LANDSLIDES IN SRI LANKA : SOME ASPECTS

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A landslide is a downslope gravitational movement of rock, earth, debris or artificial fill. The movement may be a slide, flow or fall, acting singly or together (Simonett, 1968). Landslide may be induced by natural agencies such as heavy rain, earthquake or it may be caused by human interference with the slope stability (Whittow, 1984). Among the natural hazards such as earthquakes, seismic sea waves, volcanic eruptions, tropical cyclones, monsoon storms, tornadoes, thunderstorms, sea fogs, sea ice and ice burg drift, landslides are least documented and researched. This could be because landslides are restricted to small areas or because no adequate statistics are available (WMNH, 1988; Figure 1). However, the extreme rainfall intensities, thunder and lightning, the downslope gravitational movement of rocks, debris and earth associated with landslides can damage the natural environment as well as destroy life and property within a short period of time.

Landslides in Sri Lanka

Physical Conditions of Landslide Prone Areas

The incidence of landslides in Sri Lanka has increased over the past ten years in the districts of Kegalle, Ratnapura, Kalutara, Kandy, Matale, Nuwara Eliya and Badulla. The hilly areas of these districts include Central Highlands, the Sabaragamuwa ranges, the Rakwana and the Knucles Massifs. Physiographically, the whole area ranges between 300 m and 2200 m altitude and is broadly divide into (a) uplands, and (b) highlands.

The Central Hill Country, the Knuckles Massif, the Sabaragamuwa Ranges and the Rakwana Massif are characterized by Rolling and hilly terrain (Upland I, 150 - 460 m); dissected rolling and hilly terrain (Upland II, 460 - 930 m); steeply dissected rolling and hilly terrain (Upland III, 915 - 1830 m); and Mountainous terrain (1830 m or more). The convex creep slopes, free faces of these terrains (Figure 2) are highly dissected by 1st and 2nd order streams. The slopes in the Uplands & Mountainous have gradients between 1 to 5 and 1 to 1 (Katupotha, 1992).

Rolling and hilly topography comprises dissected ridges and valleys. It is a distinctive feature developed due to the transverse valleys. Parallel drainage pettern has been developed along the tributaries in the western Sabaragamuwa Ranges and the Rakwana Massif. The dendritic drainage pattern is developed in the moderately steep, rolling and hilly terrain laid on the Highlands planation and intermediate planation surfaces of the western flanks of the Central Hill Country. Locally this drainage pattern is responsible for the formation of dissected features by 1st and 2nd order streams. According to the observations made by Cooray (1984) the highest part of the Sabaragamuwa ridges consist of a series of high plains such as Handapan Ella and Tangamale at a general elevation of 1,000 m to 1,225 m; they are surrounded by escarpments and several peaks. The more prominent peaks in the area are Beralagala (1,385 m), Gongala (1,346 m), Suriyakanda (1,310 m) and Abbey Rock (1,300 m). The Bulutota escarpment and much of the massif are made up largely of gently - dipping resistant charnockites. The other high plains can be seen between the upper Highland planation surface and the middle Highland planation surface (from Palabaddala to Balangoda). The common features of the mountain terrain are the ranges and peaks (e.g. Samanala, Pidurutalagala, Namunukula, Lunugala and Knuckles); relict plateaus, platforms and rocklands (Hatton, Kandy, Koslanda, Haputale and Eastern Platform). This Highland planation surface is strongly dissected by the upper reaches of the rivers.

Due to regional variations, the rainfall figures of the landslide districts show different maximum seasons. Ratnapura, Kegalle, Kalutara, Kandy, Kurunegala and Matale receive rainfall mainly during the southwest monsoon (May - August) and convectional-cyclonic-depression at rainfall in the inter-monsoon period (October to November). Diyatalawa, Baddula and Nuwara Eliya receive rainfalll mainly from northeast monsoon (November - February) and from the convectional - cyclonic - depressional rainfall of the inter-monsoon period (March - April).

