JAPAN INTERNATIONAL COOPERATION AGENCY

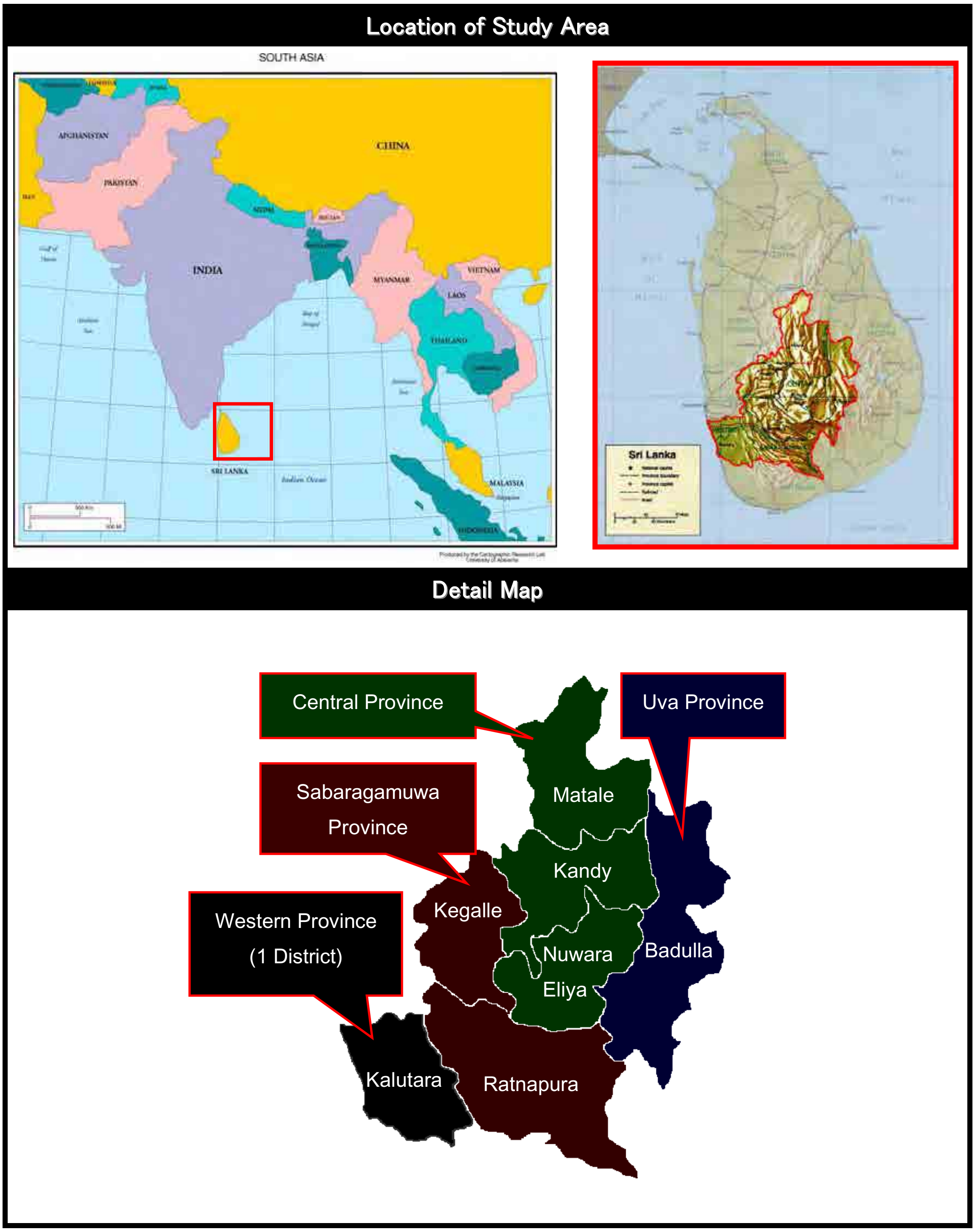
The Data Collection Survey on Road Protection against Natural Disaster (Landslide-Disaster)

FINAL REPORT (1/2)

December, 2012

KOKUSAI KOGYO CO., LTD.
ORIENTAL CONSULTANTS CO., LTD.
JAPAN CONSERVATION ENGINEERS CO., LTD.

I Location Map

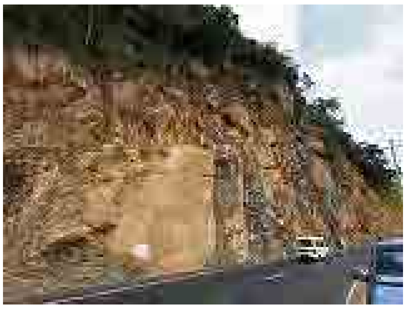


II Photos


i) Soaring escarpment with fresh traces of collapse at National Road (NR) A005


ii) Head scarp of a divided landslide just beside the main road at NR A016


iii) Typical "toe-eroded" landslide seen at NR A007


iv) Escarpment with risks of rock slides at NR A026


v) Warning signboard "Earth slip ahead!" at NR A005.


vi) A cracked road, Badulla


vii) A cracked house, Badulla


viii) An interview to the residents concerning with landslide disaster


ix) An interview at estate workers' residences


x) Discussion with villagers

III Abbreviations

ADB	Asian Development Bank
B/C	Benefit Cost Ratio
CEA	Central Environmental Authority
CL	Critical Line
DDMCU	District Disaster Management Coordination Unit
DiMCEP	The Disaster Management Capacity Enhancement Project
DOM	Department of Meteorology
DMC	Disaster Management Center
DRM	Disaster Risk Management
DS	Divisional Secretary
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL	Evacuation Line
ERD	External Resources Department
EWS	Early Warning Systems
FF	Fact Finding
F/S	Feasibility Study
Fs	Safety Factor
G/A	Grant Agreement
GDP	Growth Domestic Product
GN	Grama Niladhari
GOSL	Government of Sri Lanka
HC	Highland Complex
IEE	Initial Environmental Examination
ILSMP	Integrated Landslide Mitigation Project
JET	Japanese Expert Team
JICA	Japan International Cooperation Agency
KC	Kadugannawa Complex
L/A	Loan Agreement
LAA	Land Acquisition Act
LRRMD	Landslide Research and Risk Management Division
MDM	Ministry of Disaster Management
MoPH	Ministry of Ports and Highways
NBRO	National Building Research Organization
NCDM	National Council for Disaster Management
NDRSC	National Disaster Relief Service Center
NGO	Non Governmental Organization
NIRP	National Involuntary Resettlement Policy
NPD	National Planning Department
NPV	Net Present Value
ODA	Official Development Assistance
PWD	Public Work Department
RAP	Resettlement Action Plan
RDA	Road Development Authority
Rs.	Sri Lankan Rupee (Local Currency)
SLUMDMP	Sri Lanka Urban Multi-Hazard Disaster Mitigation Project
TOR	Terms of Reference
UNDP	United Nations Development Programme
USAID	US Agency for International Development
VOC	Vehicle Operation Cost
WL	Warning Line

IV Definitions of terms

New ODA Loan Project	Landslide Disaster Protection Project of the National Road Network
Rank A	National road sections in high risk regions
Rank B	National road sections of high priority for investigation。 National road section where landslide disaster occurred before and landslide countermeasures need to be implemented based on the detailed investigation in Rank A sections.
Rank C	Road disaster management model areas. National road section where landslide disaster occurred before, and urgent landslide countermeasures need to be implemented based on the detailed investigation in Rank B sections.

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1 Introduction

1.1 General

In Sri Lanka, with its rapidly growing economy, road transport plays a vital role in economic and social activities. To maintain economic growth at about 8%, the country has policies in place to develop and expand the road network across the country. However, Sri Lanka has suffered frequent floods and slope disasters due to its geographical conditions and climate change. More than 1.2 million people suffered from such events between December 2010 and February 2011 in five provinces, including the Eastern, Central and Uva Provinces. In addition, 18,237 km of roads in the same provinces were destroyed by flash floods and slope disasters, seriously disrupting economy activity and the lives of residents in the affected areas.

Under these circumstances, the Sri Lankan Government has set a goal of protecting the road network from such disasters, and in particular, strengthening its slope disaster management capacity in the mountainous and hilly regions most vulnerable to slope disasters as a result of heavy rain. The Road Development Authority (RDA), and the National Building Research Organization (NBRO) under the aegis of the Ministry of Disaster Management, have jointly begun to develop guidelines for Slope Management and Slope Protection (technical guidelines), and decided to enhance the landslide warning and management projects relating to road projects.

The RDA intends to apply the guidelines developed by the NBRO to national road projects in 7 districts in hilly regions; however, they have no experience in road disaster management, lack technical capacity, and face logistical issues regarding cost and capacity.

In light of this, the Survey will gather information necessary to assess the damage caused by slope disasters in Sri Lanka, and design effective support measures to strengthen current slope disaster management aimed at maintaining existing infrastructure (particularly national roads), among which will be the application of Japanese disaster management technology.

Ultimately, the Survey will seek to improve the RDA’s road disaster management capacity, in collaboration with the Japanese consultant team, taking maximum advantage of the NBRO’s experience in and knowledge of slope disaster management.

1.2 Objectives of the Project

The purpose of the Survey is to identify issues critical to strengthening slope disaster management for national roads in Sri Lanka, gather information useful in prioritizing support measures, and discuss support strategies.

➢ Overall goal

To strengthen Sri Lanka’s slope disaster management capacity

➢ Project goals

- To identify issues critical to strengthening slope disaster management for national roads

- To assess damage from slope disasters and perform risk management
- To prioritize proposed support strategies and measures.

➢ Expected outcomes

- Landslide damage (type, magnitude and economic impact) to road infrastructure (particularly national roads) will be assessed, and risk management will be performed.
- An approach to providing effective support for slope disaster management, to maintain the infrastructure (particularly national roads), will be identified.

1.3 Survey area and target national roads

In Sri Lanka, slope disasters have predominantly occurred in the hilly regions of Central, Uva, Sabaragamuwa and Western provinces. As part of the Project, a survey will be conducted in seven high-priority districts designated by the Sri Lankan Government as high disaster-risk areas (Figure 1-1).

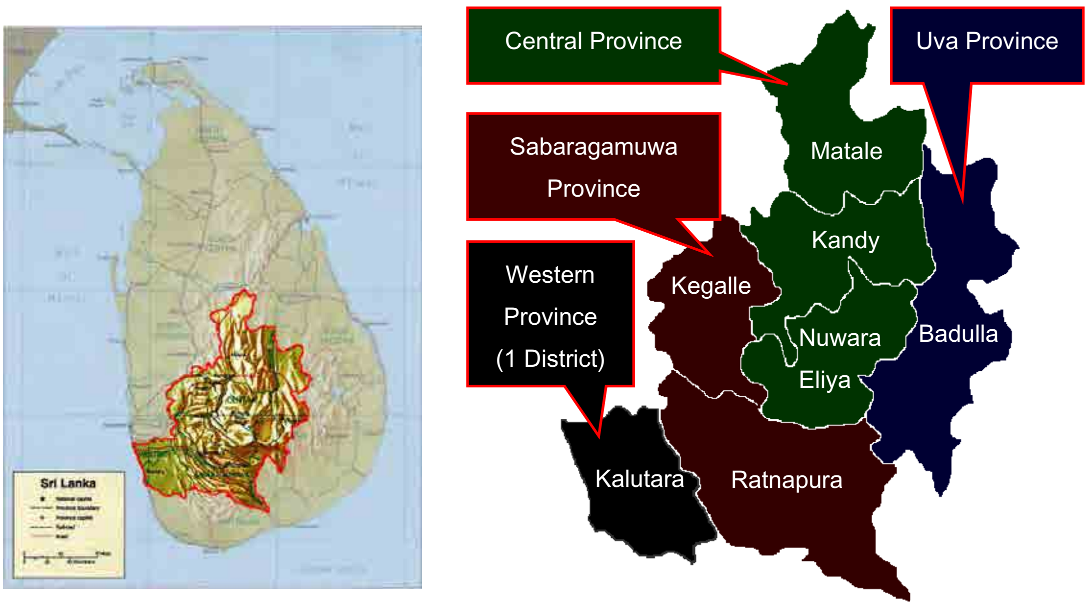


Figure 1-1: Survey areas in the Project

1.4 Implementation structure of the survey

1.4.1 JICA Survey Team

The Japan International Cooperation Agency (JICA) has set up a 14-member Japanese consultant team for the Project (Figure 1-2). The Project is scheduled to begin in June 2012 and be completed by the end of November 2012.

The Project will be implemented with close cooperation between the Japanese consultant team and their counterpart organization in Sri Lanka.

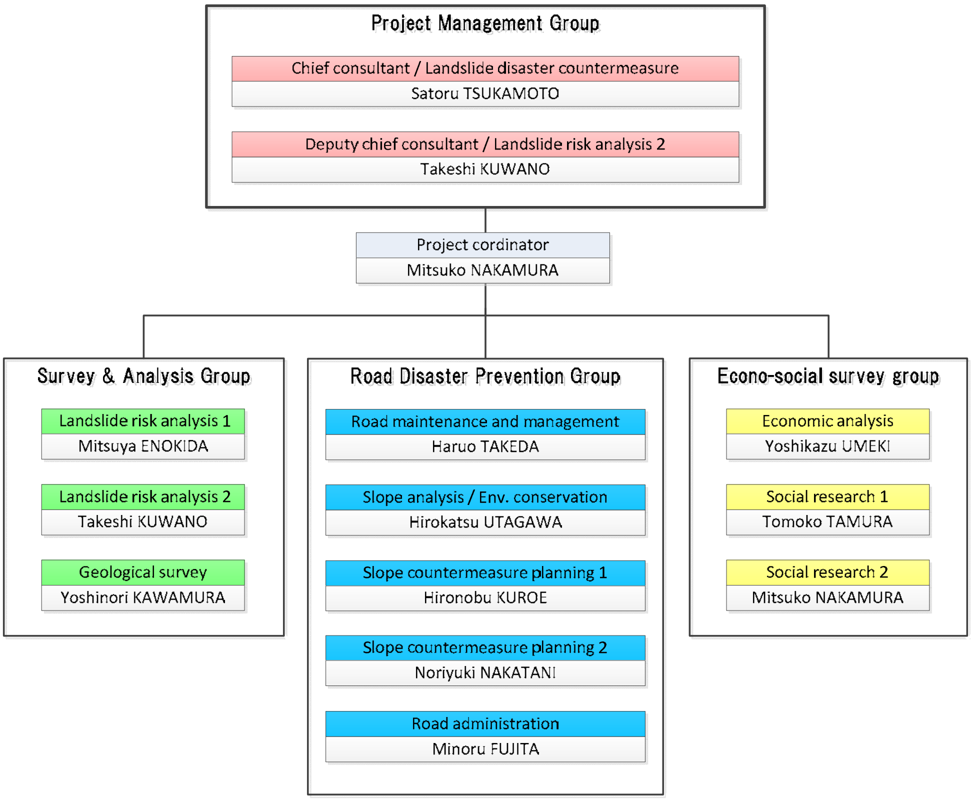


Figure 1-2: Organizational structure for the implementation of the Project

1.4.2 Government offices and organizations related

The major government ministries and agencies related in the Project are:

- The Road Development Authority (RDA) under the aegis of the Ministry of Ports and Highways
- The National Building Research Organization (NBRO) under the aegis of the Ministry of Disaster Management.

The details of both organizations will be described in Chapter 3.

2 Outline of survey area and target national roads

2.1 Natural condition of the survey area

2.1.1 Landforms and geology

a. Landforms

The Survey Team collected topographic information from Survey Department of Sri Lanka for the targeted areas as follows:

- 1:50,000 Topographic Map,
- 1:50,000 Geo-referenced Raster Images of Topographic Map,
- 1:250,000 Topographic Map (Relief Map of SE and SW parts of Sri Lanka),
- Aerial Photographs (Contact Prints and its scanned data for Rank B and C sites),

Sri Lanka is one of the most scenic places in the world with a wide range of topographic features created by tectonic movements and long lasting erosion. Figure 2-1 shows a relief map of Sri Lanka and Figure 2-1 explains relief and drainage of Sri Lanka.

By elevation, the terrain of Sri Lanka is divided into three zones; the Central Highlands, the plains, and the coastal belt. The plains have an elevation of between 30 and 200 m above sea level and occupy the dominant parts of the island. The coastal belt is surrounding the island with an elevation of lower than 30m above sea level.

The Central Highlands are the plateau areas with rugged mountains located in the south – central part of Sri Lanka and fringed by the plains. The main high plateau is running north – south for approximately 65 kilometers, with the highest peak of Pidurutalagala at 2,524 m. At the plateau's southern end, mountain ranges stretch 50 kilometers to the west toward Adams Peak (2,243 meters) and 50 kilometers to the east toward Namunakuli (2,036 meters). The Hatton Plateau is located on the west and a deeply dissected by series of ridges sloping downward toward the north. The Uva Basin is on the east and consists of rolling hills covered with grasses, traversed by some deep valleys and gorges. The parallel ridges of the Rakwana Hills lie in the south, with several peaks over 1,400 meters. The land descends from the Central Highlands to a series of escarpments and ledges at 400 to 500 meters above sea level before sloping down toward the coastal plains.

The study sites locate in the Central Highlands along Class A national roads.

Figure 2-2: Relief Map of Sri Lanka
(Source: University of Texas)

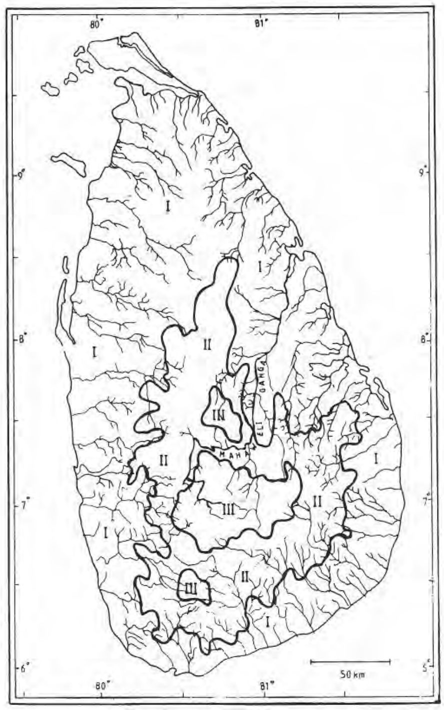


Figure 2-1: Relief Map of Sri Lanka
I: land below 200 m elevation
II: land between 200 m and 1,000 m
III: land over 1,000 m elevation
(Source: Encyclopedia of European and Asian Regional Geology)

b. Geology

The Survey Team collected geological information from Geological Survey and Mine Bureau of Sri Lanka for the targeted areas as follows:

- 1:100,000 Geological Maps,
- Geological Map of Sri Lanka,
- Metamorphic Map of Sri Lanka,
- Structural Map of Sri Lanka,
- Geological Map of Central and Western Sri Lanka

Figure 2-3 summarizes main lithotectonic units in Sri Lanka along with foliation trend lines.

More than 90 percent of Sri Lanka's surface lies on Precambrian strata of metamorphic rock of highly crystalline and non fossiliferous, some of it dating back 2 billion years. The Precambrian strata show structural trend of north-easterly – north – north-westerly and grouped into 4 complexes; Highland Complex, Kadugannawa Complex, Wanni Complex and

Vijayan Complex as shown in Figure 2-3. Most of the study sites sit in Highland Complex and some around Kandy locate in Kadugannawa Complex.

Highland Complex (hereinafter referred to as HC) is composed of inter-banded metamorphic rocks and running across the centre of the island. Metamorphic rocks in HC fall in granulite faces; dominant rock types are charnockitic gneiss, marble, quartzite and quartzofeldspathic gneiss. Metasediments of HC aged 2,000 million years; HC represents 2000 m.y. old crust. Regional metamorphism took place at 665 ~ 550 m.y. ago under medium pressure and very high temperature.

Kadugannawa Complex (hereinafter referred to as KC) is infolded with HC. Metamorphic rocks in KC experienced granulite faces metamorphism; high temperatures and pressures associated with the process of metamorphism. There are no agreements on the origin of these rocks. Representing rock types are biotite-hornblende gneiss and amphibolites.

A geologist from outside of Sri Lanka must be overwhelmed by the densely distributed faults, shear zones, and thrusts in a regional geological map in Central Highlands, even inferred from aerial photo reading. Traces of intense and repeated tectonic movements and metamorphism can be seen on sites as densely developed foliation and cracks. Weathering and alteration are intensely developed in many outcrops along the targeted road. A geologist will be also surprised by erratic weathering condition seen in an outcrop. You may find a relatively fresh rock bed just beside heavily weathered parts.

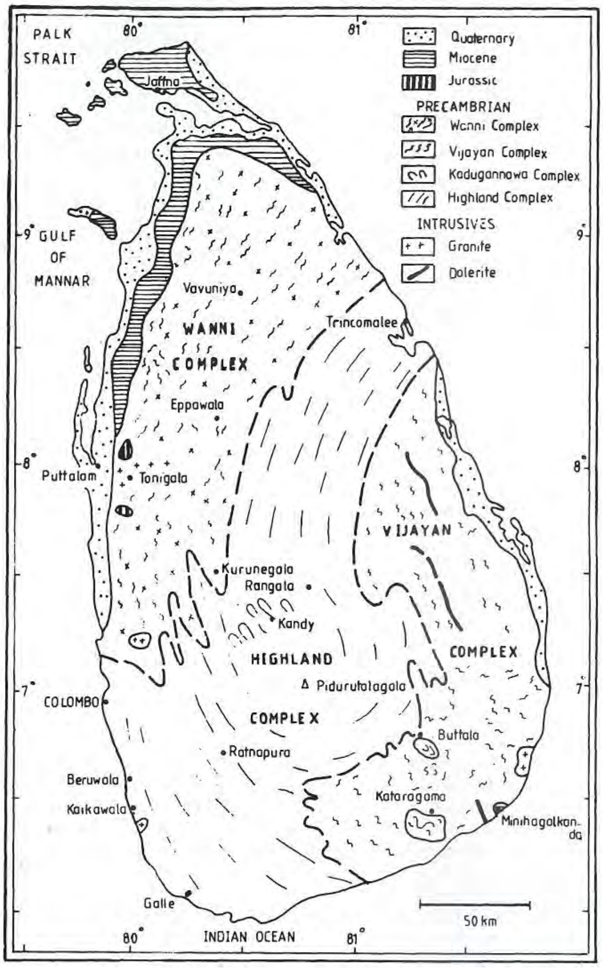


Figure 2-3: Geological Map of Sri Lanka (Source: Encyclopedia of European and Asian Regional Geology)

c. Aerialphotograph

The Study Team purchased aerial photographs and relevant information for Rank B and C sites from the Survey Department as follows:

- Contact prints of aerial photographs (72 pictures),

- Scanned image of aerial photographs (ditto),
- Flying charts (10 sheets),

Most of the aerial photographs were taken between 1999 and 2001. 3 photographs for A021-020 were in 2007. According to the homepage description of the Survey Department of Sri Lanka, the scale of these photographs is S = 1:20,000.

With the collected aerial photographs, the Study Team carried out preliminary photo reading to grasp topographic information relating to landslide landform and other geological features.

Table 2-1 organises information obtained from the photo reading as well as from the corresponding geological maps.

The notable findings through the photo reading are summarised below:

- At the site of A005-135, disturbed landform was recognised in the upper slope. This suggests some possibilities of much larger landslide than currently expected,

- At the site of A016-010, the landslide is located in a rolling slope of colluvium provided by a huge collapse of the mountain slope. The colluvium slope shows disturbed landform and several landslides were read in the upper slope of the currently supposed landslide. This suggests some possibilities of much larger landslide than currently expected,

- At B413-070, a lot of divided landslides were read as aligned terrace fields with clear head scarps or disturbed landform in tea fields or rugged slope. The landslides are distributed from the upper slopes just beside the toe of the steep cliff of Ragara Rock Mountain, to the rolling lower slopes which are cultivated as tea fields. Directions of the landslides are supposed from EES to ES,

- Since photo reading has inevitable errors due to individual difference in interpretation, further topographic investigation with detailed maps in larger scale is required.

- Photo lineaments were clearly read at around many sites. In some cases, convergence of photo lineaments was interpreted.

2.1.2 Climate

Sri Lanka enjoys warm climate due to its location of latitude between 5 and 10 degrees north, moderated by ocean winds and considerable moisture. The mean temperature ranges from a low of 15.8°C in Nuwara Eliya in the Central Highlands (where frost may occur for several days in the winter) to a high of 29°C in Trincomalee on the northeast coast (where temperatures may reach 37°C). The average yearly temperature, for the country as a whole, ranges from 26°C to 28°C. Temperatures may vary by 4 to 7°C between day and night.

Monsoon winds of the Indian Ocean and Bay of Bengal govern the rainfall pattern in Sri Lanka and provide four seasons to the tropical island.

The first monsoon season starts from mid-May and ends in October. During the first monsoon, south-westerly winds bring moisture from the Indian Ocean and unload tremendous amount of rainfall on the mountain slopes and the south-western sector of the island when encounters the south-western slopes of the Central Highlands. Some of the windward slopes receive up to 2,500 millimeters of rainfall per month, but the leeward slopes in the east and northeast receive little rain.

The second season occurs in October and November, the inter-monsoonal months. During this season, periodic squalls occur and sometimes tropical cyclones provide rains to the southwest, northeast, and eastern parts of the island.

During the third season, December to March, monsoon winds come from the northeast, bringing moisture from the Bay of Bengal. The north-eastern slopes of the mountains may receive up to 1,250 millimeters of rainfall during these months.

Another inter-monsoonal period occurs from March until mid-May, with light, variable winds and evening thundershowers.

The Survey Team collected daily precipitation data for the past 20 years from the following 12 meteorological stations:

Table 2-1: Information from Photo Reading and Geological Maps (Rank B, C)

No	Route No	Disaster Type	Category	Featuring Points	District	Aerial Photos		Photo Reading	Gelogical Map	
						Course	Number		Number	Geological Condition
A004-134	A004	Rock Fall	B		Ratnapura	2001-05	162,163	Blocked by clouds. Some phto lineaments were read.	17	$Pmgk^b$: Undifferentiated charnockitic biotite gneiss
A004-154	A004	Landslide?	B	Slope Failure in Embankment? Needs to be investigated.	Ratnapura	99-21	62,63	Shape of the landslide is unclear. But several small landslides were read along the valleys around the site. Convergence of photo lineaments was seen around the site.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmq: Quartzites. Beside a shear zone and a fault inferred by aerial photos.
A004-162	A004	Debris Flow	B	Debris Flow (L=8km)	Ratnapura	99-21	81,82,83	Sources of the debris flow were read in the mountain slopes located in the north of the site. The site is located at around the apex of the fan where the debris was accumulated.	17	Pmgga: Garnet - sillmanite - biotite gneiss. Close to a shear zone and an axis of a overturned synform.
A004-173	A004	Slope Failure	B	Adjucent to a high-tension pylon	Badulla	99-21	208,209,210	Convergence of photo lineaments was seen around the site. In the upper mountain slope, a trace of collapse was read.	17	Pmgk: Charnockitic gneiss, Pmq: Quartzites, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss.
A004-174	A004	Slope Failure	B	2 major slope failures	Badulla	99-21	208,209,210	The site is surrounded by photo lineaments.	17	Pmgk: Charnockitic gneiss, Pmq: Quartzites, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmgga: Garnet - sillmanite - biotite gneiss. Close to a probable thrust.
A004-185	A004	Landslide	B	Less Traffic	Badulla	99-21	215,216	Location shall be verified by geographical coordinate. Shape of the landslide is unclear.	17	Pmgk: Charnockitic gneiss, Pmq: Quartzites, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmgga: Garnet - sillmanite - biotite gneiss. Close to a probable thrust.
A004-193	A004	Landslide	B	Less Traffic	Badulla	99-21	183,184	Location shall be verified by geographical coordinate. Shape of the landslide is unclear.	17	$Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmgga: Garnet - sillmanite - biotite gneiss. Convergence of 4 shear zones and faults inferred by aerial photos.
A004-196	A004	Landslide	B	Less Traffic (Not confirmed)	Badulla	99-21	219,220	Location shall be verified by geographical coordinate. Shape of the landslide is unclear.	17	$Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmgga: Garnet - sillmanite - biotite gneiss. Convergence of 4 shear zones and faults inferred by aerial photos.
A005-042	A005	Landslide	B	Landslide (L=1km)	Nuwara Eliya	99-34	148, 149, 150, 151, 152	Shapes of landslides were unclear. Instad, traces of collapse and deeply erroded gullies were confirmed by photo reading.	14	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmq: Quartzites. Faults and a shear zone inferred by aerial photos.
A005-043	A005	Rock Fall, Rock Slide	B	Unstable rocks with open cracks	Nuwara Eliya	99-34	148, 149, 150, 151, 152	Photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmq: Quartzites. Faults and a shear zone inferred by aerial photos.
A005-044	A005	Rock Fall, Rock Slide	B	Unstable rocks with open cracks	Nuwara Eliya	99-34	148, 149, 150, 151, 152	Photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmq: Quartzites. Faults and a shear zone inferred by aerial photos.
A005-046	A005	Rock Fall, Rock Slide	C	Unstable rocks with open cracks	Nuwara Eliya	99-34	148, 149, 150, 151, 152	Very steep slope. Photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss, Pmq: Quartzites. Faults and a shear zone inferred by aerial photos.
A005-063	A005	Slope Failure	B		Nuwara Eliya	99-35	32,33,34	Small landslides were read as aligned terrace fields around the sites. Much larger landslides were read in the opposite side of the stream flown along the lower slope.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss. Close to a shear zone and a fault inferred by aerial photos.
A005-082	A005	Slope Failure	C	**Former 2 sections were merged in to 1 section.**	Nuwara Eliya	99-35	153,154,155	The site is surrounded by photo lineaments. The axis of the valley which the site is facing corresponds to one of the bphoto lineaments.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmc: Marble, Close to shear zones inferred by aerial photos.
A005-091	A005	Slope Failure	C		Badulla	99-27	206,207	The site is surrounded by photo lineaments. Lateral displacement over a liniament was confirmed.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss, Pmq: Quartzites. Close to shear zones inferred by aerial photos.
A005-135	A005	Landslide	C	Landslide (L=0.2 ~ 0.3km)	Badulla	99-28	53,54,55	Multiple Landslide, less clearly read, Other landslides were read in the upper slope but unclearly. This leads some possibilities of much larger landslide than currently expected. Divided landslides were seen in the lower slope.	17	Pmgk: Charnockitic gneiss, Pmq: Quartzites. Beside shear zones inferred by aerial photos.
A005-167	A005	Landslide	C	Landslide (L=0.1 ~ 0.2km) Detour by a bridge can be an option,	Badulla	99-17	35,36	Clearly read landslide. Another landslide was read on the west side but may not affect the road.	15	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmgk: Charnockitic gneiss, Pmq: Quartzites. A shear zone inferred by aerial photos.
A007-031	A007	Slope Failure	B	Eroded by Kelani River.	Kegalle	No Photo			16	Pmgga: Garnet - sillmanite - biotite gneiss, Faults inferred by aerial photos.
A007-042	A007	Landslide?	B	Landslide or Slope Failure	Nuwara Eliya	99-35	04,05,06,07	Shape of a landslide was not read at the site. Several photo lineaments were read around the site. A trace of collapse was confirmed at the upper slope upstream.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Convergence of shear zones and faults inferred by aerial photos.
A007-045	A007	Rock Fall, Rock Slide	B	Along with Slope Failure	Nuwara Eliya	99-35	04,05,06,07	Several lineaments were read around the site.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss. Close to shear zones and faults inferred by aerial photos.
A007-047	A007	Landslide	B		Nuwara Eliya	99-35	04,05,06,07	Shape of the landslide is unclear. Photo lineaments were seen around the site.	17	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmq: Quartzites. Close to a fault inferred by aerial photos.
A007-054	A007	Slope Failure	B		Nuwara Eliya	99-35	09,10	Convergence of photo lineaments was seen around the site.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss. Close to a shear zone and a fault inferred by aerial photos.
A007-057	A007	Slope Failure	B		Nuwara Eliya	99-35	95,96	Blocked by clouds. Steep planer slope. Several photo lineaments were read around the site.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Close to shear zones and a fault inferred by aerial photos.
A007-069	A007	Landslide	B	Old road was moved away by the landslide.	Nuwara Eliya	99-35	195,196	Shape of the landslide is unclear, unable to read. Photo lineaments were seen around the site.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss. Close to shear zones inferred by aerial photos.
A016-010	A016	Landslide	C	Head scarp approaching to the road shoulder	Badulla	99-22	17,18	Clearly read landslide, located in a rolling slope of colluvium provided by a huge collapse of mountain slope. In the lower slope, several small sized divided landslides were read. Several landslides were read in the upper slope. This leads some possibilities of far much larger landslide than currently expected.	17	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss. Convergence of shear zones and faults inferred by aerial photos.
A021-020	A021	Landslide	B	Land owner didn't allow RDA to investigate the site.	Kegalle	07-07	236,237,238	Shape of the landslide is unclear, unable to read. Convergence of photo lineaments was seen around the site.	13	Pmgr: Granite gneiss, $Pmgh^b$: Hornblend - biotite gneiss. Surrounded by shear zones inferred by aerial photos and probable thrusts.
A026-027	A026	Rock Fall, Rock Slide	B		Kandy	No Photo			14	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmc: Marble, Pmq: Quartzites. Faults and a shear zone inferred by aerial photos.
A026-029	A026	Rock Fall, Rock Slide	B		Kandy	No Photo			14	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss, Pmc: Marble, Pmq: Quartzites. Faults and a shear zone inferred by aerial photos.
A026-036	A026	Slope Failure	B	Damage occurred during construction. Retaining wall was constructed.	Kandy	99-29	53,54	Trace of small collapse of mountain slope was read in the upper slope. Photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgk: Charnockitic gneiss.
A026-045	A026	Slope Failure	B		Kandy	99-32	65,66,67	Photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, $Pmgk^b$: Undifferentiated charnockitic biotite gneiss. Faults inferred by aerial photos.
A026-048	A026	Slope Failure	B		Kandy	99-32	65,66,67	Terraced rice fields are on the upper slope where colluvium is supposed. Photo lineaments were seen around the site.	14	$Pmgk^b$: Undifferentiated charnockitic biotite gneiss. Faults inferred by aerial photos.
A026-049	A026	Slope Failure	B		Kandy	99-32	65,66,67	Trace of collapse of mountain slope was read in the upper slope. Photo lineaments were seen around the site.	14	$Pmgk^b$: Undifferentiated charnockitic biotite gneiss. Faults inferred by aerial photos.
A026-051	A026	Slope Failure	B	Damage occurred during construction. Retaining wall was constructed.	Kandy	99-32	65,66,67	Trace of collapse of mountain slope was read in the upper slope. Photo lineaments were seen around the site.	14	$Pmgk^b$: Undifferentiated charnockitic biotite gneiss. Faults inferred by aerial photos.
A026-055	A026	Rock Fall, Rock Slide	C		Kandy	99-32	47,48,49	Very steep planner slope. A couple of photo lineaments were seen around the site.	14	Pmgk: Charnockitic gneiss. Shear zones inferred by aerial photos.
A026-056	A026	Slope Failure	B		Kandy	99-32	47,48,49	Very steep planner slope. A couple of photo lineaments were seen around the site.	14	Pmgk: Charnockitic gneiss, Pmgga: Garnet - sillmanite - biotite gneiss, Pmq: Quartzites. Shear zones inferred by aerial photos.
A026-058	A026	Slope Failure	B		Kandy	99-32	47,48,49	Very steep planner slope. Trace of small collapse was read less clearly in the upper slope. A couple of photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, Pmq: Quartzites, Pmghb: Hornblend - biotite gneiss. Shear zones inferred by aerial photos.
A026-060	A026	Rock Fall, Rock Slide	C	Damage occurred during construction. Retaining wall was constructed.	Kandy	99-32	47,48,49	Very steep planner slope. A couple of photo lineaments were seen around the site.	14	Pmgga: Garnet - sillmanite - biotite gneiss, Pmq: Quartzites, Pmghb: Hornblend - biotite gneiss. Shear zones inferred by aerial photos.
A113-010	A113	Landslide	B		Kandy	99-10	161,162	Shape of a landslide was not read at the site. Trace of collapse of mountain slope was read in the upper slope.	14	Pmq: Quartzites. Close to a probable thrust and an axis of antiform
A113-015	A113	Landslide	C	Involving road and residence.	Kandy	99-34	135,136	Less clearly read landslide, located in a colluvium slope formed by a collapse of upper mountain slope. In the axis of the ridge of upper mountain, 2 cols were clearly read.	14	Pmghb + Pmgbh: Hornblend - biotite gneiss + Biotite hornblende gneiss. Beside a shear zone inferred by aerial photos.
B413-070	B413	Landslide	C-	Very huge maltiple landslide	Nuwara Eliya	99-17	69, 70, 71, 72	Mega scale of multiple Landslides. Some divided landslides were read as aligned terrace filelds with clear head scarps, while others were read as disturbed landform in tea fields or rugged slopes. The landslides are distributed from the upper slopes just beside the toe of the steep cliff of Ragara Rock Mountain, to the rolling lower slopes which are cultivated as tea fields. Directions of the landslides are supposed from EES to ES.	14	Pmgga: Garnet - sillmanite - biotite gneiss, Pmgc: Calc-gneisses and / or granulites, Pmq: Quartzites, Pmqs: Impure quartzites. Faults and shear zones inferred by aerial photos.

B	Category B
C-	Category C-
C	Category C

- Bandarawela
- Badulla
- Ratnapura
- Aluthnuwara
- Passara
- Welimada
- Aranayake
- Kalutara-P.W.D
- Nawalapitiya
- Matale-P.W.D
- Hakgara botanical garden
- Ramboda,

Table 2-2 shows the relation between the studied sites and the meteorological stations mentioned above.

Table 2-2: Relation between studied sites and meteorological stations

Name of the Area	Location in the road	Name of the Site	Closest Meteorological Station
Hasalaka	60 km post of A26 road	A026-060	BD61 – ALUTHNUWARA (Lat 7.32N: Long. 81.0E)
5 km before Hasalaka	55 km post of A26 road	A026-055	BD61 - ALUTHNUWARA
Ramboda	46 km post of A05 road	A005-046	NE266 – RAMBODA (Lat 7.02N: Long. 80.72E)
Boragasketiya (near Nuwara'Eliya)	82 km post of A05 road	A005-082	NE142 – HAKGALA (Lat 6.92'N: Long. 80.82E)
Keppitipola	91 km post of A05 road	A005-091	BD539 – (Welimada) (Lat 6.90N: Long. 80.90E)
Badulla	135 km post of A05 road	A005-135	479 (Badulla) (Lat 6.98N: Long. 81.05E)
Passara/Badalkumbura	167 km post of A05 road	A005-167	BD411 (Passara) –data available from Oct 2005, (Lat 6.95N: Long. 81.20E)
Haputale/Bandarawela	10 km post of A16 road	A016-010	476 – (Bandarawela) (Lat 6.82N: Long. 80.97E)
Nawalapitiya	15 km post of A113 road	A113-015	KY370 – (Nawalapitiya) (Lat 7.07N: Long. 80.53E)
Ratnapura			486 – (Ratnapura) (Lat 6.68N: Long. 80.40E)
Kegalle			KE211 – (KEGALLA) (Lat 7.18N: Long. 80.47E)

Name of the Area	Location in the road	Name of the Site	Closest Meteorological Station
Kalutara			KT200 – Kalutara (Lat 6.58N: Long. 79.95E)
Matale			ML318 – Matale (Lat 7.47N: Long. 80.62E)
B-413	70 Km post (Kandy Ragala Main road)	B413-070	NE142 – HAKGALA or BD539 – (Welimada)

Variations in daily precipitation observed in 2010 at some typical meteorological stations are graphed in Figure 2-4, 2-5, 2-6, 2-7.

