- Improve hazard consciousness among local inhabitants;
- Be prepared for emergency measures, should a mudflow occur.

Various possible countermeasures against mudflow disasters, which depend on the volume and frequency of their potential occurrence, are illustrated in *Figure 4.1*

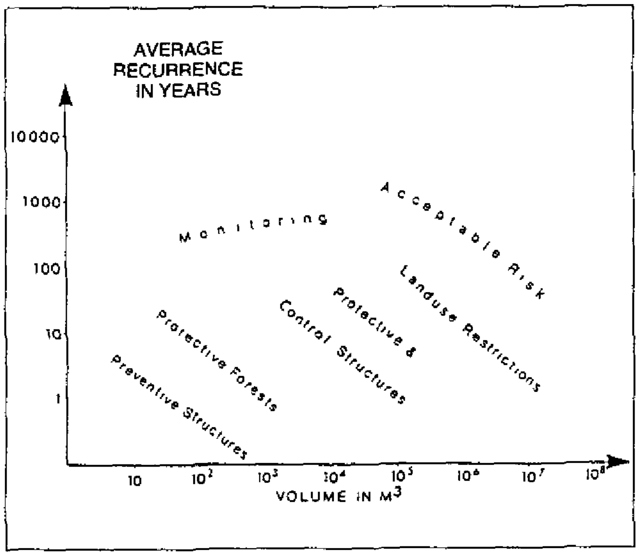

FIGURE 4.1 Possible passive and active measures for protection from mudflow events as a function of volume and frequency (Geological Survey of Canada).

The preventive measures can be broadly divided into the following two types:

- Structural measures;
- Non-structural measures.

The variety of structural and non-structural measures will be described in the following sections. In choosing appropriate countermeasures, full account has to be taken of all the factors relevant to a particular catchment or location. While it may make little economic sense to provide protective works if the cost of doing so exceeds a significant proportion (say 30 to 50 per cent) of the value of properties to be protected, human considerations may render it imperative to take every possible measure to protect the population of a catchment from loss of life due to mudflows.

4.2. Structural measures

Before implementing the structural measures, it is important to identify the requirements at a specific site. Then the types of preventive structures to fulfil them individually or collectively can be decided upon. The location and dimensions of the structures, their combination and the sequence in which they are put in place are essential planning elements. In general, structural measures entail costs, not only for the initial construction but also for the subsequent maintenance work. The order of priority of structural measures may differ from place to place, depending on the physical conditions related to the initiation, motion and stopping of mudflows, and on the socio-economic conditions of the area in question.

Figure 4.2 is a schematic diagram showing various possible structural measures to protect settlements at the mouth of a gorge or at the foot of a volcano against mudflows.

The locations of the protective structures can be classified as follows:

Location A: Slopes with potentially mobile materials;

Location B: Valleys or gorges in which mudflows run;

Location C: Alluvial cones and fans on which mudflows come to rest.