Indicators for Identification of Landslide Areas

Several visible indicators can be applied for the identification of slide, fall and flow of rocks, earths and debris in steep slopes. Formation of cracks and fractures, especially as horizontal lines on Convex Creep Slopes and free Faces, encourage seep age of rain-water down to the weathered bedrock layer. If there are iron-rich clay materials between bedrock and the top soil layer, lubrication of the weathered material is possible, and rock blocks, so that the debris and blocks of rock move downwards by the force of gravity.

Muddy water springs are another indicator of landslides. Some times, seep or saturated water flows through bedrock and the top soil, outwards from valley bottoms, road intersects of the roads and foundations. The iron-rich clay materials present in muddy waters indicate that the bond between bedrock and the top soil is broken. These features appear on steep slopes, sometimes even on 15^0 slopes subject to downward movement.

When the soils of the steep slopes are saturated, the bond between bedrock and weathered top soil is broken. Consequently, the vegetation cover would wither due to putrefication of the root-system. This indicates that there is a sign of a slope failure during the heavy rains. Furthermore, gradually inclining wire poles, telephone and electric wire poles, masonary walls, cracked rocks (Plate 1.A), and cracks of the houses on fair to moderate and steep slopes also indicate future landslides.

Causes of Landslides

The island of Sri Lanka, which is situated in the Australia-Indian Plate, is considered as tectonically stable. This land mass is made up of highly weathered metamorphosed rocks of Precambrian age (2000 m.y., Rb/Sr) and is similar to other Gondwana masses of the Indian Ocean (Crawford and Oliver, 1969). Several researchers have indicated the occurrence of high seismicity conditions between Sri Lanka and the Cocos Islands, Sri Lanka and the Carlsberg Ridge and along the Calrsberg Ridge in the Indian Ocean with earthquakes of magnitude 7 or larger as the Ritcher scale (Stover, 1966; Bangar and Sykes, 1969; Sykes, 1970). There have had an impact on the movement of landmasses in Sri Lanka. Vitanage (1990) has reported that 53 earthquakes have occurred in Sri Lanka during the period between 1823 and 1976. This indicates how deeply weathered parent materials of high slopes can be shaken and moved downwards during periods of excessive rainfall.

Highly weathered metamorphosed rocks in the hill country contain a high proportion of feldspar and they are sometimes well jointed. These rocks weather into reddish brown clayey meterial known as lithomarge in which are embedded boulders of varying size (Cooray, 1984). When this weathered material is saturated with rain water, the iron-rich clayey material acts as a lubricant, causing the mass of earth and rock to move rapidly down the slope under the force of gravity. When there is no vegetation cover to bind and hold these material together the lubrication of the rocks, debris and earth can be intensified. During heavy rains, the fall or topple of rock material may be further intensified due to shaking of weathered rocks and debris by thunder and lighting. Infiltration of water along joints and natural tunnels in dolomitic areas could also led to landslides in steep slopes.