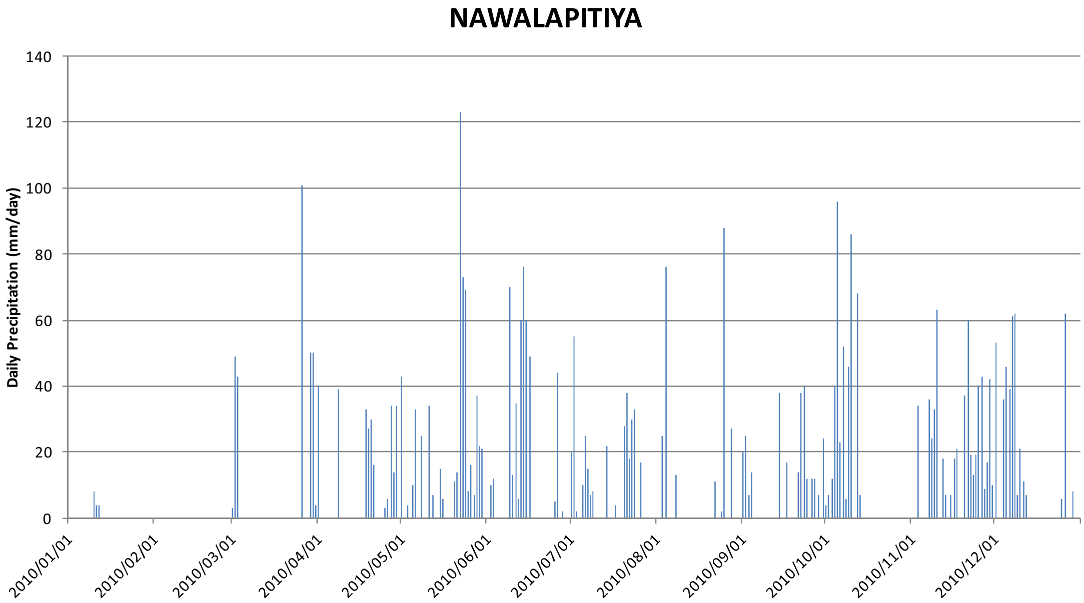


Figure 2-4: Daily Precipitation in 2010 at Nawalapitiya in Kandy District

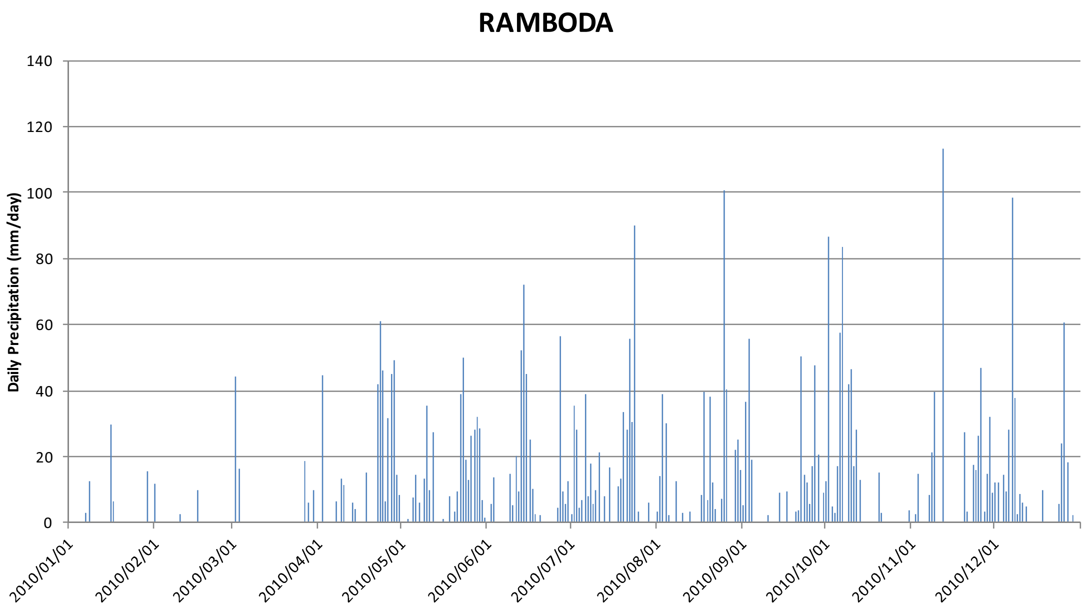


Figure 2-5: Daily Precipitation in 2010 at Ramboda in Nuwara Eliya District

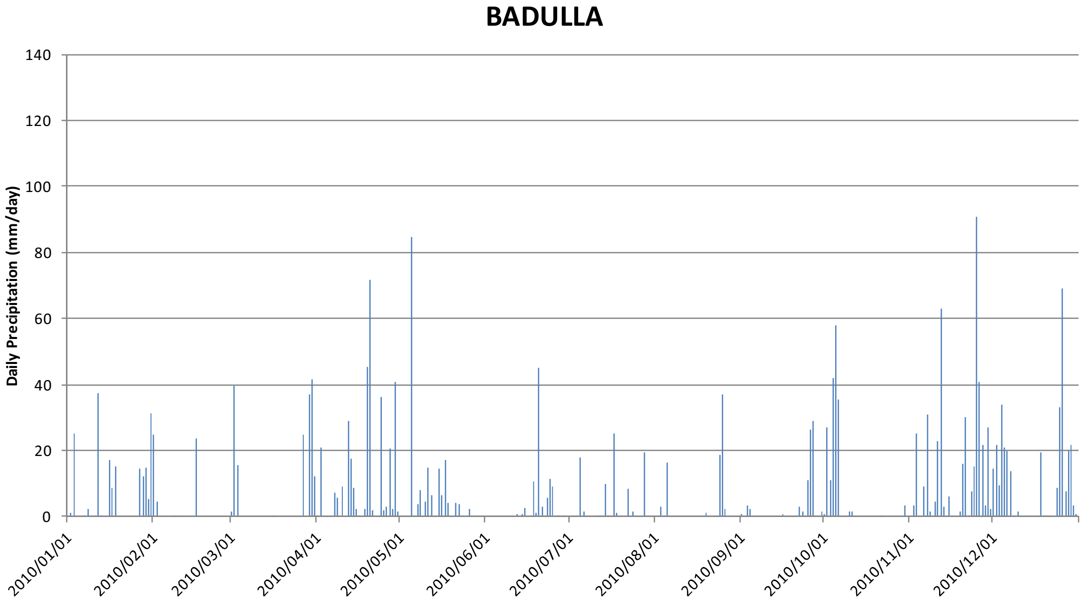


Figure 2-6: Daily Precipitation in 2010 at Badulla in Badulla District

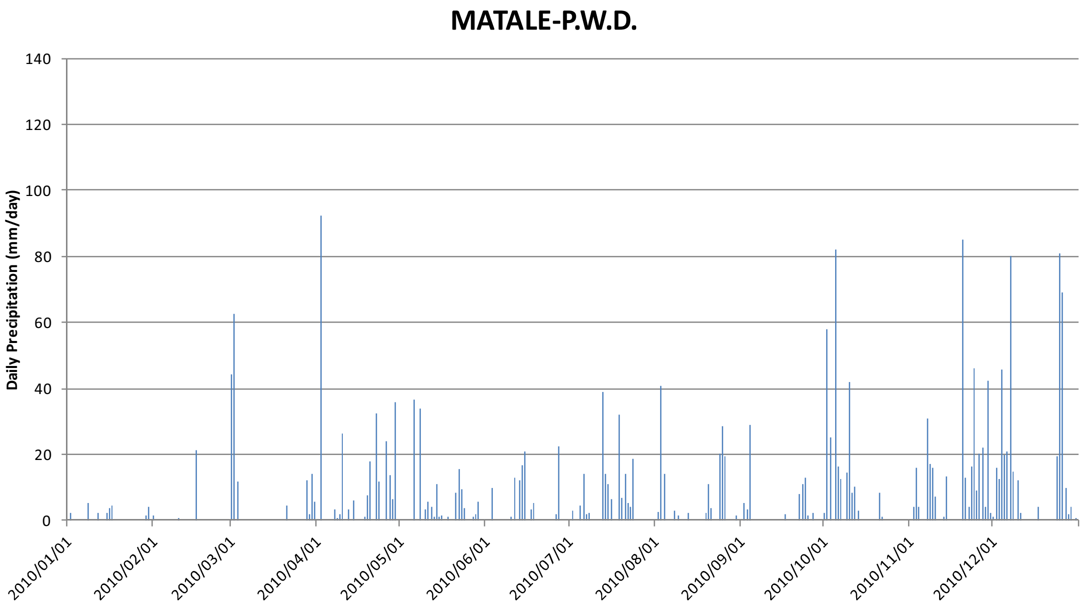


Figure 2-7: Daily Precipitation in 2010 at Matale in Matale District

The variation of precipitation explain a trend that, at some areas in the Central Highlands especially in Nuwara Eliya District, both SW monsoon and NE monsoon provide rainfall to the mountainous areas, along with squalls and tropical cyclones during the inter-monsoonal months of October and November.

2.2 Social and economic condition of the survey area

2.2.1 Population

Table 2-3 shows population, population growth rate and population density of the target districts. Kalutara district, which includes four urban councils and Kandy districts, which includes one municipal council and four urban councils, have relatively larger population.

Population densities of these two districts are also higher than those of other districts, which ranked 3rd and 4th respectively in all the 25 districts in Sri Lanka. Other districts, except Matale and Badulla also have higher population densities than the average of the country. Population density of Matale and Badulla districts are relatively lower among the target districts, however, they are among the highest half among the districts of the country. (See also Figure 2-8)

Table 2-3: Population, growth rate and density

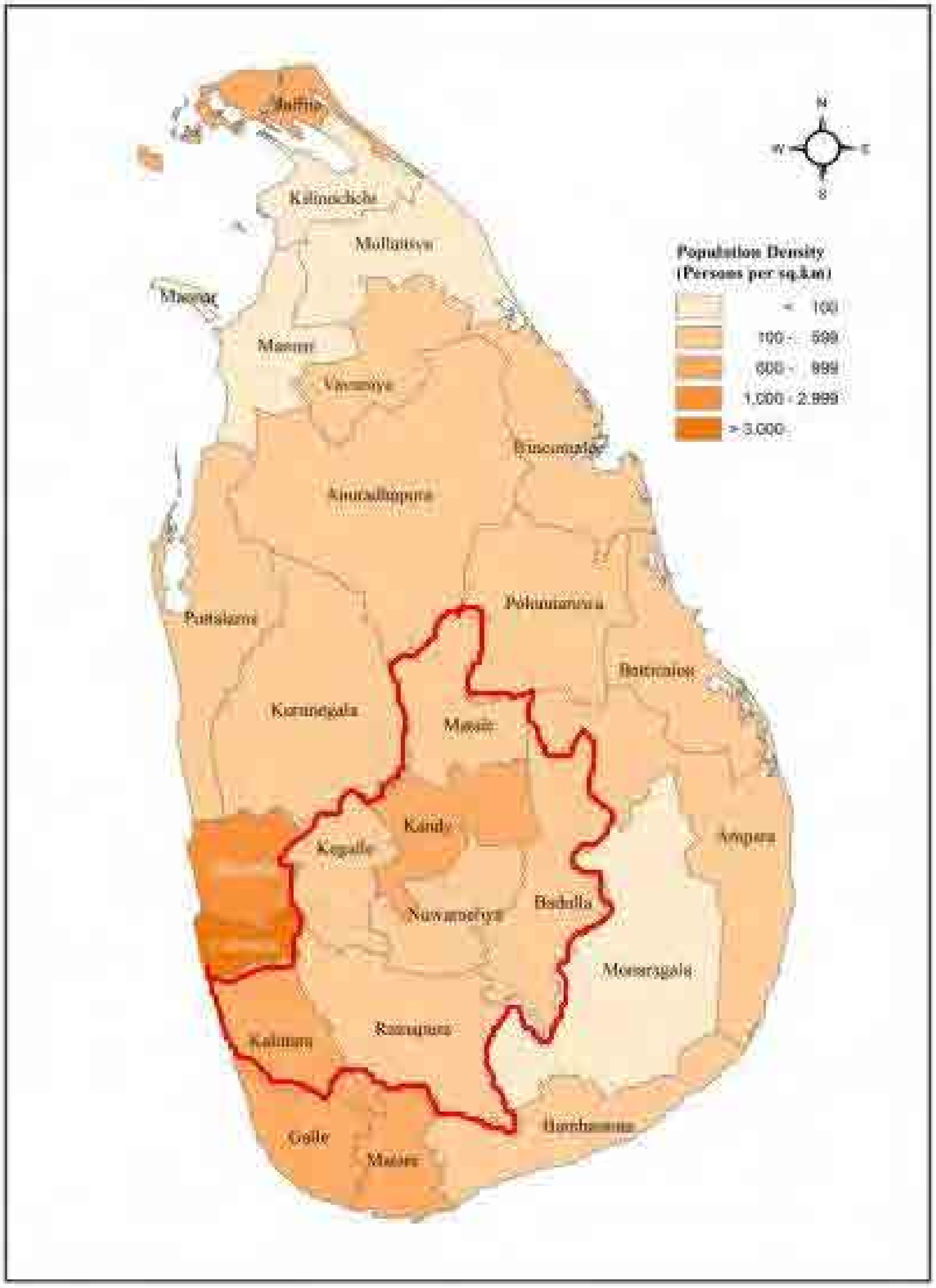
District	Population	Average annual growth rate (2001-2012) (%)	Population density (persons/km^2)	Rank of population dencity (1-25)
Kalutara	1,214,800	1.23	771	3
Kandy	1,368,216	0.65	714	4
Matale	482,348	0.88	247	14
Nuwara Eliya	706,210	0.05	414	9
Badulla	811,225	0.39	287	12
Ratnapura	1,082,299	0.59	334	11
Kegalle	837,179	0.61	497	8
Sri Lanka	**20,277,597**	**0.71**	**323**	**-**

(Source: Population senses 2012, Department of Senses and Statistics, Sri Lanka)

Kalutara district has the highest annual growth rate among the target districts. It is also the 2nd highest among all the districts in the country. It is mainly due to population inflow, by those who wish to have their own house in commutable area closer to Colombo where land prices are relatively lower than that of suburbs of Colombo. Nuwara Eliya and Badulla, which are plantation area in principle, have the lowest growth rates among the target district as well as among all the districts in the country. The main reason of this is population outflow

2.2.2 Economy and industries

Sri Lanka has been developing its economy at very high growth rates of 6% to more than 8% every year since 2005, except for 2009, as shown in Table 2-4. Per capita GDP is reached nearly US$ 3,000 at current prices in 2011. According to the "PRESS NOTE QUARTERLY ESTIMATES OF GROSS DOMESTIC PRODUCT First Quarter 2012" by the Ministry of Finance & Planning, the first quarter GDP growth rate in 2012 at 2002 constant prices to the previous year reached to 7.9 % per year. It seems that the growth speed is still continuing at a high level.



(Source: Population senses 2012, Department of Census and Statistics, Sri Lanka)

Figure 2-8: Population density

Table 2-4: Major economic indicators of Sri Lanka

Major Economic Indicators	2005	2006	2007	2008	2009	2010	2011*
GDP at Current Price (Rp.billion)	2,453	2,939	3,579	4,411	4,835	5,604	6,543
GDP at 2002 Constant Price (Rp.billion)	1,942	2,091	2,233	2,366	2,449	2,646	2,864
GDP Growth Rate (%)	6.2	7.7	6.8	6.0	3.5	8.0	8.3
per Capita GDP at Current Price (Rp.)	124,709	147,776	178,845	218,167	236,445	271,346	313,511
per Capita GDP at Current Price (US$)	1,241	1,421	1,634	2,014	2,057	2,400	2,836
Population (1000)	19,668	19,886	20,010	20,217	20,450	20,653	20,869
Population Growth (%)	1.1	1.1	0.6	1.0	1.2	1.0	1.0

Note: 2011* is provisional.
Source: Department of Census and Statistics of Sri Lanka

As to the industrial sector of Sri Lanka, the "Services" donates 58 % of the GDP, followed by the "Industry" and "Agriculture, Forestry and Fishing" with approximate shares of 30 % and 12 %, respectively as shown in Table 2-5. The shares of the three industrial sectors have been stayed almost same level basically since 2005.

Table 2-5: Percentage share of GDP by industrial sector

(Unit: %)

Industrial Sector	2005	2006	2007	2008	2009	2010	2011*
Agriculture, Forestry and Fishing	11.8	11.3	11.7	13.4	12.7	12.8	12.1
1. Agriculture, Livestock and Forestry	11.0	10.1	10.2	11.8	11.0	11.1	10.4
1.1 Tea	1.3	1.2	1.4	1.3	1.3	1.3	1.0
1.2 Rubber	0.4	0.6	0.6	0.6	0.4	0.8	0.9
1.3 Coconut	1.2	1.0	1.1	1.5	1.1	1.1	1.1
1.4 Minor export crops	0.4	0.4	0.3	0.3	0.3	0.3	0.3
1.5 Paddy	1.6	1.3	1.2	2.3	2.1	2.0	1.5
1.6 Livestock	1.0	1.0	1.1	1.0	1.1	1.0	0.9
1.7 Other food crops	3.6	3.3	3.0	3.5	3.4	3.4	3.6
1.8 Plantation Development	0.3	0.2	0.2	0.2	0.2	0.2	0.2
1.9 Firewood & Forestry	0.7	0.7	0.7	0.7	0.7	0.6	0.6
1.10 Other Agricultural Crops	0.4	0.4	0.4	0.4	0.4	0.4	0.4
2. Fishing	0.8	1.2	1.5	1.5	1.6	1.7	1.7
2.1 Inland - Fishing	0.1	0.1	0.1	0.1	0.2	0.2	0.2
2.2 Marine - Fishing	0.7	1.1	1.4	1.4	1.5	1.5	1.5
Industry	30.2	30.6	29.9	29.4	29.7	29.4	29.9
3. Mining and Quarrying	1.5	1.6	1.6	1.6	1.6	1.6	1.7
4. Manufacturing	19.5	19.2	18.5	18.0	18.1	18.0	18.2
4.1 Processing (Tea, Rubber and Coconut)	0.7	0.6	0.6	0.7	0.8	0.8	0.8
4.2 Factory industry	17.7	17.6	16.9	16.3	16.4	16.4	16.6
4.3 Cottage industry	1.1	1.1	1.0	0.9	0.9	0.8	0.8
5. Electricity, gas and water	2.4	2.5	2.5	2.4	2.4	2.3	2.2
6. Construction	6.8	7.4	7.4	7.4	7.6	7.6	7.8
Services	58.0	58.0	58.4	57.2	57.6	57.8	58.0
7. Wholesale and retail trade	23.2	22.4	22.1	21.5	19.6	19.6	20.8
8. Hotels and restaurants	0.6	0.6	0.5	0.5	0.5	0.6	0.7
9. Transportation and communication	11.7	11.7	11.8	12.0	12.4	12.7	12.5
10. Banking, insurance and real estate etc.	8.4	9.1	9.2	9.4	10.3	10.7	10.8
11. Ownership of dwellings	3.6	3.5	3.5	3.2	3.3	3.1	2.9
12. Government services	8.4	8.8	9.3	8.6	9.2	8.9	8.1
13. Private services	2.1	1.9	1.9	2.0	2.2	2.3	2.2

Note: 2011* is provisional.
Source: Department of Census and Statistics of Sri Lanka

Regarding the Agriculture, Forestry and Fishing sector, the "Rubber" and "Fishing" has doubled its share, while other sectors such as "Tea" has lost small shares since 2005.

In the "Industry" sector, "Factory" has lost a small share, while "Construction" has increased its share a bit since 2005.

The "Banking, insurance and real estate etc." has increased its share remarkably, while the "Wholesale and retail trade" has lost its share since 2005 in the "Service" sector.

Table 2-6 shows the GDP per capita by objective four Provinces as well as the all over Sri Lanka in 2010 at current prices. The GDP per capita of the Western Province is US$ 3,808, which is significantly high compared to the other Provinces and the whole nation. Other three provinces of Central, Sabaragamuwa and Uva Provinces showed lower level of the GDP per capita by ranging from US$1,597 to 1,836 which are lower than the national level.

Table 2-6: GDP per capita by province in 2010 (Current Price)

National/Provincial	GDP (Rp.million)	per Capita (Rp.)	per Capita (US$)
Sri Lanka	5,602,321	271,259	2,399
Western	2,524,812	430,488	3,808
Central	558,172	207,576	1,836
Sabaragamuwa	350,820	180,556	1,597
Uva	251,816	189,906	1,680

Source: Central Bank of Sri Lanka

Table 2-7 shows Employment share by industrial sector of the objective Provinces with reference to the whole nation. Employment of the Agriculture, Forestry and Fishing shares around one third of the total employment as an average of Sri Lank. However, the table shows a clear picture of different characteristics on the employment weight among the industrial sectors by Province. The Western Province has very small weight in the sector, while other three Provinces show higher employment weight than the national average. Uva Province, in particular, showed outstanding 63.7 % employment share. On the contrary, employments of sectors of "manufacturing", "Wholesale and Retail Trade" and "Transport, Storage and Communication" are very high in Western Province.

Table 2-7: Provincial employment by industrial sector

(Unit: %)

Industrial Sector	Sri Lanka	Province			
		Western	Central	Sabaragamuwa	Uva
Agriculture, Forestry and Fishing	32.8	9.3	43.8	44.9	63.7
Mining and Quarrying	1.2	0.6	0.3	6.1	0.4
Manufacturing	17.3	26.9	12.1	12.5	6.1
Construction	0.5	0.9	0.5	0.2	0.3
Electricity, Gas and Water	6.9	7.5	6.1	8.6	2.4
Wholesale and Retail Trade	15.9	20.6	14.1	12	9.9
Transport, Storage and Communication	7	11	5.8	4.2	4
Other Services	18.3	23.2	17.3	11.5	13.3

Source: "Consumer Finances and Socio - Economic Survey 2003/04", Central Bank of Sri Lanka

However, the objective Kalutara District, which is included in the Western Province is considered to have a similar characteristics as the other objective Districts in the three Provinces of Central, Sabaragamuwa and Uva. Therefore, it could be said that the objective Provinces are characterized as agricultural areas and efforts of the landslide disaster management should be focused on the securement of not only roads but also the agricultural land, agricultural products and critical damages to the residents.

2.2.3 Social conditions

Table 2-8 shows that majority of working population in the districts of Kalutara and Kandy are engaged in service sector, while majority of those in Matale, Nuwara Eliya, Badulla and Ratnapura districts are engaged in agriculture sector. Kegalle district has balanced working population in agriculture and service sectors.

Table 2-8: Working population by major industry group

District	Total	Major industry group		
		Agricu--lture	Indust-ries	Services
Total	100.0	32.7	24.2	43.1
Colombo	100.0	3.6	28.6	67.8
Gampaha	100.0	6.6	37.8	55.6
Kalutara	100.0	17.5	32.2	50.3
Kandy	100.0	23.1	22.2	54.7
Matale	100.0	46.5	19.6	33.9
Nuwara Eliya	100.0	68.2	8.4	23.4
Galle	100.0	33.3	27.4	39.3
Matara	100.0	36.9	24.8	38.3
Hambantota	100.0	43.6	23.3	33.2
Batticaloa	100.0	27.5	22.1	50.3
Ampara	100.0	39.2	20.0	40.8
Trincomalee	100.0	37.5	12.5	50.0
Kurunegala	100.0	38.5	23.2	38.3
Puttalam	100.0	33.3	31.3	35.4
Anuradhapura	100.0	64.2	9.8	26.0
Polonnaruwa	100.0	47.4	17.4	35.2
Badulla	100.0	61.6	11.0	27.4
Moneragala	100.0	55.0	11.6	33.4
Ratnapura	100.0	47.0	23.6	29.4
Kegalle	100.0	32.6	27.9	39.5

(Source: Annual labor force survey 2010, Department of Census and Statistics, Sri Lanka)

Table 2-9 shows poverty head count ration of the country. Poverty level of the country has declined further from 15.2% (2006/7) to 8.9% (2009/10) in three years. The target districts of the Project also had shown the same trend. Especially, poverty head count ratio of Nuwara Eliya district, which was the highest in the country, had decreased drastically in 2009/10. Poverty head count ratio of the Estate sector of the country in average, had been decreased from 32% to 11.4% in the three years. The wage hikes of plantation workers taken place during the period had given a significant influence to this improvement.

Poverty levels of the districts of Kandy, Matale, Ratnapura and Kegalle are around the average of the country, while that of Kalutara and Nuwara Eliya are lower than the average. Badulla district has highest poverty rate among the target districts of the Project.

Table 2-9: Poverty head count ratio

District	HIES survey period				
	1990/91	1995/96	2002	2006/07	2009/10
Colombo	16.2	12.0	6.4	5.4	3.6
Gampaha	14.7	14.1	10.7	8.7	3.9
Kalutara	32.3	29.5	20.0	13.0	6.0
Kandy	35.9	36.7	24.9	17.0	10.3
Matale	28.7	41.9	29.6	18.9	11.5
Nuwara-eliya	20.1	32.1	22.6	33.8	7.6
Galle	29.7	31.6	25.8	13.7	10.3
Matara	29.2	35.0	27.5	14.7	11.2
Hambantota	32.4	31.0	32.2	12.7	6.9
Jaffna					16.1
Vavuniya					2.3
Batticaloa				10.7	20.3
Ampara				10.9	11.8
Trincomalee					11.7
Kurunegala	27.2	26.2	25.4	15.4	11.7
Puttalama	22.3	31.1	31.3	13.1	10.5
Anuradhapura	24.4	27.0	20.4	14.9	5.7
Polonnaruwa	24.9	20.1	23.7	12.7	5.8
Badulla	31.0	41.0	37.3	23.7	13.3
Moneragala	33.7	56.2	37.2	33.2	14.5
Ratnapura	30.8	46.4	34.4	26.6	10.5
Kegalle	31.2	36.3	32.5	21.1	10.8

(Source: Household Income and Expenditure Survey 2009/2010, Department of Census and Statistics, Sri Lanka)

2.2.4 Road network and traffic conditions

a. Road Network

Figure 2-9 shows the road network of the Study Area of the objective seven Districts.

The road network of Sri Lanka is classified into 4 classes as shown in Table 2-10. The RDA is responsible for the Class A and B roads.

Total length of the road in Sri Lanka amounts to 115,862 km (Classes A, B, C & D) excluding rural roads, which is more than 80,000 km. Table 2-11 shows road length by District and by road class together with the national total. The total road length of the seven Districts amounts to 10,281 km, which is about 35% of the national total. However, Class A road total is 1,172 km, which shares only 28 %, though Class B and Class C road share 37.3 % and 37.2 % of the national total. Therefore, it could be said that the Class A road share of the seven Districts is a bit small compared to the national average.

Kandy District has the longest road length among the seven Districts, followed by Badulla and Ratnapura.

In terms of road density (road length / area in km^2), it seems high in the western Districts (Kandy, Kegalla and Kalutara) of the Study Area, while it looks low in the eastern Districts.

When it comes to the density by District, Kandy stays the highest position, followed by Kegalla and Kalutara as shown in Table 2-10. It should be noted that the density of the Study Area is 0.68, which is very high compared to the national average of 0.45.

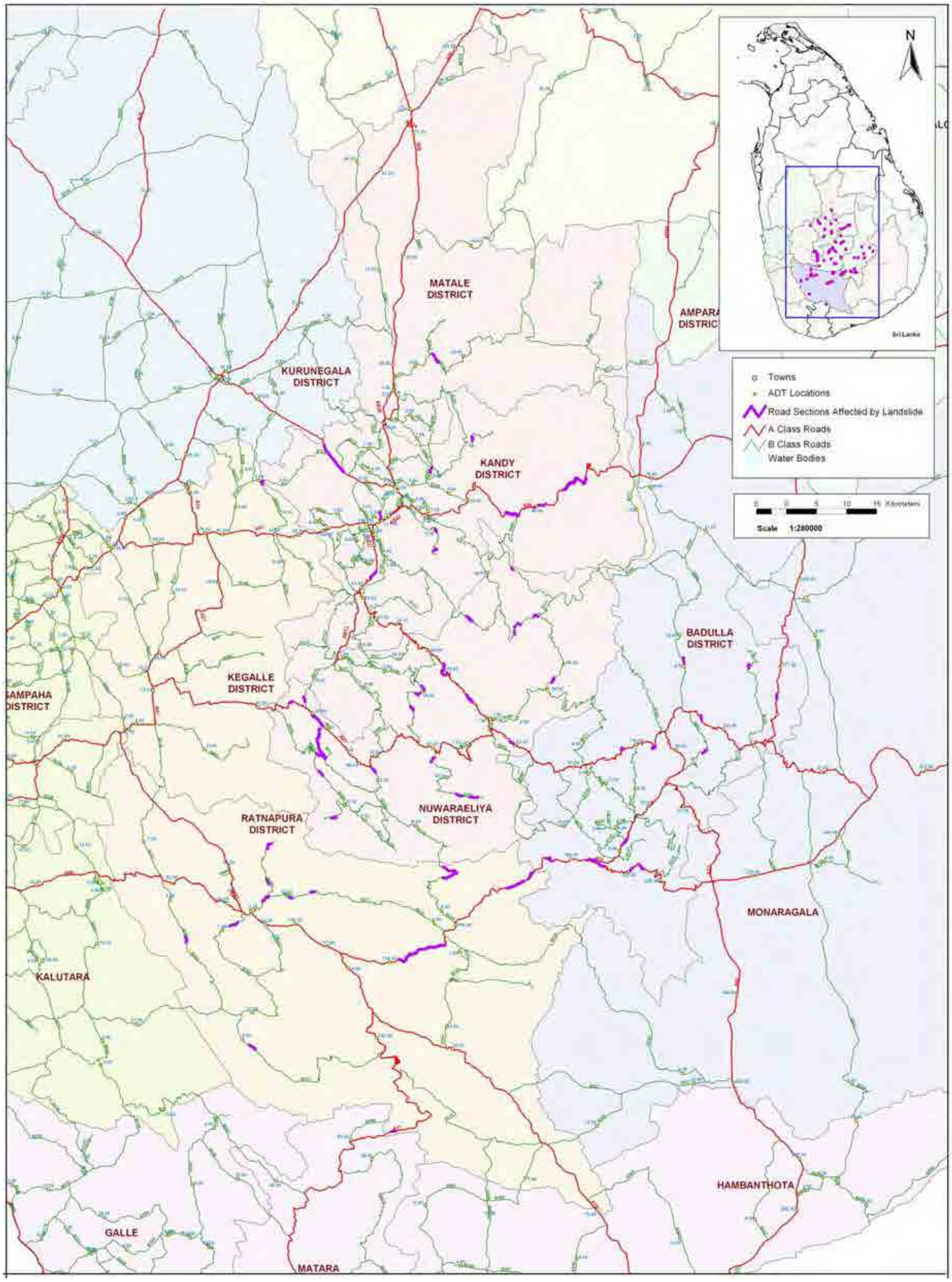


Figure 2-9: Road Network of the Study Area (Source: RDA)

Table 2-10: Road Class of Sri Lanka

Class	Description
Class A	All roads within the network of Trunk Roads connecting the national capital with the provincial capitals and also connecting these capitals with one another. Also included are other major roads (all roads paved and bitumen surfaced with carriage way between 24ft. to 36ft. and platform width 36ft. to 56ft.).
Class B	Main roads connecting other important towns and also providing important links within the trunk route system (Metalled and bitumen with a small percentage gravelled.).
Class C	Other roads such as agricultural roads and local roads (Single carriage way of 12ft. width and a platform width of 22ft. mostly metalled but with a small percentage gravelled.).
Class D	Gravelled road with 8ft. – 10ft. width surface generally motorable during dry weather only.

(Source: Central Bank of Sri Lanka, Economic and Social Statistics of Sri Lanka 2012)

Table 2-11: Road Length by Class by Seven Districts

(Unit: km)

District	Class A	Class B	Class C	Class D	Total Distance	Area (km2)	Road Density (km/ km2)
Kandy	184	555	920	352	2,011	1,940	1.04
Nuwara Eliya	120	492	442	49	1,103	1,741	0.63
Matale	105	283	303	177	868	1,993	0.44
Ratnapura	272	440	671	455	1,837	3,275	0.56
Kegalla	144	365	477	483	1,468	1,693	0.87
Badulla	267	432	1,001	180	1,880	2,861	0.66
Kalutara	80	341	417	230	1,112	1,598	0.70
7 Districts Total	1,172	2,908	4,231	1,926	10,281	15,101	0.68

(Source: Central Bank of Sri Lanka, Economic and Social Statistics of Sri Lanka 2012, p120)

b. Traffic Volume

Figure 2-10 shows traffic volume of Class A roads in 2012 in the Study Area. These numbers are average daily traffic volumes on the roads for both directions estimated by RDA based on the past traffic count information.

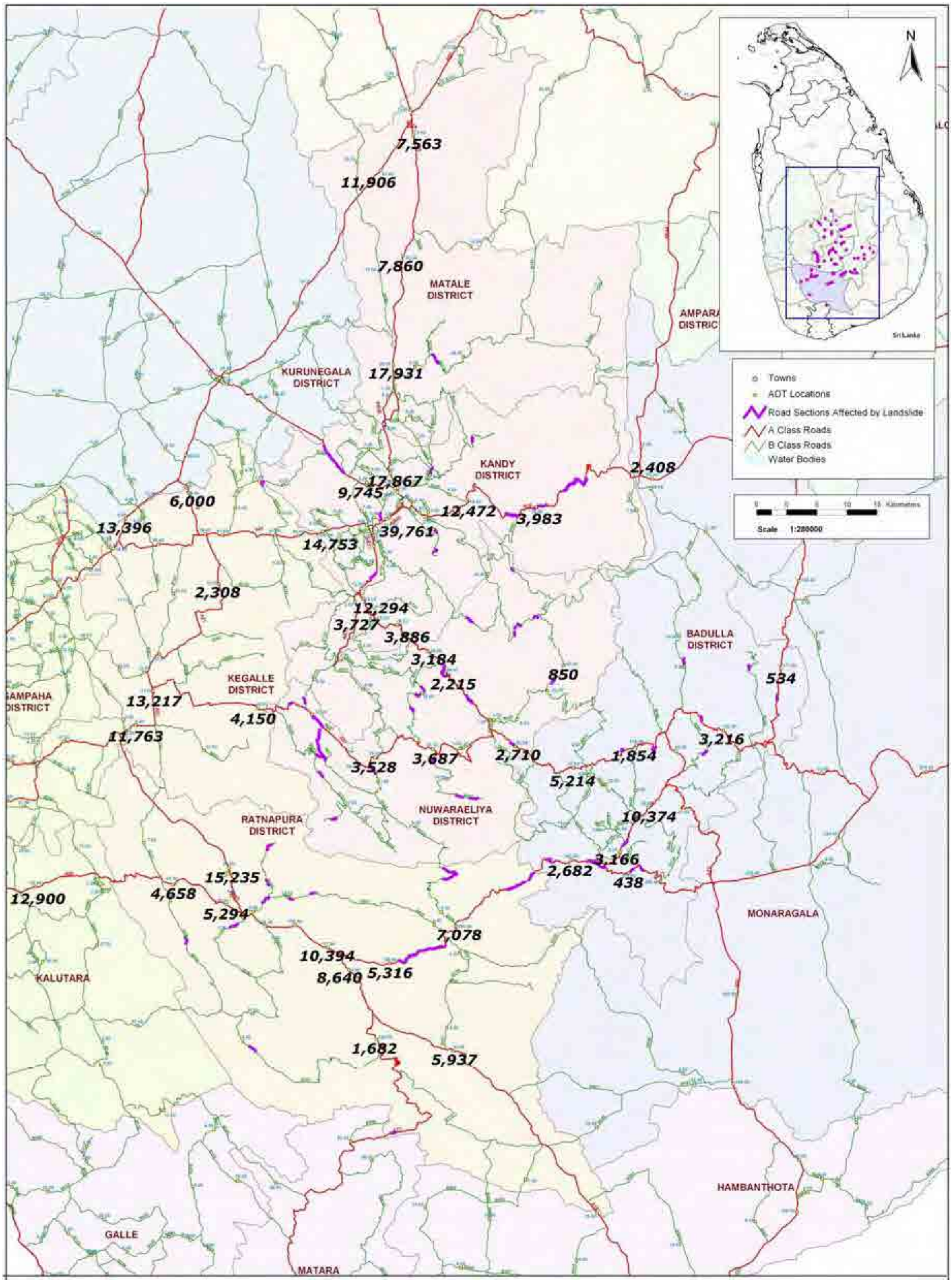
High traffic volumes of more than 10 thousand vehicle counts are seen mainly areas near to

Kandy, Kegalla and Ratnapura Districts. Relatively smaller traffic volumes of two or three thousand vehicles are seen in the eastern areas of the Study area. Traffic counts of less than one thousand vehicles are shown on the eastern A4 and eastern A5 roads.

According to RDA, traffic surveys by RDA are conducted in the following manner.

- RDA conducts manual count survey as well as mechanical count survey by using automatic traffic counters made in Australia.
- RDA owns 16 operational automatic traffic counters out of 20.
- RDA conducts traffic count surveys for consecutive 7 days during 24 hours a day to obtain weekly fluctuations of traffic volumes.
- RDA keeps permanent traffic count survey stations on A2, A3 and A4 roads.
- RDA conducts manual traffic count surveys to obtain traffic volumes by vehicle type.
- Vehicle classification of the manual count survey is the following 14.

  (1) Motorcycle
  (2) Three Wheeler
  (3) Car
  (4) VAN
  (5) Medium Bus
  (6) Large Bus
  (7) Light Good Vehicle
  (8) Medium/Large Good Vehicle;
  (9) Three-Axle Vehicle;
  (10) Articulated 3-Axle Vehicle;
  (11) Articulated 4-Axle Vehicle;
  (12) Articulated 5-Axle Vehicle;
  (13) Articulated 6-Axle Vehicle; and,
  (14) Farm Vehicle



(Both Directions, 2012; Source: Survey Team based on the information from RDA)

Figure 2-10: Average daily traffic volume of the Survey Area

2.3 Landslides in the survey area

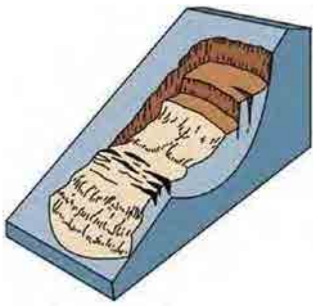
In this report, we will deal with disasters occurring in slopes along the national roads in Sri Lanka. In general, we call such disasters as “landslides”. In other words, the term of landslide is generally understood as downward movement of slope-forming material such as soil, boulder, residual soil, colluvium, weathered rock, intact rock, vegetation on the slope, and composition of them, along with groundwater and surface water, driven by gravity and triggered by rise of groundwater, and/or other factors such as erosion and rainfall.

Landslide can be categorized into many groups by its material, by speed of movement, by form of movement, by relation with water, by type of terrain it occurs, and by its size or scale. In other words, a landslide may be categorized into falls, topples, slides, lateral spreads, flows, mass movements, creeps, collapse, cutting failures, rock falls, and complex of them. In addition, there are many classification methods by authorities or by countries, which may make us confused.

Following the consideration above, the classification which is suited to the situation in Sri Lanka, is explained below:

a. Landslide (in narrow definition)

We also use a term of “slide” for the shorter term. In this meaning, landslide or slide means mass movement downward on gentler slope with relatively slower speed of movement. In many cases, a landslide activity has recurrent tendency; a landslide can be reactivated by seasonal rise in groundwater. Compared with slope failure or rock fall or rock slide explained in the following part, scale of a landslide tends to be larger. Figure 2-11 explains typical profile of landslide.



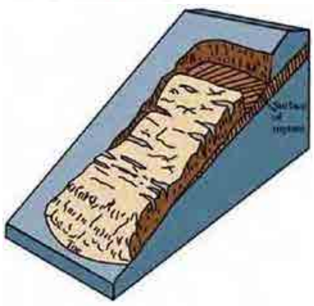


Figure 2-11: Typical Profile of Landslide

(Photo: Kokusai Kogyo & PADECO, Diagram: USGS)

b. Slope Failure (collapse, cutting failure)

We also use a term of “collapse” for the shorter term. Cutting failure has the same meaning with slope failure but cannot be used for failures in natural slope or embankment slope. Slope failure or collapse occurs in relatively steeper slope and speed of movement is far much faster than that of slide; one failure often ends within several seconds to several ten seconds.

Slope failure or collapse occurs in both natural slope and artificial slope such as cutting slope and embankment slope. The material of slope prone to slope failure is usually composed of soil, residual soil, colluvium, weathered rock and composition of them. In weathered rock, distribution and directions of foliations and cracks as well as joints govern not only possibility but scale and structure of failure. Gradient of slope is one of the primary causes of slope failure; under the same condition, steeper gradient of slope leads higher probability of failure.

Not so often like that of landslide, slope failure has some recurrent tendency, often along with retrogressive failure at shoulder of slope which often entails open cracks and subsidence. It shall be noted that slope has nature of degradation, larger or lesser, the degree of degradation depend on various factors, such as rock type, landform condition, weathering condition and groundwater condition. If placed under the same conditions, older slope has higher possibility of slope failure than newer one. Similar to slide, rise in groundwater is one of main triggers of slope failure. Surface water also facilitates activity of slope failure by causing erosion on slope such as gully erosion.

Figure 2-12: Example of Slope Failure

c. Rock Fall, Rock Slide, Topple

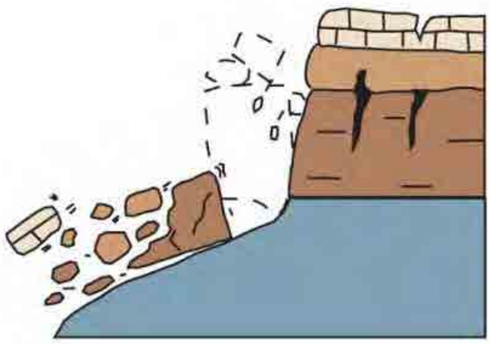
Rock fall is a term for fallen rocks or boulders from the middle or shoulder of slopes or upper slopes which extend from the shoulder. When it derives from the shoulder or the middle of rocky slopes, densely cracked part of rocky slope is one of primary causes for rock fall. When it comes from upper slope, not only densely cracked rocky outcrop but unstable boulders on the slope can cause rock falls.

Rock slide occurs in rocky slope where foliation and cracks as well as joints compose unfavorable condition for rock slide such as dip slope structure. When vertical cracks are dominant in a slope, we shall pay attention to topple.

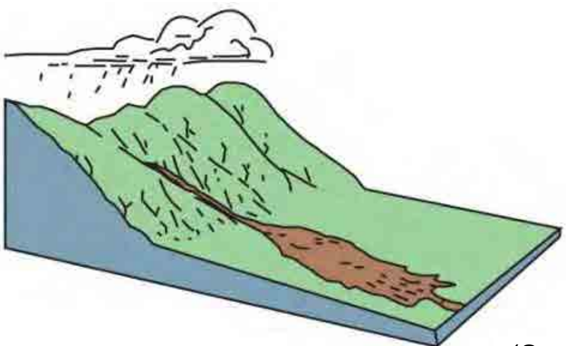
Figure 2-13: Example of Rock Slide

d. Debris Flow

Debris flow is caused by heavy rainfall and loosed mountain slope which provide vast amount of debris to downstream. Speed of debris flow is relatively fast; equal or faster than speed of automobile. Debris flow has tremendous energy which can cause devastating damage downstream including culverts and bridges.



(Source: USGS)
Figure 2-14: Topple



(Source: USGS)
Figure 2-15: Debris Flow

2.3.2 Landslide disaster in the survey area

The Survey Team collected records of landslide for each district in the survey area as shown below:

- Nuwara Eliya,
- Kandy,
- Badulla,
- Kegalle,

- Ratnapura
- Kalutara,
- Matale,

The collected records are attached to Appendix I. Table 2-12 shows the summary of the records of each district.

Table 2-12: Summary of Landslide Records in Sri Lanka

Period: 1 Jan. 2007-20 Jul.2012

District	Frequency (Times)	Deaths (Person)	Injured (person)	Miss-ing (person)	Houses Destroyed (No.)	Houses Damaged (No.)	Affected (person)	Relo-cated (person)	Evacu-ated (person)	Payment for relief-partially damaged houses (Rs.)
Nuwara Eliya	143	26	14	3	450	1,397	20,662	0	5	0
Kandy	202	10	26	0	49	185	2,759	0	93	0
Badulla	170	7	3	0	34	243	2,883	0	0	1,150,825
Kegalle	60	6	8	0	46	340	2,716	0	563	733,200
Ratnapura	96	2	2	0	16	22	1,491	0	101	1,133,885
Kalutara	41	7	4	0	10	41	1,208	0	0	10,000
Matale	9	0	0	0	1	5	2,257	0	0	0

Source: Disaster Information Management System- Sri Lanka

Due to the high mountains and steep mountain slopes as well as plenty of precipitation provided to the region, Nuwara Eliya District suffers the worst damage by landslide in the numbers of affected persons and damage to houses. As understood from the previous chapter of 2.1.2 Climate, Nuwara Eliya District receives rainfall from both SW monsoon and NE monsoon due to its high-elevated mountains.

Kandy District ranked the highest in frequency, and Badulla District follows Kandy in frequency.

2.3.3 Landslide disaster on the target national roads

In this study, all A-class national roads of the target districts are the target national roads. .The Survey Team collected records of damage to the road caused by landslide for each district in the survey area as shown below:

- Kandy,
- Matale,
- Nuwara Eliya,
- Badulla,
- Kegalle,
- Ratnapura

The collected records are attached to Appendix II and III. The Survey Team visited the sites listed in the records mentioned above mainly for A-class national roads

As the result of the desk study and site visits, the landslide disasters anticipated on the sites on the target national roads can be classified with the following supposed disaster types; landslide (in narrow definition), slope failure (collapse), rock fall and rock slide.

