REPORT ON THE JANUARY 1986 LANDSLIDES OF THE NUWARA ELIYA DISTRICT

98

MINISTRY OF LOCAL GOVERNMENT HOUSING & CONSTRUCTION

REPORT
ON THE
JANUARY 1986 LANDSLIDES
OF THE
NUWARA ELIYA DISTRICT

PREPARED BY

CENTRAL ENVIRONMENTAL AUTHORITY
MALIGAWATTE NEW TOWN, COLOMBO 10

REPORT ON THE JANUARY 1986 LANDSLIDES OF THE NUWARA ELIYA DISTRICT.

Prepared by

CENTRAL ENVIRONMENTAL AUTHORITY

Ministry of Local Government, Housing & Construction

Maligawatte New Town, Colombo 10

FOREWORD

In January, 1986, the upcountry districts experienced very heavy rainfall. For example, Badulla district had continuous rain from January 5 - 9, and three meterological stations recorded over 1000 mm. Likewise Nuwara-Eliya district also experienced heavy rain. Consequently serious landslides occured, and as much of these were in populated and developed areas, considerable damage was caused to life, property and infrastructure.

The Prime Minister, Hon. R. Premadasa, having inspected some of the disaster-struck areas soon afterwards, directed that immediate relief be provided to those affected. He also instituted investigations by a multi-disciplinary team, co-ordinated by the Central Environmental Authority, to ascertain the causes and nature of the damage and to make recommendations to the Cabinet of Ministers, on appropriate action, including mitigation measures.

Some of the predisposing factors to the occurence of landslides are excessive rainfall and slope instability caused largely by deforestation. Saturation of the sub-soil layers and increase of pore water pressure could trigger mass movement on unstable and steep slopes.

In Sri Lanka, the pressure on the land continues to increase and today the man-land ratio is about 0.2 ha. per person. Short-sighted land use practices and careless land management, compound the effects of the natural phenomena and give rise to large scale disasters.

The pages of history provide ample evidence as to how poor land management had led to the collapse of civilizations. Hence the time is opportune to manage effectively the all important resource of

(Cont'd...2)

land, in order to bring about sustainability in its use and benefits to future generations.

Due to the urgency of the problem and constraint of time, these initial investigations were done only in the Nuwara-Eliya district.

The recommendations of the multi-disciplinary team were accepted by the Cabinet and their implementation has been entrusted to the relevant ministries.

I wish to place on record my grateful thanks to the members of the team who responded enthusiastically at very short notice, and came up with a very comprehensive range of recommendations for consideration by the Government.

(K H J WIJAYADASA)
Secretary to the Prime Minister
& Chairman
CENTRAL ENVIRONMENTAL AUTHORITY

* * * * *

CONTENTS

4. **BUDGET**

4.1 Reconnaissance Aerial Survey

4.2 Preparation of Landslide Hazard Maps

4.3 Short-term Monitoring of high-risk areas

4.4 Post-Graduate Research Assistantships (Grants)

5. **SUMMARY OF RECOMMENDATIONS**

1. INTRODUCTION

" A number of landslides of varying magnitude had occurred during a period of about two to three weeks commencing January 7, 1986 in the upcountry districts of Nuwara Eliya and Badulla. Many of these landslides were triggered off after a period of heavy and intense rainfall, and the main cause of these movements was the excessive rainfall. Several human lives were lost and many were rendered homeless as a result. The damage to property - land and buildings - was also considerable. "

1.1 Background to Study :

On a directive from the Hon. Prime Minister, a number of scientists from concerned government institutions, making up a multi-disciplinary team, (appendix 1) visited some of the affected areas between January 21 and 23, 1986 to carry "out on the spot" investigations and make recommendations vis-a-vis an immediate course of action to be taken in these areas, and also suggest ways and means of safeguarding life and property in the future.

This report contains a summary of the findings of the team that inspected some of the affected areas, and the recommendations on the shor-term and medium-term strategies to be adopted in relation to these areas, as well as those areas identified as prone to landslides.

