JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
DEPARTMENT OF ROADS, MINISTRY OF WORKS AND HUMAN SETTLEMENT (DOR)

THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN

FINAL REPORT

August 2016

KOKUSAI KOGYO CO., LTD.

EARTH SYSTEM SCIENCE CO., LTD.

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

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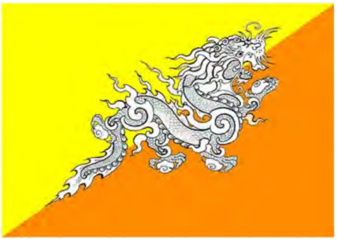
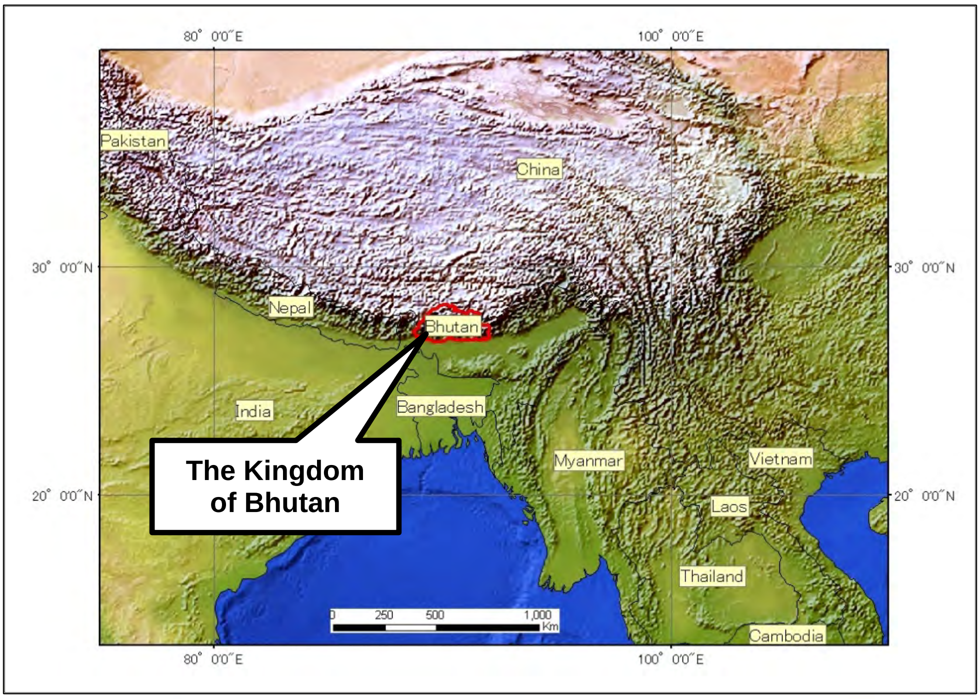
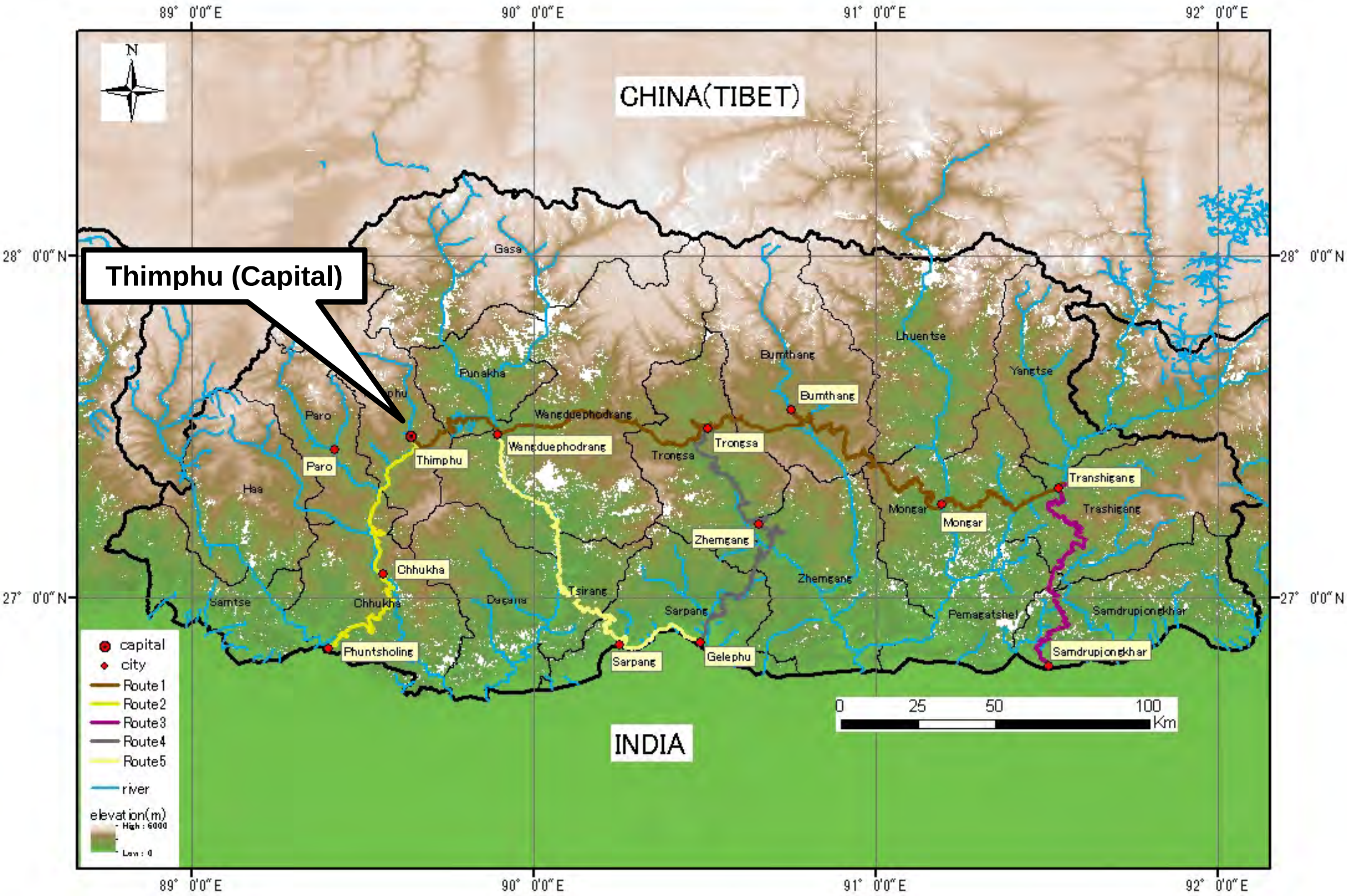
Location Map for the Project



Bhutan National Flag





～ Location of the Study Area ～

Rate of Currency Translation

1 USD	= 67.0887 BTN
	= 104.44 JPY
100 BTN	= 1.492 USD
	= 155.83 JPY

BTN: Bhutan Ngultrum

As of 15 July 2016

Photos of Project Activities (1) July 2014 – June 2016

Courtesy Call to the Department of Road (DoR), Thimphu, 10 July 2014

1st Steering Committee, Thimphu, 30 July 2014

1st Seminar [Fundamentals and basics on slope disasters], Thimphu, 19 August 2014

Calibration works for slope inspection by the JICA Expert Team, Trongsa, 2 October 2014

2nd Seminar [Slope inspection & Aerial photo-interpretation], Trongsa, 9 October 2014

3rd Seminar [Outline of slope inspection on site], Trongsa, 10 December 2014

4th Seminar [Method of slope inspection on site], Trongsa, 21 November 2014

5th Seminar [Preparation of slope inspection sheets], Dochula, 19 December 2014

6th Seminar [Road maintenance Outline of GIS database], Trongsa, 6 February 2015

1st Technical transfer workshop, Thimphu, 17 February 2015

1st Technical transfer workshop, Thimphu, 17 February 2015

7th Seminar [GPS and GIS conversion], Thimphu, 11 June 2015

Photos of Project Activities (3) July 2014 – June 2016

8th Seminar [Training for slope inspection on sites], Trongsa, 14 April 2015

Drilling works, Bangla Pokto Area, June 2015

9th Seminar [Geological investigation on sites], Trongsa, 4 July 2015

10th Seminar [Slope inspection and regular check, Geological investigation], Thimphu, 6 July 2015

Training in Japan, Hokkaido Regional Development Bureau, Sapporo, 15 July 2015

Training in Japan, Takasaki Office, Ministry of Land, Infrastructure and Transport, 21 July 2015

11th Seminar [Regular check on sites], Lingmetheng and Trongsa, 28 August and 4 September 2015

12th Seminar [Countermeasures on sites], Thimphu and Trongsa, 20 and 26 October 2015

2nd Technical transfer workshop, Thimphu, 21 October 2015

2nd Steering Committee, Thimphu, 21 October 2015

2nd Technical transfer workshop, Trongsa, 26 October 2015

13th Seminar [Regional map by using GIS], Thimphu, 22 December 2015

14th Seminar [Topographic analysis and map by QGIS], Thimphu and Trongsa, 15 and 18 January 2016

15th Seminar [Mapping by GIS, GPS and GIS conversion, slope inspection on roads], Phuentsholing, 23-25 March 2016

16th Seminar [Prioritization for countermeasures], Thimphu, 15 April 2016

17th Seminar [GIS database for slope disaster management 1], Thimphu, 1 June 2016

Submission of manuals and draft final report, Thimphu, 8 June 2016

3rd Steering Committee, Thimphu, 9 June 2016

Photos of Project Activities (6)   July 2014 – June 2016

3rd Steering Committee (signing the handover equipment documents), Thimphu, 9 June 2016

Handover equipment (two vehicles)

3rd Technical transfer workshop, Thimphu, 10 June 2016

3rd Technical transfer workshop, Thimphu, 10 June 2016

18th Seminar [GIS database for slope disaster management 2], Lobeysa, Transhigang, Thimphu and Phuentsholing, 20-29 June 2016

18th Seminar [GIS database for slope disaster management 2], Lobeysa, Transhigang, Thimphu and Phuentsholing, 20-29 June 2016

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Abbreviations

AE	Assistant Engineer
AH	Asian Highway
BCR	Benefit Cost Ratio
CDB	Construction Development Board
CE	Chief Engineer
CGISC	Centre for GIS Co-ordination
C/P	Counterpart
CU	Collection of Undisturbed
De	Difficulty of work
DEM	Digital Elevation Model
DF/R	Draft Final Report
DGM	Department of Geology and Mine
DoR	Department of Roads
DSM	Digital Surface Model
Dy EE	Deputy Executive Engineer
E	Engineer
EE	Executive Engineer
F/R	Final Report
GIS	Geographic Information System
GLOFs	Glacial Lake Outburst Floods
GNHC	Gross National Happiness Commission of Bhutan
GNSS	Global Network Satellite Survey
GoB	Government of Bhutan
GPS	Global Positioning Satellite
G2C	Government-to-Citizen
HQ	Head Quarter
ICT	Information Communication Technology
Ise	Impact on social and environment (social and environmental impacts)
IT/R	Interim Report
JE	Junior Engineer
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
JST	Japan Science and Technology Agency
MoF	Ministry of Finance
MoWHS	Ministry of Works and Human Settlement
MVC	Model View and Controller
NATM	New Austrian Tunnelling Method
NHDC	National Housing Development Corporation
NHR	National Highway Route
NLC	National Land Commission
OJT	On-the-Job-Training
PCC	Phuentsholing City Corporation
PE	Principle Engineer
PHP	Hypertext Processor
PNH	Primary National Highway
PRISM-DSM	Panchromatic Remote-sensing Instrument for Stereo Mapping – Digital Surface Model
PWD	Public Works Department

QGIS	Quantum Geographic Information System
RCIS	Road Condition Information System
R/D	Record of Discussion
RDBMS	relational database management system
RO	Regional Office
RMMS	Road Management and Maintenance System
RSTA	Road Safety and Transport Authority
SATREPS	Science and Technology Research Partnership for Sustainable Development
SC	Steering Committee
SDMD	Software Development Management Dashboard
SNH	Secondary National Highway
Sp	Score of Practicability
SPT	Standard Penetration Test
SRTM	Shuttle Radar Topography Mission
SW	Scale of work
TCC	Thimphu City Corporation
USGS	United States Geological Survey
WG	Working Group
WWF	World Wildlife Fund

Chapter 1

Introduction

1 Introduction

1.1 General

This report is a Final Report (hereinafter F/R) which covers the entire results of survey, analysis, evaluation and discussion on 1) the preparation of inspection manual, 2) the slope inspection on roads, 3) the inspection database and 4) advices for countermeasures from August 2014 to July 2016 for the Project for Master Plan Study on Road Slope Management in Bhutan (hereinafter the Project) according to the Record of Discussion (hereinafter R/D) agreed upon on the 10^{th} of March 2014, between the Gross National Happiness Commission (hereinafter GNHC) of the Kingdom of Bhutan (hereinafter Bhutan) and the Japan International Cooperation Agency (hereinafter JICA).

JICA has since dispatched ten (10) experts (hereinafter JET, or JICA Expert Team) who specialize in investigation, analysis, design and countermeasure on slope disasters on roads. The Project is conducted with members of Department of Roads (hereinafter DoR), Ministry of Works and Human Settlement (hereinafter MoWHS) as counterparts (hereinafter the C/P) from August 2014 to July 2016.

1.2 Background of the Project

Roads are major means of travel and transportation in Bhutan, and development of an efficient and safe road network is essential for Bhutan's social and economic development. The Framework for National Development "Bhutan 2020*[1]," the Road Sector Master Plan (2007 – 2027)*[2], the 10th Five Year Plan (2008 – 2013)*[3], and the 11th Five Year Plan (2013 – 2018)*[4] provide the basis for national development in the road sector. Indeed, the total road length in the country was about 2,300 km in 1990 and is increasing every year (Figure 1.2.1). Bhutan 2020 set the following numerical targets and strongly promotes road development as a major national project:

- Improve arterial roads by 2007 to allow for traffic of 30-t trucks.
- Develop a road network by 2012 that can be reached on foot in half a day by 75% of the country's population.
- Complete the second east–west road (about 794 km) by 2017.

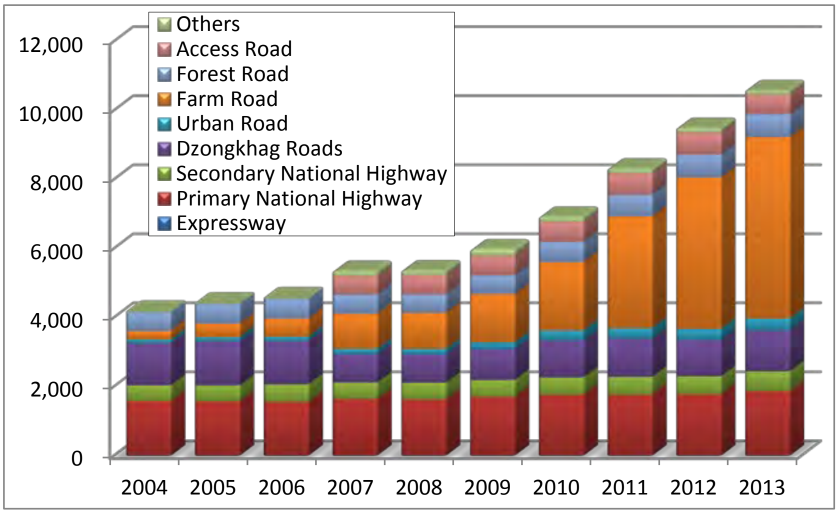


Figure 1.2.1 Increase in Total Road Length in Bhutan (Source: DoR-MoWHS Bhutan)

However, because large parts of the country consist of steep mountainous areas there are significant geological and topographic constraints to the construction of the majority of roads.

There are few roads with sufficient road slope disaster management in place. Consequently, slope failures frequently occur and isolate areas from the capital or other areas of the country, disrupting travel and the transport of agricultural crops. The DoR, which is responsible for the construction and maintenance of roads and bridges in Bhutan, has covered road slopes with vegetation and has reinforced them. However, because of a lack of skills and experience, sufficient road slope disaster management has still not been implemented.

With this background, the Government of Bhutan asked the Government of Japan for technical help to enhance the capability of DoR to identify road slopes that require slope disaster management and to implement disaster management measures. In response to this request, JICA has decided to transfer the necessary technology to Bhutan through the development of a road slope management master plan for the country's national roads. JICA has also decided to implement a technological cooperation project based on a development plan survey.

1.3 Objectives of the Project

1.3.1 Purpose of the Project

The purpose of the Project is to introduce the inspection techniques for road slope disaster management into Bhutan so that DoR can manage slope disasters. The Project identifies high-risk road slopes and contributes to the development of a road slope management master plan (including survey, monitoring, and a management plan).

1.3.2 Expected Outcome

Outcome 1: “Inspection manual”: A slope disaster inspection manual on roads is created.

Outcome 2: “Slope disaster inspection on roads”: Slope disaster inspections are performed on roads in the selected sections, and a slope inventory and a regular check will be created.

Outcome 3: “Inspection database”: A road slope disaster management database that includes the slope inventory and the regular check is developed for the surveyed sections.

Outcome 4: “Advice for countermeasures”: JET gives advice to DoR on one or two pilot sites where countermeasures are to be constructed.

1.4 Scope of the Project

1.4.1 Target Areas

The country has steep mountainous topography with significant geomorphological and geological constraints. The population of the country lives mainly in rural areas, although there is a need for the transport of people and materials to urban areas. Therefore, the importance of road transportation is increasing recently. Road closures due to road slope disasters along roads occur frequently causing a large amount of damage to the country.

The target area for the Project is selected considering many aspects such as natural and social as well as economical influences mentioned above. Meanwhile, long history to deal with these kinds of damages due to slope disasters in Japan of which similar topographical and geological aspects are recognized. Technical transfer of the knowledge to DoR personnel regarding road disaster management is also considered for the selection of the target area where they should be located a reasonable distance from their field. Typical types of slope disasters such as rock failure, slope failure, landslide and debris flow are included in the selected sections to develop the capacity of the personnel for road slope management.

The target areas of around 80km road section are proposed in the preliminary stage on the basis of the aspects mentioned above, and they are shown in the figure below.

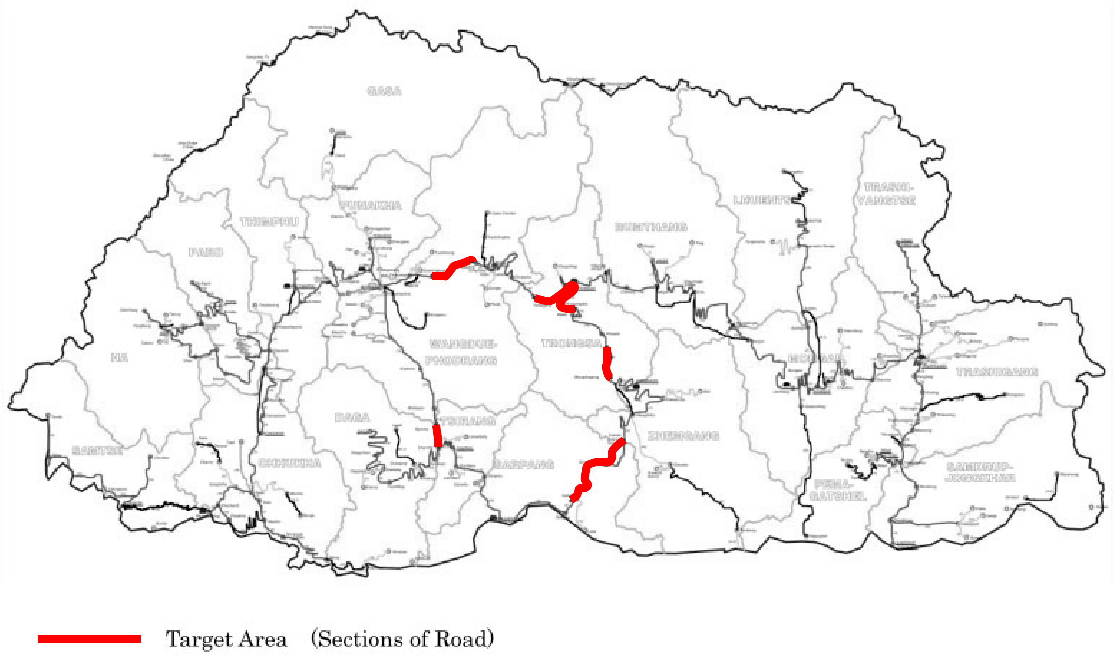


Figure 1.4.1 Target Areas in the Project (Source: JET)

However, limited revision of the area might be proposed when condition of the road changes due to unexpected occurrences of huge natural disasters and other uncontrollable factors in future stages of the Project.

The detailed procedure and methodology to select the target areas are described in Chapter 3.2 to 3.4.

1.4.2 Parties Involved in Bhutan

- Counterpart organization: DoR, Ministry of Works and Human Settlement
- Direct beneficiary: DoR
- Indirect beneficiary: the public (road users) and other relevant sectors

1.4.3 Project Duration

August 2014 to July 2016 (about 24 months)

1.4.4 List of JICA Expert Team

The names of the JICA Expert Team (JET) members are listed below. It indicates the role of each member.

Table 1.4.1 List of JICA Experts (Source: JET)

No	JICA Experts	Field of Expertise
1	KUWANO Takeshi	Team leader / Road slope management.
2	KOTOO Kimihiko	Vice team leader / Slope inspection
3	HARA Takashi	Slope stability countermeasure
4	TOZAWA Masanori	Investigation and monitoring
5	IWASAKI Tomoharu	Slope risk analysis
6	SAITO Takashi	Slope stability database system
7	SUGANUMA Yasuhisa	Road maintenance
8	SASAKI Akira	Topographical analysis
9	YAMAMOTO Yosuke	Environmental & social consideration / Coordinator
10	YOSHIDA Haruka	Environmental & social consideration / Coordinator

1.4.5 List of the Counterparts

The C/P of the Project are from DoR, and are divided into a Steering Committee (hereinafter SC) and a Working Group (hereinafter WG). SC is a committee to discuss issues, to approve plans/progress/results, to coordinate with related organizations of the Project. WG is a group to conduct actual activities and technical transfers in the Project and is composed of engineers in the headquarters and the regional offices in DoR.

Table 1.4.2 List of the Steering Committee (Source: JET)

No	Name	Organization	Title/ position
1	Karma Galay	DoR	Director
2	Tshering Wangdi ‘B’	DoR	Chief Engineer (Maintenance Division)
3	Dorji Tshering	DoR	Deputy Executive Engineer.
4	Kuwano Takeshi	JET	Team Leader/ Road slope management.
5	Kotoo Kimihiko	JET	Vice Team leader/ slope stability inspection
6	Kunzang L. Sangay	GNHC	Deputy Chief Planning Officer

Table 1.4.3 List of the Working Group in DoR (Source: JET)

No	Name	Position	Organization
1	Dorji Tshering	Deputy Executive Engineer	Headquarter, Thimphu
2	Dilip Kr. Thapa	Executive Engineer	Headquarter, Thimphu
3	Phuntsho Wangmo	Assistant Architect	Headquarter, Thimphu
4	Dhendup Dorji,	Engineer	Regional Office, Tashigang
5	Nim Dorji	Assistant Engineer	Regional Office, Lingmethang
6	Wangchuk	Engineer	Regional Office, Trongsa
7	Karma Dorji	Executive Engineer	Regional Office, Sarpang
8	Sonam Thinley	Assistant Engineer	Regional Office, Lobesya
9	Drakpa Wangdi	Executive Engineer	Regional Office, Thimphu
10	Neten Tshering	Deputy Executive Engineer	Regional Office, Samdrup Jongkhar
11	Karchung	Deputy Executive Engineer	Regional Office, Zhemgang
12	Prabin Gurung	Deputy Executive Engineer	Regional Office, Phuentsholing.

1.5 Major Activities

Component 1 “Inspection manual”, component 2 “Slope disaster inspection of roads”, component 3 “Inspection database”, and component 4 “Advice for countermeasures” have been conducted from the commencement of the Project in August 2014 up to July 2016 (Figure 1.5.1).

As the inspection manual (Chapter 2), the manual has been prepared based on the consideration of inventory format, the discussion of slope disaster types in Bhutan, and the standardization of countermeasures for slope disasters. The manual has been updated after the inspection and regular check at the sites and finalized by discussing issues with the C/Ps. A guideline for topographic analysis has been also prepared.

As “Slope Inspection” among the slope disaster inspection on roads (Chapter 3), five (5) sections for the inspection have been selected by reviewing the collected documents and information, and interviewing the C/Ps. First screening (photo interpretation) and second screening (site checking) have been conducted for the five (5) selected sections to determine areas to be inspected in the Project so that almost 460 sites along National Road No.1 and No.4 have been selected. The road slope inventory has been implemented at 457 sites, and the risk evaluation classified as rank 1, 2, and 3 was conducted at each site. Additional geological investigations and topographic analysis have been conducted in the pilot sites.

As “Regular Check” among the slope disaster inspections on roads (Chapter 4), the regular check sheets have been prepared for rank 1 (63 sites) and rank 2 (145 sites) based on the hazard analysis in the slope disasters. The regular check has been implemented for the remaining sites in the rank 1 and 2. The Master Plan on the priority of countermeasures on the slopes disaster has been discussed with the C/P and proposed as a final plan in the Project.

As the inspection database (Chapter 5), the database of slope disasters has been developed to efficiently store and update the road slope inventories and the regular check based on the discussion with the C/Ps. After development of the database, DoR will need to maintain it and update data to allow self-sustainable development in Bhutan. To help DoR with this task, JET has prepared a manual for the use of the database.

As the advice for countermeasures (Chapter 6), the background and the advice of the grant tunnel project are summarized. The advice for countermeasures in roads has been delivered to the C/Ps.

As the technical transfer (Chapter 7), the seminars for specific themes and a series of workshops for road slope disaster management by inspection are being conducted as well as the OJT (on-the-job training) in the Project. Newsletters have also been issued during the Project. The training in Japan was held in July 2015 by 12 attending C/Ps to understand the techniques used in Japan for slope disaster management inspection, along with a wide variety of slope disaster management technologies and techniques.

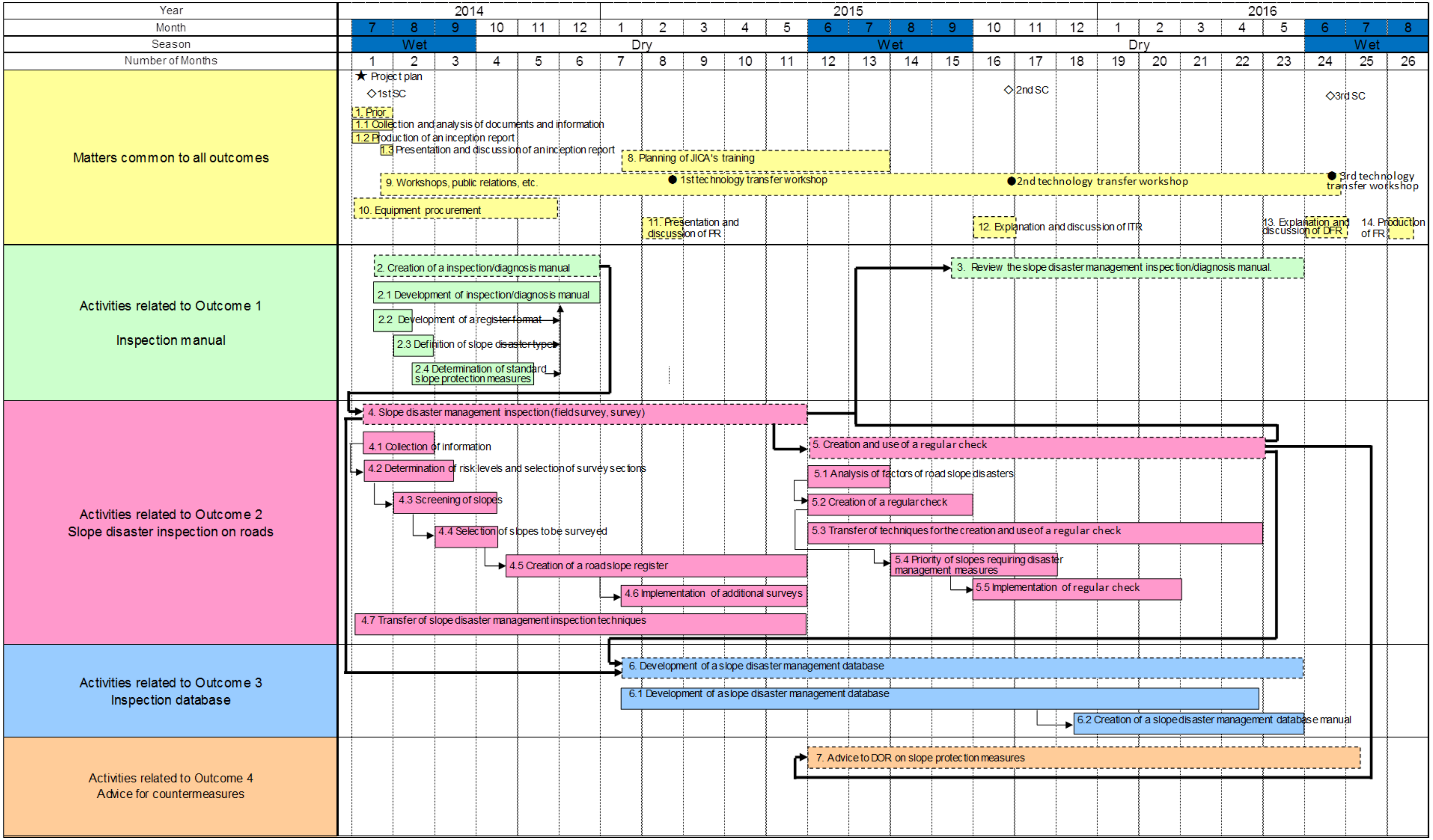


Figure 1.5.1 Flow Chart of the Project (Source: JET)

(Reference)

*1 Planning Commission, Bhutan 2020: A Vision for Peace, Prosperity and Happiness, 2011

*2 Ministry of Works and Human Settlement, Road Sector Master Plan (2007-2027), 2006

*3 Gross National Happiness Commission, 10th Five Year Plan 2008-2013, 2009

*4 Gross National Happiness Commission, 11th Five Year Plan 2013-2018, 2013

Chapter 2

Inspection Manual

2 Inspection Manual

2.1 Inspection Manual

A manual for slope disaster inspection on roads in Bhutan (hereinafter: the "Inspection Manual") is created on the basis of the Manual for Disaster Management Inspection on Roads in Japan and the Manual for Road Disaster Management by Regular Check Sheet in Japan.

The inspection manual indicates a standard methodology of how road engineers should inspect for slope disasters on roads such as landslides, rockfalls, slope failures and debris flows and compile the inspection results. Specifically the following items are described in the manual;

- Standardization of methodology of the inspection
- Clarification of points to be inspected
- Standardization of hazard and risk on evaluation of slope disasters
- Organization of the inspection results in unified formats

The inspection manual includes the description that is elaborated in the following sections of this report as follows;

- Inventory format
- Slope disaster types
- Standard countermeasures for slope disasters

During the development of the inspection manual, modifications, supplements, and additions are made as needed on the basis of a review of the results of, and improvements in, slope disaster inspection on roads in Japan, as well as on the basis of Bhutan's climate, topography, geology, traffic, implementation structure, and capacity. To provide technical guidelines that allow DoR engineers to inspect slopes by themselves after completion of the Project, the inspection manual is designed in such a way that they can easily go through it in accordance with the flow of tasks in the Project.

The inspection and the regular check sheet in the manual are aimed to evaluate the factors of potential disasters which may affect traffic and infrastructure on roads. Further detailed investigations and analysis are needed for the design and construction of countermeasures.

The manual elaborates on the methodology and procedure about 1) screening of targeted areas, 2) disaster inspection at site, 3) evaluation of slope disasters, 4) regular check sheet, and 5) management and database. The contents are as follows:

Table 2.1.1 Contents of the Inspection Manual (Source: JET)

Chapter	Title	Contents
0	Preface	- Definition of Slope Disasters
1	Outline of Slope Disaster Inspection	- General - Objectives of the Inspection - Targeted natural disasters - Significance of this manual for road engineers - Flow of the Inspection
2	Screening of Targeted Areas	- General - Screening by desk study (First step) - Screening by field reconnaissance (Second step)
3	Preparation of Disaster Inspection Sheet	- General Information Sheet - Evaluation sheet and photo sheet for Rock slope failure/Debris slope failure - Evaluation sheet and photo sheet for landslide - Evaluation sheet and photo sheet for debris flow
4	Evaluation of Slope Disaster	- Calibration - Risk assessment - Proposed countermeasures
5	Regular Check Sheet	- Outline of Regular Check Sheet - Method of Regular Check Sheet - Maintenance and management

The inspections are performed according to the inspection manual, and the inspection manual and the format of the forms or sheets are updated on the basis of the experience obtained in these inspections in order to adapt to Bhutan’s specific situation. In the review of the manual, JET particularly takes into account the ability of DoR to perform observations and fill in sheets in the field, as well as the reproducibility of findings (as determined from the information filled in on the sheets). A review then is conducted with the participation of JET and C/P. It takes into account knowledge and advice from the perspectives of inspection and countermeasures, as well as surveys, monitoring, risk analysis, database development, road maintenance, and environmental and social considerations.

