Sri Lanka
National Building Research
Organisation (NBRO)

The Democratic Socialist Republic of Sri Lanka

Technical Cooperation for Landslide Mitigation Project

Final Report

September 2018

Japan International Cooperation Agency (JICA)

Earth System Science Co., Ltd.

Nippon Koei Co., Ltd.

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Abbreviation

ADB	Asian Development Bank
ARTI	Agrarian Research and Training Institute
AWS	Automatic Weather Station
CBDRM	Community-Based Disaster Risk Management
CBO	Community Based Organization
CC&CRMD	Coast Conservation and Coastal Resources Management Department
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CHPB	Center for Housing Planning and Building
CMACast	China Meteorological Administration forecast
CMC	Colombo Municipal Council
COMS	Communication, Ocean and Meteorological Satellite
DiMCEP	Disaster Management Capacity Enhancement Project Adaptable to Climate Change
DM	Disaster Management
DMC	Disaster Management Centre
DEM	Digital Elevation Model
DOA	Department of Agriculture
DOM	Department of Meteorology
DRM-P	Disaster Risk Management through partnerships
DSWRPP	Dam Safety and Water Resources Planning Project
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EWS	Early Warning System
FEWS	Flood Early Warning System
GDP	Gross Domestic Product
GIZ	German Development Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit)
GN	Grama Niladhari
GPS	Global Positioning System
GSMB	Geological Survey and Mines Bureau
GTS	Global Telecommunication System
HFA	Hyogo Framework for Action 2005 - 2015
IATA	International Air Transport Association
ID	Irrigation Department
IFRC	International Federation of Red Cross
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LA	Local Authority
LRRMD	Landslide Reserch and Risk Management Division
MASL	Mahaweli Authority of Sri Lanka
MDM	Ministry of Disaster Management
MED	Ministry of Economic Development
MEPA	Marine Environment Protection Authority
MFPs	Minor Flood Protection schemes
MIWRM	Ministry of Irrigation and Water Resources Management
MOU	Memorandum of Understanding
NARA	National Aquatic Resources Research and Development Agency
NBRO	National Building Research Organization
NCDM	National Council for Disaster Management
NDMCC	National Disaster Management Coordination Committee
NDMP	National Disaster Management Plan
NDRSC	National Disaster Relief Service Centre
NEOC	National Emergency Operation Centre
NEOP	National Emergency Operation Plan

NGOs	Non-Governmental Organizations
NPP	National Physical Planning
NPPD	National Physical Planning Department
NSF	National Science Foundation
NWP	Numerical Weather Prediction
NWS&DB	National Water Supply and Drainage Board
PA	Public Awareness
PTWC	Pacific Tsunami Warning Center
RDA	Road Development Authority
SLIDA	Sri Lanka Institute of Development Administration
SLLRDC	Sri Lanka Land Reclamation & Development Corporation
SLRCS	Sri Lanka Red Cross Society
SOP	Standard Operation Procedure
UDA	Urban Development Authority
UNCRD	United Nations Centre for Regional Development
UNDAC	United Nations Disaster Assessment and Coordination
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNISDR	United Nations International Strategy for Disaster Reduction
VSAT	Very Small Aperture Terminal
WB	World Bank
WMO	World Meteorological Organization
WRB	Water Resource Board

Republic of Sri Lanka
Technical Cooperation for Landslide Mitigation Project
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Chapter 1 INTRODUCTION

1.1 Overview

This project (Technical Cooperation for Landslide Mitigation Project: TCLMP) was carried out following 1) to 3) in the districts of Kandy, Matale, Nuwara Eliya, and Badulla in Sri Lanka, to improve the sediment disaster management capacity of National Building Research Organisation (NBRO) and to contribute to reducing sediment disasters in the target region.

1) Research and evaluation for countermeasures of sediment disasters
2) Design, supervision, and monitoring for landslides, slope failures, and rock falls
3) Accumulation of knowledge and know-how of sediment disaster mitigation measures (including non-structural measures)

A loan agreement, “Landslide Disaster Prevention Project (LDPP),” that included seven districts of the target area of TCLMP was signed in March, 2013 and LDPP was commenced. TCLMP was implemented as a related project to the Yen Loan Project (LDPP) in order to improve the effectiveness of development by the relationship with LDPP. This project was implemented for four years, from September 2014 to September 2018.

1.2 Target Area

Figure 1.1 shows the target area of this project.

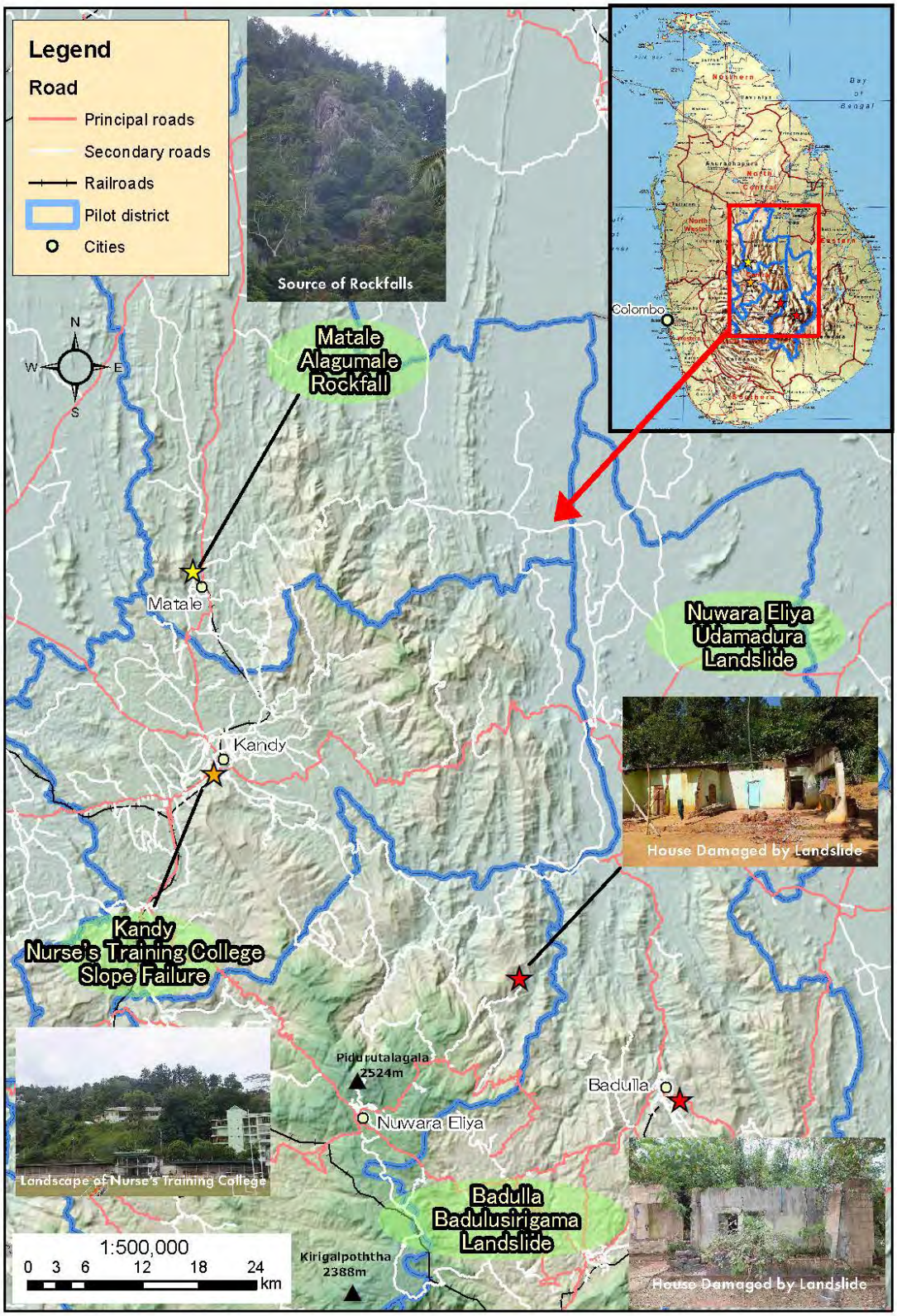


Figure 1.1 Target Area

1.3 Beneficiaries

Beneficiaries in this project are arranged in Table 1.1. NBRO as a C/P institute was under Ministry of Disaster Management (MDM) until April, 2018. After May 2018, MDM was merged with Ministry of Irrigation and Water Resource Management, and Ministry of Irrigation and Water Resource & Disaster Management was established. The organizational structure has not been yet updated as of August 2018 on the Website. Therefore, the old organizational structure of Ministry of Disaster Management and NBRO are shown in Figure 1.2

Table 1.1 Beneficiaries for Capacity Development

Benefit	Organization	Division	Number	Remarks
Directly	NBRO	Director General	1	Assigned C/P list from NBRO （Figure 1.3Figure 1.2 and Figure 1.3 show the organization chart of MDM and NBRO）
		Landslide Research and Risk Management Division	15	
		Geotechnical Engineering and Testing Division	3	
		Subtotal	19	
		Building Material Research and Testing Division	1	1) Participants of the Baseline Survey 2) Person in charge of Bid Documents
		Environmental Studies and Services Division	1	
		Human Settlement Planning and Training Division	1	
		Project Management Division	3	
		Subtotal	6	
Indirectly	DMC (Disaster Management Centre), NBRO, UDA and other governmental agencies		217	Attendance in Seminars held by short term experts and the Disaster Management Workshops (total: three times) Number of all participants from relevant agencies i) 1st workshop at Dec. 8, 2015: 52 ii) 2nd workshop at Jan. 14, 2016: 56 iii) Seminar by the short term experts at Jan. 14 2016: 68 iv) 3rd workshop at Jan. 25, 2016: 70 v) International Seminar at Feb. 21, 2017
	University of Colombo		4	
	Badulla District and other local government		5	
	Military forces, Police and Coast Guard		43	
	Mass media		7	
	UN-Habitat		4	
	Private companies and others		13	
	Japanese Embassy and JICA office		47	
	Subtotal (cumulative)		340	
Grand Total	**Direct 25 + Indirect (cumulative) 340 = 365**			

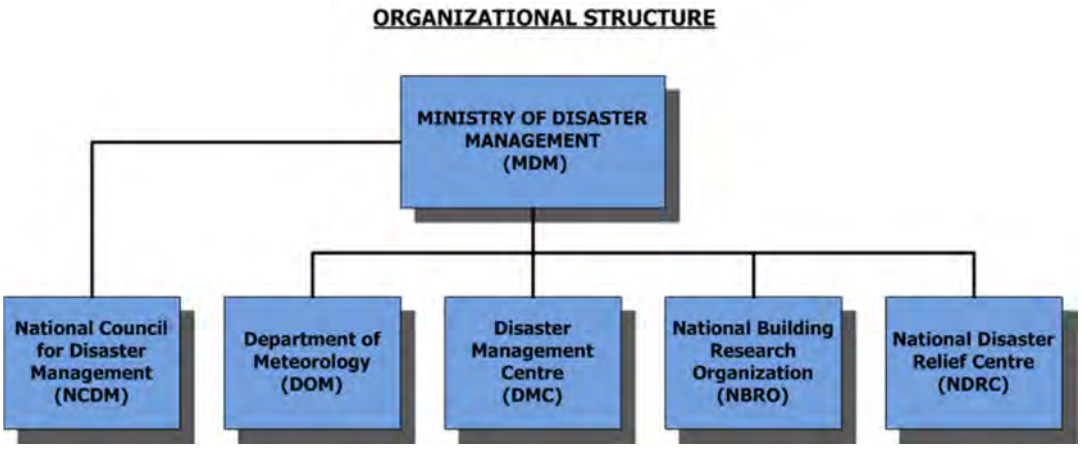


Figure 1.2 Organization Chart of MDM

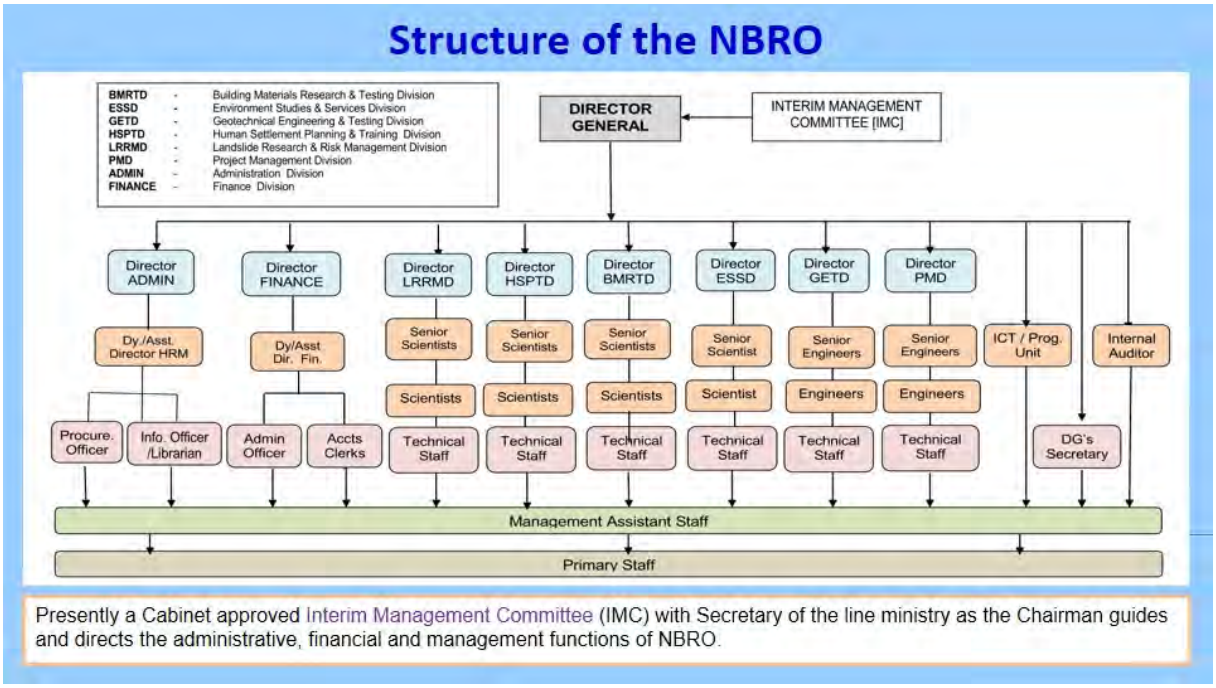


Figure 1.3 Organization Chart of NBRO

Chapter 2 METHODOLOGY OF PROJECT IMPLEMENTATION

2.1 PDM and PO

This project is implemented based on the PDM and the PO from the R/D, which was agreed on 7th Mar 2014 (Appendix 1). The PDM was updated according to the following table during the course of the project. At the 2nd JCC meeting, which was held on 12th October 2016, the update for activities at the Kandy Nurse Training School site and procurement of an air compressor was approved.

Table 2.1 Updated PDM Items

Original	Updated	Changes
Kandy Nurse Training School Site		
3.3 Prepare tender documents for slope failure mitigation measure in the pilot area.	Deleted	The result of geological survey, the geological situation was weathered deeper than expected. Then the countermeasure work based on the TECHNICAL NOTES was not applied to the site. Implementation of pilot work of this site has been determined to be inappropriate.
3.4 Evaluate tender documents and procure contractor for slope failure mitigation measure in the pilot area	Deleted	
3.5 Supervise the construction work for slope failure mitigation measure in the pilot area	Deleted	
3.6 Prepare completion report of the slope failure mitigation measure in the pilot area.	Deleted	
Procurement of Air Compressor		
Output 1: Capacity of investigation and evaluation for sediment disaster (landslide) mitigation measures is strengthened	Output 1: Capacity of investigation, **planning** and evaluation for sediment disaster (landslide) mitigation measures is strengthened	Add "**planning**" into Output 1 because of necessity of capacity development
None	1.5 Procure air compressor and make construction implementation plan utilizing air compressor to sediment disaster (landslide) mitigation measures.	Add activity for construction implementation plan using procured air compressor.

2.2 Activity Plan

Details and the concrete activity plan and performance are described in Appendix 2 "Flow chart of the project" and Appendix 3 "detailed action plan". Each activity was implemented with cooperation from the C/P based on the Technical Notes, which was agreed on 14th March 2014.

2.3 Inputs

2.3.1 Inputs from the Japanese side

1) Experts

Japanese Experts in this report period (project personnel) is shown in Appendix 4, "Experts Results (personnel planning the latest version)". Long and short-term Experts are shown in Table 2.2.

Table 2.2 Japanese Experts

Classification	Number of people	MM	Remarks
Project Experts	10	32.81 29.45	1st Term: September 2014 – February 2016 2nd Term: April 2016 – September 2018
Long-term Expert	1	16.00	
Short term Expert	4	0.70	1st Seminar: 31 August, 2016 2nd Seminar: 14 January, 2017 3rd Seminar: 20 January, 2017
Total	15	78.96	

Table 2.3 Records of Seminars and Workshops

Date	Type	Target	Contents
2014.10.6	Seminar	NBRO staff (three participants x three times)	Introduction of the Work Plan
2014.11.27	Seminar	NBRO staff (15 participants)	Midterm report on survey and design in the pilot sites
2015.7.29	Workshop	NBRO staff (30 participants)	Midterm report on survey and design in the pilot sites
2015.12.8 2016.1.14 2016.1.25	Seminar & Workshop	National organization, local government, Millitary forces, mass media (ca. 60-70 participants)	Information Management
2016.10.12	Workshop	NBRO staff (20 participants)	Midterm report on survey and design in the pilot sites
2017.2.21	Seminar	National organization, local government, Millitary forces, mass media (100 participants)	Final report of long-term expert Midterm report on survey and design in the pilot sites
2017.3.19	Workshop	NBRO staff (20participants)	Final report on survey and design in the pilot sites

(excludes mini-seminars)

2) Training in Japan

Trainings in Japan were held twice during this project. (Refer to Section 3.2)

3) Procurement

Equipment that was procured in this project is shown in Table 2.4 .

Table 2.4 List of Procured Equipment

No.	Equipment	Initial Operator Guidance	Operational Guidance	Installation /Monitoring Guidance	Quantity	Remarks
1	Desktop PC	―	―	―	1	1st Term in Sri Lanka
2	Laptop PC	―	―	―	5	1st Term in Sri Lanka
3	Printer	―	―	―	4	1st Term in Sri Lanka
4	Multifunction Printer	△	―	―	1	1st Term in Sri Lanka
5	Projector	―	―	―	1	1st Term in Sri Lanka
6	Screen	―	―	―	1	1st Term in Sri Lanka

7	Underground Water Gauge (automatic transmission record type)	△	△	◎	3	1st Term in Japan
8	Extensometer (automatic record type)	△	△	◎	7	1st Term in Japan
9	Pipe Strain Gauge with piezometer (automatic record type, with water gauge)	△	△	◎	2	1st Term in Japan
10	Inclinometer guide pipe	△	△	◎	3	1st Term in Japan
11	Boring Machine	◎	◎	―	1	1st Term by JICA
12	Air Compressor	◎	△	―	1	2nd Term by JICA

◎: Necessary △: As necessary ―: Unnecessary／Not covered

1st Term: Sep. 2014 – Feb. 2016 2nd Term: Apr. 2016 – Sep. 2018

2.3.2 Inputs from the Sri Lankan side

1) Human Resources

In response to the request from the consultant team and long-term expert, NBRO assigned C/Ps who cooperated during this project. Not only staff from headquarters, but also staffs from district offices cooperated for the site work when necessary.

Table 2.5 List of C/Ps

Affiliation	Title
NBRO Headquarters	Landslide Risk Research and Management Division (LRRMD) Director Senior Scientist
NBRO Badulla District Office	District Officer Scientist Site Engineer
NBRO Nuwara Eliya District Office	District Officer Scientist Site Engineer
NBRO Matale District Office	District Officer Scientist Site Engineer
NBRO Kandy District Office	District Officer Scientist

Note: The Kandy Office was involved during the survey and design stage.

2) Facilities

NBRO donated one office space to the Consultant team, consisting of long and short-term experts, taking into account technical transfer to the C/Ps. The office room changed when NBRO buildings were rebuilt in Dec 2016. The office space moved again due to the expiration of long-term expert.

3) Budget

NBRO secured the following budget and worked proactively in project activities.

- Labour costs of the NBRO C/Ps
- Travel expenses to the pilot project area

4) Land Acquisition

NBRO held an awareness meeting at each project site for residents. To ensure smooth construction work, NBRO asked residents to understand and cooperate for the project.

Chapter 3 ACHIEVEMENTS RELATED TO THE ENTIRE PROJECT

3.1 Review and Evaluation of the Project

3.1.1 Midterm Review

1) Results of the review

From 22nd September to 13th October 2016, a mission team for the midterm review of the project visited Sri Lanka, two (2) years from the commencement of the project. The results of the review were discussed at the 2nd JCC held on 22nd October 2016, and the Minutes of Meeting (M/M) were signed between NBRO and JICA. The M/M is attached in Appendix 6-2.

2) Recommendations of the review

Recommendations and corresponding actions taken in the project are shown in Table 3.1.

Table 3.1 Recommendations and Actions Taken during the Project (Midterm Review)

Recommendations	Actions taken after the review
(1) Revision of the Project Design Matrix (PDM) The current indicator of the Overall Goal ("Sediment disaster (landslide) in the target area is mitigated.") is revised and that another indicator is added as follows. Current indicator: Number of sediment disaster (landslide) events in the target area in 2017-2020. Revised: Number of sediment disaster (landslide) events in the target area in 2018-2020 Added: Number of sites of sediment disaster (landslide) countermeasures with acquired technology and experience from the Project implemented (including the commencement of a preliminary survey) by NBRO in 2018-2020.	PDM was revised in the 3rd JCC held during the terminal evaluation in 2018.
(2) Measures to prevent unplanned construction work a. Permanent assignment of at least one supervisor per project site b. Prior approval of any change to the construction plan	a. After the review and discussions with NBRO, a site engineer was sent to the pilot site. b. A process for approval was agreed upon with NBRO, and the process was improved based on the agreement.
(3) Improvement of communication Better and faster communication among JICA experts, NBRO, and contractors is indispensable to avoid further delay and unplanned construction work. In order to improve communication, daily, onsite meetings among the TCLMP assistant, a site engineer, field office staff of NBRO, and contractors is highly recommended. This will help confirm work progress, the quality of work, daily work plan, technical matters, and any other concerns before commencement of that day's work. In addition, JICA experts are requested to hold a monthly meeting with NBRO headquarters staff, the TCLMP assistant, a site engineer, field office staff of NBRO, and contractors in order to confirm work progress, the quality of work, technical matters, and any concerns	After the review, monthly progress meetings were held every month. Also, the communication and submission/approval of documents were improved, because a site engineer was always at the site mentioned in (2) above.

Recommendations	Actions taken after the review
(4) Further technical assistance on designing countermeasures for rock falls and landslides JICA experts are requested to provide technical transfer on how to design countermeasures for rock falls and landslides through seminars or workshops, and to conduct field verifications of the designs with NBRO design staff.	Right after the review, a workshop for landslides and rock falls was held. Site visits and technical transfer regarding design of countermeasure works were provided during monitoring.

3.1.2 Terminal evaluation

1) Results of the review

From 14th September to 4th October 2017, a mission team for terminal evaluation of the project visited Sri Lanka, one (1) year before project completion. The results of the review were discussed at the 3rd JCC held on 4th October 2017, and the Minutes of Meeting (M/M) were signed between NBRO and JICA. The M/M is attached in Annex 7-3.

2) Recommendations of the review

Recommendations of the review and actions taken during the project are shown in Table 3.2.

Table 3.2 Recommendations and Actions Taken during the Project (Terminal Evaluation)

Recommendations	Actual taken after the terminal evaluation
Recommendations for NBRO and Consultant Team	
(1) Revising the Overall Goal of the PDM The current Overall Goal: Narrative Summary: The number of sediment disaster (landslide) in the target area is mitigated. Indicator: Number of sediment disaster (landslide) events in the target area in 2017-2020 Suggested Revision: Narrative summary: Sediment disaster (landslide) countermeasures are implemented directly by NBRO or with the assistance of NBRO with acquired technology and experience from the Project. Indicator: All sediment disaster (landslide) countermeasures are implemented (including the commencement of a preliminary survey) or assisted by NBRO with acquired technology and experience from the Project.	PDM has been revised and approved at the 3rd JCC held during the terminal evaluation in 2018.
Recommendations for NBRO	
(2) Assignment of responsible personnel at NBRO local offices	During the defect liability period, site engineers were assigned at each pilot site and conducted monitoring with the consultant team.
(3) Proper maintenance of the constructed facilities after the completion of the Project	Monitoring with check sheets will be conducted at least two times a year and after heavy rainfall events. Whenever necessity arises, such as when any major damages occur, NBRO will inform the incident and actions to be taken to JICA Sri Lanka's office.
(4) Utilization and recognition of a manual on sediment disaster countermeasures as an institutional publication	NBRO will fully utilize the manual and widely share it as an institutional publication.

(5) Full utilization of the results of the Project for other activities	NBRO will be encouraged to utilize the knowledge and experience obtained from the Project for other related activities which NBRO is and will be involved in (e.g. LDPP).
Recommendations for consultant team	
(6) Provision of a training workshop on the design of sediment disaster works	A workshop regarding design and supervision of countermeasure works was held on 19th March 2018, and technical transfer was conducted.

3.2 Counterpart Training

3.2.1 First Training in Japan

Counterpart training was conducted from April 19th to 28th, 2015. The objectives of the training were as follows:

- To understand the planning, implementation and monitoring processes of Japanese sediment disaster countermeasures
- To learn representative countermeasures for landslides, slope failures and rock falls
- To learn suitable countermeasures for Sri Lanka

Five (5) staff from NBRO Headquarters, Kandy office, and Matale office participated and visited the Ministry of Land, Infrastructure Transport and Tourism (MLIT), National Institute for land and Infrastructure Management (NILIM), Public Works Research Institute (PWRI), Sabo & Landslide Technical Center (STC), MLIT Fuji Sabo Office, Shizuoka Prefecture, and Kanagawa Prefecture. Trainees received an overview of sediment disasters in Japan during the first half of the training, and visited several sites to observe actual countermeasure works in the latter half. Throughout the training, trainees actively participated and asked questions envisioning their future work in Sri Lanka.

3.2.2 Second Training in Japan

The 2nd counterpart training in Japan was held from May 14th to 27th, 2017. This counterpart training was held as a part of capacity development of NBRO. The objectives of training were as follows:

- To understand the planning, implementation, and monitoring system for sediment disasters in Japan
- To learn the representative countermeasures for slope failures, rock falls, landslides, and debris flow in Japan
- To learn countermeasures that can be applied in Sri Lanka

A total of five (5) staff was selected from NBRO Headquarters and Ratnapura and Goal District offices. The participants visited MLIT, Japan Meteorology Agency (JMA), NILIM, PWRI, STC, MLIT Fuji Sabo Office, Shizuoka Prefecture, and Kanagawa Prefecture.

Some NILIM lecturers had already been dispatched to Sri Lanka as 2nd and 3rd short-term experts. They explained how to identify risk areas for slope failures and debris flow, how to run debris flow numerical simulations, and details on critical rainfall for landslide early warning. JMA explained the meteorological observation system in Japan, early warning system based on the monitored data, and the cooperation system with local governments. Other organizations also provided overviews of sediment disasters, countermeasures, and monitoring systems in Japan. A visit to the geotechnical laboratory, a request from NBRO, was also carried out during this training.

The participants visited several sites to understand actual countermeasures in Japan, and discussed about the differences between Sri Lanka and Japan. The capacity to implement structural countermeasures is gradually improving, due to economic development and advances in the level of risk management in Sri Lanka. The need for structural countermeasures is also expanding due to population growth. On the other hand, the legal system for design, maintenance, and operation is not currently sufficient. Several laws and regulations have been formulated in Japan to regulate construction of countermeasures, land-use planning, and identification of risk areas. Training participants recognized these approaches would be necessary for Sri Lanka.

There was an active discussion and exchange of opinions through the lectures and site visits. Participants mentioned that they were provided extensive information and had ideas for countermeasure that would be applicable in Sri Lanka.

Countermeasure Work in Kanagawa Prefecture

Countermeasure Work at Yui Landslide

Geotechnical Laboratory

Shizuoka Prefecture Government Office

Photo 3.1 Training in Japan

3.3 Public Relations Activities

Public relations activities described below were implemented during the project period.