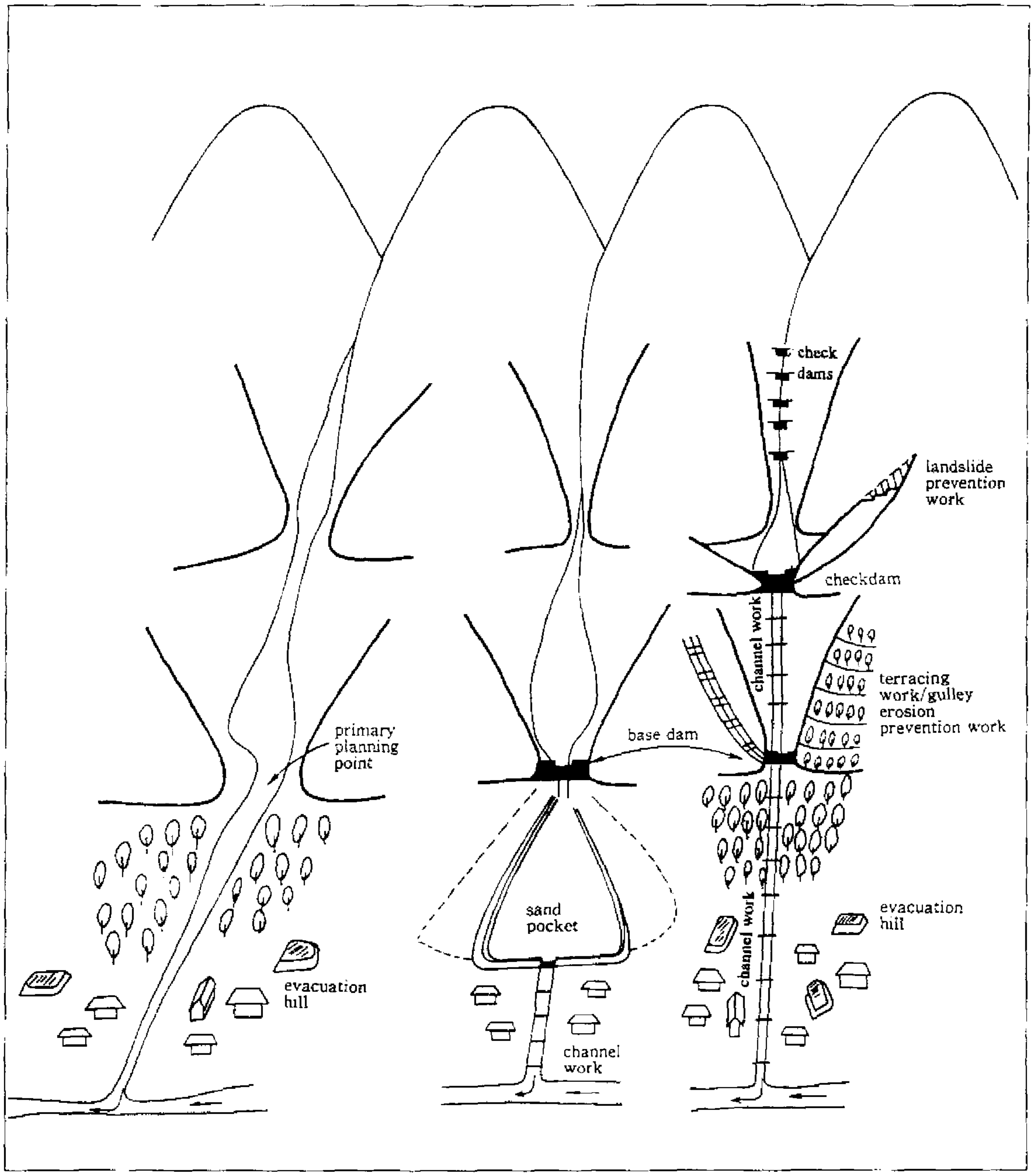

FIGURE 4.2 Schematic layout of various structural measures to protect a community at the mouth of a gorge or at the foot of a volcano, from mudflows (Ohkubo, 1989).

4.2.1. Objectives of structural measures

The objectives of structural measures in Locations A, B and C mentioned above are shown in *Table 4.1.*

TABLE 4 1

Objectives of protective structures, by location

Category	Designation	Objective	Location
(*a*) **BEFORE** initiation of a mudflow	a1	Restraining debris from moving	A
	a2	Restraining debris from moving	B
	a3	Reduction of frequency	A and B
(*b*) **AFTER** a mudflow has started.	b1	Braking of flow and removal of large-sized material	B
	b2	Removal of drifting debris	B and C
	b3	Reduction of discharge volume and peak discharge	B and C
	b4	Ensuring a hazardless passage	B and C

These objectives are briefly discussed below·

(a1) *Restraining debris from moving at Location A (slope)*

The best form of mudflow prevention is to restrain the rock, soil and wood debris on the mountain slopes from moving to begin with. Measures towards this end include terracing and planting of hillsides as shown in *Figure 4.3,* with properly-designed drainage to prevent soil erosion and ensure orderly runoff.

Depending on the nature of existing hillside vegetation cover, measures such as reforestation, arboricultural or horticultural management, and the control of grazing may be indicated Slopes covered with vegetation and correctly implemented hillside works can reduce sediment discharge by more than 90 per cent compared with that from naked slopes.