By the nature of rock fall and rock slide, both disasters tend to occur at the similar condition, such as steep slope or escarpment of hard rock which has joints system with foliation, densely cracked in places.

Slope failure tends to occur in mainly artificial slopes of residual soil and heavily weathered rock; the gradient of the slopes are generally steeper than that of stable slope, from almost perpendicular to more than 70 degrees from the horizontal line.

Meanwhile landslide lies in relatively gentler slopes than those of slope failure and rock slide; the slopes are composed of mainly colluvium, the material derived from collapse of mountain slope, containing big boulders along with clayey soil with sand and gravel. In some locations, landslides occurred in the slopes composed of colluvium and heavily weathered rock of gneiss rich in feldspar, which is prone to alter into clayey minerals when it undergoes weathering process.

◆ Slope Failures in Artificial Slopes, Steeper Gradient of Slope and Luck of Drainage System, Especially Seen in the Roads Under Construction

During the site trip, the Survey Team had some opportunities to take a glance at cutting slopes under construction from Welimada to Badulla and from Hatton to Nuwara Eliya.

Figure 2-16 shows a typical cutting slope under construction near Hatton.

According to the site condition, at many sections under construction, we anticipate slope failure in cutting slopes composed of residual soil and weathered rock. Slopes of colluvium or slopes with dip slope structure have the same risks of slope failure. In such sections, slope failure can occur by the following reasons:

- In general, steeper gradient of slope than stable is applied to the section where residual soil and weathered rock or colluvium appears. Especially for the upper sections of the slopes where overburden or residual soil appears, a gentler gradient of slope than currently applied shall be adopted.

- Furthermore, no drainage system along the shoulder of the slopes or vertical drainage system can be confirmed on site. Such drainage systems shall be duly installed on site to prevent erosion and infiltration of surface water into the ground.

Figure 2-16: Typical Cutting Slope, Too Steep, No Drainage

2.4 Importance of landslide countermeasure

2.4.1 General aspect of landslide disaster in Sri Lanka

The hilly country of Sri Lanka frequently experiences landslides that causes enormous damage to lives, properties, infrastructure, and the national economy. Nearly 20% of the land area from 65,000Km2 of total area in Sri Lanka was identified as landslide prone. These landslide prone areas are spread over in Badulla, Nuwara Eliya, Kandy, Matara and Hanbantota districts. Due to bad land use practices, cutting failure incidents are increasing at Gampaha and Colombo districts.

Incidences and frequency of landslides are growing. The present landslide density is estimated to be on the order of 1 to 2 landslides per km2. Each and every rain, it is common to have a one or two landslides or cutting failures. Landslides in Sri Lanka occurred due to natural causes as well as due to man made causes.

Disaster risk increases along the increase of population, properties and economic development. Correspond to the trend of rapid development, landslide risk has become higher and higher in Sri Lanka. So road is one of the most important infrastructures, RDA recognizes damage of road and road network affect not only road itself, but influence the local economy. Now it is time to step forward to implement permanent countermeasures for road landslide disaster.

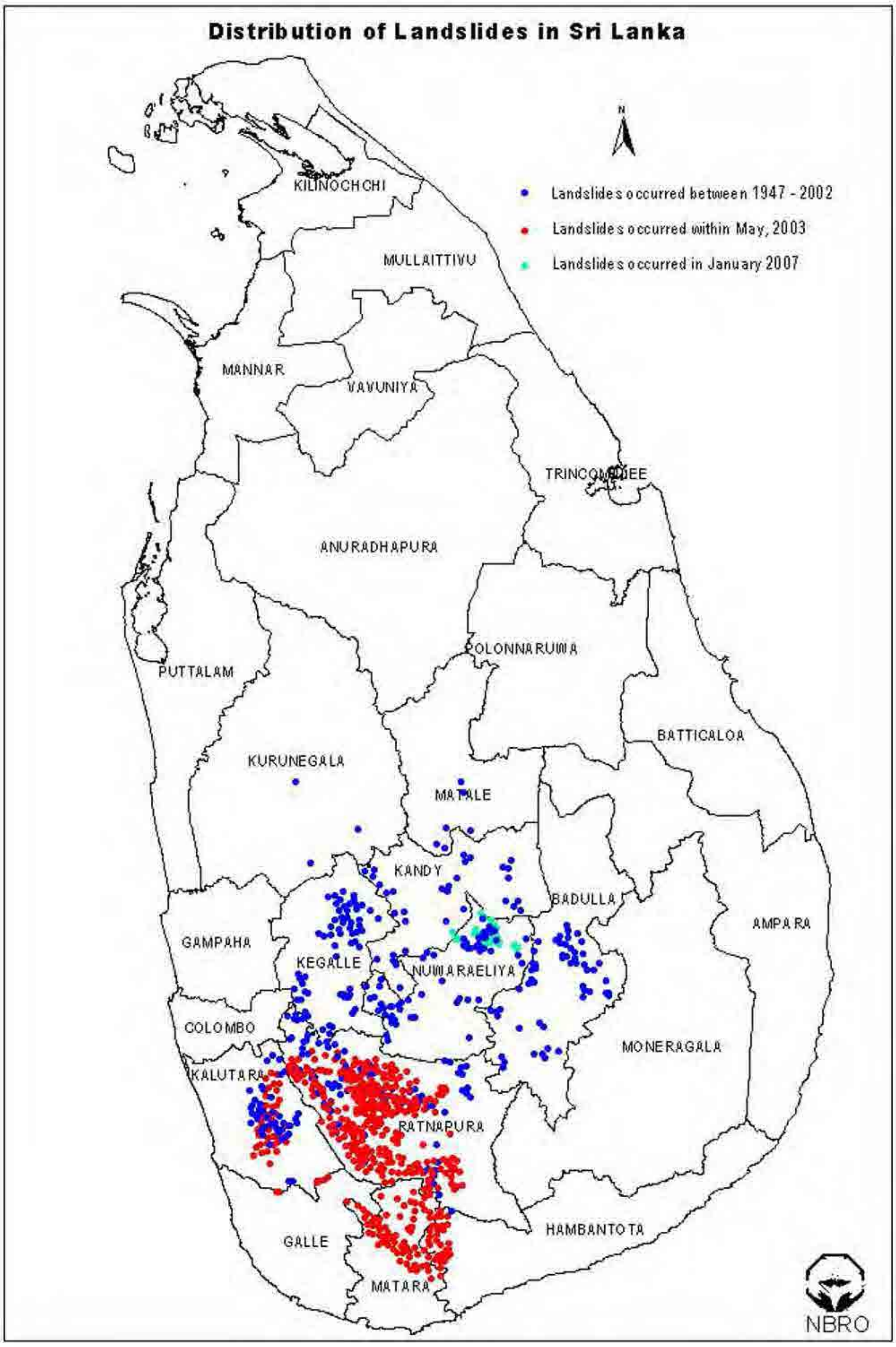


Figure 2-17: Distribution of landslides from 1947 to 2007(source: NBRO presentation)

Some examples of major landslide disasters are shown as follows.

(1) Watawala landslide disaster, Nuwara Eliya District (3 June, 1992 and 3 June, 1993)

The landslide occurred on the southern slope of the Watawala ridge in the Nuwara Eliya district, where the Colombo-Badulla railroad runs. The slope was creeping for about 50 years, and it finally failed on 3 June 1992. The total area of the moving mass was about 33,120m^2. The Colombo-Badulla railroad was heavily damaged, and thousands of passengers who use the train daily as well as tourists were in the train. The landslide caused a severe impact on the people and economy of the country.

Figure 2-18: Watawala landslide and the damage of train (photo by NBRO)

(2) Helauda landslide disaster, Ratnapura District (8 October 1993)

On 8 October 1993, an earth flow occurred on a slope approximately 3km north of the heart of Ratnapura city. The road and houses below the slope, which ran parallel with the road, were instantly swallowed, resulting in the death of 31 inhabitants. Because unstable earth and sand had previously accumulated in the meddle of hillside of the collapsed part, following that, torrential rains, as mentioned below (17 May, 2003), caused a small-scale earth flow in the same place on 24 August 2006.

Figure 2-19: Earthflow at Helauda (photo by NBRO)

(3) Palawala landslide disaster, Ratnapura District (17 May 2003)

There were also large-scale earth flows, such as in Palawale, Ratnapura District , where the gentle slope of a mountain base slid down, crossing the valley floor and ran up to the slope on the opposite side. The tail end of the earth flow combined in the small rivers and became a debris flow.

Figure 2-20: Earthflow at Palawela (2003, photo by NBRO)

(4) Walapane Sediment Disaster, Nuwara Eliya District, 12 January 2007

12 January 2007, a spate of landslide disasters occurred within Nuwara Eliya District Walapane DS. Division and Hanguruketha DS. Division.

Walapane National Highway B413 saw multiple episodes of cutting failure, landslide and debris flow. Among places along the national highway where landslide disasters occur frequently, one occurrence reached 100m. In the tracks left behind a landslide which resulted in the deaths of 10 people.

Figure 2-21: Landslide at Walapane(photo by Mr.Tsukamoto)

2.4.2 Social aspects / background of landslide

Sri Lanka had diverted a part of its human settlement from generally safe ancient settlements in dry zone to environmentally fragile and geographically sensitive wet zone due to various social, political and economic reasons since the 13th century and during the British rule in 19th century, plantation industry was introduced to central hill areas. This change altered the land use in the fragile hilly areas and created the landslide prone area in the country[1].

Heavy rains due to climate changes and geographical changes, accentuated by indiscriminate clearance of steep slopes of the mountain areas, including potato and commercial vegetable cultivation increased in recent decades, have increased the frequency of landslides especially during rainy seasons, usually start in October and end in January.

The National Physical Planning Policy of Sri Lanka gazetted in 2005 is not encouraging communities to settle down in these hilly areas, but promotes them to settle in irrigated dry zone areas which have less confrontation of the natural systems[2].

However, the people living in landslide prone areas in the mountain slopes of the central and south western regions of the country are not willing to move into other areas, such as irrigated dry zone areas spontaneously due to several reasons as follows:

Firstly, there is a hesitation among the rural people in Sri Lanka to change their geographical environment and also to change livelihood they are conducting. A study conducted by NBRO with Intermediate Technology Development Group (ITDG-South Asia) in 1999, named “Livelihood Options for Disaster Risk Reduction” clarified that there was a strong connection between livelihood and the location of settlement[3]. For example, people engage in highland vegetable or flower plant cultivation will not easily take a risk to give up their livelihood and move into an irrigated area and engage in paddy cultivation, if there wouldn’t be an appropriate and attractive programme offered by the government. Other example is that, estate workers cannot move far away from the estate because they are bound to the estate as residential workers.

Secondly, rural communities, especially economically vulnerable families sometimes have no choice but live in hazard prone areas due to scarcity of land and higher land price in residential area. As shown in Table 2.2-1 of this report, population density of the target districts of the Projects, i.e. landslide prone area, is higher than that of national average in general. The land value of residential area or suburbs of towns are much higher than that of the mountain slopes.

Slow progress of the relocation programmes by government and non-government public agencies could be another season for the population under landslide risk to keep on living in the area. It is mainly due to financial constraint of the government and other agencies, and unavailability of suitable land. The Study Team came across two exact examples of this in the field survey. In Welimada GN division in Badulla district, two households and one flower cultivator are still living in a very fragile slope of a mountain, which was affected by a landslide recently; even after they had agreed to be relocated, as there has been no offer from the divisional secretariat in the area to provide them with alternative land or compensations.

[1] Source: Sugathapala, 2008.
[2] Source: same as above.
[3] Source: same as above.

In Kahagola Watta of Nuwara Eliya district, 22 households in tea plantation are living in partly damaged houses. These families agreed to be relocated and the plantation company had allocated a land for them to be settled in. However, housing construction has not yet been started due to shortage of funds of the Plantation Human Development Trust[4].

There are several cases, such as described in the next section, that government had implemented settlement programme for landless families during 1970s, without knowing the risk of landslide.

2.4.3 Recent experience of landslide disaster and lessons learnt from the resettlement programme implemented- An example of Walapane and Hangranketha landslide

In January 2007, enormous numbers of landslides occurred in Walapane and Hangranketha area in Nuwara Eliya district. It was reported that 2,981 families were evacuated as of January 11, 2007, 413 houses were totally destroyed, and 1,500 houses were partly destroyed. Number of families identified to be resettled was 1,705 in total[5].

(Source: http://www.sundayobserver.lk/2007/01/21/fin01.asp, accessed on August 3rd. 2012)

Figure 2-22: Landslide in Walapane and Hangranketha area

Families identified for resettlement were mainly of middle and low income groups. 75% of them had a location-specific livelihood. Most of them were farmers, who were provided with land from the government in early 70's for cultivation. The government had not aware of the landslide risk in the area in those days.

The resettlement programme had shown a slow progress mainly due to the following reasons[6]:

- Most of the affected people were engaged in small-scale agriculture; however, even after 10months from the landslide, no agriculture land was ensured for them at the location of resettlement. It was difficult for the divisional secretariats of the area to find agricultural land in addition to the residential land, mainly because the area is in

4 PHDT is a tripartite organization consists of Government of Sri Lanka, Regional Plantation Companies and Plantation Trade Unions was formed by the GOSL to co-ordinate and facilitate programmes to enhance the quality of life of the plantation community..(source: www.phdt.org)

5 APCAS report, 2008 (the original is in Japanese and translated by the Study Team).

6 APCAS report, 2008.

mountain-ringed region which have little land for farming.

- There was a concern among the local politicians to lose voters from their electoral zones as a result of mass-scale relocation. Due to this concern, they were reluctant to relocate the affected people in the distance. They might have had a concern about the change of ethnic composition in the area, too[7].

There were several other issues with regard to the resettlement plan as follows[8]:

- The resettlement plan was developed by technical officers of the divisional secretariat. However, several areas for resettlement were found to be in the risk area of the hazardous map of NBRO. In fact, landslide occurred at the resettlement places while the affected people were preparing housing construction.
- The resettlement plan included housing construction only. There was no plan for public facilities, such as water supply and drainage, electricity, road, waste management and others.
- Facilities of the welfare camps, where the affected families were stayed until they resettle in new house, were inadequate. For example there were no proper drinking water supply, toilets, lighting, waste management, pre-school and others. There was no livelihood support or mental health care.
- Decisions taken by the government with regard to the assistance were not shared with the affected people. Therefore, they sometimes increased mental stress due to rumors, or wrong information.

One of the most important lessons learnt from the experience of the above-mentioned landslide assistance, including resettlement plan, was that a resettlement plan needs to address different categories of affected people. For example, the most critically affected should be given a package of housing, livelihood support, relocation allowance etc. and the others will be given option of retrofication if voluntary resettlement is not preferred[9].

Another important lesson was that decision should be taken at the time of planning of resettlement plans with consideration of possible mitigation options such as early warning, preparedness and structural mitigations, which included in the concept of" living with landslides"[10].

2.4.4 National policies and legal framework on prevention, protection and relocation

National policies and legal framework on prevention, protection and relocation of landslide affected communities are contained basically in a few parliamentary acts and cabinet papers; mainly:

- Cabinet paper in 1984 under which NBRO was established.
- National Involuntary Resettlement Policy (NIRP) adopted by cabinet of ministers in 2001.
- Sri Lanka Disaster Management Act, No 13 of 2005.

[7] The majority of the population of Nuwara Eliya district was Tamil, while most of the affected people were Sinhala. Therefore, if the affected people would move out of the district, the area would be more dominated by Tamil.
[8] APCAS report, 2008.
[9] Sugathapala, 2008.
[10] Sugathapala and Prasanna, 2009.

(a) The cabinet decision in 1984 that paved the way for establishment of NBRO assumes that it is the responsibility of the government with other relevant parties to protect the victims of landslide disasters and prevent such disasters by environmental testing, geotechnical testing, human settlement, planning and training and landslide studies etc. The policy envisages that NBRO should conduct research on environmental science, geotechnical engineering, human settlement, landslide and slope stability to serve for protection from landslides and preventing or reducing landslides.

(b) Present policy on rehabilitation of landslide affected people are of two folds; most vulnerable to be resettled and others are to be put into improvement programme. NIRP adopted by the cabinet of misters in 2001 is aiming at correcting unjustifiable practices hitherto existed with regard to prevention, protection and relocation of the affected people of disasters. Policy objectives of NIRP can be categorized as follows:

- Take all necessary steps to avoid and reduce involuntary resettlement. (relocation)
- Prepare a comprehensive Resettlement Action Plan (RAP) where 20 or more families are affected.
- Where involuntary resettlement is unavoidable affected persons should be informed fully and consulted on resettlement and compensation options.
- Affected persons should be fully involved in the selection of relocation sites, livelihood compensation and development options at the earliest opportunities.
- Cash compensation should be an option for all affected persons. Replacement land should be an option for compensation in the case of loss of land.
- Compensation for loss of land structures, where assets and income should be based on full replacement cost.
- Replacement should be planned as development activity for the affected persons.
- Absence of formal title to land by some affected persons should not be a bar to compensation.
- Particular attention has to be paid to household headed by women and vulnerable groups among affected persons and appropriate assistance provided to help them improve their status.
- Full cost of compensation and resettlement should be borne by the project proponent.

The purpose of NIRP is to avoid or reduce adverse impacts of poorly-managed resettlement or relocation, such as impoverishment, loss of land, home, livelihood, access to common facilities and property and food insecurity.

With regard to the compensation, Land Acquisition Act (LAA) No. 09 of 1950 and its subsequent amendments are silent about resettlement issues. It has provisions to provide compensation only for land, structures and crops. In a situation where public officials and the traditional leaders of the society are used to work under the practices of Land Acquisition Act, and majority of the community including the affected were ignorant about the good process of resettlement, it is necessary to bring about a huge attitudinal change to implement NIRP fully.

Even the Environment Act No. 47 of 1980 amended by Act No. 56 of 1988 has taken in to consideration only the involuntary resettlement exceeding 100 families. NIRP has reduced that number down to 20. In a situation where relevant officials are not very much familiar with NIRP always there is a possibility of arising problems.

To activate the policies introduced by NIRP cabinet has made several regulations which are useful for officials to understand the contents of NIRP correctly.

(c) Until the middle of 1990s, the government approach was to provide the affected community with a relief package. However, a clear policy of prevention and mitigation of disasters was adopted after the Great Tsunami in 2004. Sri Lanka Disaster Management Act, was enacted in May 2005 and the DMC, which has the following responsibility, was established to implement the functions indicated in the Act:

- Implementation of policies on mitigation and prevention of disasters and creating approaches to response and recovery.
- Formulate National Disaster Management Plan.
- Initiate and coordinate foreign aided projects for disaster mitigation response and recovery.
- Liaising with all stakeholders to ensure timely execution of such responsibilities.
- Coordinating and management of relief activities pertaining to disasters.
- Facilitate and promote early warning systems.

2.4.5 Roles, responsibilities and issues of government organizations related to prevention, protection and relocation of landslide affected communities

Ministry of Social Services and Department of Social Services have been established to implement general policy of the government for providing assistance to the needy community including victims of disasters.

DMC has launched four major hazard mapping projects which cover four kinds of hazard risks including landslide with fund support from UNDP. These projects are implemented through universities and suitable technical agencies. DMC has identified even the need of using space technology for hazard mapping. The main issue with regard to these activities is financial constraints. There are different training programs for disaster risk reduction. In training, it is necessary to prioritize the areas of disaster risk and focus on urgent needs. In a situation where landslide in the hill country is on the increase, one can say that the emphasis on landslide disaster is not sufficient.

Though the ministry and the DMC expect mainstreaming of Disaster Risk Reduction (DRR) in national development planning, it will take some more time to make it a reality. JICA funded Disaster Management Capacity Enhancement Project (DIMCEP) can make a greater impact if the training could be extended down to divisional secretariat level.

Decentralization of activities of DMC down to district level should be appreciated. It is also necessary to make more emphasis on preventive activities.

With regard to early warning system for landslides, DMC has to work in close cooperation with NBRO, meteorological department and divisional secretariats. District level office of DMC has to be made aware about the necessity of working in close cooperation with divisional secretariats and paying due attention to community based risks management.

NBRO is involved in several key activities. Landslide hazard zonation mapping programme has been implemented in all landslide prone districts.

Landslide Research and Risk Management Division (LRRMD) of NBRO is involved in landslide risk evaluation investigations. It also provides general guide lines for construction in landslide prone areas.

NBRO also implements structural mitigation projects; for example, in Peradeniya, Padiyapelella, Mahawewa and Gerandiella. Apart from that, it has implemented none structural mitigation projects in many areas.

LRRMD and Human Settlement Planning and Training Division of NBRO conducts training programmes for school children, decision makers, planners, administrators etc. in landslide prone districts. It also has readymade awareness material aiming at general public. LRRMD considers landslide early warning as one of its priority tasks. Another important task of NBRO is to advise Land Use Policy Planning Department on land use in landslide prone areas.

NBRO always works with or through other governmental organizations. For example, Gerandiella mitigation project is to be implemented through Nuwara Eliya divisional secretariat. This project is funded by the government. Mahawewa structural mitigation project was funded by JICA. NBRO is very straightforward in saying that it is in need of exposing itself to latest technologies in structural mitigation like that of Japan. Financial constraint is the main issue with regard to implementation of its programmes.

References:

"Impact on Livelihoods of Landslide Affected Communities due to resettlement Programmes", The First World Landslide Forum November 2008, Kushan Sugathapala, Human Settlement Division, NBRO.

"Issues in Implementation of Landslide Mitigation Programme in landslide Vulnerable areas of Sri Lanka: Special reference to Hanguranketha Landslide Area", Kishan Sugathapala & June Prasanna, Human Settlement Division, NBRO.

APCAS report on follow-up study for "project for improving sanitary condition through construction of toilets (Sri Lanka)", implemented with the assistance of Magokoro Fund, 2008 (the original is in Japanese and translated by the Study Team)

3 Current status of road protection against landslide disaster

3.1 Road Sector

3.1.1 Road Development Authority (RDA)

a. Role and its Mission

RDA's Role

The Road Development Authority (RDA) is the premier highway authority in the country and is responsible for the maintenance and development of the National Highway Network, comprising the Trunk (A Class) and Main (B Class) roads. Its role includes the planning, design, construction, operation and maintenance of new highways, bridges and expressways in addition to the existing road network.

RDA's Mission

As the premier National Organization of the road sector, RDA functions to provide an adequate and efficient network of National Highways, to ensure mobility and accessibility at an acceptable level of safety and comfort, in an environment friendly manner for the movement of people and goods for the socio-economic development of the nation

b. Organization

The RDA is a major civil engineering organization with specialized skills in highway and bridge planning, design, construction, maintenance and Highway Safety. The organizational structure is designed to carry out the functions assigned to the RDA and to achieve its goals and objectives. The organization under the Board of management has the General Manager as the Chief Executive Officer. The General Manager is assisted by 14 Directors and 1Project Director to carry out the various functions.

In addition there are 9 Directors of Project Management Units under the Ministry of Highways are appended to the RDA through the Chairman (Figure 3-1).

The RDA has a total of 2,730 employees under the control of the Shops and Office Act. In addition it has a total of 7,173 employees under the Wages Board of Engineering Services.

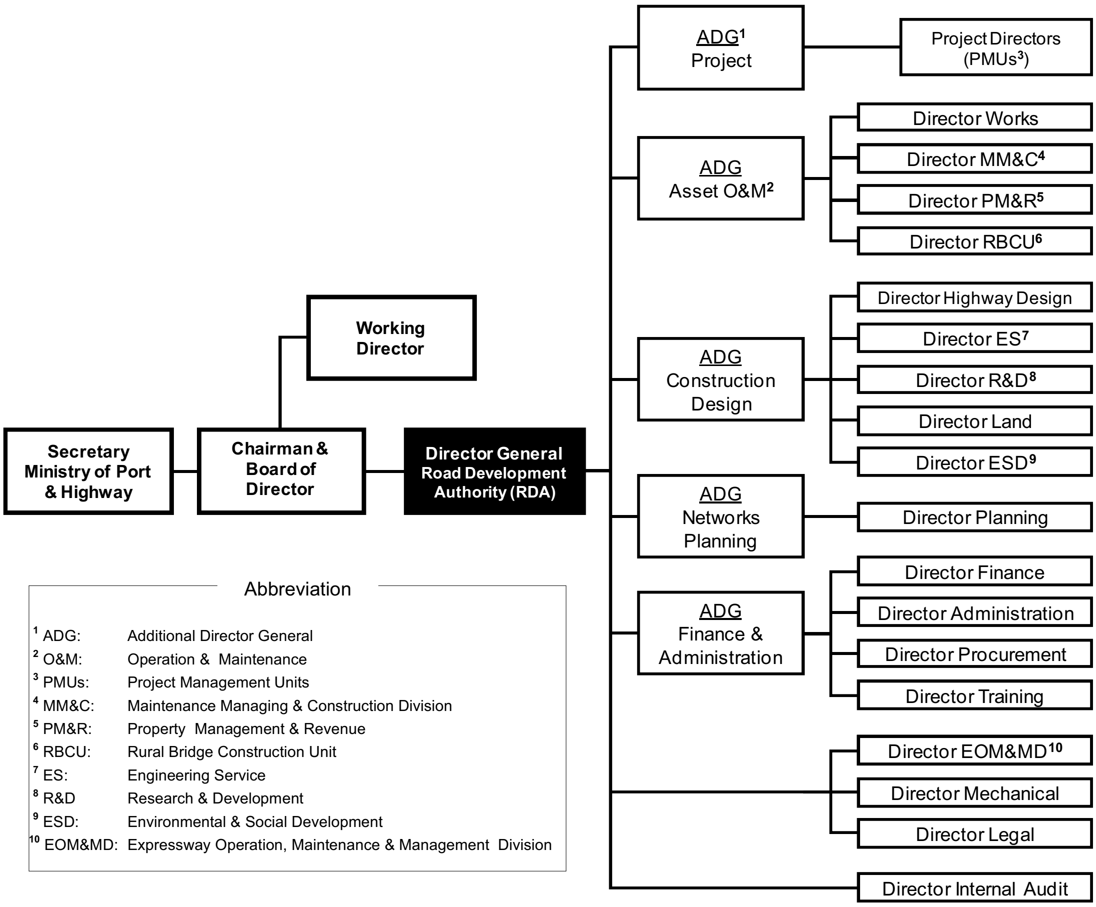


Figure 3-1: Organizational structure of RDA

c. Budget of landslide countermeasure of RDA

Landslide is one of major natural disasters in Sri Lanka. It will occur almost every year mostly in the central highlands of Sri Lanka. In year 2003 Ratnapura large flood, 150 people died due to the numerous landslides. In the past 38-years record of landslides, more than 800 people lost their life because of the landslides.

Therefore, to prevent the landslides and to maintain the safe road traffic is one of RDA's major duties in Sri Lanka. On the other hand, the landslide problems have been tackled by several related agencies in cooperation, including:

- RDA: Responsible for construction and maintenance of safe road network to prevent landslides as well as urgent recovery of the damaged roads.
- NBRO: Responsible for investigation and design against the landslides and regulating building constructions to safe guard the people and buildings.
- Ministry of Disaster Management: Responsible for overall disaster management, relief and compensation.

RDA has been taking various actions against the landslides, for instance:

- Construct various landslide countermeasures in many road improvement projects, for example, concrete retaining walls, shotcrete, gabion walls, horizontal drilling drains, slope surface drains, soil nailing and vegetation.

- Remove fallen rocks and debris immediately after landslide disasters to open the road traffic.

- Daily and routine inspection and maintenance for landslide prone areas.

Regarding maintenance budget, Table 3-1 shows the RDA's past record. Table 3-2 also shows "Road Investment Cost" including "Maintenance Cost" (source "Annual Report 2011" by Ministry of Finance & Planning). Maintenance cost between the two Tables differs significantly in the years of 2010 and 2011. But the recent range is between Rs. 5 and 7 billion.

Existing landslide related budget is indicated Item No.6."Emergency Works" in Table 3-1. It accounts for Rs. 445 million in 2011, relatively smaller budget. Foreign financial assistance will be needed to realise the required landslide countermeasures.

Table 3-1: Road Maintenance by RDA

Unit: Rs. Mil.

Maintenance Cost	2005	2006	2007	2008	2009	2010	2011
Allocation	1,880	3,010	3,410	3,103	3,530	4,200	5,000
Expenditure	1,880	2,990	3,410	3,103	3,049	4,200	5,000
1 Routine Maintenance	N.A.	N.A.	N.A.	N.A.	1,316	1,321	1,500
2 Continuation Work	N.A.	N.A.	N.A.	N.A.	409	630	690
3 Periodic Maintenance	N.A.	N.A.	N.A.	N.A.	1,134	1,643	1,480
4 Structure Improvements	N.A.	N.A.	N.A.	N.A.	187	171	612
5 Signal lights, marking and others	N.A.	N.A.	N.A.	N.A.	210	183	248
6 Emergency Works	N.A.	N.A.	N.A.	N.A.	237	233	445
7 Ferries	N.A.	N.A.	N.A.	N.A.	37	19	15

Note: "Bridge maintenance" and "Lights" in years of 2009 and 2010 are added to "Routine Maintenance"

(Source: RDA)

Table 3-2: Road Investment Cost

Rs.Bn

Category	2005	2006	2007	2008	2009	2010	2011
Expressways	2.4	6.8	7.7	14.9	24.7	24.7	25.6
Maintenance	1.8	2.9	3.4	3.1	3.1	6.4	7.8
Rehabilitation	8.6	16.9	23.7	35.4	48.2	46.3	60.4
Improvement	2.5	3.0	4.6	6.0	5.5	8.9	14.8
Upgrading	0.4	1.8	2.4	13	15.3	16.0	8.0
Land Acquisition	2.3	2.3	3.0	2.7	3.0	3.6	3.8
Other	0.8	1.2	2.1	7.5	3.6	4.1	3.7
Total	18.8	35.0	46.9	82.7	100.6	107.8	124.2

(Source: Ministry of Finance & Planning, "Annual Report 2011")

Furthermore, RDA's "National Road Master Plan (2008-2017)", December 2007, shows following maintenance and rehabilitation forecast (Table 3-3).:

Table 3-3: Road Maintenance and Rehabilitation Forecast

	Road Maintenance and Rehabilitation (Rs.: Billion)											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Periodic Maintenance & Rehabilitation	5.9	8.3	5.5	8.9	5.1	6.5	4.3	4.0	4.0	5.3	4.7	62.5
Routine Maintenance	4.5	4.7	5.0	5.2	5.4	5.7	6.1	6.5	6.8	7.2	7.6	64.8
Total	10.4	13.0	10.4	14.1	10.5	12.2	10.4	10.4	10.9	12.6	12.3	127.3

(Source: Road Master Plan (2008-2017), December 2007, RDA)

d. Authorizations

In 1989 with the devolution of power under the 13th amendment to the constitution, the C, D and E class roads totalling approximately 17,000 km and the bridges thereon were handed over to the Provincial Councils. Since then the RDA is entrusted with the development and maintenance of the National Highway Network comprising the Trunk (A class) and Main (B class) roads. The National Highway Network consists of 11, 694 km of roads and 4,048 bridges (span of more than 3m) as at end 2005 including the roads taken over as National Highways during the past few years.

<u>RDA's Authorisation</u>

- Road Development Authority Act No.73 of 1986,
- Road Development Authority (Special Provisions) Act No.5 of 1988

3.1.2 Road sector policy and development plan

a. Mahinda Chintana

In 2006, the Government launched a 10-year horizon development framework (2006-2016) as a vision for a new Sri Lanka. The vision is to attain economic growth of at least 8 % per year over the next decade. With regard to the transport sector, the vision is:

> "To provide accessibility to all population in the country and to have a high and quality mobility road network for the transportation of passengers and goods."
> (***Mahinda Chintana***, the presidential manifesto setting the Government's development agenda.)

It states a distinct emphasis on road development, while fully keeping the need for a balanced intermodal transport in view.

b. National Road Master Plan (2007-2017)

Based on the Mahinda Chintana, RDA has developed "National Road Master Plan (2007-2017). The mission of the Road Master Plan is:

> "To provide an adequate and efficient network of national highways, to ensure mobility and accessibility at an acceptable level of safety and comfort, in an environment-friendly manner for the movement of people and goods in the socio-economic development of the nation."

The Road Master Plan states, "Scarce financial Government resources are facing competing claims from various sectors. The road sector has in the past absorbed a substantial share of the resources and the implementation of the Road Master Plan will lead to increases in this regard. Therefore, proper evaluation and optimization of road expenditures become imperative."

c. Components of Road Master Plan (2007-2017)

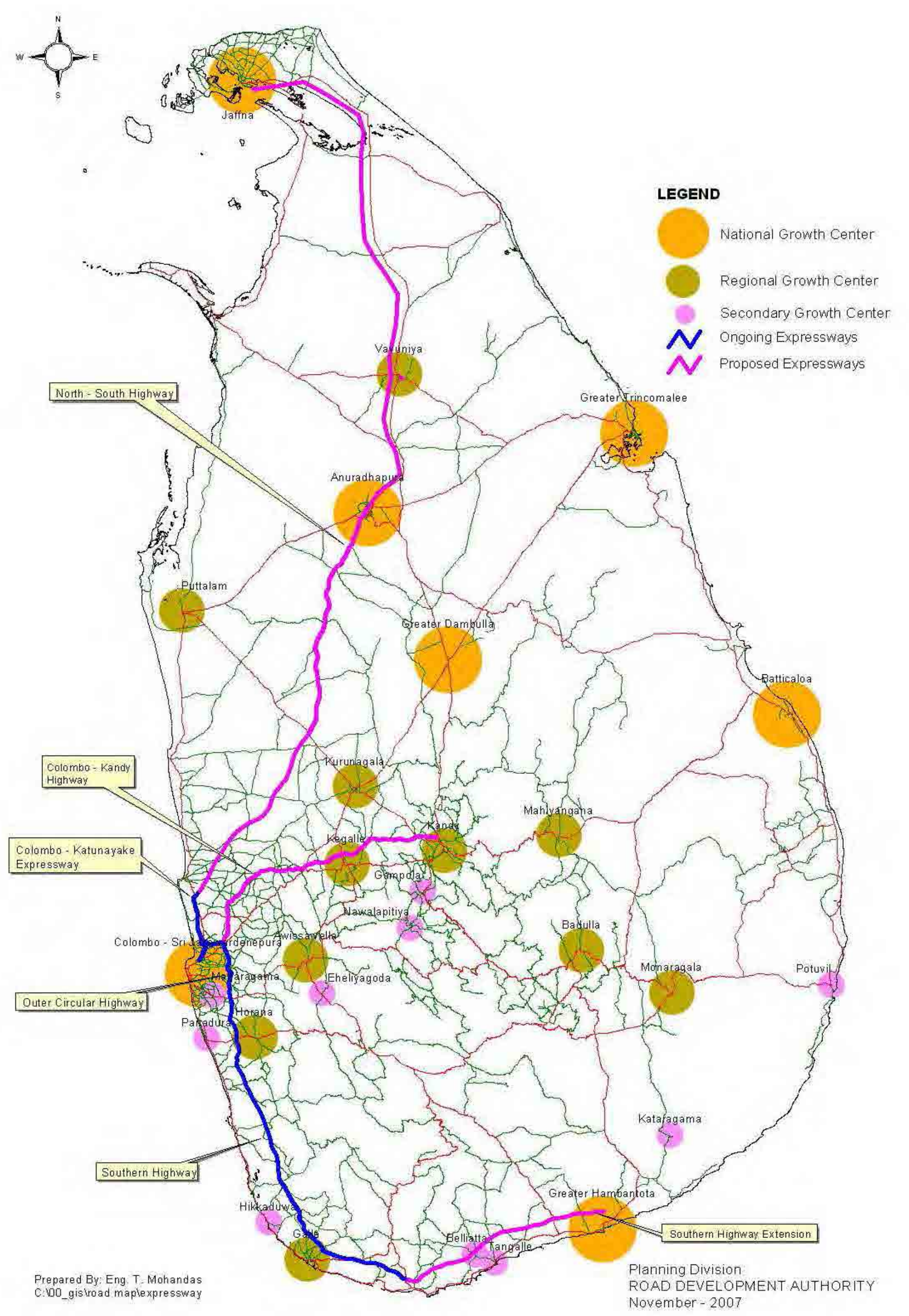


Figure 3-2: Expressway and Highway Development Plan

The Road Master Plan emphasised a well-balanced and credible 10-year investment program, covering six complementary building blocks, including

(i) Construction of expressways and highways (35.6 %),
(ii) Widening of highways (32.1 %)
(iii) Reduction of traffic congestion (3.8 %)
(iv) Road maintenance and rehabilitation (19.0 %)
(v) Bridge rehabilitation and reconstruction (2.9 %), and
(vi) Land acquisition and resettlement and all measures to protect social and environmental values (6.7 %).

The construction of Expressways and highways has the largest share (35.6 %) of the investment, while the road maintenance and rehabilitation is 19.0 %.

The expressway and highway development plan is shown in Figure 3-2. Kandy and Badulla of landslide prone areas are designated as Regional and Secondary Growth Centers in the plan.

3.1.3 Current conditions and issues in road sector

a. Situation of Road Sector in Sri Lanka

According to the RDA's official classification, the present road network conditions are as follows:

Table 3-4: Road Classes and Pavement

Rank	Class	Length	Paved	Implementation Entity
National Roads	A & B	11,671 km	100 %	RDA
Provincial Roads	C & D	15,532 km	67 %	Provincial Road Development Authority (PRDA)
Local Authority Roads	E	64,659 km	13 %	Municipal/Urban Council or Local Authority
Other Roads	Not classified	24,000 km	-	Ministry of Rural Development (MORD) Village Development Society
Total	-	115,862 km	-	-

(Source: National Road Master Plan (2008-2017), RDA, 2007)

This survey target is mainly Class A roads, only one Class B road is included. As far as the Survey Team has investigated, the road conditions are briefly presented in Table 3-5:

Table 3-5: Brief features of Class A Roads in central mountainous areas

Feature	Conditions
Pavement	All pavements (hot-mix asphalt or asphalt macadam) are good.
Alignment	Some zigzag (sharp bend) roads are included as shown below
Slope	• Many landslides (soil and rock) are observed at mountain and valley sides. • RDA constructed slope protections at certain locations but

Feature	Conditions
	many of them still remain unprotected or left as they are because of the large scale.
Maintenance	• RDA removes rocks and debris fell on the roads immediately when those failures occurred. • RDA is carrying out Periodic maintenance.
Rainfall	Heavy rainfall, 2,000-4,000 (max.) mm/year

(Source: Kandy-Hasalaka Road, 18 sharp bends, completed in May 2012 by ADB fund , ADB's News Letter, June 2012)

Figure 3-3 shows a photo of 18 sharp bends at A-26 Road near Hasalaka.

(Source: Kandy-Hasalaka Road, 18 sharp bends, completed in May 2012 by ADB fund , ADB's News Letter, June 2012)

Figure 3-3: Example of sharp bend

b. Issues in Road Sector in Sri Lanka

Although Sri Lanka's national road network has developed steadily and maintenance (or rehabilitation) works have been carried out widely, their mobility is still insufficient in comparison of recent economic development. Major issues are as follows, referring to National Road Master Plan (2007-2017):

b.1 General Issues of Class-A Roads

Various Class-A road rehabilitation works having been completed or on-going, Class-A roads have following issues:

- Most of the Class-A roads have only 2-lane, insufficient capacity for large traffic volume (e.g. Colombo-Kandy A-1 Road),
- Class-A roads pass through busy semi-urban areas, only a few bypasses,
- Horizontal curve radii are too small at certain locations,
- Still much Asphalt macadam pavement (e.g. A-21 Kegalla- Avissawella Road) remains, which has rougher surface than that of hot-mix Asphalt pavement,
- Due to above reasons, it takes longer travel times. For instance:
  Colombo-Kandy Road: L= 116 km, travel time: 4-5 hours,

Kandy-Nuwara Eliya Road: L= 77 km, travel time: 4 hours.

b.2 Encroachments

Encroachments on right-of-way by shops and parked vehicles reduce the travel speed.

b.3 Lack of slope protection

Existing slope failures at Class-A roads are being attended by RDA promptly. However, slope protection works are in slow process, mainly due to difficult solutions and limited budget for maintenance.

In recent road rehabilitation, slope protection works are included in the scope but only limited protections are provided due to technical and financial reasons.

3.1.4 Landslide countermeasures of RDA

a. General Countermeasures for Landslide

a.1 Causes of Landslides

There are two primary categories of causes of landslides: natural and human-caused. Sometimes, landslides are caused or make worse, by a combination of the two factors. Main natural cause of the landslides is rain water. Other factors are:

- Steepness of slope,
- Morphology or shape of terrain,
- Soil type,
- Underlying geology and ground water level
- Whether there are people or structures on the affected areas.

a.2 General Countermeasures

There are various counter measures from the simple ones to physical constructions including:

- Avoid construction on steep slopes and existing landslides.
- Regulate land use and development to ensure that construction does not reduce slope stability.
- Regulate the construction works according to landslide hazard maps to reduce hazard.
- Construct physical structures in cases where landslides affect existing structures or traffic.
- Provide monitor and warning systems to allow residents to evacuate temporarily when the landslide is anticipated.

b. RDA's present landslide countermeasures

At present, RDA is taking several countermeasures for landslide, including:

- Concrete retaining walls and gabion walls
- Grouted stone masonry,
- Cutting slopes for soil and rocks with easy gradient (in general),
- Removing soil and rocks after landslide as maintenance,
- Shotcrete for rock surface,

- Soil nailing, grassing and planting trees for cutting and embankment surfaces,
- Provide detour roads

Horizontal borehole of drainage were partly drilled at specific locations in Southern Expressway Construction Project assisted by Japanese ODA loans.

c. Typical countermeasures taken by RDA

c.1 Earth works

As earth works, RDA is taking following countermeasures:

- Cutting overhang and loose rocks to avoid rock falls,
- Benching of rock slope cutting (Figure 3-4),
- Remove soil from the head of a slide to reduce the driving force,
- Embank at the toe of the slope to increase the stability,

(Source: JICA survey team)

Figure 3-4: Benching for Rock Slope (Southern Expressway in Sri Lanka)

c.2 Drainage works

RDA is taking following countermeasures in drainage works:

- Slope surface drain (Figure 3-5),
- Subsurface drain,

(Source: JICA survey team)

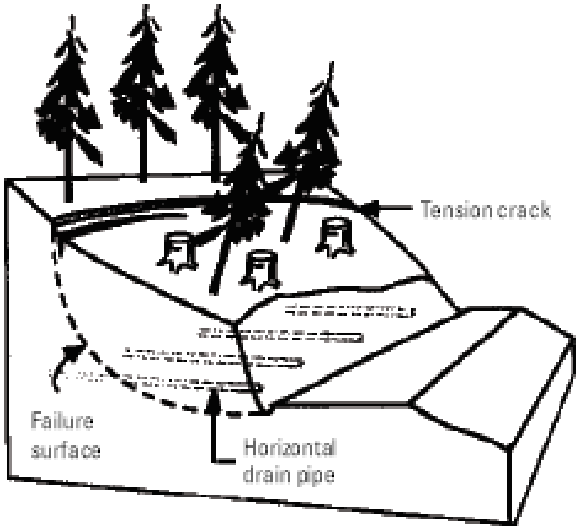
Figure 3-5: Slope Surface Drain (Southern Expressway)

c.3 Subsurface drainage

Subsurface drainage is effective for ground water drain. It is therefore essential that subsurface drain shall be used only after the ground water is identified as a cause of the slide.

c.4 Horizontal Drilling Drain

RDA is providing horizontal drilling drain only at some locations, for instance, A-5 Road, at landslide location of Hakgala and Southern Expressway.