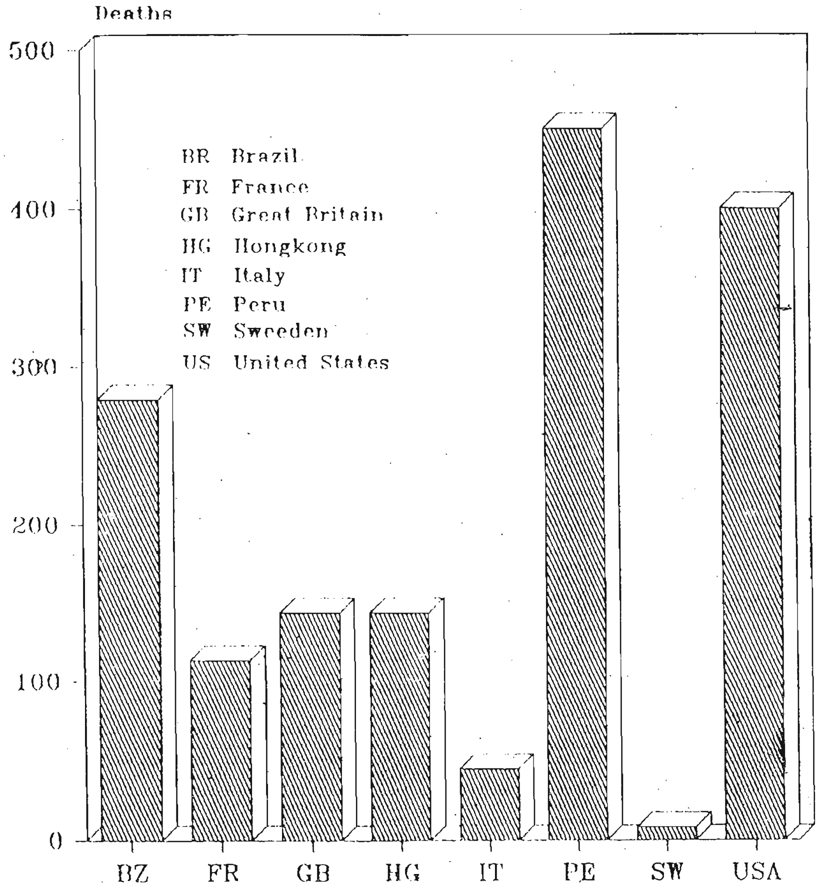

Figure 1: Mortality figures due to mass movements from 1966 to 1987.

Human Influences on Landslide Probability

The land polices in Sri Lanka adopted by the Colonial government and later by National governments since Independence can be cited as a major reason for acceleration of landslide (Madduma Bandara, 1988). Under the Land Ordinance Act of 1840, the Colonial administration forcibly acquired the land used by the peasants for plantation agriculture and extraction of timber. Prior to this, the villages were largely concentrated in the valleys and lower slopes of the hills had been cultivated from natural streams. The gentle hill slopes had been used for chena (shifting) cultivation. The absence of human settlements and other activities on steep slopes of the head streams often minimized the damage to life and kept the balance of nature during the pre-colonial times. The forest cover on the ridges, upper slopes and hilltops remained undisturbed under a canopy of tropical mountain forest.

During the time of the British colonial government, the exploitation of natural forest for timber and clearing of forest for coffee, tea and rubber plantations increased sharply. Tropical mountain forests were cleared and set on fire which broke the structural bond between natural vegetation cover and earth material. Since then , the occurrence of landslide has accelerated in proportion to the rate of clearance of forest cover. Legislation for the control and management of forest, land, soil, water and air were passed during the times of the Colonial government and later by National governments, but it has not been possible to enforce the regulations successfully (Kurunanayake and Katupotha, 1990).

Proportionate to the increase of population in the villages of the Hill Country the demand for land for settlements and agriculture has increased. The imbalance in the man/land ratio, due to the pressure of population on land has caused the dense forest, reservations and patches of grasslands *(Patana)* in the steeper slopes and peak areas to be utilized for chena cultivation (for subsidiary food crops), plantation crops (tea and rubber) and commercial crops (tobacco and potato) as well as for illicit felling for timber by small holders and landless people. As a result, the natural forest cover has been further reduced (from 44 percent in 1961 to 24 percent in 1989). Wanton utilization of land in the upper slopes, where the slopes are moderate to fair (6^0 - 8^0 in Upland I); fair to steep (11^0 - 25^0 in Upland II); steep (18^0 - $25^{0)}$ and steep to extremely steep (18^0 - 45^0) in Mountainous terrains have been used for housing schemes and cultivation.