1.2 Previous Studies

A number of previous studies on landslides have been conducted. Gourrie et al (1954) have made a comprehensive study of the landslides that occurred in the Kotmale Valley in August 1947 and some of the recommendations of those studies

appear to be relevant even now when studying the present disaster. Subsequently the Geological Survey Department has investigated a series of landslides, the most recent of which have been those that occurred in 1984 in the Agalawatta and Matugama areas.

2. FINDINGS

2.1 Geographical Location :

Fig. 1 shows the affected areas that were inspected.

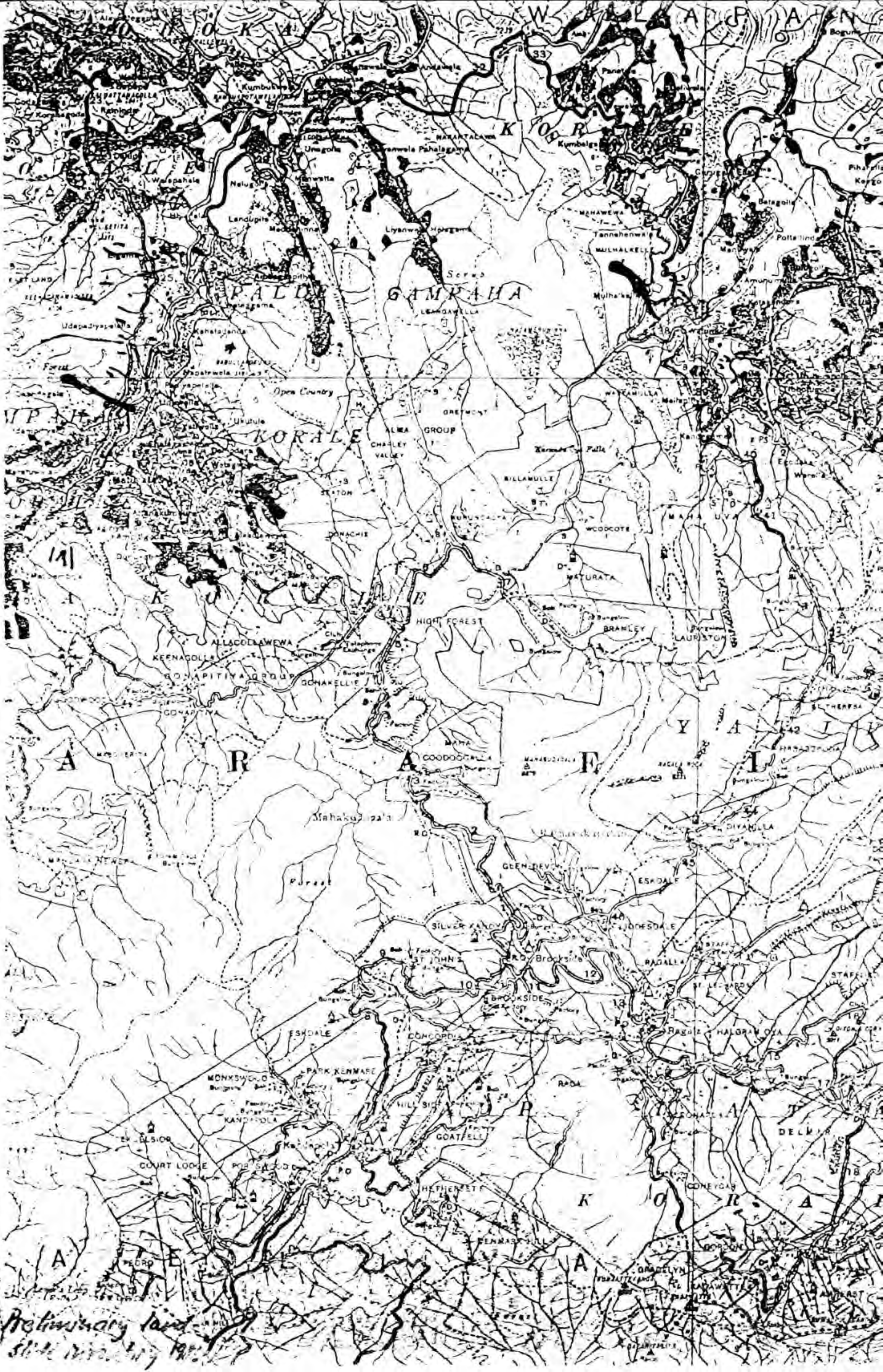
They included locations on the following roads :