2.2 Inventory Format

To enable Bhutan to develop a road slope management master plan in the future, it is of great importance to develop a set of forms, including an individual slope record, a stability assessment sheet, a disaster history sheet, and a regular check sheet, that contain information on road slope failures.

Forms that are as simple and easy to use as possible are developed on the basis of the Japanese forms. All the necessary information needs to be filled in on the form according to the condition of the road slopes in Bhutan. Fixed-point photographic observation should be used to record findings and changes in the field. There are three (3) inspection sheets:

- General information sheet
- Evaluation sheet
- Photo sheet

The slope disaster inspection is carried out using inspection sheets which are specified depending on the estimated disaster type. The evaluation sheet among the inspection sheets are prepared for four (4) types of disaster: “Rock slope failure”, “Debris slope failure”, “Landslide,” and “Debris flow” (Points to be checked in the disaster inspection are the same for both rock slope failure and debris slope failure so the same inspection sheet is utilized for both).

2.2.1 General Information Sheet

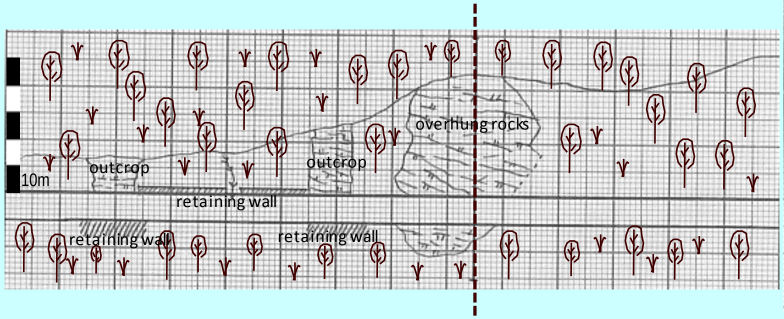
General information sheet is the one to describe the general attributes such as management office, road type/No., latitude and longitude, full view photo/schematic sketch, location map, disaster type, estimated disaster volume, proposed countermeasures, and judgment.

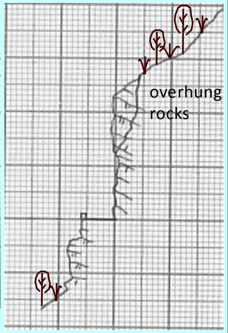
Format of the sheet is common among the four (4) types of disaster. Summary of the site conditions are shown on the sheet. The blue shaded areas of the sheets in the following figure shall be described in the inspection. Users can gain a rough understanding of the site situation from this sheet.

General Information Sheet

Management office	*Trongsa*			Road type/name	*Primary National Highway*	*No.4*	
Management No.	T R 0 4 R F 0 0 7 0	Distance from start point	*4.54* km from *Trongsa*	Length on road	*320* m	latitude *N 27°29'17.5"*	longitude *E 90°30'37.6"*
Inspector	*Takeshi KUWANO*	Organization	*JICA Expert Team*	Date	*October/ 7/ 2014*		

Full veiw photo / Schematic sketch





Road slope	Mountain side	Valley side
Disaster type	*Rock slope failure*	*Rock slope failure*
Description	*Rock slopes are mainly exposed at 3 parts. Overhung/ dip slope/ detached rocks with open cracks, which are highly unstable, are scattered in the outcrops. Roots of trees are penetrating into the cracks, which broaden the cracks. The height of the outcrop is 10-20m.* *Poor visibility by bad road alignment.* *The fallen rocks and rock masses would affect the road traffic. Countermeasure work is necessary.*	*Rock slopes are exposed in places.* *Overhung/ dip slope/ detached rocks with open cracks, which are unstable, are scattered in the outcrops.* *Several pitholes and exfoliation of the asphalt on the road surface are scattered.* *Erosion of the valley side would be exacerbated in the future.* *Though urgent countermeasure is not necessary, regular inspections are needed.*
Year of occurrence	?	
Judgment	***Rank 1B***	***Rank 2***
Estimated disaster volume	*Rockfall* *minimum: 50-300cm in diameter* *maximum: 5m * 4m * 3m =60m3*	*Collapse of the road* *Length: 60m*
Proposed counter-measures (Type, Quantity)	*Cut slope* *Length: 15m, 15m, 30m * Height: 10-20m * depth: 2-3m*	*Reinforcement of the earth retaining walls* *Length: 60m*

Location map

Figure 2.2.1 Example of General Information Sheet (Source: JET)

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2.2.2 Evaluation Sheet

a. Rock Slope Failure/Debris Slope Failure

A rock slope failure is equivalent to falls and topples. Rock slope failure is a phenomenon that occurs when foliated rocks and gravel due to enlarged cracks in the bedrock or outcropping rocks start to fall down a slope.

A debris slope failure is equivalent to falls of debris and earth material, but it does not include "rock slope failures". The debris slope failures mass detached from steep slope/cliff along surface with little or no shear displacement. It may be called a "surface failure". Compared to landslides, rock or debris slope failures are both quick and on a small-scale, and the slope angle is a relatively high (over 20 degrees).

The hazard and the risk of rock/debris slope failures are evaluated based on the effectiveness of existing countermeasures, disaster history and the predisposing causes of slope disasters such as topography, geology, and slope angle and height.

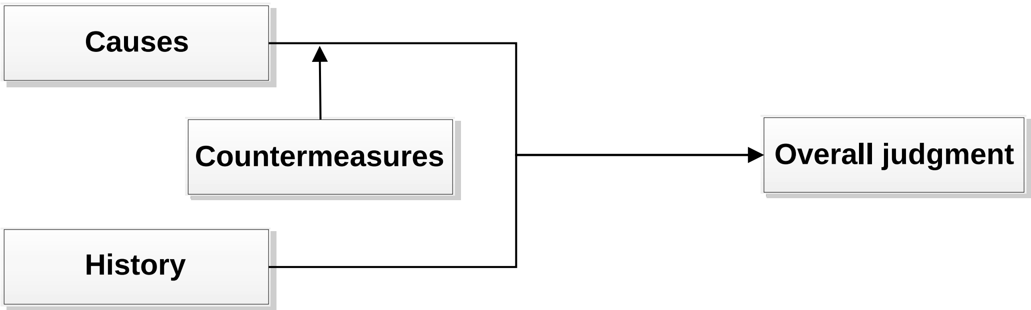


Figure 2.2.2 Evaluation of the Hazard and the Risk of a Rock Slope Failure/Debris Slope Failure (Source: JET)

b. Landslide

After a landslide inspection has been conducted, stability of the target landslide is evaluated by causes, history and existing countermeasure work of the landslide. This information can be the data to compare future condition of the target landslide for stability evaluation.

Landslide is a phenomenon in which part or all of the soil on a slope moves downward slowly (less than a few centimeters per minute) over a long duration (over 100 hours) and often the movement is repeated under the influence of groundwater and gravity. Since a large amount of soil mass usually moves, serious damage can occur. If a slide has been started, it is extremely difficult to stop.

Specific landslide topographical features can often be observed on the ground surface of a landslide. On the other hand, erosion or vegetation can sometimes obscure such specific landslide topographical features. Generally, landslides can be found within specific topographic and geological areas. Therefore, topography and geology should be checked at first, and then history and evidence of its current activity shall be checked on the site as well as effectiveness of existing countermeasure works.

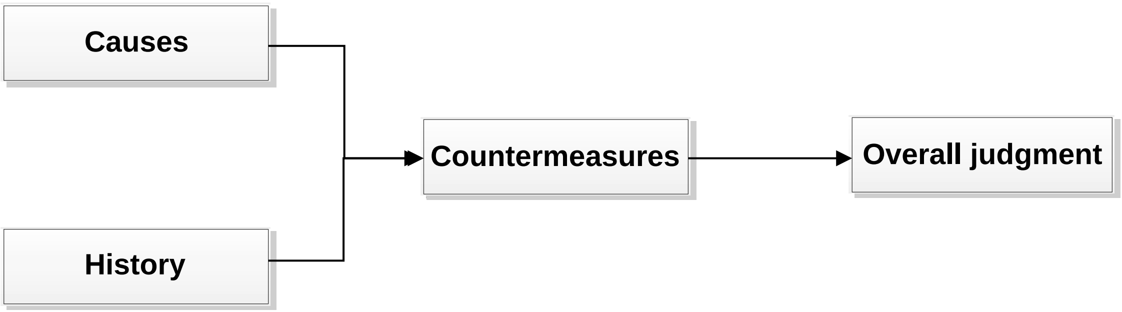


Figure 2.2.3 Evaluation of the Hazard and the Risk of a Landslide (Source: JET)

c. Debris Flow

A debris flow is equivalent to flows of debris and earth material. A debris flow is a phenomenon where soil and boulders are liquefied by surface water or groundwater and tend to flow downward rapidly through a mountain torrent. It usually has huge energy and destructive force. Debris flows tend to occur in places where there is massive sediment of unstable debris along a steep torrent, or where there is a large risk of debris slope failure due to heavy rain in the catchment basin.

The hazard and the risk of debris flow disasters are evaluated based on the causes, the countermeasures, the road structure and the disaster history.

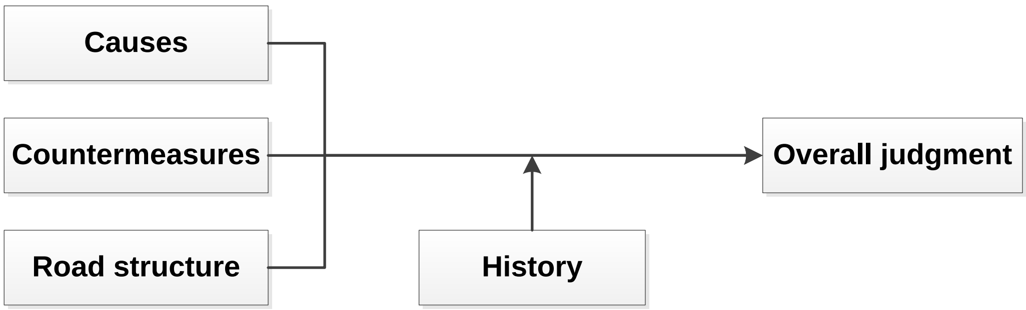


Figure 2.2.4 Evaluation of the Hazard and the Risk of a Debris Flow (Source: JET)

It is preferable to collect the following maps and photos to evaluate debris flows.

- Topographic map (Scale = 1:5,000-1:10,000)
- Aerial photos (Scale = 1:10,000-1:20,000)

Management Number	T	R	0	4	R	F	0	0	7	0

Evaluation sheet (rock/debris slope failure)

Mountain side

Inspector	Takeshi KUWANO
Organization	JICA Expert Team

[Causes] (A)

Item		factor	category of score	check	score
topography	Collapsed factor	talus slope, clear convex break of slope, eroded toe of slope , overhang, water catchment slope	3 or more correspondences	✓	
			2 correspondences		
			1 correspondences		
			no correspondence		
Geological conditions	Soil	susceptible to erosion less strength with water	marked		
			a little marked		
			None	✓	
	Rock	high density of cracks and a weak layers, susceptible to erosion, fast weathering	marked	✓	
			a little marked		
			None		
	Structure	dip slope of bedding plane	It corresponds.	✓	
			None		
		debris on impermeability bedrock, the upper part is a hard /the toe of slope is weak.	marked		
			a little marked		
			None	✓	
Surface codition	Topsoil, detached rock and unsteady rock		instability	✓	
			a little unstable		
			stability		
	Spring water		notable spring waster		
			seepage	✓	
			none		
	Surface condition		bare land with minor vagetation	✓	
			intermediate (bare･grass･tree)		
			mainly structure, mainly tree		
Profile	Height (H), dip (i)	height	H≧50m		
			30≦H<50m		
			15≦H<30m	✓	
			H<15m		
		dip	i≧70°	✓	
			45°≦i<70°		
			i<45°		
Anomaly	Surface collapse, small fallen rock, gully, erosion, piping hole, subsidence, heaving, bending of tree root, fallen tree, crack, open crack, anomaly of countermeasure		2 or more correspondences･clarity	✓	
			certain･unclarity		
			none		
			sum total	(A)	

[Disaster type]

Rock slope failure	✓
Debris slope failure	

[Main check object]

Cut slope	✓
Natural slope	✓

[Countermeasure] (B) = (A) +α or (A) ×0

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

[History] (C)

Level of disaster history	point	check
There is a history about large fallen rocks and slope failures that were obstacles to the road traffic after construction of recent measures.	100	
There is a history about large fallen rocks and slope failures that gets to the road though there is no obstacle to traffic.	70	✓
There is a history about small fallen rocks and slope failures that did not get to the road.	40	
No disaster records	0	
	(C)	70

(D) =MAX (B,C)

Score in evaluation from cause	(B)	0
Score in evaluation from history	(c)	70
Among (B)&(C), large one.	(D)=MAX(B,C)	**70**

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	✓
2	Though urgent countermeasure is not necessary, regular inspections are needed.	
3	Countermeasure work is not necessary.	

[Description]

Rock slopes are mainly exposed at 3 parts. Overhung/ dip slope/ detached rocks with open cracks, which are highly unstable, are scattered in the outcrops. Roots of trees are penetrating into the cracks, which broaden the cracks. The height of the outcrop is 10-20m. Poor visibility by bad road alignment.
The fallen rocks and rock masses would affect the road traffic.
Countermeasure work is necessary.

Figure 2.2.5 Example of Evaluation Sheet for Rock Slope Failure/Slope Failure (Source: JET)

Mangement number	T	R	0	4	L	S	0	0	9	0

Evaluation sheet (landslide)

Inspector	Takeshi KUWANO
Organization	JICA Expert Team

[Main body of landslide]

Mountain side	
Valley side	
Both	✓

[Causes] (A)

category			check	score
Topographical factor	Result of photo interpretation	exist clearly		
		exist but partial and not clear	✓	
		exist but not clear		
	Surface anomalies	large and new cracks, steps and subsidence	✓	
		small and old cracks, steps and subsidence		
		slight deformation		
		no anomalies		
Geological conditions	Geological structure	fault, fracture zone		
		dip slope		
		undip slope/ no characteristic feature	✓	
	Main rock formation of landslide body	metamorphic rock (schist, quartzite, phyllite etc.)	✓	
		sedimentary rock (sandstone, limestone etc.)		
		igneous rock (granite etc.)		
		quaternary deposit (colluvial deposit etc.)		
	Hydrological feature	much springs / much seepage		
		little springs /little seepage	✓	
		trace of w ater		
		no w ater observed		
		sum total (maximum points:100)	(A)	

[History] (B)

category			point	score
Records of Landslide	Existing record (documents or patrimony)	obvious	100	0
		slight	75	
		none	(0)	
	Damage on road facilities and houses	obvious	(100)	100
		slight	75	
		none	0	
		sum total (Among aboved scores, large one.)	(B)	100

(C)=MAX(A,B)

Score in evaluation from cause	(A)	0
Score in evaluation from history	(B)	100
Among (B)&(C), large one.	(C)=MAX(A,B)	100

[Countermeasure] (D) = (c) + α or (c) x 0

category		point (α)	check
There is no countermeasure		±0	✓
Effectiveness of countermeasure	No effect	±0	
	Some effect	-30	
	High effect	x0	
	sum total	(D)	**100**

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	✓
2	Though urgent countermeasure is not necessary, regular inspections are needed.	
3	Countermeasure work is not necessary.	

[Description]

The area is an active landslide area (length: 100m, width: 50m, depth: 5m?) due to excavation at the bottom of the valley side by the construction of hydroelectric power plant.
*Slope failures (2*3*0.5m at the start point, 4*3*0.5m at the middle point, 2*20*0.5m at the end point) at the mountain side are being occurred by the landslide movement.*
There are significant deformations/ cracks/ subsidence by the landslide are identified on the road. Step with destruction of the ditch on the road is around 20cm at the start point, and more than 100cm at the end point. There is 20cm step at the road shoulder at the valley side.

Figure 2.2.6 Example of Evaluation Sheet for Landslide (Source: JET)

Management number	T	R	0	4	D	F	0	1	7	0

Evaluation sheet (debris flow)

Inspector	Takeshi KUWANO
Organization	JICA Expert Team

[Causes](A)

itme	factor	category	point	score
Property of river	areas that river bed is 15°or more in watershed area	$0.50km^2$ or more	10	
		$0.15km^2$ - $0.50km^2$	8	10
		less than $0.15km^2$	4	(10)
	steepest slope of river bed	40°or more	10	
		30° - 40°	5	10
		less than 30°	0	(10)
Property of slope	area that slope gradient is 30° or more in watershed area	$0.20km^2$ or more	8	
		$0.08km^2$ - $0.20km^2$	6	2
		less than $0.08km^2$	2	(8)
	area that meadow and shrub (less than 10m height) occupy in watershed area	$0.20km^2$ or more	8	
		$0.02km^2$ - $20km^2$	4	8
		less than $0.02km^2$	0	(8)
	artificial works that cause negative effects	certain	5	0
		none	0	(5)
	new crack and/or slope failure in stream	certain	5	0
		none	0	(5)
	traces of large slope failure in stream	certain	10	0
		none	0	(10)
		sum total	(A) (56)	30

[Countermesure](B)

Item・category		sum total of score(A) 20 -	15 - 20	10 - 15	- 10
Effect of existing countermesure	none・low	100	70	50	30
	moderate	70	50	30	10
	high	50	30	10	0
	enough	0			
		(B)			

[Road structure](C)=(B)+α

structure	category of score	point (α)	score
River width	10m or more	-40	
	5m - 10m	-30	
	3m - 5m	-20	
	less than 3m	±0	
Beam height	less than 1m or No bridge / box culvert	±0	
	1m - 2m	-5	
	2m - 3m	-15	
	3m - 5m	-30	
	5m or more	-40	
	sum total	(C)	0

[History](D)

category of score	point	check
There is a history about debris flow that were obstacles to the road traffic after construction of recent measures.	90	
There is a history about debris flow though there is no obstacle to traffic.	40	✓
There is no history of debris flow	0	
	(D)	40

(E)=MAX(C,D)

Score from cause	(C)	0
Score from history	(D)	40
Among (C)&(D), large one.	(E)=MAX(C,D)	**40**

[Potencial disaster mode]

Damage of bridge/culvert	
Outflow of embankment	
Debris flooding on the road	✓

[Overall judgment]

Rank	Response	Check
1	Countermeasure work is necessary.	
2	Though urgent countermeasure is not necessary, regular inspections are needed.	✓
3	Countermeasure work is not necessary.	

[Description]

Since the locus of the box culvert is different from the bottom of stream, water flow is divided into 2 parts due to the topography. Debris materials are deposited at the bottom of them. The volume of the water flow is large so that the retaining wall is partially destroyed and the asphalt is eroded/exfoliated on the road surface
In case of the flowing of debris from the streams, the debris would affect the road.
Though urgent countermeasure is not necessary, regular inspections are needed.

Figure 2.2.7 Example of Evaluation Sheet for Debris Flow (Source: JET)

2.2.3 Photo Sheet

Photo sheet is composed at least the following photos;

- Front view of the target slope
- Side view of the target slope with road
- Notable findings (anomalies) on the site
- Slope surface condition
- Existing countermeasures
- Stream from top of debris flow
- Stream from bottom of debris flow
- Full view of upstream of debris flow
- Full view of downstream of debris flow
- Crossing point of road and stream from upstream of debris flow
- Crossing point of road and stream from downstream of debris flow

Management Number	T	R	0	4	R	F	0	0	3	0	Photo sheet	Date	October/ 6/ 2014


Full view of the slope at start point


Full view of the valley side at start point


Full view of the valley side at middle point


Close veiw of detached rocks at start point


Close veiw of water flow on the rock


Close veiw of overhung rocks at end point

Figure 2.2.8 Example of Photo Sheet for Rock Slope Failure/Slope Failure (Source: JET)

Management Number	T	R	0	4	D	F	0	1	3	0	Photo sheet	Date	October/ 13/ 2014

Full view of the stream

Close view of the inlet

Clearance between road and the debris from start side

Full view of the valley side

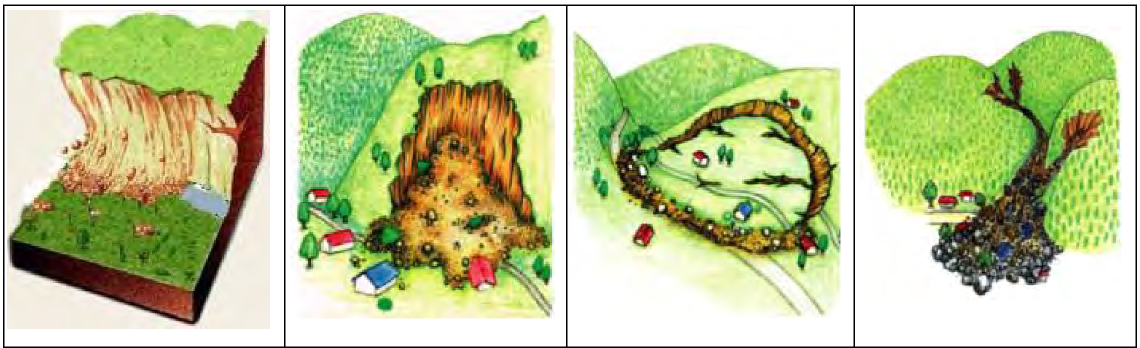
Close view of the outlet

Clearance between road and the debris from end side

Figure 2.2.9 Example of Photo Sheet for Debris Flow (Source: JET)

2.3 Slope Disaster Types

Slope disaster types are divided into four types such as Rock slope failure, Debris slope failure, Landslide, Debris flow based on the existing reports and site reconnaissance in the preliminary stage of the study. Their images are shown in the Figure 2.3.1.



Rock slope failure	Debris slope failure	Landslide	Debris flow

Figure 2.3.1 Schematic Images of the Slope Disasters (Source: JET)

There are several literatures that define the term “Slope disaster” or “Landslide”. The term “landslide” defined in United States Geological Survey (USGS) is almost interchangeably with the term “slope disaster” in general. USGS defines “Landslide” referring to Cruden[*1], and Varnes[*2]. They are as follows:

A landslide (= a slope disaster) is defined as "the movement of a mass of rock, debris, or earth down a slope"[*1]. Landslides (= slope disasters) are a type of "mass wasting" which denotes any down slope movement of soil and rock under the direct influence of gravity. The term "landslide (= slope disaster)" encompasses events such as rock falls, topples, slides, spreads, and flows, such as debris flows commonly referred to as mudflows or mudslides[*3]. Landslides (= slope disasters) can be initiated by rainfall, earthquakes, volcanic activity, changes in groundwater, disturbance and change of a slope by man-made construction activities, or any combination of these factors.

The classification by Varnes[*2] through USGS is widely applied worldwide. Figure 2.3.2 describes the updated classification.

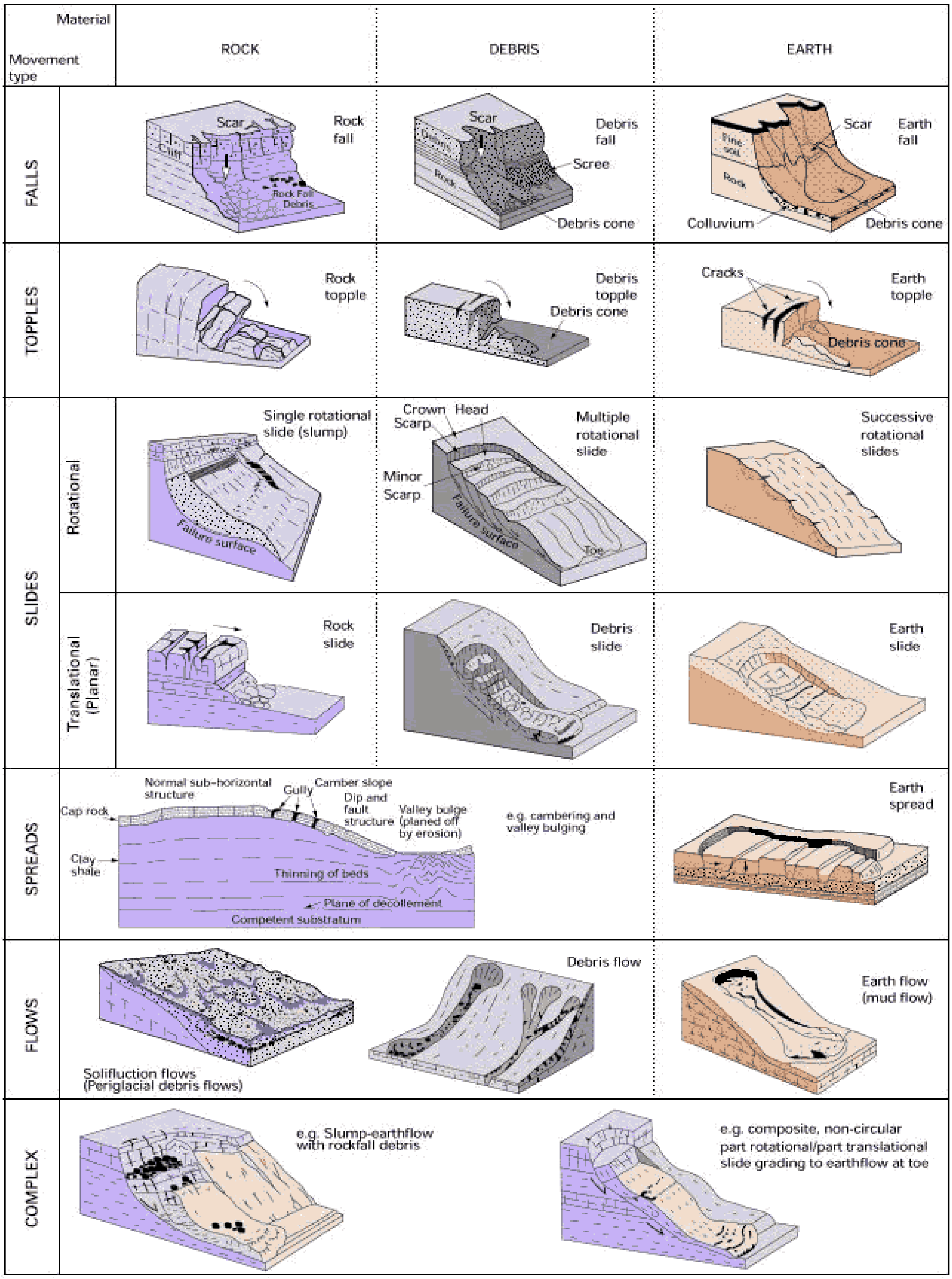


Figure 2.3.2 Classification of Types of Slope Disasters (Source: Modified after Varnes[*2])

The following figure indicates the relationship between the definition in USGS and the classified phenomenon defined in this report.

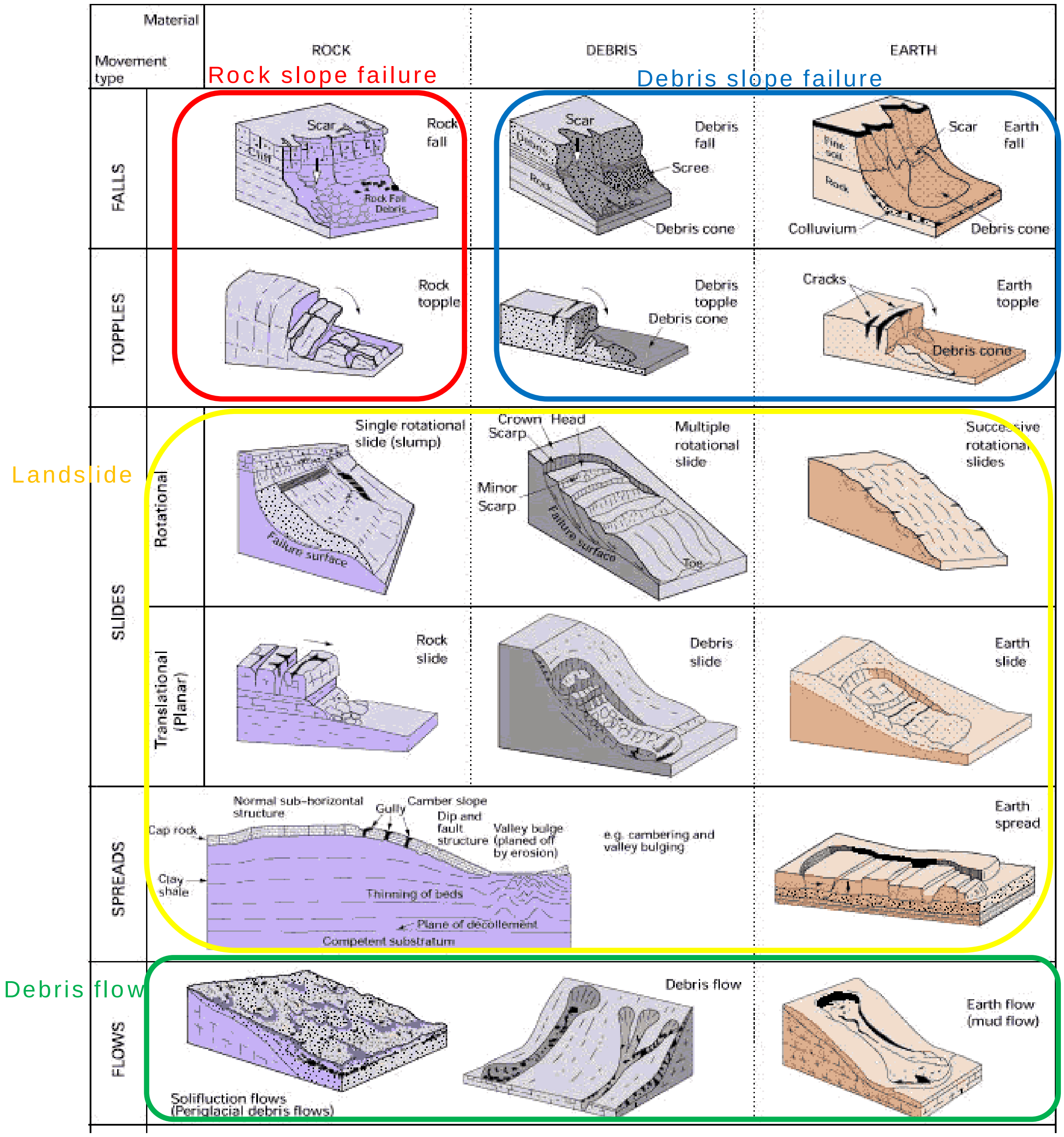


Figure 2.3.3 Relationship between the Definition in USGS and the Phenomenon in this Report (Source: same as Figure 2.3.2)

A rock slope failure, a debris slope failure, a landslide and a debris flow of classified slope disaster types are as described in the following sections.

2.3.1 Rock Slope Failure

A rock slope failure is equivalent to “Falls” and “Topples” of rock mass. Rock slope failure is a phenomenon which foliated rocks and gravels start to fall down a slope due to enlarged cracks in the bedrock or outcropped rocks.

The rock slope failures is the phenomenon which the slope collapses rapidly due to decreased resistance of the materials which constitutes the rock slope under the influence of rains, earthquakes etc.

2.3.2 Debris Slope Failure

A debris slope failure is equivalent to “Falls” of debris and earth materials, and it includes “Rockfalls” in some cases. Debris slope failures consist of failures of rock mass detached to steep slope/cliff along surface with little or no shear displacement, which may be called the “Surface failure“, and failures of a mass of debris covering weathered and/or fractured bedrock. The debris flow has a quick move in a small-scale in comparison with landslides and the inclination of the debris slope failure is a relatively higher than that of landslide.

The debris slope failure is the phenomenon in which the resistance of the material which constitutes a slope becomes weaker and a slope collapses rapidly under the influence of rain, an earthquake, etc.

2.3.3 Landslide

A landslide is equivalent to mainly “Slides”. A landslide occurs in the slopes where the soil mass on one or more failure (slip) surfaces deep in the ground. The slipped land mass gradually shifts downward, triggered by heavy rain or earthquake, river erosion, earthworks. Landslides occur in areas with specific geological structure. The land mass moves forming specific topography (landslide topography) in relatively large scale, the inclination of the landslide slope is a relatively gentle in comparison with that of debris slope failure.

The landslide is the phenomenon which clods of the slope slide under the influence of groundwater etc. and it moves downward slowly. Landslides often occur in specific geological conditions in general.