(Source: The Landslide Handbook, USGS (US Geological Survey, 2008)

Figure 3-6: Horizontal Drain

Horizontal drainpipe is widely used device for landslide prevention in highway construction. It is most effective when installed during initial excavation. The drains are effective only if:

- The pipe is carefully installed,
- The failure surface is intersected, and
- The pipe actually drains the soil.

The installation process will be as follows:
- Drill the hole up to the desired depth,
- Install the casing and clear the soil inside,
- Cover the sections of slotted PVC drainpipe with filter cloth,
- Push the casing with the drainpipe into the hole,
- Withdraw the casing and the screen is installed over the end of the drain,
- Clean the drain holes of drill cuttings and mud.

c.5 Retaining Walls

Most widely used countermeasures for landslides by RDA are Reinforced Concrete (RC) retaining walls as shown in Figure 3-7.

(Source: JICA survey team)

Figure 3-7: RC Retaining Wall at A-26 Road (Kandy)

c.6 Gabion Walls

RDA is also using many gabion walls at road side landslide areas as shown in Figure 3-8. Gabions are wire mesh, boxlike containers filled with cobble-sized rock that are 10-20 cm size. Gabion walls usually are inexpensive and are simple and quick to construct. Due to their flexibility, they can withstand foundation movement.

Gabion walls are simple and economical but the location shall be carefully selected because they are not so strong for strong backside landslide pressure. Gabion in the photo below has projected forward due to the strong earth pressure behind.

(Source: JICA survey team)

Figure 3-8: Gabion Walls (A-5 Road, km 192)

c.7 Slope Stabilization using Vegetation

RDA is using vegetation as countermeasures and environmental friendly design. Soil nailing and geo-fabric are also used with the vegetation because seeding with grasses and planting trees reduce surface erosion, which can under certain conditions lead to landslide.

- Before undertaking seeding, a person with local experience should be consulted for advice.

- The slope shall be as stable as possible before seeding to make the slope resistant to future erosion and failure.

Controlling surface water drainage, removing cut-bank overhangs, reducing slope angles, and benching, all should be done before seeding begins.

d. Road slope countermeasure guideline of RDA

In RDA, Landslide guidelines are under preparation. For instance, on 10th July 2012 "Workshop on Construction Guidelines for Disaster Resilient Roads" was held in Colombo and all stakeholders including our JICA team attended. In the workshop, 19 pages draft guidelines were discussed. But the contents are almost only Table of Contents stage with short descriptions of each subtitle (without any drawings).

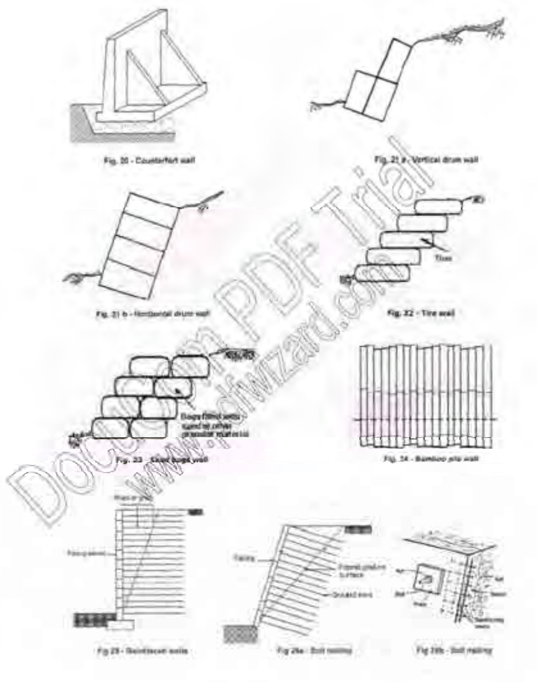
R & D of RDA said they wanted to complete the guidelines within 3 months. The early completion is awaited.

At present, there are two landslide guidelines available; both of them are related to NBRO, not RDA.

- "Guidelines for Construction in Landslide Prone Areas", Sri Lanka Urban Multi-Hazard Disaster Mitigation Project (SLUMDMP), Ministry of Housing and Plantation Infrastructure, March 2003.

- "Slope Protection Guidelines (in Sinhala)", NBRO, 2009

One of example pages of each guideline is presented in Figure 3-9.



(Source: "Guidelines for Construction in Landslide Prone Areas", Sri Lanka Urban Multi-Hazard Disaster Mitigation Project (SLUMDMP), Ministry of Housing and Plantation Infrastructure, March 2003.)

Figure 3-9: Example page of guideline

3.1.5 Trend of other donor agency and nations

a. Other Donor's Landslide Measures

When JICA team asked RDA about other donors' stance in landslide countermeasures, they replied that there were no specific budget for landslide only but slope protection is included in all road projects in general. Therefore, if this landslide project is started, this will be the first project in particular of the landslide.

For instance, the most active multi-lending agency in Sri Lanka is ADB. According to ADB's "Country Partnership Strategy, Sri Lanka 2012-2016", October 2011, various development strategies including transport sector are presented. However, landslide or road disaster is not mentioned specifically, as follows.

> "**Transport.** The government's priorities include developing an expressway network with well-connected national and provincial roads, and expansion of the rural roads network that links to the major growth centers. ADB's assistance will focus on key arterial national road links, and improve provincial and rural roads, especially in the lagging areas.(Extracts from ADB's "Country Partnership Strategy, Sri Lanka 2012-2016", October 2011)

Major donors in Highland region after 2000 are ADB, Korea, China and Japan. Recently Chinese fund projects are incerasing rapidly, especially in 2011 and 2012. Outlines and lesson learned from those projects are shown in the Table 3-6.

During the field investigation of this project, many small rack fall and cutting failures occurred on the road widening project site even by the regular rain fall. RDA has to spend time and cost to prepare and clear the fallen debris. The reasons of the rock falls, cutting slope failures, and landslides are lack of deep considerations of the slope condition by geological and geo techinical investigation in the design stage. Slope inspection during after completion should be carried out.

Table 3-6: Outline and lesson learned of the projects in Highland Regions by donors

Donor	Name of the Proiect	roject Period		Road No and site or Section	Length (km)	Tentative Estimated	Outline of the Project	Lesson Learned Good & Problems
		From	To					
ADB	National Highway Sector Project	01.11.2008	29.02.2012	A026 Road (Udathenna to Mahiyangana) 31.3 km - 72.1 km	41	4,705	Rehabilitation & upgrading of Udatenna - Mahiyangana road	Counter mesaures for steeper slopes have not been accommodated at all the locations during the construction stage and adopted measures are not enough at some places.
		01.12.2008	30.06.2012 (Programme is revised)	A005 Road (NuwaraEliya to Badulla) 75.2km -130.1km	57.5	5,318	Rehabilitation & upgrading of Nuwaraeliya - Badulla road	Considerations have not been given for the steeper slopes in the design stage
Korea	EDCF funded Road Projects	2000	2004	A004 road (Ratnapura to Balangoda)	48.25		Rehabilitation & Improvement of Ratnapura to Balangoda road	Considerations have not been given for the steeper slopes in the design stage
		2004	2008	A004 road (Balangoda to Beragala)	40		Rehabilitation & Improvement of Balangoda to Beragala road	Considerations have not been given for the steeper slopes in the design stage
		2004	2008	A016 road (Beragala to Bandarawela)	17		Rehabilitation & Improvement of Beragala to Bandarawela road	Considerations have not been given for the steeper slopes in the design stage
		01.12.2011	31.05.2014	A007 Road (Hatton to NuwaraEliya) (72km -115.5km)	43.5	5,685	Rehabilitation & Improvement of Hatton to NuwaraEliya road	Guidline issued by the NBRO is to be addressed in this project
China	Priority Road Project 1	12.12.2011	11.12.2013	B421 Road (Thiruwanaketiya to Kalawana)	33.45	2,800	Rehabilitation & Improvement of Tiruwanaketiya - Agalawatte Road	Counter mesaures for steeper slopes have not been accommodated in the design stage
	Priority Road Project 2	12.12.2011	11.12.2013	B421 Road (Kalawana to Agalawatte)	34.35	3,500	Rehabilitation & Improvement of Tiruwanaketiya - Agalawatte Road	Counter mesaures for steeper slopes have not been accommodated in the design stage
		06.12.2011	05.12.2013	B421 Road (33.45 km - 67.80km)		1,169	Reconstruction/widening of Bridges on Tiruwanaketiya - Agalawatte Road	
	Priority Road Proiect 2	07.12.2011	06.12.2013	B036 Road (Badulla-Andaulpotha)	48.2	3,370	Rehabilitation & Improvement of Badulla - Karametiya - Andaulpotha Road	Counter mesaures for steeper slopes have not been accommodated in the design stage
		07.12.2011	06.12.2013	B122(Galagedara to Rambukkana) road	18.5	1,925	Rehabilitation & Improvement of Galagedara-Rambukkana Road	Counter mesaures for steeper slopes have not been accommodated in the design stage
		20.03.2012	19.09.2014	B413 Road (Kandehandiya to Ragala) (20.30km-73.64km)	53.44	7,307	Rehabilitation & Improvement of Tennekumbura-Rikillagaskada-Ragala Road	Counter mesaures for steeper slopes have not been accommodated in the design stage
		20.03.2012	19.03.2014	Length of 85.01 km	85.01	2,876	Improvement of Provincial Roads in Nuwara Eliya District	Counter mesaures for steeper slopes have not been accommodated in the design stage
Japan	Road Network Improvement		completed in 2007	AB 013 road (Gampola to Nawalapitiya)	17	4,100	Rehabilitation & Improvement of Gampola-Nawalapitiya Road	One of Rank 'C" landslide locations(A113-015) is on this road but it has not been properly investigated during the design stage
			completed in 2007	A005 Road (Gampola to NuwaraEliya)	54		Rehabilitation & Improvement of Gampola-NuwaraEliya Road	One of Rank 'C" landslide locations(A005-045) is on this road but it has not been properly investigated during the design stage

3.1.6 Road development needs in the future

Various needs in road development are discussed here.

a. Needs in trade

Sri Lanka's transport system is roads-based and road transport is a major factor influencing the country's trade competitiveness. Trade statistics clearly show that Sri Lanka's manufacturing industry has become part of the international value chain. An efficient domestic transport system is a prerequisite for sustaining this position.

b. Motorization

In Sri Lanka, motorization has surged by on average 30 % per year from 1997 to 2006. However, the allocation of funds to road works has grown annually by only 12 % in real terms. At first, it appears as lack of maintenance. Because of funding constraints, many roads have deteriorated causing costly rehabilitation and reconstruction.

c. Design and Strategies

Strategic traffic capacity expansion to cope with the traffic growth is required in the following subjects:

- Widening roads to multi-lane carriageways,
- Improving road cross sections, particularly for drainage,
- Catering to the needs of pedestrians,
- Strategic shift from the traditional project centric approach to an approach based on the strategies in the National Road Master Plan (2007-2017).

d. Finance and other factors

Following implementation is required:

- Sustainable funding of road maintenance,
- Using various financial resources (incl. PPP or PIP) to finance the road improvement.
- Improving institutional arrangements in road sectors,
- Developing the capabilities and capacities of Sri Lankan road contractors.

3.2 Landslide-disaster countermeasures sector

3.2.1 National Building Research Organization (NBRO)[1]

a. Organization and human resource

The National Building Research Organization (NBRO) which was established in 1984 has now grown into a successful technical service provider and research and development institution where experts from multiple disciplines have teamed up and dedicated to create a

[1] The description of the chapter is referred and excerpted from Annual Report 2011, NBRO.

disaster free safe environment for the nation. NBRO's expertise extends into a wide range of disciplines such as environmental science, study of landslides and related geo hazards, human settlement planning, engineering project management, geotechnical engineering, and building materials engineering (Figure 3-9).

The objectives of NBRO have been revised to cater the mandate of the ministry of Disaster Management. All the activities are redesigned focusing the main objective of 'Disaster Risk Reduction'.

The new scheme of "Recruitment and Promotion" was approved by the Department of Management Services in this year. Accordingly a cadre of 274 positions available to carry out the activities of the organization. A staff development program is underway. .

b. Landslide Research & Risk Management Division(LRRMD)

The Landslide Research & Risk Management Division (LRRMD) of NBRO studies the landslides and related geo-hazards in the hilly areas of our country and establishes short-term and long-term mechanisms for landslide disaster management. The division is supported by the experts in the fields of geology, geotechnical engineering, geography and computer science. Services can be obtained by contacting Head (LRRMD), contacting District Officers or sending the completed application for landslide investigations. The importance of the landslide research and risk management necessitated increasing of present staff strength by about 75 while setting up district offices in 10 landslide-prone districts.

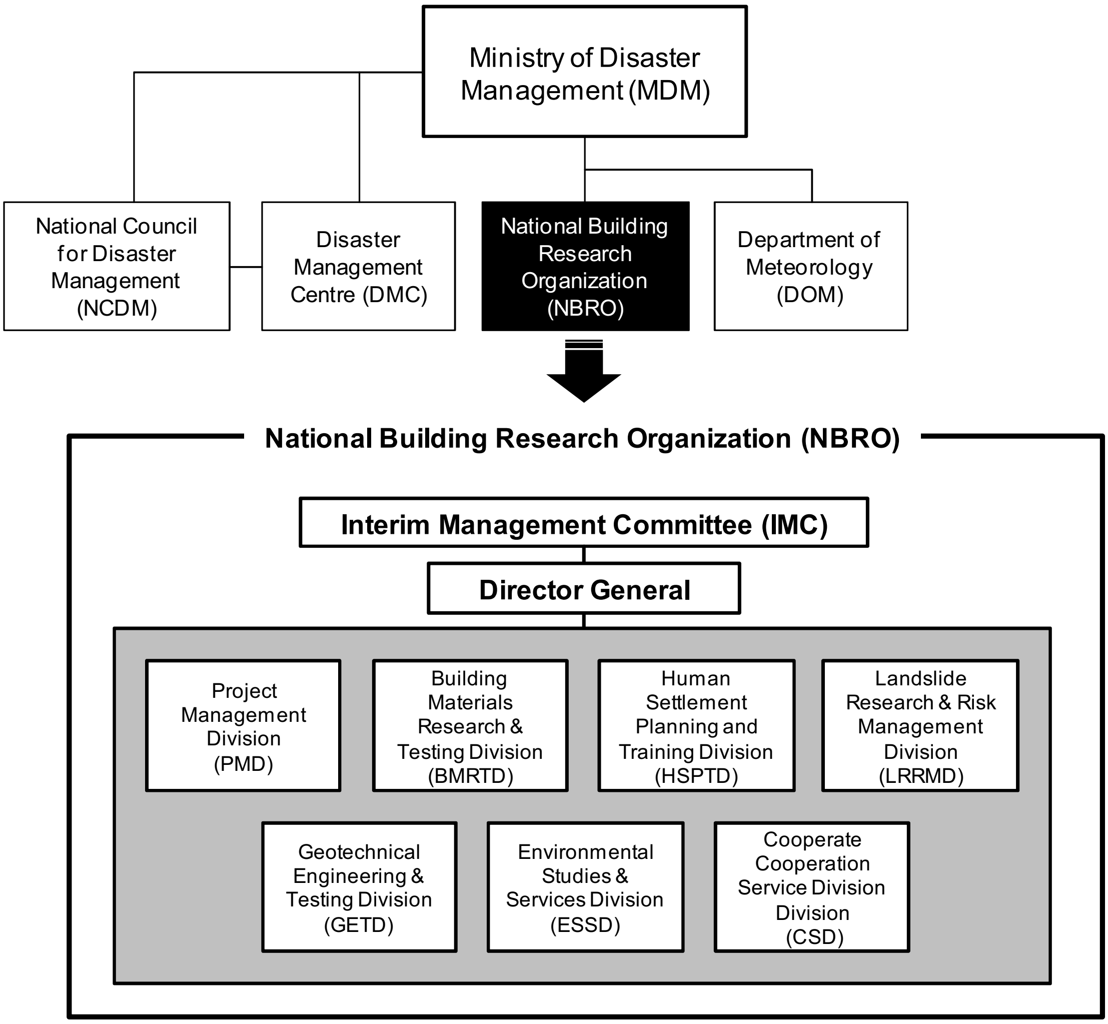


Figure 3-10: Organizational structure of NBRO

c. Budget

NBRO receives GOSL funds as capital expenditure for procurement of lab & field equipment given annually. In some instances foreign donor agencies and collaborating institutions have granted funds for research and project work of NBRO. GOSL funds are provided for landslide disaster risk mitigation as a national priority.

However NBRO heavily relies on self-earning and most of its financial requirements including recurrent expenditure are generated through consultancy and testing services offered to the state and the private sector. From 2007 to 2011 continuously a net profit was recorded, and the consolidated revenue of year under review was reported as the highest in the history of the NBRO (エラー! 参照元が見つかりません。). That is 182 million Rs. reflecting a growth of 43% over the previous year 2010. Testing and technical services shows remarkable growth at around 108 million Rs. in 2011, which account for 59% of the total income of NBRO, whereas the government grants for landslides and related research works have risen to 73 million Rs.

The budgeted total expenditure for year 2011 was 189.25 million Rs. including 52 million Rs.

for Mitigation of Peradeniya and Padiyapalalla landslides funded by the Treasury through DMC. As at 31st December 2011 only 16.0 million Rs. has been received through DMC and the balance expenditure has been met with internally generated revenue.

In addition the Government Grant for research (Landslide hazard mapping) 21.5 million Rs. was expected to be received for year 2011. 10.0 million Rs. grants were provided by the Treasury through DMC to meet the expenditure for landslide special investigations and recommendation of DRR.

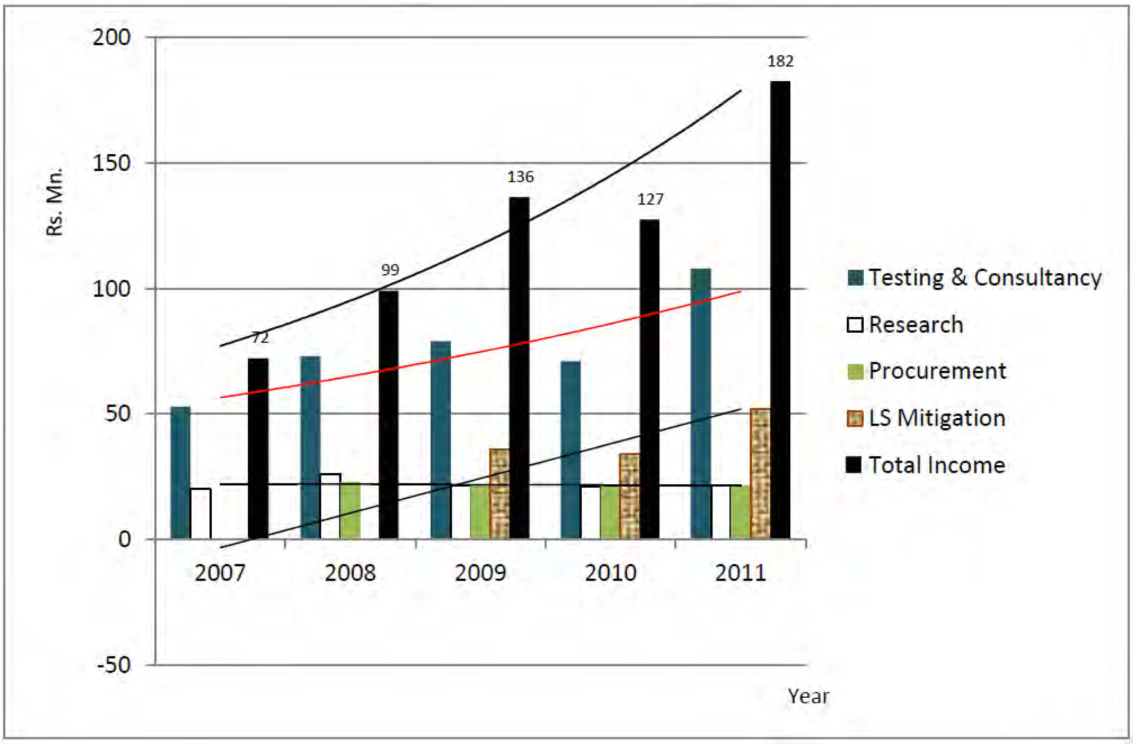


Figure 3-11: Financial performance of NBRO for the last five years
(Source: Annual Report 2011,NBRO)

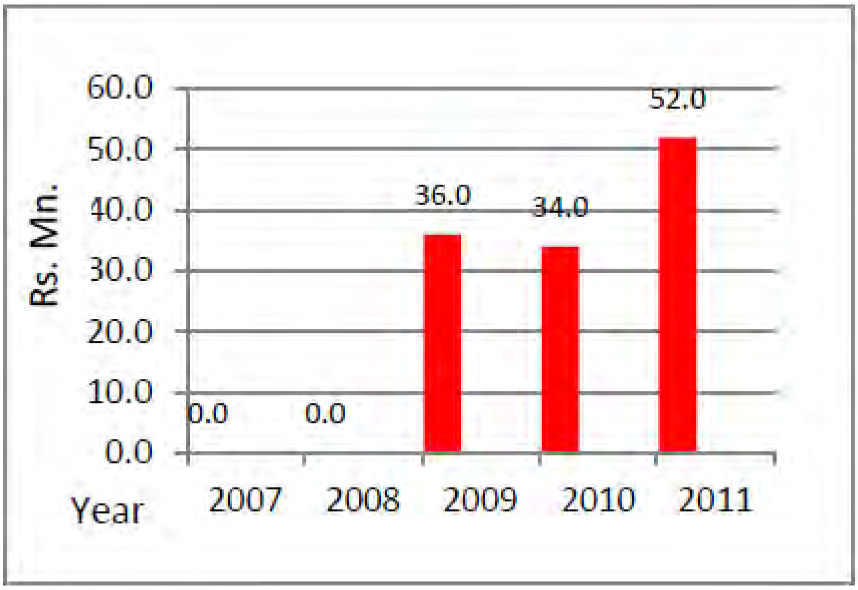


Figure 3-12: Landslide mitigation budget for the last five years
(Source: Annual Report 2011,NBRO)

d. Authorizations

NBRO's expertise extends into a wide range of disciplines such as landslides and related geo hazards, human settlements planning, geotechnical engineering, building materials technology, environmental management & engineering project management. Over the years NBRO has developed its capacity to become a competent research institution in Sri Lanka and at present NBRO serves as the research arm of the Ministry of Disaster Management. NBRO recognizes the diversity of the problems faced by the nation in their living environment, and is geared up to achieve solutions to maintain and improve the quality of life of the people.

NBRO carried out the following specific tasks in line with its designated functions and the corporate plan. Research and Development work and also provision of technical consultancy services in the fields of ;

- Landslide studies and services
- Geotechnical engineering,
- Project management services
- Building materials
- Human settlements planning
- Environmental management

3.2.2 Development policy and plan on landslide-disaster sector

One of the NBRO's goals is to assist the government in national development and thus enrich the quality of lives by alleviating poverty through Disaster Risk Reduction. The tasks of NBRO in disaster risk reduction was diversified into landslide mitigation, proper land use practices, testing and certifying building materials for strength properties, water, air and noise monitoring for environmental compliances, testing suitability of soil etc.

NBRO has established its capacity as a competent institution in landslide hazard and slope instability studies and in their mitigation. NBRO currently function as the national focal point for landslides and associated geo-hazards. As per the mandate, NBRO carries out field surveys for identification of landslide potential and hazard mapping. Issuing landslide clearance certificate/ report for development activities in landslide prone areas by NBRO has become a pre-requisite for building permits issued by the local authority.

Vulnerability due to landslide hazard has been significantly reduced over the past decade due to the intensive involvement of NBRO in landslide disaster risk reduction. Activities carried out by NBRO range from landslide hazard mapping, investigations, issuing early warning at emergency based on continuous monitoring of the risk, hazard mitigation, training and awareness of vulnerable communities. Obtaining landslide clearance certificates for any construction and development activity in landslide prone is a requirement for building permit issued by the local authorities. These have become the key instruments in national disaster risk reduction programmes by which the government has been able invest on upcountry development through well-planned risk management systems, thus making remarkable savings on disaster relief and rescue.

Technical services provided by the institution in other areas of NBRO expertise also have contributed to planned development in the country, conserving resources, optimizing outputs and reducing the potential environmental and disaster impacts thus making significant savings in the national budget.

NBRO performed well across diversified subject areas such as landslide hazard identification, landslide hazard zonation mapping, vulnerability assessment, awareness and mitigation that are commonly known.

3.2.3 Development plan of NBRO for landslide disaster risk management

NBRO's vision and mission are set to develop its capacities to cater the Ministry's DRR needs. With this view NBRO is in the process of legalizing the institution mission by an act and developing staff capacities to deliver high standard outputs. To support this, institutional capacities have to be expanded to purchase more lab and field equipment and latest analytical software, attract foreign donors and collaboration.

The forecasts by the NBRO Corporate Plan for the coming year shows anticipated government grant as 146 million Rs. which is nearly 60% of the total budget 245 million Rp. These figures may shift by a large margin because of speedy implementation of Stabilization of Garandi Ella Landslide which the government considers as a priority project and grants funds. In addition, funds are now being sought for stabilizing of other 47 sites identified as hazardous and implementation work would further exert stress to NBRO in moving its activities away from their nominal day to day work. Evaluation of the hazardous nature of these sites, and prioritization of these sites according to the vulnerability were recently completed. At present four districts namely Kandy, Matale, Badulla and Nuwara Eliya have been selected for stabilization work as the Phase I of this work. Landslides in other districts will be stabilized in Phases II and III subsequently.

Therefore, establishment of a strong project management / implementation unit focused on speedy implementation of such projects is necessary for NBRO to execute this cluster of large projects. A multidisciplinary approach is also essential to make implementation of these projects a reality.

National Physical Planning Department (NPPD) in their recent Project Proposals Sri Lanka 2010-2030 identifies many future projects in which NBRO plays a significant role. Significant concepts in this plan are the creation of human settlements away from natural disasters and remediation and reforestation of endangered land as a disaster mitigation activity.

3.2.4 Trend of other donor agency and nations

The donor organizations which have important relation with NBRO are JICA and UNDP. UNDP assisted the forming of NBRO in 1984 and continue assistance to start landslide studies 1990, especially for Landslide Hazard Zonation mapping project. The project is still continuing to cover the landslide prone area and to update the maps. Under "Multi Hazard Risk Profile Preparation Project", granted by UNDP, through the DMC was completed and finalized landslide hazard zonation maps covering 440 km2 at Nuwara Eliya district and 400 km2 at Galle district. All the completed maps were handed over to DMC.

Installation of automated rain gauges will help NBRO to issue more accurate real time landslide early warning to the people who are living in landslide prone areas of Sri Lanka. Two numbers of automated rain gauges were received from the Norwegian Geotechnical

Institute (NGI) under RECLAIM programme coordinated by Asian Disaster Preparedness Center (ADPC). Those two rain gauges were installed at Walapane and Peradeniya area.

Since the Tsunami in 2004, GOSL is working actively for Disaster Management. In responding to this situation, JICA has been conducting various supports both on structural and non-structural measures for GOSL from emergency response to rehabilitation. JICA has been also conducting the supports for the disaster management system in Sri Lanka continuously as follows, by utilizing the lessons and experiences in Japan.

2005 - 2006: The Project Formulation Study “Program on Strengthening the Disaster Management Administration”

2006 - 2009: Comprehensive Study on Disaster Management in Sri Lanka (Development Study)

2006 - 2009: The Project for Improvement of Meteorological and Information Network (Grant Aid Project)

Flood control master plan, early warning and evacuation plan, hydrological information system and intra-governmental network system, equipments for community based disaster management activities, automatic weather station system etc. are prepared and installed by above development study and grant aid project. Plans and equipments necessary for promoting the disaster management activities are prepared and the basic capacity of counterpart agencies has been improved by those projects.

The GOJ decided to implement “The Disaster Management Capacity Enhancement Project Adaptable to Climatic Change” (DiMCEP） for the necessity of capacity development of DMC,DOM,NBRO and etc., for responding to the increase of number and intensity of disaster that are said to be caused by climate change, needs to be enhanced.

Grants and technical assistance from ADPC, ITC, USAID, UNDP and JICA are continuously supporting up to date.

3.2.5 NBRO’s Landslide Countermeasures

a. Countermeasures system

Landslide countermeasure is divided into structural countermeasures and non-structural countermeasures. NBRO conducted its activities of both structural countermeasures and non-structural countermeasures under following main areas.

LRRMD, as the focal point of all landslide related studies in Sri Lanka has extensively contributed to landslide hazard mitigation during the past 25 years. It is a key player in the planning and implementation of many Government initiated meticulous actions, projects and programs for: arresting environmental degradation, improved land use planning and land management; planning and drafting activities in land settlement work; preparation of national environmental action plans and national disaster preparedness and mitigation plans; creating and enhancing awareness on land use and environment issues etc. among the resident communities and development agencies in landslide prone areas; and recommending remedial measures and guidelines with emphasis on landslides.

Main tasks of LRRMD are as follows.

1 Landslide hazard zonation mapping
2 Landslide hazard identification and assessment of landslide risk
3 Application for landslide investigation
4 Guideline for construction and land use planning in hilly areas
5 Landslide mitigation
6 Awareness and training programmes
7 Landslide early warning
8 Landslide database

NBRO has been involved in several landslide mitigation and rehabilitation works jointly with other agencies e.g., at Nawalapitiya, Beragala, Kahagolla on the national highways and at Watawala on the railway. Recently, NBRO has been engaged in implementing landslide mitigation projects at Peradeniya, Padiyapelella, Mahawewa, Malhewa and Garandiella where disastrous landslides have left potential threat to human settlements and infrastructure. Works at Malhewa is completed and the works at Peradeniya and Padiyapelella are near completion while investigations and monitoring is in progress at the others.

Recognizing the rapid transition in land use taking place due to uncontrolled development activities and human interventions in the hilly areas, NBRO is implementing a landslide mitigation project in Badulla district jointly with the Land Use Policy Planning Department of Sri Lanka. Aimed at the reduction of landslide risk through proper land use practices, NBRO will evaluate the landslide hazard potential based on updated land use maps and introduce a set of appropriate land use techniques and guidelines for building and other construction activities.

(Source: NBRO' Web site)

Figure 3-13: Landslide Countermeasure works at Padiyapelella

The NBRO in February 2011 has submitted to the government a proposal for an Integrated Landslide Mitigation Project (ILSMP) that draws attention to hazard mitigation of the most important and critical landslides in the ten hilly districts. ILSMP is proposed to be implemented in three phases through an integrated approach giving due consideration to geological, geotechnical, sociological, environmental, legislative and economic aspects with collaborative and active participation of the stakeholders and the public.

- Phase-I - Badulla, Kandy, Matale and Nuwara Eliya administrative districts,

- Phase-II - Kalutara, Kegalle and Rathnapura administrative districts
- Phase-III - Galle, Hambantota and Matara administrative districts

This Initial Technical Proposal for the Phase I of ILSMP proposes to undertake hazard mitigation of 16 most vulnerable landslides amongst 47 identified potential landslide locations within the four administrative districts, viz. Kandy, Matale and Nuwara Eliya in the Central Province and Badulla in the Uva Province. The proposal also provides for mitigation of 18 locations where schools are affected by landslides within Kandy district. Another 12 schools in Matale and Nuwara Eliya district which need landslide mitigation measures have also been identified.

3.2.6 Guidelines for Slope Management and Slope Protection (technical guidelines)

NBRO has prepared a set of general guidelines for construction in landslide prone areas. Following these guidelines minimizes the landslide threat induced by impact due to construction or other development activities. In addition, after performing a landslide potential and risk evaluation investigations, site specific guidelines are provided for land use planning, construction and other development activities to be implemented.

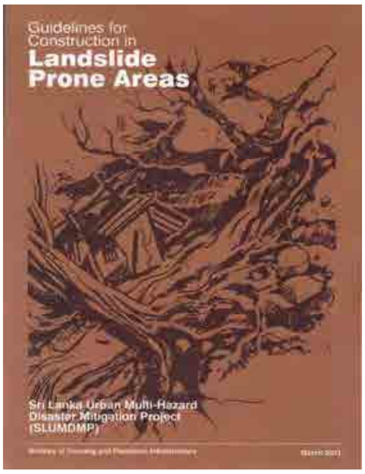
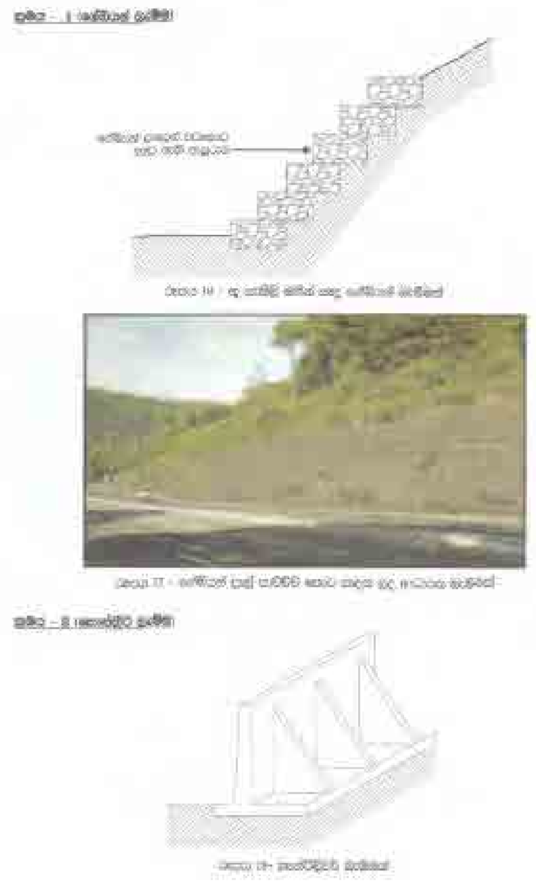


Figure 3-14: Guidelines for construction in landslide prone areas
(English and Sinhala)



(Gabion wall)

(Buttress Concrete Wall)

Figure 3-15: Example Landslide Countermeasure Works in the Guidelines
(Source: NBRO's Landslide Guidelines (in Sinhala), 2009)

Technical guidelines for Slope Management and Slope Protection has not prepared by NBRO. Current countermeasure works are designed and constructed by the knowledge and experience of NBRO, based on their researches and ideas suited for the site conditions. Through their experience, the knowledge and information to compile the methods has been accumulated to prepare the technical guideline. But for advances guideline, the knowledge and examples in foreign countries, such as Japan, should be introduced in the guideline.

NBRO expects to develop new and advanced technical guideline through the New ODA Loan Project.

3.2.7 NBRO's landslide countermeasures

The activities and progress of landslide countermeasures excerpted from the Annual Report of NBRO are shown below.

a. Landslide Hazard Zonation Mapping

By the Cabinet Paper 116 of 16th June 1986 the Government directed NBRO to undertake mapping of landslide hazards starting with the most affected districts of Badulla and Nuwara Eliya on an urgent basis. The directive underlined the need to minimize future landslide damages through landslide hazard mapping, to introduce proper land use practices and to use graded hazard maps as an essential tool in the decision making for sustainable development of the areas mapped.

After successful completion of a pilot hazard mapping project for 120 km^2 area of Obada Oya Basin in Nuwara Eliya District, NBRO launched the UNDP assisted "Landslide Hazard Mapping Project" covering the two districts of Nuwara Eliya and Badulla. Hazard zonation mapping work has been extended to all ten identified districts with landslide prone areas. Maps at 1:50,000 scale entirely for 7 districts (Matale, Kandy, Nuwara Eliya, Badulla, Kegalle, Ratnapura and Kalutara) and 88 map sheets at 1:10,000 scale for selected high priority areas in 7 districts have been completed by the end of year 2011.

1:10000 scale maps (View 1:10000 scale map) covering the selected areas within the 10 landslide prone districts are also carried out as shown in the following key map.

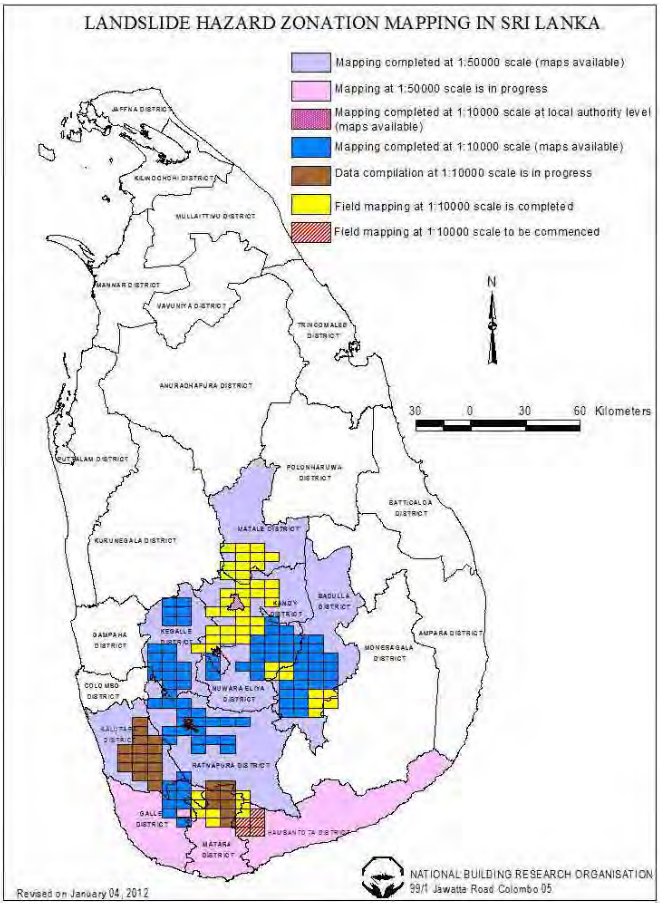


Figure 3-16: Index map of Landslide Hazard Zonation Maps

Characteristic of the Landslide Hazard Zonation Map by NBRO is that those maps were created by the analysis using the elements such as landform type, slope angle, base rock geology, soil, weathering condition, vegetation, land use, etc. by statistic method. The hazard zone of the map represents not specific instability of landslide phenomena, such as landslide in a narrow sense, slope failure, rock fall and debris flow, but comprehensive instability of the slope for mass movement. In case of creation of Road Slope Landslide Hazard Zonation Maps, it is expected to revise those maps to represent each landslide types.

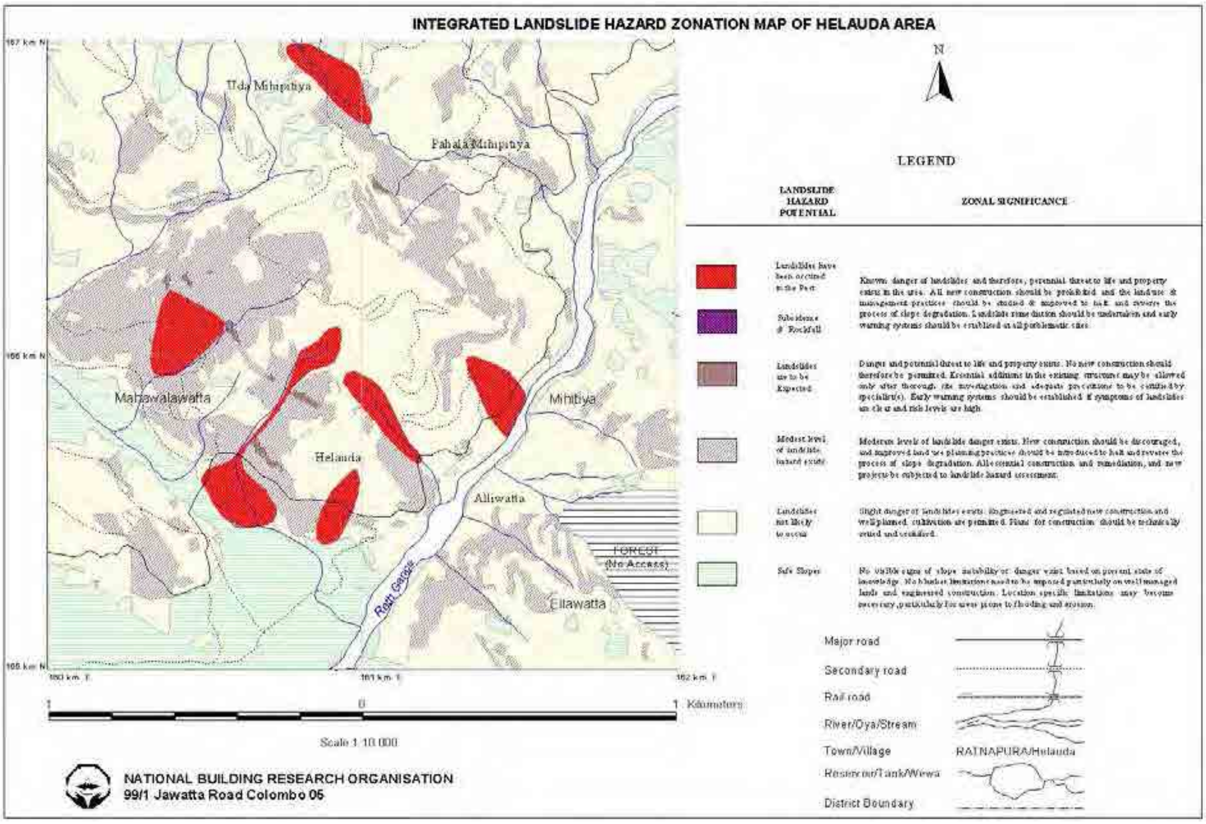


Figure 3-17: Landslide Hazard Zonation Map of 1:10,000

b. Mitigation and stabilization of slope in high risk landslide and rock fall sites in Nuwara Eliya, Kandy, Matale and Badulla districts.

Landslide Mitigation work (Structural countermeasure) was commenced under government grant according to the proposal submitted by NBRO through DMC.