(i) Hewaheta - Rikillagaskada - Watumulla
(ii) Padiyapelella - Elamulla - Mandarannuwara
(iii) Nuwara Eliya - Ragalla - Uda Pussellawa
(iv) Ragalla - Harasbedda - Watumulla
(v) Nuwara Eliya - Welimada
(vi) Suriyagaspatana - Rupaha - Nildandahinna

2.2 Rainfall Pattern :

Heavy rainfall had been experienced in the areas beofre and during the period of the disaster. The rainfall recorded at Nildandahinna by the Ceylon Tobacco Company during the week preceding 7.1.86, had exceeded 100 mm. and had been the main cause for triggering off the landslides.

A study of the rainfall during the major landslides of 1947 and 1984, indicate very high intensities. However it was quite clear to the team that the excessive rainfall had not been properly drained off the land. Bad land management, after deforestation, had been a major contributory cause.


KORALE
PALDE
GAMPAHA
Scrub
Open Country
ALMA GROUP
CHARLEY VALLEY
GRETMONT
Ukutule
MAHAWEWA
Tannahenwale
MULHALKELLE
Kerauda Falls
BILLAMULLE
WOODCOTE
MATURATA
HIGH FOREST
BRAMLEY
LAURISTON
ALLACOLLAWEWA
KEENAGOLLA
GONAPITIYA GROUP
GONAKELLIE
GONAPITIYA
MAHA UVA
COODOOGALLA
DIYAGALLA
Forest
GLEN DEVON
ESKDALE
SILVER KANDY
ST JOHN'S
Brookside
BROOKSIDE
RAGALLA
Ragala
HALGRAN OYA
CONCORDIA
MONKSWOOD
PARK KENMARE
KANDAPOLA
Kandapola
HILL SIDE
GOATFELL
EXCELSIOR
COURT LODGE
HETHERSETT
KENMARE HILL
CONEYGAR
DELMAR
GRACELYN
RAGA
ST LEONARDS
ST THERESA
Preliminary land

2.3 Geology of the Affected Areas :

Physiographically, the region consists of steep slopes associated with moderately wide valleys. Structurally these valleys are located along north-westerly plunging synclinal depressions. The bedrock geology consits predominatly of basic to intermediate charnockites interbedded with granulitic gneisses. Weathering of these interbedded strata could give rise to alternate layers of competent and incompetent soils based upon their clay content, thus creating favourable conditions for slipping under excessively high pore-water pressure conditions, during heavy rainfall.

Landslides form a minor component in the natural cycle of weathering, erosion transportation and deposition which operates continuously thus reducing the topographical irregularities on the surface of the earth. Similar to most of the natural hazards that the surface of the earth is subjected to, it is not possible to predict the exact location and timing of landslides. However, the magnitude and the frequency of occurrence of landslides, to a very large extent, are accelerated by human interference of the natural environment.

2.4 Soils and Land Use :

Unstable soils and rock materials, and extreme slopes could be contributory factors to landslides. In areas characterised by these factors, landslides could be triggered off by extreme saturation of sub-soil and subterranean seepagae of water.

The removal of forest cover from the steep slopes with unstable soil could be regarded as a forerunner to the present situation although retention of forests could not guarantee the total prevention of landslides.