Table 3.3 List of Public Relations Activities

SL	JP	Description
Press Study		
✓		Press study meeting on disaster prevention on 16th Dec. 2014.
Posting on the JICA Website		
✓	✓	Survey report of the Koslanda Landslide that occurred in Oct. 2014. https://www.jica.go.jp/srilanka/office/information/press/141107.html https://www.jica.go.jp/srilanka/office/information/press/141125.html https://www.jica.go.jp/srilanka/office/information/event/150623.html *Final report was published by English, Sinhala and Tamil language.
	✓	Report of procurement of Japanese drilling machine for NBRO. https://www.jica.go.jp/srilanka/office/information/event/150908.html
	✓	Report of training of new JICA staff for this project http://www.jica.go.jp/srilanka/office/information/event/151015.html
	✓	Survey report of the Lilisland Landslide by the JICA team http://www.jica.go.jp/srilanka/office/information/event/151029.html
	✓	Recommendations from experts about the enhancement of sediment disaster emergency response capacity, after one year from the Koslanda Landslide. http://www.jica.go.jp/srilanka/office/information/event/151119.html http://www.jica.go.jp/srilanka/office/information/event/151224.html http://www.jica.go.jp/srilanka/office/information/event/160108.html
	✓	Survey report of rainfall monitoring during the Lilisland Landslide. http://www.jica.go.jp/srilanka/office/information/event/151125.html
	✓	Report of the 1st training in Japan. https://www.jica.go.jp/srilanka/office/information/event/160613.html
✓	✓	Survey report of the Aranayke Landslide that occurred in May. 2015. https://www.jica.go.jp/srilanka/office/information/event/ku57pq00000bllgh-att/20160522_report.pdf https://www.jica.go.jp/srilanka/office/information/event/160908.html
	✓	Report of short-term experts activities. https://www.jica.go.jp/srilanka/office/information/event/ku57pq00000bllgh-att/20170202_report.pdf
SNS		
✓	✓	Project activities were uploaded on the Facebook page of JICA Sri Lanka Office. The aerial survey of the Koslanda landslide which was uploaded onto YouTube was also linked on the Facebook page of JICA Sri Lanka Office. https://www.facebook.com/jicasrilanka https://www.youtube.com/watch?v=sICaNBZHyQo
Newsletters and Booklets		
✓	✓	Activity reports of long-term experts every half year were prepared as booklet. http://www.jica.go.jp/srilanka/office/information/event/150813.html http://www.jica.go.jp/srilanka/english/office/topics/150812.html https://www.jica.go.jp/srilanka/office/information/event/160615_01.html https://www.jica.go.jp/srilanka/office/information/event/160907.html

SL	JP	Description
		https://www.jica.go.jp/srilanka/office/information/event/170209.html https://www.jica.go.jp/srilanka/office/information/event/170524.html
✓		Publication of project activities as a newsletter by NBRO http://www.nbro.gov.lk/images/content_image/pdf/jica_newsletter.pdf
Public Relations Events		
✓		Seminar about using remote sensing technologies for disaster prevention http://www.jica.go.jp/srilanka/office/information/event/150216.html
✓		Workshop about disaster prevention to the Sri Lankan government by short-term experts - 1st workshop for "Information Management" - 2nd workshop for "Review of Disaster Management Mechanism of Sri Lanka Based on the Experiences Gained in Sri Lanka and Japan" and Seminar for "Introduction of Japan's Landslide Mitigation Experiences for Sri Lanka" - 3rd workshop for "Introduction of Disaster Imagination Game and Japan's Experiences for Institutionalizing the Culture of Prevention on Disasters"
TV and Newspapers		
✓		Article in the Daily Mirror about advice on countermeasures for sediment disasters by long-term expert and the project team
✓		Article in the Lakubima Paper about disaster response of Koslanda landslide
	✓	Article about project activities in the Yomiuri News Paper, Japan
	✓	Article about the 2nd training in Japan in the Sizuoka Newspaper, TV Shizuoka, and NHK Japan
Papers in Academic Journal		
	✓	Article about project activities for "KASEN", Japan River Association Journal, Vol. Jan, 2015
	✓	Article about the situation and countermeasures of sediment disasters in Sri Lanka for "Sabo and Chisui", Japan Sabo Association Journal, Vol. Dec, 2013
	✓	Article about the Sri Lanka visit for "Sabo and Chisui", Japan Sabo Association Journal, Vol. Jun, 2014
	✓	Article about the TCLMP project for "Sabo and Chisui", Japan Sabo Association Journal, Vol. Feb, 2015
	✓	Column about Sri Lankan life for "Sabo and Chisui", Japan Sabo Association Journal, Vol. Dec, 2015
	✓	Report on sediment disaster countermeasures in Sri Lanka for "SABO", Sabo and Landslide Technical Center Journal, Vol. 2016 Winter
	✓	Column about eating out in Sri Lanka for "SABO", Sabo and Landslide Technical Center Journal, Vol. 2016 Summer
	✓	Disaster report of the Koslanda landslide which occurred on 29th October 2014 in Sri Lanka, Journal of Japan Society of Erosion Control Engineering, vol.68, No.2, p.41-44, 2015
	✓	Article about technical cooperation for non-structural countermeasures for sediment disasters in Sri Lanka for "Sabo and Chisui", Japan Sabo Association Journal, Vol. Dec, 2016
	✓	Disaster report on the Aranayake landslide in Sri Lanka, Journal of Japan Society of Erosion Control Engineering, vol.69, No.6, p.67-70,2017
	✓	Report on the technical cooperation project for sediment disasters in Sri Lanka for "Civil Engineering Journal", Public Works Research Center,vol.59, May, 2017

SL	JP	Description
	✓	Article on the technical cooperation for non-structural countermeasures for sediment disasters in Sri Lanka for “Sabo and Chisui”, Japan Sabo Association Journal, Vol. Jun, 2017
	✓	Report about the completion of dispatch as a long-term expert for the TCLMP project for “SABO”, Sabo and Landslide Technical Center Journal, Vol. 2017 Summer
	✓	Report on the international seminar for natural disaster risk and sediment disaster countermeasures in Sri Lanka for “Sabo and Chisui”, Japan Sabo Association Journal, Vol. Aug, 2017
	✓	Report about the completion of dispatch as a long-term expert for the TCLMP project for “Sabo and Chisui”, Japan Sabo Association Journal, Vol. Oct, 2017
Others		
✓		Presentation of an overview at the TCLMP disaster prevention meeting sponsored by the Sri Lankan government
✓		Aerial survey report of the Koslanda landslide and project introduction at the Human Resources Development Institute, Colombo University
✓		Presentation of an overview of the TCLMP and sediment disasters in Sri Lanka at the disaster prevention education meeting for elementary school teachers in Galle District
✓		Report on the result of the Koslanda landslide survey and an explanation of the project and the exchange of opinions in Financial Planning, Ministry of National Planning Bureau
	✓	The Koslanda landslide report was posted on the Prime Minister’s Office Website, Japan http://www.japan.go.jp/newspaper/20141201/International_Cooperation.html
✓		Introduction of the project and exhibition of the drone used in the field survey on National Safety Day in Hambantota
	✓	Dr. Asiri, Director General NBRO and Mr. Mark, Director General DMC presented on sediment disasters in Sri Lanka in the Sendai meeting
	✓	Report by long-term experts about the current situation of slope protection and future technical cooperation planned in Sri Lanka, which were requested from Overseas Project Promotion Division, MLIT, and Japan Disaster Prevention Platform (JDP)

平成２９年(2017年)５月１９日（金曜日）

砂防えん堤など視察 スリランカ職員 土砂災害対策研修

スリランカの国家建築研究所の職員5人が18日、土砂災害対策の研修で本県を訪れ、県内の地滑り防止施設や砂防えん堤などを視察した。国際協力機構（JICA）が進める土砂災害対策能力強化プロジェクトの一環。

静岡市駿河区丸子の砂防えん堤では、県砂防課の職員が過去に発生した土砂災害の様子を紹介し、えん堤の構造や土砂を食い止める機能、工事費用などについて解説した。

研修の運営担当者によると、スリランカでは山間地や急斜面に住む人が多く、土砂災害もたびたび発生している一方、土石流対策は進んでいないという。

研修に参加したワナスンダラ・アビータさん(30)は「日本の技術を活用すれば、土砂災害対策施設の建設コストを抑えることができる。研修で学んだことをスリランカの土砂災害対策に生かしたい」と話した。

県砂防課の職員から砂防えん堤の説明を受けるスリランカ政府の職員＝18日午後、静岡市駿河区

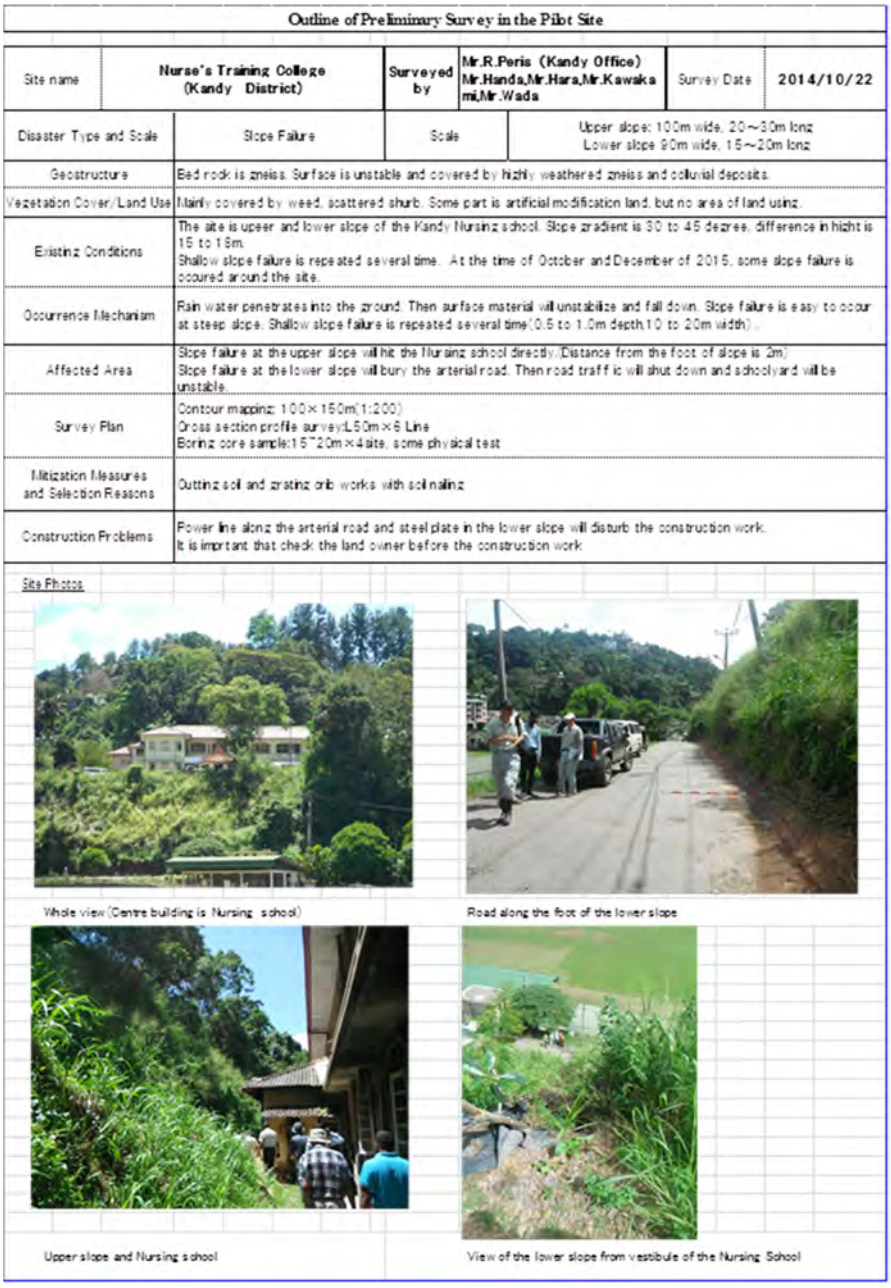
Figure 3.1　Article of Shizuoka News Paper (19th May 2017)

Figure 3.2　Evening News of Shizuoka TV (18th May 2017)

Chapter 4 ACHIEVEMENTS OF OUTPUT 1 ACTIVITIES

4.1 Conduct Preliminary Investigations on Sediment Disaster (Landslide) in Pilot Areas (Activity 1-1)

A UAV aerial-photo survey to obtain 3D terrain data on target slopes was conducted from October to November 2014 for the Pilot Project in Kandy, Matale, Nuwa Eliya and Badulla with cooperation of the NBRO district office staff. Digital Surface Models (DSM), contours, slope angles, ortho-photos, stereo-photos and anaglyphs for the pilot sites were prepared from the aerial photographs. These data were utilized for subsequent surveys and countermeasure designs. A sample of the preliminary survey result is shown in Figure 4.1



Outline of Preliminary Survey in the Pilot Site

Site name	Nurse's Training College (Kandy District)	Surveyed by	Mr.R.Peris (Kandy Office) Mr.Hands,Mr.Hara,Mr.Kawakami,Mr.Wada	Survey Date	2014/10/22
Disaster Type and Scale	Slope Failure	Scale	Upper slope: 100m wide, 20~30m long Lower slope 90m wide, 15~20m long		
Geostructure	Bed rock is gneiss. Surface is unstable and covered by highly weathered gneiss and colluvial deposits.				
Vegetation Cover/Land Use	Mainly covered by weed, scattered shurb. Some part is artificial modification land, but no area of land using.				
Existing Conditions	The site is upper and lower slope of the Kandy Nursing school. Slope gradient is 30 to 45 degree, difference in hight is 15 to 18m. Shallow slope failure is repeated several time. At the time of October and December of 2015, some slope failure is occured around the site.				
Occurrence Mechanism	Rain water penetrates into the ground. Then surface material will unstabilize and fall down. Slope failure is easy to occur at steep slope. Shallow slope failure is repeated several time(0.5 to 1.0m depth,10 to 20m width).				
Affected Area	Slope failure at the upper slope will hit the Nursing school directly.(Distance from the foot of slope is 2m) Slope failure at the lower slope will bury the arterial road. Then road traffic will shut down and schoolyard will be unstable.				
Survey Plan	Contour mapping: 100×150m(1:200) Cross section profile survey:L50m×6 Line Boring core sample:15~20m×4site, some physical test				
Mitigation Measures and Selection Reasons	Cutting soil and grating crib works with soil nailing				
Construction Problems	Power line along the arterial road and steel plate in the lower slope will disturb the construction work. It is important that check the land owner before the construction work				

Site Photos

Figure 4.1 Sample of General Condition Sheet

The Consultant team with counterparts from NBRO visited 4 pilot communities to collect information from community people to prepare for the seminar. The interview was conducted on the history of disasters, existing evacuation mechanisms, and communication methods with local governments. Table 4.1 is a summary of the interview.

Table 4.1 Information Gathered from Community Interviews

Community	Date	Summary
Nuwara Eliya Udamadura	12th Nov. 2014	According to residents, there was a landslide in 2007, and many resident homes experienced damages. GNs (Grama Niladari), village leaders, and the police conducted an awareness session in 2011. There are 15 rain gauges installed by the Sri Lanka Red Cross Society. A caretaker is selected for each rain gauge. There is a community-based warning system using the rain gauges. When the level of rainfall reaches the warning level, the caretakers inform the GNs. At the same time, the caretakers inform and instruct people to evacuate. The community center is assigned as an evacuation site, but residents are concerned about the safety of the center.
Badulla District Badulusrigama	13th Nov. 2014	There was a severe landslide in 2011 in this community, and around 20 households were damaged. After the landslide, the government formed a resettlement plan. Although community people relocated to the appointed relocation area, a majority of them returned to the original community. A resident answered that the reason was that the resettlement area was remote, and they had less business opportunities there. Since they came back from the relocation site, the residents told the team that they felt that they were abandoned by the government. There are no rain gauges installed in the community. In addition, nobody from the government comes to the community to warn them in cases of emergencies.
Kandy District Nurse's Training Collage	23th Feb. 2015	There was a slope failure in 2010. Since then, residents are implementing their own countermeasures, such as constructing water flow diversions and covering slopes with tarpaulins based on recommendations from NBRO. They have not designated an evacuation area. There was another slope failure in December 2014. When the failure occurred, some of the school windows were broken, and the classroom has not been used since.
Matale District Alagumale	23th Feb. 2015	After a rock fall, the government issued a relocation plan for 20 households in the community. Half of them came back to the community after the relocation. The reasons were that the relocation site was in a remote area and that schools were far from the site. Some of the community residents stay in their relatives' houses or temples during the rainy season for a month to a month and a half. The residents understand the risks of staying in the community, but they do not have any plans to move.

4.2 Execute Geological and Geotechnical Investigations at a Candidate Site in the Pilot Areas (Activity 1-2)

Topographic and geological surveys were undertaken in the pilot sites, and survey contents on each site are summarized in the Table 4.2. Topographic surveys were carried out by subcontractors under the supervision of the Consultant team, whereas geological surveys were done by NBRO under the guidance of the Consultant team.

In addition, one of the main purposes of the project was to obtain high-quality core samples so that visual observations could be made of geological composition/features for landslides, sliding surfaces, and/or zones. The Consultant team members worked with the NBRO drilling team to improve drilling

techniques. The Consultant team members prepared a guide, Soil and Rock Logging Guideline, and guided NBRO geologists on how to perform core observations and logs..

Table 4.2 The Performed Item and Quantity of the Surveys in the Pilot Project Site

Location	Survey Contents	Items	Quantity
Kandy	Topographic Survey	Topographic mapping	1.5ha
		Cross sections	220m
		UAV Photographs and Surveys	0.04km2
	Geological Survey	Boring explorations	BK-1 (drilling depth: 15m)
			BK-2 (drilling depth: 20m)
			BK-3 (drilling depth: 20m)
		SPTs	3 boreholes, at 1.0m interval
Matale	Topographic Survey	Topographic mapping	1.5ha
		Cross sections	200m
		UAV Photographs and Surveys	0.25km2
	Geological Survey	Boring explorations	BM-1 (drilling depth: 15m)
			BM-2 (drilling depth: 15m)
		SPTs	2 boreholes, at 1.0m interval
Nuwara Eliya	Topographic Survey	Topographic mapping	6ha
		Cross sections	1200m
		UAV Photographs and Surveys	1.37km2
	Geological Survey	Boring explorations	BN-1 (drilling depth: 30m)
			BN-2 (drilling depth: 40m)
			BN-3 (drilling depth: 40m)
			BN-4 (drilling depth: 40m)
		SPTs	3 boreholes, at 1.0m interval
		Geophysical explorations (refraction method)	1,200m * 1 line + 600m * 2 lines
		High density electric sounding	1,200m * 1 line + 600m * 2 lines
Badulla	Topographic Survey	Topographic mapping	7ha
		Cross sections	1300m
		UAV Photographs and Surveys	0.32km2
	Geological Survey	Boring explorations	BB-1 (drilling depth: 20m)
			BB-2 (drilling depth: 20m)
			BB-3 (drilling depth: 20m)
			BB-4 (drilling depth: 20m)
			BB-5 (drilling depth: 20m)
			BB-6 (drilling depth: 20m)
		SPTs	5 boreholes, at 1.0m interval
		Geophysical explorations (refraction method)	800m * 1 line + 400m * 2 lines
		High density electric sounding	800m * 1 line + 400m * 2 lines

At BN-4 (drilling depth: 40m) of the Nuwara Eliya pilot site and BB-6 (drilling depth: 20m) of the Badulla pilot site, boreholes were drilled by the project-procured rotary drilling machine using a double tube sampler. The Consultant team members worked with the NBRO drilling team to obtain high-quality drilled cores with the use of this new machine.

The recovery rate of cores using the new drilling machine was higher than that of the previous hydraulic-rotary drilling machines, but the rate only reached 60 % on average. Further improvement of the drilling technology is required to obtain high-quality core samples.

The following is a summary of issues encountered and recommendations to improve coring techniques so that good core sample quality and recovery rates can be obtained.

1) It is important to understand that the purpose of boring exploration for landslides is to collect high-quality and continuous core samples. Cores are used to observe the geological composition of landslide mass and to identify slip surfaces.

2) A driller's effort, patience, and expertise are needed and important to obtain high-quality core samples. It is thus suggested that NBRO designate younger drillers to be responsible for the new drilling machine, and to encourage them to gradually understand coring technology. NBRO should then disseminate such experiences and techniques internally.

3) Judging and controlling drilling fluids is very important, especially when dealing with unconsolidated materials and soft and fractured rocks. An excessive amount of drilling fluids under high circulation flow pressure would wash away the cored materials. In addition, a fast load turnover rate would lead to disturbed core samples and change core conditions.

4) A daily drilling report should be prepared, including circulation amount, circulation flow pressure, load turnover rate, colour change in circulation water, and drilling depth, because such data and information also can be used to estimate landslide slip surfaces.

5) NBRO drillers have little geological knowledge related to coring technology, and thus advice and assistance from geologists and geotechnical engineers would contribute to the collection of high-quality core samples.

6) A technical note was prepared to provide some key points in identifying and observing slip surfaces or zones of various landslides types based on past experiences in Japan. It is expected that this note will be revised and updated with practices of landslide investigation in Sri Lanka.

C/P Core Drilling Conditions

Core Observation Guidance to C/Ps

Core Drilling with a New Drilling Machine

Explanation of Disturbed Cores

Photo 4.1 Technical Transfer for Drilling Survey

Figure 4.2 Core Samples Drilled Using the New Drilling Machine

(An Average Recovery Rate of About 60%)

4.3 Install Necessary Monitoring Equipment such as Piezometers, Extensometers, Strain Gauges with Piezometer and Inclinometer Pipes (Activity 1-3)

The monitoring plan was prepared based on the results of preliminary investigations under the cooperation between the Consultant Team and NBRO. Planned monitoring equipment was installed at the site by NBRO under the guidance of the Consultant Team. The following table and figure show the installed monitoring equipment at pilot sites.

The monitoring equipment installed in Badulusirigama Badulla District was partially damaged by a wildfire that occurred on 6th July 2016. Detailed conditions are described in Section 5.1. The Consultant team and NBRO checked the damaged monitoring equipment, which worked without problems as of July 2018.

Table 4.3 List of Monitoring Equipment

Location	Equipment No.	Type of Equipment	Monitoring Frequency
Nuwara Eliya Udamadula	SN-1	Extensometer	1 time/month
	SN-2		1 time/month
	SN-3		1 time/month
	BN-1	Groundwater level gauge	1 time/month
	BN-2	Inclinometer (L=40m)	1 time/month
	BN-3	Pipe strain gauge(L=30m)	1 time/month
	BN-4	PVC pipe for groundwater level (L=40m)	1 time/month
Badulla Badulusirigama	SB-1	Extensometer	1 time/month
	SB-2		1 time/month
	SB-3		1 time/month
	SB-4		1 time/month
	BB-1	Pipe strain gauge (L=20m)	1 time/month
	BB-2	Inclinometer (L=20m)	1 time/month
	BB-3	Groundwater level gauge	1 time/month
	BB-4	Inclinometer (L=20m)	1 time/month
	BB-5	Groundwater level gauge	1 time/month
	BB-6	PVC pipe for groundwater level (L=20m)	1 time/month

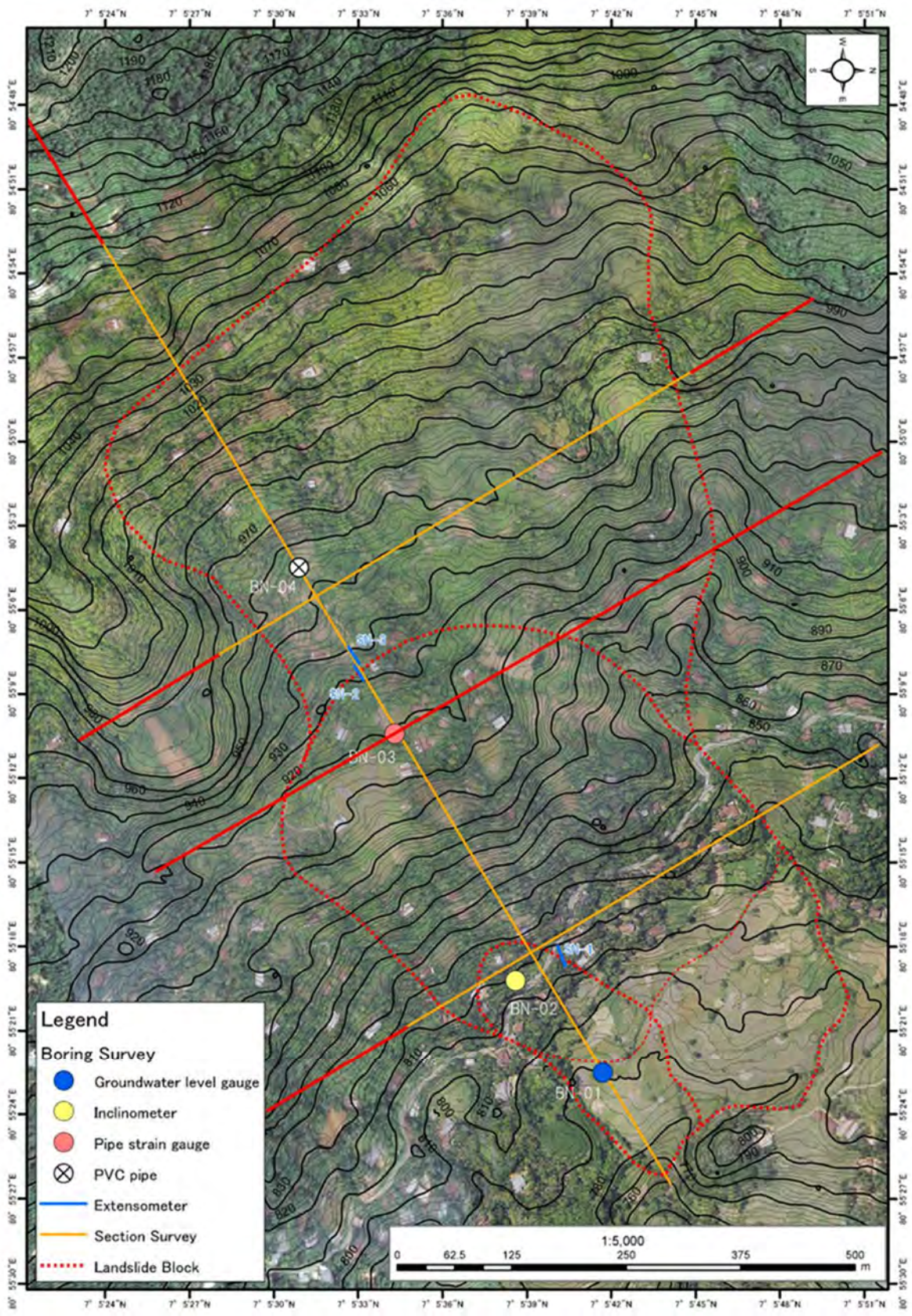


Figure 4.3 Investigation Plan (Udamadula in Nuwara Eliya District)

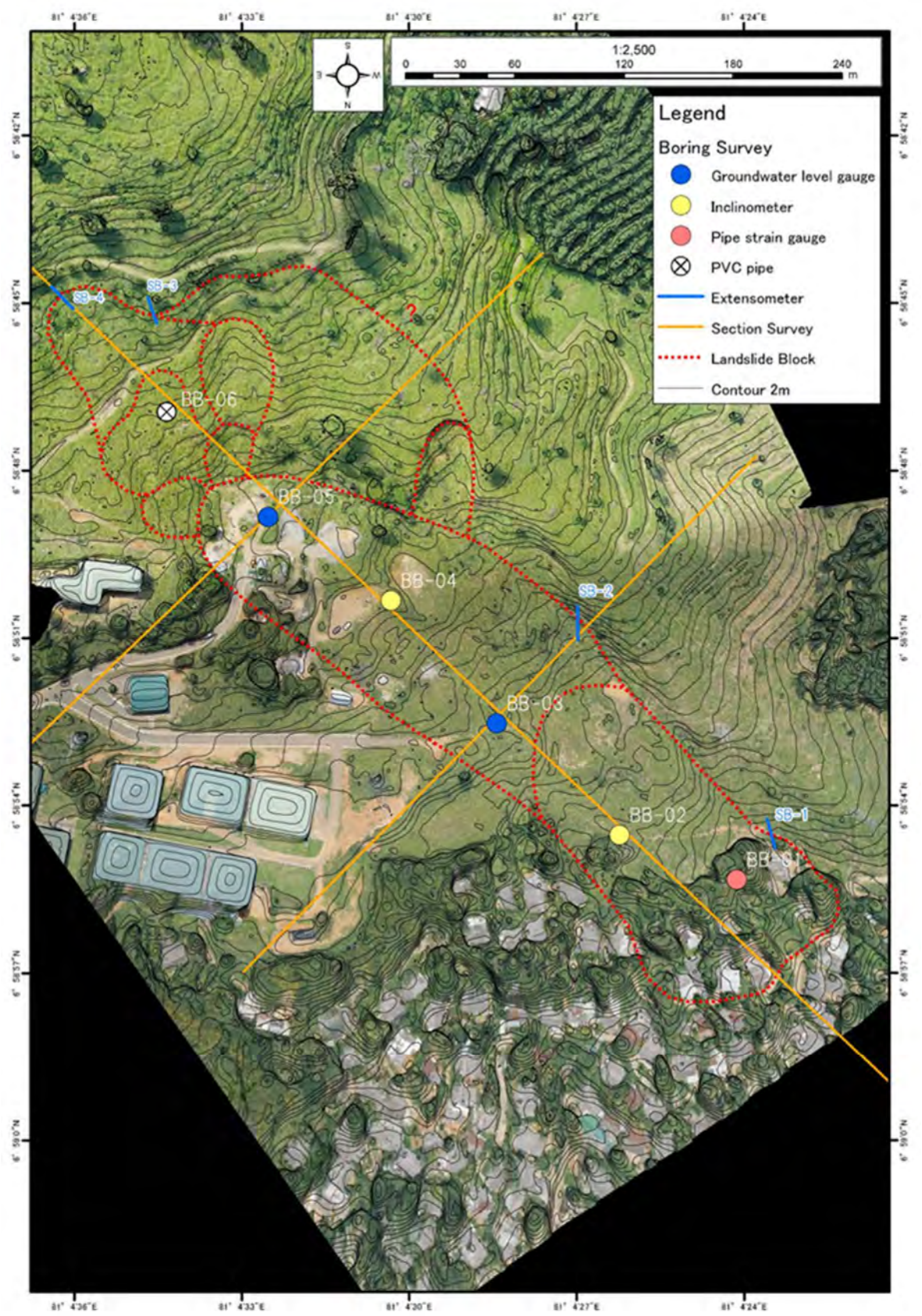


Figure 4.4 Investigation Plan (Badulusirigama in Badulla District)

Site Discussion about the Monitoring Plan

Instruction to NBRO about Extensometers

Installation of a Pipe Strain Gauge

Installation of an Extensometer

Photo 4.2 Technical Transfer for Installation of Monitoring Instruments

4.4 Examine and Determine the Concept of Sediment Disaster (Landslide) Mitigation Measures in Pilot Areas (Activity 1-4)

4.4.1 Nurse School Pilot Site in Kandy District

Technical guidance was provided at the site to NBRO headquarters staff and the Kandy District Office staff. Content included slope failure investigations and design for countermeasures.