FIGURE 4.3 Afforestation by terracing. Location: Shiga, Japan *Photo M. Watanabe.*

(a2) *Restraining debris from moving at Location B (valley)*

Landslides at the foot of riverside slopes and terraces bring blocks of debris onto the valley floor. Stabilizing the banks of a torrent or river by the use of gabions and concrete blocks may be effective in prevention of both vertical and lateral erosion. Ground sills and check dams, set up either individually or in series can heighten the valley floor and, hence, support the foot of the slope which would otherwise be prone to slip or slide. Similarly, ground sills and lined conduits can be employed to protect mobile deposit in the valley floor from erosion (*Figs. 4.4, 4.5* and *4.6*). Ground sills should be solidly anchored if they are not accompanied by a paved channel

FIGURE 4.4 Ground sills to stabilize talus deposit Location, Valais, Switzerland *Photo: M Watanabe*

Figure 4.5
Ground sills to stabilize debris on an alluvial cone.

Location:
Urt. Switzerland
Photo:
M: Watanabe.

Figure 4.6
Ground sills on an alluvial fan.

Location:
Nagano, Japan.
Photo: Ministry of construction. Japan.

Figure 4.7
Check dams to stabilize the mobile material along a river valley.

Location:
Toyama, Japan,
Photo: Ministry of construction Japan.

(a3) *Reduction of the frequency of mudflows*

Apart from the impact due to triggering phenomena, the frequency of mudflows depends chiefly on the volume of mobile material on the valley floor. Erosion-control and landslide-prevention construction on slopes and valley floors serve to reduce the frequency of mudflows.

(b1) *Braking of flow and removal of large-sized material*

The great force and destructive power of mudflows is derived from the high velocity (which may be as much as 70 km/h or more) and the presence of large boulders at the front. The key to success in reducing disasters due to mudflows is therefore, first, to brake the motion of the boulders and, second, to remove as many large boulders as possible from possible mudflow paths.

The velocity of a mudflow depends on.

- the gradient of a valley at the particular point in question as well as throughout the relevant reach;
- the flow depth;
- the grain size of the material in the flow, and
- the water content in the flow.

Mudflow velocity is proportional to the slope and the depth of flow, but is inversely proportional to the grain size. Measures which can reduce erosion of the bed and slope of a channel are effective in slowing down moving mudflows Thus a reservoir behind a check dam creates a reach with a gentle slope and a wide cross-section, as shown in ***Figure** 4.7*. The longer and gentler the reach, the greater its slowing effect on the mudflow

The depth of a mudflow will be reduced if the width of the channel can be expanded. This can be achieved by a properly-designed check dam or by a series of such dams Another measure to reduce the flow depth is to drain the water from a mudflow in motion. Horizontal or low-angled screens made of iron bars have proved to be effective in braking mudflows, as shown in *Figure 4.8*.

With regard to the boulders concentrated at the front of a mudflow, an empty reservoir can accommodate them and efficiently reduce the water content as shown in ***Figures** 4.9, 4.10* and *4.11*. A reservoir filled with boulders or other solids automatically creates a reach with a gentle slope, and an expanded cross-section (as can be inferred from the sediment-retarding basin shown in ***Figure** 4.12*).

FIGURE 4.8 Debris-flow breaker in which water is drained by an iron-bar screen. (*a*) Before

(*b*) After a mudflow.
Location: Nagano, Japan. *Photo: M. Watanabe*.

FIGURE 4.9 Hydraulic model study to demonstrate the effectiveness of a check dam in retaining large boulders. Location Ibaragi, Japan *Photo M. Watanabe*

Figure 4.10 Large boulders trapped by a check dam. Location: Kumamoto, Japan. Photo: M. Watanbe.

FIGURE 4.11 Gosuke check dam (height 30 m, length 78 m, storage capacity 300,000 m^3; (*a*) Empty reservoir

(*b*) After becoming filled with debris on 12 July 1967. Location: Hyogo, Japan. *Photo: M. Watanabe*

A: Existing river bed
B: Lower terrace
C: Upper terrace
D: Sediment-retarding basin
E: Check dam
F: Sub-dam

Figure 4.12 Hongu check dam (heigt 22 m. length 107 m. storage capacity 3 x 10 m3) Location: Toyama, Japan. Photo: Ministry of Construction.