2.3.4 Debris Flow

A debris flow is equivalent to “Flows” of debris and earth materials. A debris flow occurs in the area where soils and boulders are liquefied by surface water or groundwater and tend to flow downward rapidly through a mountain torrent. It usually has huge energy and destructive force. Debris flows tend to occur in places where there are massive sediments of unstable debris along the steep torrent in the catchment basin. A risk of debris flows is relatively high in the catchment basin where slope failures often occur.

The debris flow is the phenomenon which earth and sand flows down with waters, together with small to large boulders in general, along the mountain torrent, hillsides and rivers. The debris flow is generally caused by heavy rains of severe rains as well as rains of a long duration.

Rock slope failure	**Debris slope failure**
	
	
Landslide	**Debris flow**
	
	

Figure 2.3.4 Photos of Road Slope Disasters in Bhutan (Source: JET)

<table>
<tr><th></th><th>①Rock slope failure</th><th>②Debris slope failure</th><th>③Landslide</th><th>④Debris flow</th></tr>
<tr><td>Image figure</td><td></td><td></td><td></td><td></td></tr>
<tr><td>The feature of a phenomenon and damage</td><td>[Movement]
*Bearing force of the rock slope decrease and slope collapses rapidly.

[Disasters]
*Force is enormous, but damage is less than landslides, debris flows in general.

*Occurrence depends on topography and geology.</td><td>[Movement]
*Bearing force of the layers of slope decrease and slope collapses rapidly.

[Disasters]
*Force is enormous in disasters.

*Debris slope failures commonly occur in Bhutan.</td><td>[Movement]
*The clod of slope slides under influence of groundwater etc.

[Disasters]
*Damage is generally large in size

*Secondary damage anticipated when lake formed by landslides</td><td>[Movement]
*The earth, sand and gravels flows down with waters at once in hillside and river bed.

[Disasters]
*Movement of 20 to 40 km/h.

*Damage is bigger in downstream area than upstream in general.

*Damage encounter along streams or flows</td></tr>
<tr><td rowspan="2">Notes on Site Inspections</td><td>*Gradient of slope is more than 60 degree, height is more than 15m in general

*Slope consists of hard & compact rock (fresh or slightly weathered) in general

*Cracks is fresh without fills in general

*Condition of rock forming slope, strike & dip etc. shall be described</td><td>*Gradient of slope is more than 30 degree, height is more than 5m in general

*Slope consists of weathered rock in general

*Cracks is fresh without fills in general

*Condition of rock forming slope, weathered rock, debris and/or combined shall be described.

*Distribution of boulders shall be described if any.</td><td>*Gradient of slope is less than 30 degree

*Gradient of crown and toe portion of land mass shall be carefully observed.

*Abnormalities of road and appurtenant structures shall be checked.

*Condition of surface water and groundwater shall be observed.</td><td>*Distribution of sediments shall be checked by map and aero photo in catchment.

* Location, size, damages of structures shall be checked along the stream.</td></tr>
<tr><td colspan="4">*Observation of road slopes shall be performed in classification of ①Rock slope failure, ②Debris slope failure, ③Landslide, ④Debris flow.

*Length (width) of the road section for site inspection is determined by the observer based on the result of screening.

*No performance of the site inspection is done considering site conditions when height of the road slope is less than 5m.</td></tr>
</table>

Figure 2.3.5 Classification of Slope Disasters and Consideration of Slope Inspection
(Source: JET)

2.4 Standard Countermeasures for Slope Disasters

2.4.1 General

Countermeasures for slope disasters are divided into structural measures and non-structural measures. Basically, a structural measure shall be selected as a countermeasure for hazardous slopes. In case it is difficult to apply structural measures for hazardous slope/road sections, application of non-structural measures can be considered. Moreover, according to the site conditions, a combination of both structural and non-structural measures may also be applied.

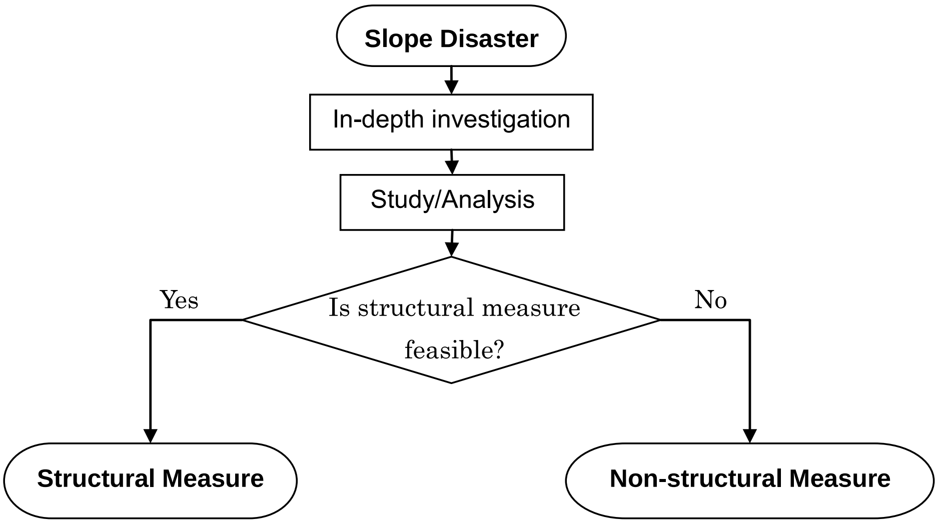


Figure 2.4.1 Flowchart to Consider the Countermeasure for Slope Disasters (Source: JET)

2.4.2 Structural Measure

There are many existing structural measures for road slope hazards. In the past, the standard countermeasure work was defined based on structural measure works. The standard countermeasures for road slope disasters mean a countermeasure which is available in Bhutan, and is applied as the proposed countermeasure work at the slope inspection stage. Even though countermeasure works have been proposed at the inspection stage, the countermeasure works might be changed at the actual design stage according to the results of further investigation and analysis. The selected countermeasure works at the inspection stage imply they (selected countermeasures) are a factor of prioritization analysis for designing the road maintenance plan.

The standard countermeasure works shall be defined in consideration of feasibility and sustainability in Bhutan. As the first step to define the standard countermeasure works, a questionnaire survey for the engineers of DoR was carried out to know the available works in Bhutan.

a. Questionnaire Survey

The survey was carried out by using a questionnaire sheet for 23 engineers who attended the 1st technical seminar in the Project. The questionnaire sheet is attached in the Appendix of the report. Since the target engineers were all from the Regional Offices of DoR, the survey result can be considered to be free of bias with respect to local conditions.

First of all, the JET introduced the common countermeasure works in Japan for each disaster type including "landslide", "debris slope failure", "rock slope failure", "debris flow" and "rockfall". After that the C/P evaluated the works to check whether it is available in Bhutan or not. Additionally, it was requested that the engineers propose countermeasure work which is available in Bhutan even though it is not mentioned on the list in the questionnaire. The results of the survey are shown in the following figures. The Y-axis of each bar chart shows the rate of engineers who evaluated that the countermeasure work is available in Bhutan.

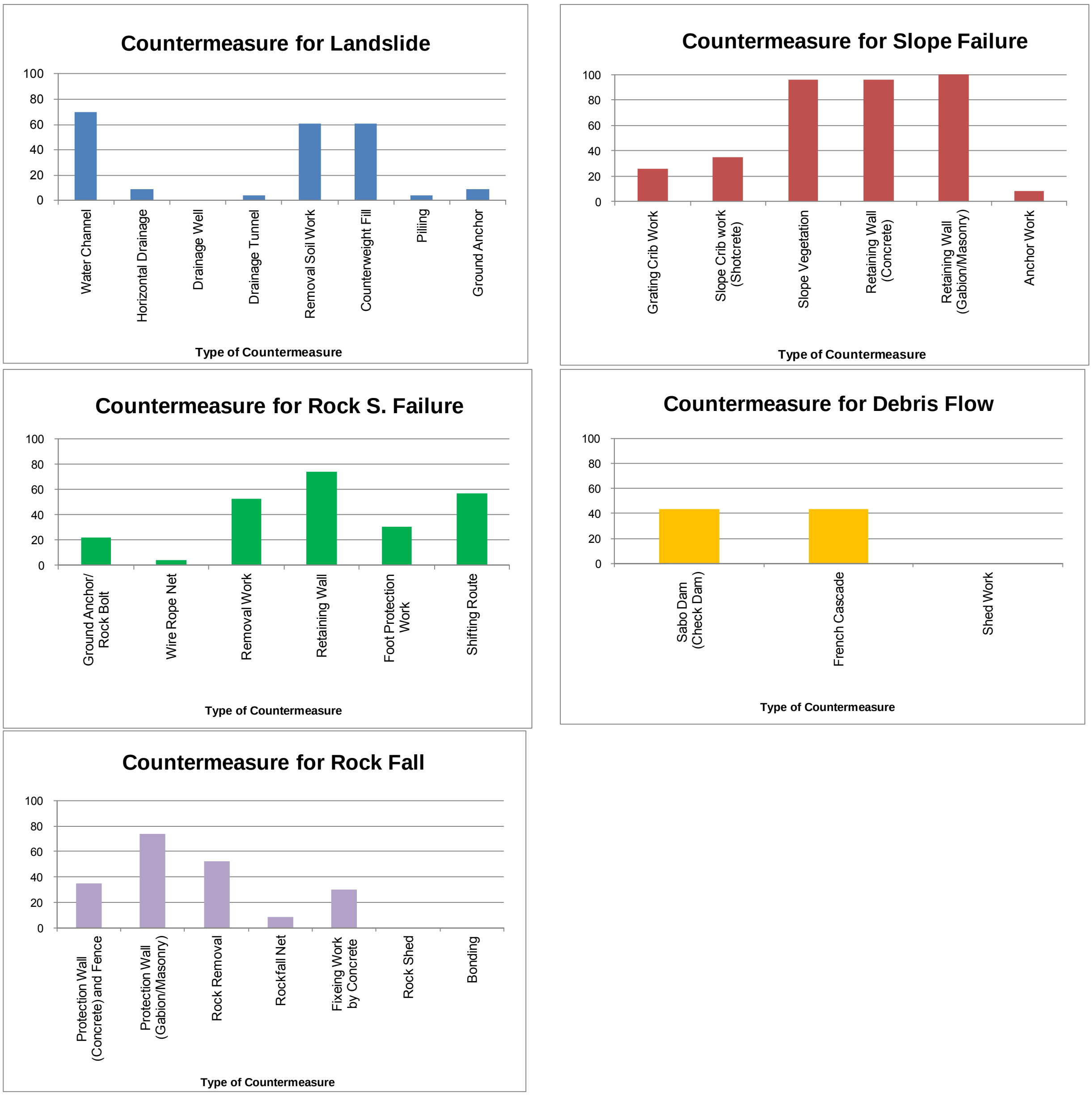


Figure 2.4.2 Result of the Questionnaire Survey for Available Countermeasure Works in Bhutan (Source: JET)

b. Discussion of Standard Countermeasures in Bhutan

As a result of the questionnaire survey and discussion with C/Ps, it has been proved that the works which can be assumed as feasible countermeasures in Bhutan have the following features:

- The work which requires particular materials and techniques is difficult to be carried out by local contractors.
- The work which can apply the traditional/simple materials and techniques in Bhutan such as masonry or gabion is available.
- The engineers consider that countermeasure works which are structures of reinforced concrete are available in Bhutan.
- The works such as Rock Shed, which require huge construction costs and techniques, are difficult to be carried out in Bhutan.
- Simple soil works such as soil removal works or filling works are available.
- Vegetation works are common and available.
- The works which use rock or wooden materials are common measures in Bhutan.
- Almost all works will be available if they can get external support such as engineering techniques and/or budget.

Evaluations on feasibility of the slope countermeasure works, based on the results of the survey, are shown in Table 2.4.1.

Table 2.4.1 Evaluation for the Standard Countermeasure Works in Bhutan (Source: JET)

LANDSLIDE		
	General Measure in Japan	Availability
Control work	Surface Drainage	A
Control work	French Drain/ Open-Blind Ditch	A
Control work	Horizontal Drainage	C
Control work	Removal Soil	A
Control work	Counterweight Fill	A
Control work	Drainage Well	C
Control work	Drainage Tunnel	C
Restraint work	Piling work	B
Restraint work	Shaft work (Manual digging)	B
Restraint work	Ground anchor	B

DEBRIS SLOPE FAILURE	
General Measure in Japan	Availability
Surface Drainage	A
Concrete Crib	C
Shotcrete	B
Vegetation	A
(Concrete Crib) Retaining wall	A
Barrier wall	A
Ground anchor	B
Removing fallen debris	A
Wicker Fence	A
Wooden log crib	A
Stone pitching	A

ROCK SLOPE FAILURE	
General Measure in Japan	Availability
Ground anchor	B
Rock bolt (Nailing)	B
Wire rope net	C
Removal rocks	A
(Concrete Crib) Retaining wall	A
Barrier wall	A
Foot Preotection	B
Removing fallen rocks	A
Route Shifting	Depending on the plan

DEBRIS FLOW	
General Measure in Japan	Availability
Sabo Dam	C
Check Dam	A
French cascade	B
Shed work	C
Training work	A
Buffer Forest (Planting Trees)	A
Culvert / Bridge	A

ROCKFALL	
General Measure in Japan	Availability
Protection wall (Concrete)	B
Protection wall (Gabion/Masonry)	A
Removal rocks	B
Rockfall net	C
Fixing work by concrete	B
Shed work	C

Legend

A : High experienced work in Bhutan

B : Available with international technical support

C : Not available in Bhutan company

Note: The evaluaiton would be considered from technical capacity and budgetary points of view.

From the results above, it can be concluded that countermeasures, which are feasible in Bhutan, might be difficult to apply for a hazardous slope which requires a huge deterrent force against estimated disaster volume.

However, there will be some cases that the works can be applied if they are constructed with appropriate quality and alignment against the disaster conditions. Regarding the defined countermeasure works as the standard countermeasure works, those advantages and features have been explained to the C/Ps of DoR through the technical transfer seminar and On-the-Job Trainings in this Project.

The features of the works are compiled as the Catalog (refer to the Appendix of the report). Additionally, flowcharts to select countermeasure works in each disaster type have been prepared. The catalog and the flowchart has been finalized through the discussions with C/Ps.

The features of the works which are evaluated by the survey as Rank-A, high experienced work in Bhutan, are described, and the flowchart to select the work in each type of disaster is shown below.

b.1 Landslide

Surface Drainage

- Purpose: To collect surface water and to properly drain it out from landslide areas
- Availability: This is one of the simplest countermeasure works for landslides. This method can be expected to avert infiltration of rainfall into the landslide blocks. Generally, maintenance of the works is not difficult.
- Limitation: The drainages may require flexible functions to follow the movement of the ground surface due to landslide activities. Otherwise the drainages are damaged by the ground moving, and then the water penetrates into landslides from the damaged points.
- Feasibility: It is feasible in Bhutan; the contractors are able to carry out this work excluding the use of special materials such as a corrugated steel pipe for the ditch construction.

Open-Blind Ditch

- Purpose: To collect and properly discharge the surface waters and shallow groundwater in landslide areas
- Availability: In case the groundwater levels are shallower in landslide areas, the works are effective in draining the groundwater and surface water.
- Limitation: If the groundwater levels are deeper than 2m from the ground surface, the blind ditch (conduit) parts do not function.
- Feasibility: It is feasible in Bhutan; if the contractors are able to carry out this work excluding the use of special materials such as corrugated steel pipes required for the surface ditch parts.

Earth Removal

- Purpose: To reduce the sliding force of landslides by removing the head part of landslide blocks
- Availability: This is one of the simplest countermeasure works for landslides. The works can be expected to have a direct effect on stability of landslides. This method can be used as an emergency countermeasure works.
- Limitation: Depending on the shape of slip surfaces, the works may not contribute to making stable conditions on the slopes
- Feasibility: It is feasible in Bhutan; any local contractor can carry out the works

<u>Counterweight Fill</u>

Purpose: To increase the resisting force against the sliding force of landslides.

Availability: This is one of the simplest countermeasure works for landslides. The works can be expected to have a direct effect on stability of landslides. This method can be used as an emergency countermeasure works.

Limitation: Depending on the locations of fills (embankments) on the slopes, the works may not contribute to making stable conditions on the slopes.

Feasibility: It is feasible in Bhutan; any local contractor is able to carry out the works

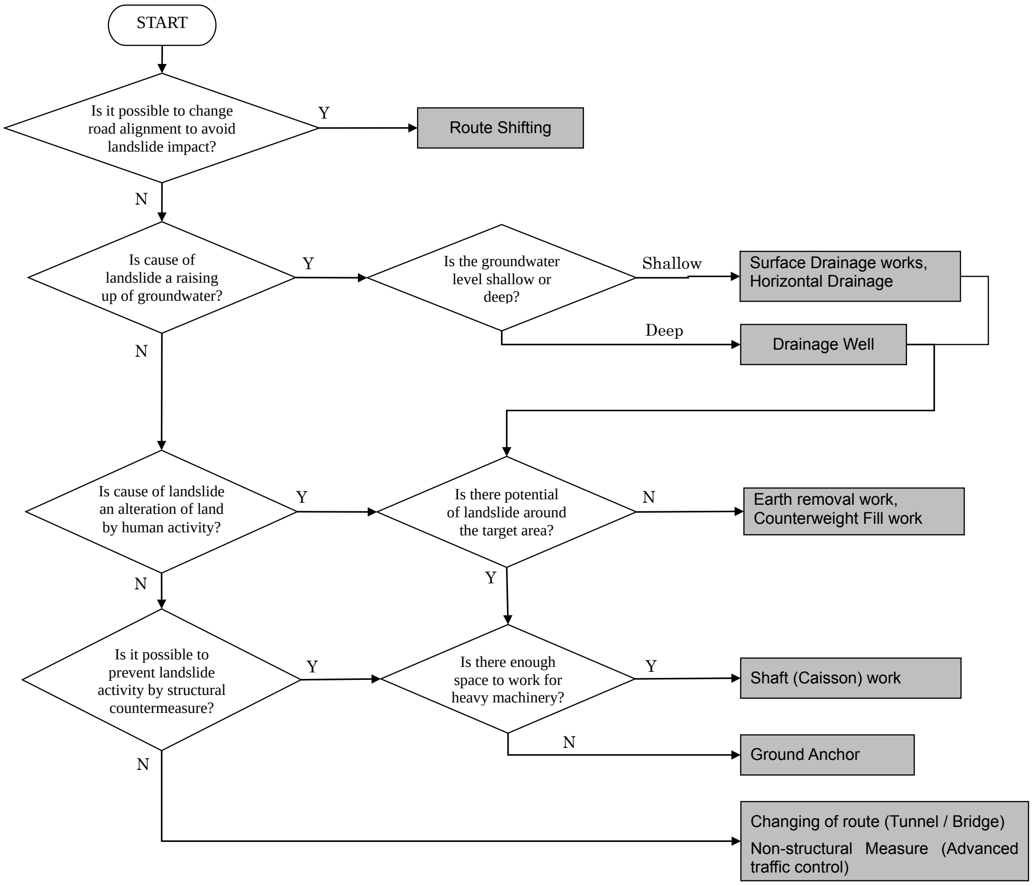


Figure 2.4.3 Flowchart to Select the Countermeasures for Landslide (Source: JET)

b.2 Debris Slope Failure

<u>Surface Drainage</u>

Purpose: To collect surface water and to properly drain it out of landslide areas

Availability: This is one of the simplest countermeasure works for landslides. The work can be expected to avert infiltration of rainfall into the slopes. Generally, maintenance of the works is not difficult.

Limitation: Nothing special

Feasibility: It is feasible in Bhutan; any local contractor is able to carry out the works. This method is one of the common slope countermeasure works in Bhutan.

<u>Re-vegetation</u>

Purpose: To support stability of a slope surface.

Availability: Re-vegetation can be recommended to apply to all cut slopes if possible.

Advantages of the works are as follows:

- Lower cost
- Easy to implement
- Good for the environment and landscapes

Limitation: Good effects are not expected on loose conditions of slope surfaces. If the work is adopted on loose surface slopes, wicker fences or crib works shall be combined with the works to keep the plants on the slopes

Feasibility: It is feasible in Bhutan; any contractor can carry out the works. This method is one of the common slope countermeasure works in Bhutan.

Wicker Fence

Purpose: To maintain stability of slope surfaces until plants grow from the re-vegetation works

Availability: This method can be adopted on loose surface slopes to keep the materials of slope surfaces. The fences can be made by wood and wooden branches. No machinery is required to implement this work.

Limitation: This method is difficult to adopt on hard rock slopes.

Feasibility: It is feasible in Bhutan; any contractor can carry out the works.

Wooden Log Crib

Purpose: To keep stability of a slope surface until plants grow from the re-vegetation work

Availability: This method has almost the same function as a wicker fence. The main materials for this work are wood and stone.

Limitation: This method is difficult to adopt on hard rock slopes.

Feasibility: It is feasible in Bhutan; any contractor can carry out the works.

Stone Pitching

Purpose: To avert erosion of slope surfaces and to keep the stability of slope surfaces

Availability: This method can have a good effect for slopes, especially sediments and weathered rock slopes. This method is designed to avert erosion and weathering on the surface of slopes. Required materials for these works are boulder and concrete.

Limitation: The stone pitching wall shall not be expected to function as support for slope stability as the retaining wall does. The wall shall not be adopted on a slope which has a lot of water seepage without any drainage work for the water.

Feasibility: It is feasible in Bhutan; any contractor can carry out this work. This method is one of the common slope countermeasure works in Bhutan.

Retaining Wall

Purpose: To support stability of slope surfaces and avoid erosion of slope surfaces

Availability: This method can be adopted in case slopes cannot be secured with the appropriate/standard angle due to the limitations of the site or topography. This method can be applied to various slope conditions such as slopes with earth pressure or failure-prone slopes from water seepage.

Limitation: This method shall not be installed at the slopes where excavation is being carried out for installation of the walls; it makes slope conditions unstable.

Feasibility: It is feasible in Bhutan; any contractor can carry out this work. This method is one of the common slope countermeasure works in Bhutan, especially

Gabion and Masonry walls

<u>Barrier Wall</u>

Purpose: To avert failed debris or fallen rocks from reaching the road

Availability: If the countermeasure works are difficult to apply on the slopes directly, this method can be installed as a prevention measure.

Limitation: Sufficient space to catch failed debris or rocks shall be required between the slope and wall

Feasibility: This method is one of the common slope countermeasure works in Bhutan, especially Gabion and Masonry walls

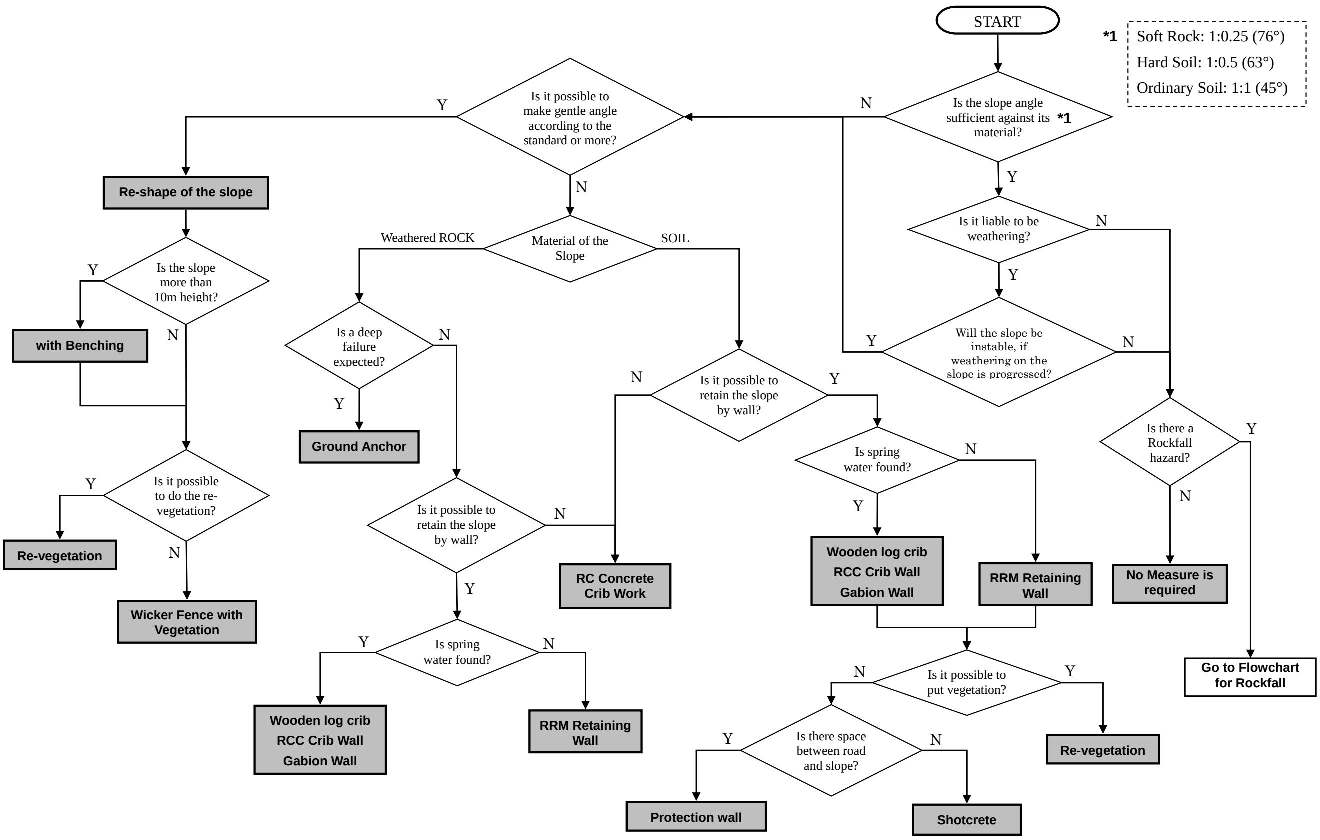


Figure 2.4.4 Flowchart to Select the Countermeasures for Debris Slope Failure
(Source: Public Works Research Institute in Japan 2004*4-alteration partially)

b.3 Rock Slope Failure

<u>Rock Removal</u>

Purpose: To remove problematic parts or unstable rocks on slopes

Availability: This method has a direct effect on hazards of rock slope failures or rockfalls. This method shall be the first option to consider for rock slope failure measures.

Limitation: The following slope conditions may not be good for implementation of this method.

- Hard and massive rocks
- Steep / overhanging slopes

- No access for the machinery for excavation

Feasibility: The work is feasible in Bhutan depending on site conditions. Knowledge and experience for the works on steep slopes are required.

Retaining Wall

Purpose: To support stability of slopes and avert erosion and weathering of slope surfaces

Availability: This method can be adopted if the slopes cannot be secured at an appropriate/standard angle due to limitations of site or topography. This method can be applied to various slope conditions such as failure-prone slopes from water seepage.

Limitation: This method shall not be installed at the slopes where excavation is being carried out for installations of the walls; it makes the condition of the slopes unstable.

Feasibility: It is feasible in Bhutan; any contractor can carry out this work. This method is one of the common slope countermeasure works in Bhutan, especially Gabion and Masonry walls.

Barrier Wall

Purpose: To avert fallen rocks from reaching the road

Availability: In case other countermeasure works are difficult to apply on the slopes directly as with rock removal or protection rock net, this method can be installed as a prevention measure.

Limitation: Sufficient space to catch failed debris or rocks shall be required between the slope and the wall.

Feasibility: This method is one of the common slope countermeasure works in Bhutan, especially Gabion and Masonry walls.

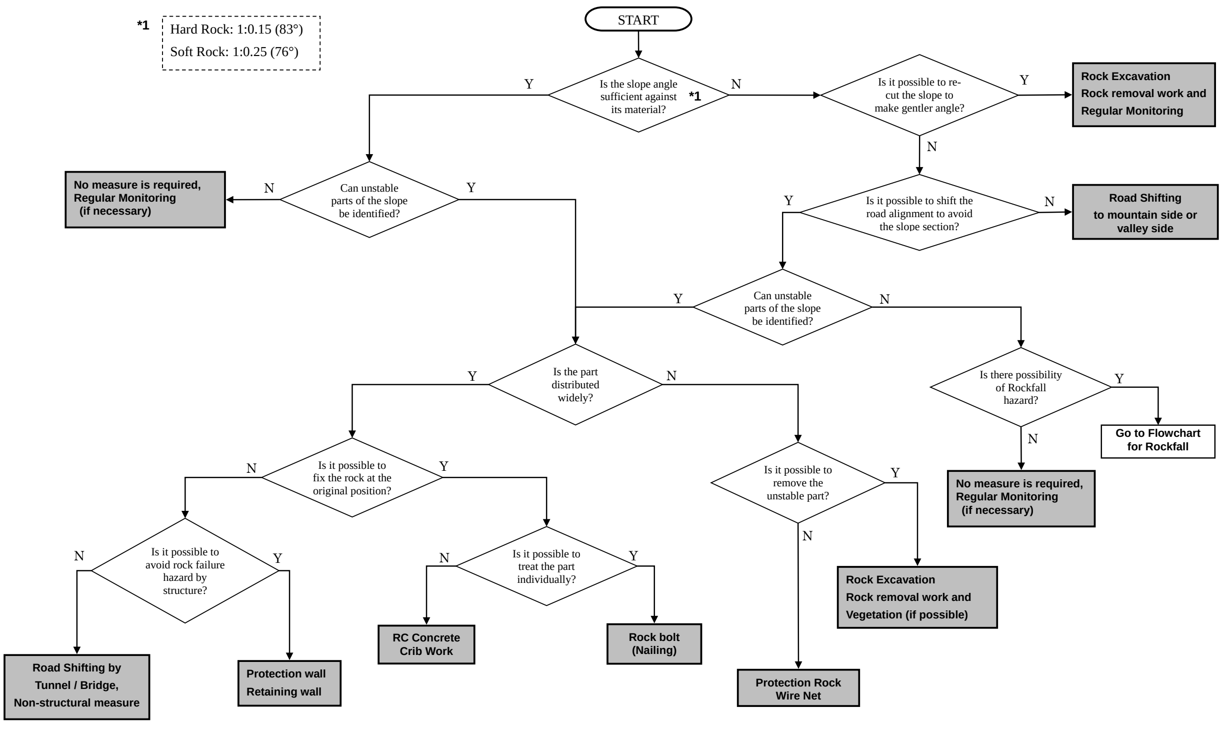


Figure 2.4.5 Flowchart to Select the Countermeasure for Rock Slope Failure (Source: JET)

b.4 Debris Flow

Generally, countermeasure work for debris flow is difficult to apply due to high costs, large scale demands, and high environmental impacts. Therefore, regarding roads, debris flow countermeasures shall apply culverts or preferentially change the route.

Culvert/Bridge

Purpose: To make flowing debris pass under the road
Availability: The work can be adapted in various conditions of water streams.
Limitation: Large size boulders or large amounts of debris surpassing the dimension of water stream are expected to flow down.
Feasibility: The work is a common facility in Bhutan.

Check Dam (Small scale)

Purpose: To break the speed of debris or water flow, and to catch some debris, boulders or wood debris from trees flowing in the river.
Availability: This method can be applied on small tributary valleys or gullies as well. This method can be adopted on various gradients of valleys.
Limitation: The dam may not work properly on valleys where a lot of debris is deposited.
Feasibility: It is feasible for Bhutan, especially if it is made by Gabion and Masonry walls.

Buffer Forest

Purpose: To reduce energy of debris flows
Availability: This method can be adopted on gentle ground.
Advantages of this method are as follows:
- Lower cost and easy to implement
- Good for the environment and landscape

Limitation: This method cannot be adopted in the following cases:
- Steep slopes
- Rocky slopes

Feasibility: It is feasible for Bhutan.