Geological survey results from this site showed that the weathered zone was deeper than expected. Therefore it is difficult to secure sufficient stability using conventional countermeasure works that had been carried out in Sri Lanka. Through discussion with NBRO and JICA, this site was excluded from the pilot work (Refer to 6.1).

The Consultant team and NBRO considered several alternatives prior to reaching this conclusion. Results were shared with NBRO as documentation of technical transfer.

4.4.2 Alagumale Pilot Site in Matale District

The target disaster type in Alagumale is rock fall. There are several rock falls which were larger than three (3) m in diameter scattered across this area. Typical protection work involves constructing structures to catch rocks, because it is difficult to stabilize a mass of unstable rocks located in the upper part of the slope. The work was determined by agreement with NBRO.

The embankment and excavating pocket which catches the rock fall is cost effective and feasible.

4.4.3 Pilot Sites at Udamadula, Nuwara Eliya, and Badulusirigama Badulla Districts

The Consultant Team advised and guided NBRO personnel in planning landslide countermeasures so that they will be able to independently consider landslide countermeasure works not only for these pilot areas but also for other areas in the future. Accordingly, the Consultant Team and NBRO worked together to select countermeasure works for each district pilot area in consideration of the landslides characteristics and in terms of technical, environmental, financial, maintenance, and management as shown in Table 4.4. In addition, the Consultant Team discussed and shared information with JICA and a long-term expert about the criteria for selection of countermeasure works.

Table 4.4 Application of Countermeasure Works against Landslide

Classification	Type of countermeasure works		Technical effectiveness	Financial cost	Environmental impact	Maintenance
Control work	Surface drainage	Water channel	Good	Very Good	Very Good	Very Good
	Underground drainage	Horizontal borehole	Good	Very Good	Very Good	Good
		Well	Very Good	Good	Good	Limited case
		Drainage tunnel	Very Good	Limited case	Limited case	Limited case
	Cutting works	-	Good	Very Good	Good	Very Good
	Embankment	-	Good	Very Good	Good	Very Good
	River cross structure	Sabo dam	Good	Good	Good	Good
Restraint work	Anchor works	-	Very Good	Limited case	Good	Limited case
	Piling works	-	Very Good	Limited case	Good	Good
	Shaft works	-	Very Good	Limited case	Good	Good

The Udamadula landslide was triggered by excessive surface water and shallow groundwater levels, and, therefore, the general landslide countermeasures chosen for the Udamadula landslide was to remove such surface water and shallow groundwater. The Consultant Team and NBRO together selected surface drainage ditches, horizontal drainage holes, and check dams as the cost-effective combination of countermeasures for the Udamadula landslide. Horizontal boring of drainage holes were planned to cover the whole landslide area.

Similarly, the general landslide countermeasures selected for the Badulusirigama landslide were to remove surface water and shallow groundwater that triggered the landslide movement. The Consultant Team and NBRO together selected surface drainage ditch and horizontal drainage holes as the landslide countermeasures and decided to target the lower area of landslide slope, in which landslide movement was relatively extensive.

In selecting these landslide countermeasures, the Consultant Team provided appropriate guidance via flowcharts and clarified important points for selecting landslide countermeasures to NBRO through regular meetings and seminars.

4.5 Procure air compressor and make construction implementation plan utilizing air compressor for sediment disaster (landslide) mitigation measures

Table 4.5 presents the equipment procured by JICA.

Table 4.5 Procured equipment

Stage	Type of equipment	Utilization	Specifications
First	Boring Machine Model: D0-D(500ST)	Drilling survey	Excavation capacity: vertical 50m Including water pump, attachment, transportation machine, etc.
Second	Air compressor Model: PDSF750S-4B3	Horizontal drilling Soil nailing	Air Pressure; app 700-850CFM Working pressure; app 10-12 bar (kgf/cm2G).

4.5.1 Assistance to install the set of procured equipment including compressor

The compressor arrived at the Colombo port on July 9, 2017. The Consultant team assisted NBRO to clear customs between 17th and 20th of July 2017, before it was installed at NBRO on July 21, 2017.

Front and Right Side

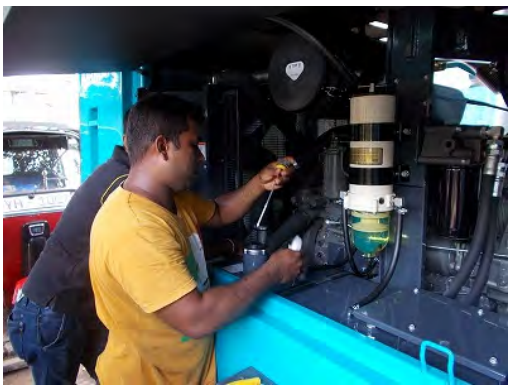
Back and Left Side

Photo 4.3 Procured Air Compressor

4.5.2 Overview of the inspection

The air compressor was unpacked with the NBRO equipment manager and the storekeeper to inspect its condition and to number the equipment. Items were well packed, without rust or damage. Since there were no missing items, the procured equipment arrived complete and in good shape. The engineer of General Sales, the local agent in Sri Lanka, inspected the condition of the compressor on July 26, 2017.

Spare Parts Inspection



Inspection by Local Agent

Photo 4.4 Goods Inspection of Air Compressor

4.5.3 Test run and guidance on maintenance and management

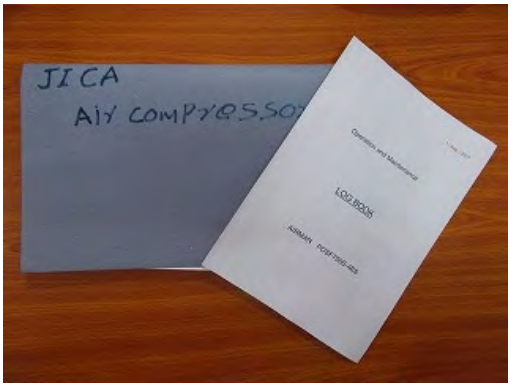
In the presence of NBRO equipment manager and compressor chief operator, the Consultant team conducted a test run of the compressor and confirmed operation procedures on July 31, 2017. The expert also gave them the following guidance on maintenance management and safety:

- How to conduct maintenance management using the logbook.
- How to use the maintenance manual and spare parts catalogue
- How to deal with defects (contact information of the local agent and person in-charge of the manufacturer)
- How to order spare parts through the local agent
- How to use the air valve and the high pressure air hose
- How to operate the emergency switch

Pre-service Inspection

Connection of Drawbar

Operation Manual and Parts Catalog



NBRO Compressor File and Log Book

Photo 4.5 Test Run and Manuals

4.5.4 Report on the inspection and technical guidance

The Consultant team reported on the inspection and technical guidance to the Director General of NBRO after the test run and guidance on the operation, maintenance, and management of the equipment. The Consultant team also reported on the completion of the procurement to JICA Sri Lanka office on August 3, 2017.

4.5.5 Tasks and propositions

1) Operation of the equipment using the logbook

The usage record and the maintenance record of the nine (9) boring machines are kept in daily service reports at NBRO. One boring machine operator is assigned to each drilling team, and only s/he is aware of the maintenance and management that boring machine. The Consultant team instructed the operators to record maintenance activities of all boring machines at the time of machine installation during the 1st term, but it was found that maintenance records were not appropriately being kept.

Upon procurement of the compressor, the Consultant team, together with NBRO's equipment manager, made a logbook so that the compressor operator who is in charge of the compressor team can record the operation status and maintenance activities. The logbook, which includes daily operation reports, daily inspection check sheets, a periodic inspection schedule table and periodic inspection check sheets, will allow the operator to easily grasp the condition of the equipment.

The logbook which was originally made for the maintenance and management of compressors, can also be used for the nine (9) boring machines, and it will hopefully enhance the maintenance and management ability of NBRO.

2) Monitoring

The equipment remains in good condition since their installation in the 1st term, but some problems were found with the record of maintenance and management. The Consultant team decided to conduct monitoring to check if the records were properly being kept using the logbook. An air compressor monitoring sheet was made together with NBRO equipment manager for this purpose.

Following the completion of sediment disaster mitigation works of the project at three locations, the Consultant team in charge of each work monitored the sites during the 1-year warranty period. The monitoring sheet also can be used for checking the condition of the air compressor at the site as well.

Chapter 5 ACHIEVEMENTS OF OUTPUT 2 ACTIVITIES

5.1 Monitor and Evaluate the Landslides in the Pilot Areas (Activity 2-1)

NBRO established a monitoring organization with the Consultant Team. The Consultant Team provided guidance on data updating, analysis, and evaluation methods to NBRO at the pilot sites in Badulusirigama, Badulla District and Udamadula, Nuwara Eliya District. Monitoring data were analysed using graphs shown in the following figure so that NBRO could easily understand the relationship between movement of landslides, rainfall, groundwater level, and effectiveness of countermeasures. The point of interest is the range of the displacement, amount of rainfall, and other data.

In addition, the Consultant Team provided Japanese landslide activity criteria and management control values that rely on, for example, data from extensometers. The Consultant team and NBRO discussed the Japanese criteria and control values and its potential applicability to landslides in Sri Lanka.

A wildfire occurred on the upper slopes of the Badulla landslide on 6th July 2016. The foundations of the extensometers SB-3 and SB-4 were damaged, but the sensors were not damaged, according to the results of operation check inspections by NBRO and JICA experts. The extensometers were re-installed and it restarted recording on 1st August 2016. The Consultant team used this event to explain how to maintain and check conditions of the equipment. NBRO, with Consultant team, continued landslide monitoring of the pilot sites in Badulusirigama, Badulla District and Udamadula, Nuwara Eliya District during and after countermeasure construction to evaluate effects of the countermeasures. Definitive landslide movements have not been observed since 2015 at Badulla and Nuwara Eliya.

In addition, it was determined that the movement of landslides in that same area tended to become more active and faster when cumulative rainfall exceeded 400 mm. The Consultant team and NBRO confirmed that this information could be used for early warning of such landslides. However there has not been any heavy rainfall since 2015, and clear displacements due to landslide movements have not been observed through the end of project.

Monitoring data in Figure 5.1 shows that groundwater levels became lower after countermeasure construction work finished. It is assumed that that is the result of effective horizontal drainages.

Data Analysis Instruction

Continuous Supervision for Monitoring

Photo 5.1 Technical Transfer for Landslide Monitoring

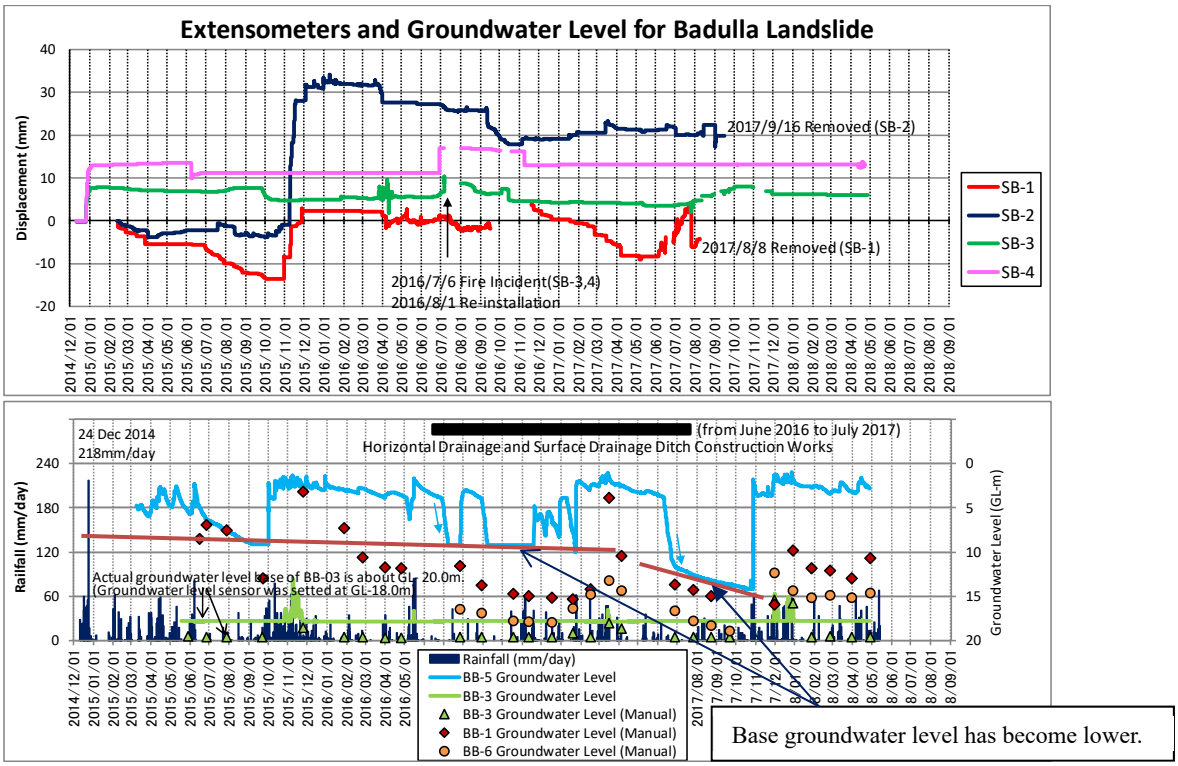


Figure 5.1 Example for Making a Graph of Extensometer (Badulusirigama in Badulla District)

5.2 Design and Estimate Construction Cost for Landslide Mitigation Measures in the Pilot Areas (Activity 2-2)

Based on the geological surveys and monitoring in landslide areas, the Consultant team designed landslide countermeasure works agreed upon by NBRO. In the design period, the Consultant team also discussed with NBRO about the stability analysis of a landslide and calculation parameters. The Consultant Team created a bill of quantities, design drawings, and cost estimates for countermeasure works. Unit prices for cost estimation were derived from NBRO-provided prices and/or market research in Sri Lanka. The Consultant Team performed these tasks together with NBRO while providing technical advice and guidance.

Plans and sections of the countermeasure work in Udamadula site and Badulasirigama site are shown below.

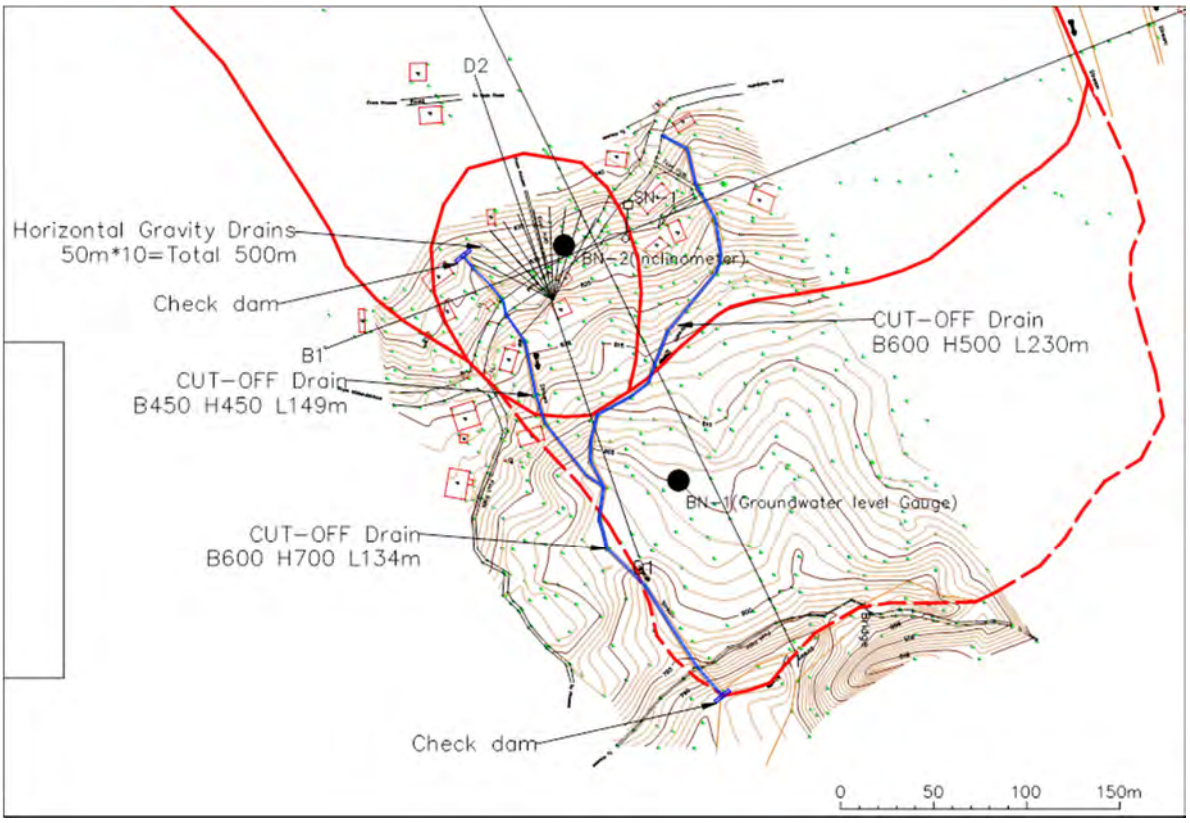


Figure 5.2 The Map of Countermeasure Work Plan in Udamadula (Priority Area)

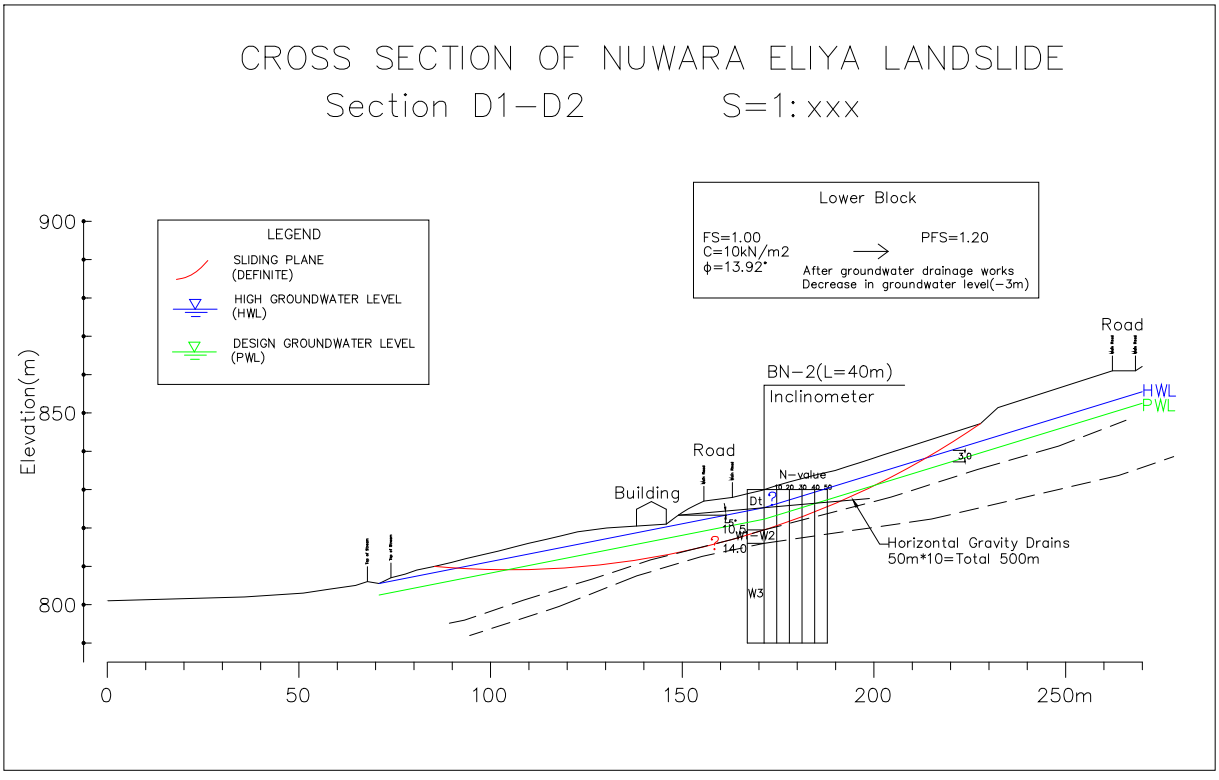


Figure 5.3 The Section of Countermeasure Work Plan in Udamadula (Priority Area)

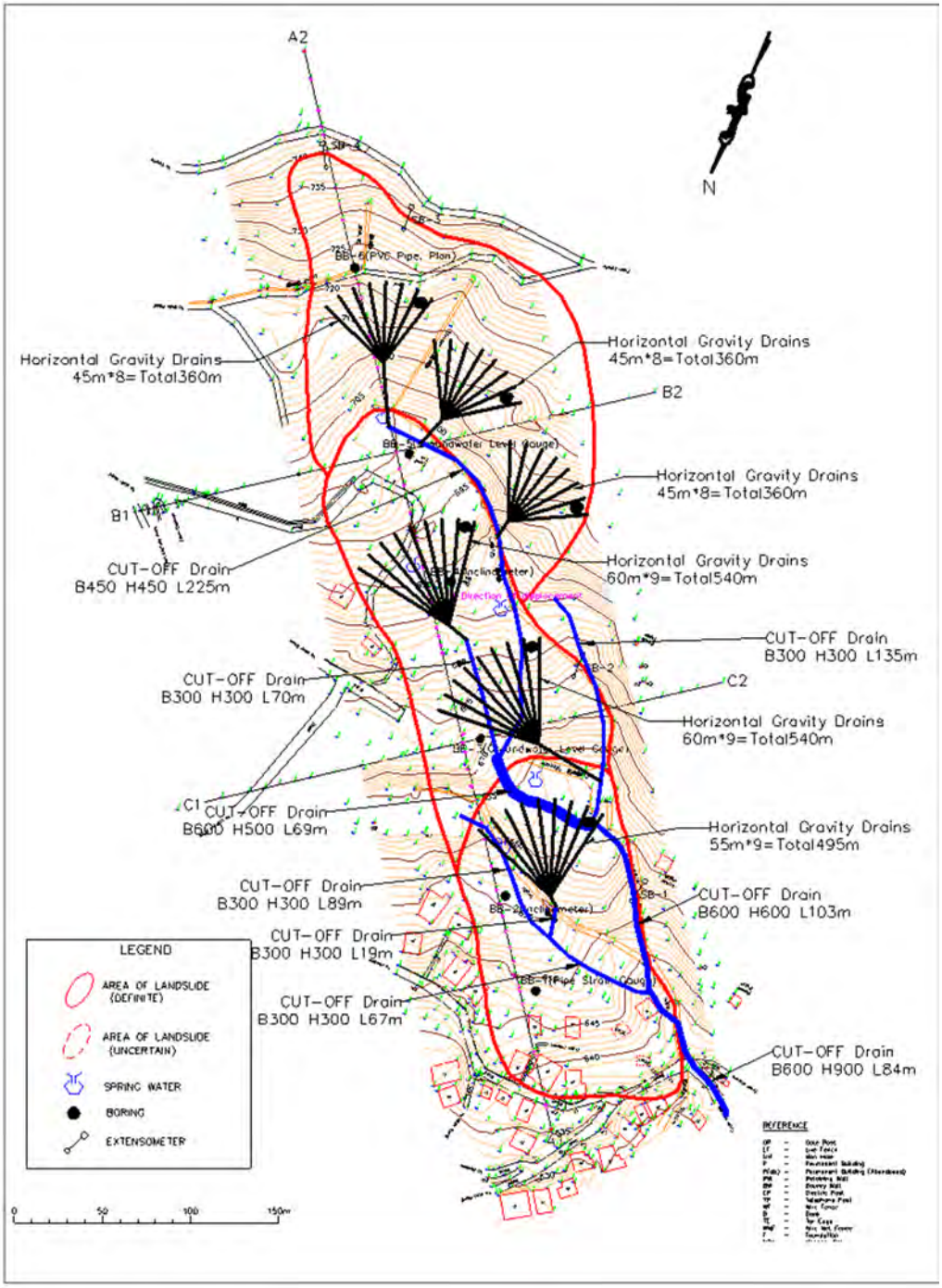


Figure 5.4 The Map of Countermeasure Work Plan in Badulusirigama

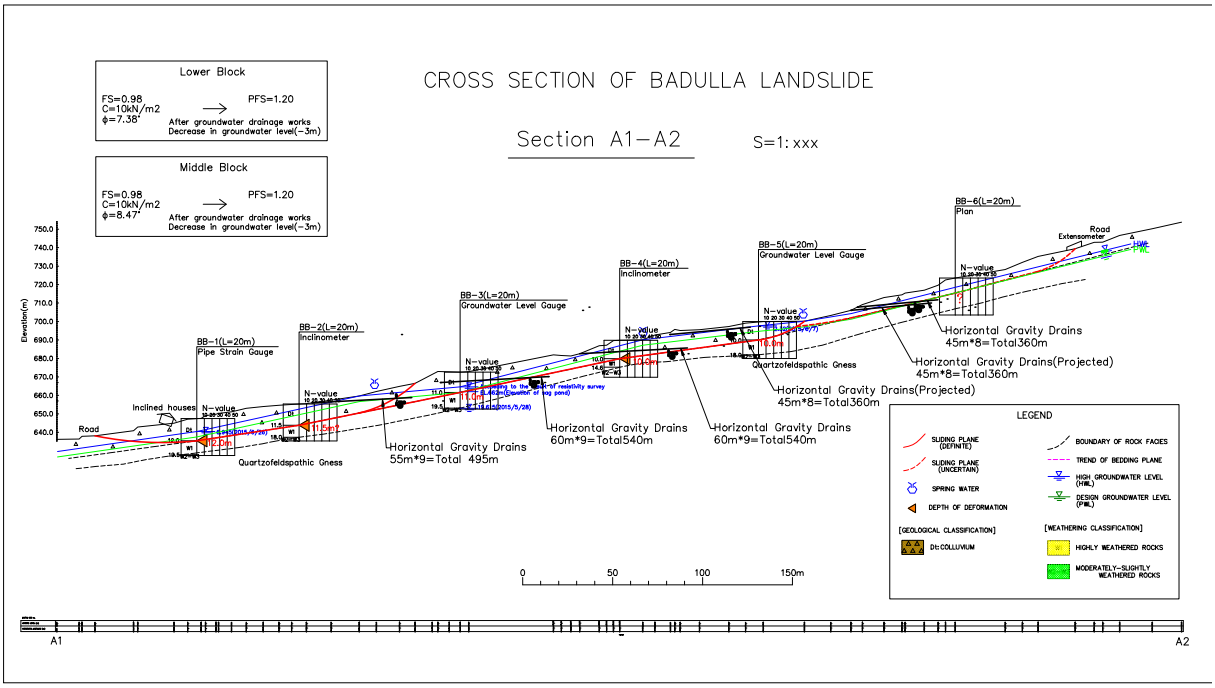


Figure 5.5 The Section of Countermeasure Work Plan in Badulusirigama

5.3 Prepare Tender Documents for Landslide Mitigation Measures in the Pilot Areas (Activity2-3)

5.3.1 Discussion on Tendering Work for Counter Measure Construction

The JICA Sri Lanka Office selected the contractor through 'open competitive bidding'. The bidding documents used in Sri Lanka are published by CIDA (Construction Industry Development Authority, former ICTAD). A seminar to compare and explain the differences between the bidding procedures of JICA and Sri Lanka was held for those taking part in the bidding process at NBRO, as the bidding for this project will be following JICA's grant aid cooperation construction bidding document. The following differences were explained to the participants:

1) Bidding process

As part of the Sri Lankan Bidding process, the Bidding opening committee announces the Bid Price in the presence of applicants at the Bid opening. The Bidding evaluation committee then evaluates the submitted Bidding Documents and decides the successful Bidder. On the other hand, JICA's Bidding process adopts the 2-Envelope method at the Bid opening. Following the evaluation of Envelope A (containing details of personnel and work schedule), Envelope B (Bid Price) of the qualified companies is disclosed, and the applicant proposing the lowest price within the ceiling price will be the successful Bidder.