Man-made causes such as construction of reservoirs (Plate 1.B), forest felling on an extensive scale, periodic uprooting of tea and rubber trees, tunneling and pumping out of water from gem pits in the valley bottoms have all led to slope failures and subsidence of the lands, creating slope instability. Therefore, inefficient drainage of steep slopes along bare rock slopes and those under plantations may also contribute to slope failure.

Table 1: Occurence of Lasndslides in Sri Lanka 1930 - 1993.

Year	District	Location	Major/ Minor	Deaths	Houses damaged
1930	Kegalle	Thalawela	Major	Not known	Not known
1947	Kegalle	Kadugannawa	Major	40	Not known
1947	Kegalle	Aranayake- Sela-wakanda	Minor	Not known	Not known
1952	Nuwara- Eliya (NE)	Udahewaheta	Minor	Not known	Not known
1957	Kegalle	Pahala-Gadugannwa	Major	05	15
1964	NE	Walapane	Minor	(17 families affected)	
1970	NE	Walapane	Major	19	Not known
1973	NE	Walapane	Major	13	Not known
1978	Kegalle	Bulath-Kohupitiya Wegalla	Major	03	10
1979	Ratnapura	Kuruwita Akurana	Major	05	10
1979	Kalutara	Bulathsinhala	Minor	Not known	Not known
1981	Kegalle	Yatiyantota Polpetiya	Major	02	20
1981	Kegalle	Aranayale- Berawala	Major	Not known	30
1982	Kegalle	Mawanella Heenalipana Kanda	Major	Not known	Not known
1982	Kandy	Pathahewaheta Paginiwela Kanda	Minor	Not known	Not known
1982	Ratnapura	Pelmadulla Pathulpana	Major	08	15
1982	Matale	Pitakanda Pansalatenna Palindagama	Major	23	Not known
1983*	Kalutara	Welkandala	Major	13	03
1983	Kegalle	Mawanella Elangapitiya Kanda	Minor	Not known	15
1983*	Matale	Rattota Pitakanda	Major	13	08
1984	Kalutara	Bulathsinhala Agalawatta Matugama	Major	42	Not known
1984	Badulla	Haliela- Baddegama	Minor	Not known	02

Table 1 Contd.

Year	District	Location	Major/ Minor	Deaths	Houses damaged
1984	Badulla	Bandarawela - Liyanagahawela	Minor	Not known	21
1984	Ratnapura	Embilipitiya Ihala Anduliwewa	Minor	Not known	21
1984	Ratnapura	Kolonna-Bulutota	Minor	02	05
1984	Ratnapura	Kuruwita Ratnapura Eheliyagoda Balangoda	(40 threats of minor earth slips reported)		
1985	NE	Noton Bridge	Minor	05	Not known
1985	NE	Town Division	Major	Not known	40
1985	Kalutara	Matugama Uduwala	Minor	Not known	Not known
1985	Kegalle	Warakapola Thiyambarahena Kanda	Minor	10	03
1985	Kandy	Galagedara Bodikulawa	Minor	Not known	Not known
1985	Kandy	Nawalapitiya Pemross Est.	Major	04	10
1985	Ratnapura	Elapata Kohombakanda	Major	Not known	46
1986*	NE	Hanguranketa Maturata	Major	06	01
1989*	Kegalle	Bambaragala Atalugankanda Panawala	Major Major Minor	24 12 01	Not known Not known 03
1989*	Kurunegala	Ridigama Katiyawa Walimunukanda	Major	03	05
1989*	Ratnapura	Hinidunkanda	Major	01	03
1990*	Badulla	Welimada Gawammana	Major	05	Not known
1990*	Matale	Ukuwela Elkaduwa	Major	03	Not Known
1992*	Kalutara	Bulathsinhala	Major	05	03
1993*	Ratnapura	Kalawana Town Division	Minor	03	-

*Source: NARESA 1990; * Katupotha 1992 and Field observations.*

Impact of Landslides

Landslide prone areas in Sri Lanka are shown in Figure 3. The incidence of landslide which had increased in 1983, 1986, 1989 and 1992 caused 323 deaths and the loss of property and livelihood of 1327 families (Table 1).