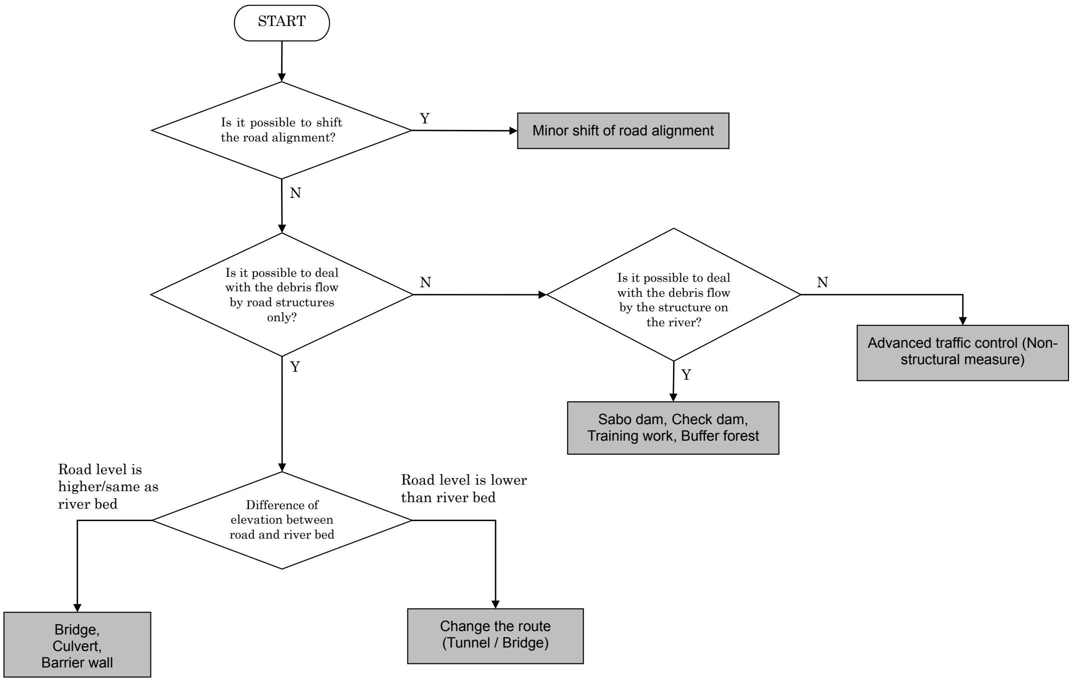


Figure 2.4.6 Flowchart to Select the Countermeasure for Debris Flow
(Source: Public Works Research Institute in Japan 2004*4^-Modfied^)

b.5 Rockfall

<u>Rock Removal</u>

Purpose: To remove unstable rocks on slopes

Availability: This method has a direct effect on the hazard of rockfalls. This method shall be the first option to consider for rockfall measures.

Limitation: The following slope conditions may not be good for the implementation of this method:
- The place is too high to operate on.
- No access for the machinery for excavation.

Feasibility: The work is feasible in Bhutan depending on site conditions. Knowledge and experience for the work on steep slopes are required.

<u>Protection Wall</u>

Purpose: To avert fallen rocks from reaching the road

Availability: If the countermeasure works are difficult to apply on the slope directly as with rock removal or protection rock net, this method can be installed as a prevention measure.

Limitation: Sufficient space to catch failed (falling) debris or rocks shall be required between the slopes and the walls.

Feasibility: This method is one of the common slope countermeasure works in Bhutan, especially Gabion and Masonry walls.

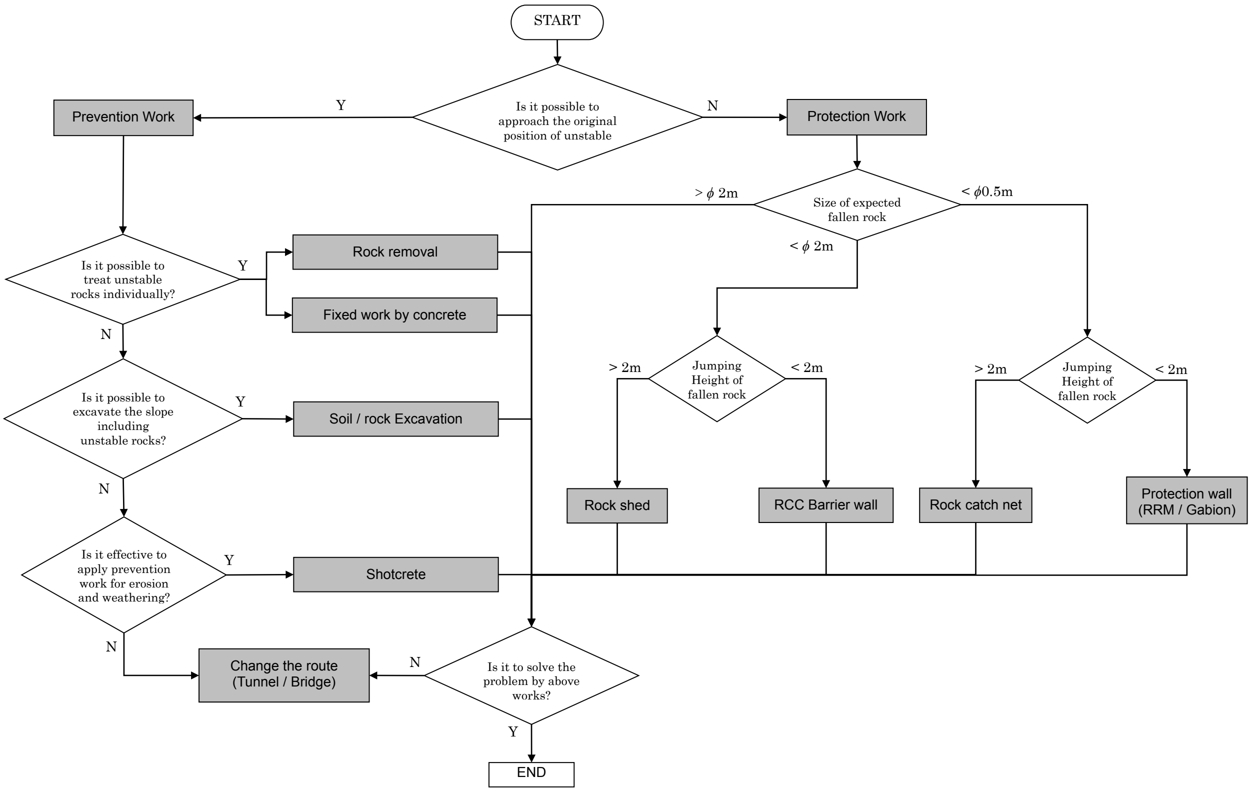


Figure 2.4.7 Flowchart to Select the Countermeasure for Rockfall
(Source: Public Works Research Institute in Japan 2004*4[-alteration partially])

Countermeasures for rockfalls can be divided into prevention works and protection works. Prevention works are applied to treat an original position of unstable rock. Protection works are applied to mitigate damage by falling rocks.

In the slope inspections and the regular checks, proposed countermeasure works for hazardous slopes have been selected using the standard countermeasure catalog and flowchart to select countermeasure works for each disaster.

2.4.3 Non-Structural Measure

The non-structural measure is applied in case it is difficult to apply structural measures, such as in the following conditions:

- The cost that a proposed structural countermeasure work requires is too high.
- A proposed structural countermeasure work requires too much volume and time for construction.
- Cost-effectiveness of a proposed structural countermeasure work is extremely low.
- The road safety may not be secured from estimated disaster on a target hazardous slope by the standard countermeasure works.

Features of some non-structural measures for road slope disaster are mentioned below.

a. Early Warning System (Traffic Control System)

The purpose of the system is not to stop or control disaster, but to mitigate/prevent damage of road users from disasters. The system is managed by monitoring instruments installed at hazardous slope/road section(s). When a sign of disaster is detected, the road authority issues a warning to compel road users or neighbors to evacuate before a disaster occurs, and it (road authority) controls the traffic of hazardous slope/road section(s).

For applying the system, the threshold to control traffic shall be determined. The threshold shall be determined in consideration of the particular condition of the target site. Therefore, the threshold shall be different in each site.

As a case example, the early warning system for roads in Japan is mentioned below.

The advance traffic control system is one of the early warning systems for roads in Japan. The concept of the advance traffic control is to secure the safety of road users by temporary road closure in advance of the occurrence of serious slope disasters. Therefore, there may be cases when roads are closed by the advance traffic control system even though no slope disaster occurred. The traffic control shall be applied for specific road sections which are evaluated as high potential of serious slope disasters. Serious slope disaster entails roads will be completely damaged or disaster involving loss of life. The target road section shall be selected based on the past experience of disasters or result of the regular slope inspection. The criteria (threshold) of the traffic control to close/ open the road shall be based on precipitation. In other words, the criteria of the traffic control shall be decided according to the history of rainfall condition on/near the target road section.

The schematic flow of the advance traffic control system is shown in Figure 2.4.8 below.

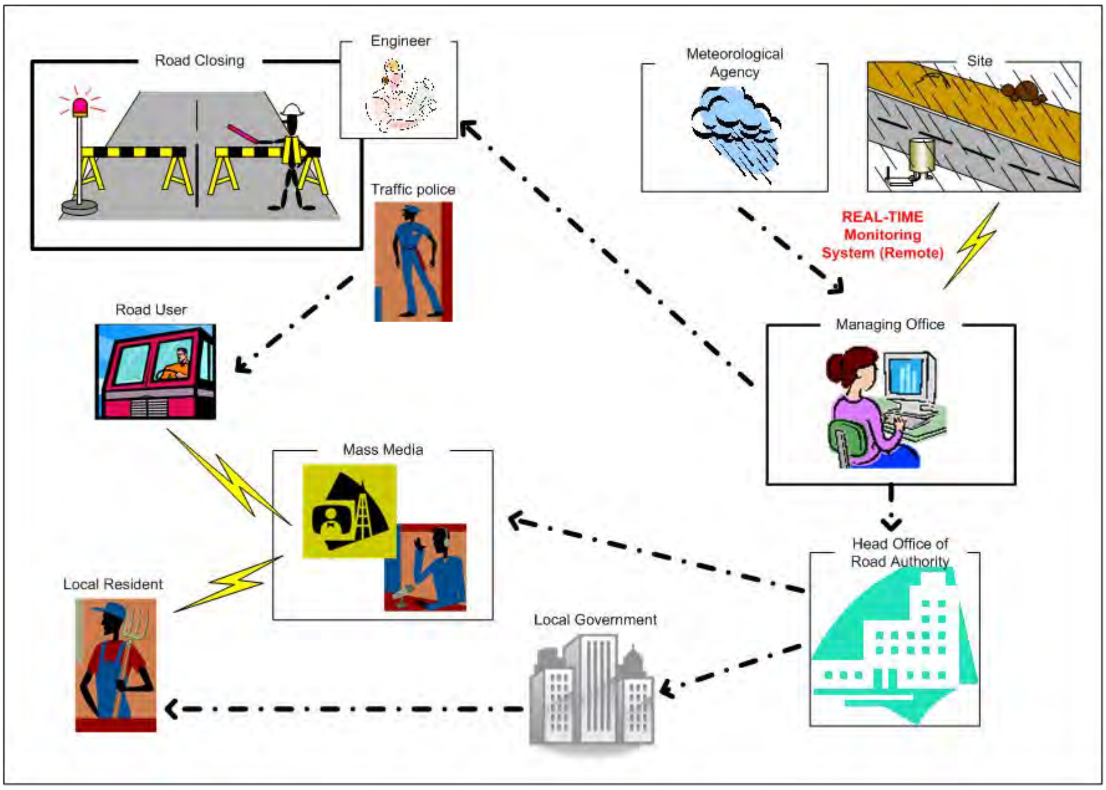
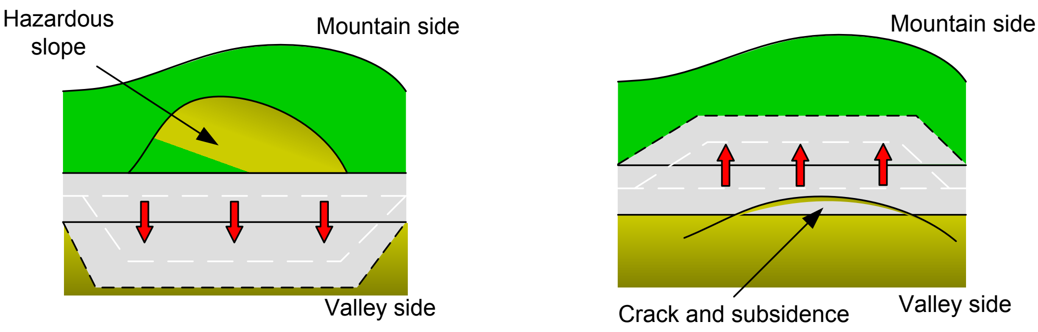


Figure 2.4.8 Schematic Flowchart of the Advance Traffic Control in Japan (Source: JET)

In case of the advance traffic control system, precipitation is applied as a threshold of the system. However, other monitoring devices can be applied as a threshold to traffic control or evacuation of people in the hazard area. The monitoring device for threshold shall be selected carefully in consideration of estimated type of disaster, mechanism of failure and trend of disaster based on past experiences.

b. Road Alignment Changing/Shifting

In case it is technically or economically difficult to deal with hazardous road section(s) by structural countermeasure work, road alignment changing/shifting can be one of the measures to avoid the disaster. If the target road section is not a long stretch, minor road shifting can be applied to shift road alignment to the opposite side of hazardous slope (refer to Figure 2.4.9).



Filling to expand road width and shifting road alignment

Excavation to expand road width and shifting road alignment

Figure 2.4.9 Schematic Drawings of Examples of Minor Shifting of Road Alignment (Source: JET)

In case the hazardous road section is a long stretch, it can be skipped by tunnel or bridge.

Site conditions, especially topography, are one of the essential factors of planning a tunnel or bridge. Additionally, not only natural conditions, but social and environmental impacts by the tunnel or bridge construction shall be considered at the planning stage.

Figure 2.4.10 Case Example of Road Alignment Change due to Slope Disaster in Japan (Source: JET, base map is Google Earth)

c. Sign Board to Warn Road Users of a Hazard

It is a fundamental measure for road disaster. It can be applied with a structural or other non-structural measure.

Figure 2.4.11 Photo of Sign Board to Notify a Landslide Zone (Source: JET)

Figure 2.4.12 Photo of the Sign on Road to Notify Corrugated Road Surface on Ahead (Source: JET)

2.5 Manual of Topographic Analysis

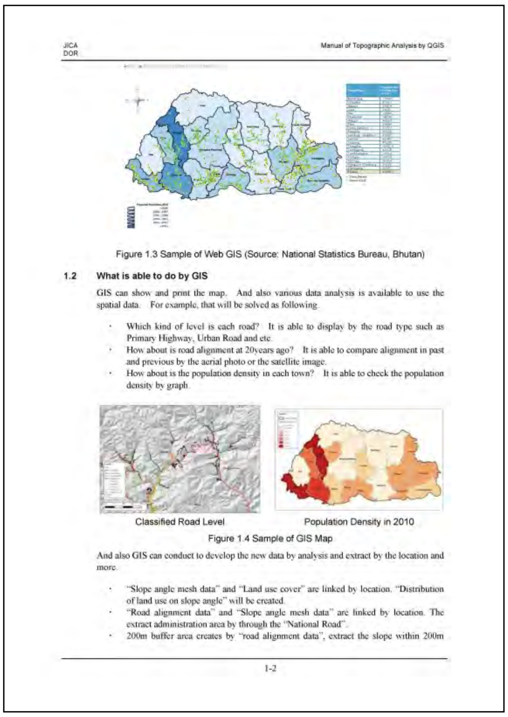
In this Project, inspections of the slopes are carried out based on the information such as topography and disaster history, and to create the regular check sheet on the study area. Regarding topographic information, satellite elevation data (PRISM-DSM: Panchromatic Remote-sensing Instrument for Stereo Mapping - Digital Surface Model, 10 m resolution) which have been provided from the Science and Technology Research Partnership for Sustainable Developments (SATREPS) project for “Glacier Lake Outburst Floods (GLOFs) in the Bhutan Himalayas (2008–2010)” has been used for the surveys and the slope inspection sheet because the existing topographic information in Bhutan was only a topographic map (scale of 50,000).

Furthermore, DoR does not have a recent road map based on its own data such as road alignment, result of measurement surveys, and open data sources from each relevant organization (such as satellite images, settlements, health centers and river catchments). DoR and the regional office do not have a road base map for reference of construction and planning. Generally, development of this kind of map is used in GIS software. However, under the current conditions, DoR does not have members who have an experience of using GIS software and map-designing. Therefore, DoR should be required to improve the minimum amount of skills for topographical data processing and analysis in order to implement surveys, continuously update the slope inspection sheet, and design countermeasures.

The Project provides a manual for topographic analysis and map-designing by using GIS software. As a result of the discussions with DoR, the format and contents of the user manual are focused on the method of analysis and tools of the GIS software. Regarding the selection of GIS software, DoR has been provided an official ArcGIS (ESRI) license from MoWHS, however the quantity of licenses is limited. Hence the manual was prepared using QGIS, which is a free and open source software, in order to promote data sharing and utilization by relevant people. The table of contents of the manual is shown in Table 2.5.1, and technical transfer has been carried out through the OJT.

Table 2.5.1 Contents of Topographic Analysis Manual (Source: JET)

Chapter	Title	Description
1	Basic Knowledge of GIS	・ What is GIS? ・ What can we do with GIS? ・ What is QGIS? ・ Advantage of QGIS ・ Supported Data Formats ・ Data Format of QGIS ・ Coordination System ・ Technical Word of GIS
2	Setting of QGIS	・ Download ・ Installation ・ Initial Setting ・ Toolbar Setting ・ Basic Operation
3	Creation of Thematic Map	・ Working with Projections ・ Preparation of Background Map ・ Working with Vector Data ・ Working with Raster Data ・ Working with GPS Data ・ Layer Management
4	Editing Data	・ Joining of Attribute Table ・ Data Selection ・ Editing of Attribute Table ・ Measurement of Distance and Area ・ Feature Identification
5	Print Composer	・ Print Composer ・ Add Map ・ Add Items ・ Print ・ Print Setting ・ Exporting to File ・ Exporting as Map Atlas



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Manual of Topographic Analysis by QGIS

Figure 1.3 Sample of Web GIS (Source: National Statistics Bureau, Bhutan)

1.2 What is able to do by GIS

GIS can show and print the map. And also various data analysis is available to use the spatial data. For example, that will be solved as following.

- Which kind of level is each road? It is able to display by the road type such as Primary Highway, Urban Road and etc.
- How about is road alignment at 20years ago? It is able to compare alignment in past and previous by the aerial photo or the satellite image.
- How about is the population density in each town? It is able to check the population density by graph.

Classified Road Level

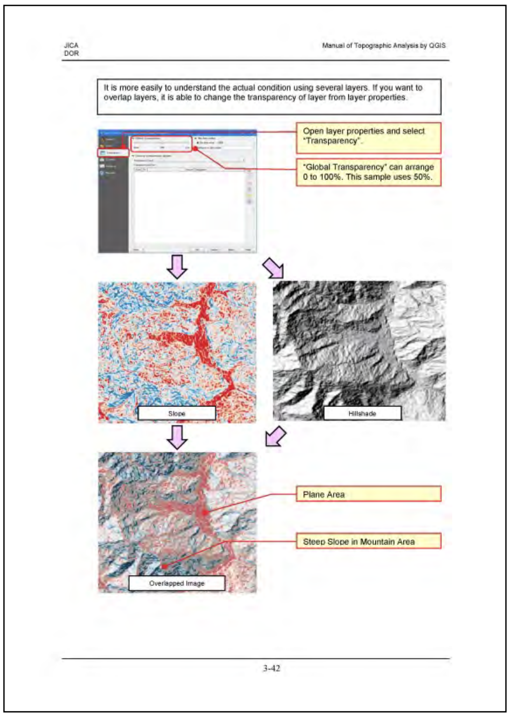
Population Density in 2010

Figure 1.4 Sample of GIS Map

And also GIS can conduct to develop the new data by analysis and extract by the location and more.

- "Slope angle mesh data" and "Land use cover" are linked by location. "Distribution of land use on slope angle" will be created.
- "Road alignment data" and "Slope angle mesh data" are linked by location. The extract administration area by through the "National Road".
- 200m buffer area creates by "road alignment data", extract the slope within 200m

1-2



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It is more easily to understand the actual condition using several layers. If you want to overlap layers, it is able to change the transparency of layer from layer properties.

3-42

Figure 2.5.1 Sample of the Topographic Analysis Manual (Source: JET)

(Reference)

*1 Cruden D. M., A Simple Definition of a Landslide. Bulletin of the International Association of Engineering Geology, No. 43, pp. 27-29, 1991

*2 Varnes D. J., Slope movement types and processes. In: Schuster R. L. & Krizek R. J. Ed., Landslides, Analysis and Control. Transportation Research Board Sp. Rep. No. 176, Nat. Acad. oi Sciences, pp. 11–33, 1978

*3 Cruden D. M. and Varnes D. J., Landslide Types and Processes, in Turner, A. K., and R.L. Schuster, Landslides: Investigation and Mitigation, Transportation Research Board Special Report 247, National Research Council, Washington, D.C.: National Academy Press, 1996

*4 Public Works Research Institute in Japan, Manual for Highway Earthworks in Japan, 2004

Chapter 3

Slope Inspection on Road

3 Slope Inspection on Road

3.1 Data/information Collection

The slope inspection work on the roads in Bhutan is one of the main purposes of this Project. A clear understanding of natural and social conditions in Bhutan is needed. The data of these conditions are shown below.

3.1.1 General Introduction

Bhutan is situated between the Tibetan plateau to the north and the Indian plain to the south, and is a small landlocked rocky country with a population of 733,004[*1], and a geographic area of approx. 40,000 km^2. The country is almost entirely mountainous dissected by an intricate system of several rivers, rivulets, and streams with nearly 95 percent of the country being above 600 meters altitude[*2] as shown in Table 3.1.1.

Table 3.1.1 Ratio of the Altitudes Classification in Bhutan
(Source: Ministry of Agriculture[*2])

Altitude (m)	0-600	600-1,200	1,200-1,800	1,800-2,400	2,400-3,000	3,000-3,600
Ratio (%)	5.3	9.8	12.6	13.4	14.3	13.2
Altitude (m)	3,600-4,200	4,200-4,800	4,800-5,400	5,400-6,000	6,000-6,600	> 6,600
Ratio (%)	10.9	9.9	6.8	2.7	0.9	0.2

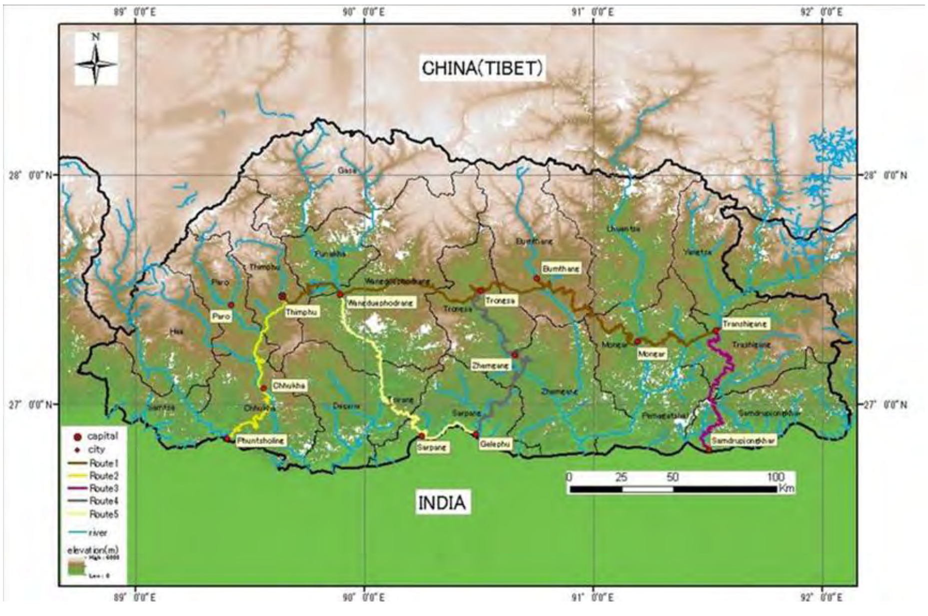


Figure 3.1.1 Road Network and Altitude Information in Bhutan (Source: JET)

a. Land Use

Land use is characterized as shown in Table 3.1.2. Forests are the dominant land cover, and occupy 72.5 % of the total land. A lot of people are living in the low land area in the south part of Bhutan including Samtse, Chhuka, Sarpang, and Samdrup Jongkhar as shown in Figure 3.1.2, and the population distribution is correlated with the altitude of the land.

Table 3.1.2 Ratio of the Land Use Classification in Bhutan
(Source: Ministry of Agriculture[*2])

Item	Forest	Agriculture	Pasture	Horticulture	Settlement	Others*	Total
Area(km^2)	29,045	3,088	1,564	58	31	6,289	40,075
Ratio (%)	72.5	7.7	3.9	0.1	0.1	15.7	100

*Note: Others; Snow/Glaciers (2,989km^2(7.5%)), Rock Outcrops (2,008km^2(5.0%)), Water Spread (304 km^2 (0.8%)), Marshy areas (35km^2(0.1%)), Land slip/Erosion area (954km^2 (2.4%)) (referred to Appendix 6)

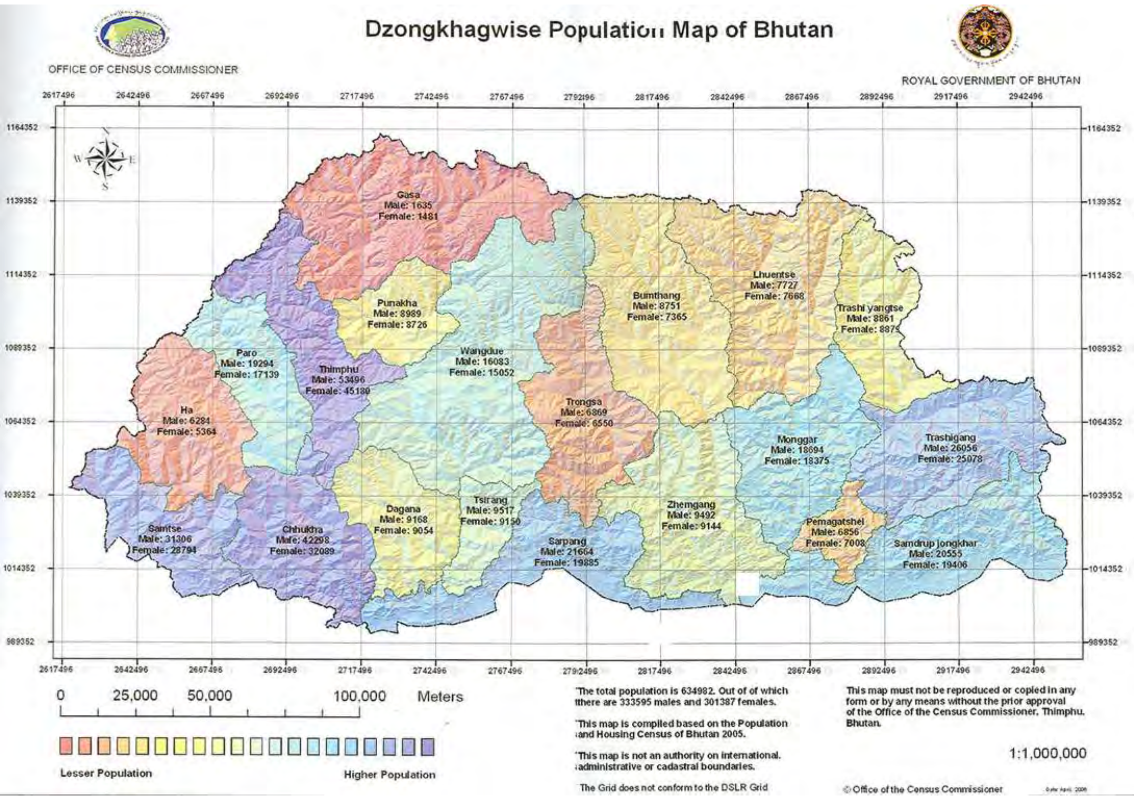


Figure 3.1.2 Population of Classification by 20 Areas (Dzongkhag)
(Source: National Statistics Bureau[*1])

b. Road Network

The major highway network in Bhutan consists of five (5) national highways as shown on Figure 3.1.1. The national highway route 1 is transversally crossing the country in a direction of east and west for approx.400km. The other National Highways Route 2, Route 3, Route 4, and Route 5 are advancing southwards to the border with India.

c. National Protection Area

Natural environment in Bhutan is exceptionally rich and has stunning biodiversity at the ecosystem. As shown in Figure 3.1.3, there are five (5) national parks (Jigme Dorji National Park, Thrumseng la National Park, Jigme Singye Wangchuck National Park, and Royal Manas National Park), few wildlife sanctuaries and biological corridors in Bhutan. And these are specified as the important protected area, any development actions including construction works in the national protected areas are strictly regulated for the protection of precious natural resources as environmental and social consideration.

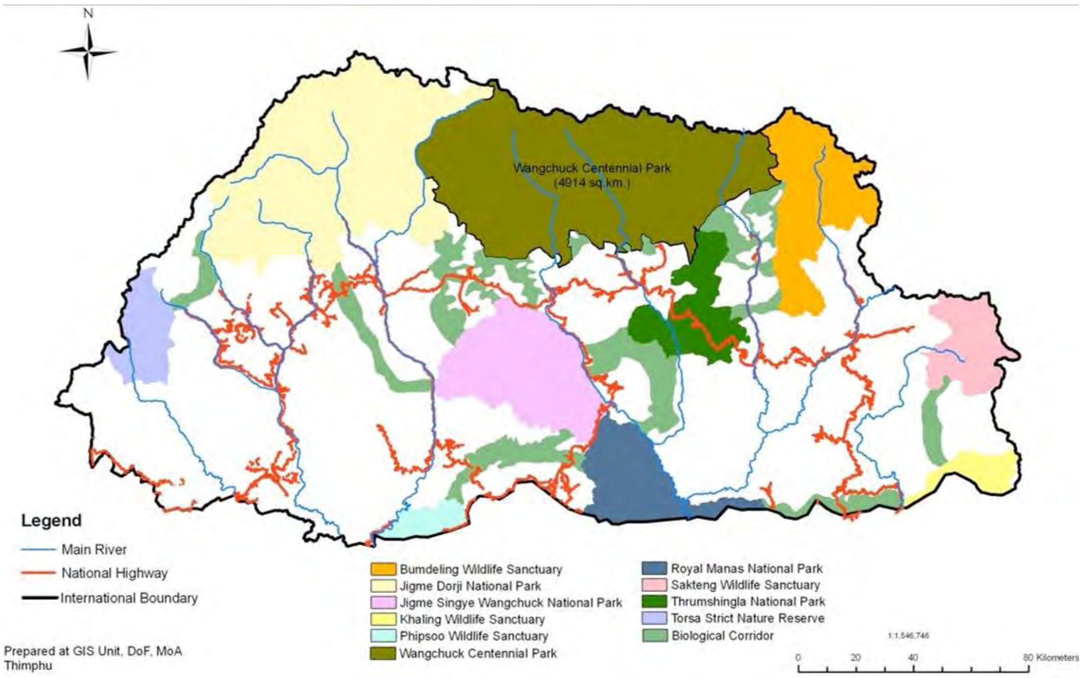


Figure 3.1.3 Map on Bhutan Protection Area and Biological Corridors of Bhutan

(Source: WWF Bhutan[*3])

3.1.2 Topography

The geomorphic features in Bhutan are characterized by the abrupt rise of the topography from the Indian flood plain to Himalayan Mountains.

70 million years ago, during the Cretaceous period, the Tethys Sea covered the area where the Himalayas are found in the recent times. The Asian continent is to the north of the Tethys Sea and the Indian Continent is to the south of this sea. During the Tertiary period, more than 10 million years ago, tectonic movements pressed the Indian Plateau against the Asian, and the Himalayans range was erected. The way which the Himalayans were created explains the topography and geology of Bhutan today. The V-shaped valleys and U-shaped glacial valleys, which were formed by the erosion of rivers and streams, between the high mountain ranges and the high altitudes in the north to the plains in the south (referred as Figure 3.1.3). Within a short south-north distance of some 170km, the altitude declines from approximately 7500m to only approximately 200m above sea level as described in Figure 3.1.1 and Figure 3.1.4

In addition, the height difference is extreme from the mountain ridges and the knick lines to river valleys. The very steep slopes are reached from the rivers to the knick lines as described in Figure 3.1.5.

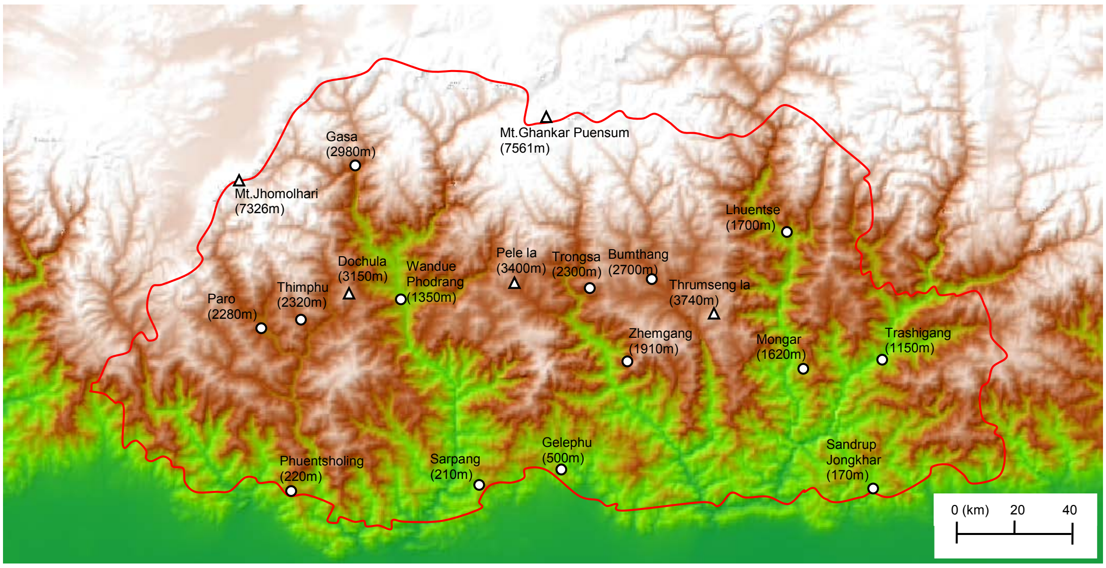


Figure 3.1.4 Topographic Map in Bhutan (Source: JET)

Figure 3.1.5 Sample Image of 3D-Topography around Trongsa Town (Source: JET)

3.1.3 History Information of Slope Disaster

A questionnaire research to collect the past information of road slope disaster was implemented, and road slope disaster information collected in region office was compiled as shown in Table 3.1.3 and Figure 3.1.6. The number of the collecting disaster information is only 45 slopes (referred to Appendix), and there is almost no practice to collect all of the road slope disaster information in Bhutan. If there is new some additional information, it shall be revised.