There are a number of studies which support higher incidence of landslides due to removal of the forest cover. These contributory factors could get compounded by unscientific land management subsequent to deforestation. Tobacco and Vegetable cultivation are two examples. Road-cuts and lack of side drains may trigger slope failures. Vibrations in the form of either natural minor earth tremors or m an induced explosions also lead to slides.

The soils at Maturata, Mulhalkelle, and Rupaha areas are Immature Brown Loams which are very unstable. The topography of these areas is also extremely steep, ranging from 25 to 80 slopes. The soils at Nildannahinna and Harasbedde are the more stable Red - Yellow Podzolic soils and the slopes range from 20 to 30 . At Maturata and Rupaha, where new cracks in the soil were observed, there is an imminent danger of more landslides occuring, either immediately with more rain or with the omset of the next monsoon in May/June.

Removal of forest cover from steep slopes with unstable soils has been a contributory factor. Tsukemoto and Kusakabe (1984) have classified slope types and roughly estimated the susceptibility to landslides.

The classification is as follows :

Type A Slope :

has a shallow soil layer overlying rock with no fissures. This slope is very unstable. This type of slope may even enhance the occurence of landslides due to the additional weight.

Type B Slope :

has a shallow soil layer overlying rock where no fissures exist. Roots of trees can pernetrate the fissures, provide anchorage and help reduce the incidence of landslides. Removal of forest cover will drastically deccrease the stability of the land. The lands at Maturata, Mulhalkelle and Rupaha are in this category.

Type C Slope :

has a soil layer overlying a transition layer. The transition layer is compact and has some weathered rock. The roots of trees can penetrate the transition layer to a certain extent and stabilize the slope.

Removal of trees and subsequent decay of tree roots destabilizes the land to a great extent. The lands at Nildandahinna and Harasbedde are similar to Type C Slopes.

Type D Slope :

has very deep soils and are generally stable.
Although retention of forests cannot guarantee prevention of landslides, there are a number of studies which report increased incidence of landslides due to removal of forest cover. These are O'Loughlin and Pearce (1976) and Burroughs and Thomas (1977).

Under conditions of soil saturation, upto 80 per cent of the total shear strength of a soil is attributed to tree roots (O'Loughlin, 1974) and (O'Loughlin and Watson, 1979).

2.5 Extent of Damage :

Damage to the road network has been one of the major problems in the areas visited. The Road Development Authority and other local authorities responsible for the maintenance of roads were not properly geared to clear the landslides. Since then, it has been reported that the pace of work has been accelerated.

A large number of houses have been damaged beyond repair, while others have been damaged to varying degrees.

Damage to agricultural land, sstreams, natural waterways, townships and the Mulhalkelle hospital has also been considerable.

The main areas of damage have been along the roads mentioned in 2.1.

2.5.1 High Landslide Risk Areas:

The probability of future landslides of high magnitude could be predicted by the presence of extensive semi-arcuate, near parallel sets of soil cracks on the hill crests and steep slopes. Apart from the localised landslides three main epi-centres or high landslide risk areas were identified in the Nuwara Eliya District (Figure 1). These 3 epi-centres are described below.

(i) **Maturata - Mandarannuwara Area :**

In addition to gully erosion which buried 13 people at the Ketayapathana Village, the entire hill slope east of Maturata town is unstable and likely to generate future landslides.

On this ridge the displacement of the soil cracks is as high as 1.5 inches and if activated due to heavy rainfall will destroy a major protion of the Maturata town. Similar unstable slopes have been noted at Dunukebedda (south-east of Maturata) and south of Uduwela near Mandarannuwara.

(ii) **Mulhalkelle - Kumbalgamuwa Area :**

The main landslide active at present is a linear mudflow down a narrow valley located about 1.5 miles north of Watumulla along the Ragalla - Kandy road. This mudflow covers an area of over 6 acres and the flow has originated from the eastern talus slope below the precipitous scarp of the Watumulla - Nayamaruhinna mountain range (elevation over 5000 feet). The main mudflow is in a south-east direction and half way down a major bifurcation was observed before the mudflow crosses the Kandy - Ragalla road at this point. The southern arm of this bifurcation has damaged the Out-Patients Department building of the Mulhalkelle hospital.