Excessive rains between 29 May and 5 June in 1989 caused damage to 56 villages in the Ratnapura district (Karunanayake and Katupotha 1990) and 40 villages in the Kegalle district (Katupotha, 1992). During this period, 280 deaths were reported and 346 families (nearly 2100 persons) were rendered destitute in the Kegalle district alone. The intensity of damage to houses and properties, is related to the landslide types and to their magnitude. This includes bedrock-related materials (rock fall, rock topple, rock slump, rock block slide and rock slide), debris movement (debris fall, debris slump, debris slide and debris flow) and earth movement (earth slump, earth slide and earth flow) where they occur. Bedrock-related materials (debris and boulder) have been toppled at Hettikands (Hinidunkanda) in the Ratnapura district and at Berannewa in the Kegalle district. As a consequence, 24 deaths occurred and paddy fields were covered by boulder-rock slide with earth flow at Bambaragala (Kegalle district) during the same period. Debris and earth movements have occurred at Atalugankanda, Punugala, Minimaruwa, Gatemulla, Warawela, Malmaduwa, Makura (Kegalle district), Wewalgama and Dodamgahaela (Kurunegala district). The excessive rains in 1989 also caused damage to the Kandy - Mahiyangana road (at Hunnasgiriya) by displaced debris and boulders (Plate 2.A). Slope slumping in several places of these areas appeared singly or as a combination of two or more types (Katupotha, 1991). Due to excessive rainfall between 25 and 30 May in 1992, a catastrophic slide of debris and rock blocks caused five deaths, and three families were rendered destitute at. Bulatsinhala in the Kalutara district (Plates 3 and 4). Based on a recent study, Katupotha (1992) indicated that the occurrence of landslides has increased in areas of the Provincial Secretariat Divisions at Ridigama and Ibbagamuwa in the Deduru Oya basin; Bulatsinhala, Matugama (Plate 2.B), Agalawatta, Ayagama, Elapata, Kalawana, Ratnapura, Kahawatta, Kuruwita, Pelmadulla in the Kalu Ganga basin; and Weligepola, Haputale, Godakawela, and Kolonna in the Walawe River basin. Landslides in these areas have altered the micro relief and causing changes in the flow pattern of streams either through damming or diversion and deposition of rock, debris and earth.

Similar occurrences frequently take place around newly constructed reservoirs such as Victoria, Kotmale, Rantambe, Randenigala and Samanalawewa, and in tunneled areas. Slope slumping in those areas is due to wanton and unplanned investigations of local geologic parameters. Blasting of highly weathered metamorphosed rock for road building (e.g. the Kandy - Mahiyangana road), mining of graphite using heavy explosives