NBRO recently stepped into mitigating landslides in urban and semi urban areas where resettlement is not an economical option. Mitigation of Peradeniya, Padiyapalalla landslides and Garandiella landslide stabilization program were implemented. Plans have already being made to commence about 16 more landslides located in the Central Province and the Badulla District within the next 5 years.

c. Landslide awareness and training

Landslide awareness programmes were not organized by NBRO during this year due to lack of fund but landslide experts and resources from the division were participated for the awareness programmes organized by different government and non government organizations such as, Metrological Department, DMC, Universities, UNDP, JICA, Red cross, Asian Foundation, etc.

Directions and Guide lines were given to more than 38 Reach students from Universities and schools to conduct their B.Sc., M.Sc. thesis and school advance reports.

d. Landslide early warning system (EWS)

As the main focal point of landslide early warning system in Sri Lanka, LRRMD of NBRO gave it services, in time during the every rainy period throughout the year successfully.

The detail of the EWS is described in Chapter 5.3.

e. Special investigations

Special investigation for landslide and recommendations based on the detail investigation were given to the government organizations, NGOs and private sector. Among these investigations, division has completed very special investigations related to National projects and actively participated as a project approving organization at the EIA process of major development projects such as Kaluganga Hydropower project at Elahera area.

f. Special projects

At the approval of the District Secretary, Nuwara Eliya District for the landslide mitigation proposal for the Mallhewa rock fall site at Kotmale divisional secretariat area was completed on 2011.

Investigation of the Grandiella landslide area was commenced on August 2011 and continued. Four numbers of drill holes covering total length of m were completed. Resistivity survey of the area was commenced by using the newly purchased resistively imaging equipment. Total value of the investigation received from the treasury was 5million Rs.

Two landslide sites were selected from Mahawewa, in Walapane and Galaboda, in Ratnapura to conduct detail studies for mitigation activities under JICA study program(DiMCEP). All monitoring equipments were installed at these two sites on 2010 and the monitoring was in progress until 2013. With the results from the monitoring data it was decided to introduce mitigation measures to the Galaboda landslide site by the JICA and NBRO teams. Designing of mitigation measures are in progress

g. Research work

Special attention was not put for the research work due to lack of research personal and separate funds. But parallel to the landslide hazard zonation mapping, real time forecasting, and landslide mitigation work, most of our scientist use to analysis the data to develop the effective landslide EWS and effective as well as the better landslide mitigation methodologies.

h. Issuing landslide clearance certificates /reports for any type of construction in landslide prone areas of Sri Lanka

After getting the approval from the Cabinet of Sri Lanka parliament, circular was issued to the all local government agencies and to the project approving agencies by the Secretary to the Ministry of Disaster management on 15th February 2011.With the results of the circular NBRO was stabilized nine numbers of regional offices at Badulla, Nuwara Eliya, Kandy, Matale, Kegalle, Rathnapura, Kalutara, Galle, Matara and Hambantota districts with appropriate facilities from 1st March 2011. Process of issuing clearance certificates were continued during the year 2011. During the period of 1st March 2011 to 31st December 2011, 12,301 applications have been received. 11,485 investigations have been completed while 9,995 clearance certificates have been issued.

4 Risk assessment and analysis on landslide disaster

4.1 Examples of major landslide disaster on the target national roads

Before discussion of risk assessment and analysis on landslide disaster in Sri Lanka, the features of several typical landslides are summarized. Typical examples of slope failure, rock fall/rock slide, and landslide on the target national roads are shown in this section.

- **National Road of A026**

Disaster type: rock fall and rock slide,

Geological condition: charnockitic gneiss, fresh and weathered,

This site is a typical site of rock fall as well as rock slide and located at around Km 55 on the national road of A026. (Referred to as A026-055) In addition, A026-055 can suffer from slope failure in the section where residual soil and weathered rock are distributed. Figure 4-1 and Figure 4-2 show photographs of A026-055.

As understood from the photos in Figure 4-1, unstable rocks are remaining on the shoulder of the slope, the height of which was estimated to reach 15 metres. These unstable rocks shall be removed or fixed. Besides, Figure 4-2 illustrates dangerous rock wall in which potential rock slide is anticipated. As understood from the close up view in Figure 4-2, open cracks were confirmed behind some rock parts on the steep rocky slope. These unstable rock parts shall be removed or fixed by physical method.

Between the rocky parts, weathered parts were confirmed on site. Thus this site requires countermeasures against rock fall, rock slide and slope failure of the weathered parts.

(Full view)

(Close up view of the above)

Figure 4-1: A026-055 at the ending side

(Full view)

(Close up view of the above)

Figure 4-2: A026-055 at the beginning side

- **National road of A005**

Disaster type: rock fall and rock slide

Geological condition: charnockitic gneiss, fresh and rich in crack

This site is located at around Km 46 on the national road of A005(Referred to as A005-46). A005-046 is a site of magnificent rock wall locating just beside the A-class national road of A005, the main road connecting Kandy and Nuwara Eliya. Figure 4-3 depicts the rock wall of A005-046.

The highest part of the escarpment was estimated to reach 50 metres or more. This height means devastating energy to be provided from fallen boulders or detached rocks sliding down from around the shoulder when rock fall or rock slide occurs.

In addition, the almost vertical gradient of the escarpment will hamper both study and implementation for direct countermeasures against the disasters. The direct countermeasures may include removal of unstable parts and fixing by physical methods such as rock bolts and concrete cribs. Temporary works such as scaffolding, however, are inevitably required during execution of the direct countermeasures. The temporary works are thought to occupy considerable areas for its installation. Thus it shall be considered whether necessary areas can be secured on site or not; i.e. during the execution, A005 may be blocked by the scaffold

Other than the direct countermeasures, engineers may come up with a detour plan of the road by utilizing bridges which may jut from the existing road shoulder and enable the road to secure enough distance from the escarpment. The steep lower slope will force difficulties in construction of the bridges but supposed temporary works may not affect the road. In case bridges are not applicable to this site, rock shed may be a candidate for the countermeasures.

Figure 4-3: Great wall of A005-046

- **National road of A005**

Disaster type: Slope failure (collapse),

Geological condition: residual soil, weathered rock of gneiss,

This site is located at around Km 91 on the national road of A005(Referred to as A005-091). A005-091 is a typical site of slope failure involving residual soil and weathered rock, located at around Km 91 on A005, the main road connecting Nuwara Eliya, and Badulla.

Weathered rock of gneiss composes the main parts of the slope, while thin layer of residual soil covers the weathered rock. The height of the slope is estimated to reach around 15 metres. As like other cutting slopes along the A-classes national roads in the Central Highlands, the gradient of the slope seems too steep to keep stable condition. In addition, traces of gully erosion were found on some parts of the slope. This suggests no surface drainage ditches surrounding the slope were installed or functioning.

Other phenomena which attracted our attentions were tension cracks with subsidence which developed on the terraces behind the shoulder of the slope failure. Such tension cracks opening and developing behind the existing slope failure suggest an imminent threat of a retrogressive development of the failure which entails further collapse of the slope.

Figure 4-4 explains the condition of the slope failure of A005-091.

Figure 4-4: Slope failure of A005-091 (Full view)

(Tension cracks with subsidence and opening)

Figure 4-5: Slope failure of A005-091

- **National Road of A005**

Disaster type: Landslide,

Geological condition: colluvium,

This site is located at around Km 135 on the national road of A005 (Referred to as A005-135). A005-135 is a typical site of landslide along A005 near Badulla.

The landslide of A005-135 is categorized as a multiple landslide in which many divided landslides move separately or interdependently. The size of the whole landslide was estimated to reach 200-300 metres in length. The landslide occurred in a gentle slope of a tea plantation and has destructed many buildings inside its area, including a hospital, office buildings and schools for the plantation as well as houses for officials and labours. A005 runs along the toe of the landslides and has repeatedly suffered from blockades or disruption by debris flown out from the toe of the landslide.

Figure 4-6: Condition of the landslide of A005-135

- **National Road of B413**

Disaster type: Landslide,

Geological condition: colluvium, (possibly) weathered rock of gneiss,

This is a site of an extensive landslide encompassing a small bridge at Km 70 and both sides of B413 road with considerable stretches in its middle (Referred as B413-070). According to

NBRO, the size of the landslide reaches 2,000 metres in length and more than 500 meters in width. A visual observation from the escarpment, however, suggests a much larger width of around 2,000 meters, same magnitude with the length. The main head scarp is located at the slope of a divided ridge of Ragala Rock Mountain and shows multiple terrace formation. The divided ridge runs parallel to the main ridge of Ragala Rock Mountain. Another landslide lies between the divided ridge and the mountain slope of Ragala Rock showing its axis pararell to the ridges. This landslide converges with the main landslide in the middle, after the divided ridge disappears.

This huge landslide also shows typical topographic features of multiple landslides such as a number of head scarps scattered inside the landslide and terrace shaped surface aligning downward by suggesting the shape of divided landslides. Small head scarps or opened tension cracks were seen even in the middle or lower parts of the landslide. The road surface of B413 was severely damaged by the landslide activities including cracks and subsidence of the pavement. Cracks were also observed at the abutments of the small bridge at KM 70. In addition, remnant of abandoned road and bridge were confirmed downstream, suggesting a past relocation of B413 due to landslide movements. The landslide is said to have started its activities in 1960s.

No investigations were made so far for this landslide and the following information is left unclear:

- Depth and shape of slip surfaces,
- Shape of landslide as a whole,
- Location of the side boundaries as well as the toe of landslide,
- Distribution and shape of divided landslide blocks
- Material of landslide mass,
- Groundwater condition,
- Hydrological condition,

The information mentioned above is essential for mitigation of landslide. Thus before considering optimal countermeasures, basic and detailed investigation shall be done for this extensive landslide.

The B-class national road of B413 will be improved by Chinese fund and is called Kandy – Ragala main road. According to RDA, however, the short stretch section including this extensive landslide of B413-070 was omitted from the sections to be improved, because of the difficulties derived from the landslide activities.

Figure 4-7 shows some features of the landslide of B413-070.

(From the main head scarp)

(Middle of the landslide)

(Subsidence of pavement on B413)

(Crack on the abutment of the small bridge at Km 70)

Figure 4-7: Landslide of B413-070

4.2 Outline of risk assessment and analysis method

The surveys in seven (7) high risk districts selected from 10 priority areas for landslide disaster management designated by the Sri Lankan Government have been conducted in the Project. In the survey, damage from landslide disasters for national road sections in high risk regions and their impact on key infrastructure and the lives of local people over the last 10 years have been investigated with the focus on the types of disasters and economic impact. A risk assessment and analysis are implemented based on the results of the survey.

In general, a road authority is required to manage the natural disasters on road effectively and efficiently under limited budget and human recourses as well as to discharge the accountability regarding landslide risk on road for road users and neighboring residents. The rationalized priority setting and the plan of countermeasures on the disaster is important for the effective landslide management on road. In order to discuss the rationalized priority for landslides, it is necessary to quantify, assess and predict the risk on road for the targeted districts. The risk analysis helps us to implement useful road management in the Sri Lanka.

Categorization for targeted roads/sections is useful for the risk assessment. The road sections for the Survey to be investigated are divided into the following three (3) ranks, Rank

A, B and C. Each rank is defined as follows;

Rank A: National road section in high risk region

Rank B: National road area of high priority for investigation

Rank C: Road disaster management model area where schematic plans of countermeasure are discussed

The screening of Rank A, Rank B and Rank C is conducted in the Survey, and a risk assessment is implemented in consideration of their hazards, traffic volume, local economic indices, etc in each stage of screening. Rank A and B are screened based on the existing data and knowledge owned by the RDA and NBRO. Rank C for which countermeasures are examined and their prioritization are determined by the discussion among RDA, NBRO and JET after conducting a field reconnaissance and a detail economic analysis. The flow of the screening is outlined as follows, and the flowchart and schematic image are shown in Figure 4-8 and Figure 4-9 respectively. The screening process for target areas is Table 4-1.

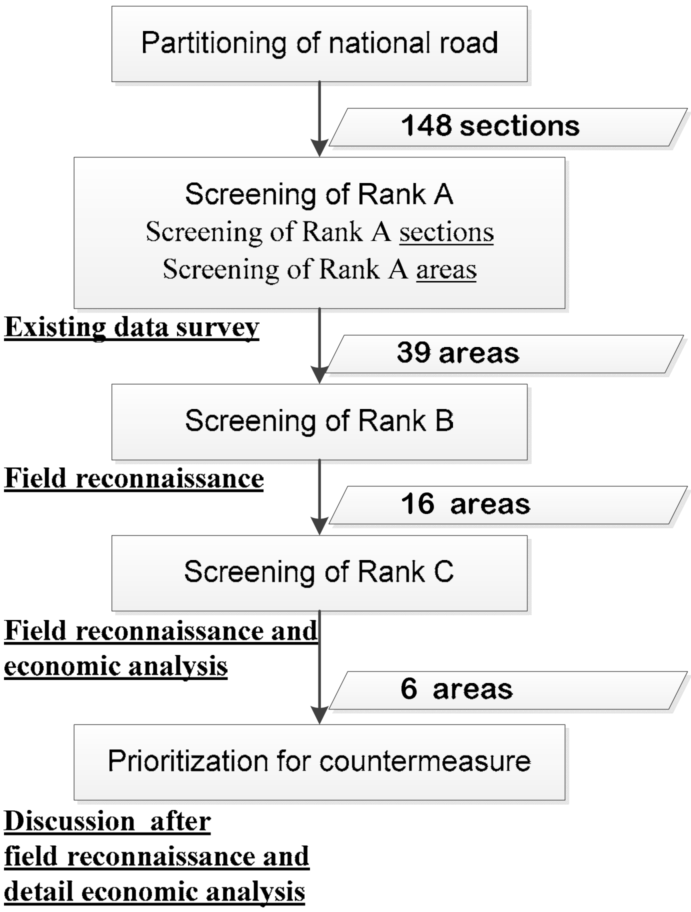


Figure 4-8: Flowchart of screening of Rank A, B and C

1. Partitioning of national road: All "A roads" in 7 districts are divided into short sections as a unit of intercity road around 3-10km length. It is 148 sections.

2. Screening of Rank A: Rank A areas are selected based on the existing data from the above 148 sections. It is 39 areas.

3. Screening of Rank B: Rank B areas are selected based on field reconnaissance from Rank A sections. It is 16 areas.

4. Screening of Rank C: Rank C areas are selected based on field reconnaissance and economic analysis from Rank B areas. It is 6 areas.

5. Prioritization: The prioritization on Rank C areas is determined by the discussion among RDA, NBRO and JET after a field reconnaissance and a detail economic analysis

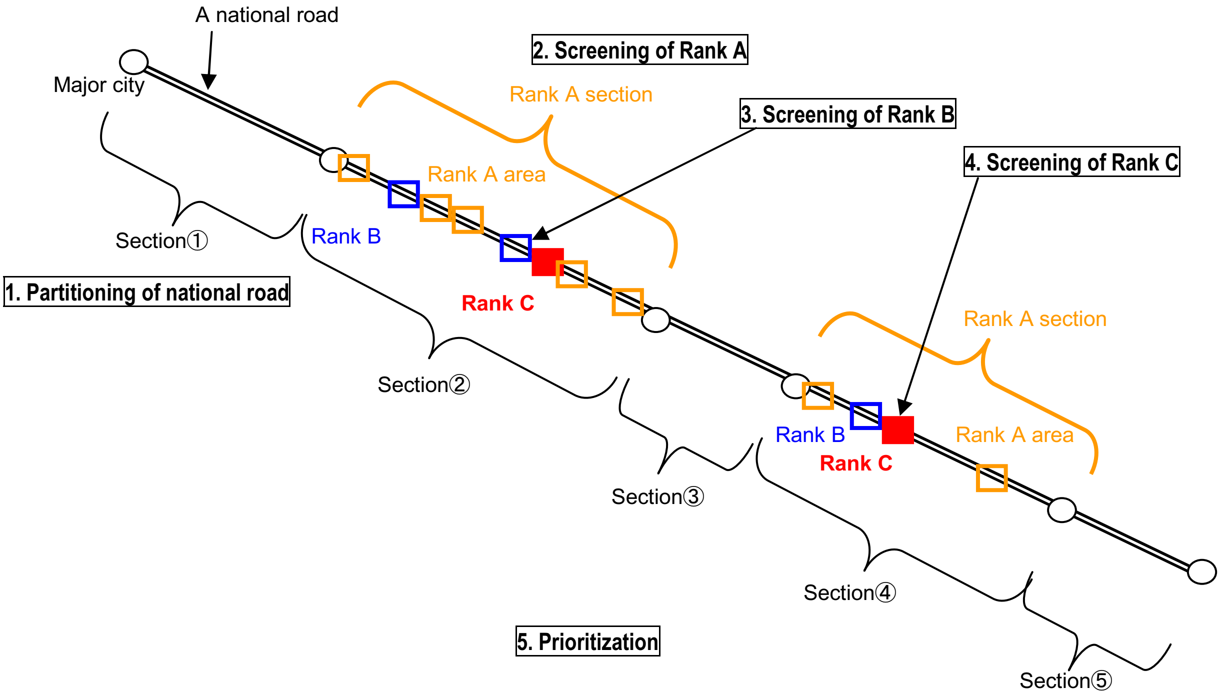


Figure 4-9: Schematic image of the screening

Table 4-1: Screening process for target areas

Stage	Target areas	Description	Quantity
stage.0	All "A roads" in 7 provinces	Partitioning of national road: "A roads" in 7 districts are divided into short sections as a unit of intercity road around 3-10km length among all roads (10,000km) around the country which have potential landslide disasters.	148 sections
stage.1			
stage.1-1	Rank A sections	A simple scoring method using several indicators is adopted (The indicators are composed of disaster records, a natural condition and social conditions). The full score by the indicators is 40, and a section where the sum is 22 points (55 %) or more by the method is a Rank A section.	
stage.1-2	Rank A areas	Rank A areas were selected based on the site checks by professional engineers who has affluent experience more than 20 years on landslide disaster. The check points are classified for each disaster type, slope failure/rockfall, landslide and debris flow.	39 areas
stage.2	Rank B areas	Site investigation by using site investigation sheet: slope type, slope height, main composition of slope, condition of slope, possible disaster, landslide surface anomalies, installed countermeasure , environmental issue (more than 50 scores on the sheet)	16 areas
stage.3	Rank C areas	Scoring by inspection sheet which calculates the danger of the slope itself and evaluates the hazard on slope in Rank B (16 areas). The areas which are more than 70 scores on the inspection sheet are Rank C.	6 areas

4.3 Screening of "Rank A" (National road sections in high risk regions)

4.3.1 Partitioning of national road

First, to implement the screening of Rank A, all "A national roads, A001, A002, A004, A005, A006, A007, A008, A009, A010, A016, A017, A018, A019, A021, A022, A023, A026, A113" in high risk 7 districts are divided into short sections by a road map and Kilometer Post documents from RDA. The partitioned short section is composed of intercity roads between major cities, which is around 3-10km length. The partitioned short sections are total 148 in the 7 districts and shown in Table 4-2.

Table 4-2: List of partitioned national roads

No	District	Name of road	City/Town		Kilometer Post		Distance
			St.	En.	St.	En.	
A001	Kegalle	Colombo - Kandy	Province boundary	Junction of B457	55.682	56.855	1.173
A001	Kegalle	Colombo - Kandy	Junction of B457	Ambepussa	56.855	59.175	2.320
A001	Kegalle	Colombo - Kandy	Ambepussa	Nelundeniya	59.175	66.401	7.226
A001	Kegalle	Colombo - Kandy	Nelundeniya	Galigomuwa	66.401	71.998	5.597
A001	Kegalle	Colombo - Kandy	Galigamuwa	Kegalla	71.998	77.634	5.636
A001	Kegalle	Colombo - Kandy	Kegalle	Junction of B199	77.634	81.612	3.978
A001	Kegalle	Colombo - Kandy	Junction of B199	Mawanella	81.612	90.489	8.877
A001	Kegalle	Colombo - Kandy	Mawanella	District boundary	90.489	98.812	8.323
A001	Kandy	Colombo - Kandy	District boundary	Kadugannawa	98.812	100.209	1.397
A001	Kandy	Colombo - Kandy	Kadugannawa	Junction of B6	100.209	104.270	4.061
A001	Kandy	Colombo - Kandy	Junction of B6	Peradeniya	104.270	109.434	5.164
A001	Kandy	Colombo - Kandy	Peradeniya	Kandy	109.434	115.880	6.446
A002	Kalutara	Colombo - Galle - Hambantota - Wellawaya	District boundary	Panadura	22.000	26.657	4.657
A002	Kalutara	Colombo - Galle - Hambantota - Wellawaya	Panadura	Wadduwa	26.657	32.663	6.006
A002	Kalutara	Colombo - Galle - Hambantota - Wellawaya	Wadduwa	Kalutara	32.663	42.134	9.471
A002	Kalutara	Colombo - Galle - Hambantota - Wellawaya	Kalutara	Paiyagala	42.134	50.000	7.866
A002	Kalutara	Colombo - Galle - Hambantota - Wellawaya	Paiyagala	Beruwara	50.000	55.000	5.000
A002	Kalutara	Colombo - Galle - Hambantota - Wellawaya	Beruwala	Province boundary	55.000	60.505	5.505
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Province boundary	Getahetta	63.680	65.500	1.820
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Getahetta	Eheliyagoda	65.500	70.949	5.449
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Eheliyagoda	Parakaduwa	70.949	78.000	7.051
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Parakaduwa	Pussella	78.000	81.200	3.200
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Pussella	Kuruwita	81.200	86.900	5.700
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Kuruwita	Ratnapura	86.900	95.115	8.215
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Ratnapura	Tiruwanaketiya	95.115	103.942	8.827
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Tiruwanaketiya	Pelmadulla	103.942	118.521	14.579
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Pelmadulla	Opanayaka	118.521	128.300	9.779
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Opanayaka	Balangoda	128.300	143.331	15.031
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Balangoda	Samanala wewa bridge	143.331	153.000	9.669
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Samanalawewa bridge	Belihul oya	153.000	158.200	5.200
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Belihul oya	Halpe	158.200	167.000	8.800
A004	Ratnapura	Colombo-Ratnapura-Wellawaya-Batticaloa	Halpe	Province boundary	167.000	168.363	1.363
A004	Badulla	Colombo-Ratnapura-Wellawaya-Batticaloa	Province boundary	Kalupahana	168.363	173.700	5.337
A004	Badulla	Colombo-Ratnapura-Wellawaya-Batticaloa	Kalupahana	Beragala	173.700	181.621	7.921
A004	Badulla	Colombo-Ratnapura-Wellawaya-Batticaloa	Beragala	Galkanda new	181.621	189.200	7.579
A004	Badulla	Colombo-Ratnapura-Wellawaya-Batticaloa	Galkanda new	Laymastotte	189.200	195.000	5.800
A004	Badulla	Colombo-Ratnapura-Wellawaya-Batticaloa	Laymastotte	Koslanda	195.000	199.373	4.373
A004	Badulla	Colombo-Ratnapura-Wellawaya-Batticaloa	Koslanda	District boundary	199.373	216.300	16.927
A005	Kandy	Peradeniya - Badulla - Chenkaladi	Peradeniya	Gelioya	0.000	6.092	6.092
A005	Kandy	Peradeniya - Badulla - Chenkaladi	Gelioya	Gampola	6.092	13.358	7.266
A005	Kandy	Peradeniya - Badulla - Chenkaladi	Gampola	Atabage oya bridge	13.358	20.188	6.830
A005	Kandy	Peradeniya - Badulla - Chenkaladi	Atabage oya bridge	Pussellawa	20.188	30.356	10.168
A005	Kandy	Peradeniya - Badulla - Chenkaladi	Pussellawa	District boundary	30.356	38.500	8.144
A005	Nuwaraeliya	Peradeniya - Badulla - Chenkaladi	District boundary	Nawakadadora	38.500	40.100	1.600
A005	Nuwaraeliya	Peradeniya - Badulla - Chenkaladi	Nawakadadora	Delunthalamada	40.100	45.100	5.000
A005	Nuwaraeliya	Peradeniya - Badulla - Chenkaladi	Delunthalamada	Ramboda	45.100	52.500	7.400
A005	Nuwaraeliya	Peradeniya - Badulla - Chenkaladi	Ramboda	Puha oya bridge	52.500	64.700	12.200
A005	Nuwaraeliya	Peradeniya - Badulla - Chenkaladi	Puha oya bridge	Nuwara eliya	64.700	68.894	4.194
A005	Nuwaraeliya	Peradeniya - Badulla - Chenkaladi	Nuwara eliya	Province boundary	68.894	78.477	9.583
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Province boundary	Keppetipola	78.477	87.067	8.590
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Keppetipola	Wellimada	87.067	93.923	6.856
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Wellimada	Etampitiya	93.923	107.762	13.839

No	District	Name of road	City/Town		Kilometer Post		Distance
			St.	En.	St.	En.	
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Etampitiya	Hali ela	107.762	117.511	9.749
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Hali ela	Badulla	117.511	125.518	8.007
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Badulla	Passara	125.518	140.184	14.666
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Passara	Tennugewatta	140.184	153.100	12.916
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Tennugewatta	Lunugala	153.100	172.100	19.000
A005	Badulla	Peradeniya - Badulla - Chenkaladi	Lunugala	District boundary	172.100	178.700	6.600
A006	Kegalle	Ambepussa - Kurunegala - Trincomalee	Ambepussa	Province boundary	0.000	7.250	7.250
A006	Matale	Ambepussa - Kurunegala - Trincomalee	Province boundary	Polgahawela	7.250	15.550	8.300
A006	Matale	Ambepussa - Kurunegala - Trincomalee	Polgahawela	Bulugolla	15.550	21.560	6.010
A006	Matale	Ambepussa - Kurunegala - Trincomalee	Bulugolla	Dambokka	21.560	27.930	6.370
A006	Matale	Ambepussa - Kurunegala - Trincomalee	Dambokka	Kurunegala	27.930	36.176	8.246
A006	Matale	Ambepussa - Kurunegala - Trincomalee	Kurunegala	Ibbagamuwa	36.176	46.980	10.804
A006	Matale	Ambepussa - Kurunegala - Trincomalee	Ibbagamuwa	Province boundary	46.980	69.260	22.280
A007	Kegalle	Avissawella - Hatton - Nuwara Eliya	Avissawella	Dehiowita	0.000	7.870	7.870
A007	Kegalle	Avissawella - Hatton - Nuwara Eliya	Dehiowita	Karawanella	7.870	13.910	6.040
A007	Kegalle	Avissawella - Hatton - Nuwara Eliya	Karawanella	Yatiyantota	13.910	19.270	5.360
A007	Kegalle	Avissawella - Hatton - Nuwara Eliya	Yatiyantota	Kitulgala	19.270	37.200	17.930
A007	Kegalle	Avissawella - Hatton - Nuwara Eliya	Kitulgala	Province boundary	37.200	41.300	4.100
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Province boundary	Junction of B189	41.300	43.150	1.850
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Junction of B189	Ginigathena	43.150	53.000	9.850
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Ginigathena	Junction of B71	53.000	58.040	5.040
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Junction of B71	Rozella	58.040	63.960	5.920
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Rozella	Hatton	63.960	72.000	8.040
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Hatton	Kotagala	72.000	74.670	2.670
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Kotagala	Dimbulla	74.670	82.120	7.450
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Dimbulla	Talawakele	82.120	88.410	6.290
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Talawakele	Lindula	88.410	92.370	3.960
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Lindula	Nanu oya	92.370	108.700	16.330
A007	Nuwaraeliya	Avissawella - Hatton - Nuwara Eliya	Nanu oya	Junction of A5	108.700	116.920	8.220
A008	Kalutara	Panadura - Nambapana - Ratnapura	Panadura	Alubomulla	0.000	4.930	4.930
A008	Kalutara	Panadura - Nambapana - Ratnapura	Alubomulla	Bandaragama	4.930	9.870	4.940
A008	Kalutara	Panadura - Nambapana - Ratnapura	Bandaragama	Horana	9.870	18.270	8.400
A008	Kalutara	Panadura - Nambapana - Ratnapura	Horana	Kalupahana	18.270	24.900	6.630
A008	Kalutara	Panadura - Nambapana - Ratnapura	Kalupahana	Ingiriya	24.900	32.160	7.260
A008	Kalutara	Panadura - Nambapana - Ratnapura	Ingiriya	Province boundary	32.160	36.490	4.330
A008	Ratnapura	Panadura - Nambapana - Ratnapura	Province boundary	Nambapana	36.490	43.400	6.910
A008	Ratnapura	Panadura - Nambapana - Ratnapura	Nambapana	Idangoda	43.400	51.000	7.600
A008	Ratnapura	Panadura - Nambapana - Ratnapura	Idangoda	Gorakaela	51.000	57.200	6.200
A008	Ratnapura	Panadura - Nambapana - Ratnapura	Gorakaela	Kahangama	57.200	63.300	6.100
A008	Ratnapura	Panadura - Nambapana - Ratnapura	Kahangama	Ratnapura	63.300	68.900	5.600
A009	Kandy	Kandy - Jaffna	Kandy	Katugastota	0.000	4.260	4.260
A009	Kandy	Kandy - Jaffna	Katugastota	Akurana	4.260	10.600	6.340
A009	Kandy	Kandy - Jaffna	Akurana	District boundary	10.600	17.100	6.500
A009	Matale	Kandy - Jaffna	District boundary	Matale	17.100	25.300	8.200
A009	Matale	Kandy - Jaffna	Matale	Palapatwela	25.300	32.540	7.240
A009	Matale	Kandy - Jaffna	Palapatwela	Kavudupelella	32.540	38.800	6.260
A009	Matale	Kandy - Jaffna	Kavudupelella	Madawala	38.800	42.700	3.900
A009	Matale	Kandy - Jaffna	Madawala	Nalanda	42.700	49.200	6.500
A009	Matale	Kandy - Jaffna	Nalanda	Naula	49.200	54.180	4.980
A009	Matale	Kandy - Jaffna	Naula	Pannampitiya	54.180	64.000	9.820
A009	Matale	Kandy - Jaffna	Pannampitiya	Dambulla	64.000	73.080	9.080
A009	Matale	Kandy - Jaffna	Dambulla	Province boundary	73.080	75.000	1.920
A010	Kandy	Katugastota - Kurunegala - Puttlam	Katugastota	Hedeniya	0.106	8.647	8.541
A010	Kandy	Katugastota - Kurunegala - Puttlam	Hedeniya	Galagedara	8.647	13.697	5.050
A010	Kandy	Katugastota - Kurunegala - Puttlam	Galagedara	Province boundary	13.697	16.368	2.671
A016	Badulla	Beragala - Hali-Ela	Beragala	Haputale	0.000	6.570	6.570
A016	Badulla	Beragala - Hali-Ela	Haputale	Bandarawela	6.570	16.630	10.060
A016	Badulla	Beragala - Hali-Ela	Bandarawela	Junction of A23	16.630	25.130	8.500
A016	Badulla	Beragala - Hali-Ela	Junction of A23	Demodara	25.130	30.080	4.950
A016	Badulla	Beragala - Hali-Ela	Demodara	Hali ela	30.080	38.640	8.560
A017	Ratnapura	Galle - Deniyaya - Madampe	Province boundary	Hayes	86.700	96.500	9.800
A017	Ratnapura	Galle - Deniyaya - Madampe	Hayes	Suriyakanda	96.500	112.940	16.440
A017	Ratnapura	Galle - Deniyaya - Madampe	Suriyakanda	Rakwana	112.940	130.580	17.640
A017	Ratnapura	Galle - Deniyaya - Madampe	Rakwana	Madampe	130.580	143.270	12.690
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Pelmadulla	Kahawatta	0.000	7.000	7.000
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Kahawatta	Madampe	7.000	13.020	6.020
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Madampe	Godakawela	13.020	20.900	7.880
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Godakawela	Pallebedda	20.900	26.730	5.830
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Pallebedda	Udawalawe	26.730	43.150	16.420

No	District	Name of road	City/Town		Kilometer Post		Distance
			St.	En.	St.	En.	
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Udawalawe	Udagama	43.150	53.480	10.330
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Udagama	Suriyawewa	53.480	66.260	12.780
A018	Ratnapura	Pelmadulla - Embilipitiya - Nonagama	Suriyawewa	Province boundary	66.260	68.750	2.490
A019	Kegalle	Polgahawela -Kegalle	Province boundary	Kegalle	2.718	11.820	9.102
A021	Kegalle	Kegalle - Bulathkohupitiya - Karawanella	Kegalle	Hettimulla	0.000	6.260	6.260
A021	Kegalle	Kegalle - Bulathkohupitiya - Karawanella	Hettimulla	Undugoda	6.260	14.500	8.240
A021	Kegalle	Kegalle - Bulathkohupitiya - Karawanella	Undugoda	Bulathkohupitiya	14.500	25.220	10.720
A021	Kegalle	Kegalle - Bulathkohupitiya - Karawanella	Bulathkohupitiya	Ranawitiya	25.220	30.500	5.280
A021	Kegalle	Kegalle - Bulathkohupitiya - Karawanella	Ranawitiya	Anguruwella	30.500	37.090	6.590
A021	Kegalle	Kegalle - Bulathkohupitiya - Karawanella	Anguruwella	Karawanella	37.090	41.850	4.760
A022	Badulla	Tennugewatta - Hulandawa	Tennugewatta	District boundary	0.000	6.000	6.000
A023	Badulla	Wellawaya - Ella - Kumbalwela	District boundary	Ella	14.100	27.310	13.210
A023	Badulla	Wellawaya - Ella - Kumbalwela	Ella	Junction of A16	27.310	30.390	3.080
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Kandy	Junction of B311	0.000	4.550	4.550
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Junction of B311	Junction of B256	4.550	14.260	9.710
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Junction of B256	Hulu ganga bridge	14.260	17.800	3.540
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Hulu ganga bridge	Meegahamaditta	17.800	25.300	7.500
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Meegahamaditta	Medamahanuwara	25.300	32.800	7.500
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Medamahanuwara	Hunnasgiriya	32.800	38.700	5.900
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Hunnasgiriya	Madugoda	38.700	45.900	7.200
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Madugoda	Umbugala	45.900	54.200	8.300
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Umbugala	Hasalaka	54.200	64.800	10.600
A026	Kandy	Kandy - Mahiyangana - Padiyatalawa	Hasalaka	Province boundary	64.800	72.230	7.430
A026	Badulla	Kandy - Mahiyangana - Padiyatalawa	Province boundary	Belilgalla	72.230	84.742	12.512
A026	Badulla	Kandy - Mahiyangana - Padiyatalawa	Belilgalla	Province boundary	84.742	98.862	14.120
A113	Kandy	Gampola - Nawalapitiya	Gampola	Junction of B431	0.000	8.597	8.597
A113	Kandy	Gampola - Nawalapitiya	Junction of B431	Nawalapitiya	8.597	17.190	8.593

4.3.2 Screening of Rank A section

Rank A or "national road sections in high risk regions" are selected A as following a step-by-step method.

1. Screening of Rank A sections from the partitioned short section
2. Screening of Rank A areas form Rank A sections

Here, a section is a road zone which has around 3-10 km length, while an area is a slope point on road which is less than 1 km length.

Rank A sections are selected from the above partitioned 148 sections in the 7 districts based on the existing data. A simple scoring method using several indicators is adopted for the screening in this stage.

The indicators are composed of disaster records, a natural condition and social conditions. Each indicator and its scoring method are shown in Table 4-3.

Table 4-3: Scoring methods for the selected indicators in screening Rank A sections

Indicator		Method		Data source
		Referential data	Scoring	
Disaster record	Disaster record	Records of landslide/rock fall/ slope failure disasters on road at target section in 1960s – 2012 [number]	• 1 or more disaster: 10 points • No disaster: 0 point	Internal data form RDA/NBRO

Natural condition	Rainfall condition	Annual average rainfall [mm/year]	• 4,000-5,000 mm/year: 10 points • 3,000-4,000 mm/year: 8 points • 2,000-3,000 mm/year: 6 points • 1,500-2,000 mm/year: 4 points • 1,000-1,500 mm/year: 3 points • -1,000 mm/year: 2 points	National Atlas of Sri Lanka 1)
Social condition	Traffic amount	Forecasted ADT: Average Daily Traffic (2012) [vehicle number]	• 40,000-50,000: 10 points • 30,000-40,000: 8 points • 20,000-30,000: 6 points • 10,000-20,000: 4 points • -10,000: 2 points	Internal data form RDA
	Detour	Distance loss by using the detours between intercity [km]	• 50km - : 10 points • 20 - 50km: 7 points • - 20km: 4 points	Road & Tourist map of Sri Lanka 2)

(Source: National Atlas of Sri Lanka 2nd edition P.61, Department of Survey in Sri Lanka; Road & Tourist map Sri Lanka, Department of Survey in Sri Lanka)

The full score of the method is 40, and a section where the sum is 22 points (55 %) or more by the method is a Rank A section. The selected Rank A sections are total 33 sections and shown in the following table. The detail of the results of the scoring method is shown in Appendix VIII..

Table 4-4: Selected Rank A sections by scoring method

No	District	City/Town		Kilometer Post		Score
		St.	En.	St.	En.	
A004	Ratnapura	Opanayaka	Balangoda	128.300	143.331	28
A004	Ratnapura	Samanalawewa bridge	Belihul oya	153.000	158.200	26
A004	Ratnapura	Belihul oya	Halpe	158.200	167.000	26
A004	Badulla	Province boundary	Kalupahana	168.363	173.700	26
A004	Badulla	Kalupahana	Beragala	173.700	181.621	26
A004	Badulla	Beragala	Galkanda new	181.621	189.200	23
A004	Badulla	Galkanda new	Laymastotte	189.200	195.000	23
A004	Badulla	Laymastotte	Koslanda	195.000	199.373	23
A005	Nuwaraeliya	Nawakadadora	Delunthalamada	40.100	45.100	23
A005	Nuwaraeliya	Delunthalamada	Ramboda	45.100	52.500	23
A005	Nuwaraeliya	Ramboda	Puha oya bridge	52.500	64.700	25
A005	Nuwaraeliya	Nuwara eliya	Province boundary	68.894	78.477	23
A005	Badulla	Province boundary	Keppetipola	78.477	87.067	22
A005	Badulla	Keppetipola	Wellimada	87.067	93.923	22
A005	Badulla	Badulla	Passara	125.518	140.184	23
A005	Badulla	Tennugewatta	Lunugala	153.100	172.100	25
A007	Kegalle	Avissawella	Dehiowita	0.000	7.870	24
A007	Kegalle	Yatiyantota	Kitulgala	19.270	37.200	30
A007	Kegalle	Kitulgala	Province boundary	37.200	41.300	22
A007	Nuwaraeliya	Province boundary	Junction of B189	41.300	43.150	32
A007	Nuwaraeliya	Junction of B189	Ginigathena	43.150	53.000	32
A007	Nuwaraeliya	Ginigathena	Junction of B71	53.000	58.040	32
A007	Nuwaraeliya	Rozella	Hatton	63.960	72.000	27
A016	Badulla	Beragala	Haputale	0.000	6.570	26
A016	Badulla	Haputale	Bandarawela	6.570	16.630	23
A017	Ratnapura	Province boundary	Hayes	86.700	96.500	26
A021	Kegalle	Undugoda	Bulathkohupitiya	14.500	25.220	23
A026	Kandy	Meegahamaditta	Medamahanuwara	25.300	32.800	23
A026	Kandy	Medamahanuwara	Hunnasgiriya	32.800	38.700	26
A026	Kandy	Hunnasgiriya	Madugoda	38.700	45.900	22
A026	Kandy	Madugoda	Umbugala	45.900	54.200	28
A026	Kandy	Umbugala	Hasalaka	54.200	64.800	28
A113	Kandy	Junction of B431	Nawalapitiya	8.597	17.190	29

4.3.3 Screening of Rank A area

An "area" is a slope unit, which is divided by geological unit and/or topographical unit, corresponding to a realistic construction zone for countermeasures as well as which is extracted the area more than 5m height and more than 30 degree at slope gradient in a section. Therefore, a section has several "area".

JET conducted site check/confirmation on the road for the Rank A sections to screen Rank A areas. Rank A areas were selected based on the site checks with visual check by professional engineers who has affluent experience more than 20 years on landslide disaster. The check points are classified for each disaster type, slope failure/rockfall, landslide and debris flow as following table.

Table 4-5: Check points for each disaster type

Slope Failure/ Rock Fall	Landslide	Debris Flow
① Talus slope/ bare land ② Clear convex break of slope ③ Eroded toe of slope ④ Overhang ⑤ Susceptible soil/rock to erosion ⑥ High density of cracks and a weak layers ⑦ Dip slope of bedding plane ⑧ Detached rock and unstable rock, unstable soil ⑨ Spring water ⑩ Other anomaly (gully, piping hole, subsidence, heaving, open crack, anomaly of countermeasure)	① Landslide topography (cliff, hill, gentle slope, anomaly of contour, heaving of bottom) ② Crack, uplift, subsidence of slope ③ Crack, uplift, subsidence of slope ④ Spring water ⑤ No effect of countermeasure	① Abundant unstable debris in stream ② New crack and/or cliff in stream ③ New slope failure in stream ④ No effect of countermeasure ⑤ Deficient beam height/width

Based on the site check by JET, the Rank A areas were extracted from each section. Some sections do not have any Rank A area where the JET identified as a high risk site. As the result, the screened Rank A is 39 areas. The number of Rank A area from each section in shown in Table 4-6, and Rank A is shown in. Table 4-7,.