However, the major risk area lies to the north-east of the current mudflow. The eastern slope of the ridge running north of the Mulhalkelle hospital is a potentially unstable slope due to the presence of extensive soil cracks. This landslide, if reactivated, can destroy parts of the Kumbalgamuwa village. There is also an additional danger from this mudflow if it flows into the Kurundu-Oya drainage system and eventually finds its way to the Randenigala reservoir thereby accelerating the silting of this reservoir.

(iii) **Ambaliyadda - Rupaha Area :**

Five locations of major gully erosion and major soil subsidences were observed between the Ambaliyadda and Rupaha Villages. Although no human lives were lost and only a few houses were damaged, the entire eastern-half of this ridge is highly unstable and is a potential risk area that may trigger off a major landslide when conditions are predisposing.

3. RECOMMENDATIONS

As landslides are caused by a combination of many factors like heavy rainfall, seepage, steep slopes, less competent soils, poor land management and undercutting, the remedial measures are best planned by a multidiciplinary team of scientists consisting of geologists, geotechnical engineers, soil scientists, agriculturists, foresters, environmental scientists, highway engineers, meteorologists and land use planners.

3. Short-Term Strategy :

3.1.1 Evacuation:

Evacuation of people specially from Maturata and Rupaha - Ambaliyadda areas has to be given the highest priority due to the apparent danger of more disastrous earthslips. Such evacuation should be carried out before the next monsoonal rains in May, 1986.

3.1.2 Resettlement :

Resettlement of the people evacuated from potential danger areas should be done on areas known to be safe and stable.

Slope stabilities of the uncertain areas should be studied in close collaboration with the Geological Survey Department prior to any land alienation. The sociological aspects in such a resettlement programme that have to be seriously considered are, the least disruption to their life styles and continuous source of income from paddy cultivation and homestead gardens. The study team observed that the people affected by the recent earthslips are anxious to settle on tea estates in close proximity to their villages. Resettlement of affected families on imarginal lands may cause more problems as such activity will further accelerate land degradation. Strict vigilance will have to be exercised by the different authorities to ensure that the settlers do not carry out unscientific irrigation and agricultural practices which may precipitate further landslides. Land use maps prepared by the Irrigation iDepartment for the Nuwara-Eliya District can be used as a major guide to such resettlement.

3.1.3 Acquisition of high-risk areas :

Once people are evacuated from the high-risk areas, prompt action should be taken to prevent such people coming back to these lands once the slopes are stabilised. Some people expressed the desire to settle in the Mahaweli downstream areas. The time lag for a repetition of a landslide can vary from a few weeks to about fifty to sixty years or more and because of this increasing time lag, people tend to resettle (illegally or legally) in these high-risk areas. Steps should be taken to acquire such lands, afforest them and declare them as forest reserves.

However socio-economical aspects and life patterns of the evacuated people should be considered in any resettlement programme.

3.1.4 Monitoring

Although the prediction of the exact timing of a landslide is not possible, early indicatins of such hazards could be monitored so that adequate warnings for evacuation of the villages in the vicinity could be given. These features will include the appearance of soil cracks and new springs from the hill slopes, sudden changes in the turbidity of existing springs and unusual flow of natural streams.

It is proposed to train a group of G.C.E. Advanced Level students and teachers from the Maha Vidyalayas in close proximity to high risk-areas in carrying out landform and geological surveys. Such training will enable these personnel to determine the locations of potential landslide areas before the next southwest monsoon.

The above training programme will also include a 2-day workshop with the main objective of introducing various laboratory and field techniques in order to undertake the field survey. Once this programme is over, field surveys will be carried out by these trained students and teachers during the weekends and holidays under the guidance of the Final Year Geology students from the Geology Department of the University of Peradeniya.