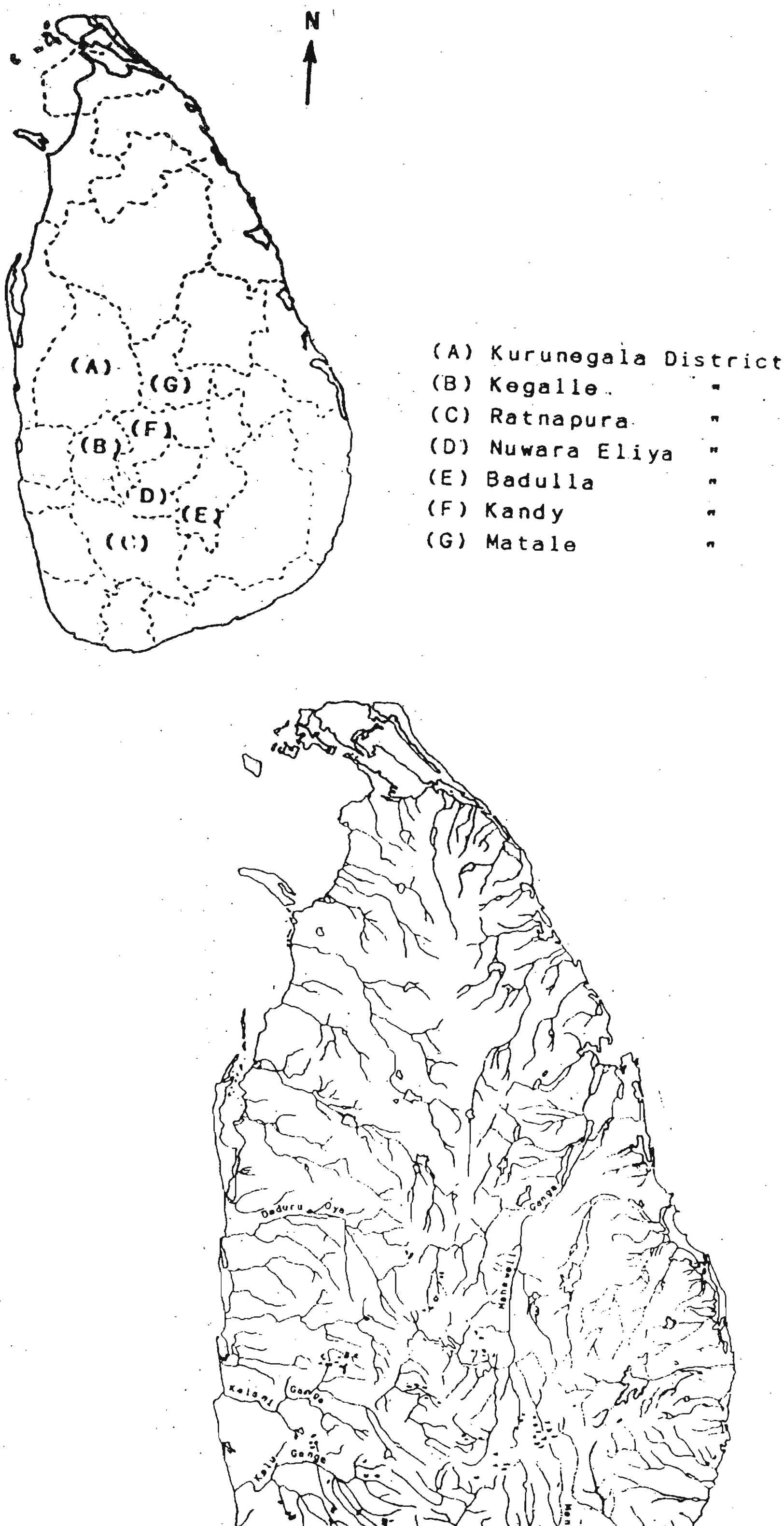

Figure 2: Landslide prone areas of the Central Hill Country, Sabaragamuwa Ranges, Rakwana and Knuckles Massives.