Table 4-6: The number of Rank A

No	District	City/Town		Kilometer Post		The number of Rank A
		St.	En.	St.	En.	
A004	Ratnapura	Opanayaka	Balangoda	128.300	143.331	1
A004	Ratnapura	Samanalawewa bridge	Belihul oya	153.000	158.200	1
A004	Ratnapura	Belihul oya	Halpe	158.200	167.000	1
A004	Badulla	Province boundary	Kalupahana	168.363	173.700	1
A004	Badulla	Kalupahana	Beragala	173.700	181.621	1
A004	Badulla	Beragala	Galkanda new	181.621	189.200	1
A004	Badulla	Galkanda new	Laymastotte	189.200	195.000	1
A004	Badulla	Laymastotte	Koslanda	195.000	199.373	1
A005	Nuwaraeliya	Nawakadadora	Delunthalamada	40.100	45.100	3
A005	Nuwaraeliya	Delunthalamada	Ramboda	45.100	52.500	1
A005	Nuwaraeliya	Ramboda	Puha oya bridge	52.500	64.700	1
A005	Nuwaraeliya	Nuwara eliya	Province boundary	68.894	78.477	0
A005	Badulla	Province boundary	Keppetipola	78.477	87.067	1
A005	Badulla	Keppetipola	Wellimada	87.067	93.923	1
A005	Badulla	Badulla	Passara	125.518	140.184	1
A005	Badulla	Tennugewatta	Lunugala	153.100	172.100	1
A007	Kegalle	Avissawella	Dehiowita	0.000	7.870	0
A007	Kegalle	Yatiyantota	Kitulgala	19.270	37.200	1

No	District	City/Town		Kilometer Post		The number of Rank A
		St.	En.	St.	En.	
A007	Kegalle	Kitulgala	Province boundary	37.200	41.300	0
A007	Nuwaraeliya	Province boundary	Junction of B189	41.300	43.150	1
A007	Nuwaraeliya	Junction of B189	Ginigathena	43.150	53.000	2
A007	Nuwaraeliya	Ginigathena	Junction of B71	53.000	58.040	2
A007	Nuwaraeliya	Rozella	Hatton	63.960	72.000	1
A016	Badulla	Beragala	Haputale	0.000	6.570	0
A016	Badulla	Haputale	Bandarawela	6.570	16.630	1
A017	Ratnapura	Province boundary	Hayes	86.700	96.500	0
A021	Kegalle	Undugoda	Bulathkohupitiya	14.500	25.220	1
A026	Kandy	Meegahamaditta	Medamahanuwara	25.300	32.800	2
A026	Kandy	Medamahanuwara	Hunnasgiriya	32.800	38.700	1
A026	Kandy	Hunnasgiriya	Madugoda	38.700	45.900	1
A026	Kandy	Madugoda	Umbugala	45.900	54.200	3
A026	Kandy	Umbugala	Hasalaka	54.200	64.800	4
A113	Kandy	Junction of B431	Nawalapitiya	8.597	17.190	2

Table 4-7: List of Rank A

No.	Route No	Name	Kilometer Post		Disaster Type
			St.	En.	
1	A004	A004-134	134/15	134	Rock Fall
2	A004	A004-154	154/7		Landslide?
3	A004	A004-162	162/8		Debris Flow
4	A004	A004-173	173/11		Slope Failure
5	A004	A004-174	175/1	175/3	Slope Failure
6	A004	A004-185	185/6		Landslide
7	A004	A004-193	194/11		Landslide
8	A004	A004-196	196+300	196+800	Landslide
9	A005	A005-042	43/1	43/6	Landslide
10	A005	A005-043	43/8	43/9	Rock Fall/Rock Slide
11	A005	A005-044	44/2	44/3	Rock Fall/Rock Slide
12	A005	A005-046	46/5	46/6	Rock Fall/Rock Slide
13	A005	A005-063	63/3		Slope Failure
14	A005	A005-082	82+100	82+700	Slope Failure
15	A005	A005-091	91+019		Slope Failure
16	A005	A005-135	135+200	135+700	Landslide
17	A005	A005-167	168/8	168/9	Landslide
18	A007	A007-031	31/1	31/2	Slope Failure
19	A007	A007-042	42/14		Landslide?
20	A007	A007-045	45		Rock Fall/Rock Slide
21	A007	A007-047	47	48/1	Landslide
22	A007	A007-054	54/1		Slope Failure
23	A007	A007-057	57/9		Slope Failure
24	A007	A007-069	68	69/1	Landslide
25	A016	A016-010	10/12	11/1	Landslide
26	A021	A021-020	19+800	20+000	Landslide
27	A026	A026-027	27	28/1	Rock Fall/Rock Slide
28	A026	A026-029	29	30/1	Rock Fall/Rock Slide
29	A026	A026-036	36	37/1	Slope Failure
30	A026	A026-045	46/2	46/3	Slope Failure
31	A026	A026-048	48/9	48/10	Slope Failure
32	A026	A026-049	50/4	50/5	Slope Failure
33	A026	A026-051	51/1	51/2	Slope Failure
34	A026	A026-055	55/4	55/6	Rock Fall/Rock Slide
35	A026	A026-056	56		Slope Failure
36	A026	A026-058	58/2	58/4	Slope Failure
37	A026	A026-060	60/3	60	Rock Fall/Rock Slide
38	A113	A113-010	11/2	11/3	Landslide
39	A113	A113-015	16/5	16/6	Landslide

4.4 Screening of “Rank B” (National road areas of high priority for investigation)

Rank B is selected from Rank A sections. JET conducts site investigation in the candidates of Rank B by using the following sheet (Figure 4-9: Schematic image of the screening) to identify the potential triggers of landslide disaster.

Survey of road slope face

		Date of investigation:	dd-mm-yyyy	Score
Investigator name:		Research company name:		
Route No:		Location(latitude,longitude):	,	
Name of Road:		Location(start, end)(km):	(km)– (km)	
type:	☐cut slope ☐collapse ☐quarry ☐other( )			
Slope width(m):		Slope height or length(m):		
Main composition of slope	☐soil and residual Soil ☐weathered rock ☐rock ☐composite ☐colluvium			
Condition of slope	☐remarkable erosion ☐traces of collapse ☐ cracks ☐No damage ☐other( )			
Possible disaster	☐rock fall ☐collapse ☐rock mass failure ☐slide ☐nothing ☐other( )			
Landslide surface anomalies	☐large and new cracks ☐small and old cracks ☐slight deformation ☐no anomalies			
Environmental issue	☐exist ☐no exist			
Installed countermeasure	☐No countermeasure/ no effect ☐Some effect ☐High effect ☐Completely effect			
maintenance entity in the vicinity				sum Total (A) 0
Slope situation (photograph)	Situation photograph			sum Total (B) 0
Location map	Reduced scale(1:)			Environmental issue 0
Comment concerning slope situation				

Figure 4-10: Schematic image of the screening

The slope condition is quantified based on the items of the site investigation sheets. The items and the scoring method are shown in Table 4-8.

Table 4-8: Scoring methods used for the selected indicators in screening Rank B

Item	Max score	Scoring
Slope type	15	• Cut slop: 5points • Collapse: 10points • Quarry: 0points • Other: 0points
Slope height	18	• >50m: 18 points • 30 - 50m: 12 points • 15 - 30m: 8 points • <15m: 5 points
length(for Landslide)	20	• <200m: 20 points • 200-500m: 15 points • 500-800m: 5 points • ＞800m: －30 points
Main composition of slope	50	• Soil and residual Soil: 20 points • Colluvium: 15 points

Item	Max score	Scoring
		• Composite: 10 points • Weathered rock: 5points • Rock: 0 points
Condition of slope	60	• Remarkable erosion: 30 points • Traces of collapse: 20 point • Cracks: 10 points
Possible disaster	50	• Collapse: 15 points • rock mass failure: 15 points • slide: 10 points • rock fall: 5 points • other: 5 points
Landslide surface anomalies(In case of the landslide)	30	• large and new cracks: 30 points • small and old cracks: 20 points • slight deformation: －10 points • no anomalies: －20 points
Installed countermeasure	－30	• No countermeasure/ no effect: 0 points • Some effect: －10 points • High effect: －30points • Completely effect : ×0
Environmental issue	0	• exist: ×0 • no exist: 0 points

With regards to slopes in Rank A, the results of the risk assessments which were carried out are shown in Table 4-9. An evaluation of the existing countermeasures are added to score (A), which is produced by a risk assessment of slopes, and the score of (B) is calculated. An evaluation of environmental issues is then added, and the final score(C) is calculated.

Table 4-9: Summary of results of Rank A risk assessment

No.	Route No.	Km	score (A)	Evaluation of existing countermeasure (B)	Evaluation of environmental issue (C)	Final evaluation
1	A004	134	40	40	40	Rank A
2	A004	154	50	50	50	Rank B
3	A004	162	25	25	25	Rank A
4	A004	173	110	110	110	Rank B
5	A004	174	123	123	123	Rank B
6	A004	185	10	0	0	Rank A
7	A004	194	10	10	10	Rank A
8	A004	196	30	30	30	Rank A
9	A005	42	25	25	25	Rank A
10	A005	43	82	82	82	Rank B
11	A005	44	82	82	82	Rank B
12	A005	46	88	88	88	Rank B
13	A005	63	55	55	55	Rank B
14	A005	82+700	110	110	0	Rank A
15	A005	91	113	113	113	Rank B
16	A005	135	70	70	70	Rank B
17	A005	167	80	80	80	Rank B
18	A007	31	105	105	105	Rank B

No.	Route No.	Km	score (A)	Evaluation of existing countermeasure (B)	Evaluation of environmental issue (C)	Final evaluation
19	A007	42	33	33	33	Rank A
20	A007	45	100	100	100	Rank B
21	A007	47	13	3	3	Rank A
22	A007	54	73	73	73	Rank B
23	A007	57	105	105	105	Rank B
24	A007	69	23	23	23	Rank A
25	A016	10	70	70	70	Rank B
26	A021	20	30	30	30	Rank A
27	A026	27	105	105	0	Rank A
28	A026	29	78	78	0	Rank A
29	A026	36	78	68	0	Rank A
30	A026	45	113	113	0	Rank A
31	A026	48	80	80	0	Rank A
32	A026	49	80	80	0	Rank A
33	A026	51	105	105	0	Rank A
34	A026	55	88	88	0	Rank A
35	A026	56	90	90	0	Rank A
36	A026	58	105	105	0	Rank A
37	A026	60	85	85	0	Rank A
38	A113	10	20	10	10	Rank A
39	A113	15	65	65	65	Rank B

From Table 4-9, the points where the final score(C)'s values were higher than 50 were selected as Rank B areas. The screened Rank B is 16 areas and shown in Table 4-10.

Table 4-10: List of candidates of Rank B areas

Route No	No.	Name of road	Landslide record	Kilometer Post		Disaster Type
				St.	En.	
A004	A004-154	Colombo-Ratnapura-Wellawaya-Batticaloa Road	2009	154/7		Slope Failure
A004	A004-173	Colombo-Ratnapura-Wellawaya-Batticaloa Road	2000	173/11		Slope Failure
A004	A004-174	Colombo-Ratnapura-Wellawaya-Batticaloa Road	2000	175/1	175/3	Slope Failure
A005	A005-043	Peradeniya-Badulla-Chenkaladi	2011	43/9		Slope Failure (Rock Slide)
A005	A005-044	Peradeniya-Badulla-Chenkaladi	2011	44/3		Slope Failure (Rock Slide)
A005	A005-046	Peradeniya-Badulla-Chenkaladi	2011	46+600		Slope Failure (Rock Slide)
A005	A005-063	Peradeniya-Badulla-Chenkaladi	2011	63/3		Slope Failure
A005	A005-091	Peradeniya-Badulla-Chenkaladi	2007	91+019		Slope Failure
A005	A005-135	Peradeniya-Badulla-Chenkaladi	2011	135+200	135+700	Landslide
A005	A005-167	Peradeniya-Badulla-Chenkaladi Road	2012	167+497	167+541	Landslide
A007	A007-031	Avissawella-Hatton-Nuwara Eliya	2007	31/1	31/2	Slope Failure
A007	A007-045	Avissawella-Hatton-Nuwara Eliya	2011	45		Rock Fall, Rock Slide
A007	A007-054	Avissawella-Hatton-Nuwara Eliya	2011	54/1		Slope Failure
A007	A007-057	Avissawella-Hatton-Nuwara Eliya	2011	57/9		Slope Failure
A016	A016-010	Beragala-HaliEla Road	1996	10		Landslide
A113	A113-015	Gampola - Nawalapitiya	2010	16/5	16/6	Landslide

4.5 Screening of "Rank C" sections ("Road disaster management model areas") and their prioritization

4.5.1 Screening of Rank C areas

A detailed slope chart to evaluate the selected candidate area of rank C should be created, and the potential risk is evaluated as numbers or points. An example of filling in the detailed slope chart is shown below. This sheet has divided into a general information sheet and a detailed sheet of each disaster type.

General Information Sheet

Management office									
Management number		Route No		Location(m)		to		Distance	m
Disaster		Name of Road		Landmark		latitude		longitude	

Schematic sketch	Reporter's name :	
	Date of report :	
	Description	
	Hisrtory	New failure Movement/extension
Location map (Scale: 1:15,000)	Estimated disaster volume	
	Proposed countermeasures — Type:	
	Specifi -cation:	
	Quantity	
	Cost (million Birr):	

Figure 4-11: Example of filling in inspection sheet (General Information Sheet)

Mangement number	

Evaluation sheet (landslide)

Evaluator	
Organization	

[Causes]（A）

Category			Check	score
Topographical factor	Result of photo interpretation	exist clearly		Max=30
		exist but partial and not clear		
		exist but not clear		
	Surface anomalies	large and new cracks, steps and subsidence		Max=30
		small and old cracks, steps and subsidence		
		slight deformation		
		no anomalies		
Geological conditions	Geological structure	fault, fracture zone		Max=18
		dip slope		
		undip slope/ no characteristic feature		
	Main rock formation of landslide body	colluvium		Max=18
		Gneiss		
		Charnokite		
		Quartzite		
		Marble		
		Schist		
		Serpentite		
		Granite		
	Hydrological feature	much springs / much seepage		Max=10
		little springs /little seepage		
		trace of water		
		no water observed		
		sum total	0	(A)

[History]（B）

Category			Check	score
Records of Landslide	Existing record (documents or patrimony)	obvious		
		slight		
		none		
	Damage on road facilities and houses	obvious		
		slight		
		none		

[Countermeasure]（c）

Category		Check	score
There is no countermeasure			±0
Effectiveness of countermeasure	No effect		±0
	Some effect		−20
	High effect		×0
	Score in evaluation from cause	0	(B)

Monitoring		Check	score
There is monitoring for landslide			
Monitoring devices			
Organization			

[Description]

Figure 4-12: Inspection sheet (for Landslide)

Management Number	

Evaluation sheet (rockfall･slope failure)

Evaluator	
Organization	

[Causes]（A）

Item		factor	category of score	point	score
topography	collapsed factor	talus slope clear convex break of slope eroded toe of slope overhang、water catchment slope	3 or more correspondences		Max=3
			2 correspondences		
			1 correspondences		
			no correspondence		
geological conditions	soil	susceptible to erosion less strength with water	marked		Max=8
			a little marked		
			None		
	rock	high density of cracks and a weak layer susceptible to erosion fast weathering	marked		Max=12
			a little marked		
			None		
	structure	dip slope of bedding plane	It corresponds.		Max=8
			None		
		debris on impermeability bedrock The upper part is a hard /the toe of slope is weak.	marked		Max=6
			a little marked		
			None		
surface codition		Topsoil, detached rock and unsteady rock	instability		Max=12
			a little unstable		
			stability		
		spring water	notable spring waster		Max=8
			seepage		
			None		
		surface condition	bare land with minor vagetation		Max=5
			intermediate（bare･grass･tree）		
			mainly structure, mainly tree		
figure		dip（i）、height	height: H≧50m		Max=18
			height: 30≦H＜50m		
			height: 15≦H＜30m		
			height: H＜15m		
			dip: i≧70°		Max=10
			dip: 45°≦i＜70°		
			dip: i＜45°		
anomaly		targeted slope（surface collapse･small fallen rock･gully･erosion･piping hole･subsidence･heaving･bending of tree root･fallen tree･crack･open crack･anomaly of countermeasure)	2 or more correspondences･clarity		Max=5
			certain･unclarity		
			None		
		sum total	0		（A）

[Main check object]

cut slope	
natural slope	

[Main slope disasters]

rockfall	
slope failure	

[Countermeasure]（B）=（A）+α or（A）×0

effectiveness of existing countermeasures	point（α）	check
Potential rockfall and slope failure are prevented enough, or, it is defended enough when it is generated.	×0	
Potential rockfall and slope failure are considerably prevented, or it is considerably defended when it is generated.	−20	
Potential rockfall and slope failure are partly prevented, or it is partly defended when it is generated. However, it is not enough for the remaining factors.	−10	
There is no countermeasure, or there is not effective even if countermeasures are not performed.	±0	
sum total	（B） 0	

[History]（C）

Level of disaster history	point	check
There is a history about large fallen rocks and slope failures that were obstacles to the road traffic after construction of recent measures.		
There is a history about large fallen rocks and slope failures that gets to the road though there is no obstacle to traffic.		
There is a history about small fallen rocks and slope failures that did not get to the road.		
No disaster records		
	（C） 点	

（D）=MAX（B,C）

Score in evaluation from cause	（B） 0
Score in evaluation from history	（C） 0
Among (B)&(C), large one.	（D）=MAX（B,C） 0

[Overall judgement]

response	judgment
The countermeasure work is necessary.	
Though the urgent countermeasure is not necessary, regular inspections are needed.	
The countermeasure work is not necessary.	

[Description]

Figure 4-13: Inspection sheet (for rock fall-slop failure)

A table of points for cases in which the hypothesised disaster is a landslide is shown in Table 4-11. Table 4-12 shows cases in which the hypothesised disaster is a rockfall or a slope failure.

Table 4-11: Scoring methods used for the selected indicators in screening Rank C (for Landslide)

Item	Max score	Scoring
Result of photo interpretation	30	• exist clearly: 30 points • exist but partial and not clear: 15 points • exist but not clear:　7 points
Surface anomalies	30	• large and new cracks: 30 points • small and old cracks: 20 points • slight deformation: 5 points • no anomalies: 0 points
Geological structure	18	• fault, fracture zone:18 points • dip slope : 7 points • undip slope/ no characteristic feature: 0 points
Main rock formation of landslide body	18	• colluvium: 7 points • Gneiss: 3 point • Charnokit : 3 points • Quartzite: 0 points • Marble: 0 points • Schist: 3 points • Serpentite: 1 points • Granite: 1 points
Hydrological feature	10	• much springs / much seepag: 10 points • little springs /little seepage: 7 points • trace of water: 5 points • no water observed : 0 points
Installed countermeasure	－30	• No countermeasure/ no effect: 0 points • partially effect: －30points • completely effect: ×0

Table 4-12: Scoring methods used for the selected indicators in screening Rank C (for RF, SF)

Item	Max score	Scoring
collapsed factor	3	• 3 or more correspondences : 3 points • 2 correspondences : 2 points • 1 correspondences : 1 points • no correspondence: 0 points
geological conditions (soil)	8	• marked: 8 points • a little marked: 4 points • None: 0 points
geological conditions (rock)	12	• marked: 12 points • a little marked: 6 points • None: 0 points
geological conditions (structure: dip slope of bedding plane)	8	• It corresponds: 8 points • None: 0 points
geological conditions (structure: debris on impermeability bedrock)	6	• marked: 6 points • a little marked: 4 points • None: 0 points
Topsoil, detached rock and unsteady rock	12	• instability: 12 points • a little unstable : 6 points • stability: 0 points

Item	Max score	Scoring
spring water	8	• notable spring waster: 8 points • seepage: 4 points • None: 0 points
surface condition	5	• bare land with minor vegetation: 5 points • intermediate （bare・grass・tree）: 3 points • mainly structure, mainly tree: 1 points
height	18	• >50m: 18 points • 30 – 50 m: 12 points • 15 – 30m:: 8 points • <15m: 5 points
dip	10	• >70°: 10 points • 45° – 70°: 10 points • <45°: 5 points
anomaly	5	• 2 or more correspondences・clarity: 5 points • certain・unclarity: 3 points • None: 0points
Installed countermeasure	－20	• No countermeasure/ no effect: 0 points • Some effect: －10 points • High effect: －20points • Completely effect : ×0

The results of risk assessments carried out in 16 Rank B locations are shown in Table 4-13. Evaluation points in relation to hypothesised disasters are included. From this, in which Rank C areas were selected on the basis of having over 70 evaluation points, 6 places in Rank C areas were selected.

Table 4-13: Summary of results of Rank B areas risk assessment

No.	Route No.	Km	Score (Landslide)	Score (Rockfall/Slope failure)	Final evaluation
1	A004	154	-	51	Rank B
2	A004	173	-	66	Rank B
3	A004	174	-	59	Rank B
4	A005	43	-	62	Rank B
5	A005	44	-	69	Rank B
6	A005	46	-	75	Rank C
7	A005	63	-	52	Rank B
8	A005	91	-	71	Rank C
9	A005	135	77	-	Rank C
10	A005	167	98	-	Rank C
11	A007	31	-	42	Rank B
12	A007	45	-	56	Rank B
13	A007	54	-	48	Rank B
14	A007	57	42	49	Rank B
15	A016	10	74	-	Rank C
16	A113	15	75	-	Rank C

The list and ranks is shown in Table 4-13 about all slopes. Table 4 14 lists the areas of Rank C and B.

A Map of Tentative selection of Rank B and Rank C is shown in Figure 4-14: Map of Tentative selection of Rank B and Rank C. The green circles on the map are Rank B areas, and the orange circles are Rank C areas.

Table 4-14: List of Slopes and Ranks

No.	Route No.	Name of the Road	Year of Landslide recorded	Location Start (km)	Location End (km)	Disaster Type	Rank	Feature	EE Division	District
A004-134	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2009	134/15	134	Rock Fall	A		Pelmadulla	Ratnapura
A004-154	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2009	154/7		Landslide?	B		Pelmadulla	Ratnapura
A004-162	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2003	162/8		Debris Flow	A	Debris Flow (L=8km)	Pelmadulla	Ratnapura
A004-173	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2000	173/11		Slope Failure	B	Adjacent to a high-tension pylon	Bandarawela	Badulla
A004-174	A004	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Rose Garden Land Slide)	2000	175/1	175/3	Slope Failure	B	2 major slope failures	Bandarawela	Badulla
A004-185	A004	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Pahala Viharagala Land Slide)	2000	185/6		Landslide	A		Bandarawela	Badulla
A004-193	A004	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Leemastota Land Slide)	2011	194/11		Landslide	A		Bandarawela	Badulla
A004-196	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Nakatiya Land Slide)	1999	196+300	196+800	Landslide	A		Bandarawela	Badulla
A005-042	A005	Peradeniya-Badulla-Chenkaladi	2011	43/1	43/6	Landslide	A	Landslide (L=1km)	Nuwara Eliya	Nuwara Eliya
A005-043	A005	Peradeniya-Badulla-Chenkaladi	2011	43/8	43/9	Rock Fall, Rock Slide	B	Unstable rocks with open cracks	Nuwara Eliya	Nuwara Eliya
A005-044	A005	Peradeniya-Badulla-Chenkaladi	2011	44/2	44/3	Rock Fall, Rock Slide	B	Unstable rocks with open cracks.	Nuwara Eliya	Nuwara Eliya
A005-046	A005	Peradeniya-Badulla-Chenkaladi	2011	46/5	46/6	Rock Fall, Rock Slide	C	Unstable rocks with open cracks	Nuwara Eliya	Nuwara Eliya
A005-063	A005	Peradeniya-Badulla-Chenkaladi	2011	63/3		Slope Failure	B		Nuwara Eliya	Nuwara Eliya
A005-082	A005	Peradeniya-Badulla-Chenkaladi	2011	82+100	82+700	Slope Failure	A	Former 2 sections were merged in to 1 section. **(Buffer zone of Hakgala Strict Natural Reserve)**	Nuwara Eliya	Nuwara Eliya
A005-091	A005	Peradeniya-Badulla-Chenkaladi	2007	91+019		Slope Failure	C		Bandarawela	Badulla
A005-135	A005	Peradeniya-Badulla-Chenkaladi (2nd Mile Post Land Slide)	2011	135+200	135+700	Landslide	C	Landslide (L=0.2 ~ 0.3km)	Bandarawela	Badulla
A005-167	A005	Peradeniya-Badulla-Chenkaladi Road (Lunugala Land slide)	2012	168/8	168/9	Landslide	C	Landslide (L=0.1 ~ 0.2km) Detour by a bridge can be an option,	Bandarawela	Badulla
A007-031	A007	Avissawella-Hatton-Nuwara Eliya	2007	31/1	31/2	Slope Failure	B	Eroded by Kelani River.	Ruwanwella	Kegalle
A007-042	A007	Avissawella-Hatton-Nuwara Eliya	1989, 2005	42/14		Landslide?	A	Landslide or Slope Failure		Nuwara Eliya
A007-045	A007	Avissawella-Hatton-Nuwara Eliya	2011	45		Rock Fall, Rock Slide	B	Along with Slope Failure		Nuwara Eliya
A007-047	A007	Avissawella-Hatton-Nuwara Eliya	2011	47	48/1	Landslide	A			Nuwara Eliya
A007-054	A007	Avissawella-Hatton-Nuwara Eliya	2011	54/1		Slope Failure	B			Nuwara Eliya
A007-057	A007	Avissawella-Hatton-Nuwara Eliya	2011	57/9		Slope Failure	B			Nuwara Eliya
A007-069	A007	Avissawella-Hatton-Nuwara Eliya	2011	68	69/1	Landslide	A	Old road was moved away by the landslide.		Nuwara Eliya
A016-010	A016	Beragala-HaliEla Road (Kahagolla Land slide)	1996	10/12	11/1	Landslide	C	Head scarp approaching to the road shoulder	Bandarawela	Badulla
A021-020	A021	Kegalle-Bulathkohupitiya-Karawanella	2006	19+800	20+000	Landslide	A	Land owner didn't allow RDA to investigate the site.	Ruwanwella	Kegalle
A026-027	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2007	27	28/1	Rock Fall, Rock Slide	A	**(Sanctuary)**	Kundasale	Kandy
A026-029	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2007	29	30/1	Rock Fall, Rock Slide	A	**(Forest Ordinance)**	Kundasale	Kandy
A026-036	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2007	36	37/1	Slope Failure	A	Damage occurred during construction. Retaining wall was constructed. **(Sanctuary)**	Kundasale	Kandy
A026-045	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2010	46/2	46/3	Slope Failure	A	**(Forest Ordinance)**	Kundasale	Kandy
A026-048	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2011	48/9	48/10	Slope Failure	A	**(Sanctuary)**	Kundasale	Kandy
A026-049	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2011	50/4	50/5	Slope Failure	A	**(Sanctuary)**	Kundasale	Kandy
A026-051	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2011	51/1	51/2	Slope Failure	A	Damage occurred during construction. Retaining wall was constructed. **(Sanctuary)**	Kundasale	Kandy
A026-055	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2010	55/4	55/6	Rock Fall, Rock Slide	A	**(Within Victoria Randenigala Rantembe Sanctuary)**	Kundasale	Kandy
A026-056	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2011	56		Slope Failure	A	**(Sanctuary)**	Kundasale	Kandy
A026-058	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2011	58/2	58/4	Slope Failure	A	**(Sanctuary)**	Kundasale	Kandy
A026-060	A026	Kandy-Mahiyanganaya-Padiyatalawa road	2011	60/3	60	Rock Fall, Rock Slide	A	Damage occurred during construction. Retaining wall was constructed. **(Within Victoria Randenigala Rantembe Sanctuary)**	Kundasale	Kandy
A113-010	A113	Gampola - Nawalapitiya	2011	11/2	11/3	Landslide	A		Kadugannawa	Kandy
A113-015	A113	Gampola - Nawalapitiya	2010	16/5	16/6	Landslide	C	Involving road and residence.	Kadugannawa	Kandy

(purple)	**Deleted due to Environmental issue**
A	Rank A
B	Rank B
C-	Rank C- (Deleted)
C	Rank C

Table 4-15: Summary of selection of Rank B and C

No.	Route No.	Name of the Road	Year of Landslide recorded	Location Start (km)	Location End (km)	Disaster Type	Rank	Feature	EE Division	District
A004-154	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2009	154/7		Landslide?	B		Pelmadulla	Ratnapura
A004-173	A004	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2000	173/11		Slope Failure	B	Adjacent to a high-tension pylon	Bandarawela	Badulla
A004-174	A004	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Rose Garden Land Slide)	2000	175/1	175/3	Slope Failure	B	2 major slope failures	Bandarawela	Badulla
A005-043	A005	Peradeniya-Badulla-Chenkaladi	2011	43/8	43/9	Rock Fall, Rock Slide	B	Unstable rocks with open cracks	Nuwara Eliya	Nuwara Eliya
A005-044	A005	Peradeniya-Badulla-Chenkaladi	2011	44/2	44/3	Rock Fall, Rock Slide	B	Unstable rocks with open cracks.	Nuwara Eliya	Nuwara Eliya
A005-046	A005	Peradeniya-Badulla-Chenkaladi	2011	46/5	46/6	Rock Fall, Rock Slide	C	Unstable rocks with open cracks	Nuwara Eliya	Nuwara Eliya
A005-063	A005	Peradeniya-Badulla-Chenkaladi	2011	63/3		Slope Failure	B		Nuwara Eliya	Nuwara Eliya
A005-091	A005	Peradeniya-Badulla-Chenkaladi	2007	91+019		Slope Failure	C		Bandarawela	Badulla
A005-135	A005	Peradeniya-Badulla-Chenkaladi (2nd Mile Post Land Slide)	2011	135+200	135+700	Landslide	C	Landslide (L=0.2 ~ 0.3km)	Bandarawela	Badulla
A005-167	A005	Peradeniya-Badulla-Chenkaladi Road (Lunugala Land slide)	2012	168/8	168/9	Landslide	C	Landslide (L=0.1 ~ 0.2km) Detour by a bridge can be an option,	Bandarawela	Badulla
A007-031	A007	Avissawella-Hatton-Nuwara Eliya	2007	31/1	31/2	Slope Failure	B	Eroded by Kelani River.	Ruwanwella	Kegalle
A007-045	A007	Avissawella-Hatton-Nuwara Eliya	2011	45		Rock Fall, Rock Slide	B	Along with Slope Failure		Nuwara Eliya
A007-054	A007	Avissawella-Hatton-Nuwara Eliya	2011	54/1		Slope Failure	B			Nuwara Eliya
A007-057	A007	Avissawella-Hatton-Nuwara Eliya	2011	57/9		Slope Failure	B			Nuwara Eliya
A016-010	A016	Beragala-HaliEla Road (Kahagolla Land slide)	1996	10/12	11/1	Landslide	C	Head scarp approaching to the road shoulder	Bandarawela	Badulla
A113-015	A113	Gampola - Nawalapitiya	2010	16/5	16/6	Landslide	C	Involving road and residence.	Kadugannawa	Kandy

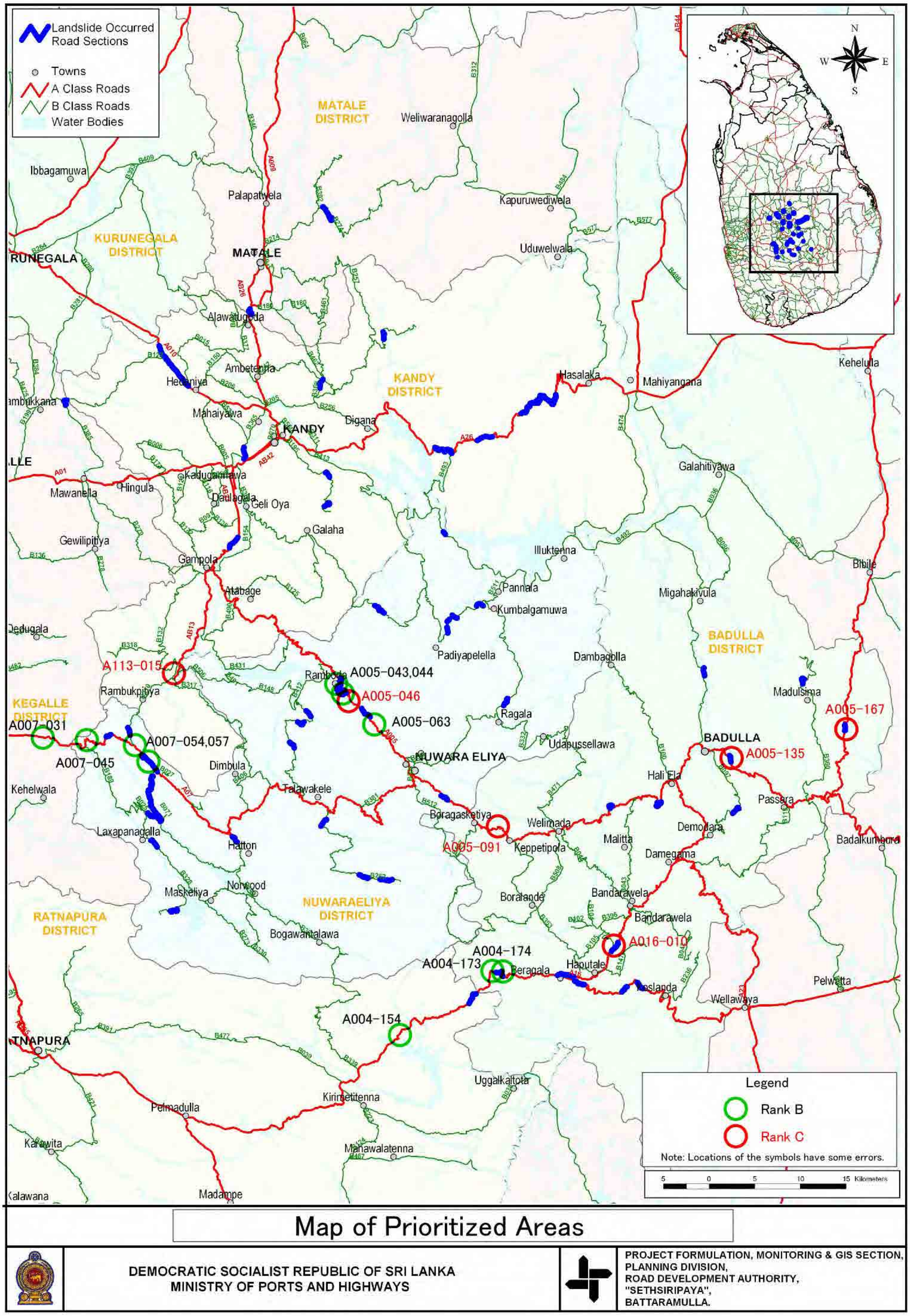


Figure 4-14: Map of Tentative selection of Rank B and Rank C

4.5.2 Priority setting in Rank C areas

Priority within Rank C areas was determined with comprehensive evaluation of the degree of risk, the economic effects and technical transfer advantage. Table 4-16 shows a list of the scores for risk assessment in Rank C areas, evaluation of the economic effects (EIRR) and technical transfer advantage. Results of the investigation into Priority are shown in the table.

Table 4-16: Summary of risk assessment results and economic effects for Rank C areas

No.	Area	Risk evaluation		Results of economic analysis		Advantage of technical transfer (C)	Score of priority evaluation (A*30+B*30+C*40)	Priority
		Score	Order (A)	(EIRR %)	Order (B)			
1	A005-046	75	3	11.5%	2	3	270	2
2	A005-091	71	6	12.1%	1	1	250	1
3	A005-135	77	2	7.9%	6	2	320	4
4	A005-167	98	1	9.0%	4	4	310	3
5	A016-010	74	5	8.4%	5	5	500	6
6	A113-015	75	3	11.3%	3	6	420	5

4.5.3 Priority setting in Rank B areas

Priority within Rank B areas was determined with comprehensive evaluation of both the degree of risk and the influence on maintenance object. Table 4-17 shows a list of evaluation of property and facility to be protected and the scores of risk assessment in Rank B areas. Results of the investigation into Priority are shown in the table.

Table 4-17: Summary of risk assessment results and property and facility to be protected for Rank B

No.	Area.	Score of risk evaluation		Property and facility to be protected		Score of priority evaluation (A*50+B*50)	Priority
		Score	Order (A)	Description	Order (B)		
1	A004-154	51	7	No property.	10	850	9
2	A004-173	66	2	･Two houses on the lower slope and one on the upper slope and a boutique ･The cultivatable land on both slopes, which is owned by 3 families. ･The power transmission towers located near the shoulder of the landslide on the upper slope.	3	250	1
3	A004-174	59	4	No property.	10	700	7
4	A005-043	62	3	･A semi-permanent house ･The tea estate on upper slope can be cultivatable if countermeasure is implemented	6	450	5
5	A005-044	69	1	･The shop-cum-residence at the right side in front of rock and 10 families living about 500 mt. away on the down slope ･Tea estate on upper slope	5	300	2
6	A005-063	52	6	･6 houses on the lower slope and four	1	350	3

No.	Area.	Score of risk evaluation		Property and facility to be protected		Score of priority evaluation (A*50+B*50)	Priority
		Score	Order (A)	Description	Order (B)		
				houses on the upper slopes. ・Vegetable cultivation on the lower slopes ・Electricity and telephone poles. The post office, GN Office, two shrine houses.			
7	A007-031	42	10	・The cultivatable land on both slopes ・Electricity poles	8	900	10
8	A007-045	56	5	・Around 10 houses on the lower slope. ・Rubber plantation on the upper slope.	2	350	3
9	A007-054	48	9	・A house and several shops on the lower slope and several commercial buildings on upper slope. ・Cultivatable land on lower slope ・Electricity poles.	4	650	6
10	A007-057	49	8	・Plantation on upper slope. ・Telephone poles and line.　Water canal of a private power station.	7	750	8

4.5.4 Method of risk analysis

Here, there was an evaluation of the disaster outbreak probability necessary for calculation of risk analysis for Rank C areas and EIRR. The results are shown below.

a. Records of landslides in the target region

Table 4-18 shows landslide records which are recorded on the Disaster information management system- Sri Lanka database (written as Disaster DB below). 39 years of data spanning from 1974 to 2012 has been recorded in this database. The database does not classify disasters in accordance to type, such as landslide, slope failure, debris flow etc, but has data which is considered to reflect the scale of disaster, such as Affected etc.

Table 4-18: Summary of Landslide Records in Sri Lanka

Period: 1 Jan. 2007-20 Jul.2012

District	Frequency (Times)	Deaths (Person)	Injured (person)	Miss-ing (person)	Houses Destroyed (No.)	Houses Damaged (No.)	Affected (person)	Relo-cated (person)	Evacu-ated (person)	Payment for relief-partially damaged houses (Rs.)
Nuwara Eliya	143	26	14	3	450	1,397	20,662	0	5	0
Kandy	202	10	26	0	49	185	2,759	0	93	0
Badulla	170	7	3	0	34	243	2,883	0	0	1,150,825
Kegalle	60	6	8	0	46	340	2,716	0	563	733,200
Ratnapura	96	2	2	0	16	22	1,491	0	101	1,133,885
Kalutara	41	7	4	0	10	41	1,208	0	0	10,000
Matale	9	0	0	0	1	5	2,257	0	0	0

Source: Disaster Information Management System- Sri Lanka

Based on date information recorded on the Disaster DB, Figure 4-15 shows a change in the number of recorded disasters on a yearly basis in all 7 target districts.

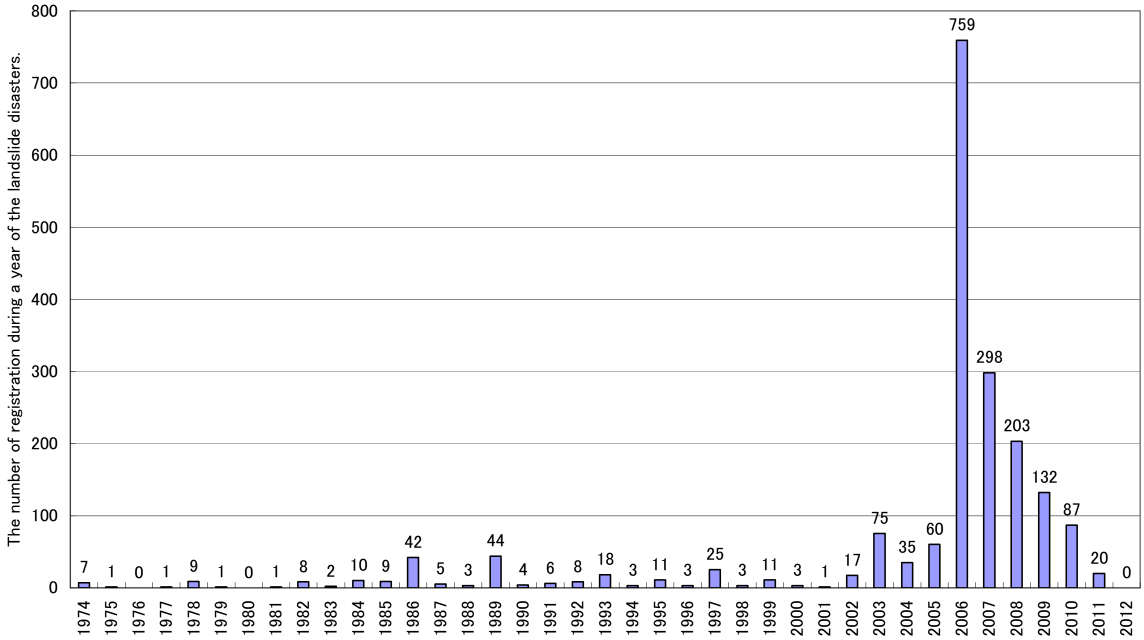


Figure 4-15: Change in the number of recorded landslide disasters by year
(Source: Disaster information management system – Sri Lanka)

The number of landslides (including some rockfall) which occurred in the 7 districts in the target area over 39 years is 1,925. On average, this is 49.4 cases per year. There were 759 cases in 2006, an abnormally high amount.

On the other hand, Table 4-19 and Table 4-20 show individual cases of landslides in Districts in 2003 and 2006, compiled by NBRO. In the NBRO data in Table 4-19 and Table 4-20, information about the date, time and scale of each individual landslide is not included. Looking at these columns, there were 211 landslide occurrences in 2003 in south west Sri Lanka, a year when there was heavy flooding. In 2006 there were 68 cases, which was at the same level as the database average of 49.4 cases per year in Figure 4-15. In contrast with 759 cases, this is a far smaller amount.

Table 4-19: Landslides and Cutting failures in 2003 (Source: NBRO)

Districts	Landslides	Rock Fall	Old Landslides	Cutting Failures	Unstable Slopes
Ratnapura	117	21	23	68	138
Galle	5	1	1	12	3
Hambantota	11	-	-	-	-
Kalutara	7	4	6	18	7
Matara	71	7	6	25	39
Total	*211*	*33*	*36*	*123*	*187*

Table 4-20: Landslides and Cutting failures in 2006

Districts	Landslides	Rock Falls	Old Landslides	Cutting Failures
Kandy	7	-	-	54
Kegalle	46	-	-	49
Badulla	9	1	2	22
Matale	3	1		10
Kalutara	-	-	-	5
Ratnapura	3	1	3	2
Gampha	-	-	-	6
Colombo	-	-	-	3
Total	*68*	*3*	*5*	*151*

(Source: NBRO)

The date information for Figure 4-15 does not provide the days on which the disaster occurred, and in order to maintain this database, it can be assumed to be the day on which the disaster records were investigated. Furthermore, information such as that relating to rainfall is sometimes shown as a factor in this database, but these values are not entered with all applicable landslides. Because date information does not include the day of occurrence, it is not possible to obtain specific information about rainfall on the day of occurrence for each individual landslide.

Table 4-20 is a summary of recorded landslide occurrences on A national highways in the target area. This is based on information obtained from RDA-related documents, such as GIS data which is controlled by RDA. The year of occurrence shown in the table is the last year of occurrence. There are many areas where multiple landslides have occurred in the same location in previous years.