3.1.5 Aerial Surveys :

As landslides have complex geometric forms the overall extent is best studied using remote sensing techniques (i.e. low-attitude aerial photography). Remote sensing techniques have been proved to be more effective than actual ground checking due to :

(a) A synoptic view being available over a large area and

(b) the facility of studying simultaneously the many factors causing landslides.

It is proposed to obtain low-altitude aerial photographs of high-risk areas periodically to monitor any further movements in such areas. This exercise will be undertaken in addition to the study of the systematic aerial photographs taken over the same areas, during the preparation of the Landslide Hazard Maps described in section 3.2.5.

3.2 Medium-Term Strategy :

3.2.1 Stabilization of Areas Affected by Landslides :

Stablization of areas affected by landslides specially on steep hill slopes is of vital importance so as to minimize further land degradation during heavy rainfall.

Such activities should be directed at the control of the movement of debris and soil so as to avoid siltation of reservoirs and water courses downstream. These stabilization procedures will include vegetative, and mechanical measures and control of artificial drainage caused by landslides.

3.2.2 Vegetative Measures:

Vegetation, specially trees play a major role in slope stabilization through reduction of soil water via evapotranspiration, consolidation of soil-mass by root systems and anchoring of the regolith to the bed rock in areas where the rock is either partly weathered or fractured. Reestablishment of trees will take a long period of time and therefore, as a complementary short-term measure, grasses with shallow root systems and deep rooting legumes should be grown to bind the masses of soil together.

The Forest Department should identify the different tree and grass species that are fast growing and act as slope stabilizers. Considering the present demand for arable land, the utilization aspects of these trees too should be taken into consideratin. Concepts of agro-forestry seem most suitable in the current situation and are worth trying out.

3.2.3 Drainage Measures :

One of the main factors triggering-off landslides is the high pore-water pressure in the sub-soil caused by excessive infiltration of water. Excess water should be carefully led off the land. Very often this situation is created by water seeping from drainage channels. It is very essential to line irrigation channels along high seepage zones. Such irrigation channels should be carefully maintained by de-silting so as to prevent seepage of water to the sub-soil by overflow. The construction of small reservoirs on crests of hills should also be avoided so as to prevent underground seepage of water along the hill slopes.

3.2.4 Preparation of Landslide Hazard Maps :

Potential high Landslide Risk areas can be delineated by studying the composition and texture of the soils, landforms, nature of the slopes, drainage, land use, bedrock geology and rainfall data. It is proposed to prepare "Landslide Hazard Maps of Sri Lanka" covering the central hill country and the south-western hills. Most of this information will be collected by remote sensing techniques (ie. 1:10,000 aerial photographs and stereo-pairs). Once the data is gathered, extensive ground follow-up will be done using 1:10,000 scale controlled/semi-controlled mosaics. All this information will finally be assembled as "Landslide Hazard Maps" to the scale of 1:50,000 covering the required areas of each administrative district.

These maps will show the nature and probability of the risk and will serve as a valuable guide to development planners, land use planners and local administrators.

It must be stressed that land use planners, Urban Development and Town and Country Planning Authorities, should work in close collaboration with the Geological Survey Department specially when planning development activities in highland areas.

3.2.5 Monitoring of Micro-seismic Activity and Rainfall Intensity :

It is proposed to instal equipment to monitor microseismic activity and rainfall intensities in the high-risk landslide areas. The monitoring will have to be done continuously by the Meteorology Department. Funds should be made available to the Meteorology Department to purchase and maintain the equipment necessary.

3.2.6 Post-Graduate Research Grants :

It is proposed to provide three post-graduate research grants, each of 2-years duration in the Geology Department of the University of Peradeniya. These grants should be for the study of landslides and the effective remedial measures that have to be taken to arrest such hazards. The recipients of these grants should carry out a 2-year post-graduate research project in this field.