2) Bid Price

In Sri Lanka, it is possible to be a successful Bidder even if the Bid Price exceeds the ceiling price, if the cost of materials has risen after the submission of Bid and the ceiling price had been based on prices before the cost increase. Under the JICA method, however, applicants cannot be a successful Bidder if their Bid Price exceeds the ceiling price calculated based on the BOQ.

5.3.2 Preparation of PQ Announcement, PQ Documents and Bidding Documents

The PQ announcement, PQ Documents and Bidding Documents were discussed with the person in charge of procurement at the JICA Sri Lanka Office. The same Bidding Document format was applied to the three pilot projects (three Lots). The relationship between each Lot and the pilot project site is as follows,

- Lot 1: Badulusirigama, Badulla District
- Lot 2: Udamadula, Nuwara Eliya District
- Lot 3: Alagumale, Matale District

The PQ announcement and PQ Documents were in conformity with JICA's grant aid cooperation standards, and the Bidding Documents are in conformity with the documents compiled by the JICA Sri Lanka Office in 2011. The instructions to Bid of 2011 JICA Office version was based on the Sri Lankan Bidding standards, whereas its Contract document was based on JICA's grant aid contract document. The Sri Lankan standard and the JICA standard were used for the Bidding Documents for this project. Because construction for this project required special techniques and the Bidding process needs to be finished within the specified period, a new set of Bidding Documents was made based on the 2011 JICA Sri Lanka Office version. The altered items were as follows:

Table 5.1 Bidding Documents

Bidding documents	Base standards	Reason
PQ announcement and PQ Documents	JICA's grant aid cooperation standards	The documents comply with JICA standards so that it will be possible to determine bidder experience in special construction procedures.
Bidding Document	JICA Sri Lanka Office Bidding document (2011version)	The bidding documents comply with JICA Sri Lanka Office standards to facilitate preparation of bidding documents by local contractors.
Contract Document	JICA's grant aid contract document	The contract document complies with JICA standards as it is a JICA pilot project.

Major changes of the bidding documents compared to those of JICA Sri Lanka office in 2011.

1) Bid Price

A lump sum price was used in the 2011 version, whereas the new version allows for changes in the contract price based on mutual agreement, because works involved may require changes due to geological features and ground conditions.

2) Payment

Advanced payment in the 2011 version is 40% of the Contract Price and final payment is 60%,, but the new version adopted the quarterly payment method based on work completed. Construction work takes more than a year, and terms of payment in Sri Lanka is usually based on work completed. In addition, 10% of the payment based on work completed will be retained until the Certificate of Completion of the Work is issued, as stipulated in the JICA regulations.

5.4 Evaluate Tender Documents and Procure Contractor for Landslide Mitigation Measures in the Pilot Areas (Activity 2-4)

5.4.1 PQ Evaluation

PQ Documents were handed to 17 companies, 11 of which submitted documents. Out of the 7 applicants for Lots 1 and 2, 3 companies qualified and the rest were disqualified for not having ICTAD SP2 registrations. Out of the 9 companies that applied for Lot 3, 6 applicants were qualified. One was disqualified because it failed to submit the ICTAD registeration document and 2 were disqualified because they lacked experience of performing similar works.

1) Applicants qualified for Lots 1 and 2

1) GEO ENGINEERING CONSULTAMTS (PVT) LTD.

2) ELS CONSTRUCTION (PVT) LTD.

3) SOIL TECH (PVT) LTD.

2) Applicants disqualified for Lots 1 and 2

1) RING ENGINEERING (PVT) LTD.

ICTAD（SP2）Not registered on ICTAD SP2 and less than 4 similar work experiences

2) PRIME TECH SOLUTIONS (PVT) LTD.

ICTAD（SP2）Not registered on ICTAD SP2 and less than 4 similar experiences on Prime contract

3) KONDASINGHE CONSTRUCTIONS

ICTAD（SP2）Not registered on ICTAD SP2, lack of geological engineer and incomplete documents

4) DHAMADASA CONSTRUCTION & ENTERPRISES

ICTAD（SP2）Not registered on ICTAD SP2 and incomplete documents

3) Applicants qualified for Lot 3

1) RING ENGINEERING (PVT) LTD.

2) ELS CONS TRUCTION (PVT) LTD.

3) SOIL TECH (PVT) LTD.

4) STATE ENGINEERING CORPORATION OF SRI LANKA

5) SANGUINE ENGINEERING (PVT) LTD.

6) GEORGE STEUART ENGINEERING (PVT) LTD.

4) Applicants disqualified for Lot 3

1) KONDASINGHE CONSTRUCTIONS

No experience in similar works

2) DHAMADASA CONSTRUCTION & ENTERPRISES

No experience in similar works during the past 5 years

3) S.M.A CONSTRUCTION

Lack of ICTAD register document

5.4.2 Site Visit and Pre Bid Meeting

Site visits and pre-bid meetings were held from 1st to 3rd December 2015. The schedule and applicants were as follows.

Table 5.2 Applicants Participating in the Site Visit

Date	1st Dec	2nd Dec	3rd Dec
Lot No and Site / Company Name	Lot 3 Matale	Lot 2 Nuwara Eliya	Lot 1 Badulla
GEO ENGINEERING CONSULTAMTS (PVT) LTD.	-	✓	✓
ELS CONS TRUCTION (PVT) LTD.	✓	✓	✓
SOIL TECH (PVT) LTD.	✓	✓	✓
RING ENGINEERING (PVT) LTD.	✓	PQ disqualified	PQ disqualified
SANGUINE ENGINEERING (PVT) LTD.	✓	-	-
Total	4	3	3

The site visit started at the district office with an explanation of the countermeasure work at the pilot site. The applicants went to the site to confirm the site location, construction methods, and quantities. After the site visit was finished, the Consultant team accepted questions from the applicants by letter and distributed the minutes of the pre-bid meeting to the applicants.

The Consultant team replied to the questions and informed all applications of revisions of the Bid Document by e-mail by 25th December 2015 (Appendix 7).

Photo 5.2 Pre-Bid Meeting (Matale)

Photo 5.3 Site Visit (Nuwara Eliya)

5.4.3 Bidding

Bidding was held at JICA Sri Lanka Office on 5th January 2016. The applicants and bidding results were as follows.

Table 5.3 Result of the Bidding

Company	Bidding Price (1st)	Rank	Bidding Price (2nd)	Rank
Lot 1: Badulusirigama, Badulla District				
ELS CONSTRUCTION (PVT) LTD.	47,670,040.00	2	38,900,000.00	1
SOIL TECH (PVT) LTD.	45,058,370.50	1	39,800,000.00	2
GEO ENGINEERING CONSULTAMTS (PVT) LTD.	51,559,722.50	3	39,887,248.50	3
Lot 2: Udamadula, Nuwara Eliya District				
ELS CONSTRUCTION (PVT) LTD.	20,991,300.00	3	14,090,000.00	2
SOIL TECH (PVT) LTD.	16,985,463.00	1	14,700,000.00	3
GEO ENGINEERING CONSULTAMTS (PVT) LTD.	18,597,205.00	2	12,900,000.00	1
Lot 3: Alagumale, Matale District				
ELS CONSTRUCTION (PVT) LTD.	Declined			
SOIL TECH (PVT) LTD.	Declined			
RING ENGINEERING (PVT) LTD.	Disqualified			
SANGUINE ENGINEERING (PVT) LTD.	31,895,864.00	1	30,669,100.00	1

Currency: LKR

The first bid price exceeded the ceiling price in all lots, but since the second bidding price was within the ceiling price, the company with first negotiation rights were successfully selected. Lot 1 and Lot 2 were competitive bids between three companies, but only one company bid for Lot 3. Two companies had declined the bidding and one company had been disqualified.

Photo 5.4 Bidding (JICA Sri Lanka Office)

5.4.4 Bidding Negotiations

JICA Sri Lanka Office and the Consultant team had a meeting with the contractor before signing a contract. The meeting was an explanation of the contract documents and confirmed the other details (payment, schedule, equipment, and materials.). The meeting was held on 18th and 19th Jan 2016 at the JICA Sri Lanka Office. The contract was signed at the end of January.

5.5 Supervise the construction work for landslide mitigation measures in the pilot areas. (Activity 2-5)

5.5.1 Preparation of construction supervision documents

All contractors performed construction and construction supervision based on the submitted Construction Plan to the Engineer. Basic documents related to the construction work were already submitted at the time of the bidding. However the specific construction plan reflecting the actual conditions of the site (such as the temporary access road plan, facility layout plan, and detailed safety management plan) was not included. Therefore the construction plan was compiled reflecting all of the related documents including shop drawings.

The Engineer held a briefing to explain quantity management, quality management, monthly reporting, and quarterly reporting to the Contractors.

The following table shows the documents related to construction supervision.

Table 5.4 Documents for Construction Supervision

No	Title	Contents	Remarks
1	Management for Quantity	Volume breakdown manual, to calculate the completion ratio for each engineering component according to the BoQ and to calculate the overall progress rate	Calculation results are reported quarterly and is the basis for determining interim payment
2	Check sheet for Quantity Management	Quantity sheet that is the basis to complete the Breakdown Statement.	Check whether quantities satisfy construction standards
3	Standard for forms	Standards to determine completion level for each structure (dimensions)	Construction standards of Japan were adjusted to take into account the construction situation of Sri Lanka

Construction supervision of the pilot sites was performed by NBRO and the Consultant Team. NBRO was the main actor for the supervision. Techniques, such as meeting with the Contractors, issuing letters based on the meeting, approving the letters, construction standards, and methods of construction works were transferred to NBRO by the Consultant Team.

5.5.2 Udamadura Pilot Site in Nuwara Eliya District

1) Overview

An awareness meeting for residents around the construction site was held by NBRO on 10th April 2016 with the contractor. Around 50 people attended the meeting, and NBRO explained the purpose of the construction, its effectiveness for the landslide, basic information about the construction, such as schedule and area, and its impact on the environment. Residents were interested and cooperated during the construction.

The contractor did not have experience in preparing and submitting a Construction Plan document. At first, they separately submitted items, such as planned machines, work schedules, human resources and planning. The contractor also lacked experience in preparing and submitting a safety management plan. Instructions were provided by NBRO, and finally, the contractor submitted the plans.

For the technical assistance for construction supervision, the Consultant team visited the pilot sites each month and provided advice depending on the progress of construction work and the standard of supervision prepared with NBRO. Construction quantities were checked with NBRO using the standard and the Consultant team gave support and advice to the contractors so that they could prepare the monthly report. At the beginning of the construction work, it was a problem that NBRO site engineers had not fixed, but at the time of the inspection in August 2016, a responsible person had been assigned and supervision had been continuously implemented.

2) Horizontal drilling

Regarding horizontal drillings, the instruction of the angle of the drillings was conducted. At the same time, instructions for photograph management for drilling, completion of the drilling, and installation of PVC pipes was provided.

During the drilling period, some cracks appeared in May and August of 2016 at the houses around the site. Monitoring of the cracks was conducted and the drilling method was changed after the appearance of these cracks. The record of crack appearance is shown below.

Table 5.5 Record of Cracks and Responses in May 2016

Date		Response
7th May, 2016	Sat	No.5 commencement of the drilling (0-22.5m)
8th	Sun	Drilling (22.5-40.0m)
9th	Mon	The drilling reached the rock. Preparation of installation of PVC pipes. Cracks appeared around 17:30
10th	Tue	Confirmation of the depth of drilling (40.0m). Installation of PVC pipes. Start monitoring of the cracks.
11th	Wed	Stop the drilling work
12th	Thu	Site inspection by the C/P, TCLMP and the contractor
13th	Fri	Crack survey of the houses around the site
14th	Sat	Crack survey of the houses around the site
16th	Mon	Discussion of the plan against the cracks with the C/P, TCLMP and the contractor

The appearance of cracks in May 2016 was quite unexpected, because the distance was 20m away horizontally and 15m away vertically from the end of the drilling. However, because of the possibility of a relationship between the cracks and the drilling work, the drilling method was changed. After the change, expansion of the cracks has not been observed.

Table 5.6 Record of the Cracks and Responses in August 2016

Date		Response
22nd Aug 2016	Mon	Cracks appeared
23rd	Tue	Inspection for the site (TCLMP)
24th	Wed	Meeting with the contractor (NBRO Head office)
25th	Thu	Inspection for the site (NBRO)
26th	Fri	Meeting with NBRO (NBRO Head office)

The cracks appeared in August 2016. The distance was farther than the house cracks that occurred in May 2016. There was no possibility of the relationship between the cracks and the drilling work. The drilling method had been already changed. However, the cracks were monitored, and their expansion was not observed.

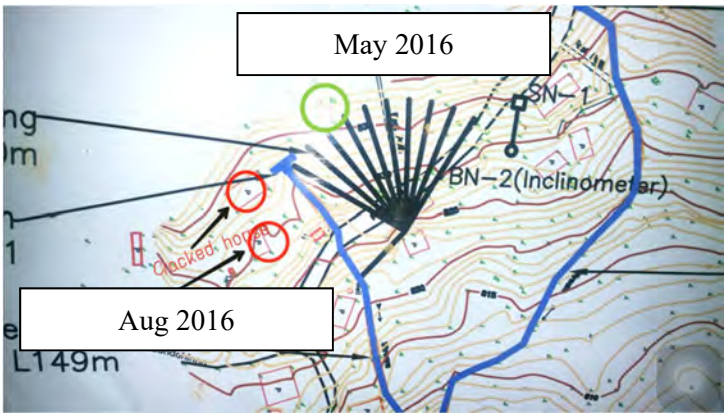


Figure 5.6 Location of the Cracks

Figure 5.7 Cracks in May 2016

3) Ditch works

Construction of the very poor quality has been confirmed in September 2016. NBRO inspected the site at first and the Engineer also did the inspection.

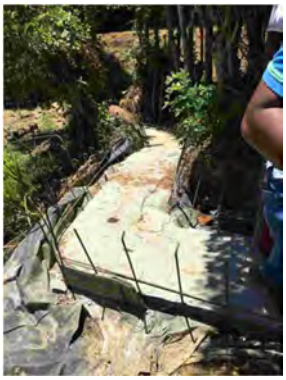
The main situation of poor quality was as follows

- Poor concrete placing called the Honeycomb (so-called junka)
- Not constructed as designed. For example, the ditch line turns almost at a right angle
- Not constructed as designed. For example, the intervals and angles of reinforcing bars are not constant.

Regarding the above situation, the contractor carried out reconstruction at the company's own expense.

Construction period was extended to deal with the occurrence of cracks caused by horizontal boring and poor quality of the ditch works. The construction finally lasted from 15th November 2016 to 15th March 2017, after experiencing schedule extensions twice.

The situation of construction failures and photographs after modification are below.

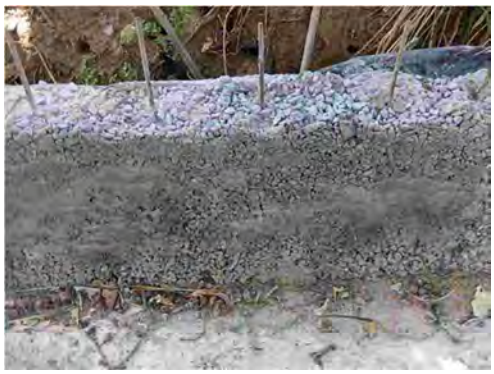


Ditch line turns almost at right angle

Smoothly modified ditch line

Unnatural linear ditch line

Smoothly modified ditch line



Honeycomb

After restoration work

Reinforcing bars are not constantly placed

After restoration work

Photo 5.5 Construction Failures and Photographs After Modification

4) Completion inspection

Completion inspection was conducted on 15th March 2017 in presence of JICA Sri Lanka office, NBRO and the Consultant team. Comments on the completion inspection are shown in Table 5.7.

Table 5.7 Comments on Each BoQ Item by the Employer in Nuwara Eliya Site

Contents		Comment
2.1	Health and safety measures	Attach photos and descriptions corresponding to work instructions for the final report
2.2	Environmental protection	Attach guidance comments (log notes) from NBRO, corresponding work photos and explanations for the final report.
3.1	Insurance, Compensation	Attach copies of certification documents, such as insurance policies, to the final report.
4.1	Project signboard	Attach a picture and explanation to the final report.
5	Testing report	Attach the test result document with the signature of The Engineer to the final report.
6.2	As built drawings	Attach the drawing with the signature of the person responsible to the final report
7.1	Temporary works	Add an explanation to the situation photo
7.2-7.3	Horizontal drillings	Describe the data in the letter, and organize the breakdown table of the rock quality classification.
9 10 11	Draining ditch work Catch pit work Small dam work	Arrange the final quantity breakdown corresponding to each item in the Measurement sheet and attach the signature of NBRO's site engineer to the final report
Additional Work		Describe the additional approval for the proposal letter, attaching construction photos Attach the photo of before backfilling work at 160 mm pipe connection point.

Comments by the Employer following the site inspection

(Agreed that there is no change in the BoQ or amount according to instructions)

- To immediately complete the construction work at the end of the drainage ditch Type C (just around the water collecting pit)
- To repair the water leak on the sidewall of the drainage ditch (Type B section)
- To complete surface and cross-sectional work on the section where runoff flows into the ditch (Type B section)

For the above mentioned repair parts, the Contractor agreed to send photographs showing the completed work to the Engineer as soon as possible. The Engineer checked the completed work condition through the photographs sent by the Contractor on 16th March 2017 and confirmed that the construction was completed as instructed except for the water collecting pit. In addition, repair work could not be completed around the water collecting pit within the construction schedule because of the water flow during the rainy season. The repair work for the ditch around the water collecting pit was done during the Defect Reliability Period and was confirmed at the defect reliability inspection.

Proposal by the Engineer

- To consider reducing the water velocity in the water collecting pit at the connecting sections of drainage ditches, for example, by placing stones inside the pits.
- To backfill along the side walls of the drainage ditches, where water erosion was occurring or where puddles were being formed.

- To periodically remove sediment deposited inside the water collecting pits.

The Consultant Team advised NBRO to regularly monitor the site and to instruct the Contractor depending on the site situation.

5) Defect Reliability Inspection

Inspection after the Defect Reliability Period was carried out on 8th March 2018. The repair work described above was completed before the inspection except for some structures around the collecting pit. Repair of this structure was confirmed at the time of this inspection. Repair work was completed by the Contractor on inspection day, and the Engineer checked the photographs thereafter. Inspection after the Defect Reliability Period was finished by this check, and the completion certificate was issued from NBRO on 14th March 2018. However, it was found that the slope besides the horizontal boring had collapsed under heavy rain on 29th January 2018 during inspection that day. This collapse was not caused by the Contractor's defect reliability and was judged to be a natural disaster. The Employer, JICA Sri Lanka office, suggested that countermeasure work by NBRO would be desirable, the organization responsible for maintenance at the time of the inspection.

Moreover, subsequent monitoring confirmed that water overflows where the ditch turns at an acute angle during times of heavy rain. The suggestion was made by the Engineer that countermeasure work, such as installing a concrete cover, would be required.

Photo 5.6 Collapse besides the horizontal drilling

Photo 5.7 Stream Overflow from the Ditch

6) Delegation of Management Authority

Discussions about delegating management authority from NBRO to Walapane Division were held at the Walapane Divisional Secretariat Office on 6th December 2017 and on 10th July 2018. Through these discussions, NBRO and Walapane Division consented on the delegation.

At the same time, the horizontal drainage holes were confirmed to be damaged at the defect reliability inspection. This defect was not determined to be due to natural disaster, and therefore, the restoration work was to be conducted by NBRO, the present management representative. After completion of the restoration work, the delegation of management authority to Walapane Division was to be carried out. The delegation will be completed with signatures on both NBRO and Divisional Secretariat letters.

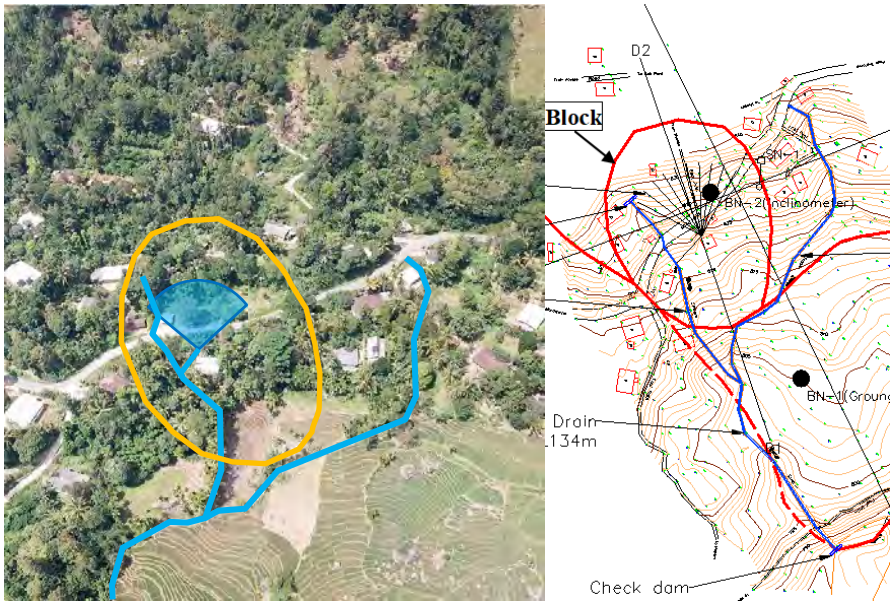


Figure 5.8 UAV Photograph after the Completion of Construction Work at the Udamadula Site

5.5.3 Badulusirigama Pilot Site in Badulla District

1) Overview

At the start of construction, a meeting to explain to local residents (Awareness Meeting) was held with the contractor on 30th April 2016 which was sponsored by NBRO. About 50 residents participated, and the contractor and NBRO explained the purpose of the construction, the effect on the landslide, general construction information (e.g. what was being constructed, the construction period, and the construction zone.). Residents' were very interested. They readily accepted the construction work and seemed to be cooperative.

The Contractor had no experience in submitting the summarized plan of construction work documents. All documents such as construction machines, work schedules, and personnel plan were submitted separately. They had never submitted safety plan documents before either. The Engineer instructed them, and the documents were made and submitted by the contractor.

2) Horizontal Drilling

For horizontal drilling, the Engineer instructed the measurement of the digging angle to be taken and the digging, its completion, and PVC pipe insertion be documented by photograph management.

When NBRO checked the depth of horizontal drilling after construction, it was confirmed that many holes had not reached the design depth. But these holes had already been completed with a PVC pipe installed. The pipe was also filling due to soils being deposited in the pipe. The filter materials were not properly mounted around PVC pipe. The Engineer ordered for the installation of the filter material in the PVC pipe. Thereafter, soil deposits in the PVC pipe were decreased. However, impact of soil erosion was not entirely mitigated. Therefore, the Engineer advised to wash out the hole. The Engineer checked the depth again thereafter. If the depth had not reached design depth, the Engineer advised that the hole needed to be re-drilled so that all the holes would reach design depth.

It is confirmed at several slopes that the contractor cut more than required for the horizontal boring, because they used a large boring machine. Small landslide movements were observed at drilling

point No.1 and No.4 after rain events. Especially, the No.4 hole was completely filled by collapsed sediments. At drilling point No.1, soil flowed out of the side of the gabion caused by sediment movement. No.1 and 4 were reshaped by earthwork and these slopes were stabilized.

The Engineer advised to conduct minor earthwork to increase slope stability and to get permission from NBRO if cutting more than the fixed height was required, because the specification document had not clearly mentioned cutting earthwork at the time of horizontal boring work.

Mounting failure of filter material

After modification

Cutting work at drilling point No.1

Cutting work at drilling point No.4

Photo 5.8 The Situation of Horizontal Drilling

3) Surface Drainage

The Engineer provided detailed instruction on how to control work progress. The Engineer explained about water collecting pits as a way Japan controlled surface drainage on steep slopes, which was a contrast to the concrete steps in Sri Lanka.

However, NBRO and the contractor did not understand the surface drainage design (the change of the drainage cross-section and the function of the water collecting pit). The main challenges concerning the plan and construction of surface drainage were as follows.

Change of the drainage section

Lack of understanding that cross-section of drainage was based on water flow calculations.

Function of Water Collecting Pit

Lack of understanding that the function of the water collecting pit is to allow for sedimentation of mud and dead leaves by a mud reservoir, and to reduce water velocity at the drainage junction.

The cross-section of ditch was constructed as a design length from the downstream end, and not changed the section at the point of pit. This remains as is, since the pit and drainage were already constructed.

At the time of construction of the crossing point of the Type B section and Type E section, it was confirmed that there is a large rock on the planning line of Type E. The contract modification was required for additional work to crush the rock, and it will be take time. Therefore, the Engineer suggested the change of the alignment of Type E drainage. However, the water collecting pit had already been constructed at the point of planning crossing point using initial design. For this reason, changing the location of the pit according to the changed alignment was not applied so that the drainage was connected incorrectly. As a result of discussion with JICA, re-construction was performed under contractor's responsibility.

A lot of spring water was observed in the upper-part of the slope at drilling point No.4. The Engineer instructed to move the construction point of Type E near the spring water to promote water drainage. In addition, a significant amount of spring water appeared in the upper part of slope No.1. Additional surface drainage was installed to promote drainage.

The modified section of surface drainage (Type A and Type B)

Crossing point of Type B and Type E

Springwater of drilling point at upper part of No.4

Springwater of drilling point at upper part of No.1

Photo 5.9 Surface Drainage

4) Completion Inspection

Completion inspection was carried out on 26th July 2017 by JICA Sri Lanka office with NBRO and the Consultant team. Comments at the time of final inspection are shown below.

Table 5.8 Comments on Each BoQ Item by the Employer in Badulla Site

Contents	Comment
2. Health, Safety and Environment	Attach safety photos for evidence
3. Insurance, bonds and securities	Attach the copy of Insurance
5. Site Investigation / Testing	Attach the Site Investigation record of result test copy for Evidence
7. Horizontal Drainage Holes	Attach the Photos and Drawings of Temporary Working. Describe the Temporary road in as built Drawing and Attach the Photos for Evidences
9. Surface Drainage	Describe all drainage line, Horizontal drainage and pit in as built drawing
Additional Work	Attach the stone filling measurement and photos behind the gabion works Attach photos and drawings or Measurement sheet

Comments by the Employer following site inspection

(Agreed that there is no change in the BoQ or amount according to the instructions)

- Water collecting pit - Type 3 water collecting pit (1 site) is to be relocated at the connection of drainage ditches according to the original design concept at contractor cost.

The Contractor agreed to send a completion picture and inspection picture to the Engineer by 11th August 2017. The Engineer checked the completed work condition through the photos sent by the Contractor and confirmed that the construction work was carried out as instructed.

Proposals by the Engineer

- To clean the construction site at the completion of construction work before demobilization
- To submit the completion report shortly after the completion of the relocated water collecting pit (by 19th August 2018)

The Consultant team advised NBRO to regularly monitor the site and to instruct the Contractor depending on the site situation.

After the completion of all construction work in each pilot project site, a progress meeting was held with NBRO engineers and the contractor staff from all three sites on 21st September 2017. This meeting was to share information, such as construction technology and management engineering of the pilot project sites for the future.

5) Defect Liability Inspection

Defect liability inspection was carried out on 19th July 2018 under the presence of JICA Sri Lanka office, the Contractor, NBRO and the Consultant team. This inspection confirmed that periodic removal of sediment materials in water collecting pits is necessary for maintaining the completed pit.