Table 3.1.3 Number of Slope Disaster Historical Information Reported by Bhutan Regional Offices (Source: JET and DoR)

Regional Office	Number
Lingmethang office, Mongar	1
Sarpang office, Gelephu	7
Trongsa office	2
Phuentsholing office, Chhuka	7
Samdrup Jongkhar office	14
Tingtibi office, Zhemgang	5
Lobeysa office, Phunaka	9
Total	45

Figure 3.1.6 Procuring Archival History of Slope Disaster in Bhutan
(Source: JET and DoR)

3.1.4 Countermeasure Situation against Slope Disaster

In Bhutan, countermeasures such as mortar masonry and gabion retaining wall are being covered in some vulnerable road slopes. However, the numbers of such countermeasures are not so many. In majority, there are no countermeasure facilities against road slope failures. Therefore, there is an exceptionally high incidence of rock falls and debris derived from the road slopes.

The locations and types of countermeasure facilities have been inspected with the pocket GPS by DoR regional engineers throughout Bhutan. The results for the countermeasures situation are described on the inspection sheets of the slope inventory.

	
Mortar Masonry Retaining Wall	**Box Culvert**
	
Gabion Wall	**Stone Masonry Wall**

Figure 3.1.7 Photos of Countermeasure Situation in Bhutan (Source: JET)

3.2 Selection of Survey Sections

3.2.1 National Highways

Survey sections for this project have been selected considering many aspects such as natural, social as well as economical influences in each stage of the screening. The country has steep mountainous topography with significant geomorphological and geological constraints. The population of the country lives mainly in rural areas, although people are moving toward urban areas increasing the transportation of materials resources are and others, therefore the importance of road transportation is increasing recently. National highways are most important for the country and they are described as follows:

National Highway Route 1

This route is the most important east-west cross road in Bhutan, therefore it is called as the primary national route (Thimphu - Wangdue Phodrang - Trongsa - Mongar - Trashigang). Traffic volume of the section in the eastern part of Trongsa is less than that of the section between Thimphu and Trongsa.

National Highway Route 2

This route is the main traffic route to India (Thimphu - Chukha - Phuentsholing) and is named as Asian Highway 48. National Highway Route 2 will be reserved for upcoming southern east-west highway, which is presently under construction in stretches.

National Highway Route 3

This route is the national highway leading to India (Trashigang - Samdrup Jongkhar). The maintenance works have been delayed.

National Highway Route 4

Although it is the national highway leading to India, the construction of the road is particularly delayed, and large-scale slope failures occurred frequently.

National Highway Route 5

This route is to India (Wangdue Phodrang - Damphu - Sarpang - Geylegphug). Construction of the road is being carried out along with hydroelectric power projects along the road.

3.2.2 Survey Sections

Five sections of the National Highway Route 1, Route 4 and Route 5 are selected considering the natural, social as well as economic influences and constraints in the preliminary stage of the screening. The road sections of around 140 km in total length are proposed for the survey sections in the preliminary stage and they are shown in Table 3.1.1 and Figure 3.2.1.

Table 3.2.1 List of Survey Sections (Source: JET)

	Route	Distance	Coordinate	
			Start point	End point
Section I	NHR .1	16.3km	N 27° 29' 58.34" E 90° 04' 03.44"	N 27° 32' 43.87" E 90° 08' 59.59"
Section II	NHR.1&4	44.2km	N 27° 27' 15.48" E 90° 23' 22.59"	N 27° 27' 46.48" E 90° 30' 03.37"
Section III	NHR .4	13.8km	N 27° 16' 54.56" E 90° 37' 15.57"	N 27° 13' 35.10" E 90° 37' 28.70"
Section IV	NHR .4	53.0km	N 27° 04' 22.77" E 90° 38' 23.46"	N 26° 56' 06.05" E 90° 30' 34.27"
Section V	NHR .5	13.7km	N 27° 06' 48.35" E 90° 04' 18.77"	N 27° 01' 37.09" E 90° 04' 32.38"

NHR: National Highway Route

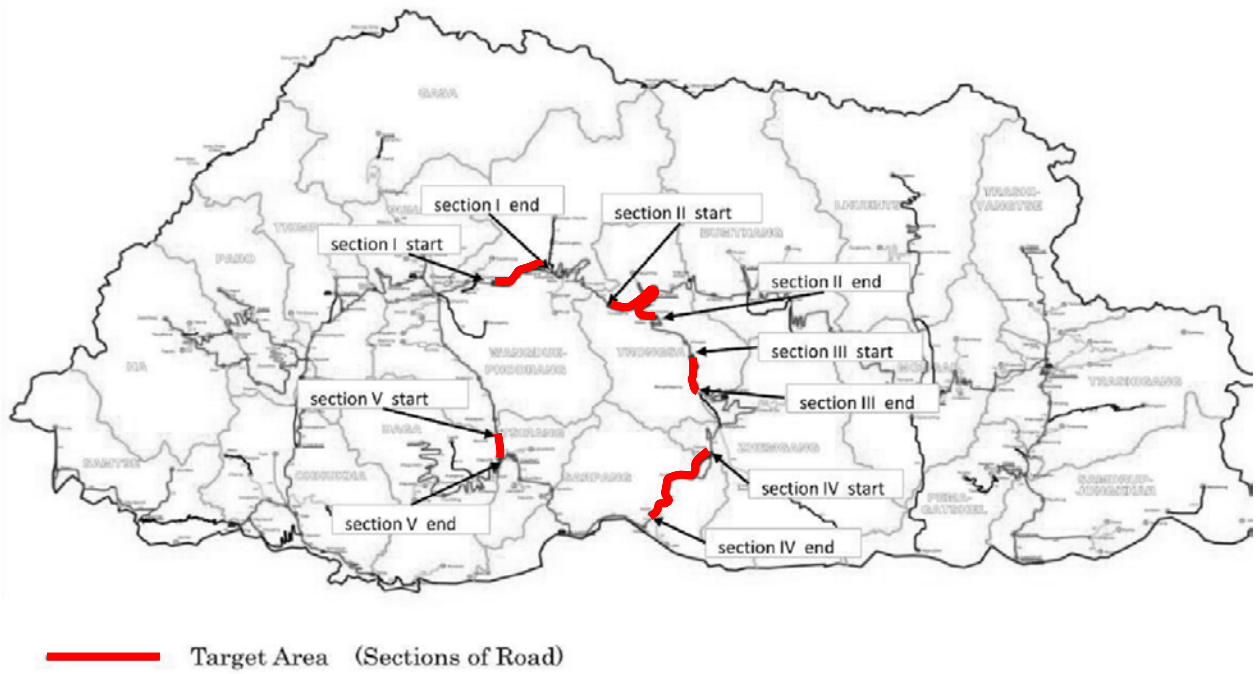


Figure 3.2.1 Location of Survey Sections (Source: JET)

3.3 Screening

3.3.1 Desktop Screening

The screening for the slope inspections was conducted on the five (5) survey sections which were selected on the Chapter 3.2 as discussed above.

The desktop screening as shown in was carried out by using the satellite image namely ALOS (2.5m grid) which was provided in the Project by JST/JICA, and the high resolution satellite images (refer to Table 3.3.1) which can be obtained in Japan.

After the study in the primary screening about the rough condition and scale of the selected survey sections to refine the candidate sites for the slope inspections, the refined candidate slopes are studied by using more detail data and information in the secondary screening.

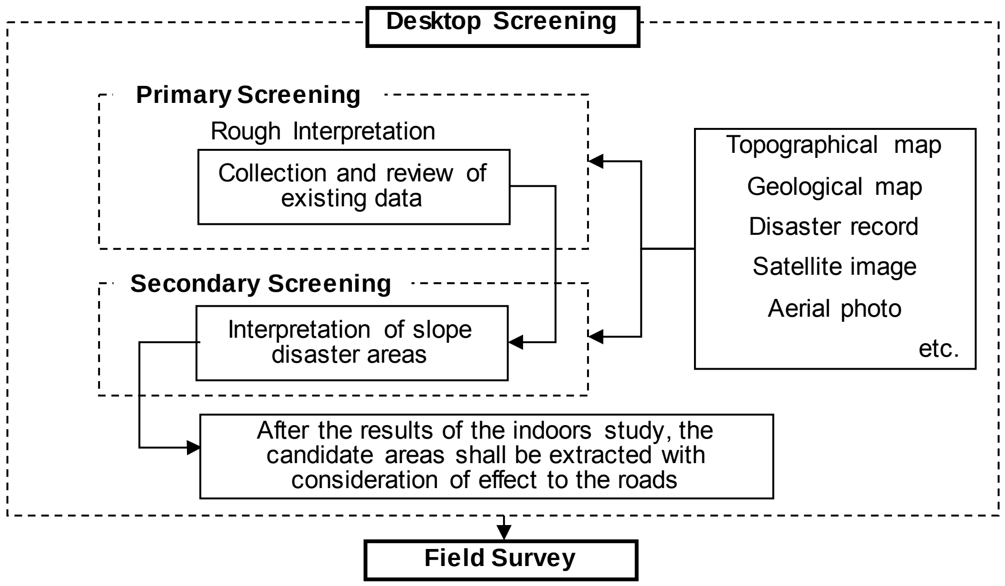


Figure 3.3.1 Workflow of Desktop Screening (Source: JET)

a. Primary Screening

The data and information for the Primary screening are as follows:

- Topographical map 1/50,000 (Hard copy)
- ALOS satellite image (Ortho-photo by Department of Geology and Mine (DGM))
- Satellite image (Google Earth)

The following points for the primary screening are studied.

- The starting points and end points of the survey sections are the cross points of the roads and valleys.
- Condition of land usage
- Presence of collapsed slopes

- Presence of topography of large scale of landslides
- Condition of the slopes (plain lands or slope lands)
- Contribution of river system

As a result of the primary screening, the selected survey sections were evaluated as the sections are appropriate for the slope inspection because the sections pass through the mountainous/hilly areas and even topographical features of large scale landslides were not found.

The map of Section 1 which was prepared in the primary screening study is shown on Figure 3.3.2 below. The maps of other sections are attached on the Appendix of this report.

Figure 3.3.2 Map for the Primary Screening for the Survey Section 1 (Source: JET)

b. Secondary Screening

In the secondary screening, the survey sections were divided into slopes for the inspections, and the divided slopes were classified as type of disasters. In the secondary screening the disaster types were classified into "Landslides", "Debris Slope Failures", "Rock Slope Failures" and "Debris Flows", and rockfalls shall be considered in the Debris Slope Failures and Rock Slope Failures depending on the site situation.

The screening used the method of topographical interpretation to identify the topographical features of landslides or debris flows, and the method of interpretation of satellite images to evaluate the type of slopes whether these are rock slopes or debris slopes.

According to the methods of screening for the slope inspections in Japan, the condition to select the slopes for the inspections shall be as follows:

- 15m or more height of natural / cut slope
- 45 or more degrees of natural slope

However, the data for the secondary screening was not sufficiently accurate for the evaluation based on the conditions mentioned above. Therefore, these conditions were not applied in the secondary screening. The final decision regarding to the slopes for the inspections shall be carried out by actual site checking.

The data and information for the secondary screening are as follows:

- Digital data of topography (40m contour map)
- High resolution satellite images (1.0m grid)

Specification of the high resolution satellite images for the secondary screening is shown on Table 3.3.1 and Appendix.

Table 3.3.1 High Resolution Satellite Images Used for Secondary Screening (Source: JET)

Area	Name of Satellite	Resolution	Shooting Date
Section I (East part)	IKONOS 2	1.0m	20/02/2014
Section I (West part)	IKONOS 2	1.0m	03/03/2014
Section II (Northwest part)	IKONOS 2	1.0m	09/02/2007
Section II (West part)	QuickBird 2	1.0m	02/04/2014
Section II (Middle part)	Geoeye 1	1.0m	06/01/2010
Section II (South part)	QuickBird 2	1.0m	22/02/2007
Section II (Middle-east part)	QuickBird 2	1.0m	22/02/2007
Section II (Part of Middle east part)	IKONOS 2	1.0m	25/03/2014
Section II (East part)	Geoeye 1	1.0m	11/01/2013
Section III	QuickBird 2	1.0m	22/02/2007
Section IV (North part)	IKONOS 2	1.0m	11/03/2014
Section IV (Middle part)	QuickBird 2	1.0m	22/02/2007
Section IV (Part of middle part)	QuickBird 2	1.0m	17/11/2012
Section IV (South part)	Geoeye 1	1.0m	30/01/2013
Section V (North-South part)	Geoeye 1	1.0m	01/02/2014
Section V (End of South part)	Geoeye 1	1.0m	04/03/2013

Notable topographical features or land surface conditions (hazard factors) which are considered to relate with slope disasters shall be identified by interpretation using of the materials mentioned above. Hazard factors of slope disaster show on Table 3.3.2.

The general hazard factors which can be considered to be related to effectiveness of road traffic shall be selected and as the candidate of targeted areas for slope inspection.

Table 3.3.2 Hazard Factors of Slope Disasters (Source: JET)

Category	Item	Content
Slope	Boundary of slope of water catchment area	The boundary shall be unit of area for slope inspection
Notable Topographical Features and land surface conditions	Rock avalanche	Rock outcrops, rock wall, steep slope with more than 45 degrees, overhang with more than 90 degrees
	Rock fall	Unstable rock
	Slope failure	Knick line
		Concave knick line
		Collapse
		Water catchment area
		Gap / Crack
		Bare land/ poor vegetation area
	Debris flow	Gully
		River and soil sediment
	Landslide	Characteristic feature of landslide
		Depression zone
	Collapse	Colluviums
		Talus deposit
	Debris sediment	Alluvial fan
Road Facility (if required)	Road	Width of road
	Embankment	Embankment section and slope angle
	Cut slope	Length and height
Others (if required)	Terrace	If required to identify as plane of terrace
	Lineament	Fault or geological boundary
	Area of interpretation	If required to identified the area of interpretation

The target slopes for inspections were selected based on the following policies.

- The target sections for the inspections are divided in consideration of both sides' conditions (mountain side and valley side) of the slopes.
- The road sections were divided based on the estimated type of disasters.

The result of the Secondary screening was compiled on the topographical map of the 5 selected survey sections. Examples of the results are shown on Figure 3.3.3. All result maps of the Secondary screening are attached in Appendix of the report.

Total numbers of the selected road sections for the inspection are shown on Table 3.3.3.

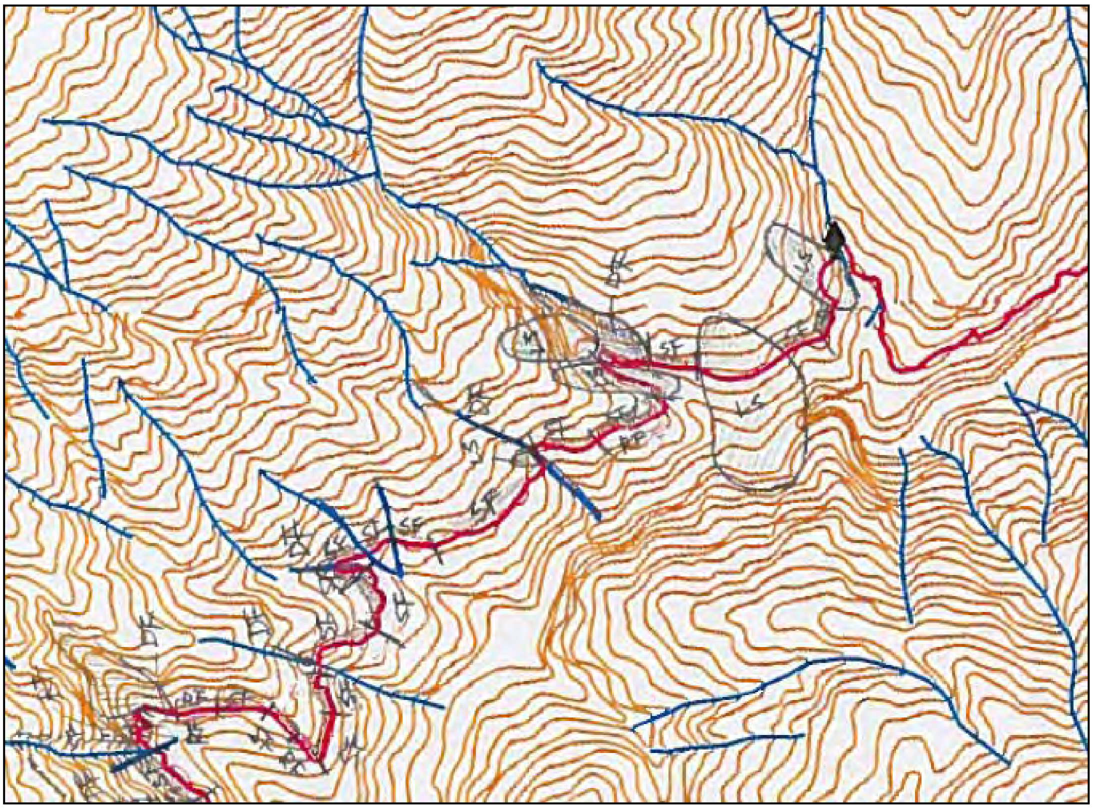


Figure 3.3.3 A Part of the Secondary Screening Map (Source: JET)

Table 3.3.3 Number of Target Sections for the Inspection Selected in the Secondary Screening (Source: JET)

	Landslide	Debris Flow	Debris Slope Failure	Rock Slope Failure	Total
Section I	11	23	39	4	77
Section II	30	70	160	3	263
Section III	2	10	44	0	56
Section IV	15	38	268	3	324
Section V	9	11	33	0	53
Type- total	67	152	544	10	773

The target sections for the inspections shall be finalized by the filed survey/reconnaissance based on the results of the desktop screening.

3.3.2 Re-consideration of Survey Sections

In the course of the screening, various information was obtained for the Project including classification of disaster types in each section. Selection of the survey sections for the site inspection of road slopes have been carried out as the result of site inspections as well as interviews from the DoR, JICA Bhutan and other agencies concerned.

Target areas of section I, II and III were selected to perform site inspection considering the following reasons.

- Section I and section II are located in the primary national highway which is the most important road in the country.
- One of the largest scale unstable slopes is located in the section III.
- Section IV and section V are less important for transportation in comparison with sections I – III.
- Section IV and section V are located near the southern border where social constraints appear to increase.
- Section I, II and III seem to be convenient for DoR staff to carry out site inspections and join the site seminars due to reasonable distance from their offices.

Total number of the sites obtained among selected sections is 396 in the section I (77 slopes), section II (263 slopes) and section III (56 slopes) as shown in Table 3.3.4 below (Referred to Figure 3.3.4, Figure 3.3.5, Figure 3.3.6, and Figure 3.3.7). The site inspection of the road slopes of the target areas have been carried out and supposed to be completed in the summer of 2015.

Table 3.3.4 Selection of Survey Sections (Source: JET)

Section	Economic Impact	Social Impact	Location	Consideration of Selection and Remarks	Selection	No. of Target Section
I	Excellent	Excellent	Good	· The section is in the Primary National Highway · Preferable location for on-the-job training · Consisting of various types of slopes	Selected	77
II	Excellent	Excellent	Good	· The section is in the Primary National Highway · Preferable location for on-the-job training · Preferable section for road & slope inventory	Selected	263
III	Good	Good	Good	· Large landslide in this section and located near Trongsa, the key town of primary National Highway · Preferable location for on-the-job training · Consisting of various types of slopes	Selected	56
IV	Inferior	Inferior	Inferior	· Section is selected in the future stage considering less priority in comparison with Section I-III	–	
V	Inferior	Inferior	Inferior	· Section is selected in the future stage considering less priority in comparison with Section I-III	–	

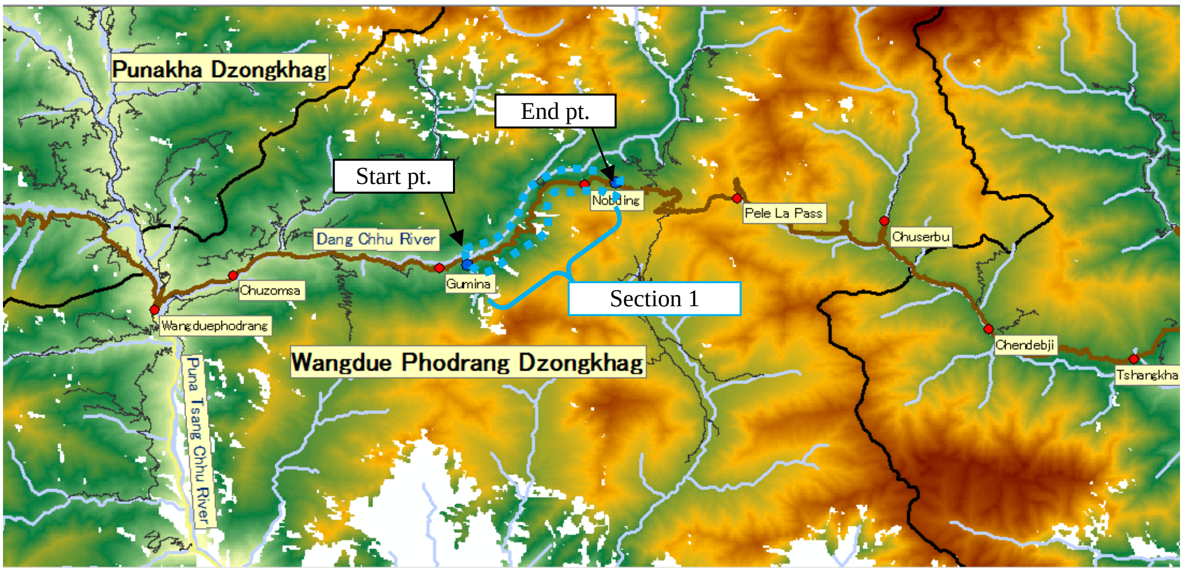


Figure 3.3.4 Location of Target Site on Section 1 (map scale: 1:162,500) (Source: JET)

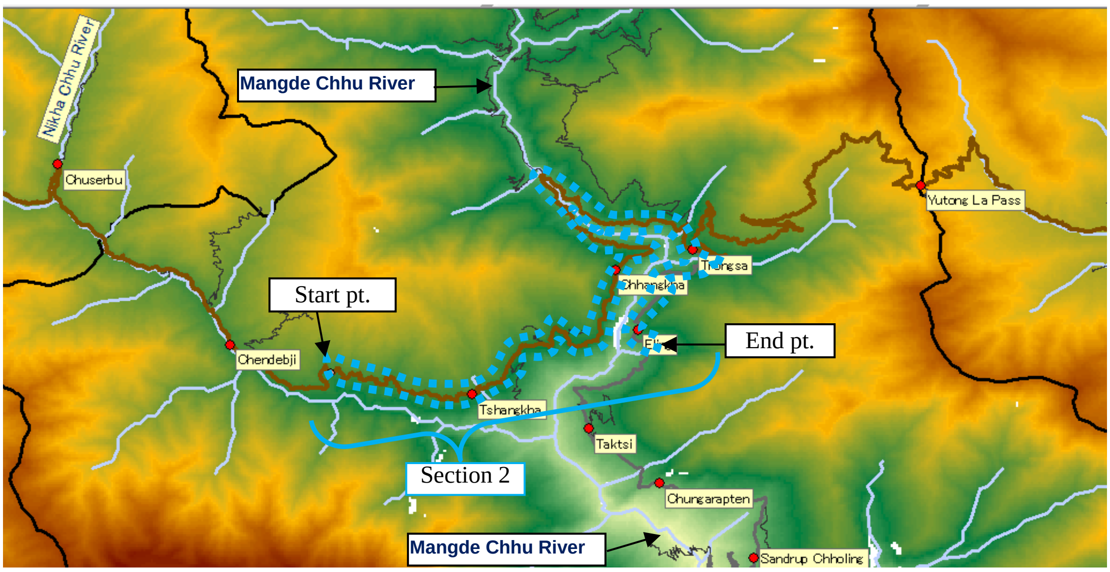


Figure 3.3.5 Location of Target Site on Section 2 (map scale: 1:120,000) (Source: JET)

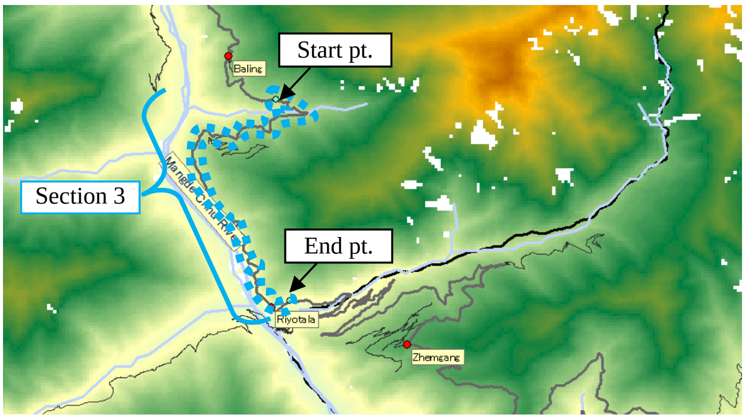


Figure 3.3.6 Location of Target Site on Section 3 (map scale: 1:100,000) (Source: JET)

Section 1		
	Start Point N 27° 29' 58.34" E 90° 04' 03.44"	End Point N 27° 32' 43.87" E 90° 08' 59.59"
Section 2		
	Start Point* N 27° 27' 15.48" E 90° 23' 22.59"	End Point N 27° 27' 46.48" E 90° 30' 03.37"
Section 3		
	Start Point N 27° 16' 54.56" E 90° 37' 15.57"	End Point N 27° 13' 35.10" E 90° 37' 28.70"

Figure 3.3.7 Image of Each Start Point and End Point in the Target Sections (Source: JET)

* Note: The coordination start point of section 2 is not on the road, but it is situated on slope near to the valley-side as shown in the photo.

3.4 Determination of Survey Sections (Field Screening)

Prior to the site survey, the results of topographic interpretation were reflected on the accurate 1:10,000 topographic map that covered all area from section 1 through section 3.

The conceptual process of determination of survey sections are shown in Figure 3.4.1 below. In the combining of 1 and 2 steps in Figure 3.4.1, the following regards were taken as the priorities.

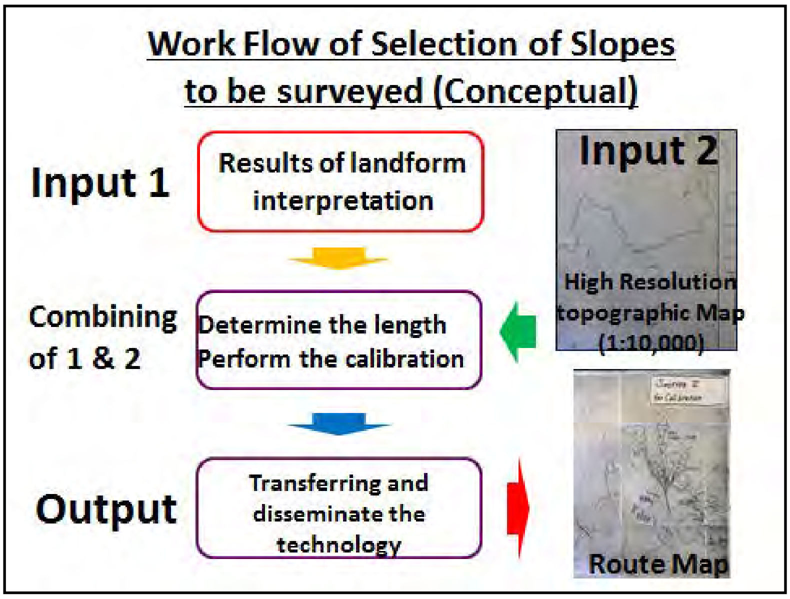


Figure 3.4.1 Work Flow of Selection of Slope to Be Surveyed (Source: JET)

- Determining the survey scope (Top and back of the slope, appropriate segment of length).
- Performing the calibration to share the knowledge of determining the disaster mode.
- Forming the teams so that the allocated DoR staff can obtain the on-the-job training.

The disaster mode (debris flow, landslide and rock/debris slope failure) were exemplified in the calibration step on site. The topographical features were indicated as the important points when the regular check sheet was filled in. Each topographical feature was described in detail accordingly below part. In the determining step 1), Landform Interpretation was reflected into the high resolution topographic map (1:10,000) and reexamined by its morphology or shape of landform so that the interpretation became consistent with the shape of counter in the high resolution topographic map. Especially in case of landslide, the position of the top and toe of landslide (interpretation) should be become consistent with the gradient formed by counter of map (1:10,000). The flank or side line of the landslide should follow the valley-like topography formed by the map (1:10,000). In case of debris-flow, the flow was be able to be interpreted to have occurred along the valley or stream so that the reflection could be judged to be put along the valley formed in the dented form by the counter in the map.

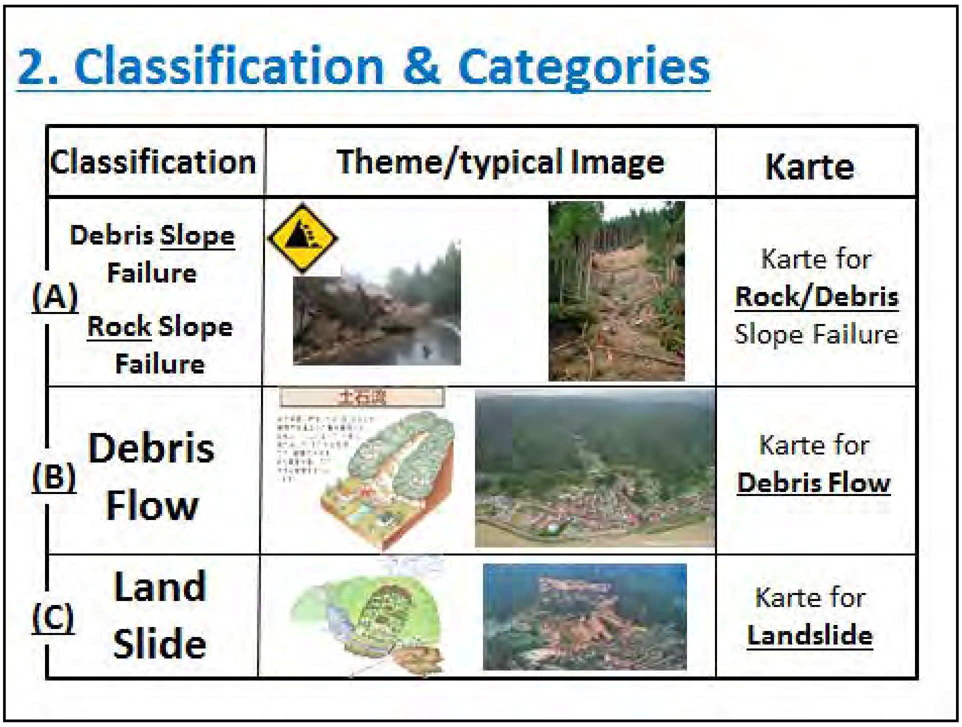


Figure 3.4.2 Typical Disaster Mode (Source: JET)

The calibration works were performed in the Tshangkha Community at the distance 10 km west from Trongsa Town on October 2014 along the National Highway Route 1. The Large landslide are formed at the top road and caused the bending of the shape of the road.