3.2.7 Permanent Investigatin Committee :

As Sri Lanka has a surface area of only about 25,000 sq. miles, and cannot afford mass scale land degradation, rapid siltation of reservoirs and recurrent expenditure on disaster rehabilitation, it is proposed to have a permanent multi-disciplinary committee of appropriate specialists to arrest such phenomena as early as possible.

This team should have representation of specialists from the agencies listed below and will involve the following Government Departments and Agencies.

(a) Geological Survey Department

(b) Land Use Division of the Irrigation Department

(c) Forest Department

(d) Agriculture Department

(e) Town and Country Planning Department

(f) Urban Development Authority

(g) National Building Research Organisation (NBRO)

(h) Geology Department of the University of Peradeniya

(i) Survey Department

(j) Ministry of Education

(k) Road Development Authority

It is proposed that the Chairman, Central Environmental Authority should be the Chairman of the Committee.

3.2.8 Co-ordinating Agency :

It is also proposed that the Central Environmental Authority should co-ordinate and monitor the implementation of both the short-term and medium-term strategies as proposed in this report.

4. COST ESTIMATES

The tentative cost estimates given in this report will include the costs of reconnaissance aerial surveys (3.1.5), preparation of landslide hazard mapas (3.2.5), short-term monitoring of high risk areas (3.1.4) and post-graduate research grants (3.2.6). The costs for evacuation (3.1.1), resettlement (3.1.2), land acquisition (3.1.3) stabilization of landslides (3.2.1) and monitoring of micro-seismic activity and rainfall intensity (3.2.5) have not been included in these cost estimates. Such figures will be provided subsequently by the relevant organisations.

4.1 Reconnaissance Aerial Survey :

Reconnaissance Aerial Survey	Rs.60,000		
Photographic equipment and Processing	Rs. 2,000		
Miscellaneous expenditure	Rs. 1,000		
Total Cost		Rs.63,000.00	
No.of flights anticipated for 3 years		10^2	
Sub Total A			Rs.6,30,000.00

4.2 Preparation of Landslide Hazard Maps :

(i) Cost of 1:10,000 stereopairs ;Rs.3,000,000.00
1:10,000 mosaic and
drafting and printing
(Tentative Estimate)

(ii)	Cost of maintaing a project office for 3 years	Rs. 800,000.00	
	Cost of 2 Nos. 4-wheel Drive Vehicles	Rs. 800,000.00	
	Cost of maintaining a field camp (for 30 months)	Rs. 150,000.00	
	Subsistence	Rs. 540,000.00	
	Fuel	Rs. 187,500.00	
	Stationery	Rs. 10,000.00	
	Casual Labour	Rs. 300,000.00	Rs.5,787,500.00
	Sub Total B		Rs.5,787,500.00

4.3 Short-term monitoring of high risk areas :

(i)Training of Local personnel	Rs. 20,000.00	
(ii)Detailed field checking	Rs. 65,000.00	
(iii)Transport	Rs. 50,000.00	Rs.135,000.00
Sub Total C		Rs. 135,000.00

4.4 Post-Graduate Research Assistantship (Grants) :

Cost for 3 Research Assistantships	Rs. 180,000.00	Rs.180,000.00
Sub Total D		Rs. 180,000.00

4.5 Cost of Reforestation :

Costs per acre	Rs. 6,000.00	
Approximate acreage in the Nuwara-Eliya District that needs re-forestation:1500 ac.)		
Cost of Reforestation= 1500 x 6000	Rs.9,000,600.00	Rs.9,000,600.00
Sub Total E		Rs.9,000,600.00

4.6 Cost of Rain Gauges :

5 Rain Gauges	Rs.150,000.00	Rs.150,000.00
Sub Total F		Rs. 150,000.00

TOTAL ESTIMATED COST : Rs.15,882,500.00

5. SUMMARY OF RECOMMENDATIONS

5.1 Short-Term Strategies :

The following short-term strategies are recommended for implementation before the monsoonal rains in May, 1986.