Table 4-21: Record of landslide cases on target roads by RDA

Route No.	No.	Name of the Road	Year of last landslide recorded	Location			Disaster Type	Disaster scale	Feature	EE Division	District
				Start (km)	End (km)	distance (km)		S/M/L			
A004	A004-134	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2009	130	140	10.00	Rock Fall			Pelmadulla	Ratnapura
A004	A004-154	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2009	153+700		0.10	Landslide?			Pelmadulla	Ratnapura
A004	A004-162	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2003	163	167	4.00	Debris Flow	L	Debris Flow (L=8km)	Pelmadulla	Ratnapura
A004	A004-168	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2000	168+450	168+850						
A004	A004-173	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Marangahawela Land Slide)	2000	172+900	173+000	0.10	Slope Failure		Adjacent to a high-tension pylon	Bandarawela	Badulla
A004	A004-174	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Rose Garden Land Slide)	2000	174+100	175+000	0.90	Slope Failure		2 major slope failures	Bandarawela	Badulla
A004	A004-185	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Pahala Viharagala Land Slide)	2000	185+000	186+000	1.00	Landslide			Bandarawela	Badulla
A004	A004-193	Colombo-Ratnapura-Wellawaya -Batticaloa Road (Leemastota Land Slide)	2011	193+000	193+800	0.80	Landslide			Bandarawela	Badulla
A004	A004-196	Colombo-Ratnapura-Wellawaya-Batticaloa Road (Nakatiya Land Slide)	1999	196+300	196+800	0.50	Landslide			Bandarawela	Badulla
A005	A005-015	Peradeniya-Badulla-Chenkaladi	2010	15.00	16.00	1.00				Pilimatalawa	Kandy
A005	A005-042	Peradeniya-Badulla-Chenkaladi	2011	42.00	45.00	3.00	Landslide Slope Failure	M	Landslide (L=1km)	Nuwara Eliya	Nuwara Eliya
A005	A005-061	Peradeniya-Badulla-Chenkaladi	2011	61.00	62.00	1.00				Nuwara Eliya	Nuwara Eliya
A005	A005-074	Peradeniya-Badulla-Chenkaladi	2011	74.00	75.00	1.00	Slope Failure			Nuwara Eliya	Nuwara Eliya
A005	A005-082	Peradeniya-Badulla-Chenkaladi	2011	82+100	82+700	0.60	Slope Failure		Former 2 sections were merged in to 1 section. **(Buffer zone of Hakgala Strict Natural Reserve)**	Nuwara Eliya	Nuwara Eliya
A005	A005-091	Peradeniya-Badulla-Chenkaladi	2007	91+019		0.10	Slope Failure	M	Crumbling slopes every rainy season, 2 day road closure in 2007	Nuwara Eliya	Nuwara Eliya
A005	A005-104	Peradeniya-Badulla-Chenkaladi	2011	104.00	105.00	1.00				Nuwara Eliya	Nuwara Eliya
A005	A005-119	Peradeniya-Badulla-Chenkaladi Road (Moretota Land Slide)	2010	119+300	119+360	0.60				Bandarawela	Badulla
A005	A005-135	Peradeniya-Badulla-Chenkaladi (2nd Mile Post Land Slide)	2011	135+200	135+700	0.50	Landslide		400m change recorded in 2010, occurrence of change every year during rainy season	Bandarawela	Badulla
A005	A005-167	Peradeniya-Badulla-Chenkaladi Road (Lunugala Land slide)	2012	167+497	167+541	0.05	Landslide		Occurrence of change every year during rainy season	Bandarawela	Badulla
A007	A007-003	Awissawella-Hatton-Nuwara Eliya	2005	2+100	2+200	0.10					
A007	A007-25	Awissawella-Hatton-Nuwara Eliya	2009	24+800		0.10					
A007	A007-27	Awissawella-Hatton-Nuwara Eliya	2011	26+600	26+700	0.10					
A007	A007-29(1)	Awissawella-Hatton-Nuwara Eliya	2010	28+100		0.05					
A007	A007-29(2)	Awissawella-Hatton-Nuwara Eliya	2010	28+900		0.05					
A007	A007-031	Awissawella-Hatton-Nuwara Eliya	2007	30+100	30+200	0.10	Slope Failure		Eroded by Kelani River.	Ruwanwella	Kegalle
A007	A007-036	Awissawella-Hatton-Nuwara Eliya	2011	35+500	35+600	0.10					
A007	A007-042	Awissawella-Hatton-Nuwara Eliya	2005	41+900		0.10	Landslide?		Landslide or Slope Failure	Norwood	Nuwara Eliya
A007	A007-045	Awissawella-Hatton-Nuwara Eliya	2011	44+000		0.10	Rock Fall, Rock Slide		Along with Slope Failure	Norwood	Nuwara Eliya
A007	A007-047	Awissawella-Hatton-Nuwara Eliya	2011	47.00	48.00	1.00	Landslide			Norwood	Nuwara Eliya
A007	A007-054	Awissawella-Hatton-Nuwara Eliya	2011	53+100		0.10	Slope Failure			Norwood	Nuwara Eliya
A007	A007-055	Awissawella-Hatton-Nuwara Eliya	2011	55.00	58.00	3.00	Slope Failure			Norwood	Nuwara Eliya
A007	A007-069	Awissawella-Hatton-Nuwara Eliya	2011	68+000	68+100	0.10	Landslide		Old road was moved away by the landslide.	Norwood	Nuwara Eliya
A009	A009-017	Kandy-Jaffna Road	2010	17.00	18.00	1.00				Kundasale	Kandy
A010	A010-011	Katugastota - Kurunegala - Puttlam	2010	11.00	16.00	5.00				Kandy	Kandy
A016	A016-001	Beragala-HaliEla Road (Kahagolla Land slide)	1988	0+500	2+000	1.50				Bandarawela	Badulla
A016	A016-010	Beragala-HaliEla Road (Kahagolla Land slide)	2012	6+570	14+900	8.33	Landslide		Landslide change seen once every 2 years since 1996	Bandarawela	Badulla
A017	A017-087	Galle - Deniyaya - Madampe	2007	87.00	88.00	1.00				Embilipitiya	Ratnapura
A021	A021-020	Kegalle-Bulathkohupitiya-Karawanella	2006	19+800	20+000	0.20	Landslide		Land owner didn't allow RDA to investigate the site.	Ruwanwella	Kegalle
A026	A026-027	Kandy-Mahiyanganaya-Padiyatalawa road	2007	28+000	28+100	0.10	Rock Fall, Rock Slide		**(Sanctuary)**	Kundasale	Kandy
A026	A026-029	Kandy-Mahiyanganaya-Padiyatalawa road	2007	29.00	31.00	2.00	Rock Fall, Rock Slide		**(Forest Ordinance)**	Kundasale	Kandy
A026	A026-036	Kandy-Mahiyanganaya-Padiyatalawa road	2007	37.00	39.00	2.00	Slope Failure		Damage occurred during construction. Retaining wall was constructed. **(Sanctuary)**	Kundasale	Kandy
A026	A026-045	Kandy-Mahiyanganaya-Padiyatalawa road	2012	45.00	55.00	10.00	Slope Failure		**(Forest Ordinance)**	Kundasale	Kandy
A026	A026-056	Kandy-Mahiyanganaya-Padiyatalawa road	2011	56+000	56+100	0.10	Slope Failure		**(Sanctuary)**	Kundasale	Kandy
A026	A026-058	Kandy-Mahiyanganaya-Padiyatalawa road	2011	57+200	57+400	0.20	Slope Failure		**(Sanctuary)**	Kundasale	Kandy
A026	A026-060	Kandy-Mahiyanganaya-Padiyatalawa road	2011	59+300	60+000	0.70	Rock Fall, Rock Slide		Damage occurred during construction. Retaining wall was constructed. **(Within Victoria Randenigala Rantembe Sanctuary)**	Kundasale	Kandy
A113	A113-010	Gampola - Nawalapitiya	2011	10+200	10+300	0.10	Landslide			Kadugannawa	Kandy
A113	A113-015	Gampola - Nawalapitiya	2010	15+500	15+600	0.10	Landslide		Landslide change (10-15cm) during rainy season and in December	Kadugannawa	Kandy
A113	A113-015	Gampola - Nawalapitiya	2010	29.00	30.00	1.00				Pilimatalawa	Kandy

The accumulated landslide history data of individual landslides was drawn up, but aside from the information above, no further data could be obtained.

However, in addition to the information in Table 4-19 and Table 4-20, the NRBO, which deals with landslide disasters in Sri Lanka, also produced results for landslides in 2007, 2010 and 2011. The results in 2007 were only for Galle and Kalutara, and the results in 2010 and 2011 were recorded by type, such as landslide, cutting failure, rock fall, slope failure, etc. However, these results were taken over a four month period from November 2010 to February 2011, so the findings are from only five of the districts; Nuwara Eliya, Matale, Badulla, Kandy and Kegalle.

Based on these circumstances, it was concluded that long-term recordings which would enable an understanding of the types of landslides, and the date, time and scale of disasters in the 7 districts, were no longer available in Sri Lanka. Furthermore, it was also concluded that the data that was obtained for the project at that time is almost all the information remaining on landslides in the 7 districts.

b. Frequency of occurrence, and return periods of landslides in the 7 districts of the target area

Although there is much information present in the Disaster DB in regards to the scale of a disaster, there is not much information input in regards to landslides. Amongst those items which are input into the database is 'Affected.' 'Affected' refers to the number of people who have been affected by the disaster. This value is thought of as a numerical value which indirectly expresses the scale of a disaster. We analyzed the number of occurrences for every size in regards to the 'Affected' condition over the last 39 years. The results are shown in Table 4-22.

Table 4-22: Connection between Affected and the number of occurring landslides (39 year period)

affected	affected median	Number of incidents	Average number of occurrences per year
0-1	0.5	499	12.795
1-10	5	821	21.051
10-100	50	427	10.949
100-1000	500	162	4.154
1000-5000	2500	13	0.333
5000-12000	6000	3	0.077
Total		1925	39.36

For each occurrence for every level of Affected over the past 39 years, the average number of landslides that occur per year was calculated, and a connection to the intermediate value of Affected (disaster scale) was sought. These results are shown in Figure 4-16. The trend shows that when the disaster scale (Affected) was smaller, the frequency of yearly occurrences was higher. However, when there was less than one Affected, the number of occurrences became less than ten. It was concluded that this was because landslides that were too small were not included in the investigation.

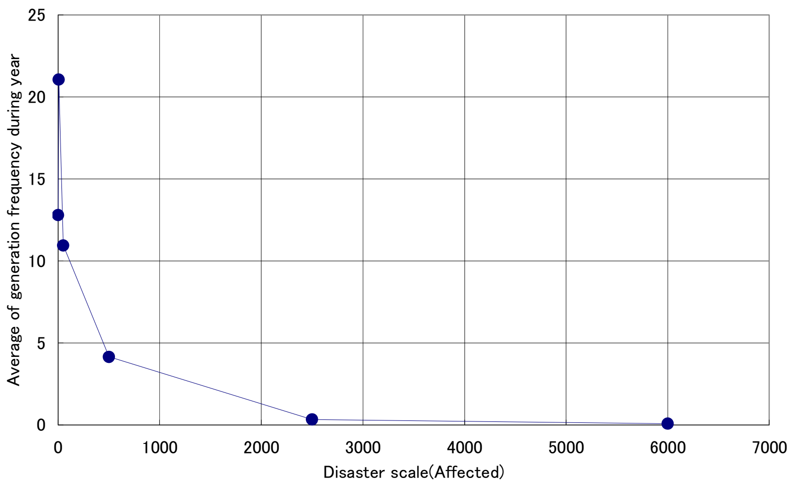


Figure 4-16: Connection between disaster scale (Affected) and the average number of landslide occurrences per year

Because the statistics on the Disaster DB are from over a period of 39 years, the experiential return period of the largest scale disaster during this time was 65.33 years, according to a Cunnane plot. Table 4-23 calculates the assumed return period T' as T'=1/n, based on the average number of occurrences per year n of each scale, and taking the return period of the largest scale disaster as Cunnane plot's experiential return period 65.33 years, revises the return periods for each scale according to the ratio with the provisional return periods T'.

Table 4-23: Connection between Affected and number of landslide occurrences per year (39 year period)

affected	affectedmedian	Number of incidents	Average number of incidents per year	Assumed return period T'(year)	Revised return period values according to Cunnane plot T(year)
0-1	0.5	499	12.795	0.078	0.393
1-10	5	821	21.051	0.048	0.239
10-100	50	427	10.949	0.091	0.459
100-1000	500	162	4.154	0.241	1.210
1000-5000	2500	13	0.333	3.000	15.077
5000-12000	6000	3	0.077	13.000	65.333
Total	-	1925	49.36	-	-

The connection between the disaster scale (Affected) and the estimated return period is shown in Figure 4-17. The return period for large-scale disasters (Affected= more than 5000, largest value is Affected = 11,090) in all 7 districts is estimated to be 65 years, and the return period of mid scale disasters (Affected = 1000 – 5000) is estimated at 15 years.

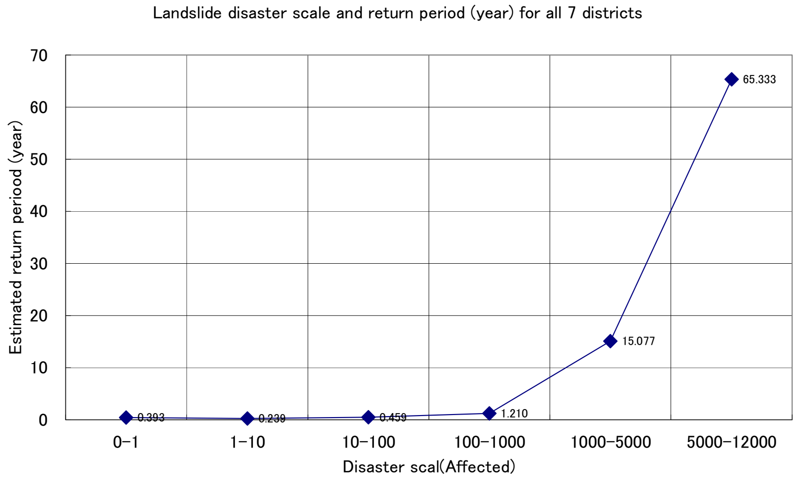


Figure 4-17: Connection between disaster scale (Affected) and estimated return period (All 7 districts)

Reference Data: Calculation of experiential return period by Cunnane plot

The Cunnane plot is a method of calculating experiential return period using SLSC (standard least-squares criterion) to find the probability distribution compatible with the observation data of a location, when the Japanese Meteorological Agency searches for an excess probability value for the maximum annual precipitation, using a probability distribution method such as Gumbel or GEV (generalized extreme value) distribution. When there is an observed value of N, the return period T(i) of the i data of the largest value is assumed as below.

$$T(i) = (N + 0.2)/(i - 0.4)$$

c. Frequency of occurrence of landslides, and return period on target highways

The return period of landslides examined in the preceding section are values across all 7 districts, but the essential return period in this project are those which directly influence the target highways.

The data shown in Table 4-21 is the only available landslide history information for the highways. The information recorded in this table is that of the location of occurrence of disasters on the highways, and the year in which the last landslide occurred. It is understood that multiple landslides occur in the same location, but the details of landslides prior to the most recent are uncertain. The oldest date in which a landslide was previously recorded is 1988, and the most recent is 2012. In other words, from 1988 onwards, there is at least 24 years' worth of information summarized in Table 4-21. This "Year of last landslide recorded" data can be considered to reflect to some extent the return periods for landslides in each location. For example, if the year is 1988, this means that a landslide has not occurred in the location for at least 24 years. If the year is 2012, it can be assumed that landslides occur every year at that location. Amongst the records of Table 4-21, the only large scale disaster which caused the loss of the roadbed itself occurred due to a landslide (avalanche) on the A004-162 in 2003. This was the one large-scale disaster which occurred on the target highways recorded in 24 years worth of statistics since 1988.

The compilation of the number of locations in which landslides occurred for every year in regards to previously recorded landslides results in Table 4-24. The connection between the number of years that have elapsed since the last disaster, and the number of points is shown in Figure 4-18. When a longer period of time has passed since the previous landslide, the number of points is fewer. When a shorter period of time has passed, there are a larger number of locations. This trend shows the same tendency as the connection between frequency of occurrence and disaster scale for the 7 districts, which is shown in. Figure 4-16

As such, Figure 4-18 is thought to reflect to some extent the connection between the disaster scale in the disaster danger point of the target highways, and the frequency of occurrence. The number of years elapsed, as shown in Figure 4-18, is taken to reflect the scale of the disaster, and are categorized as large-scale, mid-scale and small-scale. There is only one example of a large-scale disaster in the last 24 years, small-scale disasters are taken as those within 2 years, and everything else is taken as mid-scale.

For each individual disaster scale, a weighted average of the number of years that have elapsed is calculated, and these values are taken as the return periods per one disaster danger point which represents each disaster scale. These results are shown in Table 4-25. As previously mentioned, the only large-scale disaster since 1988 to have occurred on the highways in question occurred on the A004-162 in 2003. When this is expressed as an experiential return period by the Cunnane plot, it corresponds to a return period of 40.3 years.

Table 4-24: Connection between the year of last landslide on subject highways, and number of occurrences (24 year period)

Year of last occurrence	Number of years passed	Number of points	Length of interval (km)	Number of points per unit length of interval (1/km)	Number of points per unit length of interval (1/km)	Years passed x number of points (year)
1988	24.1	1	1.5	0.015485	0.666667	24.1
1989	23.1	-	-	-	-	-
1990	22.1	-	-	-	-	-
1991	21.1	-	-	-	-	-
1992	20.1	-	-	-	-	-
1993	19.1	-	-	-	-	-
1994	18.1	-	-	-	-	-
1995	17.1	-	-	-	-	-
1996	16.1	-	-	-	-	-
1997	15.1	-	-	-	-	-
1998	14.1	-	-	-	-	-
1999	13.1	1	0.5	0.015485	0.032051	13.1
2000	12.1	4	2	0.061939	0.128205	48.4
2001	11.1	-	-	-	-	-
2002	10.1	-	-	-	-	-
2003	9.1	1	4	0.015485	0.032051	9.1
2004	8.1	-	-	-	-	-
2005	7.1	2	0.2	0.030969	0.064103	14.2
2006	6.1	1	0.2	0.015485	0.032051	6.1
2007	5.1	6	5.3	0.092908	0.192308	30.6
2008	4.1	-	-	-	-	-
2009	3.1	3	10.2	0.046454	0.096154	9.3
2010	2.1	8	8.8	0.123877	0.25641	16.8
2011	1.1	18	13.5	0.278724	0.564617	19.8
2012	0.1	3	18.38	0.046454	0.094103	0.3
計		48	64.58	0.743264		191.8

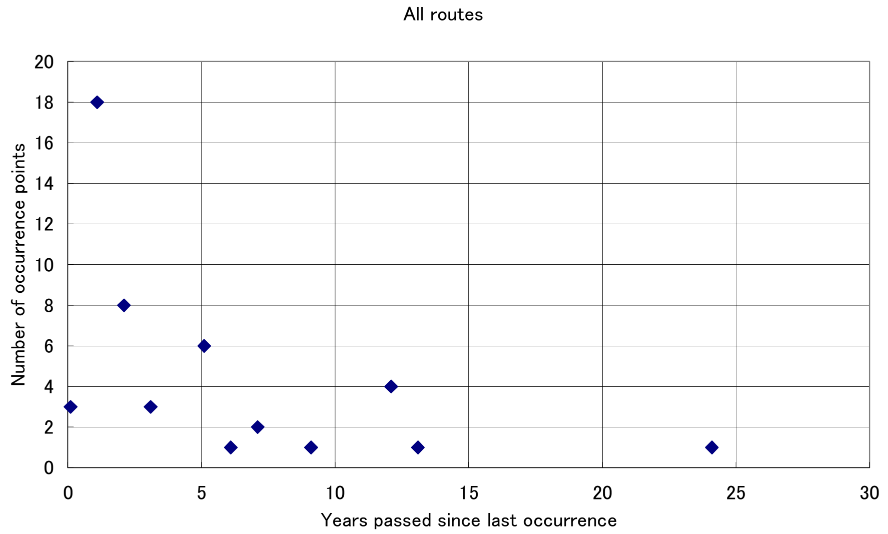


Figure 4-18: Connection between number of points and number of years passed since last disaster (Subject highway A)

Assuming that the return period for large-scale disasters on the subject highways is 40.3 years, the return periods were revised per one dangerous area in the case of each disaster scale. These values are shown in Table 4-25. According to this, the return period for large-scale disasters is approximately 40 years, and that of mid-scale disasters is around 10 years.

Table 4-25 shows a comparison of the return period for each separate disaster scale, which were examined over the 7 subject districts. But the difference between large-scale and mid-scale disasters is around 1.6 times, so the results of the return period ratios were more or less the same. The reason why the large-scale disaster return period are longer than the 7 districts as a whole is due to differing yearly statistics. However, looking at it in another way, in the largest disaster over the entirety of the 7 districts, the number of Affected is approximately 11,000 people, and while this is a considerably large landslide, 'large-scale disasters' on highways in this project are taken to be those such as landslides which cause roads to spill out, and even with the same 'large-scale disaster' the assumed disaster scales will both differ. Therefore, the differences in return period for both are judged as valid.

Table 4-25: Estimated results of return periods of disaster danger point on subject highways seen in every disaster scale

Disaster Scale	∑(years passed x number of points)	Total occurrence number of points	Danger interval length (km)	Total interval length (km)	Estimated return period T'per one point	Return period revision T by Cunnane plot (year)	Landslide return periods of 7 districts (B) (year)	Ratio of return periods with 7 districts (B/T)
Large-scale	24.1	1	0.2	1.5	24.1	40.33	65	1.61
Mid-scale	147.6	26	0.2	31.2	5.68	9.50	15	1.58
Small-scale	20.1	21	0.2	31.88	0.96	0.96	1	1.04

Table 4-26 shows recent disaster occurrence circumstances of Rank C sections, and estimated return periods of each separate disaster scale. The return periods of small-scale disasters here are values estimated from recent disaster occurrence circumstances in the area concerned.

Table 4-26: Disaster occurrence circumstances of Rank C sections in recent years, and estimated return periods of each separate disaster scale

No.	area	Disaster type	Length of disaster occurrence danger interval km	Circumstances of recent disaster occurrences	Estimated return period (year)		
					Small scale	Mid-scale	Large scale
1	A005-046	Rock fall/Rock slide	200	Frequent rockfall	1	10	40
2	A005-091	Slope Failure	50	Occurrence of slope failure every year, 2 day road closure in 2007 due to earth & sand	1	10	40
3	A005-135	Landslide	250	400m change of position recorded in 2010, change occurs every year during rainy season	1	10	40
4	A005-167	Landslide	100	Occurrence of change every year during rainy season	1	10	40
5	A016-010	Landslide	200	Landslide change observed once every 2 years since 1996	2	10	40
6	A113-015	Landslide	100	Landslide change twice a year- during rainy season and in December (10-15cm)	0.5	10	40

4.5.5 Setting method of the disaster extent

An earth-and-sand extent is calculated by the following two methods. And both are compared and the wider range is set as the damage range.

(1) From the width W of a landslide disaster and the correlation diagram of length and a width ratio (L/W) in the actual condition of the landslide disaster of Sri Lanka indicated to "Landslide hazard mapping in Sri Lanka", after setting up the envelop line of both relation, From width W' of an object slope, the extreme breadth of the landslide disaster range is presumed to be W=2・W' (the B/C calculation technique of Japan), and L of an earth-and-sand extent is presumed from W using the regression equation of a envelop line. Although an envelop line here adopts the envelop line of "Cutting Failure" as a standard, when it is judged that there is possibility of mobilization from the situation of the lower part of a slope of an object point, the envelop line of "Earthflow" is adopted.

(2) It calculates with the damage delimitation technique adopted by the cost-benefit analysis in the landslide and the measure against a steep slope of Japan. The damage range of both a landslide and a steep slope is compared, and the wider range will be adopted.

Since the extent of access of earth and sand changes with geographical features, vegetation, etc. of a lower part slope of the point for earth and sand considerably, the final damage extent is set to origin for the damage range calculated by the above-mentioned technical technique by a specialist's engineer judgment.

The results from a correlation diagram of width and length / width-length ratio (L/W) of earth and sand disasters in Sri Lanka, recorded in "Landslide hazard mapping in Sri Lanka", are shown in Table 4-27.

Table 4-27: Estimated results of damage range from disaster history of Sri Lanka

Area (Disaster type)	Size of Landslide/slope			Landslide hazard mapping in SriLanka		
				Damage range		
				Extended width W'	Damage length L'	
	width	length	hight	2×W	SF/LS	L'
	W (m)	L (m)	H (m)	(m)	(m)	(m)
A005-046(Rock fall/Rock slide)	200	50	50	400	292	-13640
A005-091(Slope Failure)	30	30	15	60	311.04	687.6
A005-135(Landslide)	200	300	-	400	292	-13640
A005-167(Landslide)	100	150	-	200	670	-1460
A016-010(Landslide)	200	500	-	400	292	-13640
A113-015(Landslide)	60	100	-	120	527.76	410.4

Table 4-28 shows the results calculated by a damage range configuration technique, which is used for cost-benefit analysis in Japan's landslides and slope measures. Selecting the largest case from both Table 4-27 and Table 4-28 results in

Table 4-29. This damage range is taken as the damage range of Rank C areas.

Table 4-28: Results of damage range estimated by Japan's method of cost-benefit analysis

Area (Disaster type)	Range of cost-benefit analysis in Japen					
	Steep Slope		Landslide			
	Upper most distance from top	Lowest distance from tip	Back extended possible range	Lowest distance from tip	Side extended possible range	Damage width from tip to lowest part
			=L/2		=W/4	W2
	(m)	(m)	(m)	(m)	(m)	(m)
A005-046(Rock fall/Rock slide)	50	100	-	100	-	400
A005-091(Slope Failure)	15	30	-	60	-	60
A005-135(Landslide)	-	-	150	600	300	400
A005-167(Landslide)	-	-	75	300	150	200
A016-010(Landslide)	-	-	250	1000	300	400
A113-015(Landslide)	-	-	50	200	90	120

Table 4-29: Estimated results of damage range of Rank C areas

Area (Disaster type)	Assumed damage range			
	Upper most distance from top	Lowest distance from tip	Damage width from tip to upper most part	Damage width from tip to lowest part
	L1	L2	W1	W2
	(m)	(m)	(m)	(m)
A005-046(Rock fall/Rock slide)	50	292	200	400
A005-091(Slope Failure)	15	688	30	60
A005-135(Landslide)	150	600	300	400
A005-167(Landslide)	75	670	150	200
A016-010(Landslide)	250	1000	300	400
A113-015(Landslide)	50	528	90	120

Box 1: Earth-and-sand Extent of Access in "Landslide Hazard Mapping in Sri Lanka"

In Sri Lanka, investigation is conducted about the plane form of the earth-and-sand extent of access after the following landslide disaster generating from the survey of earth-and-sand disasters, such as a landslide which occurred in the past, a mudflow, and a ground flow.

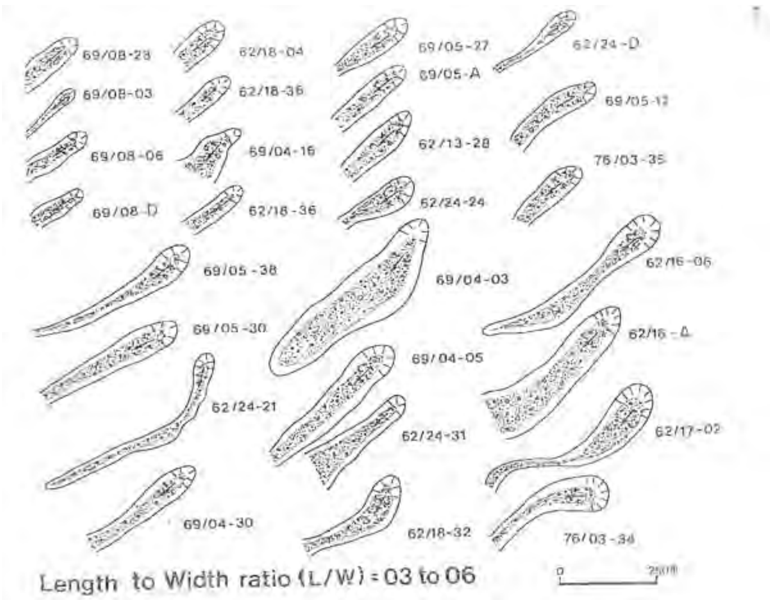


Figure 4-19: Cases with the shape of landslides in Sri Lanka (NBRO,1995)

The graph which totaled the earth-and-sand extent of access after these landslides disaster generating using by the width W, and length and a width ratio (L/W) is shown below.

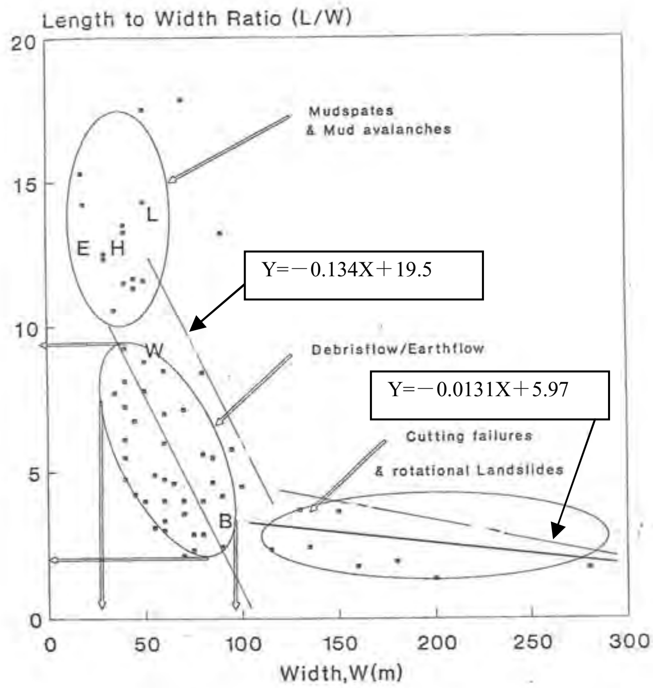


Figure 4-20: Relation between length to width ration and width of landslides

(NBRO, 1995, Equations and regression line in Figure is retouched)

In this graph, when "Cutting Failures & rotational landslide" and "Earthflow" are observed, the envelop line and regression line of each distribution are as follows.

〇Cutting Failures & rotational landslide

・Envelop line：Y=－0.0131X＋5.97

・Regression line：Y=－0.0075X＋4.14

〇Earth flow

・Envelop line：Y=－0.134X＋19.5

・Regression line：Y=－0.133X＋14.4

Reference: NBRO(1995):Manual - Landslide hazard mapping in Sri Lanka, Landslide Hazard Mapping Project SRL89/100

Box 2: Setup of the Range of the Cost-Benefit Analysis in the Landslide and the Measure against a Steep Slope in Japan

a) Steep slope (steep slope contiguous to flat grounds, such as a plain)

・The zone within the horizontal distance same to the upper part from the superior extremity of a steep slope as the height of a steep slope

・The zone of the horizontal distance of twice less than the height of a steep slope to lower part from the lower end of a steep slope

b) Landslide

Length：Horizontal distance which corresponds the twice of the length of landslide mass from a landslide zone lower end

Width：Width which corresponds the twice of the width of landslide mass

Provided that, when a moving mass flows into a mountain stream, the mudflow flood assumption range by the inflow mass is also included.

・When an object river is a dangerous stream of debris flow, it is the range of a debris flow danger area

・When an object river is not a dangerous stream of debris flow, it is the river bed to a point until a stream bed slope will be 3 degrees and the flat part (A fan and a bottom-of-a-valley plain) which relative height from river bed is several meters

・When an object river is not a dangerous stream of debris flow and moreover river bed slope is less than 3 degrees, an inundated area is set up according to the downstream situation

Box 3: The earth-and-sand extent of access in Japanese scientific articles

According to the research of Moriwaki and Hattanji of National Research Institute for Earth Science and Disaster Prevention, the moving range of the landslide mass (shows) that 2.0~2.5 times of the length of the movable body in a generating area are the maximum.

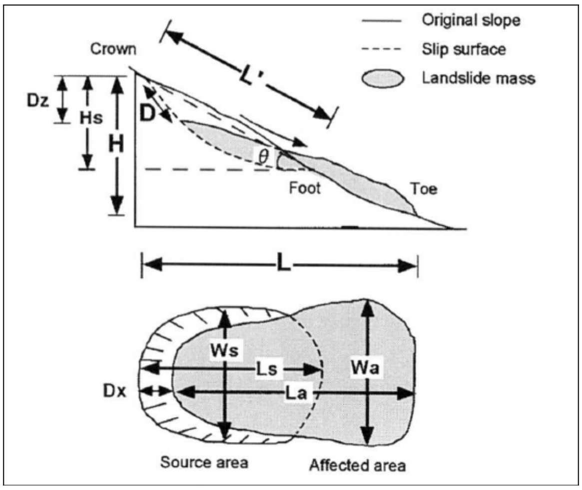


Figure 4-21: Geometry of a landslide and measured parameters

(Source: Moriwaki and Hattanji, 2002)

Reference: Hiroshi Moriwaki, Tsuyoshi Hattanji (2002): Morphometric analysis of landslides based on landslide maps, journal of Japan Landslide society, Vol.39, No.2, pp.54-62.

5 Aid approaches and strategies to the countermeasures for landslide disaster

5.1 Subjects for landslide countermeasure on the national roads

Based on the collected data and analysis, subjects for landslide countermeasures are summarized as follows. The national roads in the Highland area own very important role to the dairy life, economic development, tourism, and so on. Once landslide blocks the traffic, damage and influence to the area is enormous by isolation. Sri Lanka becomes middle developed country to catch up the developed countries in the field of road disaster prevention in the mountain area. Japan which has long time experience is one of the model countries of road disaster prevention for Sri Lanka. To conserve the beautiful scenery of Highland area, afforestation is also important technology for slope protection.

Table 5-1: Subject for landslide countermeasure on the national roads

Subject	Detail proposals
Aspect of policy	The view point of safety is indispensable for road development. Road disaster prevention plan of middle to long term shall be settled based on the determination of landslide prone section and prioritization.
Technical aspect	Improvement of landslide investigation methods and evaluation method of specific landslide hazard, development of monitoring devices shall be established by NBRO. RDA collects and accumulates the data of the disaster and keeps studying countermeasure methods from other developed countries such as Japan. Based on the activities and information, the guideline of road disaster prevention and detailed technical manual shall be prepared.
Aspect of disaster prevention	In addition to structural countermeasures, alert system and traffic control system shall be examined and prepared. Through collection of the long term data, the system become more reliable. Traffic control system connecting to the monitoring system shall be outlooked and installed.
Aspect of records	Disaster record and maintenance record should be recorded and accumulated.
Aspect of implementation and organization	RDA shall prepare road disaster and risk management section in the organization structure. Furthermore, capacity development program to foster specialists of disaster prevention shall be prepared in connection with NBRO experts.
Aspect of budget	In addition with the budget of recovery works, RDA shall prepare the fund of disaster prevention or preparedness. The budget shall be planed in the Road disaster prevention plan of middle to long term. Support from donors shall be continued.

5.1.1 Situation of RDA and NBRO

Due to the limitation of budget and technical aspects, road slope protection and landslide countermeasures have not been sufficiently implemented in Sri Lanka. Although national road sections in highland areas are very long and landslide disasters occur frequently, RDA relatively gives priority not to slope protection, but to new road construction and widening the roads. When landslides occur on the roads in highland areas, traffic is completely blocked and cities and towns can be isolated. Landslide on the highland roads is a crucial problem for the life and economy of the highland areas. Therefore the landslide countermeasure project is significant and will be a new aid approach to increase safety of the road.

RDA has responsibility to maintain the roads in good condition as well as secure the safety of lives and traffic. By implementing road slope protection, especially protection against landslides, RDA can contribute not only to road safety, but also to prevent losses of communities and the economy in the highland regions. Expected effects of the landslide countermeasures are as follows,

Effect1: Prevention and/or mitigation of landslide disasters

Effect2: Reduction of closing time to vehicles

Effect3: Improvement of safety and reliability

Effect4: Reduction of reconstruction cost

To achieve these effects, this study strongly proposes basic strategies and four aid approaches and to the countermeasures for landslide disaster using the Japanese new Project in the future.

Although, until now, RDA's road disaster prevention has focused on disaster response and recovery, in order to mitigate the damage to roads and the influence this has on traffic, preventive countermeasures such as slope protection, slope inspection and early warning are indispensable.

Discussions with RDA and NBRO can make them come to realize the importance of landslide countermeasures. Those ideas of risk management are new in RDA, but the knowhow and experience of the research and countermeasures for landslide have been accumulated in NBRO, utilizing their knowhow is indispensable.

Now, RDA and NBRO have started to grasp flows, such as a priority of the sites and project procedures (plan, budgeting, preparation of TOR, order and contract, construction, completion). The roles of RDA and NBRO in a new Project are as follows, based on the task, experience and capacity.

Table 5-2: Identification of Role of RDA and NBRO of a new Project

Period	RDA	NBRO
Preparation period	Jointly with NBRO	Jointly with RDA
Planning period	RDA will identify the unstable road slope locations along the main roads. Site selection will be carried out with the consultation of NBRO.	NBRO will identify the unstable road slope locations and possible landslide areas along the main roads and it will be discussed with RDA. NBRO will offer the local expert knowledge for planning, designing and costing for stabilizing the slopes and landslides
Implementation period	RDA will implement the project with the selected contractors under the JICA condition. RDA will assign staff for on the job training during construction.	NBRO will provide the necessary Technical Inputs and involve in Investigation, Designing, Construction Supervision and Monitoring during the project. NBRO will assign staff for on the job training for above mentioned tasks. Equipment and training requirement for NBRO to be included in the project.
Maintenance and Monitoring period	RDA will carry out the necessary maintenance and monitoring.	NBRO will carry out periodic monitoring, inspection, analysis, early warning and advice RDA where necessary.
Transfer of Technology	Investigation of unstable slopes, Design of mitigation measures and implementation of mitigation measures and maintenance.	Investigation of unstable slope / landslides, design, implementation and monitoring of mitigation measures. Preparation of manual for road construction in hill slope.

		Specialized equipments/Technology that will be used in the project will retain upon the completion of the project for future use
Budget allocation (RDA to NBRO?)	Funds will be allocated for RDA including NBRO component for their involvement.	NBRO allocation will be included in RDA budget

From interview to RDA and NBRO

5.1.2 Effective countermeasures for landslide disaster management

Based on the risk assessment of landslide, ease of construction, effects of countermeasures, and costs, suitable countermeasure works and implementation process are proposed. The Survey Team first proposes how to prioritize countermeasures and the RDA and NBRO examine the proposals and make a decision. The order of implementing priority countermeasures should be determined comprehensively in consideration of costs, ease of construction, environmental/social considerations, and benefits and effects. If the size of the landslide is too large to control and prevent the movement, transference of alignment is one effective countermeasure. In Japan, construction of tunnels and bridges to keep distance from the landslides is a common countermeasure.

Structural countermeasures are not perfect against disaster. To make fail-safe road system and to mitigate the human damage and traffic, early waning system should be installed in the highland area to prevent damage inflicted by landslides.

The Figure 5-1 shows the schematic relations among three elements for landslide disaster countermeasures. Not only structural countermeasures, but also early warning system and road planning support the safety of the highland roads.

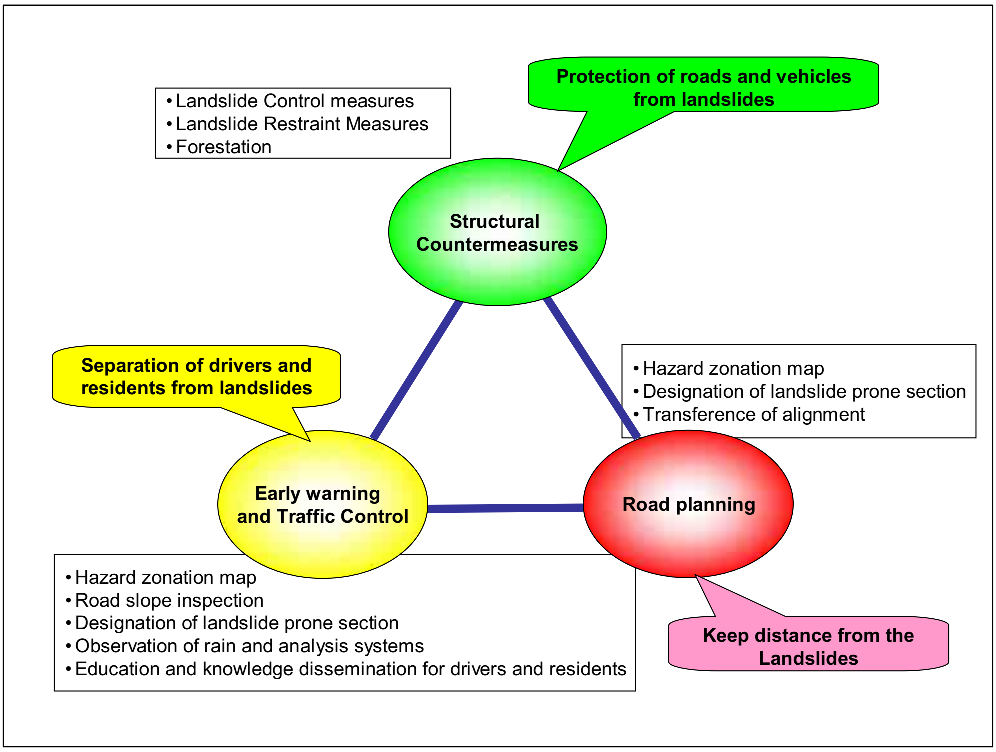


Figure 5-1 Three main elements for landslide disaster countermeasures

One of JICA's policies is to enhance the capacity of the counterparts through the project. JICA proposes a capacity improvement program of RDA and NBRO, which are required to implement countermeasures based on the mandate, work flow, and division of roles of respective organizations.

Road slope inspection is an important routine task to maintain roads in good condition and to identify the required type of measure.

5.2 Investigation and monitoring at "Rank C"

Prior to detail design and construction works, slope condition and landslide mechanism should be understood. The survey, research and monitoring shown below (Table 5-3) are expected to carry out before detail design. Cost estimation on each "Rank C" sites are shown in Table 5-3.

Table 5-3: Type of survey at "Rank C" site

Items	Type of survey
Topographic survey	Topographic mapping
	Cross section (Transverse Section)
	Cross section (Longitudinal Section)
Geological survey	Field survey
	Drilling (all core sampling, SPT and measurement of soil parameters)
Geophysical exploration	Laboratory test
	Simple seismic exploration
Hydrological investigation	High density electric sounding
	Rain gauge setting
Monitoring Items	Ground water level gauge setting
	Extensometer setting
	Pipe strain gauge setting
	Inclinometer guide pipe setting
	Rain observation
	Ground water level observation
	Extensometer observation
	Pipe strain gauge observation

Table 5-4: Cost estimation of investigation/monitoring at "Rank C"

No		Route No	Location		Type of landslide	Total US$
			Start (km)	End (km)		
1	A005-046	A005	46+600		Slope Failure (Rock Slide)	24,788
2	A005-091	A005	91+019		Slope Failure	18,431
3	A005-135	A005	135+200	135+700	Landslide	1,131,725
4	A005-167	A005	167+497	167+541	Landslide	1,330,063
5	A016-010	A016	10		Landslide	1,388,713
6	A113-015	A113	16/5	16/6	Landslide	362,038
Ground Total						4,255,758

5.2.1 Topographic survey

Large-scale topographical maps above 1/10,000 are available in Sri Lanka, and those maps shall be used for landslide hazard mapping. But for the detail investigation and design, large scale topographic map, such as 1/1,000 or larger is necessary. Landslide blocks are identified by analyzing topographical features, and represented in the detailed topographic maps. For detail design of countermeasure, large scale topographic map should be prepared.