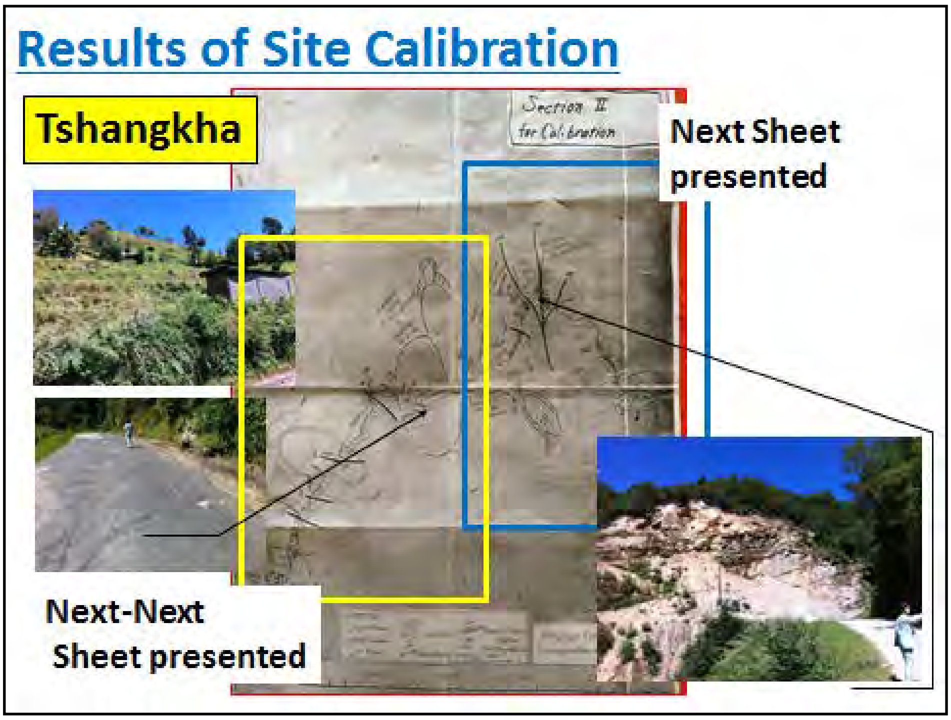


Figure 3.4.3 Calibration Works (Source: JET)

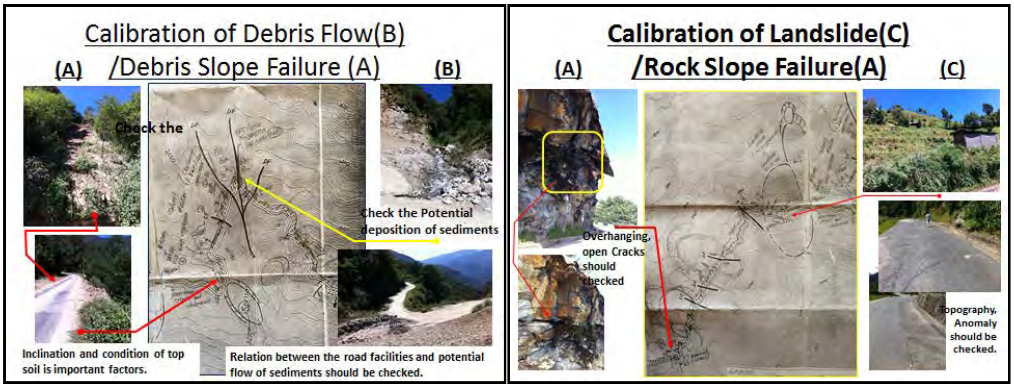


Figure 3.4.4 Calibration at Each Disaster Mode (Source: JET)

The slope failure (rock/debris) were checked and examined in consideration of its potential influence against the vehicles on the road near the slope. In case of slope/rock failure (referred as Figure 3.4.5), the joints in the overhang excavation face should be checked in relation to the possibility of falling onto the traffic along the road. The open joints or weathered joints in the face should be examined by the hammer and the bounce back of hammer is considered as the health or soundness of the rock/joints (The stronger the weathering occurs along the joints, the weaker the bounce back should be reflected by the hammer.). The results should be recorded in the regular check sheet as some of comments.

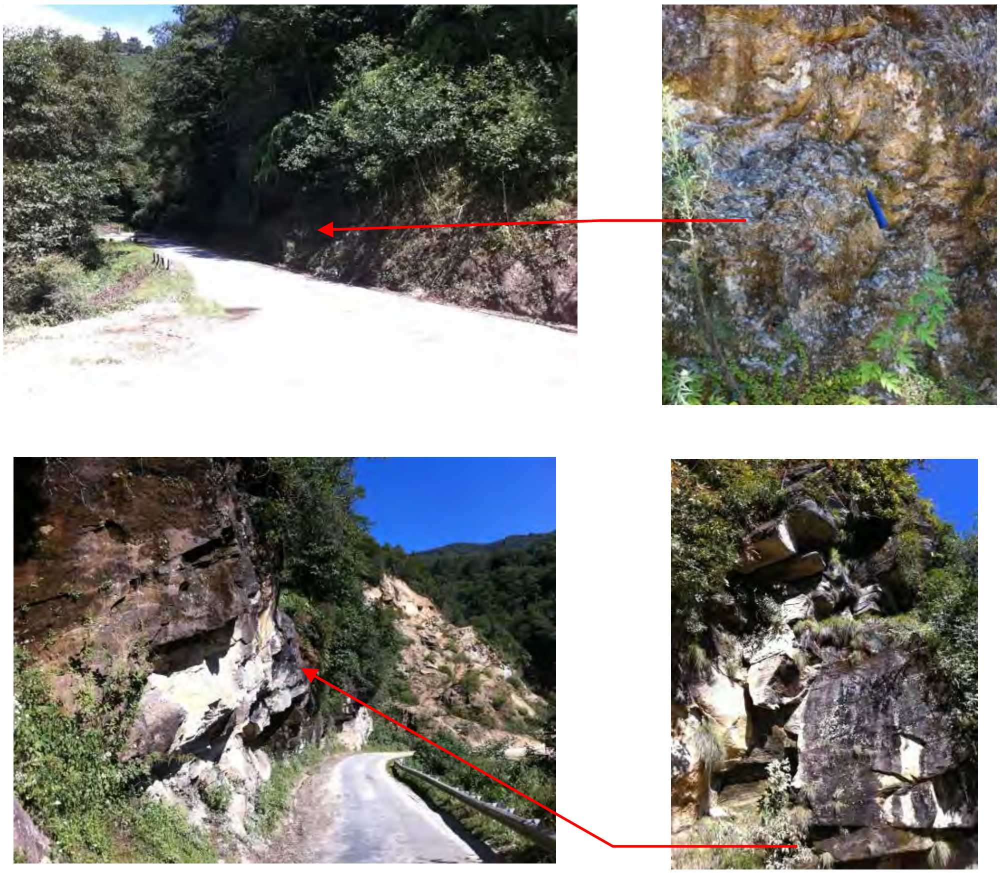


Figure 3.4.5 Examples of Rock/Slope Failure in Case of (A) (Source: JET)

It was important in the checking the debris flow in case of (A) that the volume of the sediment along the stream was evaluated and checked in correlation with the robustness of the culvert situated downstream of the debris flow. The deposit or sedimentation is estimated to have accumulated due to multiple occurrence of debris in the past influenced by the downpour (flash flooding). The distribution of the boulder/rock is random. The debris was produced from the upstream of the valley so the topographical anomaly such as steep gradient (erosion front) or landslide shall be advisable to be checked in the map (1:10,000) before the on-site checking. The typical form of debris flow is shown in Figure 3.4.6 below. The large boulder, if any, should be checked with its dimension (width, height and depth), so as to examine the possibility where the boulder can hit the culvert downstream or not. The checking requires the measure such as a bar with alternation of indication (white & red marker).

Figure 3.4.6 Example of Debris Flow in the Stream (Source: JET)

It was indicated in the calibration that the landslide tended to cause the crack on the road pavement and its landform at the top (horseshoes shaped scarp) was characteristic. The overall morphology of landslide was horse-shoe shaped in the top (scarf) in a view from a far position. When in on-site checking, it is important to take a look at the landform from a distance along the road. Typically in many cases in landslide the land use becomes different from that in surrounding area because the repeated disturbances due to the slope motion affected by the gravity lead to change in the permeability and stability in the ground/soil in the landmass. Accordingly the seepage or pond can be observed in the upper part of the landslide. On site the stream could be checked along the flank (side part) of the landslide. The pavement of the road crossing the landslide is affected by the movement of the landslide so that the fissure/cracks are widened on the pavement. The measuring of the openness is advised to monitor the movement of the landslide as well as the checking the deformation formed on the pavement (referred to Figure 3.4.7).

Figure 3.4.7 Deform and Cracks on the Pavement in the Landslide (Source: JET)

3.5 Preparation of Road Slope Inventory

3.5.1 Methodology of Road Slope Inventory

The road slope inventory was carried out in the selected slopes by conducting the screening of the targeted areas and risk evaluation of slope disasters. The road slope inventory was performed according to the procedure described in Figure 3.5.1.

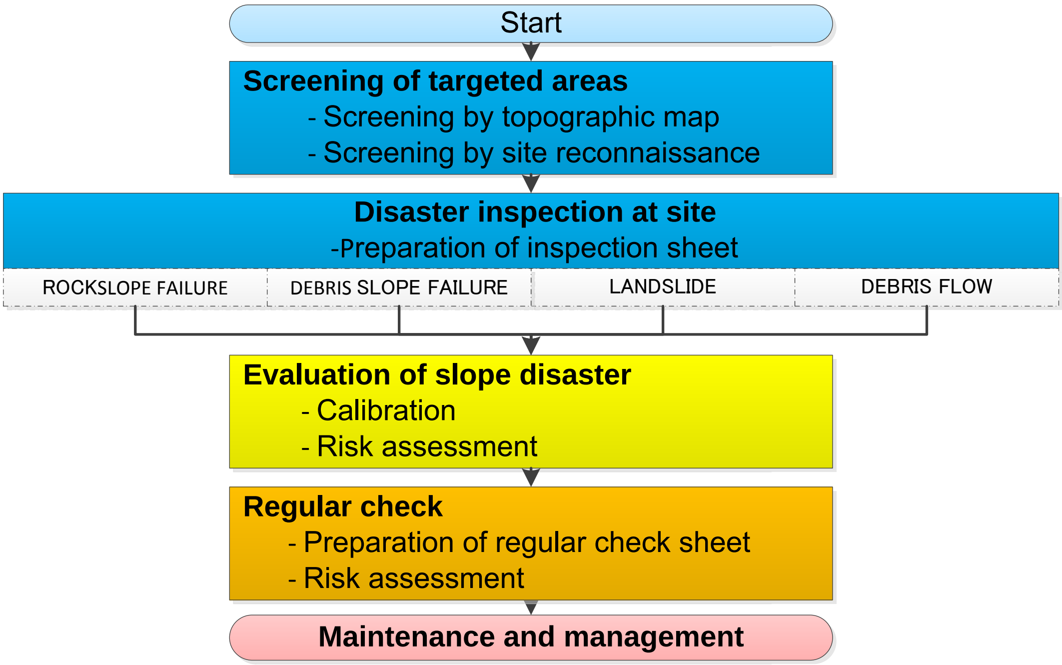


Figure 3.5.1 Flowchart of Inspections for Slope Disaster on Roads (Source: JET)

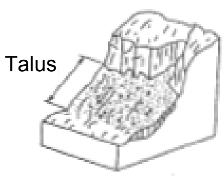
Topography, geology, surface condition and anomaly of slopes were carefully observed and evaluated during the inventory survey. These are described as follows:

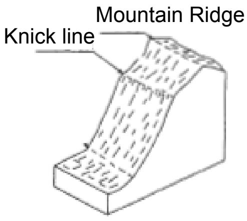
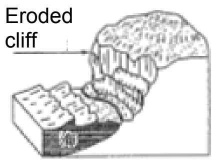
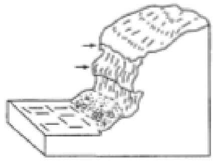
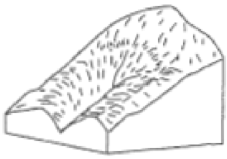
a. Topography

Generally specific topographical features which are created as the result of the activity of rock slope failure/debris slope failures can be found at rock slope failure/debris slope failure prone area. The topographical feature which has those factors of collapse is as follows.

Inspector checks how much the collapsed factor can be matched to the target slope.

Table 3.5.1 Topographical Factor (Source: Road Management Technical Center[*4])

Talus slope		It is a natural slope which is shown sudden gentle angle at the lower part of the slope. Talus slope is created by sedimentation of fallen debris from upper part of the slope. Talus part, generally consist of gravely soil and is loose condition.

Clear convex break of slope (Knick line)		It is a line connecting the point which is changed suddenly from gentle angle to steep angle of slope in view from top of the natural slope. Generally, occurrence of erosion and collapse is significant in case that the line is shown clearly. In case that there are a number of knick lines, it is focused on the clearest line.
Eroded toe of slope		Generally, the part of the slope which faces curved river line is eroded by river flow. Those parts show rock exposure or bare land.
Overhang		Overhang can be found on the undulated rock or soil slope surface. Overhang part shows more than 90 degree of slope angle.
Water catchment slope		Water catchment slope shows a basin-shape valley and the flow down area is narrow. It is notable that debris can flow down from small scale of water catchment slope and mountain stream.

b. Geological Condition

Soil, rock and geological structures which are prone for a collapse to occur are evaluated based on the following standard. When it is difficult to observe those factors on the target slope, it can be evaluated from neighbor slope condition or existing data if it is available. In case that the condition of slope is not uniquely; it is evaluated based on the most unstable condition on that slope.

b.1 Soil

The inspector checks whether condition of the most parts of the target cut/natural slope conform to the following soil material, and evaluate as “marked”, “a little marked” and “none” according to the actual condition.

- The soil which is “susceptible to erosion”

Volcanic ash, highly weathered rock, terrace gravel and sand, sandy soil, etc.

- The soil which has “less strength with water”

The soil is prone to reduce the strength when it is water bearing. Silty sand, sandy silt, silty cohesive soil, fine grain soil, etc.

b.2 Rock

The inspector checks whether condition of the most parts of the target cut/natural slope conform to the following rock condition, and evaluate as same as b.1 case above.

- The rock which has “high density of cracks and a weak layers”

The rock has crack or weak layer (joint, fault, weak bedding plane, schistosity, intrusion plane, etc.) developing within 20cm to 30cm interval, and shows its fragment in the form of plate, column or cubic.

- The rock which is “susceptible to erosion”

The rock is soft rock. The rock can be broken by hammer easily. The rock slope is prone to small scale surface collapse frequently.

- The rock which is “fast weathering”

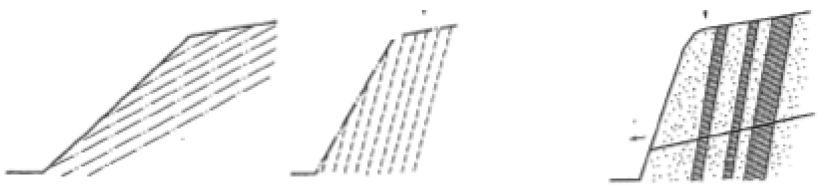
It is expansive rock and rock which is prone to slaking (mudstone, shale, tuffaceous sedimentary rock, weathered schist, etc.). These rocks contains expansive cohesive mineral, and is prone to be fragmented or be muddy condition as part of weathering, even though the rocks look hard.

b.3 Geological Structure

The inspector checks whether condition of the most parts of the target cut/natural slope conform to the following geological structures condition, and evaluate as same as b.1 case above.

- The structure which shows “dip slope of bedding plane”

Check the target slope condition based on the following figures



(a) Dip slope (b) Steeper dip slope more than slope angle (c) Combine many types of dip joints on the slope

Figure 3.5.2 Examples of Dip Slope (Source: Road Management Technical Center[*4])

- Debris on impermeable bedrock

Check the target slope condition based on the following figures

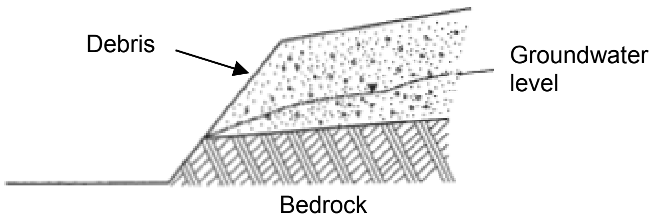


Figure 3.5.3 Example of Debris on Impermeable Bedrock
(Source: Road Management Technical Center[*4])

- The upper part is hard / the toe of slope is weak

This condition is as the following figure. This geological structure can be known as the Cap rock structure. The inspector checks not only the structure but deformation of soft rock layer at lower part of the slope and vertical cracks of hard rock layer at upper part of the slope also.

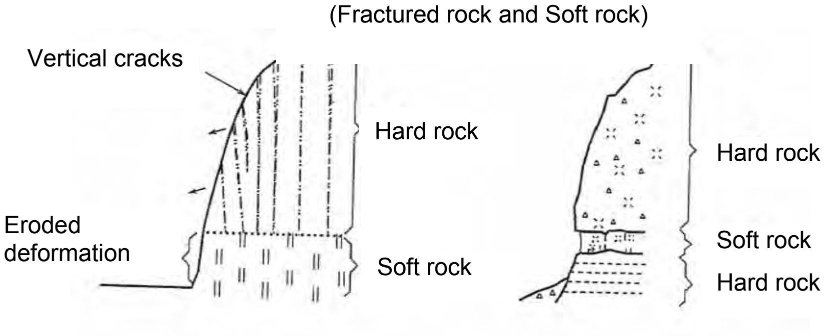


Figure 3.5.4 Example of Cap Rock Structure (Source: Road Management Technical Center[*4])

c. Surface Condition

c.1 Topsoil, Detached Rock and Unsteady Rock

Since it is an important factor to evaluate stability of cut/natural slope, it requires careful observation and evaluation. Stability of topsoil, detached rock and unsteady rock is evaluated in reference from Table 3.5.2.

In case of evaluation of instability, it is evaluated based on recent rock slope failure, unsteady rock, bedrock condition around detached rock, bearing condition of fallen rocks, soil and vegetation condition as well.

Table 3.5.2 Criteria of Stability of Topsoil, Detached Rock and Unsteady Rock (Source: Road Management Technical Center[*4])

Category of factor	Topsoil	Detached rock and Unsteady rock
Instability	- Thick topsoil layer (more than 50cm) , - Erosion - Trace of movement	A number of the rocks with the following condition are found. - 2/3 part of the fallen/ detached rock exposes from ground. - Detached completely or estimated to be moved even by a human power
A little unstable	- No eroded and trace of movement even if topsoil layer is thick. - Topsoil layer is thin but it is eroded or has trace of movement.	- The above condition rocks are found but are not so many. - Grade of exposure of rocks is less than 2/3. - Detached slightly, and it is estimated to be hard to move by human power.
Stability	- There is no or thin topsoil layer, and is not trace of movement.	- No detached and unsteady rock. - Detached/ fallen rocks are under stable condition.

Figure 3.5.5 Insufficient Bearing Condition of Detached/Fallen Rocks
(Source: Road Management Technical Center[*4])

c.2 Spring Water

Even though number of water spring points and amount of water flow is changed between after rainfall and before rainfall, it is evaluated following three (3) stage approach.

- Notable spring water

More than one point of spring water can be found. The spring water has amount of water which can be recognized as water flow or affect the deterioration of soil strength. Artificial water flow from top part of natural slope is included.

- Seepage

It is the wet condition on cut/natural slope, or spring water which is less amount water volume than the condition of “Notable spring water”.

- None

c.3 Surface Condition

It is selected from the following three conditions.

- Bare land with minor vegetation

The slope consists of rock and gravel or soil mainly and/or the natural slope with grass plant which has weak binding force for covered soil

- Intermediate (bare, grass, tree)

Slope surface condition is non-uniform. The slope is covered with mixed condition with bare land, planting part and tree part.

- Mainly structure/mainly tree

It is the slope which is covered with artificial structure or trees.

d. Figure

The inspector measures a height (H) and a dip (i) of the target slope in reference with the following figures.

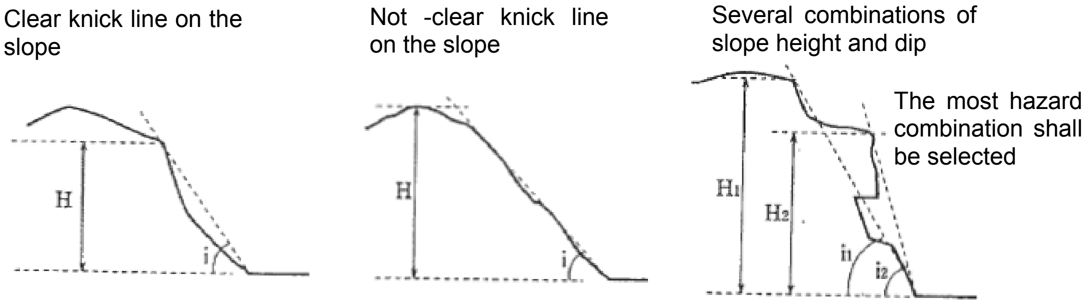


Figure 3.5.6 Methodology of Measurement of Slope Height and Dip
(Source: Road Management Technical Center[*4])

e. Anomaly

Anomalies on cut/natural slope are indication to evaluate a stability of the target slope. Anomalies which are related with slope stability are as follows:

Surface collapse, small fallen rock (more than a few cm diameter), gully, erosion, piping hole(more than a few cm diameter), subsidence (more than 10cm width), heaving (more than 10cm width), bending of tree root, fallen tree, crack, open cracks, anomaly on existing countermeasure.

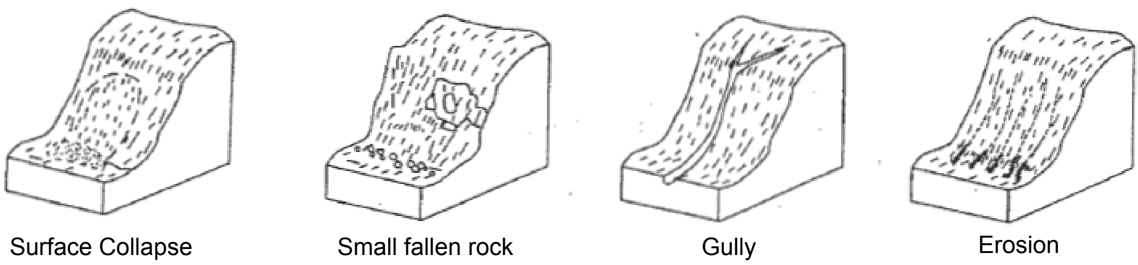


Figure 3.5.7 Anomalies on the slope (Source: Road Management Technical Center[*4])

3.5.2 Hazard Evaluation

Hazards of slopes on the roads have been evaluated by the results of the road slope inventory such as topography, geological conditions, soil, effectiveness of existing countermeasures and disaster history. Inspection engineers decide future response for the potential disasters.

The hazard evaluation is classified into four (4) ranks as shown below. The rank is utilized on the roads in Bhutan. The typical example photos of each rank are shown in the following figures.

Table 3.5.3 Rank of the Hazard Evaluation in Bhutan (Source: JET)

Rank	Contents
1A	Countermeasure works are necessary. (Technical assistance)
1B	Countermeasure works are necessary. (Bhutanese technology)
2	Although urgent countermeasures are not necessary, regular check is needed.
3	Countermeasure work is not necessary.

- Rank 1A: Countermeasure works are necessary. (Technical assistance)

[Definition] Countermeasures are needed because the slope disaster happen and affect the road traffic. Technical assistance is needed for the countermeasures since the technology in Bhutan would not be sufficient to control the slope disasters.

---> Regular check sheets are prepared for the slope disaster. The regular check should be continuously implemented until the confirmation of the stability after completion of countermeasures.

- Rank 1B: Countermeasure works are necessary. (Bhutanese technology)

[Definition] Countermeasures are needed because the slope disaster happen and affect the road traffic. The technology in Bhutan is available to control the slope disasters.

---> Regular check sheets are prepared for the slope disaster. The regular check should be continuously implemented until the confirmation of the stability after completion of countermeasures.

- Rank 2: Although urgent countermeasures are not necessary, regular checks are needed.

[Definition] Countermeasures are preferable in the future because the slope disaster could happen and affect the road traffic. However, the emergency level of the disaster is lower than the one in Rank 1 so the regular check should be implemented for the time being.

---> Regular check sheets are prepared for the slope disaster. The regular check should be continuously implemented until the confirmation of the stability after completion of countermeasures.

- Rank 3: Countermeasure work is not necessary.

[Definition] Countermeasures are not needed for now because potential failure/rockfall/deformation is minor so daily maintenance by DoR is sufficient to control the slope disasters.

---> Regular check sheets are not prepared for the slope disaster. The regular check is not implemented.

Figure 3.5.8 Typical Examples of Each Rank (Source: JET)

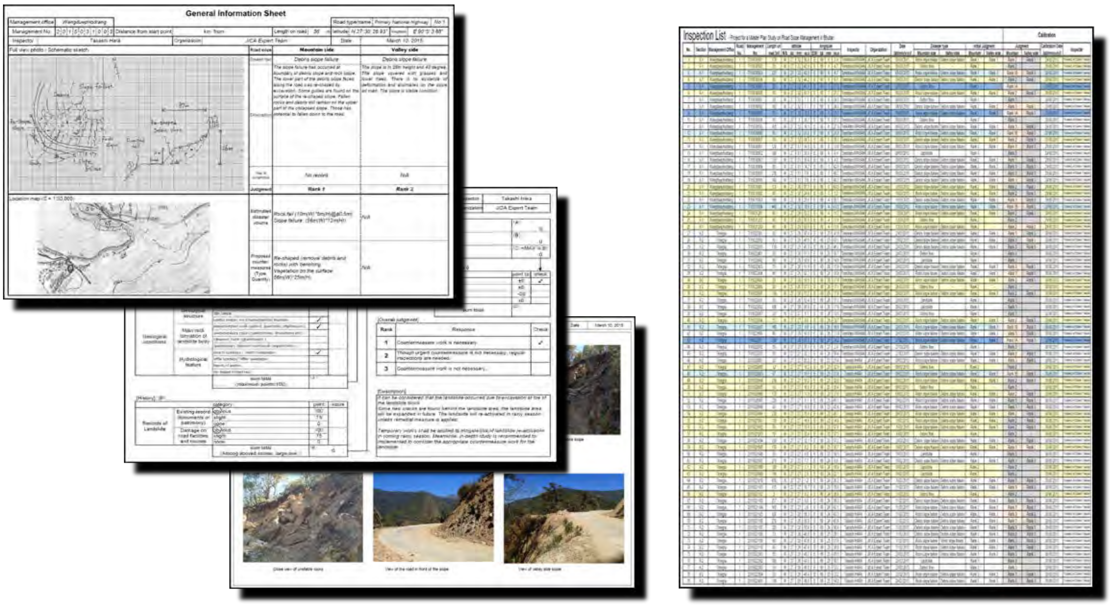
3.5.3 Inventory Results

a. General

The site inspections were used to form a road slope inventory (Figure 3.5.9). The road slope inventory consists of an inspection list and three (3) inspection sheets; a general information sheet, an evaluation sheet, and a photo sheet. The site inspections were carried out using an inspection manual - described in Chapter 2 - for the slope of three sections (Section I, II and III) chosen by screening, which is covered in Chapter 3.4 and 3.5. The inspectors consist of JET and DoR.

Table 3.5.4 Specifications of the Site Inspections (Source: JET)

Item	Specifications
Inspection area	Section I, II and III
Number of slopes	457 slopes
Inspector	JICA expert team and DoR
Inspection period	3rd October 2014 – 12th April 2015
Calibration period	29th June 2015 – 2nd July 2015



a) Inspection Sheet   b) Inspection List

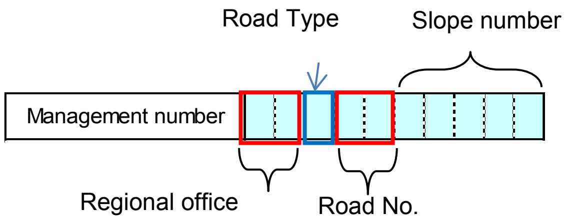
Figure 3.5.9 Example of a Slope Inventory (Source: JET)

The inspections needed to take place within the dry season, so the site inspections were performed as efficiently as possible to inspect 457 slopes during the dry season in the first year (October 2014 - April 2015). The inspection data have been recorded in a road slope inventory (Figure 3.5.9).

Calibration: The survey methods and the evaluation and rating criteria were standardized before the inspection started. However, variations may occur in the inspection results, depending on the inspector and the area. Therefore, a calibration of the results of the site inspections has been performed by a team of experts different from the site inspection teams in June – July 2015. Thus, the inspection results have been thoroughly cross-checked.

Figure 3.5.10 Site Inspections for the Selected Roads (Source: JET)

Management No.: This is a unique number that identifies the target slope. The number is set in 10 digits of texts and numbers which represent the following: management office, road type, road number and slope number. An explanation of the makeup of the management number is shown below.



- Regional office (2 digits): TR: Trongsa
  WP Wangdue Phodrang
  TH: Thimphu
- Road Type (1 digit): P: Primary National Highway
  S: Secondary National Highway
  D: Dzongkhag Road
  F: Farm Road/GC Road
- Road No. (2 digits): 01, 02, 03…
- Slope number (5 digits): [from the start point on each Section]
  Section I: 10010, 10020, 10030…
  Section III: 30010, 30020, 30030…
  Section VI: 60010, 60020, 60030…

Figure 3.5.11 Explanation of the Makeup of the Management Number (Source: JET)

b. Result of Slope Inventory

The inspection sheets, which shows the results of slope inventory for all target slopes, are attached as Appendix, and an inspection list is shown in from Table 3.5.5 to Table 3.5.7.