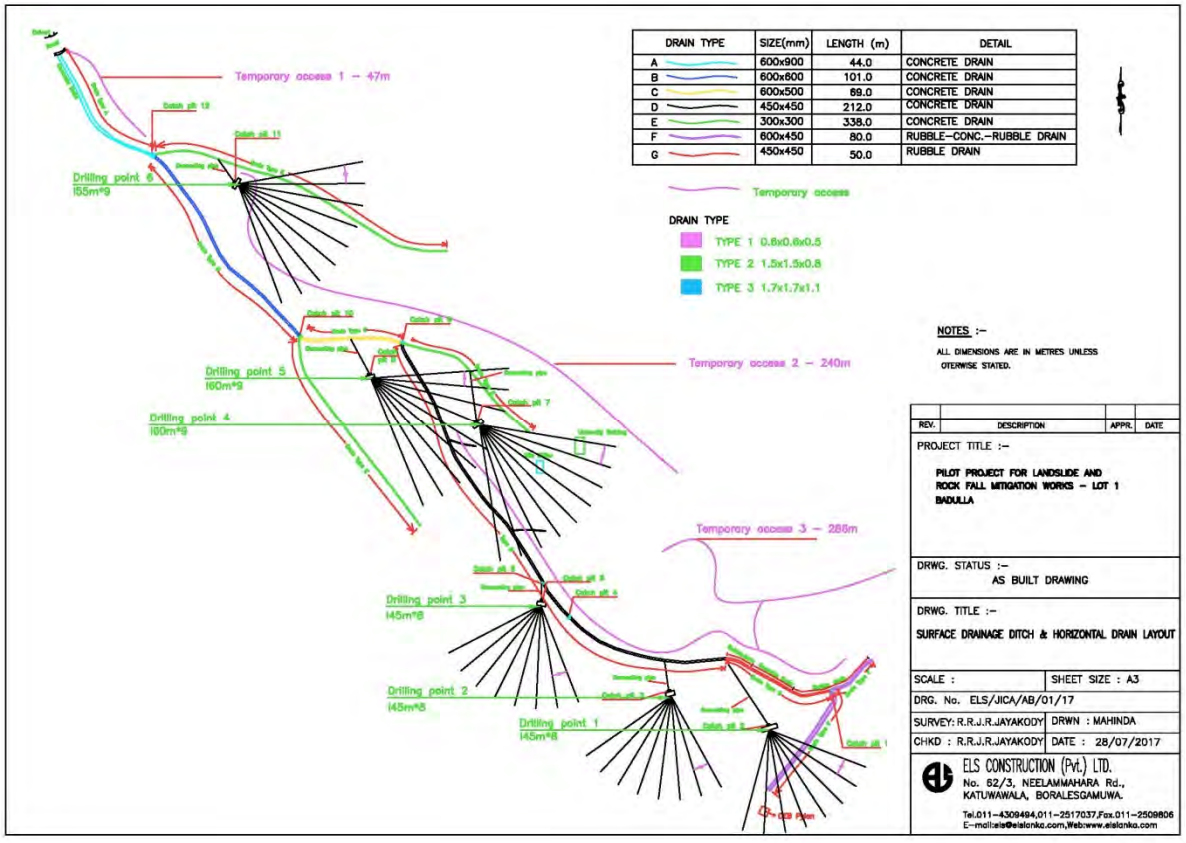


Figure 5.9 As built drawings at Badulusirigama site

6) Delegation of Management Authority

Consultation about delegating management authority from NBRO to Uva Wellasa University was held on 28th February 2018. University officials, NBRO and the Consultant team jointly inspected the completed work sites. The university and NBRO have consented to the delegation.

Meeting between the University and NBRO

Explanation to University Officials in Charge of the Site

Photo 5.10 Meeting with University Officials and Site Inspection

Table 5.9 Attendance from Uva Wellassa in This Meeting

Name	Organization and Position
Dr. H.M.J.S.P. Pitawala	Faculty of Science and Technology Department of Science and Technology Head of the Department, Senior Lecturer
Dr. Sisira Ediriweera	Professor
Dr. Tharanga Udagedara	Senior Lecturer
Mr. A.J.M.D.N.B. Nawela	Senior Assistant Registrar (General Administration)

The handover meeting was conducted on 8th August 2018 at Uva Wellassa University. The responsibility for maintaining the site was transferred from NBRO to the university. The Consultant team provided recommendations for the maintenance work, such as removal of sediments, to ensure safety for residents at the site.

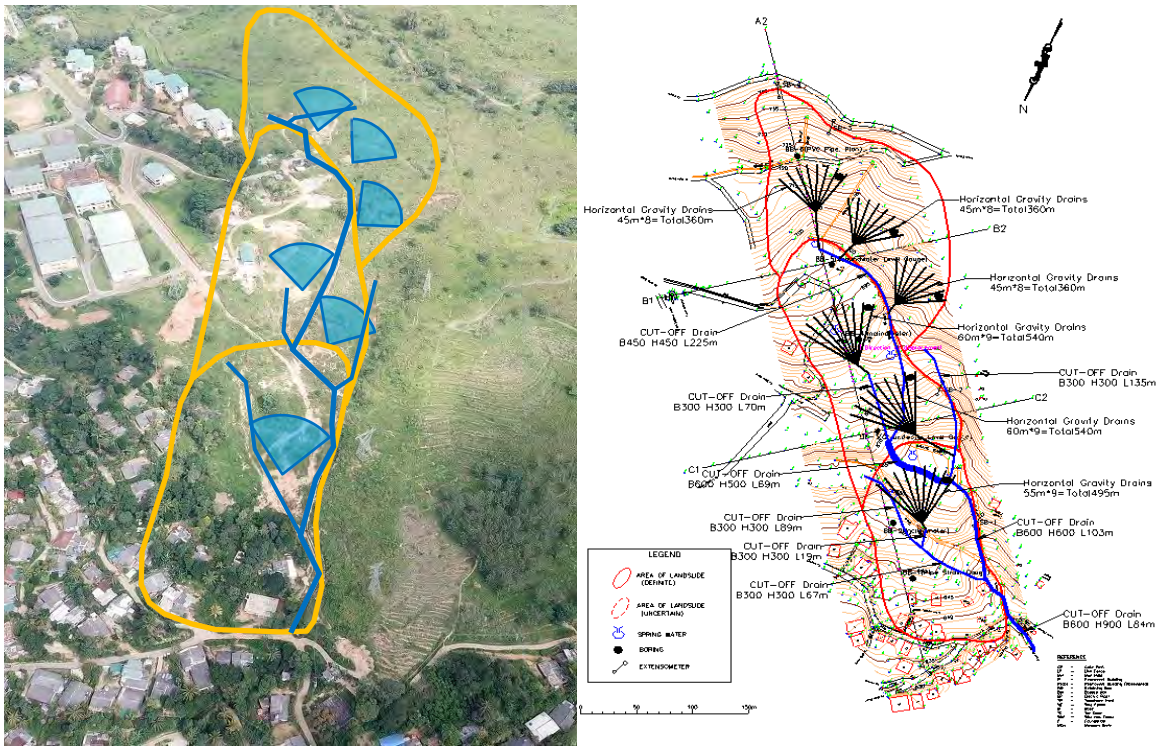


Figure 5.10 UAV Photograph after the Completion of Construction Work at the Badulusirigama Site

5.6 Prepare completion report of the rock fall mitigation measure in the pilot area (Activity2-6)

After completion inspection, the completion report was submitted by the contractor to NBRO (Appendix 8-5). To prepare the completion report, the Consultant team requested the following contents, which usually use included in Japanese construction work reports. NBRO has checked each content and description.

Contents of Completion Reports

1 Bill of Quantity
2 Amendment of Contract
3 Variation and Rate Analysis
4 Completed work item in BOQ
5 Final Progress Report
6 Construction Drawings
7 Construction Programme

Chapter 6 ACHIEVEMENTS OF OUTPUT 3 ACTIVITIES

6.1 Monitor and Evaluate the Slope Failure in the Pilot Area (Activity 3-1)

The location of the pilot site is the Kandy Nurse training school. There is a history of occurrence of slope failures, which has been repeated on the slopes. In addition, in October 2014 and December 2014, new slope failures occurred due to heavy rainfall around the site and the Kandy District. After the slope failures occurred, a site survey was implemented. At the time, the Consultant team and NBRO had a common understanding about disaster occurrence factors and disaster characteristics during the rainy season.

6.2 Design and Estimate Construction Cost for Slope Failure Mitigation Measure in the Pilot Area (Activity 3-2)

The design work is shown in the appendix "survey design report." Technical transfer for slope stability analysis, framework, soil nailing, and ground anchoring was provided. The project cost was calculated in the course of construction method comparison. Design standards, design statements and design quantities are shown in the survey design report. The planning plane and cross-sectional view is shown in Figure 6.1, Figure 6.2 and Figure 6.3.

A Japanese style countermeasure was adopted for the design of the work for the following reasons:

1) Based on the geological survey, it was confirmed that more intensive countermeasure work has to be implemented than the initial plan
2) Sri Lankan style countermeasures would require resettling the nursing school and to close road traffic
3) Japanese style countermeasures, such as anchor work, are more suitable for this site. It is not necessary to resettle the school and close the road

For these reasons, Japanese style countermeasures were adopted in this area. However, the pilot site was excluded, because the scale of work would be much bigger than the initial plan (refer to 2.1 PDM and PO). Therefore "activities 3-2" of this project has not been implemented. However, countermeasure work of the lower slope near the nurse training school was under construction as of Aug 2018 under another JICA project "Verification Survey with the Private Sector for Disseminating Japanese Technologies for Slope Disaster Mitigation Technology with Shotcrete Cribwork using Unit type Wire net Formwork". The slope stability countermeasure work of the upper slope near the nurse training school has been completed by the project of Ministry of Health.

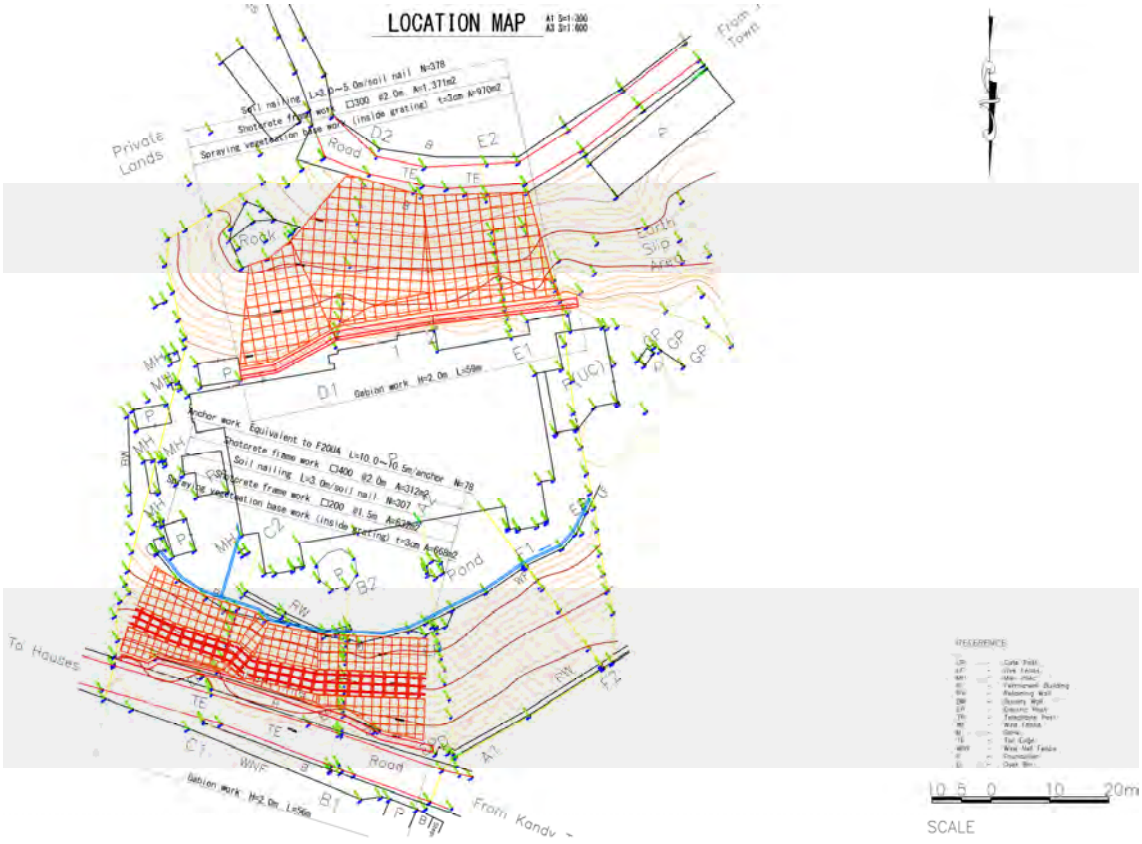


Figure 6.1 The Map of Countermeasure Work Plan in Kandy Nurse School

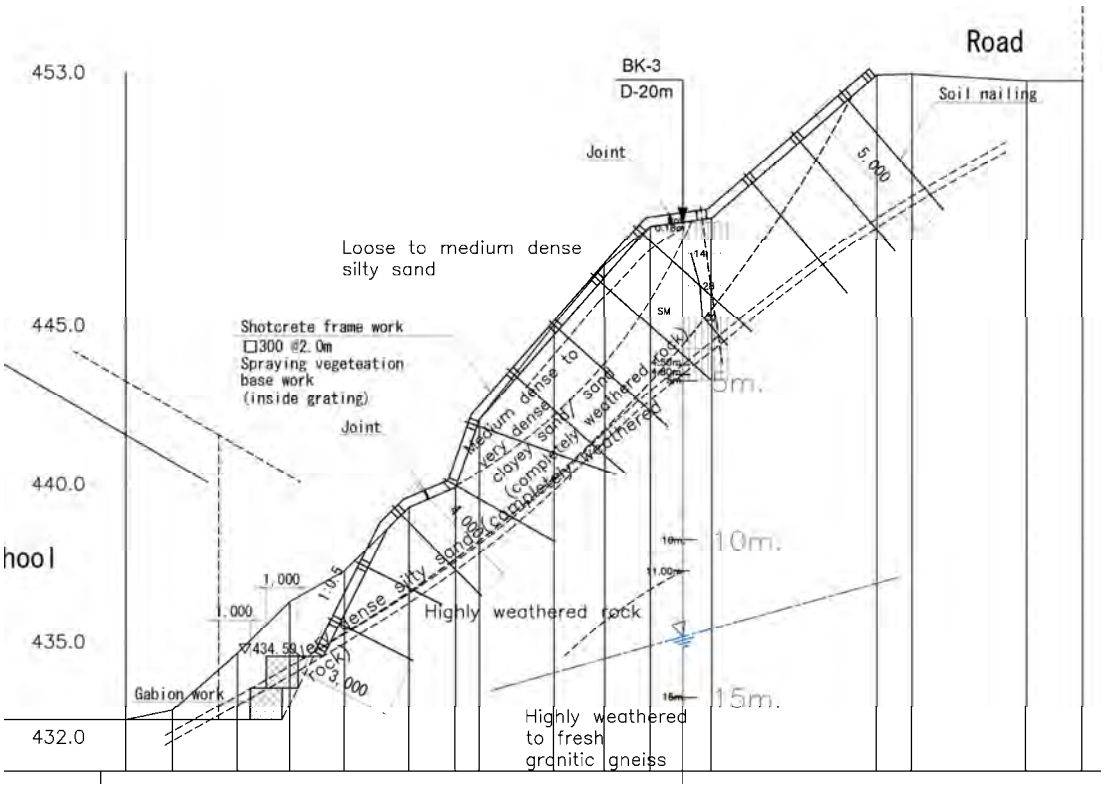


Figure 6.2 The Section of Countermeasure Work Plan in Kandy Nurse School (upper slope)

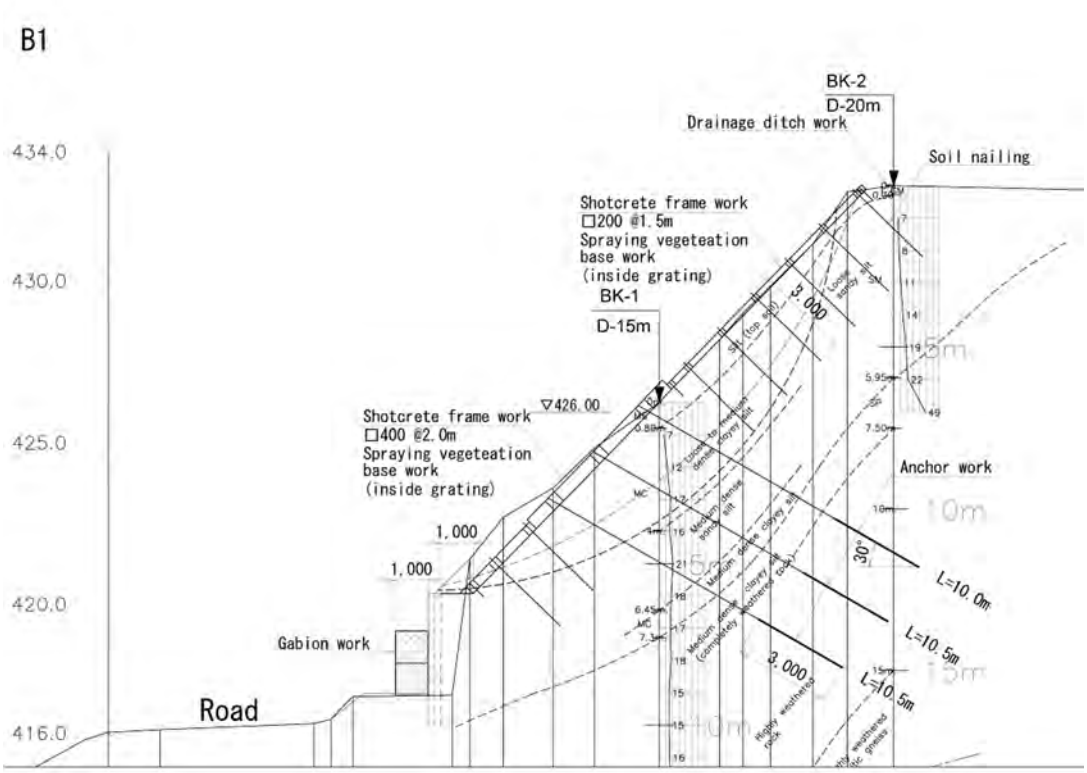


Figure 6.3 The Section of Countermeasure Work Plan in Kandy Nurse School (lower slope)

Photo 6.1 Drone view after construction (23th Mar 2018)

Chapter 7 ACHIEVEMENTS OF OUTPUT 4 ACTIVITIES

7.1 Monitor and Evaluate the Rock Fall in the Pilot Area (Activity 4-1)

Many rocks that were more than three (3) meters in diameter had fallen and scattered around the site. Field surveys were performed to identify the location of the main rocks falls. It was confirmed that to the team needed to identify the exact rock mass location at 15 points. The Consultant team and staff of the NBRO Matale District Office conducted a field survey of the top and bottom of the rock fall area in order to verify the source of the rock fall on 19th February 2015. Based on the results of the field survey, there was a massive rock that exceeded the relative elevation by more than 30m, and there were unstable boulders around the massive rock.

According to the result of field survey, it was confirmed that this area is at risk of rock falls due to topographical conditions. Countermeasure works would be effective in a rock fall-concentrated area.

7.2 Design and Estimate Construction Cost for Rock fall Mitigation Measure in the Pilot Area (Activity 4-2)

The design work is shown in the appendix "Survey design report". The project cost was determined by preparing bidding documents based on the design results. Design standards, design statements, design quantities are shown in the "Survey design report". The planning plane and cross-sectional view are shown in the following figures.

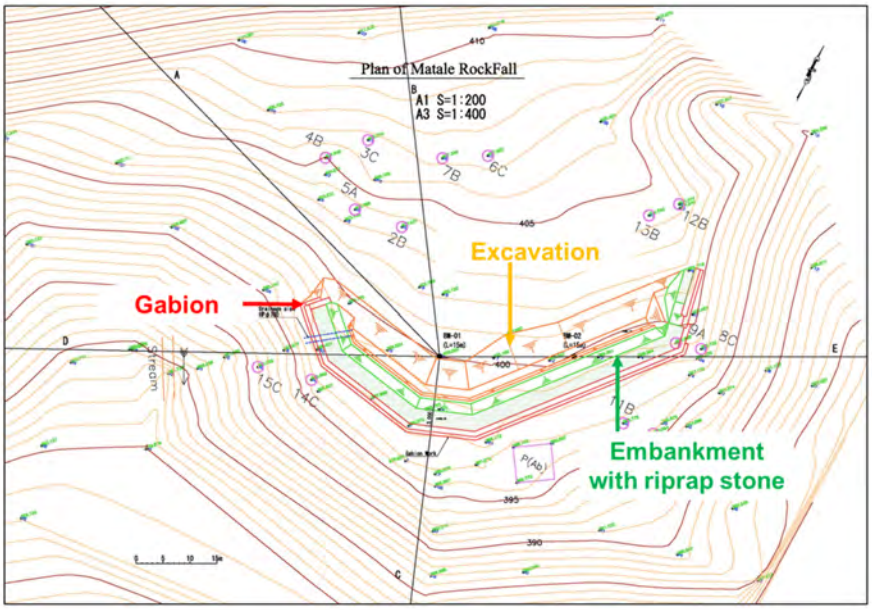


Figure 7.1 The Map of Countermeasure Work Plan in Alagumale

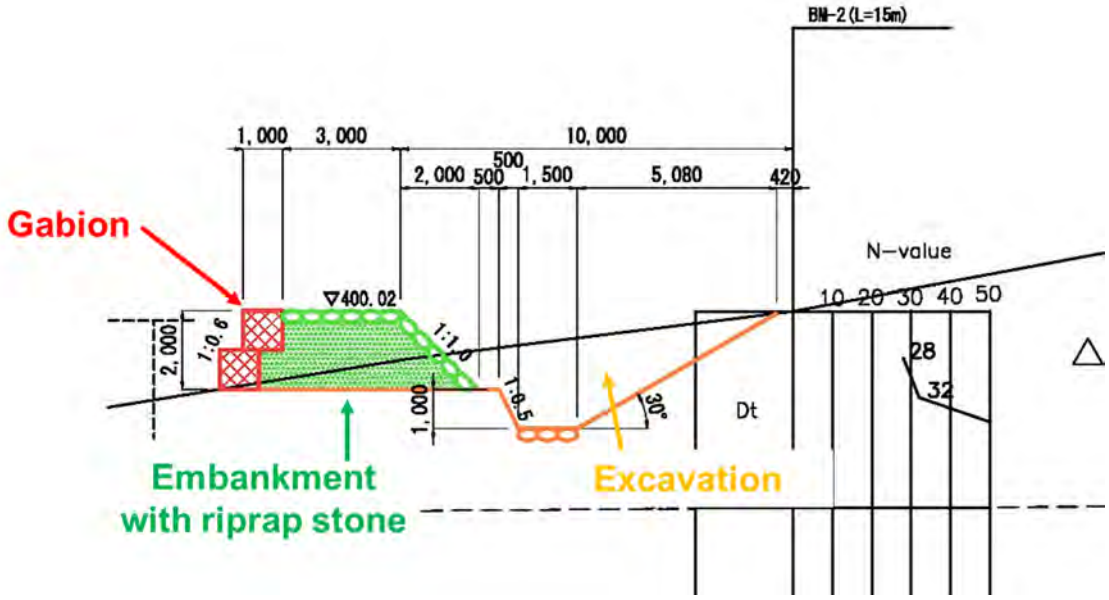


Figure 7.2 The Section of Countermeasure Work Plan in Alagumale

After the topographic survey was conducted, a fallen rock survey was performed, and locations and diameters of fallen rocks were surveyed. Also a site survey for the source of fallen rocks was conducted with NBRO, and the source of the rock falls was assumed. Based on the survey data, a rock fall simulation was run and the energy of rock falls was estimated. Selected countermeasure works should endure the rock fall energy. Excavation and earth dykes (embankment with riprap) were selected due to technical effectiveness, cost-effectiveness, and easy maintenance.

These surveys were conducted with NBRO. Also, technical transfer of analysis and design was conducted through discussions, seminars, and workshops.

7.3 Prepare Tender Documents for Rock Fall Mitigation Measure in the Pilot Area (Activity 4-3)

In the same manner as described in Section 5.3.

7.4 Evaluate Tender Documents and Procure Contractor for Rock Fall Mitigation Measure in the Pilot Area (Activity 4-4)

In the same manner as described in Section 5.4.

7.5 Supervise the construction work for Rockfall mitigation measures in the pilot areas. (Activity 4-5)

7.5.1 Creation of construction supervision documents

In the same manner as described in Section 5.5.1.

7.5.2 Technical transfer for construction supervision (Matale District)

1) Overview

The awareness meeting was held on 9th Apr 2016 by NBRO with the contractor. The participants were about 20 residents. NBRO explained the purpose of the project, the effectiveness of the countermeasure work, general information about the construction (e.g. construction plan, construction period, and construction area) and the impact on the surrounding environment. Interest of the residents was high, and they accepted and cooperated with construction work.

At the Matale district site, the first construction work was earthwork for the embankment. Therefore, technical transfer for supervising the site was managing the quantities of earthwork and the number of gabion work.

2) Lessons from supervising construction

In August 2016, there was a delay of the site work due to miscommunication between workers at the site. Then a meeting of the representatives of the project was held. The participants were the manager and engineers of the district office, the technical officer at the site, and the Consultant team. At the meeting, all of the members reconfirmed their tasks and understanding and purpose of this project. The purpose of this project was the technical transfer of construction supervision. This project is different from the usual construction work implemented by NBRO.

On the other hand, one of the problems was that the technical officer of NBRO only visited the site once a month, because he was responsible for supervising three (3) other sites at the same time from the beginning of the site work. The Consultant team continuously asked NBRO to have the technical officer check the site. Finally, the site engineer visited the site regularly.

Under the initial design, a buried hume pipe was planned to drain water inside the pocket. As a result of field reconnaissance and consultation with the NBRO, it was determined that if the hume pipe were to be blocked by rock masses and sediments during a short-term heavy rain event, triggered by climate change, surface water would temporarily remain inside the pocket. In that case, a significant volume of soil and rock will move towards the houses. Therefore, in order to prevent clogging of the pipe, an open channel was planned instead to drain water, to maintain the stability of the lower slope, and to secure safety for homes. Due to this additional work, the construction period was extended from January 16th, 2017 to March 16th, 2017. The main construction work at this site was earth cutting and embankment, so there were no particular technical problems.

Photo 7.1 Drone view after construction (22th Mar 2018)

Split stone block

Meeting of representatives

Open channel

Inside of the pocket

Surface of the embankment

Surface of the embankment

Front view of the embankment

Front view of the embankment

Photo 7.2 Countermeasure work of the rock fall

3) Completion inspection

On 14th March 2017, completion inspection was conducted with participation from JICA Sri Lanka office, NBRO and the Consultant team. Comments on completion inspection are shown in Table 7.1.

Table 7.1 Comment of the Final Inspection in Nuwara Eliya Site

Item of BOQ		Comment
2.1	Health and safety measures	Attach photographs and descriptions corresponding to work instructions to the final report
3.1	Insurance, Compensation	Attach copies of certification documents, such as insurance policies, to the final report
4.1	Project signboard	Attach a picture with an explanation to the final report
6.2	As built drawings	Attach the drawing with the signature of the person responsible to the final report

Recommendations from The Engineer

- Materials like sand bags will be necessary to maintain stability of channel work because it is located on a steep slope
- The mountain side of the excavation surface is bare. There is a risk that erosion will occur from future rain events and sediment will accumulate in the falling rock pocket. Vegetation should be planted to prevent erosion

In response to these comments, the Contractor conducted improvement works at the site. From the completion inspection to August 2018, there has not been any heavy rainfall at the site, and problems have not been found.