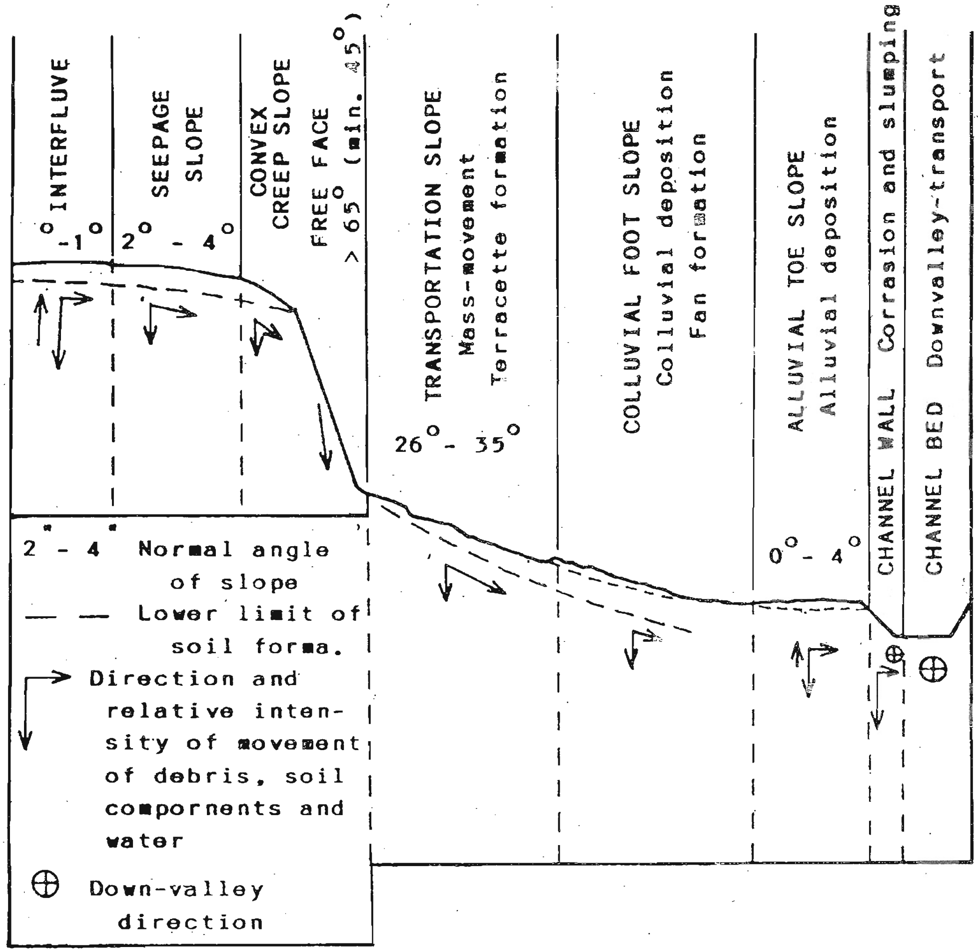

Figure 3: Slope units on a hypothetical land surface (Whittow 1984). Convex creep slope and free face are mainly subjected to landslide.

(Kurunegala and Kegalle district), gemmining (Ratnapura district), and forest or grassland fires on steep slopes (Kegalle, Ratnapura and Badulla districts) have increased the occurrence of landslides as well as of land subsidence on steeper slopes.

Recommended Preventive Measures

The intensity of environmental damage caused by landlides has increased as a result of inadequate investigations of geological structure, increased constructional activities, short-sighted land policies of the government and over-exploitation of natural forest resources in the uplands and mountainous areas. Therefore, several measures are urgently needed in order to protect the environment. Karunanayake and Katupotha (1990) recommended following conservation measures for the Ratnapura district, either singly or in combination; (a) reaforestration; (b) preventing haphazard forest clearance; (c) monitoring of 'suspect' areas; (d) grading of steep slopes according to the gradient and provision providing of contour drains; (e) terracing and nonutilization of landslide affected slopes either for human settlement or agriculture.

They have further pointed out that the adoptation of long-term strategies for hazard management is constiained by several factors. Example, a basic drawback is the absence of a landslide preparedness plan within the context of an overall district natural disaster preparedness strategy. Other contiants are that technical advice on the conservation of landslide-prone areas is inadequate and, given the paucity of funds, the implementation of conservation measures is made extremely difficult; and lack of inter-agency (district administration, JEDB, line departments and NGO's) coordination.