Table 3.5.5 Inspection List (1) (Source: JET)

Basic Information							Final Judgment			
Section	Management Office	Road No.	Management No.	Distance Mark			Judgment & Score			
				km	from	to	Mountain	Score	Valley side	Score
S-1	Wangduephodrang	1	WPP0120010	40.34	Wangduephodrang	Trongsa	Rank 3	45	-	
S-1	Wangduephodrang	1	WPP0120020	40.15	Wangduephodrang	Trongsa	Rank 3	28	Rank 2	0
S-1	Wangduephodrang	1	WPP0120030	39.73	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120040	39.34	Wangduephodrang	Trongsa	Rank 2	56	Rank 2	70
S-1	Wangduephodrang	1	WPP0120050	39.33	Wangduephodrang	Trongsa	Rank 2	65	-	
S-1	Wangduephodrang	1	WPP0120060	39.19	Wangduephodrang	Trongsa	Rank 3	10	Rank 3	0
S-1	Wangduephodrang	1	WPP0120070	39.17	Wangduephodrang	Trongsa	Rank 2	70	-	
S-1	Wangduephodrang	1	WPP0120080	39.16	Wangduephodrang	Trongsa	Rank 3	27	Rank 3	0
S-1	Wangduephodrang	1	WPP0120090	39.07	Wangduephodrang	Trongsa	Rank 2	61	Rank 2	40
S-1	Wangduephodrang	1	WPP0120100	39.02	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120110	38.78	Wangduephodrang	Trongsa	Rank 1B	70	Rank 2	0
S-1	Wangduephodrang	1	WPP0120120	38.74	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-1	Wangduephodrang	1	WPP0120130	38.56	Wangduephodrang	Trongsa	Rank 2	41	Rank 3	0
S-1	Wangduephodrang	1	WPP0120140	38.55	Wangduephodrang	Trongsa	Rank 2	65	-	
S-1	Wangduephodrang	1	WPP0120150	38.30	Wangduephodrang	Trongsa	Rank 3	18	Rank 3	0
S-1	Wangduephodrang	1	WPP0120160	38.15	Wangduephodrang	Trongsa	Rank 3	35	-	
S-1	Wangduephodrang	1	WPP0120170	38.15	Wangduephodrang	Trongsa	Rank 3	22	Rank 3	0
S-1	Wangduephodrang	1	WPP0120180	37.90	Wangduephodrang	Trongsa	Rank 3	18	Rank 3	0
S-1	Wangduephodrang	1	WPP0120190	37.84	Wangduephodrang	Trongsa	Rank 2	70	Rank 2	70
S-1	Wangduephodrang	1	WPP0120200	37.64	Wangduephodrang	Trongsa	Rank 1B	86	Rank 3	0
S-1	Wangduephodrang	1	WPP0120210	37.63	Wangduephodrang	Trongsa	Rank 2	75	-	
S-1	Wangduephodrang	1	WPP0120220	37.43	Wangduephodrang	Trongsa	Rank 2	75	Rank 3	0
S-1	Wangduephodrang	1	WPP0120230	37.42	Wangduephodrang	Trongsa	Rank 2	75	-	
S-1	Wangduephodrang	1	WPP0120240	37.22	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120250	37.19	Wangduephodrang	Trongsa	Rank 2	65	-	
S-1	Wangduephodrang	1	WPP0120260	37.03	Wangduephodrang	Trongsa	Rank 2	44	Rank 3	0
S-1	Wangduephodrang	1	WPP0120270	36.87	Wangduephodrang	Trongsa	Rank 1B	100	Rank 2	0
S-1	Wangduephodrang	1	WPP0120280	36.71	Wangduephodrang	Trongsa	Rank 3	26	Rank 3	0
S-1	Wangduephodrang	1	WPP0120290	36.54	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-1	Wangduephodrang	1	WPP0120300	36.46	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120310	36.41	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-1	Wangduephodrang	1	WPP0120320	36.38	Wangduephodrang	Trongsa	Rank 2	73	Rank 3	0
S-1	Wangduephodrang	1	WPP0120330	36.37	Wangduephodrang	Trongsa	Rank 1A	95	-	
S-1	Wangduephodrang	1	WPP0120340	36.24	Wangduephodrang	Trongsa	Rank 3	28	Rank 3	0
S-1	Wangduephodrang	1	WPP0120350	36.14	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120360	35.97	Wangduephodrang	Trongsa	Rank 2	48	-	
S-1	Wangduephodrang	1	WPP0120370	35.90	Wangduephodrang	Trongsa	Rank 2	56	Rank 3	0
S-1	Wangduephodrang	1	WPP0120380	35.89	Wangduephodrang	Trongsa	Rank 3	40	-	
S-1	Wangduephodrang	1	WPP0120390	35.84	Wangduephodrang	Trongsa	Rank 2	55	-	
S-1	Wangduephodrang	1	WPP0120400	35.84	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120410	35.61	Wangduephodrang	Trongsa	Rank 2	40	Rank 2	40
S-1	Wangduephodrang	1	WPP0120420	35.49	Wangduephodrang	Trongsa	Rank 3	7	Rank 3	0
S-1	Wangduephodrang	1	WPP0120430	35.27	Wangduephodrang	Trongsa	Rank 3	18	Rank 3	0
S-1	Wangduephodrang	1	WPP0120440	34.93	Wangduephodrang	Trongsa	Rank 3	7	Rank 3	0
S-1	Wangduephodrang	1	WPP0120450	34.83	Wangduephodrang	Trongsa	Rank 3	26	Rank 3	0
S-1	Wangduephodrang	1	WPP0120460	34.71	Wangduephodrang	Trongsa	Rank 2	70	Rank 2	70
S-1	Wangduephodrang	1	WPP0120470	34.53	Wangduephodrang	Trongsa	Rank 2	80	Rank 2	70
S-1	Wangduephodrang	1	WPP0120480	34.52	Wangduephodrang	Trongsa	Rank 3	25	-	
S-1	Wangduephodrang	1	WPP0120490	34.15	Wangduephodrang	Trongsa	Rank 2	54	Rank 2	70
S-1	Wangduephodrang	1	WPP0120500	34.13	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-1	Wangduephodrang	1	WPP0120510	34.07	Wangduephodrang	Trongsa	Rank 1B	89	Rank 3	0
S-1	Wangduephodrang	1	WPP0120520	33.88	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120530	33.87	Wangduephodrang	Trongsa	Rank 3	25	-	
S-1	Wangduephodrang	1	WPP0120540	33.78	Wangduephodrang	Trongsa	Rank 1A	90	Rank 3	0
S-1	Wangduephodrang	1	WPP0120550	33.61	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120560	33.60	Wangduephodrang	Trongsa	Rank 3	45		
S-1	Wangduephodrang	1	WPP0120570	33.44	Wangduephodrang	Trongsa	Rank 1B	71	Rank 3	0
S-1	Wangduephodrang	1	WPP0120580	33.42	Wangduephodrang	Trongsa	Rank 3	35	-	
S-1	Wangduephodrang	1	WPP0120590	33.23	Wangduephodrang	Trongsa	Rank 3	40	-	
S-1	Wangduephodrang	1	WPP0120600	33.19	Wangduephodrang	Trongsa	Rank 2	41	Rank 3	0
S-1	Wangduephodrang	1	WPP0120610	33.06	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120620	32.98	Wangduephodrang	Trongsa	Rank 3	7	Rank 1A	100
S-1	Wangduephodrang	1	WPP0120630	32.82	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120640	32.50	Wangduephodrang	Trongsa	Rank 2	40	Rank 2	40
S-1	Wangduephodrang	1	WPP0120650	32.42	Wangduephodrang	Trongsa	Rank 1B	70	Rank 2	40
S-1	Wangduephodrang	1	WPP0120660	32.25	Wangduephodrang	Trongsa	Rank 1B	70	Rank 2	40
S-1	Wangduephodrang	1	WPP0120670	32.24	Wangduephodrang	Trongsa	Rank 2	40	-	
S-1	Wangduephodrang	1	WPP0120680	32.13	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120690	31.94	Wangduephodrang	Trongsa	Rank 3	24	-	
S-1	Wangduephodrang	1	WPP0120700	31.79	Wangduephodrang	Trongsa	Rank 3	12	Rank 3	0
S-1	Wangduephodrang	1	WPP0120710	31.53	Wangduephodrang	Trongsa	Rank 2	40	Rank 2	40
S-1	Wangduephodrang	1	WPP0120720	31.11	Wangduephodrang	Trongsa	Rank 1B	93	Rank 2	70
S-1	Wangduephodrang	1	WPP0120730	31.10	Wangduephodrang	Trongsa	Rank 3	40	-	
S-1	Wangduephodrang	1	WPP0120740	30.82	Wangduephodrang	Trongsa	Rank 2	75	-	
S-1	Wangduephodrang	1	WPP0120750	30.81	Wangduephodrang	Trongsa	Rank 1A	100	Rank 2	70
S-1	Wangduephodrang	1	WPP0120760	30.75	Wangduephodrang	Trongsa	Rank 2	57	Rank 3	0
S-1	Wangduephodrang	1	WPP0120770	30.72	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120780	30.70	Wangduephodrang	Trongsa	Rank 2	75	-	
S-1	Wangduephodrang	1	WPP0120790	30.44	Wangduephodrang	Trongsa	Rank 2	60	Rank 3	0
S-1	Wangduephodrang	1	WPP0120800	30.38	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120810	30.33	Wangduephodrang	Trongsa	Rank 3	31	Rank 2	40
S-1	Wangduephodrang	1	WPP0120820	30.06	Wangduephodrang	Trongsa	Rank 2	43	Rank 2	40
S-1	Wangduephodrang	1	WPP0120830	29.76	Wangduephodrang	Trongsa	Rank 2	44	Rank 2	40
S-1	Wangduephodrang	1	WPP0120840	29.69	Wangduephodrang	Trongsa	Rank 3	23	Rank 3	0

Table 3.5.6 Inspection List (2) (Source: JET)

Basic Information							Final Judgment			
				Distance Mark			Judgment & Score			
Section	Management Office	Road No.	Management No.	km	from	to	Mountain	Score	Valley side	Score
S-1	Wangduephodrang	1	WPP0120850	29.48	Wangduephodrang	Trongsa	Rank 3	5	Rank 3	40
S-1	Wangduephodrang	1	WPP0120860	29.30	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0120870	29.11	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-1	Wangduephodrang	1	WPP0120880	28.27	Wangduephodrang	Trongsa	Rank 1A	94	Rank 2	70
S-1	Wangduephodrang	1	WPP0120890	28.26	Wangduephodrang	Trongsa	Rank 3	23	-	
S-1	Wangduephodrang	1	WPP0120900	28.26	Wangduephodrang	Trongsa	Rank 2	45	-	
S-1	Wangduephodrang	1	WPP0120910	28.12	Wangduephodrang	Trongsa	Rank 3	23	Rank 2	40
S-1	Wangduephodrang	1	WPP0120920	27.95	Wangduephodrang	Trongsa	Rank 2	50	-	
S-1	Wangduephodrang	1	WPP0120930	27.74	Wangduephodrang	Trongsa	Rank 3	29	Rank 2	40
S-1	Wangduephodrang	1	WPP0120940	27.73	Wangduephodrang	Trongsa	Rank 3	0		
S-1	Wangduephodrang	1	WPP0120950	27.34	Wangduephodrang	Trongsa	Rank 3	16	Rank 3	0
S-1	Wangduephodrang	1	WPP0120960	27.03	Wangduephodrang	Trongsa	Rank 3	40	-	
S-1	Wangduephodrang	1	WPP0120970	26.99	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-1	Wangduephodrang	1	WPP0120980	26.93	Wangduephodrang	Trongsa	Rank 1B	76	Rank 3	0
S-1	Wangduephodrang	1	WPP0120990	26.92	Wangduephodrang	Trongsa	Rank 3	35	-	
S-1	Wangduephodrang	1	WPP0121000	26.85	Wangduephodrang	Trongsa	Rank 2	66	Rank 3	0
S-1	Wangduephodrang	1	WPP0121010	26.67	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0121020	26.22	Wangduephodrang	Trongsa	Rank 1B	92	Rank 3	0
S-1	Wangduephodrang	1	WPP0121030	25.73	Wangduephodrang	Trongsa	Rank 1A	95	Rank 2	70
S-1	Wangduephodrang	1	WPP0121040	25.72	Wangduephodrang	Trongsa	Rank 3	35	-	
S-1	Wangduephodrang	1	WPP0121050	25.51	Wangduephodrang	Trongsa	Rank 3	37	-	
S-1	Wangduephodrang	1	WPP0121060	25.35	Wangduephodrang	Trongsa	Rank 3	41	-	
S-1	Wangduephodrang	1	WPP0121070	25.22	Wangduephodrang	Trongsa	Rank 2	45		
S-1	Wangduephodrang	1	WPP0121080	24.87	Wangduephodrang	Trongsa	Rank 3	7		
S-1	Wangduephodrang	1	WPP0121090	24.56	Wangduephodrang	Trongsa	Rank 2	35		
S-1	Wangduephodrang	1	WPP0121100	24.36	Wangduephodrang	Trongsa	Rank 2	40	Rank 2	0
S-1	Wangduephodrang	1	WPP0121110	24.25	Wangduephodrang	Trongsa	Rank 2	53	Rank 2	0
S-1	Wangduephodrang	1	WPP0121120	24.10	Wangduephodrang	Trongsa	Rank 2	65	-	
S-1	Wangduephodrang	1	WPP0121130	24.07	Wangduephodrang	Trongsa	Rank 2	61	Rank 2	70
S-1	Wangduephodrang	1	WPP0121140	23.98	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-1	Wangduephodrang	1	WPP0121150	23.96	Wangduephodrang	Trongsa	Rank 3	30	-	
S-1	Wangduephodrang	1	WPP0121160	23.66	Wangduephodrang	Trongsa	Rank 2	60	-	
S-1	Wangduephodrang	1	WPP0121170	23.65	Wangduephodrang	Trongsa	Rank 1B	90	-	
S-1	Wangduephodrang	1	WPP0121180	23.58	Wangduephodrang	Trongsa	Rank 1B	86	-	
S-2	Trongsa	1	TPP0120010	122.93	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0120020	122.75	Wangduephodrang	Trongsa	Rank 3	17	Rank 3	0
S-2	Trongsa	1	TPP0120030	122.55	Wangduephodrang	Trongsa	Rank 3	11	Rank 3	0
S-2	Trongsa	1	TPP0120040	122.19	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0120050	121.39	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0120060	121.22	Wangduephodrang	Trongsa	Rank 2	37	-	
S-2	Trongsa	1	TPP0120070	121.03	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0120080	121.00	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0120090	120.74	Wangduephodrang	Trongsa	Rank 3	24	-	
S-2	Trongsa	1	TPP0120100	120.56	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-2	Trongsa	1	TPP0120110	120.42	Wangduephodrang	Trongsa	Rank 2	70	-	
S-2	Trongsa	1	TPP0120120	119.86	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-2	Trongsa	1	TPP0120130	119.79	Wangduephodrang	Trongsa	Rank 1B	100	-	
S-2	Trongsa	1	TPP0120140	119.38	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-2	Trongsa	1	TPP0120150	118.92	Wangduephodrang	Trongsa	Rank 3	26	Rank 1B	100
S-2	Trongsa	1	TPP0120160	118.40	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0120170	118.40	Wangduephodrang	Trongsa	Rank 2	56	Rank 3	0
S-2	Trongsa	1	TPP0120180	118.06	Wangduephodrang	Trongsa	Rank 1A	100	Rank 1B	100
S-2	Trongsa	1	TPP0120190	117.39	Wangduephodrang	Trongsa	Rank 3	16	Rank 1B	100
S-2	Trongsa	1	TPP0120200	117.22	Wangduephodrang	Trongsa	Rank 3	30	-	
S-2	Trongsa	1	TPP0120210	117.13	Wangduephodrang	Trongsa	Rank 3	10	Rank 3	0
S-2	Trongsa	1	TPP0120220	117.12	Wangduephodrang	Trongsa	Rank 2	30	-	
S-2	Trongsa	1	TPP0120230	116.92	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120240	116.66	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120250	116.41	Wangduephodrang	Trongsa	Rank 3	32	Rank 3	0
S-2	Trongsa	1	TPP0120260	116.39	Wangduephodrang	Trongsa	Rank 2	30	-	
S-2	Trongsa	1	TPP0120270	116.26	Wangduephodrang	Trongsa	Rank 2	21	Rank 2	0
S-2	Trongsa	1	TPP0120280	116.24	Wangduephodrang	Trongsa	Rank 2	40	-	
S-2	Trongsa	1	TPP0120290	115.96	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120300	115.74	Wangduephodrang	Trongsa	Rank 2	32	Rank 3	0
S-2	Trongsa	1	TPP0120310	115.72	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0120320	115.38	Wangduephodrang	Trongsa	Rank 2	32	Rank 3	0
S-2	Trongsa	1	TPP0120330	115.06	Wangduephodrang	Trongsa	Rank 1B	47	Rank 3	0
S-2	Trongsa	1	TPP0120340	114.87	Wangduephodrang	Trongsa	Rank 2	32	Rank 3	0
S-2	Trongsa	1	TPP0120350	114.50	Wangduephodrang	Trongsa	Rank 3	22	Rank 2	0
S-2	Trongsa	1	TPP0120360	114.28	Wangduephodrang	Trongsa	Rank 3	32	Rank 3	0
S-2	Trongsa	1	TPP0120370	114.15	Wangduephodrang	Trongsa	Rank 1B	40	Rank 3	0
S-2	Trongsa	1	TPP0120380	113.89	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-2	Trongsa	1	TPP0120390	113.62	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-2	Trongsa	1	TPP0120400	113.40	Wangduephodrang	Trongsa	Rank 1B	50	Rank 3	40
S-2	Trongsa	1	TPP0120410	113.39	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0120420	113.22	Wangduephodrang	Trongsa	Rank 2	50	Rank 3	40
S-2	Trongsa	1	TPP0120430	112.99	Wangduephodrang	Trongsa	Rank 2	32	Rank 3	0
S-2	Trongsa	1	TPP0120440	112.96	Wangduephodrang	Trongsa	Rank 1B	50	-	
S-2	Trongsa	1	TPP0120450	112.76	Wangduephodrang	Trongsa	Rank 2	46	-	
S-2	Trongsa	1	TPP0120460	112.42	Wangduephodrang	Trongsa	Rank 3	27	Rank 3	0
S-2	Trongsa	1	TPP0120470	112.40	Wangduephodrang	Trongsa	Rank 3	50	-	
S-2	Trongsa	1	TPP0120480	112.20	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0120490	111.96	Wangduephodrang	Trongsa	Rank 2	39	Rank 3	0
S-2	Trongsa	1	TPP0120500	111.80	Wangduephodrang	Trongsa	Rank 2	28	-	

Table 3.5.7 Inspection List (3) (Source: JET)

Basic Information							Final Judgment			
				Distance Mark			Judgment & Score			
Section	Management Office	Road No.	Management No.	km	from	to	Mountain	Score	Valley side	Score
S-2	Trongsa	1	TPP0120510	111.76	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120520	111.72	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0120530	111.46	Wangduephodrang	Trongsa	Rank 2	32	Rank 3	0
S-2	Trongsa	1	TPP0120540	111.28	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120550	111.25	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0120560	110.94	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120570	110.75	Wangduephodrang	Trongsa	Rank 1A	74	Rank 2	0
S-2	Trongsa	1	TPP0120580	110.72	Wangduephodrang	Trongsa	Rank 3	50		
S-2	Trongsa	1	TPP0120590	110.45	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0120600	110.11	Wangduephodrang	Trongsa	Rank 3	24	Rank 3	0
S-2	Trongsa	1	TPP0120610	109.80	Wangduephodrang	Trongsa	Rank 3	24	Rank 3	0
S-2	Trongsa	1	TPP0120620	109.53	Wangduephodrang	Trongsa	Rank 2	35	Rank 2	0
S-2	Trongsa	1	TPP0120630	109.29	Wangduephodrang	Trongsa	Rank 2	52	Rank 3	0
S-2	Trongsa	1	TPP0120640	109.01	Wangduephodrang	Trongsa	Rank 3	24	Rank 3	0
S-2	Trongsa	1	TPP0120650	108.77	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120660	108.43	Wangduephodrang	Trongsa	Rank 3	24	Rank 3	0
S-2	Trongsa	1	TPP0120670	108.22	Wangduephodrang	Trongsa	Rank 2	24	Rank 3	0
S-2	Trongsa	1	TPP0120680	108.10	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120690	107.94	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120700	107.93	Wangduephodrang	Trongsa	Rank 3	50	-	
S-2	Trongsa	1	TPP0120710	107.81	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120720	107.80	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0120730	107.63	Wangduephodrang	Trongsa	Rank 2	46	Rank 3	0
S-2	Trongsa	1	TPP0120740	107.61	Wangduephodrang	Trongsa	Rank 3	50	-	
S-2	Trongsa	1	TPP0120750	107.38	Wangduephodrang	Trongsa	Rank 1A	42	Rank 3	0
S-2	Trongsa	1	TPP0120760	107.17	Wangduephodrang	Trongsa	Rank 2	24	Rank 3	0
S-2	Trongsa	1	TPP0120770	106.89	Wangduephodrang	Trongsa	Rank 2	24	Rank 3	0
S-2	Trongsa	1	TPP0120780	106.75	Wangduephodrang	Trongsa	Rank 2	24	Rank 3	0
S-2	Trongsa	1	TPP0120790	106.64	Wangduephodrang	Trongsa	Rank 3	26	Rank 3	0
S-2	Trongsa	1	TPP0120800	106.62	Wangduephodrang	Trongsa	Rank 3	50	-	
S-2	Trongsa	1	TPP0120810	106.53	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120820	106.51	Wangduephodrang	Trongsa	Rank 2	40	-	
S-2	Trongsa	1	TPP0120830	106.45	Wangduephodrang	Trongsa	Rank 3	26	Rank 3	0
S-2	Trongsa	1	TPP0120840	106.43	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0120850	106.27	Wangduephodrang	Trongsa	Rank 1A	100	Rank 1A	90
S-2	Trongsa	1	TPP0120860	106.25	Wangduephodrang	Trongsa	Rank 2	40	-	
S-2	Trongsa	1	TPP0120870	105.94	Wangduephodrang	Trongsa	Rank 1A	69	Rank 3	40
S-2	Trongsa	1	TPP0120880	105.80	Wangduephodrang	Trongsa	Rank 1A	52	Rank 3	0
S-2	Trongsa	1	TPP0120890	105.69	Wangduephodrang	Trongsa	Rank 3	43	Rank 3	0
S-2	Trongsa	1	TPP0120900	105.68	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0120910	105.57	Wangduephodrang	Trongsa	Rank 1B	70	Rank 3	0
S-2	Trongsa	1	TPP0120920	105.55	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0120930	105.29	Wangduephodrang	Trongsa	Rank 1B	57	Rank 3	0
S-2	Trongsa	1	TPP0120940	105.10	Wangduephodrang	Trongsa	Rank 2	58	Rank 3	0
S-2	Trongsa	1	TPP0120950	104.76	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0120960	104.46	Wangduephodrang	Trongsa	Rank 3	21	Rank 3	0
S-2	Trongsa	1	TPP0120970	104.33	Wangduephodrang	Trongsa	Rank 3	17	Rank 3	0
S-2	Trongsa	1	TPP0120980	104.31	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0120990	104.24	Wangduephodrang	Trongsa	Rank 3	13	Rank 3	0
S-2	Trongsa	1	TPP0121000	103.92	Wangduephodrang	Trongsa	Rank 3	13	Rank 3	0
S-2	Trongsa	1	TPP0121010	103.65	Wangduephodrang	Trongsa	Rank 3	13	Rank 3	0
S-2	Trongsa	1	TPP0121020	103.21	Wangduephodrang	Trongsa	Rank 3	17	Rank 3	0
S-2	Trongsa	1	TPP0121030	103.20	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0121040	103.13	Wangduephodrang	Trongsa	Rank 3	17	Rank 3	0
S-2	Trongsa	1	TPP0121050	103.12	Wangduephodrang	Trongsa	Rank 3	10	-	
S-2	Trongsa	1	TPP0121060	102.85	Wangduephodrang	Trongsa	Rank 3	17	Rank 3	0
S-2	Trongsa	1	TPP0121070	102.84	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0121080	102.74	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-2	Trongsa	1	TPP0121090	102.73	Wangduephodrang	Trongsa	Rank 2	65	-	
S-2	Trongsa	1	TPP0121100	102.67	Wangduephodrang	Trongsa	Rank 3	26	Rank 3	0
S-2	Trongsa	1	TPP0121110	102.65	Wangduephodrang	Trongsa	Rank 3	45	-	
S-2	Trongsa	1	TPP0121120	102.55	Wangduephodrang	Trongsa	Rank 1B	70	Rank 3	0
S-2	Trongsa	1	TPP0121130	102.22	Wangduephodrang	Trongsa	Rank 2	40	Rank 3	0
S-2	Trongsa	1	TPP0121140	101.88	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121150	101.58	Wangduephodrang	Trongsa	Rank 3	18	Rank 3	0
S-2	Trongsa	1	TPP0121160	101.40	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121170	101.38	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0121180	100.97	Wangduephodrang	Trongsa	Rank 3	31	Rank 1A	100
S-2	Trongsa	1	TPP0121190	100.97	Wangduephodrang	Trongsa	Rank 3	44	Rank 3	0
S-2	Trongsa	1	TPP0121200	100.80	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-2	Trongsa	1	TPP0121210	100.79	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	TPP0121220	100.61	Wangduephodrang	Trongsa	Rank 3	70	-	0
S-2	Trongsa	1	TPP0121230	100.60	Wangduephodrang	Trongsa	Rank 2	40	-	
S-2	Trongsa	1	TPP0121240	100.24	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121250	100.20	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0121260	100.07	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	40
S-2	Trongsa	1	TPP0121270	99.89	Wangduephodrang	Trongsa	Rank 3	32	-	
S-2	Trongsa	1	TPP0121280	99.87	Wangduephodrang	Trongsa	Rank 3	35	-	
S-2	Trongsa	1	TPP0121290	99.75	Wangduephodrang	Trongsa	Rank 3	35	-	
S-2	Trongsa	1	TPP0121300	99.45	Wangduephodrang	Trongsa	Rank 3	46	-	
S-2	Trongsa	1	TPP0121310	99.24	Wangduephodrang	Trongsa	Rank 1B	75	-	
S-2	Trongsa	1	TPP0121320	99.17	Wangduephodrang	Trongsa	Rank 2	64	Rank 2	0
S-2	Trongsa	1	TPP0121330	99.02	Wangduephodrang	Trongsa	Rank 1B	73	Rank 3	0
S-2	Trongsa	1	TPP0121340	98.86	Wangduephodrang	Trongsa	Rank 2	77	-	

Table 3.5.8 Inspection List (4) (Source: JET)

Basic Information							Final Judgment			
Section	Management Office	Road No.	Management No.	Distance Mark			Judgment & Score			
				km	from	to	Mountain	Score	Valley side	Score
S-2	Trongsa	1	TPP0121350	98.80	Wangduephodrang	Trongsa	Rank 3	45	Rank 3	0
S-2	Trongsa	1	TPP0121360	98.55	Wangduephodrang	Trongsa	Rank 3	46	-	
S-2	Trongsa	1	TPP0121370	98.35	Wangduephodrang	Trongsa	Rank 1A	90	Rank 3	0
S-2	Trongsa	1	TPP0121380	98.28	Wangduephodrang	Trongsa	Rank 3	44	Rank 3	0
S-2	Trongsa	1	TPP0121390	98.15	Wangduephodrang	Trongsa	Rank 1B	89	Rank 3	0
S-2	Trongsa	1	TPP0121400	98.10	Wangduephodrang	Trongsa	Rank 2	73	Rank 3	0
S-2	Trongsa	1	TPP0121410	98.09	Wangduephodrang	Trongsa	Rank 3	20	-	
S-2	Trongsa	1	TPP0121420	97.99	Wangduephodrang	Trongsa	Rank 3	22	-	
S-2	Trongsa	1	TPP0121430	97.99	Wangduephodrang	Trongsa	Rank 2	55	Rank 3	0
S-2	Trongsa	1	TPP0121440	97.99	Wangduephodrang	Trongsa	Rank 2	65	-	
S-2	Trongsa	1	TPP0121450	97.96	Wangduephodrang	Trongsa	Rank 2	61	Rank 3	0
S-2	Trongsa	1	TPP0121460	97.86	Wangduephodrang	Trongsa	Rank 3	33	-	
S-2	Trongsa	1	TPP0121470	97.86	Wangduephodrang	Trongsa	Rank 3	43	Rank 3	0
S-2	Trongsa	1	TPP0121480	97.77	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121490	97.64	Wangduephodrang	Trongsa	Rank 3	16	-	
S-2	Trongsa	1	TPP0121500	97.50	Wangduephodrang	Trongsa	Rank 2	43	Rank 3	0
S-2	Trongsa	1	TPP0121510	97.49	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	TPP0121520	97.30	Wangduephodrang	Trongsa	Rank 1A	80	Rank 3	0
S-2	Trongsa	1	TPP0121530	97.29	Wangduephodrang	Trongsa	Rank 2	70	-	
S-2	Trongsa	1	TPP0121540	97.24	Wangduephodrang	Trongsa	Rank 3	0	Rank 3	0
S-2	Trongsa	1	TPP0121550	97.23	Wangduephodrang	Trongsa	Rank 3	45	-	
S-2	Trongsa	1	TPP0121560	97.20	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121570	97.19	Wangduephodrang	Trongsa	Rank 3	20	-	
S-2	Trongsa	1	TPP0121580	97.09	Wangduephodrang	Trongsa	Rank 3	34	Rank 3	0
S-2	Trongsa	1	TPP0121590	97.05	Wangduephodrang	Trongsa	Rank 3	0	Rank 3	0
S-2	Trongsa	1	TPP0121600	97.03	Wangduephodrang	Trongsa	Rank 3	45	-	
S-2	Trongsa	1	TPP0121610	96.76	Wangduephodrang	Trongsa	Rank 3	30	-	
S-2	Trongsa	1	TPP0121620	96.74	Wangduephodrang	Trongsa	Rank 3	20	Rank 3	0
S-2	Trongsa	1	TPP0121630	96.59	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121640	96.50	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	40
S-2	Trongsa	1	TPP0121650	96.43	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121660	96.35	Wangduephodrang	Trongsa	Rank 3	15	Rank 3	0
S-2	Trongsa	1	TPP0121670	96.03	Wangduephodrang	Trongsa	Rank 3	25	Rank 3	0
S-2	Trongsa	1	TPP0121680	95.94	Wangduephodrang	Trongsa	Rank 3	10	Rank 3	0
S-2	Trongsa	1	TPP0121690	95.92	Wangduephodrang	Trongsa	Rank 3	30	-	
S-2	Trongsa	1	TPP0121700	95.87	Wangduephodrang	Trongsa	Rank 1A	100	-	
S-2	Trongsa	1	TPP0121710	95.59	Wangduephodrang	Trongsa	Rank 3	5	-	
S-2	Trongsa	1	TPP0121720	95.46	Wangduephodrang	Trongsa	Rank 3	4	Rank 3	0
S-2	Trongsa	1	TPP0121730	95.45	Wangduephodrang	Trongsa	Rank 3	0	-	
S-2	Trongsa	1	TPP0121740	95.25	Wangduephodrang	Trongsa	Rank 3	0	-	
S-2	Trongsa	1	TPP0121750	95.04	Wangduephodrang	Trongsa	Rank 3	22	Rank 3	0
S-2	Trongsa	1	TPP0121760	95.03	Wangduephodrang	Trongsa	Rank 3	10	-	
S-2	Trongsa	1	TPP0121770	94.91	Wangduephodrang	Trongsa	Rank 3	6	Rank 3	0
S-2	Trongsa	1	TPP0121780	94.91	Wangduephodrang	Trongsa	Rank 2	50	-	
S-2	Trongsa	1	TPP0121790	94.69	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121800	94.42	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121810	94.29	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121820	94.12	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121830	93.87	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121840	93.85	Wangduephodrang	Trongsa	Rank 2	65	-	
S-2	Trongsa	1	TPP0121850	93.73	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121860	93.72	Wangduephodrang	Trongsa	Rank 3	0	-	
S-2	Trongsa	1	TPP0121870	93.47	Wangduephodrang	Trongsa	Rank 3	42	Rank 3	0
S-2	Trongsa	1	TPP0121880	93.45	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0121890	93.16	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0121900	92.92	Wangduephodrang	Trongsa	Rank 2	75	-	
S-2	Trongsa	1	TPP0121910	92.86	Wangduephodrang	Trongsa	Rank 2	75	-	
S-2	Trongsa	1	TPP0121920	92.68	Wangduephodrang	Trongsa	Rank 3	30	-	
S-2	Trongsa	1	TPP0121930	92.47	Wangduephodrang	Trongsa	Rank 3	9	Rank 3	0
S-2	Trongsa	1	TPP0121940	92.40	Wangduephodrang	Trongsa	Rank 3	26	Rank 3	0
S-2	Trongsa	1	TPP0121950	92.39	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0121960	92.33	Wangduephodrang	Trongsa	Rank 3	29	Rank 3	0
S-2	Trongsa	1	TPP0121970	92.16	Wangduephodrang	Trongsa	Rank 3	15	Rank 3	0
S-2	Trongsa	1	TPP0121980	92.15	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0121990	92.02	Wangduephodrang	Trongsa	Rank 3	5	Rank 3	0
S-2	Trongsa	1	TPP0122000	91.94	Wangduephodrang	Trongsa	Rank 3	36	-	
S-2	Trongsa	1	TPP0122010	91.85	Wangduephodrang	Trongsa	Rank 3	40	Rank 2	70
S-2	Trongsa	1	TPP0122020	91.74	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0122030	91.73	Wangduephodrang	Trongsa	Rank 2	70	-	
S-2	Trongsa	1	TPP0122040	91.70	Wangduephodrang	Trongsa	Rank 2	73	Rank 3	0
S-2	Trongsa	1	TPP0122050	91.62	Wangduephodrang	Trongsa	Rank 2	70	Rank 2	0
S-2	Trongsa	1	TPP0122060	91.61	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0122070	91.37	Wangduephodrang	Trongsa	Rank 2	55	Rank 3	40
S-2	Trongsa	1	TPP0122080	91.28	Wangduephodrang	Trongsa	Rank 3	38	Rank 3	0
S-2	Trongsa	1	TPP0122090	91.26	Wangduephodrang	Trongsa	Rank 2	45	-	
S-2	Trongsa	1	TPP0122100	91.05	Wangduephodrang	Trongsa	Rank 2	70	Rank 3	0
S-2	Trongsa	1	TPP0122110	90.95	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0122120	90.74	Wangduephodrang	Trongsa	Rank 3	40	Rank 3	0
S-2	Trongsa	1	TPP0122130	90.60	Wangduephodrang	Trongsa	Rank 2	66	Rank 3	0
S-2	Trongsa	1	TPP0122140	90.59	Wangduephodrang	Trongsa	Rank 2	70	-	
S-2	Trongsa	1	TPP0122150	90.44	Wangduephodrang	Trongsa	Rank 2	76	Rank 3	0
S-2	Trongsa	1	TPP0122160	90.37	Wangduephodrang	Trongsa	Rank 1B	77	Rank 3	0
S-2	Trongsa	1	TPP0122170	90.36	Wangduephodrang	Trongsa	Rank 2	50	-	
S-2	Trongsa	1	TPP0122180	90.33	Wangduephodrang	Trongsa	Rank 3	42	Rank 3	0

Table 3.5.9 Inspection List (5) (Source: JET)