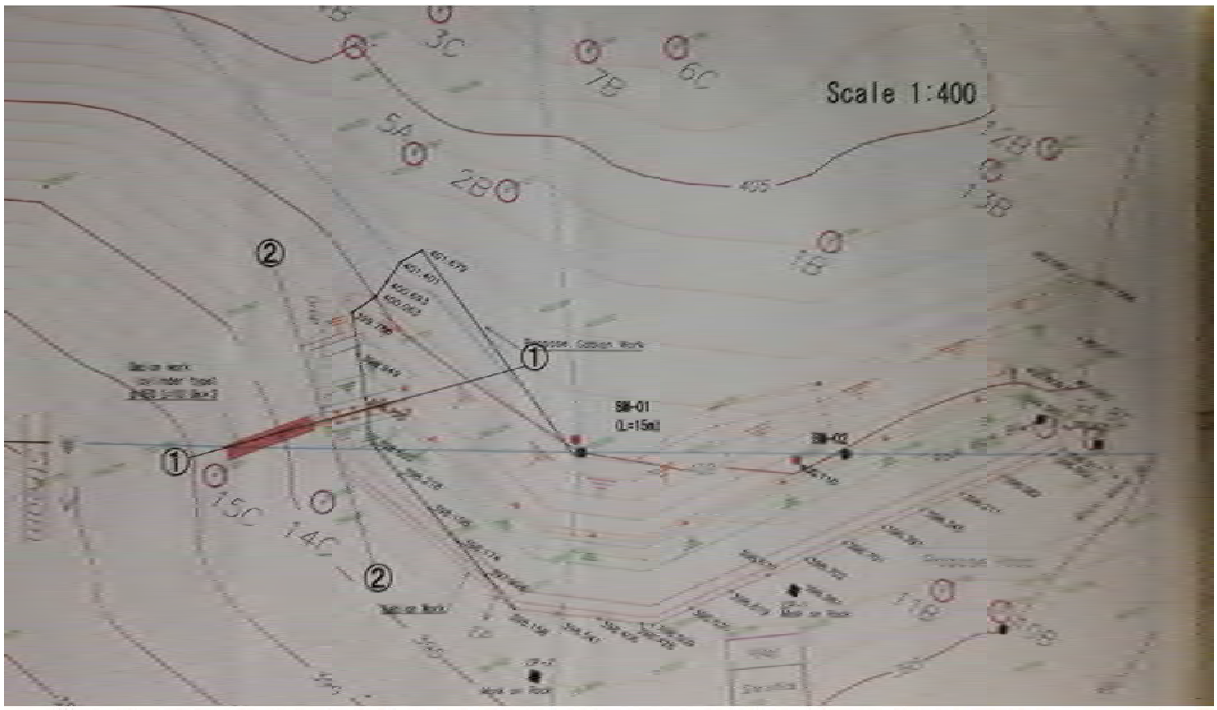


Figure 7.3 Built Drawing

4) Defect Liability Inspection

The Defect Liability Inspection was carried out on 3rd March 2018 by the JICA Sri Lanka office, NBRO, the Consultant team, and the Contractor. For technical transfer of maintenance work, it was made clear that it is necessary to remove falling rocks and soil inside the pocket. All participants understood the importance of the maintenance work at the site.

5) Handover meeting

The handover meeting was conducted on 16th July 2018 at the Matale Divisional Secretariat office. The responsibility for maintaining the site condition was transferred from NBRO to Matale Division. The Consultant team gave advice, such as removing rocks and soil for maintenance and to keep residents around the site safe.

7.6 Prepare completion report of the rock fall mitigation measure in the pilot area (Activity4-6)

After completion inspection, a completion report was submitted by the Contractor to NBRO (Appendix 8-5). The contents of the completion report are same as other sites.

Chapter 8 ACHIEVEMENTS OF OUTPUT 5 ACTIVITIES

8.1 Review and Update the Existing Manual and Technical Standard on Sediment Disaster (Landslide) Mitigation on Structural Measures (Activity 5-1)

Existing guidelines of landslides in Sri Lanka provide only an overview. Separately, there is a guidebook named "Guideline for Construction in Landslide Prone Areas (Ministry of Housing and Plantation Infrastructure, March 2003)," which is intended to deal with landslides. There are no official guidelines which deal with a variety of sediment-related disasters comprehensively.

Currently, the road sector Japanese yen loan project "Landslide Disaster Protection Project (LDPP) of the National Road Network" was conducted with RDA, focusing on road disaster prevention. In that project also, guidelines to support technology transfer are now being compiled. The guidelines aim to improve Sri Lanka's disaster prevention technology based off of the Japanese technology. The theme of that guideline overlaps with the theme of this project. Given such circumstances and through a meeting with NBRO, it was decided that the activities related to the integrated disaster prevention guidelines would be carried out with the ODA loan project in the second phase of the TCLMP project. When the guidelines are completed, it will be utilized in a number of sectors involved in disaster prevention.

8.2 Conduct Trainings Using the Revised Technical Standard and Manual on Sediment Disaster (Landslide) Mitigation on Structural Measures (Activity 5-2)

The Consultant team conducted trainings and workshops using the prepared manual. The main activities are as follows:

- Design and supervision of countermeasure works
- Investigation for countermeasure design
- Monitoring methods during and after construction
- Completion Inspection and Defect Liability Inspection

8.3 Conduct Technical Seminars and Workshops on Sediment Disaster (Landslide) Mitigation for Both Structural and Non-structural Measures (Activity 5-3)

Technical seminars and workshops have been conducted as the project has progressed. Through these sessions, the organizational system and regulations of Japan's disaster management, construction work at pilot sites, and the experience of non-structural measures in Japan has been explained. An overview of seminars/workshops is shown in Table 8.1.

Table 8.1 Seminar and Workshop organized through the Project

No	Description	Date	Participants
1	Kick-off Seminar	6th Oct. 2014	NBRO staff: 9 people
2	Progress Report for Pilot Site Survey	27th Nov. 2014	NBRO staff: 15 people
3	Progress Report for Design of Pilot Construction Work	29th Jul. 2015	NBRO staff: 30 people
4	Information Management	8th Dec. 2015	Central government, municipalities, military personnel, and mass media
5	Review of Disaster Management Mechanism of Sri Lanka based on the Experience Gained in Sri Lanka and Japan	14th Jan. 2016	

No	Description	Date	Participants
6	Introduction of Disaster Imagination Game (DIG) and Japanese Experience for Institutionalizing the Culture of Prevention on Disaster	25th Jan. 2016	Around 60 to 70 people participate each time
7	- Introduction of Debris Flow Disaster and countermeasures in Japan - Summary of the Setting Method of the Yellow Zones based on "Sediment Disaster Prevention Act" in Japan	30th Aug. 2016 1st Sep. 2016	NBRO staff: 15 people
8	- Introduction of Debris Flow Disaster and countermeasures in Japan - Summary of the Setting Method of the Yellow Zones based on "Sediment Disaster Prevention Act" in Japan	31st Aug. 2016	Central government, municipalities, military personnel, and mass media. In Total 92 people
9	Review of Project Activities and Issues based on the result of Mid-term Evaluation and Confirmation of Next Activities	12th Oct. 2016	NBRO staff:17 people
10	Presentation on Annual NBRO Symposium - Introduction of the Result of Survey and Design for Pilot Site of TCLMP - Progress of Supervision of Construction Work - Introduction of Landslide Monitoring through the Project	6th and 7th Dec. 2016	Central government, municipalities, military personnel, and mass media. 1st day : 220 people 2nd day: 152 people
11	- Exercise for Yellow Zone Setting based on "Sediment Disaster Prevention Act" in Japan - Exercise for Debris Flow Numerical Simulation	23th to 25th Jan. 2017	NBRO staff: 8 people
12	- Early Waring for Sediment Disasters and Effective Evacuation - Introduction of Identification of Sediment Disasters Warning Area and Consideration for application in Sri Lanka	27th Jan. 2017	Central government, municipalities, military personnel, and mass media In Total 67 people
13	Sediment Disaster Risk Assessment and Countermeasures in Japan - Sediment Disaster Warning System using IT technologies - Suggestion and Activities of Non-Structural Measures through in this Project - Suggestion and Activities of Structural Measures in through Project - Introduction of "Verification Survey for Slope Disaster Mitigation Technology with Shotcrete Cribwork using Unit Type Wire Net Formwork" in Kandy Nurse School	21st Feb. 2017	Central government, municipalities, military personnel, and mass media. In Total 100 people
14	Exercise for Topographical Analysis using UAV Survey Result	27th Feb. 2018	NBRO staff: 8 people
15	- Application of UAV Survey for Landslide Survey - Review of Non-Structural Measures - Review of Design of Structural Measures - Review of Supervision for Structural Measures - Lessons and Learned from the Project Activities	19th Mar. 2018	NBRO staff: 37 people

Sediment disasters, which occurred during the project period, and those survey results were also used as topics for the seminars and workshops. In the latter half of the project, case studies of debris flow disasters were introduced upon a request from NBRO, and discussions were held about the risk evaluation methods, early warning systems, and land use regulations in Japan.

Short-term experts who were experienced in this field were dispatched three times in total as mentioned in Table 8.2. They held seminars and workshops about response and organizational structure during the disaster period, the risk assessment method, and early warning system in Japan. In addition, they visited the landslide sites which occurred in recent years with NBRO.

Table 8.2 Activity of Short-Term Experts

No	Name	Duration	Working Contents
1	Satoru NISHIKAWA	25th Jan. 2016	Workshop for Improvement Process of Disaster Mitigation Structure in Japan
2	Taro UCHIDA Koichi ISHIO	26th Aug. - 3rd Sep. 2016.	- A visit to the JICA Sri Lanka office and the Embassy of Japan - Site visits to previous landslides (Koslanda, Lilpora, Kotmale and Aranayake) - Workshop and seminar - Discussion about early warning and land use regulations with NBRO
3	Taro UCHIDA Yoichi WASHIO	20th - 28th Jan. 2017	- A visit to the JICA Sri Lanka office and the Embassy of Japan - Site visits to previous landslides (Lilpora and Aranayake) - Workshop and seminar - Discussion about early warning and land use regulations with NBRO

8.4 Stakeholder Consultation on Land Use Regulation for Sediment Disaster (Landslide) Mitigation (Activity 5-4)

8.4.1 Sediment Disaster Risk Evaluation by NBRO

Several sediment disasters occurred during this project period, and it caused significant damages in the mountainous areas. In Sri Lanka, NBRO is identified as the responsible organization for structural and non-structural measures against sediment disasters. NBRO has conducted many activities such as technical surveys, risk assessments, landslide early warning issuance, public awareness, and provision of advice to relative organizations. Particularly in recently years, their responsibilities and roles for disaster management has become more institutionalized.

On the other hand, laws and regulations for land use have not been clearly established at the national level. Technical advice is only given to regulating organizations or applicants based on the topological and geographical conditions, past disaster records, and the Landslide Hazard Zonation Map (LHZM) which was developed by NBRO.

The LHZM has been developed in each scale from 1990 under the support of UNDP, and they have been prepared in 10 districts of the central mountain area that have high landslide risk. The hazard has been evaluated according to six (6) factors, including historical disasters, geology, hydrology, surface covering, and slope gradient, and the risk is classified into 4 groups. NBRO continues to expand the coverage area and tries to update and improve the accuracy of these maps. The LHZMs for the locations of the pilot sites are shown in Figure 8.1 and Figure 8.2, and the coverage area of the LHZM is shown in Figure 8.3.

For consideration of the land use regulations on sediment disasters, the following workshops were held to increase understanding of the response and to build relationships between related organizations in case disasters occur.

- Information Management
- Review of Disaster Management Mechanism of Sri Lanka based on the Experiences Gained in Sri Lanka and Japan
- Introduction of Disaster Imagination Game (DIG) and Japanese Experiences for Institutionalizing the Culture of Prevention on Disasters

The same staff from each institution participated in seminars and workshops as much as possible, and they discussed about current disaster situations, issues, and needs for each organization in their

group work. The large-scale debris flows, like the Koslanda disaster in 2015 and the Aranayeke disaster in 2016, has frequently occurred in recent years, and there was a tendency that the necessity of countermeasures against debris flow had increased for these related organizations.

Based on the opinion gained at these workshops and based on the several sediment disasters that had occurred during this project period, the 2nd and 3rd short-term experts explained the basic phenomenon, precautions and early warning, and dissemination of risk information about debris flow. In addition, the Yellow Zone Setting method was introduced for steep slope collapse and debris flow based on the “Sediment Disaster Prevention Act in Japan”.

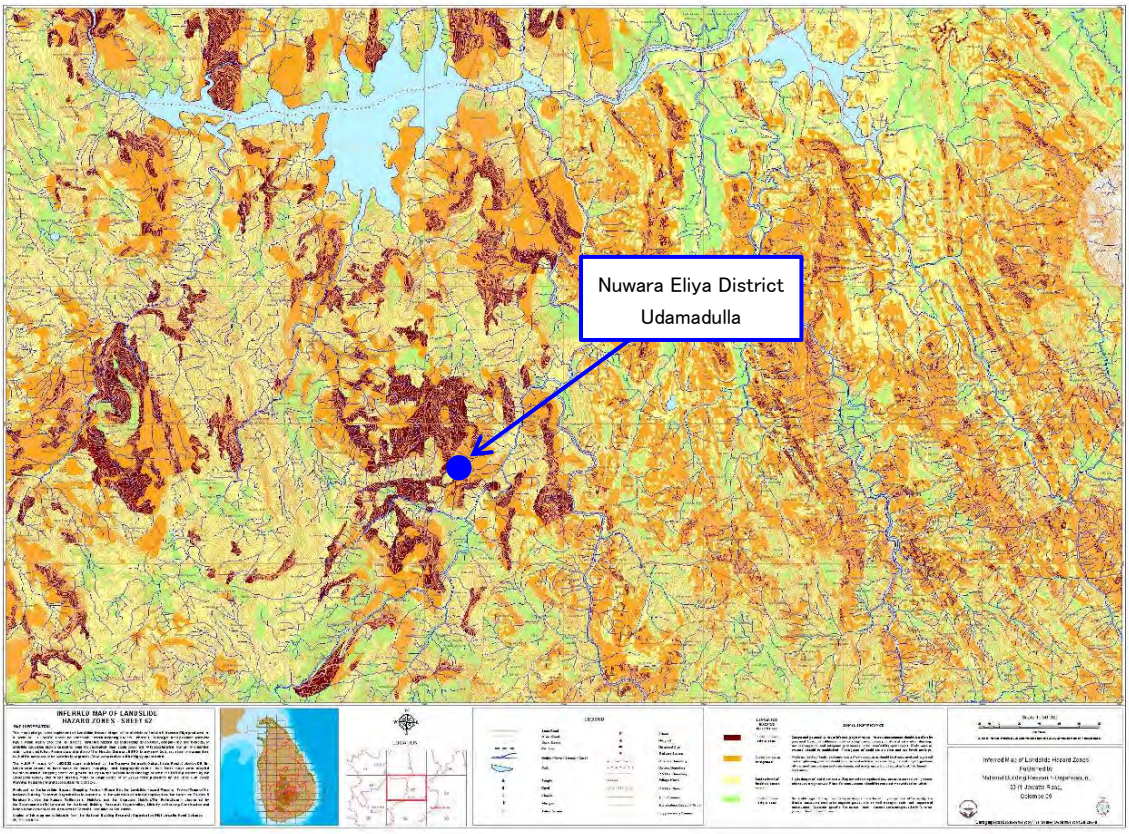


Figure 8.1 An Example of LHZM (1:50,000 scale)

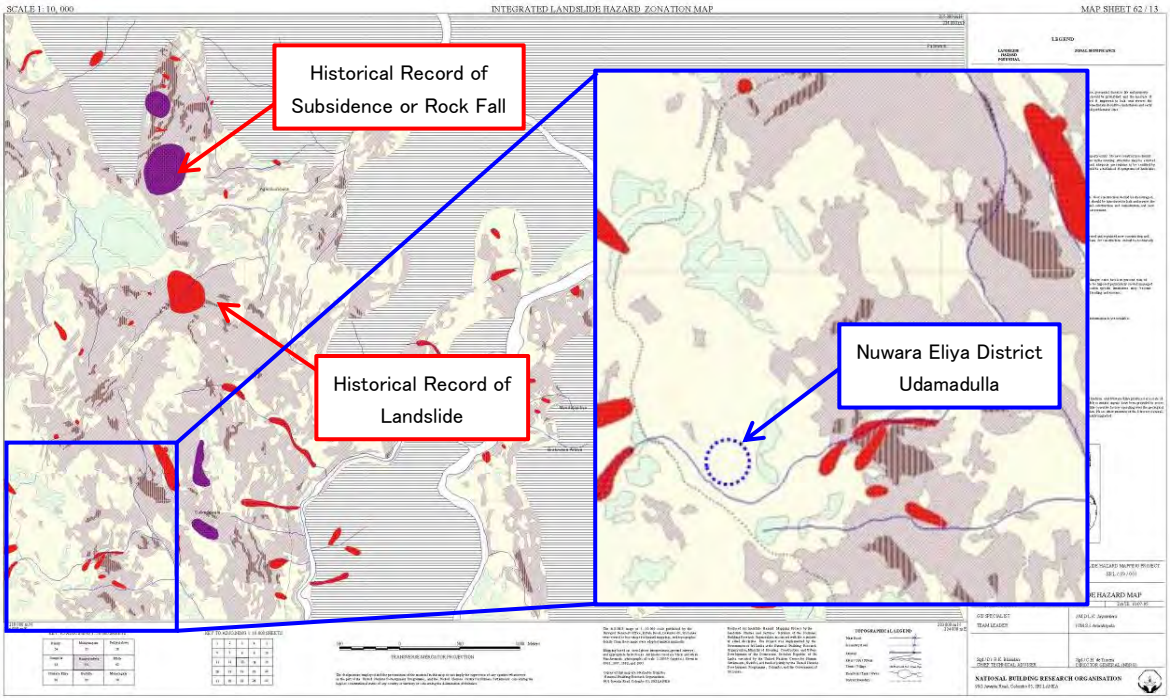


Figure 8.2 An Example of LHZM (1:10,000 scale)

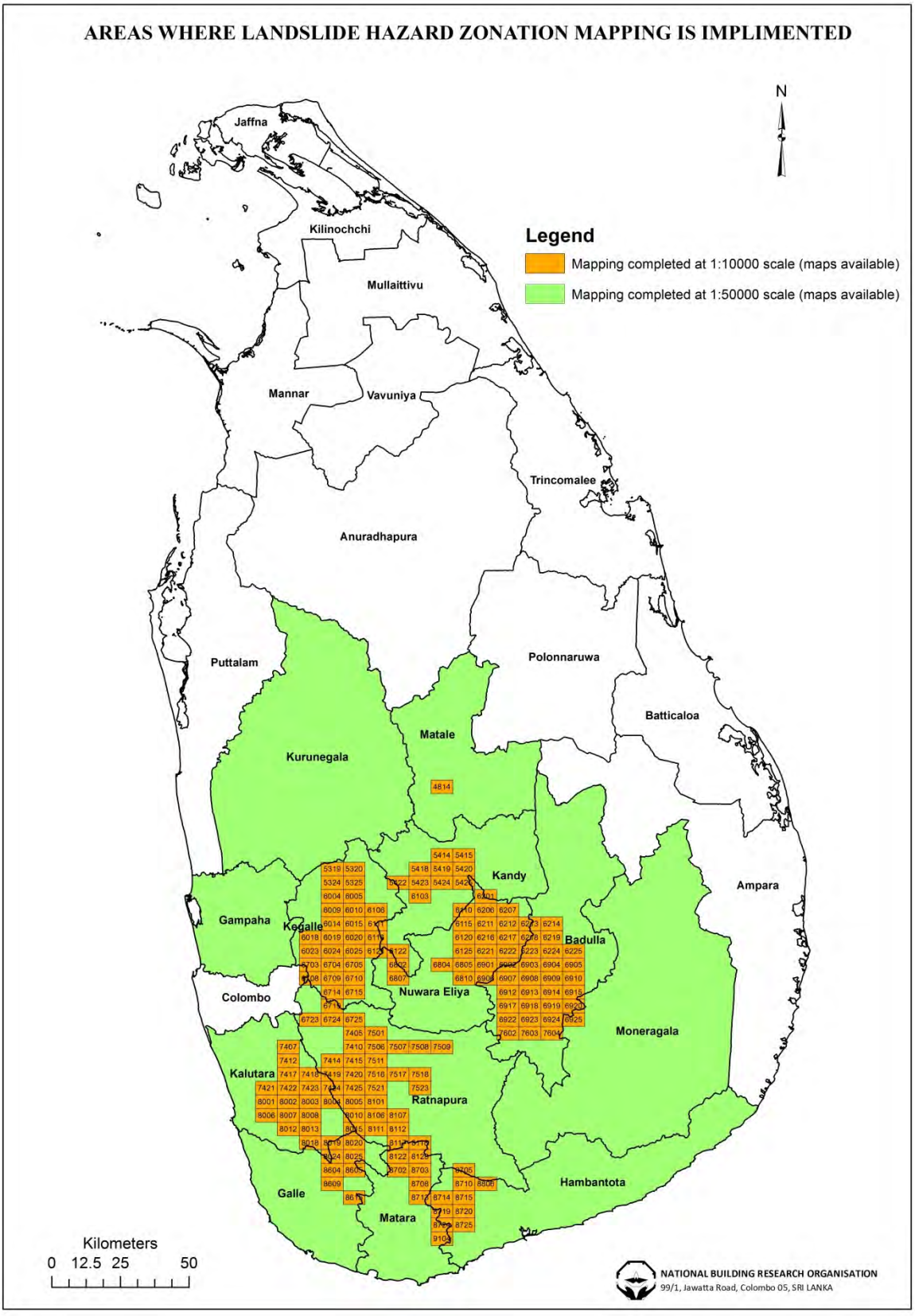


Figure 8.3 Coverage Area of LHZM (1:10,000 and 1:50,000 scale)

8.4.2 Application of Yellow Zone Setting Method in Sri Lanka

The 2nd and 3rd short-term experts visited the recent landslide sites that with staff from the NBRO head office and members of the District Office. They discussed about post-disaster survey and evaluation methods and the necessity to increase people's awareness in the surrounding area.

As mentioned in above, the LHZM identifies only areas in danger of sediment disaster occurrence. The hazard is not categorised into each sediment disaster type, such as landslides, steep slope collapse, or debris flow. However, the suitable method for evaluation and countermeasures required for each disaster type is different, due to the difference of the occurrence mechanism, phenomena characteristic, and the area of influence. Through the dispatch of short-term experts, the method of estimation and evaluation of the debris flow influence area, the legal basis for designating dangerous areas in Japan, and selection of priority dangerous areas were discussed, providing an opportunity for Sri Lankan agencies to consider how they should address their debris flow risk.

Site Visit of Recent Landslides

Workshop held by Short-Term Experts

Photo 8.1 Activities of 2nd Short-Term Experts

The 3rd round of short-term experts was from 20th to 28th January 2017. Based on discussions and the result of the site survey left by the 2nd round of short-term experts, they performed a debris flow numerical simulation and designated dangerous areas prone to sediment disasters, applying the Yellow Zone Setting method used in Japan to the Aranayake landslide that occurred in May 2016. Selected members from NBRO participated in the entire process during the dispatch period, including site visits, simulation exercises, discussions, a workshop and a seminar for technical discussions and promotion of understanding.

Estimating the affected area and designating dangerous areas according to the "Sediment Disaster Prevention Act in Japan" for the debris flow was conducted during the exercise. Participants compared the results of 1D and 2D numerical simulations and the actual disaster, and discussed about the effectiveness of that method and the issues for its application in Sri Lanka.

As mentioned above, the current sediment disaster assessment reflected on LHZMs is focused on the identification of disaster sources. In the future, a risk assessment method that considers and identifies specific dangerous area will become necessary, as the rapid economic growth in Sri Lanka continues. However, several issues still remain, such as the difference of land use in mountainous areas, legal and regulatory system, and recognition in government organizations which are responsible for development activities.

NBRO also considered the above points as an issue for the organization. NBRO submitted the "National Building Research Institute Act (NBRI Act)" to the Cabinet Office for the establishment of NBRO also as a national institute. New legal authority to undertake various measures in sediment disaster-prone areas would be provided after the formulation of the NBRI Act. Then, there would be a high possibility that NBRO could promote activities to develop legal and organizational systems and to apply a new risk assessment method.

Exercise of Setting Yellow Zones

Discussion with HSPTD

Photo 8.2 Activities of 3nd Short-Term Exports

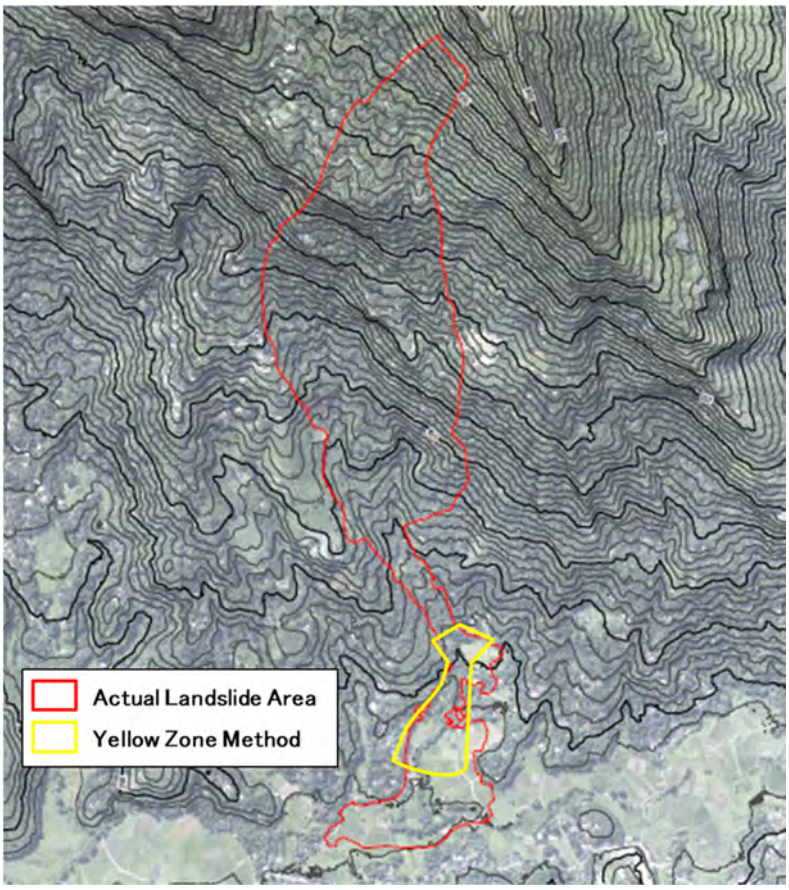


Figure 8.4 Example of Yellow Zone Setting Method (Aranayake Landslide)

8.4.3 Resettlement in Landslide Prone Area

NBRO identifies the high risk areas from the LHZM and the occurrence of past disasters, and recommends local residents living that area for resettlement to a more safe area. In the resettlement programme, beneficiaries are given support from the government or donors, such as land, constructed houses, and cash for house construction, reducing the burden on victims. The specific support is different depending on the programme. NBRO also provides technical support, such as land selection, house planning, and house construction during the implementation phase and coordinates stakeholders.

The physical transfer and the economic transfer are often mentioned as the main issues for resettlement. Physical transfer means relocation or loss of a residential area, and economic transfer refers to the loss of land, property, property access, source of income, and livelihood. These issues are similar to cases in other countries, the following obstacles can be also attributed to Sri Lanka.

- Lack of understanding of the resettlement purpose and its process
- Disagreement over compensation money amount and alternative site conditions
- Difficulty of livelihood rehabilitation at the alternative site

Resettlement has a large impact especially for farmers and workers on tea plantations, and many of them live in identified high risk areas. Therefore, NBRO needs the legal authority to develop support mechanisms and to address these issues.