Landslide cross sections shall be drawn on the geological cross sections. The cross sectional line is equal to the main traverse line or sub main traverse line which are the same as the direction of the movement of landslide. The cross section reflects the geological survey information and landslide anomaly information (such as position of crown and toe, angle of crown cliff and other information regarding the estimation of slip surface).

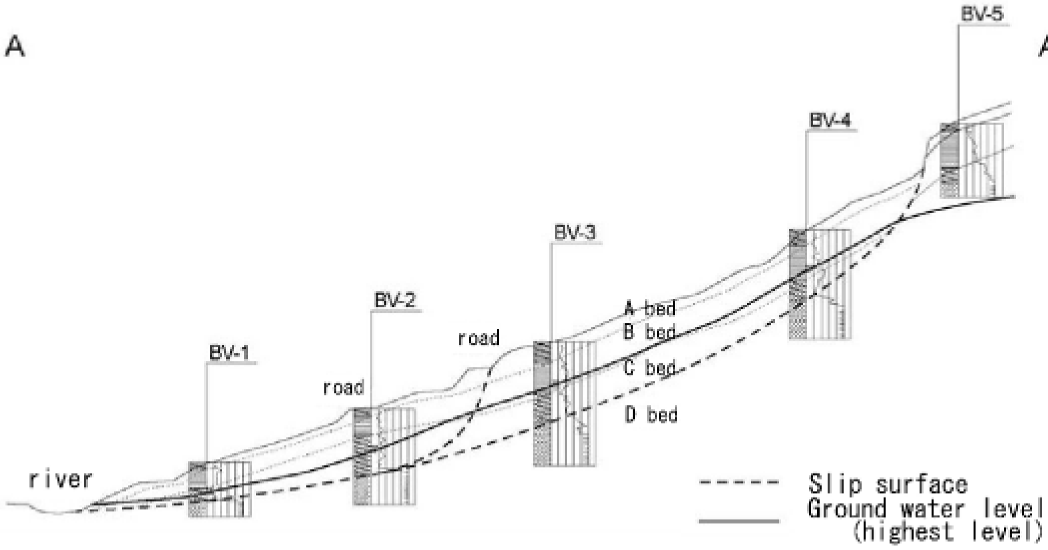


Figure 5-2: An example of landslide cross section

5.2.2 Geological survey

The geological survey should be conducted to figure out the slope condition, mechanisms of landslides and their impacts to the road. It is also necessary to study the literature of previous research before the field surveys to identify the geological setting of the site.

Table 5-5: Items of field investigation

Investigation Item		Description
Geomorphological information	Landslide landform	Distribution and orientation of main scarps, Distribution and orientation of steps and cracks Distribution and orientation of mounds and depressions
	Slope failure landform	Type and size of slope failure Old slope failures
	Erosion landform	Gullies and rills, erosion by stream
Geological information	Surface geology	Materials, hardness, thickness of soil, stability
	Base rock	Rock type, facies, hardness, age of rock, metamorphism, weathering
	Structure	Distribution and orientation of faults and fracture, strike and

Investigation Item		Description
		dip, joint,
Hydrological information	Surface water	Stream water channel, pond, swamp
	Ground water	Spring water
History of activities and damage	Activities	Date of the movement, rate of the movement,
	Damage	Date and period of damage, objects, type of damage, countermeasure work
Susceptibility of landslide		Activity, Influence to the objects, for example road and houses, risk evaluation

5.2.3 Landslide monitoring by instruments

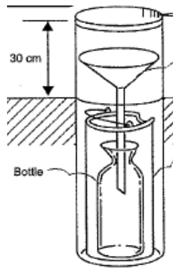
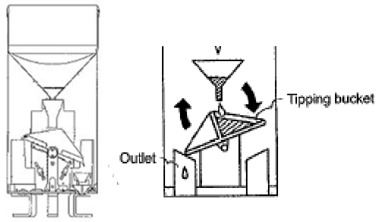
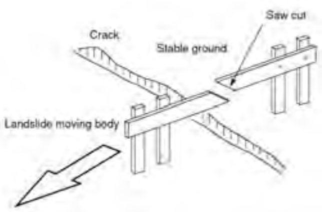
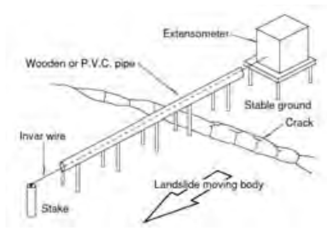
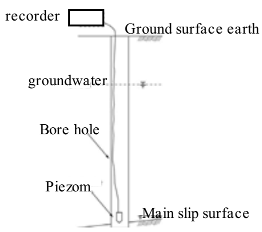
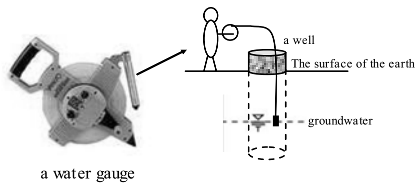
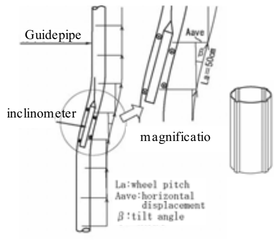
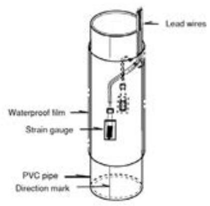
Monitoring is conducted to observe landslides and investigate the mechanisms. Main observation to investigate landslide mechanism is measuring the amount of movement, the circumstances of slip surfaces, change of groundwater levels. It concludes what kind of rainfall events and groundwater situations cause landslides and we can assess in the landslide details (e.g. depth of slip surface, slide direction and the slipping velocity) from the results. In addition, the monitoring makes landslide predictions possible. Therefore, it can prevent damage to the roads.

Landslide Monitoring is divided into 4 types as follows.

a. Monitoring rainfall
b. Monitoring surface deformation
c. Monitoring ground water level
d. Monitoring subsurface (slip surface) movement

Common observation equipment is show in Table 5-6. It provides a general explanation of monitoring equipment with a focus on the equipment installed in Sri Lanka.

Table 5-6: Observation types and equipments

<table>
<tr><th>Observation type</th><th colspan="2">Equipment</th></tr>
<tr><td>a. Monitoring rainfall</td><td>Standard rain gauge (reservoir-type) : Rain is received in a reservoir and an observer measures the quantity accumulated over a certain period of time with a measuring cylinder.

</td><td>Tipping-bucket rain gauge : If a certain amount of rainfall accumulates in a tipping-bucket, it will fall automatically.

</td></tr>
<tr><td>b. Monitoring surface deformation</td><td>Simple deformation detection board：simplified extensometer, easy, and many can be set up

</td><td>Extensometer： measuring the amount of movement, recording data continuously.

</td></tr>
<tr><td>c. Monitoring ground water level</td><td>Automatic water level meter：investigating the distribution area, ground water level and aquifer characteristics.

</td><td>※Usage confirmation of groundwater (as appropriate)：conducting a measurement of groundwater level in the case of groundwater use.

</td></tr>
<tr><td>d. Monitoring subsurface (slip surface) movement</td><td>Borehole inclinometer：measuring the amount of movement, investigating the position of a slip surface. It can not be used for active landslides

</td><td>Pipe Strain Gauge：measuring the amount of a landslide movement and a position of a slip surface, records data continuously, is durable (1-2 years), It can be used for active landslides.

</td></tr>
</table>

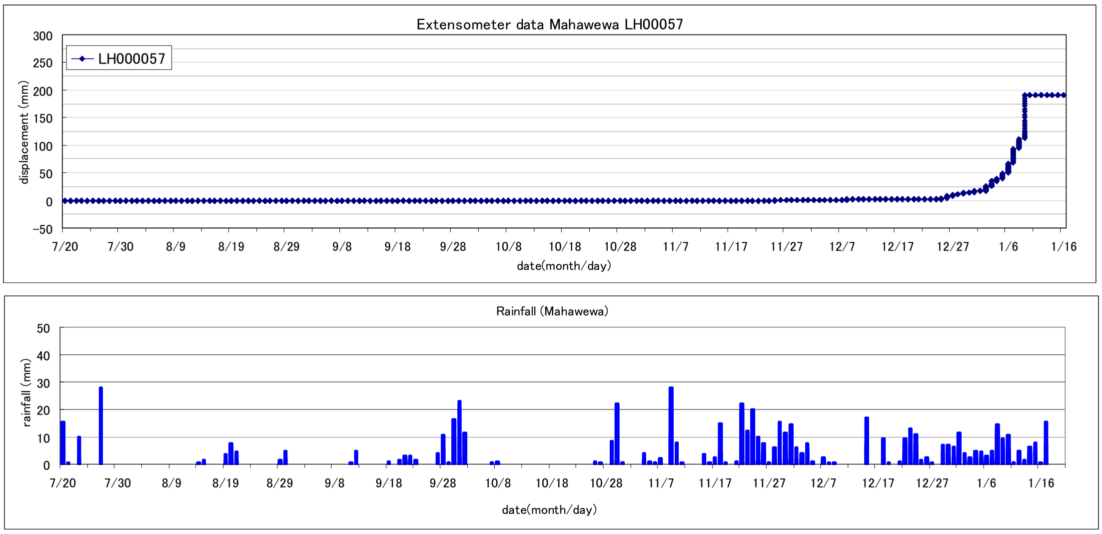


Figure 5-3: Sample fixed data-set of Extensometer（source: DiMCEP）

5.2.4 Drilling survey

Drilling survey is implemented to sample soil and rock in the ground orderly and to clarify the geology, geological structure and slip surface. In principal, all-core sampling should be conducted. The diameter of the borehole depends on subsequent surveys and loggings such as inclinometer, Pipe Strain Gauge, groundwater level meter or ground water logging etc.

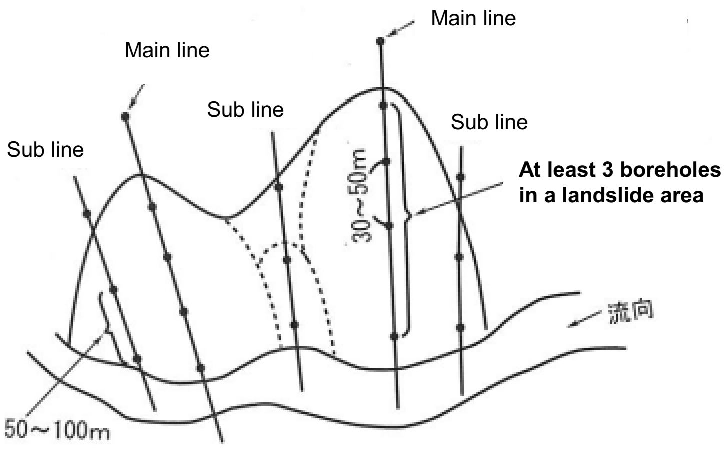


Figure 5-4: Location and quantity of drilling survey

1) Classification of drilling machine

The drilling machines are generally classified into three categories which are a percussion type, a rotary type and a rotary percussion type.

2) Core sampling and method

For core sampling, rotary type drilling machines are used. About boring technology, there are lots of requests from geologists related to the precision of an investigation purpose. Improvement of the core recovery rate is regarded as the most important factor of geological investigation boring. In addition, it is important to grasp the geological data precisely and record the boring information and to submit the drilling report which is necessary for geological investigation analysis. There are core boring data such as geological conditions, change of stratums, situation of the clay which is related to landslides, situation of the groundwater seepages out and in, lost circulation zone, bit load, rotation speed, and core boring penetration rate.

5.2.5 Geophysical exploration

1) Seismic exploration

The purpose of the elastic wave exploration is to estimate the underground structure and to obtain the basic information for groundwater drainage design. In this investigation, seismic refraction method of elastic wave exploration (P-wave) using hammer blowing (it is called stacking method) was conducted.

By using hammer blowing as the elastic wave source, strong waves as that caused by explosive agent cannot be obtained. Hence, when the receiving point is far from the shot point, the wave transmitted from the shot point may become weak because of the possible absorption by the ground vibration. To increase the intensity of the signals, repeated shots at the same shot point are necessary. Through the superimposing of the received signals, the ratio of signal to noise (abbreviated as S/N) can be increased. This method is called stacking method (vertical stacking).

2) Electrical prospecting

The purpose of the electrical prospecting is to estimate weathered layer of landslide slope, bedrock layer, permeable layer and their continuity, the existence of the faults and their continuity, based on the two dimensional distribution of the ground resistivity, and to obtain the basic information for the planning of the groundwater drainage work.

In the electrical prospecting for the purpose of civil engineering, resistivity method is one of the most popular methods. The resistivity method is also commonly used in landslide investigation. In Japan, the two dimensional electrical prospecting with resistivity method is mainly and widely used.

5.3 Early warning system and traffic control

Preventing the occurrence of landslide disasters by controlling the mechanical and incident factors with the installation of structural works is the most basic approach, and all who are involved in disaster prevention efforts are arduously waiting it to be realized. However, the rage of the disaster sometimes attacks us with a magnitude beyond our expectation. Because it is extremely difficult to identify the disaster site and the occurrence time in advance, complete prevention of landslide disasters is virtually impossible.

Accordingly, together with the continuous efforts to prevent the occurrence of landslide disasters, another important aspect has to be focused which is to prevent the enlargement of damage after a disaster has occurred on roads. It is well known that a traffic control and early warning are extremely effective in preventing and mitigating damage to humans and infrastructures on roads by landslide disasters.

As non-structural measures against landslide disasters, two methods are considered: (i) to establish traffic control based on the rainfall that becomes the trigger of landslide disasters on roads, (ii) to develop early warning system.

The approach of traffic control and early warning system on roads is explained as an effective support strategy countermeasure for landslide in this chapter.

5.3.1 Current status of early warning system and traffic control

a. RDA

RDA closes national road or blocks the half of road when serious landslide disasters occur on roads. However, as traffic controls before landslide disaster happening, there is no system for early warning, traffic control on road only for landslides.

The Disaster Management Centre (DMC) has developed warning and evacuation system involving local bodies such as Divisional secretariats, Pradeshiya Sabhas and local NGOs for any natural disaster.

b. NBRO

NBRO initiated issuing of early warnings of potential landslides to keep the concerned district officials and the local residents vigilant at the times of heavy rains. Having been identified by the "Disaster Management Road Map" of DMC as the designated agency for issuing landslide early warning, NBRO formally issues such warnings since October 2008.

NBRO has already developed a model for land sliding for selected catchments in the Elapatha, Nivithigala, Kahawatta, Kalawana and Pelmadulla divisions in Ratnapura district based on the above parameters as a pilot project. After the Ratnapura Project, 2 sites were selected for rain gauge installation site, at Peradeniya and Walapane. From this two sites, rainfall data is transferred through network system to the Web site and mobile phones of the officers in charge.

Based on the success of the pilot project, NBRO expect to expand the model for issuing early warning at national level.

NBRO has discussed the reference rainfall for early warning on landslide disasters in local communities. Although the reference rainfall has been established through past rainfall data at site, the main issue of the reference is that the forecast ratio is not good; i.e. a landslide disaster occurs before ever the rainfall get up to the reference, or any landslide does not occur even over the reference rainfall.

However, NBRO thinks that the continuous rainfall monitoring is necessary to develop a highly accurate early warning system on landslide disasters in the future.

Figure 5-5: Output of Cumulative Rainfall of 24 Hours
(Source: NBRO's Presentation)

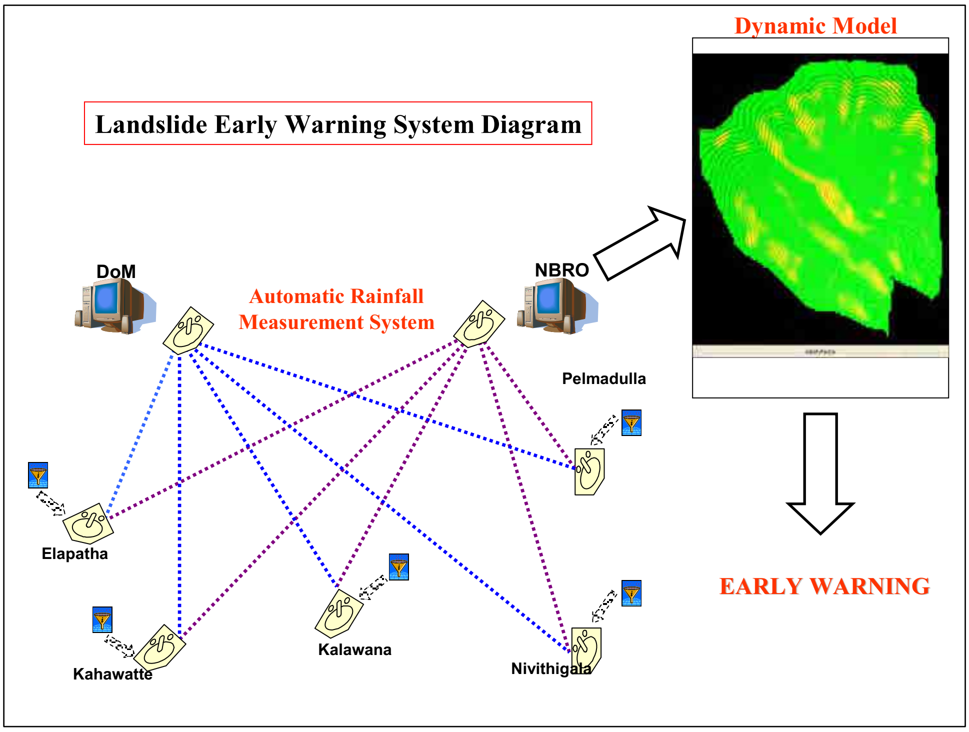


Figure 5-6: Curent Landslide Early Warning System in Ratnapura District
(Source: NBRO's Presentation)

Table 5-7: Current threshold limits for landslide early warning

Reference rain fall	Action to be taken
75mm within 24hr.	Alert
100mm within 24hr.	Warning (to prepare)
150mm within 24hr. and/or 75mm within one hr.	Evacuation

c. Local community

Several local communities have their own early warning/evacuation system for landslide disasters as follows. However there is no traffic control system even in the local communities.

c.1 A005-42/43 Ramboda GN division, Kotmale DS division, Nuwara Eliya district (Ramboda Landslide)

The residents are aware about the risk of landslides when continuous rainfall more than five days happens. Although NBRO announces to residents that more than 25mm/hour rainfall may be trigger landslides, there is neither system nor monitoring device for rainfall in the community. NBRO is planning a program of the development of an alarming system on landslide, but it has not been implemented.

c.2 A016-010 Panketiya, Haputale DS division (Kahagala estate), Badulla district

The community living on the down slope is aware about the risk of landslides. They also have a disaster management committee and a co-coordinator. The task assigned to the co-coordinator is to activate the warning system making a warning noise by hitting a metal plate like a “skillet” using a metal rod like a “ladle”. The decision of the warning is made by the co-coordinator’s feelings.

c.3 A026-055 Oyathenna Landslide in Kandy District

There is no disaster management committee, program for early warning. However, the residents move to a friend’s or relative’s home as voluntary evacuation when it rains hard. The residents consult with an administrative officer on the village over the phone in such an occasion to get his advice.

c.4 A113-015 Nawalapitiya Landslide

RDA has continuous programs to check the soil instability through,

1) monitoring of the possible change of ground levels;

2) monitoring of ground water level;

3) observation of cracks, small collapses and rock falls on slope/road.

RDA installed “level stones” to monitor the ground levels, which are concrete piles around 20-30 cm height as measurement devices at different spots. RDA also keeps to clean drains to avoid overflow by heavy rainfall. However, the officer of RDA who is in-charge does not have scientific assessment methods for the landslide risks, and not issue warning to the community or communicate with relevant authorities.

There is no disaster management committee or program for early evacuation for the residents. The residents are not informed of the result of the monitoring, nor aware necessary actions they should take accordingly.

5.3.2 Methodology of traffic control and early warning system on roads

In order to establish traffic control and early warning system on roads, the procedure is as follows;

a. Collection and arrangement of rainfall data and landslide disaster records
b. Setting of reference rainfalls for traffic control and early warning
c. Decision of roles of organizations responsible for delivery and transmission of information
d. Operation of traffic control and early warning against landslide disasters

a. Collection and arrangement of rainfall data and landslide disaster records

The activity and movement of landslide disaster are highly connected to ground water level in the landslide mass. The ground water level is shifted by the amount of rainfall, especially hourly rainfall and daily rainfall. Therefore, establish traffic control based on the rainfall that becomes the trigger of landslide disasters on roads, it is inevitable to collect the rainfall data and landslide disaster records and to analyze the relationship and the correlativity.

a.1 Rainfall data

After the decision of rainfall stations located in and around each landslide disaster hazard area, the rainfall data as shown below is collected at representative rainfall stations.

- Daily rainfall: Daily rainfall data during a longest possible period (generally, 10-20 years) is collected.
- Hourly rainfall: 1) Rainfall data at the time of disaster occurrence (causing rainfall): hourly rainfall during a series of rains (a continuous rain having a period of no rainfall for 24 hours or over before and after) including the time when a disaster occurred. 2) Rainfall data other than above (non-causing rainfall): hourly rainfall during a series of rain which include a rain having a continuous rainfall of 40 mm or over or hourly rainfall intensity of 10 mm or over.
- Past maximum rainfall: Daily rainfall and hourly rainfall intensity that are ranked as the upper ten including the past maximum.
- Results of rainfall analysis: Probability daily rainfall and probability hourly rainfall

a.2 Landslide disaster records

Landslide disaster records during a longest possible period (generally, 10-20 years) regardless of damage as shown below is collected from a road authority.

- Date and location.
- Disaster type (debris flow, landslide, slope failure, rock fall etc.).

- Damage situation (human damage, building damage, road damage, and damage cost and its calculation method).

- Duration for the disaster recovery.

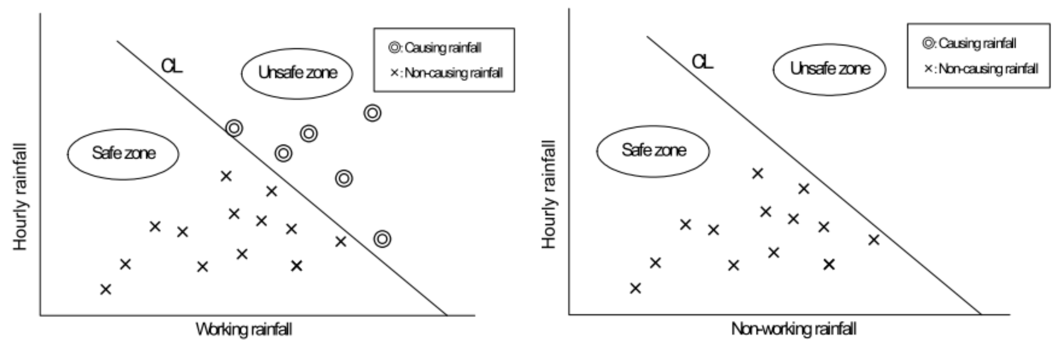
- Countermeasure works and the countermeasure cost.

b. Setting of reference rainfalls for traffic control and early warning

The rainfall data at the time when a landslide disaster, a debris flow or a slope failure, was caused (called the causing rainfall) and the rainfall data at the time when those disasters were not caused (called the non-causing rainfall) shall be collected and recorded.

Using past records and through an inquiry to the local people, the occurrence time of past debris flows and slope failures shall be identified. These data and the rainfall data obtained at a representative rainfall station shall be recorded. Because the total rainfall differs by the time of disaster occurrence, it is very important to obtain the highly accurate information about the exact occurrence time. From various data on a series of rain collected at a representative gauging station, the non-causing rainfall data shall be taken out. They are used to find a critical line that separates the occurrence and non-occurrence of landslide disasters.

Based on the collected data, An X-Y graph is prepared as shown in Figure 5-7. In the Figure, a boundary line is drawn between the landslide causing rainfalls and the non-causing rainfalls. The upper right side of the boundary line is the unsafe zone where a landslide disaster may occur and the lower left side of the line is the safe zone where a landslide disaster may not occur. This boundary line is called the CL (Critical Line) which distinguishes the occurrence and non-occurrence of a landslide disaster.



(a) If causing rainfalls are available **(b) If causing rainfalls are not available**

Figure 5-7: Boundary between landslide causing rainfalls and non-causing rainfalls

Methods for setting the reference rainfall for issuing a warning "WL (Warning Line)" and the reference rainfall for instructing an evacuation "EL (Evacuation Line)"are explained. Before setting the WL and EL, it is needed to determine the timing to give a warning issuance or an evacuation instruction. It means that how many hours before the forecasted occurrence time a warning issuance or an evacuation instruction should be given so that people as well as organizations can take necessary actions for safety. After that, the WL and EL are set in consideration of an estimated rainfall during the spare hours (forecasted rainfall) and the CL. But, the timing of warning issuance and evacuation instruction can be determined based on the conditions of each area. As to the estimated rainfall during the spare hours, the probable rainfall or the short-term rainfall may be used depending on conditions, such as the non-hit rate of a warning. Japan.

Table 5-8 shows examples of the reference rainfalls for traffic control and early warning in Japan.

Table 5-8: Examples of the reference rainfalls for traffic control and early warning in Japan

Location	Average annual rainfall (mm)	Probability precipitation		CL (mm)		WL (mm)		EL (mm)	
		Daily rainfall (mm)	Hourly rainfall (mm)	X-intercept	Y-intercept	X-intercept	Y-intercept	X-intercept	Y-intercept
1	—	329	81.4	86	238	—	—	—	—
2	—	329	81.4	86	238	—	—	—	—
3	—	329	81.4	86	238	—	—	—	—
4	2,913	329.7	82.8	178	178	43	108	85	134
5	3,078	355.7	99.1	367	317	222	474	266	361
6	4,345	395.5	113.4	446	385	572	321	436	446
7	2,160	396.5	104.2	218	218	101	251	133	209
8	—	416	98	433	140	114	174		
9	1,103	436.3	71.8	379	34				
10	2,415	303.4	84.8	182	182	55	138	91	143
11	2,193	318.3	59.8	246	246	141	349	170	268
12	2,560	330.5	76.4	257	257	129	319	169	266
13	2,265	336.8	69.8	222	222	105	260	139	219
14	2,324	355.5	74.3	318	318	192	476	231	364
15	2,191	364.4	76.5	167	167	54	133	80	127
16	2,568	407.8	75	201	201	71	175	112	177
17	2,087	170	71.6	216	216	150	370	166	261
18	2,779	211.6	56.3	193	193	129	319	143	225
19	2,049	225.1	42.9	204	204	141	349	158	248
20	2,671	233.2	46.8	195	195	135	333	150	236
21	—	236.9	50	181	181	122	300	140	220
22	3,004	266.5	60.3	208	208	142	351	156	245
23	—	334.1	73.5	404	135	112	94	196	104
24	1,875	335.3	85.9	253	253	146	362	179	282
25	2,702	338.7	72.7	275	275	158	391	193	303
26	2,097	350.3	81.1	213	213	90	224	126	198
27	2,533	364.9	95.7	274	274	140	346	179	281
28	2,521	372.8	91.4	225	225	105	260	133	209
29	2,070	398.9	119.3	264	264	137	339	170	268
30	2,314	446.8	95.3	326	326	203	504	240	378
31	2,522	448	74	330	330	220	544	252	397
32	2,214	527.3	123.8	272	272	147	363	180	283

c. Decision of roles of organizations responsible for delivery and transmission of information

The roles of organizations responsible for delivery and transmission of information for landslide disaster should be decided in advance for the effective establishment of traffic control and early warning system.

Organizations responsible for the delivery of warning information on landslide disasters shall: 1) formulate plans for the landslide disaster monitoring system, the rainfall gauging system, and the landslide disaster forecast system; 2) operate and maintain those systems; and

3) deliver warning information on landslide disaster to the organizations responsible for emergency measures, based on the monitoring results and disaster forecast results.

It is important to clearly specify the responsible organizations that undertake emergency measures when a landslide disaster is forecasted. The principal roles of responsible organizations for emergency measures against landslide disasters are:

1) Collection and transmission of disaster-related information;

2) Transmission of warnings on landslide disasters;

3) Establishment of landslide disaster hazard areas;

4) Order to take emergency response against landslide disasters;

5) Traffic control instruction for emergency response against landslide disasters; and

6) Emergency measures for emergency response against landslide disasters.

d. Operation of traffic control and early warning against landslide disasters

A traffic control and early warning against landslide disasters must be based on monitoring and observation of landslide disasters or forecast by reference rainfalls for warning. Then the system shall be used for the prediction of landslide disasters. Warning information by the system must be informed to road users and it must be used for traffic control and its action.

In Sri Lanka, a telemeter system is not established. Therefore, an observer must collect the information on rain gauge installed near the area, and visual observation of landslide disasters. Then an observer must contact to the disaster monitoring center and must report the detected information to the center. A warning system can be operated as follow.

1) Observers of rainfall and landslide disasters must contact to the disaster monitoring center with a radio or a cellular phone when the risk of landslide disasters is detected.

2) In response, a center predicts landslide disasters and judges the necessity of traffic control recommendation.

3) When an alarm is given, signals to control the traffic will be on.

In operation of traffic control and early warning system, it is necessary to build staff arrangement and organization required for landslide disasters information, and carry out the suitable operation.

5.3.3 Approach of traffic control and early warning system

In order to develop the effective traffic control and early warning system, the continuous and high accurate monitoring of rainfall and the analysis between the rainfall and landslide movement is necessary. Therefore, the equipment provision of monitoring device and the establishment of the traffic control and early warning system for landslide disaster is proposed.

NBRO has discussed the reference rainfall for early warning on landslide disasters in local communities. Although the reference rainfall has been established through past rainfall data at site, the main issue of the reference rainfall is that the forecast ratio is not good; i.e. a landslide disaster occurs before ever the rainfall get up to the reference, or any landslide does not occur even over the reference rainfall. However, NBRO thinks that the continuous rainfall monitoring is necessary to develop a highly accurate early warning system on landslide disasters in the future.

The purpose of this project is to support the establishment of the traffic control and early warning system for landslide disaster by providing of the automatic rain gauges and their real-time monitoring systems.

This project is aiming at setting a warning threshold based on the relationship among the landslide movement, the new rainfall gauges and other monitoring devices (extensometer, groundwater level meter and inclinometer) which were provided by previous JICA's projects. As one possibility, a Doppler radar which will be installed to DOM (Department of Meteorology) in another JICA's project can be linked to the traffic control and early warning system. Table 5-9 shows the outline of the equipment provision for EWS by rain fall observation.

Table 5-10: Outline of equipment provision for EWS by rain fall observation

Project title	Early Warning System for the Traffic Control
Brief summary	This project is to support the establishment of the traffic control and early warning system for landslide disaster by providing of the automatic rain gauges and their real time monitoring systems.
Overall goal	To mitigate landslide problems along the national road in Sri Lanka
Project objective	To support the establishment of the traffic control and early warning system for landslide disaster
Implementation organization	NBRO/RDA
Related organization	DMC, DOM, DDMCU, DS etc.
Project period	1 year for installation, 5 year for monitoring and operaton
Outputs	
1. Automated rain gauges with data logger and solar battery system are installed in 30 areas 2. Real-time monitoring systems and its communication network are established 3. Warning thresholds based on monitoring are examined 4. Traffic control and early warning system is considered	
Inputs	
Equipment and tool	1) Automated rain gauge * 30 2) Solar battery system* 30 3) Data logger* 30 4) Web based data monitoring software* 30 5) Desk top PC* 2 6) Web server* 2 7) 42 LCD displays* 2 8) Lap top PC* 1 9) Server rack* 2 10) Media tabs* 2 11) Server room preparation* 2

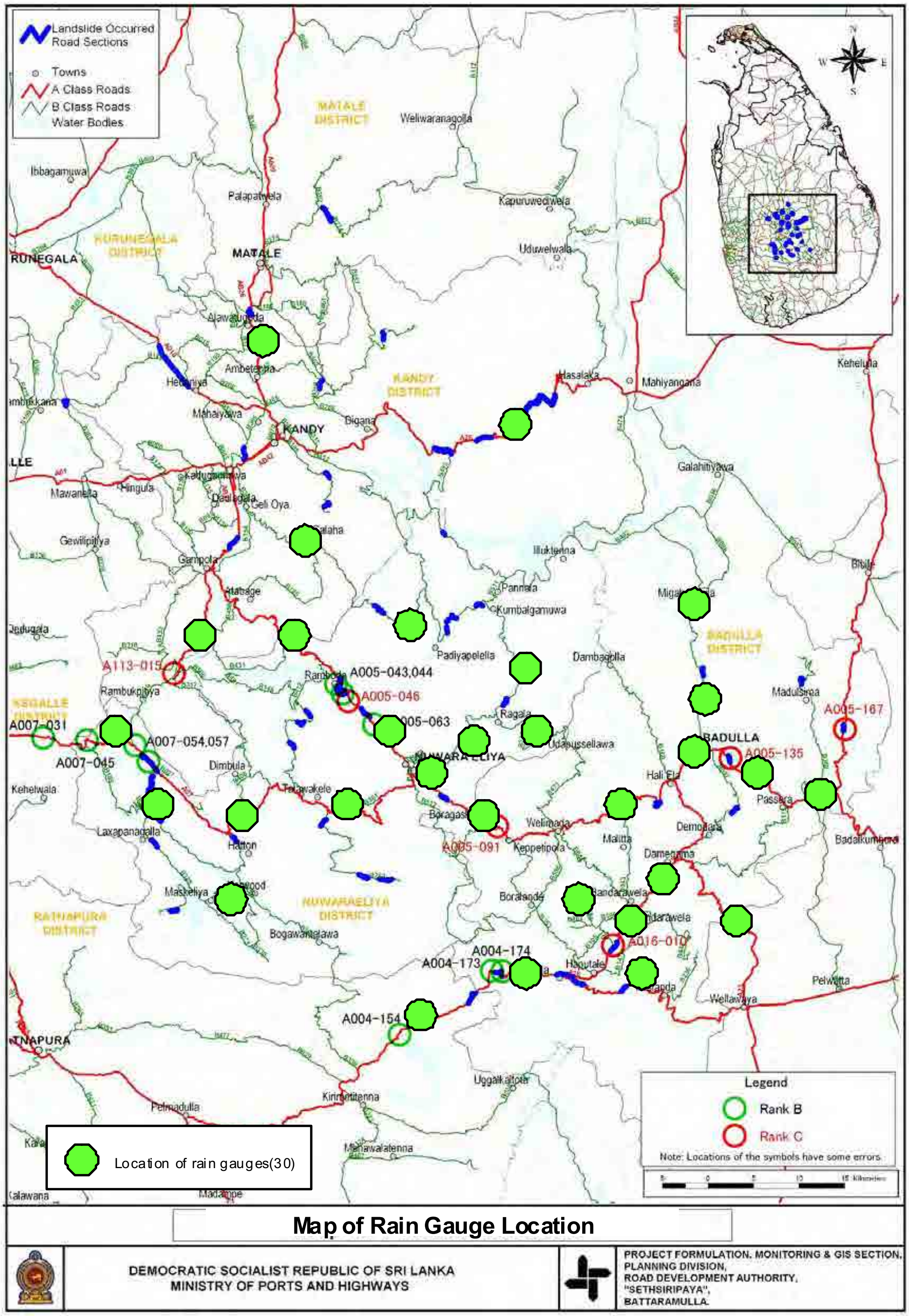


Figure 5-8: Map of rain gauge location for the Early Warning System

NBRO has long time experience for rain data collection, analysis and issue of warning, and forms government level network. In the New ODA Loan Project, NBRO has a plan that EWS is to be included in the government level net work for disaster prevention.

Through the discussion between RDA and NBRO, rain data collection and analysis are carried out by NBRO and comparison with the amount of reference rain fall, NBRO transfer the situation to RDA. Main organization for construction of the EWS should be NBRO (Figure 5 9).

In the stage of selection of the equipment, NBRO expressed maintenance problems are important. Procurement of the new equipment and spare parts should be easy in Sri Lanka.

At present, it is needed to go to a disaster site to collect observation data on landslides. However, phone line or wireless networks could make real-time data acquisition from remote locations and proper traffic control possible. In addition, prediction methods can be developed by progress of disaster observation techniques. We aim to achieve safe road management in the near future.

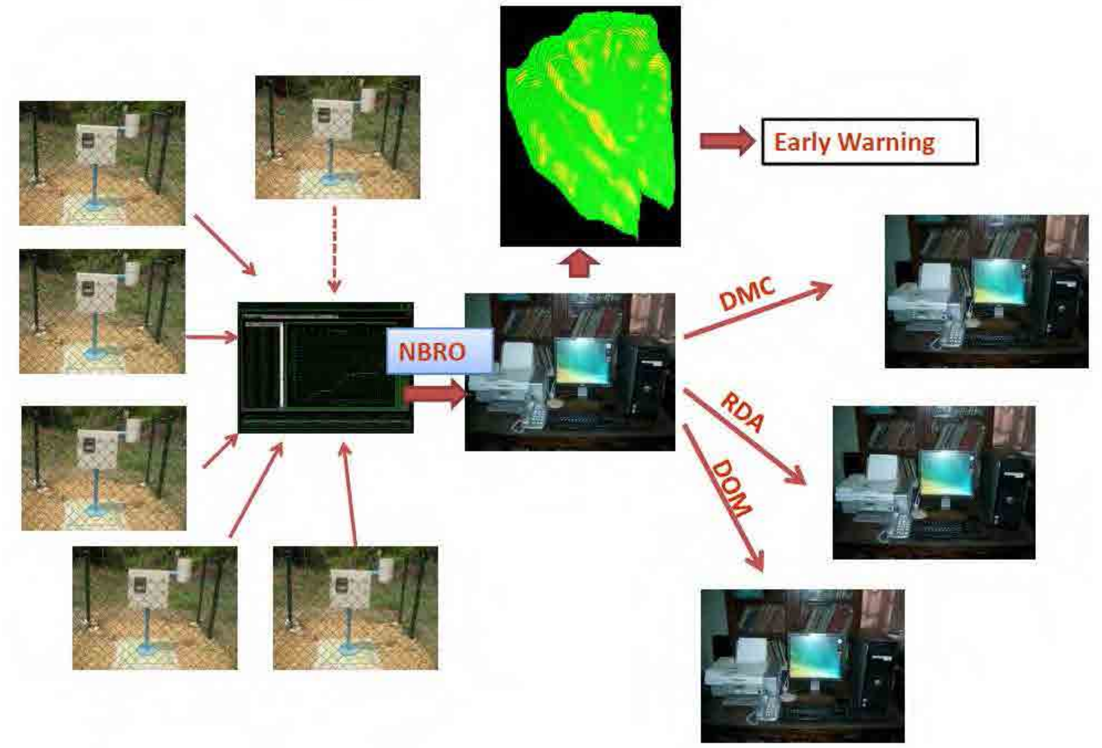


Figure 5-9: Images of a rain data transfer and warning system for landslide

5.4 Capacity development project on landslide management in RDA/NBRO

In order to avoid landslide disasters on roads, the installation of structural works is one of the best countermeasures. However, even if the structural works for landslide would be constructed on all over the roads, the related organization such as RDA and NBRO should manage the countermeasure works and establish the management system for the prevention of future landslide disasters.

Therefore a capacity development on landslide management is proposed to avoid the above mentioned problems. This capacity development is aimed at transferring a series of technologies including investigation, design, construction management, and thus develops the abilities of the related organization such as RDA and NBRO to ensure that it can utilize the supplied equipment, understand the mechanism of landslide, and implement landslide countermeasures through On-the-Job-Training (OJT) at Rank B and C sites by the support of Japanese side.

RDA will receive on the job training for Investigation of unstable slopes, Design of mitigation measures and implementation of mitigation measures.

NBRO will receive on the job training for Investigation of unstable slope / landslides, design, implementation and monitoring of mitigation measures. Preparation of manual for road construction in hill slope is included in Transfer of Technology. Specialized equipments/Technology that will be used in the project will retain upon the completion of the project for future use.

The basic policy of this capacity development is to provide technical transfer to the related organization such as RDA and NBRO regarding the overall flow of landslide countermeasures, individual countermeasure technologies, and their position in the road disaster prevention policies in order to establish a system that enables spontaneous road disaster prevention management. Table5-9 shows the outline of the capacity development.

Table 5-11: Outline of capacity development on landslide management

Brief summary	The capacity development is aimed at transferring a series of technologies including investigation, design, construction management, and thus develops the abilities of the related organization to ensure that it can utilize the supplied equipment, understand the mechanism of landslide, and implement landslide countermeasures
Target organization	RDA, NBRO, Sub-contractors, Local consultants
Outputs	
1. Landslide monitoring is carried out to analyze landslide mechanism 2. Countermeasure work is effectively carried out	
Inputs	
Training/seminar	1) OJT at Rank B and C sites 2) Seminars (2-4 times a year)

The detail of the activities to input is as follows;

1. Landslide monitoring is carried out to analyze landslide mechanism

Landslides and countermeasure works will be monitored. When monitoring is started, discussions on the type, method, and measurement frequency will be held.

2. Countermeasure work is effectively carried out

- Preparation of basic designs

The basic design greatly affects the quality of the subsequent detailed design and construction. Also, a system will be constructed for design technology for landslide countermeasures so that in the future RDA will provide technical support, and in the detailed design, etc., RDA will provide advice to the external consultants.

- Preparation of technical specifications for external commissions

Detailed design and calculation of landslide countermeasures will be commissioned from private consultants, and special construction work in the countermeasure construction work, such as landslide control piles or anchors, etc., will be commissioned from external private contractors. At this time, the technical specifications necessary for commissioning the work will be prepared mainly within RDA. Therefore guidance will be provided for the appropriate preparation of technical specifications.

- Quality control of externally-commissioned construction

Site supervision of the construction and site management of medium term countermeasure construction will be carried out, or be commissioned from an external private consultant. Technical guidance will be given to RDA/NBRO, through OJT with the objective of ensuring sufficient quality of construction on site.

- Quality management for construction

Parameters such as quality control items and construction procedures indicated in the technical specifications and design drawings for countermeasure construction will be studied and discussed sufficiently with externally-commissioned consultants. Criteria for selection of external construction contractors will be based on a comprehensive evaluation with emphasis on cost comparison as well as construction management capability.