The District Ministries concerned should take immediate steps to evacuate people from the high risk areas as identified in this report.

5.1.2 The Ministries of Lands and Land Development and Agricultural Development and Research and the other relevant Ministries, Departments and the District Ministries should carry out a co-ordinated programme of studies to identify suitable lands for resettlement of the people who are to be evacuated from high risk areas and also stipulate land use policy and standards for land management.

5.1.3 All high risk areas should be acquired and a programme of land rehabilitation and afforestation set in motion by the Ministry of Lands and Land Development in close collaboration with the Forest Department and the Plantation Agencies.

5.1.4 The Ministry of Higher Education through the Geology Department of the University of Peradeniya should undertake workshops and training programmes in early identification of landslides and earthslips with a view to evacuation of people well in time.

5.1.5 The Ministry of Lands and Land Development should, through the Survey Department and in collaboration with the

Geological Survey Department, carry out periodical aerial surveys of the high-risk areas in order to be able to issue prior warnings to the people.

5.1.6 **Medium-Term Strategies** :

The following Medium-Term Strategies are recommended for implementation within the next 3-years period.

5.1.7 The Ministry of Lands and Land Development in collaboration with the relevant Agencies should launch a programme of stabilisation of the areas affected, through vegetative, mechanical and other appropriate measures.

5.1.8 The Ministry of Industries and Scientific Affairs will ensure that the Department of Geological Survey gives high priority to the preparation of Landslide Hazard Maps of Sri Lanka covering the Central Hill iCountry and the South western hills.

5.1.9 The Ministry of Industries and Scientific Affairs will ensure the installation of equipment necessary for the monitoring of Micro-seismic activity and rainfall intensities in high-risk areas through the Department of Meteorology.

5.1.10 The Ministry of Higher Education should provide for 3 Post-Graduate Grants, each of 2-years duration in the Gelogy Department of the University of Peradeniya for study of landslides and effective remedial measures for mitigation of such landslides.

5.1.11 The Central Environmental Authority should set up a permanent multi-disciplinary committee of experts to monitor mass scale land degradation and make recommendations to the Government on the remedial measures to be taken.

5.1.12 The Central Environmental Authority should co-ordinate and monitor the implementation of the short-term and medium-term strategies outlined in this report.

APPENDIX - I

(i) Mr. Sunil Dimantha
Senior Specialist Officer
Land Use Division
Irrigation Department

(ii) Mr.M. R. D. Fernando
Deputy Director
Geological Survey Department

(iii) Dr. Leslie Herath
Geologist/Photogeologist

(iv) Mr. P. Krishnarajah
Soil Conservation Officer
Department of Agriculture

(iv) Mr. Padmasiri Ranasinghe
Geologist
Geological Survey Department

(v) Mr. Kirthi Sri Senanayake
Senior Scientist
National Building Research Organization

(vi) Prof. P.W. Vitanage
Department of Geology
University of Peradeniya and

(vii) Mr. R. A. Wijewansa
Director (Environmental Management)
Central Environmental Authority

REFERENCES

(1) O'Loughlin, C.L & Pearce A. J. 1976. Influence of Cenozoic geology on mass movement and sediment yield response to forest removal, North Westland, New Zealand. Bulletin of the International Association of Engineering Geology. 14: 41-48.

(2) Burroughs, E.R., & Thomas B. R. 1977. Declining root strength in Douglas Fir after felling as a factor in slope stability. Research Paper INT-190. Inter-mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Ogden.

(3) O'Loughlin, C.C. 1974. The effect of timber removal on the stability of forest soils. Hydrology 13: 121-134.

(4) O'Loughlin C.L. & Watson A. J. 1979 Root Wood Strength detioration in Radiata Pine after clear felling. New-Zealand Forestry - I Science 9. 284-293.

****