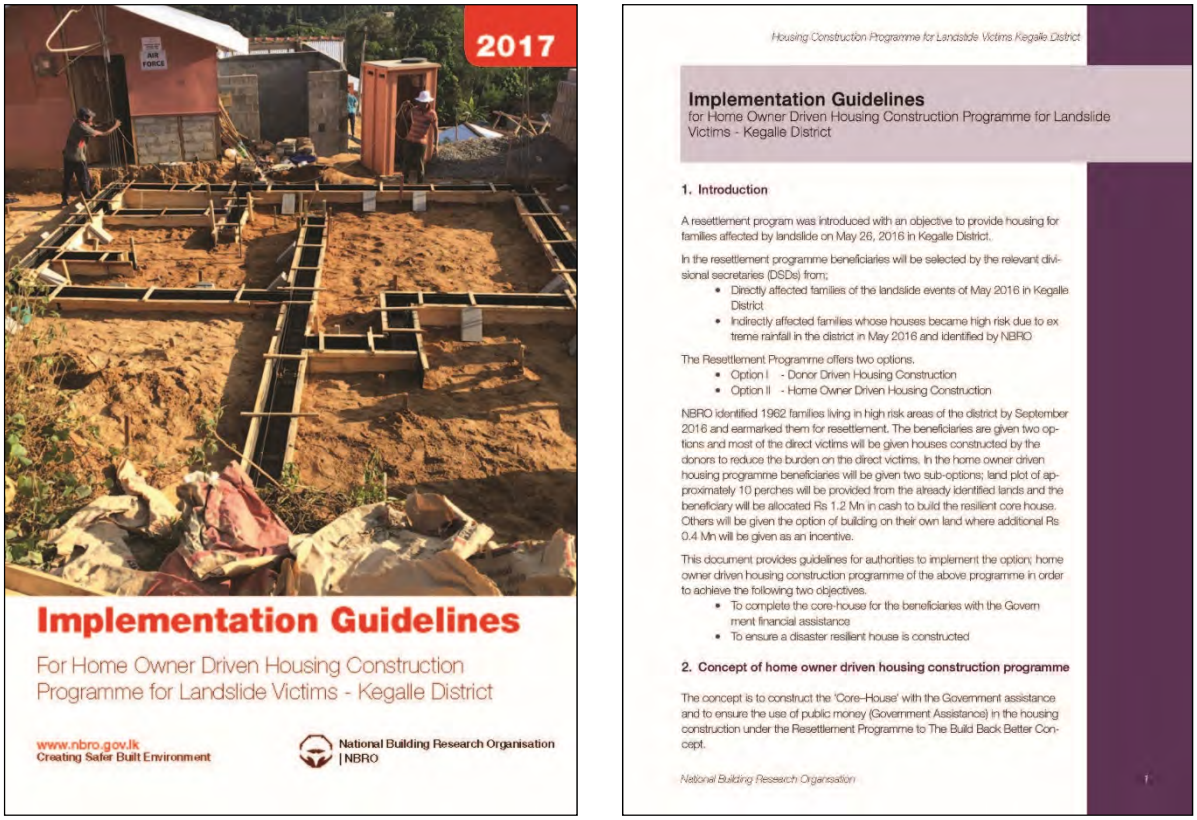


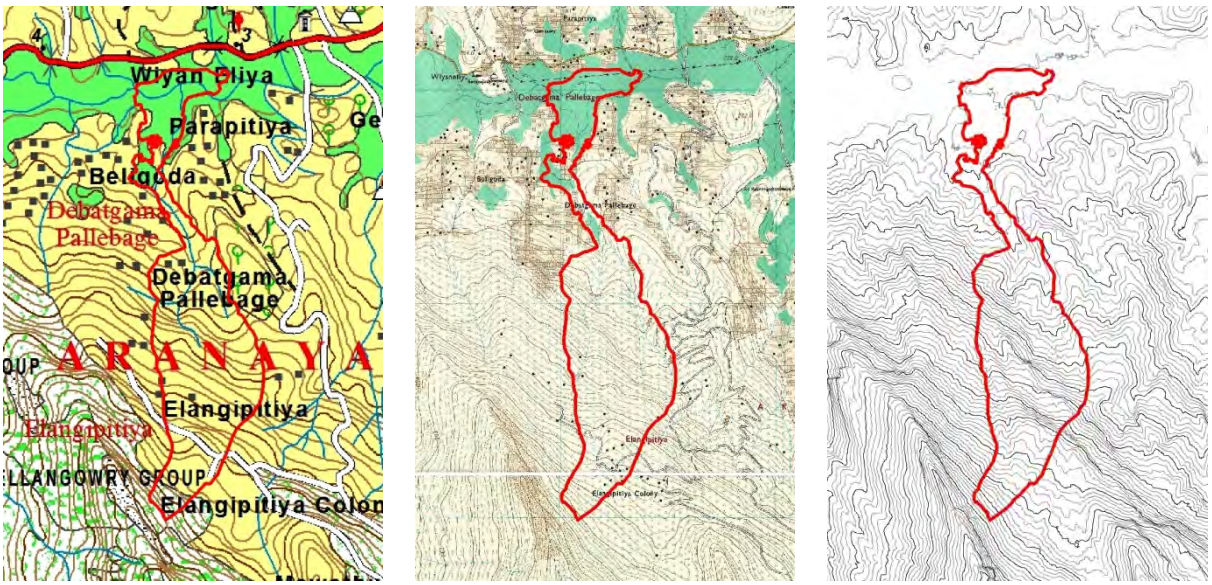
Figure 8.5 Implementation Guidelines Aranayake Landslide in 2016

8.5 Prepare Materials on Land-use Regulation for Sediment Disaster (Landslide) Mitigation (Activity 5-5)

As mentioned in 8.4, seminars and workshops for the land-use regulation in Sri Lanka, were held several times, and short-term experts were dispatched during the project. Based on these activities, the long-term experts held an international seminar on sediment disaster in February 2017. The issues and proposals related to land-use regulations are shown below.

Topographic Classification using detailed DEM/DSM

"The Capacity Development Project for Creating Digital Elevation Model Enabling Disaster Resilience" was conducted by the Survey Department in Sri Lanka under cooperation with JICA. This project conducted a LiDAR survey on the western and central part of Sri Lanka. They are processing and developing a detailed DEM (Digital Elevation Model). The topographic map used for risk assessment in NBRO does not have high accuracy and has not been updated. If the detailed topographic map/data can be used for the risk assessment, the traces of past sediment disasters, such as landslides and debris flows, can be more clearly found, and, hence, it would be easier to identify high potential risk areas. The accuracy differences of the topographic maps are shown in Figure 8.6.



1/50,000 scale　　1/10,000 scale　　LiDAR Survey

Figure 8.6 Comparison of Topographic Maps on Aranayake Landslide

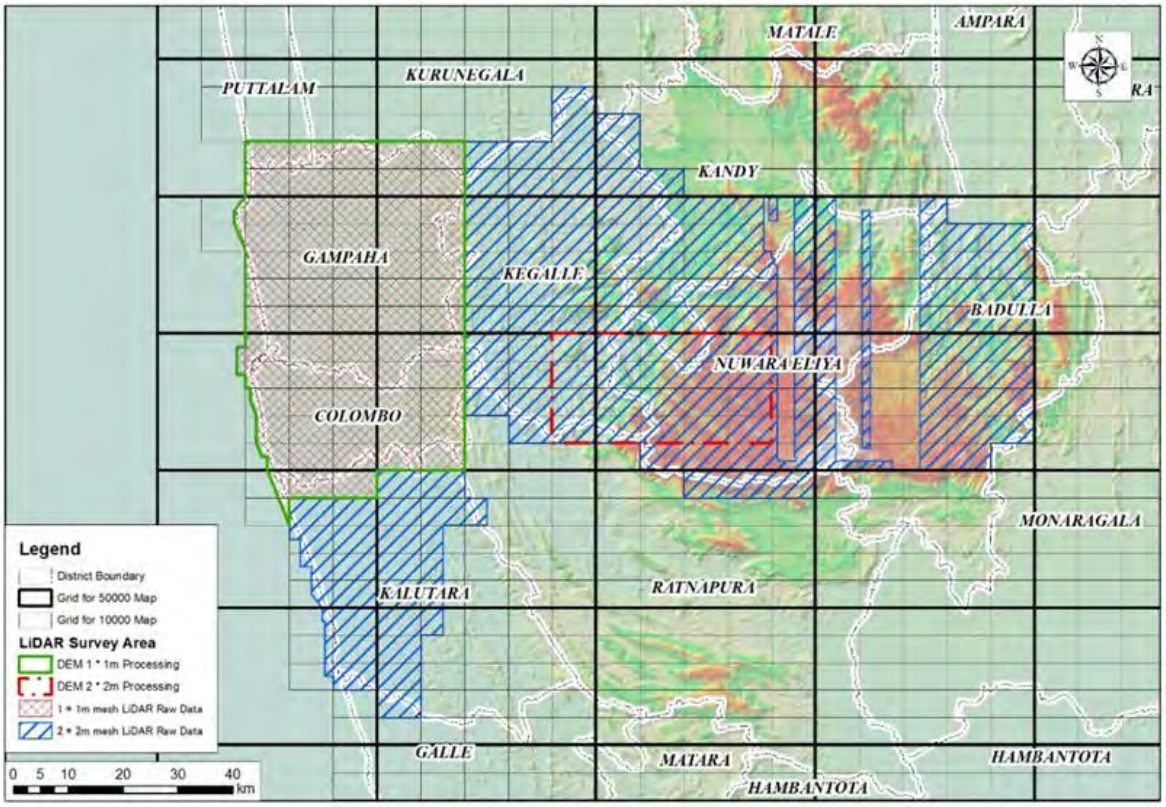


Figure 8.7 Scope of LiDAR Survey Area

Source: Modified of Capacity Development Project for Creating Digital Elevation Model Enabling Disaster Resilience

Individual Risk Assessment for Different Disaster Types

In Japan, the sediment disasters are classified into landslide, steep slope failure (collapse), rock fall and debris flow. The specific classification and definitions are not important, because that is different for each country. However some form of classification will be required to consider and determine affected areas and to plan countermeasure work. The LHZM, which is the current risk assessment process, applies the same factors for different disaster characteristics. This does not provide enough basic information for risk evaluation and land-use planning. The LHZM focuses instead on identifying the disaster source.

NBRO also have started surveying and researching the identified areas affected by sediment disasters, considering recent disaster occurrence trends. In addition, NBRO and NILIM (National Institute for Land and Infrastructure Management) in Japan signed a memorandum of cooperation for "Joint research and development in the field of landslide and sediment disaster risk management". Its aim is to strengthen the scientific and technological cooperation for sediment disaster hazard mapping, including numerical simulation, landslide early warning, and slope protection work. This memorandum also contributes to research and development for NBRO.

Considering the increasing need for structural countermeasures against sediment disasters, it will be required that the appropriate survey and design of countermeasures will be applied, depending on the disaster type in the future. From the viewpoint of prioritizing countermeasures and identification of high risk areas, it is first necessary to establish a risk assessment method.

Development of Disaster Database

NBRO maintains a record of all disasters, including basic information such as occurrence date, location, scale, and rainfall. A lot of paper-based disaster records are filed in each district office, and each person is collecting it depending on the needs of his/her research and activities. However, the disaster record has not been compiled in a unified format, because the record is different by each staff.

A consolidated disaster record would be useful for research activities and to compile important knowledge for comparison of disaster types and consideration of countermeasures. As described in 8.6.2, information can be analyzed to determine the relationship between rainfall and occurrence of sediment disasters, which would allow for an update of landslide early warning. Currently, NBRO is starting to develop an Excel database, which includes the location, occurrence date, rainfall during the disaster, disaster type, scale, and damages. Developing a system to allow access to the compiled disaster records will also contribute to various activities. Development of a disaster database does not immediately provide a great result by itself. A statistical analysis is required to update and examine early warning thresholds, so it is recommended that NBRO starts accumulating data and information as soon as possible.

8.6 Stakeholder Consultation on Early Warning and Disseminating Risk Information for Sediment Disaster (Landslide) Mitigation Based on the Experiences in Japan (Activity 5-6)

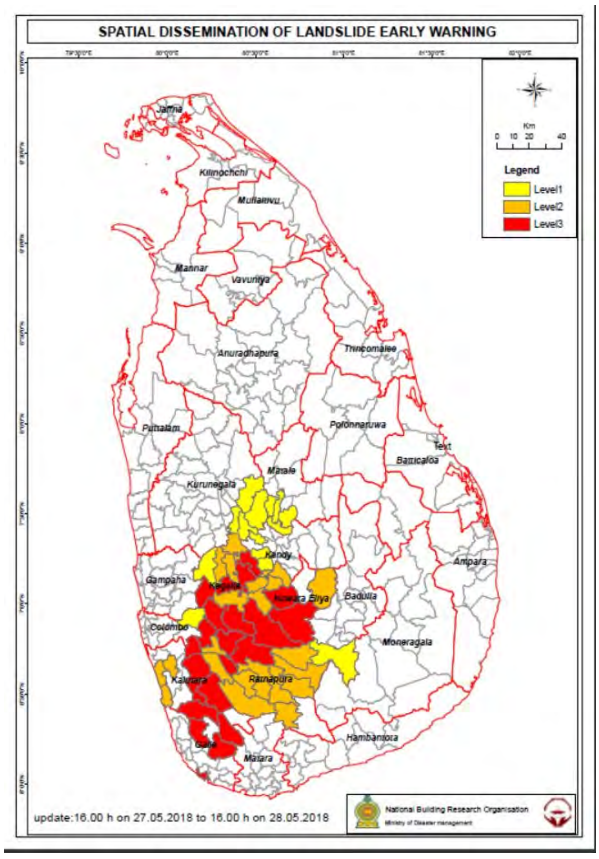
In Sri Lanka, NBRO is responsible for issuing Landslide Early Warnings in landside potential areas. Early Warning is based on rainfall monitoring by NBRO and DOM, and it is issued through an internal process. The current threshold is shown in Table 8.2

However, the same values for the current rainfall threshold are applied to whole country. This is one of the issues for NBRO, and they understand that the accuracy of early warning will not improve by only installing more rain gauges. The sales and proposal of early warning system was conducted by several entities such as DGI and many companies from each country. It is expected that a suitable early warning system in Sri Lanka will be developed by them.

Table 8.3 Threshold of Landslide Early Warning in NBRO

Alert Level	Color Code	Required Action	Threshold
Level 1	Yellow	Watch	Rainfall within the past 24 hours has exceeded 75mm
Level 2	Amber	Alert	Rainfall within the past 24 hours has exceeded 100mm
Level 3	Red	Evacuation	Rainfall within the past 24 hours has exceeded 150mm, or has exceeded 75mm in the past1 hour

Until 2017, NBRO had issued early warnings based on this threshold at the District level, but from the beginning of 2018, it has been possible to issue the warmings at the Division level with the increase in rain gauges and improvement of data accuracy. The update of the bulletin format and mapping of the warning area, which is published on the NBRO website, was carried out to improve understanding by related organizations and the common people. The updated early warning format is shown in Figure 8.8



Sample of Warning Area Map

Sample of Bulletin Format

Figure 8.8 Updated Early Warning Format in NBRO

8.6.1 Disseminating Risk Information

After starting the project, the Koslanda landslide occurred in October 2014. The project team conducted the After Action Review (AAR), and it was confirmed that the weather warning and Landslide Early Warning had not been disseminated to local residents at the beginning of the disaster period.

NBRO is responsible for submitting the landslide early warning to DMC through fax and telephone. This information is then disseminated to the common people and local governments, such as the District Secretary, by the DMC. According to the result of interviews with local residents around Koslanda, the project team requested the local consultant to conduct a data collection survey for the disaster management system from MDM and relative organizations in 2015 and 2016. It was confirmed that DMC had disseminated disaster information through the several channels like mass media, SNS, websites, and email. It seems that information dissemination using SNS was particularly effective with the current development of communication systems and social media. But it was confirmed that the disaster information had not reached the GN (Grama Niladhari) who is the closest person to local residents for disaster response.

The same situation could have occurred not only for sediment disasters but also for all disaster types, as information is issued by the same process. It is recommended that the dissemination system is continuously discussed with organizations related to disaster response, such as Department of Meteorology and Irrigation Department, although NBRO's responsibility for landslide early warning is only to report to the DMC.

8.6.2 Update for Early Warning Threshold

Improving landslide early warning, such as by updating thresholds and initiating detailed identification of potential risk, is one priority issue in NBRO. They are considering several approaches. The suitable method in Sri Lanka will be decided through their research activities. It is possible to apply the Japanese experience and knowledge in that field, and it is necessary that Japan continuously supports them.

In addition, the long-term expert who was dispatched to MDM from 2017, also support and is following up for non-structural measures. The project team recommends to JICA to share information with people concerned continuously.

Photo 8.3 Lecture for Landslide Early Warning Threshold by JICA Long-Term Expert dispatched to MDM

The following is an overview of a proposed method to update landslide early warning through this project.

1) Soil Water Index

The Sediment Disaster Warning Information in Japan is issued at the municipality level based on the soil water index. An overview of this system and procedure was introduced through workshops and seminars held by short-term experts. But the calculation of the soil water index in Japan is based on observations from the radar rain gauge system, so it is difficult to immediately apply it in Sri Lanka. On the other hand, the Doppler radar will be donated to DoM by a JICA grant aid project. It is better while considering future operation situation and technical assistance.

To apply the soil water index into Sediment Disaster Warning Information, it is necessary not only to improve technical matter but also to collect data of past and future disaster records and to verify its correlation with rainfall and sediment disaster occurrence. In any case, cooperation with DoM is required.

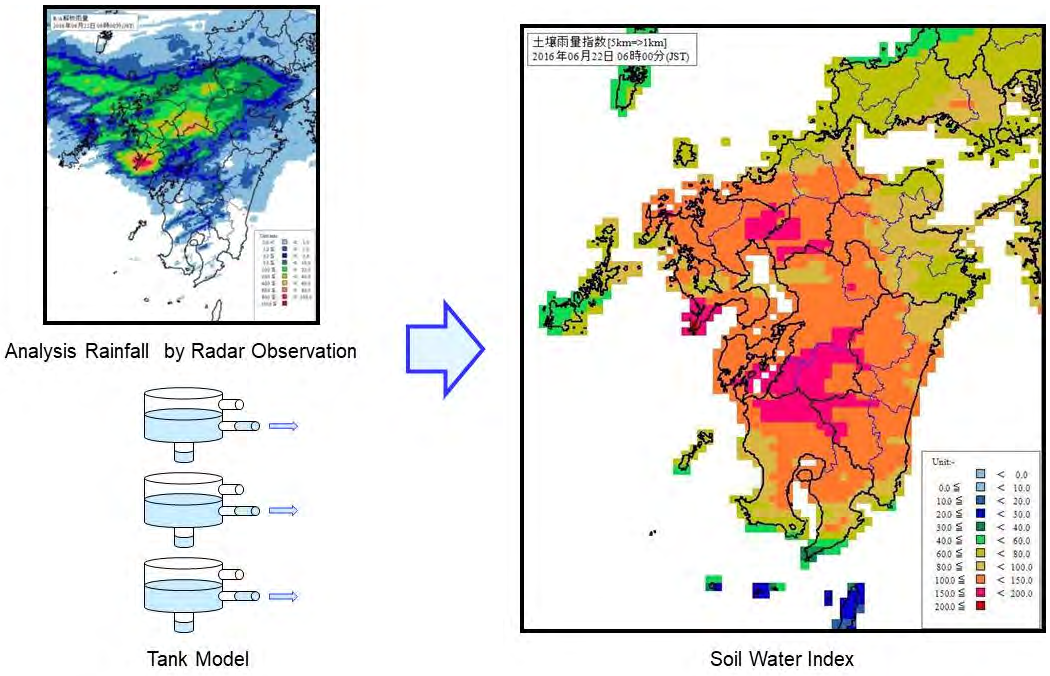


Figure 8.9 Overview of Soil Water Index in Japan

2) Effective Rainfall

As mentioned in above, it takes time for the application of the soil water index. The Consultant team also proposed effective rainfall as a more simple method to revise the early warning threshold limit. That method had been proposed in LDPP as well, which is the Japanese yen loan project with RDA and some trial cases has been already summarized. The effective rainfall method allows for setting the threshold limit based on the comparison between rainfall amount during the disaster period and the occurrence of sediment disaster. It is more suitable to the current situation because the initial capital cost is small.

8.7 Prepare materials on Early Warning and Disseminating Risk Information for Sediment Disaster (Landslide) Mitigation Based on the Experiences in Japan (Activity 5-7)

The Consultant team proposed the following for revising the early warning system and disseminating risk information.

Revision of the Landslide Early Warning Threshold

This project has introduced several methods to revise the early warning threshold, including actual examples of operation and achievements in Japan. NBRO has already started the technical study with related donors and research institutes. It is expected that the appropriate threshold will be formulated with consideration of the developing legal systems under the NBRI Act and that it will respond to the social and economic environment including the disaster risk reduction.

The revision of the threshold has been proposed from this project and another JICA project several times, and it is thought that a trend toward the revision is currently growing. Phase-2 of this project

has been adopted by the Japanese government. Continuous technical support from Japan in the Phase-2 project will be beneficial depending on NBRO's request and future development plan.

Disseminating Risk Information

In case of sediment disasters, NBRO's role in disseminating risk information is to report the landslide early warning to DMC, based on rainfall observation data by NBRO and DoM. In addition, NBRO confirms the actual situation at the site when disaster occurs. There seems to be no big issues in this role between each organization. However, as mentioned in 8.6.1, it was confirmed that early warning has not reached the GN and local residents. This problem is very difficult to solve by only NBRO, and cooperation with DMC and other disaster response organizations is required.

In addition, the Sri Lankan government has two administrative lines in parallel. The one is called "National Administration Line" and another one is "Local Administration Line". Functions of both lines are separate with separate personnel and budgets. For that reason, some parts do not have a close relationship, and is not a clear instruction system between the two sides. The dissemination of risk information is an example. The cooperation with the Local Administration Line and between DMC and NBRO district offices is required for prompt dissemination of risk information from the central government to local residents.

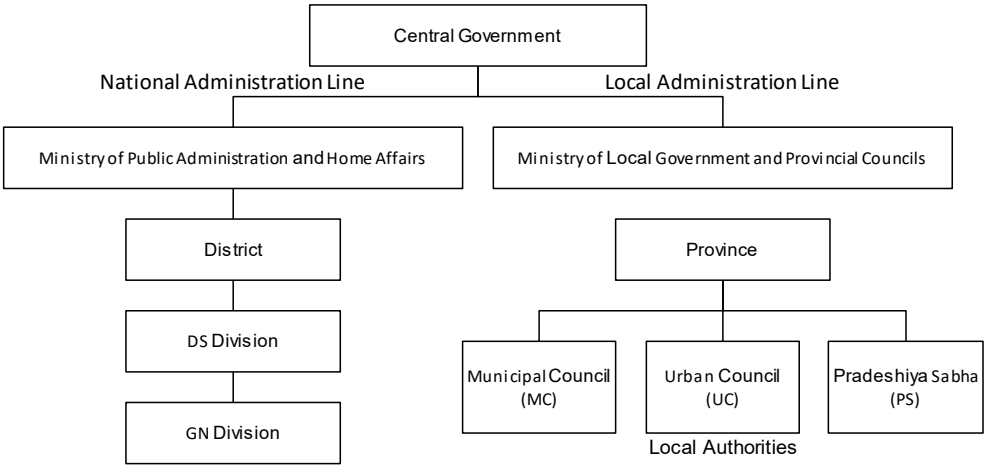


Figure 8.10 Composition of National and Local Administrative Lines

Source: JICA Study on Disaster Management System in Sri Lanka (2016)

Response to Secondary Disasters

It is necessary to pay sufficient attention to rescuers, so that they will not be affected by the secondary disaster during the rescue period. In Sri Lanka, only NBRO has experience and the understanding of the sediment disaster phenomena. NBRO can predict the risk of secondary disasters and could provide necessary advice to site managers. Unfortunately according to SOP in NBRO, such kind of advice for site managers cannot be given directly, but it is recommended that the staff of NBRO also participate in the rescue activity as much as possible, considering safety control at the disaster site.

8.8 Timeline Investigation of Emergency Response for the Disaster and Analysis of Fine Landslide Mechanism

8.8.1 Action Review Survey

A severe landslide occurred on October 29th, 2014 in Meeriyabedha, Koslanda, Badulla District. The Consultant team implemented an after action review survey. The objectives of this survey were to review actions taken by selected stakeholders, including the community, to find gaps in emergency response and the early warning system and come up with recommendations for further development of emergency response and the early warning system. The survey was conducted as OJT for the counterparts. Therefore a working group was formed with NBRO and DMC. The following organizations were interviewed for the survey:

- NBRO (Head office and Badulla District Office)
- EOC (Emergency Operation Center)
- DMC (Disaster Management Center) Badulla District Office
- Department of Meteorology
- Additional District Secretary of Badulla District
- Divisional Secretary of Bandarawela Division
- Admin. Officer of Halldumulla Divisional Secretary's Office
- Relief Officer of Halldumulla Divisional Secretary's Office
- Community people

It is important to review the correspondence after disasters to improve the emergency response and to enhance preparedness and the post disaster phase. According to NBRO it was the first time for them to conduct this kind of survey in their organization. At the end of the survey, the counterparts commented that they would like to conduct a similar survey on another case study.

Photo 8.4 Action Review Survey

8.8.2 Analysis of the Mechanism of Landslide

An aerial survey from a helicopter and a site survey were conducted in the Koslanda landslide and analysis of the mechanism of the landslide was also conducted. One person from NBRO, one person from DMC, two people from the JICA Sri Lanka Office, a long-term expert, and one member from the Consultant team participated in the helicopter survey.

In Japan, once a large scale landslide like this occurs, a helicopter survey is conducted as soon as possible. The actual condition of the landslide is confirmed and the possibility of damages in the lower stream caused by a breach of landslide dams will be also confirmed.

Several seminars were held for NBRO, DMC and DOM regarding the purpose of the survey and the result of analysis using photos taken from the helicopter.

DMC conducted a helicopter survey for a flood that occurred in 2015, meaning they understood the purpose and importance of the survey.

After the helicopter survey, a site survey was conducted in order to confirm the detailed situation of the landslide and to conduct interview surveys in the damaged area regarding the actual situation of the occurrence of the landslide. After the site survey, a site survey was conducted with a seminar of remote sensing. Three people from NBRO and three people from DMC participated, and the technology of the survey was transferred.

NBRO understood the purpose of the survey and the methods of preparation of the survey report clearly. For a landslide occurred in 2015, it was obviously developed in preparation of the survey report by NBRO.

Photo 8.5 C/Ps Participated in the Helicopter Survey

Photo 8.6 Technical Transfer in the Site Survey

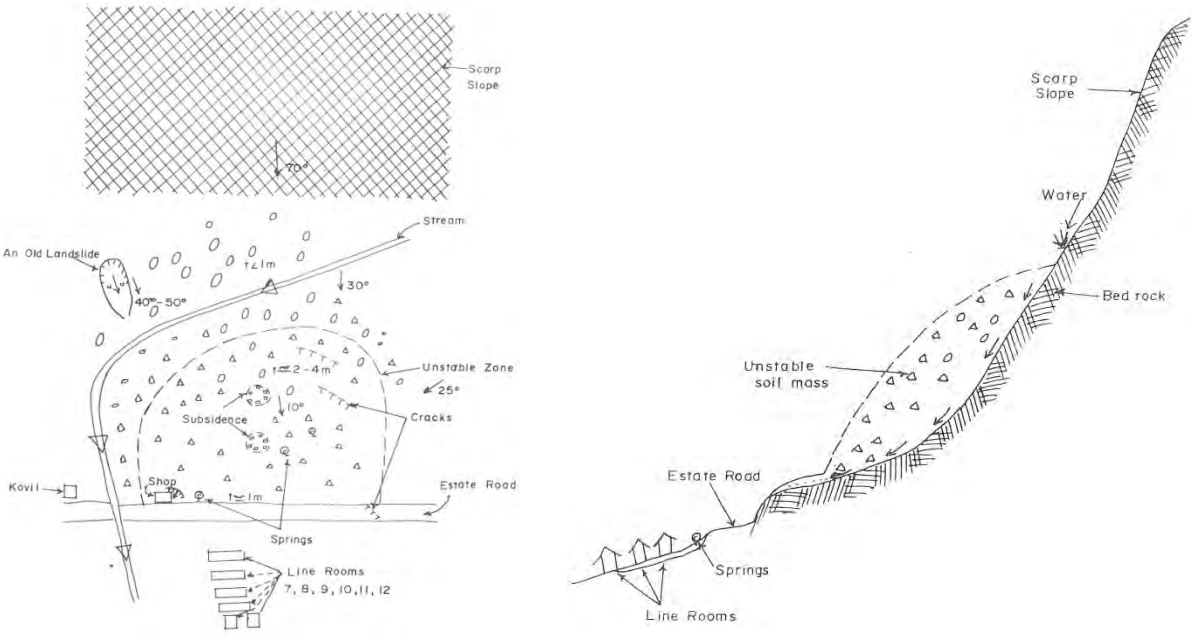


Figure 8.11 Plan and Cross section in Koslanda Landslide Report in 2005

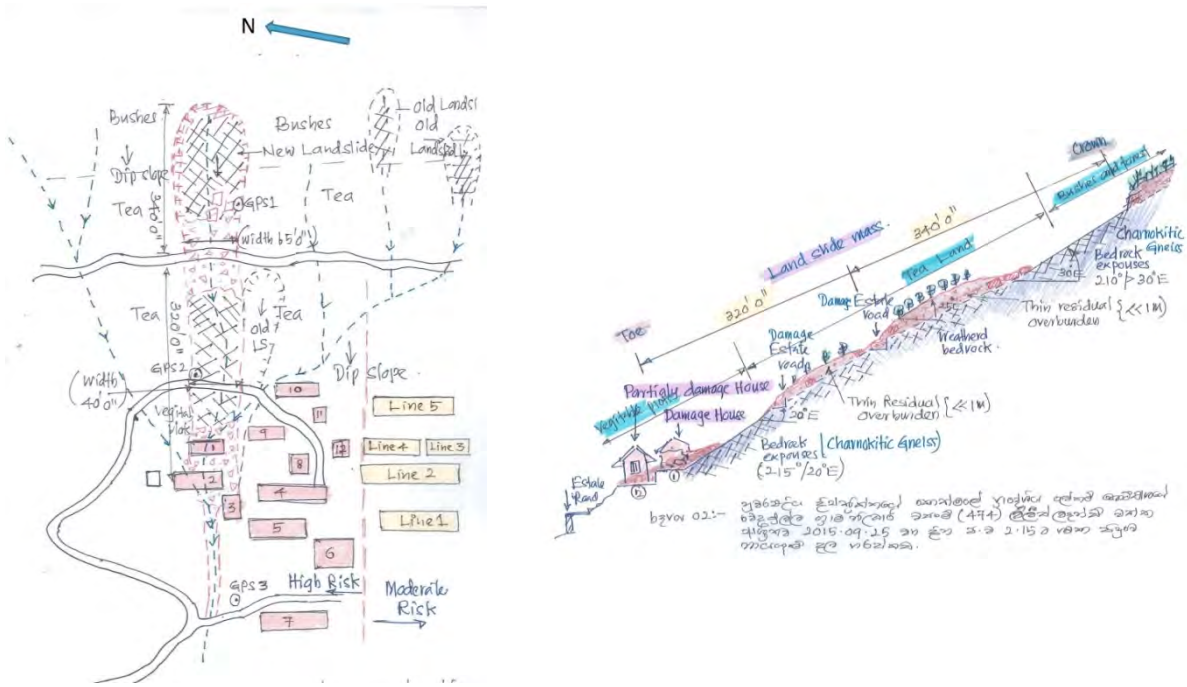


Figure 8.12 Plan and Cross Section in Lilisland Landslide Report in 2015

Chapter 9 CHANGE OF STATE BY PROJECT TECHNICAL TRANSFER

The change in C/P's state, such as awareness and capacity, by the technical transfer through the Project activity is summarized as shown in Table 9.1. The table compares the state from the commencement of the project, October 2014 to that of the end of the project, August 2018.