For the settlement of evacuees the following options have to be considered: (a) resettle the evacuees in the areas around their homeland where suitable land is available; (b) the evacuees could be absorbed into surrounding estates as employees; (c) relocating them in

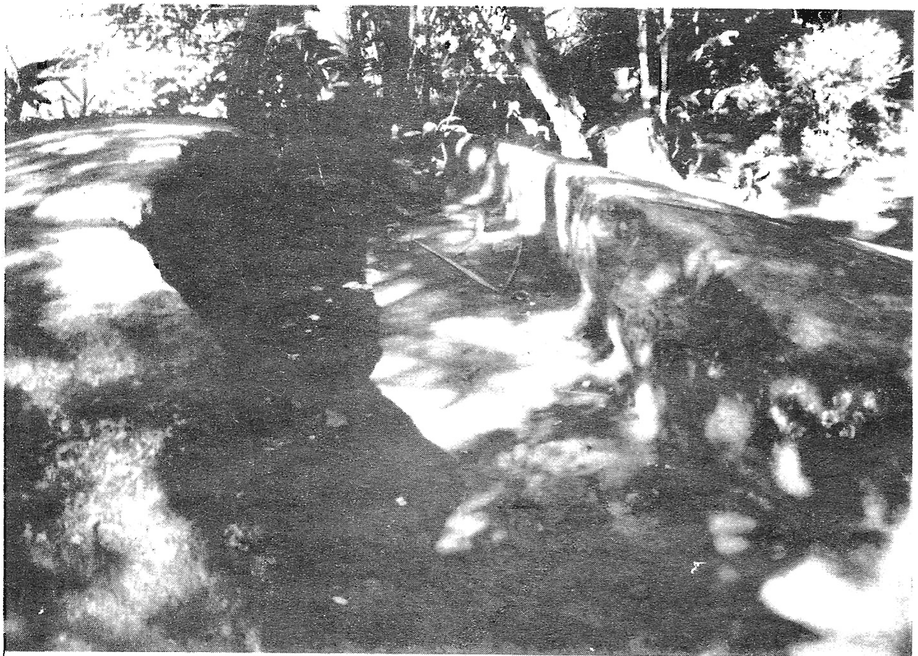

Plate 1:

(A) Cracked rock at Palankanda (Openayaka) indicates the gradual movement of the landmass. (B) Newly constructed reservoir (part of a Victoria reservoir) and road intersects (Kandy - Mahiyangana road) of the Central Hill Country will be subjected to future landslides.

Plate 4: (A) Damaged rooms in one of the houses shown in Plate 3(B). (B) rock and other debris of the same landslide of Plate 3.

downstreame areas of the Mahaweli Development project and absorbing them for present agriculture. For this purpose, it is necessary to provide reasonable quantity of land, e.g., about 2.0 ha. for a family to grow seasonal crops (chillies, onion and leguminous crops), annual crops (sugar cane) and animal husbandry. Moreover, the imbalance in the man/land ration due to the increase of population, the poverty of the people, vocational and educational background of the younger generation should be taken into consideration.

Katupotha (1992) has also recommended the following measures that might minimize occurence of the landslides in Sri Lanka.

a Grading of slopes into moderate (6^0 - 11^0), fair to steep (11^0 - 25^0) and steep and extremely steep (18^0 - 45^0) or over for the management of landslides and soil erosion. However, and steep to extremely steep or over slopes should not be used at all for human settlements and agriculture.

b Minimize the use of moderate slopes for human settlements and agriculture.

c Continue reforestation and forbid the unplanned and illicit forest fellings in graded slopes.

d Monitoring haphazard quarrying of rocks and other mining activities in fair to steep or over slopes.

e Forbid or manage the use of explosives in the mining activities, e.g., graphite, rocks, gems, in moderate to extremely steep or over slopes.

f Provide contour drains and terracing to protect the high slopes from soil erosion.

g Systematic and careful uprooting methods of plantation crops are needed to protect high slopes from landslides and soil erosion.

h Enforcement of existing Laws pertaining to the protection and management of natural resources.

The above mentioned recommendations can be implemented as short-term, medium-term and long-term strategies to prevent landslide hazards.

Plate 3: (A and B) Deposition of rocks, debris and earth by landslide in 1992 caused the damage of three houses and five deaths at Bulatsinhala (Kalutara district).