Table 9.1 Change in C/P State by Technical Transfer

No.	Activities	Progress Ratio (%)	Change in C/P (such as awareness and capacity)	
			State at the commencement of the Project (October 2014)	Present (August 2018)
Output 1	Capacity of investigation and evaluation for sediment disaster (Landslide) mitigation measures is strengthened.			
1-1	Conduct preliminary investigations on sediment disaster (Landslide) in pilot areas.	100	No particular technical transfer is included in this activity, since these are preliminary investigations on the pilot sites and C/Ps have already recognized these are high risk areas, therefore there are no changes in this item..	
1-2	Execute geological and geotechnical investigations at a candidate site in the pilot area	100	No particular technical transfer is included in the topographical survey, since the survey is subcontracted to a local consultant. As for the geological survey, C/Ps conducted drilling works by themselves and the technical transfer of improving core sample recovery rate was conducted by the Consultant team. In the beginning of the project, most of the soft soils were washed out and lost. And descriptions on drilling logs were mainly geological features of core samples.	The core sample recovery rate has been improved a little bit. Technical transfer with a new drilling machine was conducted in the 2nd Term. Geological features related to design of countermeasure works have been described in drilling logs.
1-3	Install necessary monitoring equipment such as piezometers, extensometers, strain gauges with piezometer and inclinometer pipes.	100	No particular technical transfer is included in this activity, since C/Ps have enough experience of installation of monitoring equipment, therefore there are no changes in this item. Conditions of installation of equipment are very good.	
1-4	Examine and determine the concept of sediment disaster (Landslide) mitigation measures in pilot areas.	100	As for the types of the sediment disasters, C/Ps seemed to understand differences of each type of sediment disasters Firstly C/Ps understood the differences of the types of sediment disasters, since the concepts of sediment disasters are different according to the types of sediment disasters.	The Consultant team explained types of sediment disasters in training, seminars, and workshops. Most of the C/Ps understands the differences of types of sediment disasters. Further explanations are required.

No.	Activities	Progress Ratio (%)	Change in C/P (such as awareness and capacity)	
			State at the commencement of the Project (October 2014)	Present (August 2018)
Output 2	Capacity of design, construction supervision, and monitoring for landslide mitigation measure is strengthened.			
2-1	Monitor and evaluate the landslides in the pilot areas.	100	C/Ps have experiences of monitoring for landslide movement, however experiences for making graph and analysis and evaluation of the graph were not enough.	C/Ps could be able to conduct analysis and evaluations of monitoring data with making graphs of data.
2-2	Design and estimate construction cost for landslide mitigation measures in the pilot areas.	100	As for the stability analysis, C/Ps conducted the analysis based on the result of soil tests. Therefore actual stability was not reflected in the stability analysis. As for cost estimation, no particular technical transfer is included, since C/Ps have experience of cost estimation.	After the technical transfer of back stability analysis considering geological and geotechnical condition, C/Ps could reflect actual stability of slopes to stability analysis.
2-3	Prepare tender documents for landslide mitigation measures in the pilot areas.	100	No particular technical transfer is included in this activity, since C/Ps have experience of preparation of tender documents, therefore there are no changes in this item.	
2-4	Evaluate tender documents and procure contractor for landslide mitigation measures in the pilot areas.	100	No particular technical transfer is included in this activity, since C/Ps have experience of tender, therefore thereare no changes in this item.	
2-5	Supervise the construction work for landslide mitigation measures in the pilot areas.	100	The construction works have been commenced in the 2nd term and already completed. Firstly, the contractor the construction plan was submitted as separated documents. Construction management standard for landslide countermeasure works did not exist and awareness regarding the supervision and safety management were not so high.	Check and confirmation of the construction plan were conducted together with the consultant team, C/Ps could instruct the contractor to prepare the construction plan as one document including any necessary items. Based on the construction standard in Japan and discussion of the construction standard, C/Ps could conduct inspection based on the construction standard. Awareness of the safety management was improved with submission of the safety management plan
2-6	Prepare completion report of the landslide mitigation measures in the pilot areas including an evaluation on effectiveness of the measures	100	This report and annexes.	

No.	Activities	Progress Ratio (%)	Change in C/P (such as awareness and capacity)	
			State at the commencement of the Project (October 2014)	Present (August 2018)
Output 3	Capacity of design, construction supervision, and monitoring for slope failure mitigation measure is strengthened.			
3-1	Monitor and evaluate the landslides in the pilot areas.	100	No particular technical transfer is included in this activity, since these are preliminary investigations on the pilot sites and C/Ps have already recognized these are high risk areas. Therefore there are no change in this item	
3-2	Design and estimate construction cost for landslide mitigation measures in the pilot areas.	100	As for the stability analysis, C/Ps conducted the analysis based on the result of soil test. Therefore actual stability was not reflected on the stability analysis. As for the cost estimation, no particular technical transfer is included, since C/Ps have experience of cost estimation.	After the technical transfer of back stability analysis considering geological and geotechnical condition, C/Ps could reflect actual stability of slopes to stability analysis.
Output 4	Capacity of design, construction supervision, an d monitoring for rock fall mitigation measure is strengthened.			
4-1	Monitor and evaluate the landslides in the pilot areas.	100	No particular technical transfer is included in this activity, since these are preliminary investigations on the pilot sites and C/Ps have already recognized these are high risk areas. Therefore there is no change in this item.	
4-2	Design and estimate construction cost for landslide mitigation measures in the pilot areas.	100	C/Ps have no particular guidelines and manuals, C/Ps conducted designs based on their experiences.	The method of simulation of rock fall and the design of countermeasure against rock fall have been transferred to the C/Ps. However, this method is completely new to them and they have understood the basic method of simulation and design of rock fall.
4-3	Prepare tender documents for landslide mitigation measures in the pilot areas.	100	No particular technical transfer is included in this activity, since C/Ps have experience of preparation of tender documents. Therefore, there are no changes in this item.	
4-4	Evaluate tender documents and procure contractor for landslide mitigation measures in the pilot areas.	100	No particular technical transfer is included in this activity, since C/Ps have experience of tender. Therefore there are no changes in this item.	
4-5	Supervise the construction work for landslide mitigation measures in the pilot areas.	100	The construction works have been commenced in the 2nd term and already completed. Firstly, the contractor the construction plan was submitted as separated documents. Construction management standard for landslide countermeasure works did not exist and awareness regarding the	Check and confirmation of the construction plan were conducted together with the consultant team, C/Ps could instruct the contractor to prepare the construction plan as one document including any necessary items. Based on the construction standard in Japan and discussion of the construction standard,

No.	Activities	Progress Ratio (%)	Change in C/P (such as awareness and capacity)	
			State at the commencement of the Project (October 2014)	Present (August 2018)
			supervision and safety management were not so high.	C/Ps could conduct inspection based on the construction standard. Awareness of the safety management was improved with submission of the safety management plan
4-6	Prepare completion report of the landslide mitigation measures in the pilot areas including an evaluation on effectiveness of the measures.	100	This report and annexes	
Output 5	Knowledge and know-how for landslide mitigation measures are improved.			
5-1	Review and update the existing guidelines and technical manual on sediment disaster (Landslide) mitigation on structural measures.	100	Technical transfers of survey method, analysis of monitoring, mechanism analysis and design of countermeasure works have been conducted through the Output 1- 4. LDPP has prepared guideline and manual and DiMCEP has already prepared a general manual, Therefore a manual has been prepared mainly for design and supervision of countermeasure works based on the experiences and lessons learned from this project.	
5-2	Conduct training using the revised guideline and technical manual on sediment disaster (Landslide) mitigation on structural measures.	100	The investigation method, analysis of monitoring data, mechanism analysis and design methods have been transferred through outputs 1-4 with using existing Japanese guidelines and manuals. Also the technical transfer was conducted in workshops and site visits with using the manual prepared in the activity 5-1.	
5-3	Conduct technical seminars and workshops on sediment disaster (Landslide) mitigation for both structural and non-structural measures.	100	Seminars regarding the activities of the project, remote sensing, and disaster risk management and a workshop regarding investigation, monitoring, analysis and design of sediment disasters were held. Also mini seminars were held for working level in NBRO.	
5-4	Stakeholder consultation on land use regulation for sediment disaster (Landslide) mitigation.	100	The short-term experts hold a small scaled seminar in NBRO, and they explained the land use regulation in Japan. 20 counterparts participated in the seminar, and had a discussion with the expert. In addition, the short term experts introduced their experiences in disaster responses, and discussed the experiences with the counterparts. The activities were carried out with long and short term experts and are to be continued in the second term of the Project.	
5-5	Prepare materials on land use regulation for sediment disaster (Landslide) mitigation.	100	The experts are to confirm the current situation of Sri Lanka through seminars. The experts are to compile information in the second term of the Project.	
5-6	Stakeholder consultation on early warning and disseminating risk information for sediment	100	The experts hold a small scaled seminar to introduce early warning system in Japan and had a discussion with 20 counterparts. In addition, the short term experts introduced their experiences in disaster responses, and discussed the experiences with the counterparts. The activities were carried	

No.	Activities	Progress Ratio (%)	Change in C/P (such as awareness and capacity)	
			State at the commencement of the Project (October 2014)	Present (August 2018)
	disaster (Landslide) mitigation based on the experiences in Japan.		out with the long and short term experts and are to be continued in the second term of the Project.	
5-7	Prepare materials on early warning and risk information dissemination for sediment disaster (Landslide) mitigation based on the experiences in Japan.	100	The experts are to confirm the current situation of Sri Lanka through seminars. The experts are to compile information in the second term of the Project.	

The achievement of the Project objectives in the PDM after the commencement of the Project in October 2014 to the end of the project in September 2018 is shown in Table 9.2.

Table 9.2 Achievement of Project Objectives

Outputs	Indicators	Means of Verification in PDM	Achievement	Remarks
1: Capacity of investigation and evaluation for sediment disaster (Landslide) mitigation measures is strengthened.	a. Number of reports on survey and evaluation for selection of sediment disaster(landslide) mitigation measures in the pilot areas。	- Reports on survey and evaluation for selection of sediment disaster (landslide) mitigation measures in the pilot areas - Geological investigation report - Monthly report on monitoring data, analysis and evaluation result and maintenance - Result of examination conducted by the project	100%	A series of reports, from investigation reports to design reports, are prepared in each pilot site.
	b. Number of reports on geological investigation		100%	Geological investigations are described in the reports above.
	c. Number of reports on monitored data, analysis and evaluation for the pilot areas.		100%	Monitoring data, mechanism analysis and evaluations are described in the reports above. Maintenance and monitoring were conducted in the 2nd Term and monitoring sheets have been prepared.
2: Capacity of design, construction supervision , and monitoring for landslide mitigation measure is strengthened.	a. Number of reports on NBRO's activities for implementation of landslide measure work in a pilot area	- Completion Reports of sediment disaster (landslide) measure works in each pilot area - Tender Documents on respective measure work in sediment disaster measure works in the pilot area - Tender Evaluation Reports for respective sediment disaster measure work in the pilot area - Reports of construction supervision of respective sediment disaster measure works in the pilot area	100%	Supervision was already completed and technical transfer of monitoring was conducted in the 2nd Term.
3: Capacity of design, construction supervision, and monitoring for slope failure mitigation measure is strengthened.	a. Number of reports on NBRO's activities for implementation of slope failure measure work in a pilot area		100%	Designs are described in the reports above.
4: Capacity of design, construction supervision , an d monitoring for rock fall mitigation measure is strengthened.	a. Number of reports on NBRO's activities for implementation of rock fall measure work in a pilot area		100%	Supervision was already completed and technical transfer of monitoring was conducted in the 2nd Term.
5: Knowledge and know-how for landslide mitigation measures are improved.	a. Number of documents including technical standard and manual for design and construction supervision of sediment disaster (landslide) mitigation measures as well as materials on land	- Completion reports of sediment disaster mitigation measures in 2014-2017 - NBRO's Annual Report in	100%	A manual has been prepared based on the experiences and lessons learned from this project.

Outputs	Indicators	Means of Verification in PDM	Achievement	Remarks
	use regulation, and early warning and risk information dissemination	2014-2017 - Project Progress Report		
	b. . Number of participants in seminars / workshops		100%	Seminars and workshops were held several times and a reasonable number of participants participated.

Chapter 10 SUMMARY OF THE PROJECT AND RECOMMENDATIONS TO ACHIEVE THE OVERALL GOAL

10.1 Summary of the project (issues, efforts and lessons learned from the project)

10.1.1 1st Term

1) Amendment of activities in Kandy pilot site and its influence to other activities

In JCC and other meetings, NBRO recommended that countermeasure construction in the Kandy pilot site, activities relating to Output 3, is the first priority. In addition, NBRO suggested that countermeasure works need to be started as soon as possible. Thus, the project team revised the schedule of the countermeasure work. As a result, it was decided that the Consultant team advanced the date of bidding for the pilot project in Kandy, which had been scheduled in the 2nd term, to the 1st term. Investigations like geological surveys were also conducted earlier than initially planned.

However, countermeasure work in the Kandy pilot site as part of activities of Output 3 were not conducted based on the conditions below.

1) Based on the result of geological surveys, the geological conditions are quite soft up to the deeper part of the slope (more than five (5) meters) instead of what was expected (approximately one meter) before the surveys.
2) The original countermeasure plan in the Technical Notes was to install a combination of crib works, what is called "Free frame work" in Japan and soil nailing. The countermeasure work would not require much excavation work.
3) If soil nailing is applied to the slope without excavation, the length of soil nails would have to be more than five (5) meters. In this case, the length of soil nails would not satisfy the Japanese standard (2-5 meters), and therefore, it was deemed difficult to apply this countermeasure work in the project.
4) The design of the Sri Lankan style crib work is based on experience and the beam usually does not have enough strength when actually construction. Also, when the Sri Lankan style crib work is installed, big slope cutting work is required and the crib work is installed in ditches along slopes. Therefore based on reasons of design method and construction method, it is difficult to install Sri Lankan style crib work in the project.
5) Based on the design of the Sri Lankan style crib work, a cutting slope or embankment is required on the slope. Because of limited land acquisition in the target area, it is difficult to install Sri Lankan style crib work on the slope.
6) Without cutting slope or embankment into the slope, the combination of crib work in Japanese style and rock bolts are required for stabilization of the slope.
7) When Japanese style crib work is installed, unit type wire formwork is required, as well as a pre-mixing type shotcrete machine. However, it is difficult to procure these materials and equipment in Sri Lanka.

Based on the reasons above, the originally planned countermeasure works were not installed in the pilot area.

It took considerable time for the members in charge of slope failure to try to design an alternative countermeasure works to solve the issues above. As a result, other members had to assist the

activities of the member in charge of slope failure, and this situation influenced other member's activities.

Even though the results of the geological surveys were quite different from the original plan, the response to the matter was delayed. The Consultant team should carefully control the schedule with close coordination with JICA and the NBRO.

It was determined not to construct the countermeasure works in the Kandy site, since there was a concern that the start of the construction works would be in the rainy season based on the schedule and due to the delay of the boring survey. Therefore the bidding, which was planned in the 2nd term, was held originally was in the 1st term.

2) Procurement/ Tender Evaluation

It took a considerable amount of time to prepare specifications of the drilling machine, more than expected for the procurement of the drilling machine.

Also it took a considerable amount of time to prepare tender documents for landslide and rock fall countermeasure works, more than expected for activities of Output 2 and 4.

Accordingly, the Project achievement for this output has fallen short of expectations. The initial preparation schedule should have been examined more carefully. The Consultant team will control the schedule carefully in close coordination with JICA and the NBRO, since the preparation of the documents is critical to the overall Project progress.

3) Boring Survey

The boring survey and the installation of the monitoring equipment conducted by NBRO were delayed due to the influence of the Landslide Disaster Prevention Project (LDPP) implemented by the Road Development Authority (RDA). Drilling and installation were initially planned to be completed in January 2015. However, these activities were delayed and completed in June 2015.

NBRO was one of the subcontractors of the consultant team of the LDPP. Therefore NBRO gave priority to the LDPP project. NBRO and the Consultant team conducted the boring survey in Kandy pilot site as a priority site and also tried to mobilize boring machines according to found conditions, such as geomorphological conditions and the depth of the boring. In spite of the above mentioned efforts, the survey was delayed. Accordingly, design works and cost estimation work in each pilot site were delayed.

The influence of another project was unexpected, and therefore NBRO and the Consultant team tried to mobilize boring machines. However it was impossible to avoid delay due to the limitation of the number and types of boring machines owned by NBRO.

4) JCC

JCC had planned to convene in the 1st term and the PDM criteria was planned to be determined. However, at the moment, it was impossible to convene the JCC due to the reasons below.

a. The 1st JCC convened on 14th October, 2014 for "The Project for Improving of Meteorological Observation, Weather Forecasting and Dissemination". In the JCC, the contents of the Work Plan were discussed.

b. The 2nd JCC meeting was scheduled to be held in January, 2015 based on the discussion with the Secretary of the Ministry of Disaster Management. However, Presidential elections were held on 8th January, 2015, and accordingly the organizational structure of the government was reformed. Also, elections of members of Parliament were held in August 2015. Until the members of the

Parliament were set, the organizational structure was provisional, and therefore, it was impossible to convene the 2nd JCC.

c. At the time of the election, most of the activities of the project have been completed except for bidding, and therefore, the JCC will be held at the beginning of the 2nd term.

5) Signing of Minutes of Understanding (MOU)

The MOU was almost finalized in August 2015 as Minutes of Discussion (M/D). However, its finalization was delayed due to the influence of the condition of the Kandy site described in 1) above, and the condition of the bidding in 2) and the delay of the boring survey in 3). The M/D between JICA Sri Lanka Office and NBRO was planned to be signed as soon as possible after the bidding is finished.

10.1.2 2nd Term

1) Timing of the tender of the construction works

The tender of construction works was conducted in the 1st term, and contracts between JICA and the contractors were concluded during the gap between the 1st term and the 2nd term. Therefore, the consultant team could not perform their activities right after contracts agreements were signed. The consultant team could only start their activities after the commencement of the 2nd term. Due to this condition, the commencement of the construction works were delayed a little.

The main reason was the change of the tender from 2nd term to the 1st term because the tender for the Kandy pilot site took place prior to the other pilot sites and at the commencement of the 1st term. Hereafter, the timing of tender and the commencement of construction works should be considered in similar projects.

2) Supervision

There are many issues on supervision of construction works in Sri Lanka such as construction management and safety management. These capacities should be improved in the 2nd term, however these issues depend on experiences of the contractors. The level of construction works were not the same in each pilot site. Especially, the work of less experienced contractors depends on the experiences and skills of the workers. Thus it is quite difficult to develop their capacities of construction works.

NBRO should recognize the differences in the level of technical capacities among contractors and instruct the contractors in accordance with their capacities.

3) Unexpected events

After the commencement of horizontal drilling works in Lot 2, Nuwara Eliya, some cracks occurred in a vicinal house and on the ground around the house. The house was located 20m away horizontally, and 15m away vertically, from the drilling site, which would be quite a rare phenomenon in Japan. The cause and effect relationship between the cracks and the horizontal drillings was not clear, but there may have been be some relationship between them. Therefore the drilling method was changed from rotary percussion to rotary drilling and the horizontal drilling works was restarted. At the same time, monitoring of the width of the cracks was conducted. After the change of the drilling method, the cracks did not expand and the drilling of the hole was completed.

However, before the completion of all horizontal drilling, another crack occurred at another house. In this case, the location of the house was farther than the first house and the drilling method had already been changed. Therefore, the cause and effect relationship was deemed to be smaller than

the first case. Also monitoring of the width of the cracks was conducted, and expansion of the cracks was not observed.

These phenomena would be expected in Japan; however, natural conditions such as geology, and geomorphology in Sri Lanka are different than in Japan. The Project should be careful and/or some unexpected phenomena should be expected during construction work in foreign countries.

In the cases above, NBRO responded quickly and the consultant team was physically in Sri Lanka. Hence, actual conditions were confirmed quickly.

A wildfire occurred in July 2016 in Lot 1, Badulla, and some extensometers were damaged, such as burnt PVC pipes. The function of extensometers had no problems, and, therefore, the extensometers were reinstalled and monitoring continued.

It is difficult to predict unexpected phenomena; however, a management system assuming such unexpected phenomena should be established.

4) Understanding of design of countermeasure works

Faulty construction was found due to the lack of understanding of design of the surface drainage ditch in Badulla. Especially, NBRO and the contractor did not understand the function of the water collecting pit and the change of cross-sections of the ditch at the confluence of ditches. Therefore they didn't notice that was a fault of construction work.

The design of surface drainage ditch and water collecting pit have been transferred in monthly progress meetings and seminars.

10.2 Recommendations to achieve the overall goal

The overall goal and the indicators are shown in Table 10.1

Table 10.1 Overall goal and indicator

Overall goal	Sediment disaster (landslide) countermeasures are implemented directly by NBRO or with the assistance of NBRO with acquired technology and experience from the Project.
Indicator	All sediment disaster (landslide) countermeasures are implemented (including the commencement of a preliminary survey) or assisted by NBRO with acquired technology and experience from the Project
Definition of indicator	"Acquired technology and experience from the Project" are defined as either of the following technologies and its experiences. - Use of drone technology for landslide mitigation survey - Design of countermeasures using back analysis - Long horizontal drilling with a casing (longer than 30 meters) - Systematic construction supervision with a measurement sheet

Issues and recommendations regarding the four experiences and technologies as defined by the indicators are shown below.

1) Utilization of UAV for survey of landslide countermeasure work

UAV was actively utilized after the technical transfer from this project. At the moment, Human Settlement Planning and Training Division (HSPTD) has UAVs and they were used for the after disaster survey in May 2017. NBRO conducted the damage and loss assessment of the disaster at 35

heavily damaged locations and prepared the “Landslide Disaster May 2017 Damage and Loss Assessment”.

Landslide Research and risk Management Division (LRRMD) obtained a new UAV and future utilization is expected.

In this project, technical transfer on how to use UAVs was through training; however it was impossible to do technical transfer through an actual UAV survey. Therefore, one of the remaining issues is to improve the capacity of LRRMD so that they can better prepare survey plans, perform topographic analysis, and design basic countermeasure work. There may be no problems in using UAVs; however technical transfer for its utilization in planning, analysis and design is necessary.

2) Design of countermeasure work with back analysis

Transferring technologies of back analysis in developing countries is a problem. One of the reasons is that the back analysis is based on experiences in design of countermeasure works against landslides in Japan. It is common for technical transfer of back analysis to be quite difficult for developing countries, because it is difficult to understand the experiences in Japan.

However, during terminal evaluation of the project, some NBRO said that one of the lessons learned is back analysis, showing that NBRO sufficiently understood back analysis through seminars, workshops, and technical transfer of design in the Kandy pilot site.

Therefore, there may be no big problems to apply back analysis. However, technical transfer of back analysis was mainly for staff in headquarters, so it would be important to share their experiences with district offices. Also, considering knowledge transfer among NBRO offices, it would be better to share experiences with staff that are not in charge of design.

3) Long horizontal drilling with using casing (more than 30m)

Importance of using casings for long horizontal drilling is understood by NBRO through working on pilot projects. Drilling teams managed directly by NBRO have started using casings for horizontal drilling showing that this technical transfer should be sufficient.

Contractors of Lot 1 and 2 have understood the importance of casing, and they have been able to conduct horizontal drilling for other projects.

On the other hand, other contractors that failed the bid of the pilot projects do not understand the importance of casings. They had some problems in other projects funded by NBRO, because they could not conduct horizontal drilling without casings.

NBRO might be able to transfer the technology to the contractors; however NBRO should be careful to transfer technology, because it might be an intervention in private company competition.

There should not be problems in horizontal drilling directly managed by a NBRO team and the contractors of this project; however it may be problem to disseminate its use to other contractors.

It would be better to include the use of casing in technical specifications or contract documents and to disseminate the technology to contractors while considering intervention to competition principal of private companies.

4) Systematic supervision with measurement sheets

NBRO staff in charge of pilot projects have understood the importance of systematic supervision with measurement sheets. On the other hand, it could be cumbersome with the increasing number of documents.

It is better to include items for supervision with measurement sheets in the technical specification or contract documents and to request contractors to prepare measurement sheets. Disseminating use of these sheets for systematic supervision to other NBRO staff is also encouraged.

Chapter 11 COMMENTS FROM CONSULTANT TEAM LEADER

1) Design of the project

One of the characteristics of this project is that the project includes larger scale pilot projects than other ordinary technical cooperation projects. At first, the number of the pilot project sites was four (4), and it took three (3) hours to travel from site to site.

Also the number of boreholes required for the geological survey was too much. NBRO directly conducted the drillings, but the survey was delayed due to the number of boreholes and impact from another project.

In Kandy, during the survey and design stages, it became clear that it was improper to construct the countermeasure works in this project due to the geological condition and characteristics of the countermeasure works. These countermeasure works had been installed by another JICA project, "Verification Survey with the Private Sector for Disseminating Japanese Technologies for Slope Disaster Mitigation Technology with Shotcrete Cribwork using Unit type Wire net Formwork."

These matters had been recommended in the terminal evaluation, and it significantly influenced this project. Therefore project design should be quite important for the actual management of the project. Hereafter it should be quite important to plan detailed design projects while considering locations of the pilot projects, assumed countermeasure works, and capacity of survey and design for countermeasure works of C/P organizations.

2) Technical transfer of UAV survey

As described in the Chapter 10, it would be no problem to use UAV itself. UAV surveys were not included in the scope of the project; however the consultant team proposed additional of the UAV survey in the proposal considering the increasing trend to use UAVs. UAV surveys have been disseminated inside NBRO after the introduction and technical transfer by the project.

In the future, it would be better to transfer technologies regarding preparation of survey plan, topographic analysis and basic design of countermeasure works, using UAV survey results. It could be possible to prepare basic maps or data for non-structural measures with the technology transfer of these technologies above. It would be quite effective to prepare of hazard maps and risk evaluation as well, for example.

3) Technical transfer of non-structural measures

This project was mainly for technical transfer of structural measures through pilot projects for sediment disasters. At the same time, the importance of non-structural measures was transferred through seminars and workshops performed by long -term experts and short-term experts.

Generally, structural measures are costly and it requires enough budget; therefore, it would be difficult to implement a lot of structural measures in a lot of sediment disaster prone areas with the budget of NBRO. It would be better to conduct non-structural measures such as early warning systems, hazard mapping, risk evaluation, and development planning/development control for mitigation of damages by sediment disasters.

Especially, NBRO is preparing hazard maps with classification of risks according to parameters such as inclination of slope and geology. On the other hand, it has become clear that landslide areas of the pilot sites of the project were not classified as risk areas based on the parameters applied by NBRO due to the gentle slope. Therefore, one of the important next steps is to prepare appreciated hazard maps. At the same time, it would be important to consider how early warning should be issued during heavy rain events according to the risk evaluation.

It was found that there was a gap in transferring disaster information in October 2014, for the Koslanda landslide. It would be better to confirm actual conditions and issues in the protocol of early warning, and they should be improved accordingly.

Moreover, development plans/development control in sediment disaster prone areas based on the risk evaluation with hazard maps should be one of the important items of non-structural measures. It would be better to confirm laws/regulation regarding development plans/development control, determine actual conditions of development control by relevant organizations, and prepare counterplans in consideration of these issues based on the actual condition.