Basic Information							Final Judgment			
Section	Management Office	Road No.	Management No.	Distance Mark			Judgment & Score			
				km	from	to	Mountain	Score	Valley side	Score
S-2	Trongsa	1	**TPP0122190**	90.30	Wangduephodrang	Trongsa	Rank 2	50	-	
S-2	Trongsa	1	**TPP0122200**	90.20	Wangduephodrang	Trongsa	Rank 2	55	Rank 3	0
S-2	Trongsa	1	**TPP0122210**	90.19	Wangduephodrang	Trongsa	Rank 3	25	-	
S-2	Trongsa	1	**TPP0122220**	89.91	Wangduephodrang	Trongsa	Rank 1A	81	Rank 3	0
S-2	Trongsa	1	**TPP0122230**	89.90	Wangduephodrang	Trongsa	Rank 3	40	-	
S-2	Trongsa	1	**TPP0122240**	89.55	Wangduephodrang	Trongsa	Rank 3	7	Rank 3	0
S-2	Trongsa	4	**TRP0450010**	8.80	Trongsa	Gelephu	Rank 1B	83	Rank 2	70
S-2	Trongsa	4	**TRP0450020**	8.78	Trongsa	Gelephu	Rank 2	50	-	
S-2	Trongsa	4	**TRP0450030**	8.64	Trongsa	Gelephu	Rank 3	11	Rank 3	0
S-2	Trongsa	4	**TRP0450040**	8.62	Trongsa	Gelephu	Rank 3	40	-	
S-2	Trongsa	4	**TRP0450050**	8.42	Trongsa	Gelephu	Rank 3	40	Rank 3	0
S-2	Trongsa	4	**TRP0450060**	8.11	Trongsa	Gelephu	Rank 3	40	Rank 3	40
S-2	Trongsa	4	**TRP0450070**	8.07	Trongsa	Gelephu	Rank 1A	100	-	
S-2	Trongsa	4	**TRP0450080**	7.65	Trongsa	Gelephu	Rank 3	14	Rank 3	0
S-2	Trongsa	4	**TRP0450090**	7.25	Trongsa	Gelephu	Rank 3	20	Rank 3	0
S-2	Trongsa	4	**TRP0450100**	7.24	Trongsa	Gelephu	Rank 3	25	-	
S-2	Trongsa	4	**TRP0450110**	7.00	Trongsa	Gelephu	Rank 2	53	Rank 3	0
S-2	Trongsa	4	**TRP0450120**	6.98	Trongsa	Gelephu	Rank 3	40	-	
S-2	Trongsa	4	**TRP0450130**	6.67	Trongsa	Gelephu	Rank 2	74	Rank 3	40
S-2	Trongsa	4	**TRP0450140**	6.33	Trongsa	Gelephu	Rank 3	14	Rank 3	0
S-2	Trongsa	4	**TRP0450150**	6.14	Trongsa	Gelephu	Rank 1B	80	Rank 3	40
S-2	Trongsa	4	**TRP0450160**	6.11	Trongsa	Gelephu	Rank 3	40	-	
S-2	Trongsa	4	**TRP0450170**	6.02	Trongsa	Gelephu	Rank 1A	81	Rank 3	0
S-2	Trongsa	4	**TRP0450180**	5.76	Trongsa	Gelephu	Rank 3	10	Rank 3	0
S-2	Trongsa	4	**TRP0450190**	5.48	Trongsa	Gelephu	Rank 3	36	-	
S-2	Trongsa	4	**TRP0450200**	5.32	Trongsa	Gelephu	Rank 3	38	-	
S-2	Trongsa	4	**TRP0450210**	5.19	Trongsa	Gelephu	Rank 3	24	-	
S-2	Trongsa	4	**TRP0450220**	4.84	Trongsa	Gelephu	Rank 3	33	-	
S-2	Trongsa	4	**TRP0450230**	4.35	Trongsa	Gelephu	Rank 3	32	-	
S-2	Trongsa	4	**TRP0450240**	4.19	Trongsa	Gelephu	Rank 3	34	Rank 3	0
S-2	Trongsa	4	**TRP0450250**	4.04	Trongsa	Gelephu	Rank 3	38	-	
S-2	Trongsa	4	**TRP0450260**	3.88	Trongsa	Gelephu	Rank 2	70	Rank 1B	100
S-2	Trongsa	4	**TRP0450270**	3.63	Trongsa	Gelephu	Rank 2	70	-	
S-2	Trongsa	4	**TRP0450280**	3.46	Trongsa	Gelephu	Rank 1A	100	Rank 2	70
S-2	Trongsa	4	**TRP0450290**	3.43	Trongsa	Gelephu	Rank 1B	90	-	
S-2	Trongsa	4	**TRP0450300**	3.28	Trongsa	Gelephu	Rank 3	20	-	
S-2	Trongsa	4	**TRP0450310**	3.28	Trongsa	Gelephu	Rank 1B	82	Rank 2	70
S-2	Trongsa	4	**TRP0450320**	3.10	Trongsa	Gelephu	Rank 3	18	Rank3	0
S-2	Trongsa	4	**TRP0450330**	3.09	Trongsa	Gelephu	Rank 3	0	-	
S-2	Trongsa	4	**TRP0450340**	2.86	Trongsa	Gelephu	Rank 2	50	Rank 3	0
S-2	Trongsa	4	**TRP0450350**	2.86	Trongsa	Gelephu	Rank 3	25	-	
S-2	Trongsa	4	**TRP0450360**	2.50	Trongsa	Gelephu	Rank 2	70	Rank 3	0
S-2	Trongsa	4	**TRP0450370**	2.50	Trongsa	Gelephu	Rank 3	30	-	
S-2	Trongsa	4	**TRP0450380**	2.31	Trongsa	Gelephu	Rank 2	52	Rank 3	0
S-2	Trongsa	4	**TRP0450390**	2.04	Trongsa	Gelephu	Rank 3	25	-	
S-2	Trongsa	4	**TRP0450400**	2.04	Trongsa	Gelephu	Rank 3	19	Rank 3	0
S-2	Trongsa	4	**TRP0450410**	1.83	Trongsa	Gelephu	Rank 2	52	Rank 3	0
S-2	Trongsa	4	**TRP0450420**	1.70	Trongsa	Gelephu	Rank 2	50	Rank 3	0
S-2	Trongsa	4	**TRP0450430**	1.39	Trongsa	Gelephu	Rank 3	32	-	
S-2	Trongsa	4	**TRP0450440**	1.33	Trongsa	Gelephu	Rank 3	0	-	
S-2	Trongsa	4	**TRP0450450**	1.33	Trongsa	Gelephu	Rank 3	19	Rank 3	0
S-2	Trongsa	4	**TRP0450460**	0.99	Trongsa	Gelephu	Rank 3	38	Rank 3	0
S-2	Trongsa	4	**TRP0450470**	0.97	Trongsa	Gelephu	Rank 1B	70	-	
S-2	Trongsa	4	**TRP0450480**	0.82	Trongsa	Gelephu	Rank 3	0	Rank 3	0
S-2	Trongsa	4	**TRP0450490**	0.81	Trongsa	Gelephu	Rank 1B	90	-	
S-2	Trongsa	4	**TRP0450500**	0.70	Trongsa	Gelephu	Rank 3	38	Rank 3	0
S-2	Trongsa	4	**TRP0450510**	0.68	Trongsa	Gelephu	Rank 3	30	-	
S-2	Trongsa	4	**TRP0450520**	0.36	Trongsa	Gelephu	Rank 3	40	Rank 3	0
S-2	Trongsa	4	**TRP0450530**	0.35	Trongsa	Gelephu	Rank 3	40	-	
S-2	Trongsa	4	**TRP0450540**	0.15	Trongsa	Gelephu	Rank 3	14	Rank 3	0
S-2	Trongsa	4	**TRP0450550**	0.03	Trongsa	Gelephu	Rank 1B	100	-	
S-3	Trongsa	4	**TRP0420010**	82.92	Trongsa	Gelephu	Rank 1A	78	Rank 2	0
S-3	Trongsa	4	**TRP0420020**	82.61	Trongsa	Gelephu	Rank 1A	78	Rank 2	0
S-3	Trongsa	4	**TRP0420030**	82.29	Trongsa	Gelephu	Rank 2	40	Rank 3	0
S-3	Trongsa	4	**TRP0420040**	81.98	Trongsa	Gelephu	Rank 1A	78	Rank 3	0
S-3	Trongsa	4	**TRP0420050**	81.71	Trongsa	Gelephu	Rank 2	88	Rank 3	0
S-3	Trongsa	4	**TRP0420060**	81.50	Trongsa	Gelephu	Rank 2	58	Rank 2	0
S-3	Trongsa	4	**TRP0420070**	81.29	Trongsa	Gelephu	Rank 1A	50	Rank 2	0
S-3	Trongsa	4	**TRP0420080**	80.94	Trongsa	Gelephu	Rank 1A	58	Rank 2	40
S-3	Trongsa	4	**TRP0420090**	80.78	Trongsa	Gelephu	Rank 2	32	Rank 3	0
S-3	Trongsa	4	**TRP0420100**	80.77	Trongsa	Gelephu	Rank 3	30	-	
S-3	Trongsa	4	**TRP0420110**	80.65	Trongsa	Gelephu	Rank 2	32	Rank 3	0
S-3	Trongsa	4	**TRP0420120**	80.63	Trongsa	Gelephu	Rank 3	50	-	
S-3	Trongsa	4	**TRP0420130**	80.22	Trongsa	Gelephu	Rank 1B	70	Rank 1A	40
S-3	Trongsa	4	**TRP0420140**	80.21	Trongsa	Gelephu	Rank 3	100	-	
S-3	Trongsa	4	**TRP0420150**	80.10	Trongsa	Gelephu	Rank 1A	95	-	
S-3	Trongsa	4	**TRP0420160**	79.79	Trongsa	Gelephu	Rank 1A	100	Rank 1A	90
S-3	Trongsa	4	**TRP0420170**	79.72	Trongsa	Gelephu	Rank 3	44	Rank 3	0
S-3	Trongsa	4	**TRP0420180**	79.70	Trongsa	Gelephu	Rank 3	40	-	
S-3	Trongsa	4	**TRP0420190**	79.46	Trongsa	Gelephu	Rank 3	45	Rank 3	0
S-3	Trongsa	4	**TRP0420200**	79.44	Trongsa	Gelephu	Rank 3	40	-	
S-3	Trongsa	4	**TRP0420210**	79.24	Trongsa	Gelephu	Rank 2	40	Rank 3	0
S-3	Trongsa	4	**TRP0420220**	78.87	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	**TRP0420230**	78.85	Trongsa	Gelephu	Rank 2	40	-	

Table 3.5.10 Inspection List (6) (Source: JET)

Basic Information							Final Judgment			
Section	Management Office	Road No.	Management No.	Distance Mark			Judgment & Score			
				km	from	to	Mountain	Score	Valley side	Score
S-3	Trongsa	4	TRP0420240	78.63	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420250	78.36	Trongsa	Gelephu	Rank 3	29	Rank 3	0
S-3	Trongsa	4	TRP0420260	78.35	Trongsa	Gelephu	Rank 3	50	-	
S-3	Trongsa	4	TRP0420270	78.23	Trongsa	Gelephu	Rank 3	44	Rank 3	0
S-3	Trongsa	4	TRP0420280	78.22	Trongsa	Gelephu	Rank 3	25	-	
S-3	Trongsa	4	TRP0420290	77.94	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420300	77.69	Trongsa	Gelephu	Rank 3	11	Rank 3	0
S-3	Trongsa	4	TRP0420310	77.41	Trongsa	Gelephu	Rank 3	11	Rank 3	0
S-3	Trongsa	4	TRP0420320	77.19	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420330	77.17	Trongsa	Gelephu	Rank 3	40	-	
S-3	Trongsa	4	TRP0420340	76.81	Trongsa	Gelephu	Rank 3	20	Rank 3	0
S-3	Trongsa	4	TRP0420350	76.62	Trongsa	Gelephu	Rank 3	18	Rank 3	0
S-3	Trongsa	4	TRP0420360	76.33	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420370	75.93	Trongsa	Gelephu	Rank 3	18	Rank 3	0
S-3	Trongsa	4	TRP0420380	75.67	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420390	75.37	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420400	74.97	Trongsa	Gelephu	Rank 3	20	Rank 3	0
S-3	Trongsa	4	TRP0420410	74.96	Trongsa	Gelephu	Rank 3	30	-	
S-3	Trongsa	4	TRP0420420	74.60	Trongsa	Gelephu	Rank 3	17	Rank 3	0
S-3	Trongsa	4	TRP0420430	74.25	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420440	74.24	Trongsa	Gelephu	Rank 3	50	-	
S-3	Trongsa	4	TRP0420450	74.04	Trongsa	Gelephu	Rank 3	21	Rank 3	0
S-3	Trongsa	4	TRP0420460	73.69	Trongsa	Gelephu	Rank 2	21	Rank 3	0
S-3	Trongsa	4	TRP0420470	73.29	Trongsa	Gelephu	Rank 3	14	Rank 3	0
S-3	Trongsa	4	TRP0420480	73.02	Trongsa	Gelephu	Rank 3	15	Rank 3	0
S-3	Trongsa	4	TRP0420490	73.01	Trongsa	Gelephu	Rank 3	75	-	
S-3	Trongsa	4	TRP0420500	72.80	Trongsa	Gelephu	Rank 3	16	Rank 3	0
S-3	Trongsa	4	TRP0420510	72.50	Trongsa	Gelephu	Rank 3	14	Rank 3	0
S-3	Trongsa	4	TRP0420520	72.19	Trongsa	Gelephu	Rank 3	14	Rank 3	0
S-3	Trongsa	4	TRP0420530	71.85	Trongsa	Gelephu	Rank 3	17	Rank 3	0
S-3	Trongsa	4	TRP0420540	71.84	Trongsa	Gelephu	Rank 3	70	-	
S-3	Trongsa	4	TRP0420550	71.55	Trongsa	Gelephu	Rank 2	70	Rank 2	0
S-3	Trongsa	4	TRP0420560	71.10	Trongsa	Gelephu	Rank 1A	70	Rank 1A	70
S-3	Trongsa	4	TRP0420570	70.74	Trongsa	Gelephu	Rank 2	70	Rank 3	0
S-3	Trongsa	4	TRP0420580	70.73	Trongsa	Gelephu	Rank 2	40	-	
S-3	Trongsa	4	TRP0420590	70.58	Trongsa	Gelephu	Rank 2	70	Rank 3	0
S-3	Trongsa	4	TRP0420600	70.33	Trongsa	Gelephu	Rank 3	24	Rank 3	0

b.1 The Number of the Target Slopes of Each Section

The number of the target slopes of each section is shown in the table below. Section II has the most target slopes (279 slopes), occupying 61.1% of all the 457 slopes. Section I has the second largest number of slopes at 118 slopes, and Section III has the fewest number of slopes at 60 slopes.

Table 3.5.11 The Number of the Target Slope of Each Section (Source: JET)

Section	Number of the Slop	Percentage
Section I	118 slopes	25.8%
Section II	279 slopes	61.1%
Section III	60 slopes	13.1%
Total	457 slopes	100.0%

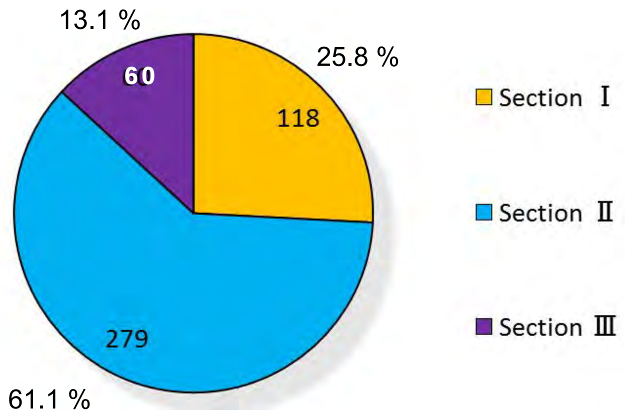


Figure 3.5.12 The Ratio of the Slope Number (Source: JET)

b.2 The Number of Each Slope Disaster Type

The number of each slope disaster type is shown in the table below. Debris slope failures have occurred on the greatest number of slopes, 186, which amounts to 40.7% of the total. Debris flows have occurred on 120 slopes (26.3%) and rock slope failures have occurred on 108 slopes (23.6%). Landslides have occurred on the least number of slopes at 41 slopes and represent 9.4% of the total number of slopes.

Table 3.5.12 The Number of Each Type of Slope Disaster (Source: JET)

Slope Disaster Type	Number of the Slope	Percentage
Debris slope failure	186 slopes	40.7%
Debris flow	120 slopes	26.3%
Rock slope failure	108 slopes	23.6%
Landslide	43 slopes	9.4%
Total	457 slopes	100.0%

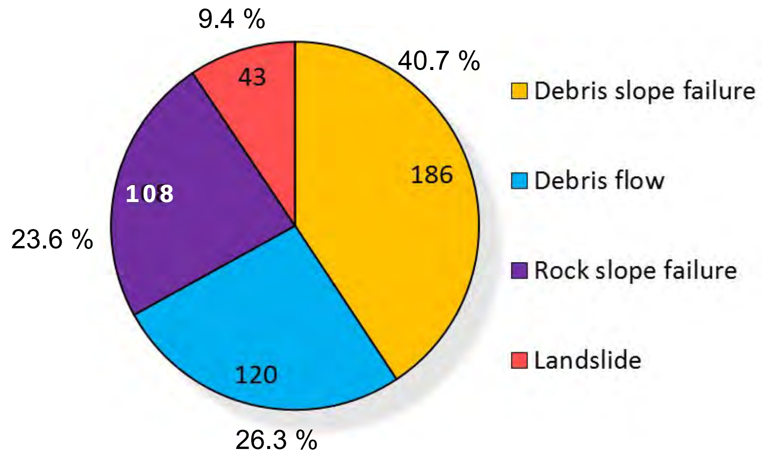


Figure 3.5.13 The Ratio of Each Type of Slope Disaster (Source: JET)

b.3 The Number of Slopes for Each Risk Rank

The number and the ratio of risk rank for slope disaster are shown in the table below. Rank 1 (countermeasure works are necessary) accounts for 13.7%, with a total of 63 slopes, and the ratio of Rank 1A (Technical assistance is needed) to Rank 1B (Technology in Bhutan is available) is 29:34.

Table 3.5.13 The Number of Each Risk Rank (Source: JET)

Risk Rank	Number of Slopes		Percentage	
Rank 1A	29 slopes	Total 63 slopes	6.3%	Total 13.7%
Rank 1B	34 slopes		7.4%	
Rank 2	145 slopes		31.7%	
Rank 3	249 slopes		54.5%	
Total	457 slopes		100.0%	

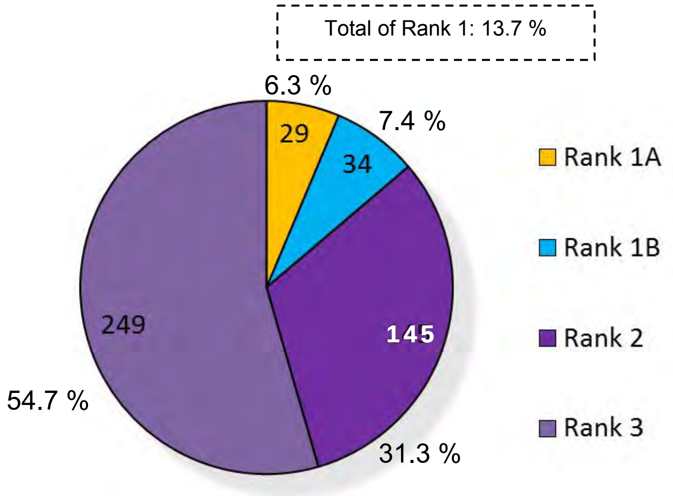


Figure 3.5.14 The Ratio of the Risk Rank (Source: JET)

b.4 The Number of Each Slope Disaster Type in Risk Rank

The Number of Slope Disaster Type in each Risk Rank is shown in the table below. Regarding Rank1A and Rank1B (needing the enforcement of the countermeasure), rock slope failures have occurred on the highest number of slopes for all disaster types at 35 slopes. Debris slope failures have occurred on 13 slopes, and debris flow (8 slopes) and landslide (7 slopes) disasters have occurred on much fewer slopes.

Table 3.5.14 The Number of Each Slope Disaster Type in Each Risk Rank (Source: JET)

Slope Disaster Type	Number of the Slop				
	Rank 1A	Rank 1B	(Total of Rank 1)	Rank 2	Rank 3
Debris slope failure	7	6	(13)	53	120
Debris flow	2	6	(8)	39	73
Rock slope failure	18	17	(35)	41	32
Landslide	2	5	(7)	12	24

b.5 The Number of Each Section in Risk Rank

The number of slopes in each section of disaster type is shown in the table below. Regarding Rank1A and Rank1B (needing the enforcement of the countermeasure), Section II has the highest number of slopes of all sections at 36 slopes. Section I has 18 slopes, and Section III has even fewer slopes with 9 slopes.

Table 3.5.15 The Number of Each Section in Risk Rank (Source: JET)

Section	Number of the slope				
	Rank 1A	Rank 1B	(Total of Rank 1)	Rank 2	Rank 3
Section I	6	12	(18)	55	45
Section II	14	22	(36)	78	165
Section III	9	0	(9)	12	39

b.6 Score of the Evaluation Sheet in Each Risk Rank

In this project, based on the result of the hazard analysis in road slope disaster, the new evaluation sheet (4.1 in Chapter 4) for inspection in Bhutan was proposed by JET. The scoring of the new evaluation sheet has been adjusted, with 100 points as the maximum.

The score range of the evaluation sheet in each disaster type/rank is as follows.

Table 3.5.16 The Score of the Evaluation Sheet in Each Disaster Type/Rank (Mountain side) (Source: JET)

Score range	Frequency - Mountain side											
	Debris slope failure			Rock slope failure			Debris flow			Landslide		
	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3
- 10	0	0	14	0	0	2	0	0	8	0	0	2
11 – 20	0	0	36	0	0	3	0	0	3	0	0	2
21 – 30	0	6	36	0	0	9	0	2	23	0	1	7
31 – 40	1	19	35	0	5	14	0	7	23	0	2	12
41 – 50	3	5	4	1	5	6	1	13	13	0	4	3
51 – 60	1	5	0	2	11	0	0	1	0	0	1	0
61 – 70	1	16	0	7	9	1	1	12	1	0	1	0
71 – 80	2	0	0	8	7	0	0	4	1	1	3	0
81 – 90	0	0	0	9	1	0	3	0	0	1	0	0
91 – 100	2	0	0	8	0	0	3	0	1	3	0	0
Total	*10*	*51*	*125*	*35*	*38*	*35*	*8*	*39*	*73*	*5*	*12*	*26*

Table 3.5.17 The Score of the Evaluation Sheet in Each Disaster Type/Rank (Valley side)
(Source: JET)

Score range	Frequency - Valley side					
	Debris slope failure			Rock slope failure		
	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3
- 10	0	11	207	0	5	26
11 - 20	0	0	0	0	0	0
21 - 30	0	0	0	0	0	0
31 - 40	0	2	6	1	10	4
41 - 50	0	0	0	0	0	0
51 - 60	0	0	0	0	0	0
61 - 70	0	7	0	1	7	0
71 - 80	0	0	0	0	0	0
81 - 90	1	0	0	1	0	0
91 - 100	5	0	0	1	0	0
Total	*6*	*20*	*213*	*4*	*22*	*30*

3.6 Geological Investigation

3.6.1 Summary and Results

Generally, the purpose of geological investigation has many points. This includes deciding the design parameters for subsequent construction phases by giving detailed geological information using investigation tools. Geological investigation in the road construction especially contributes to the decision making of whether the planned routes will be appropriate to the natural conditions on site.

Therefore, in this Project, the geological investigation was implemented as a show-case of the standardized methodology adopted in Japan according to the above concept. The following items listed below are part of the geological investigation, and were accomplished on each selected site, Site 1 (Thumang Cliff) and Site 2 (Bangla Pokto). The subsurface investigations were to be carried out to obtain geological information below the natural ground in the Project area. The results were obtained based on the plane map (topographical map) prepared by the topographical survey before the geological investigation was implemented.

- Subsurface investigations (core drilling)
- Standard Penetration Test (SPT)
- Ground water measurement
- Collection of undisturbed (UD) samples
- Laboratory investigations
- Geophysical investigations (seismic exploration)

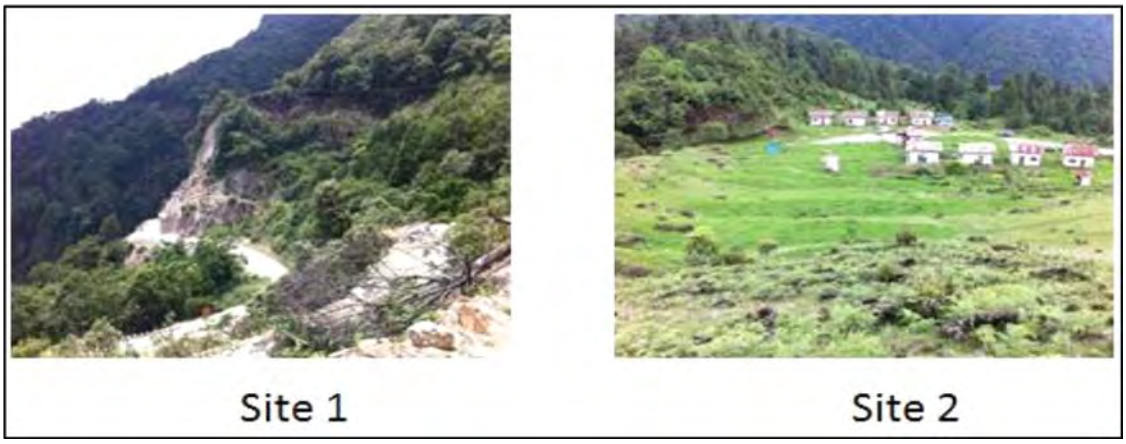


Figure 3.6.1 Overview of each site (Site 1: Thumang Cliff, Site 2: Bangla Pokto)
(Source JET)

Thumang Cliff, Site 1, was selected as the representative site for investigations in “landslide” areas, which were categorized according to the classification system used in this Project. Bangla Pokto, Site 2, was designated as the representative site for investigations in “Rock Slope Failure” areas, which were categorized according to the classification system used in this Project. Each item and volume included in each investigation activity is presented in Table 3.6.1. Both investigation activities include the survey (Topographical Mapping), Geophysics (Elastic Wave Exploration) and Drilling (Boring).

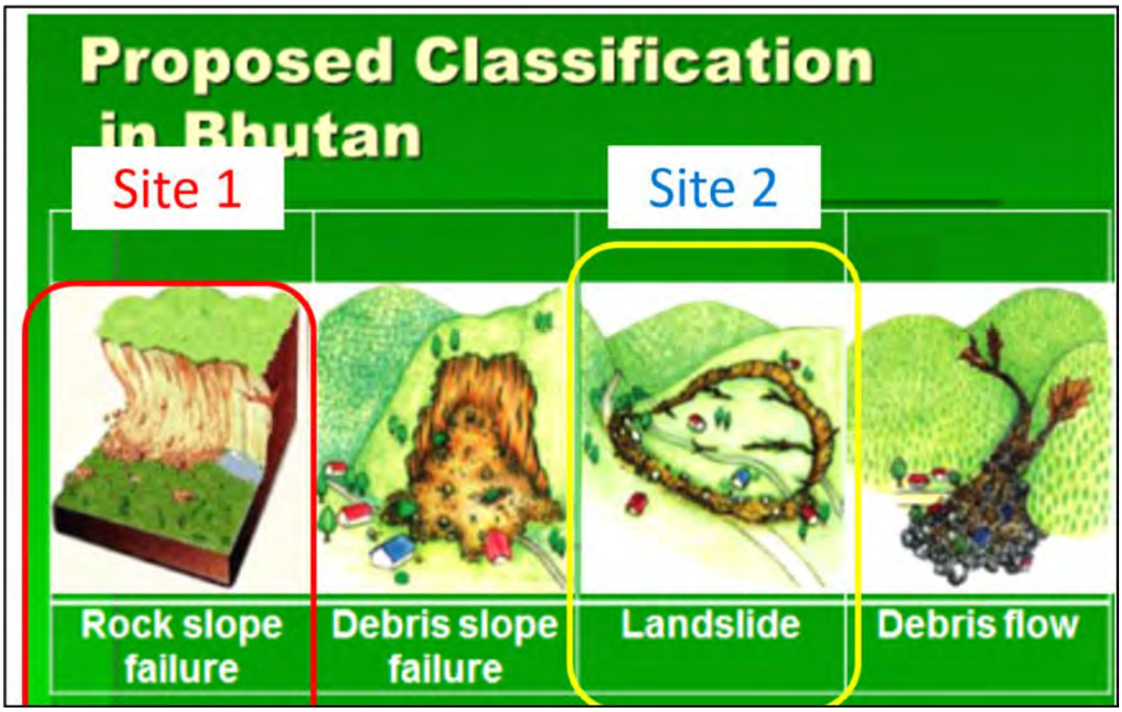


Figure 3.6.2 Classification system proposed in this Project (Source JET)

Table 3.6.1 Classification system proposed in this Project (Source JET)

Category	Sub-Category	Slope No1	Slope No2	Total
Place/Site		Thumang Cliff	Bangla Pokto	
Survey Measuring	Plane	200m by 200m	300 m by 200m	100,000 m²
	Cross-sectional	200m × 3 section	300m × 1 section	900m
Drilling	Core Drilling	60m, 50m, 50m (160m in total)	25m, 25m (50m in total)	210m
	Laboratory	3 samples	3 samples	6 samples
Geophysical	Elastic Wave Exploration	200m × 3 section	300m × 1 section	900m

The results of each investigation are described briefly below and detailed in the Appendix and Attachment.

As for the results obtained from the investigation implemented in Site 1, the sub-surface condition is clarified as follows:

- The topography map gives the assumption that the area designated for the investigation (lined by the cross section marked with SRT-1, 2 and 3) has contours that are characteristic of the morphology of some talus deposits with its contours slightly disturbed (Figure 3.6.3).

- The elastic wave exploration results show that the area has a relative thin layer of overburden with a low velocity. This means that the underlying bed-rock can be judged to be observed at a relatively shallow level.

- The correlation between the elastic wave profile and bored core observation shows that potential movement layer is shallow and is overlaying the bedrock (Figure 3.6.4).

- The area above the site is the catchment area for rain, so the surface underground water will penetrate and flow in the overburden (overlying) layer. This means that some kind of water drainage works will be advisable for the safety of the slope (Figure 3.6.5).

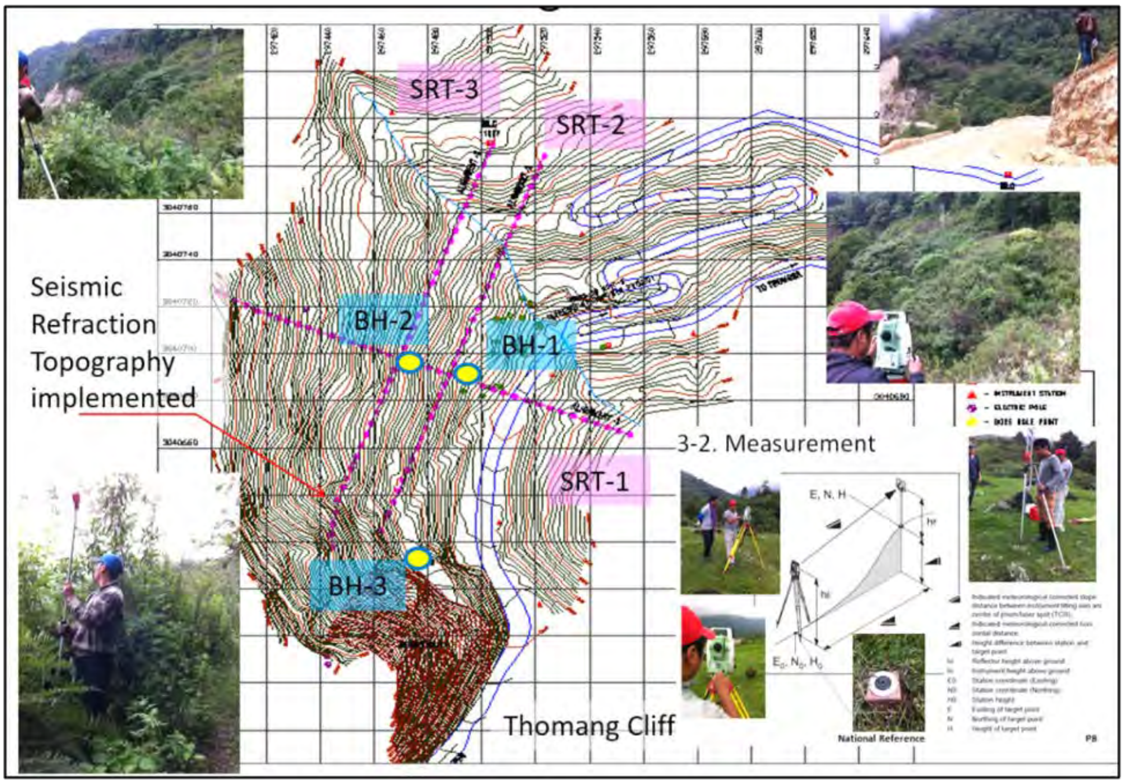


Figure 3.6.3 Topography of the Site 1 (Source JET)

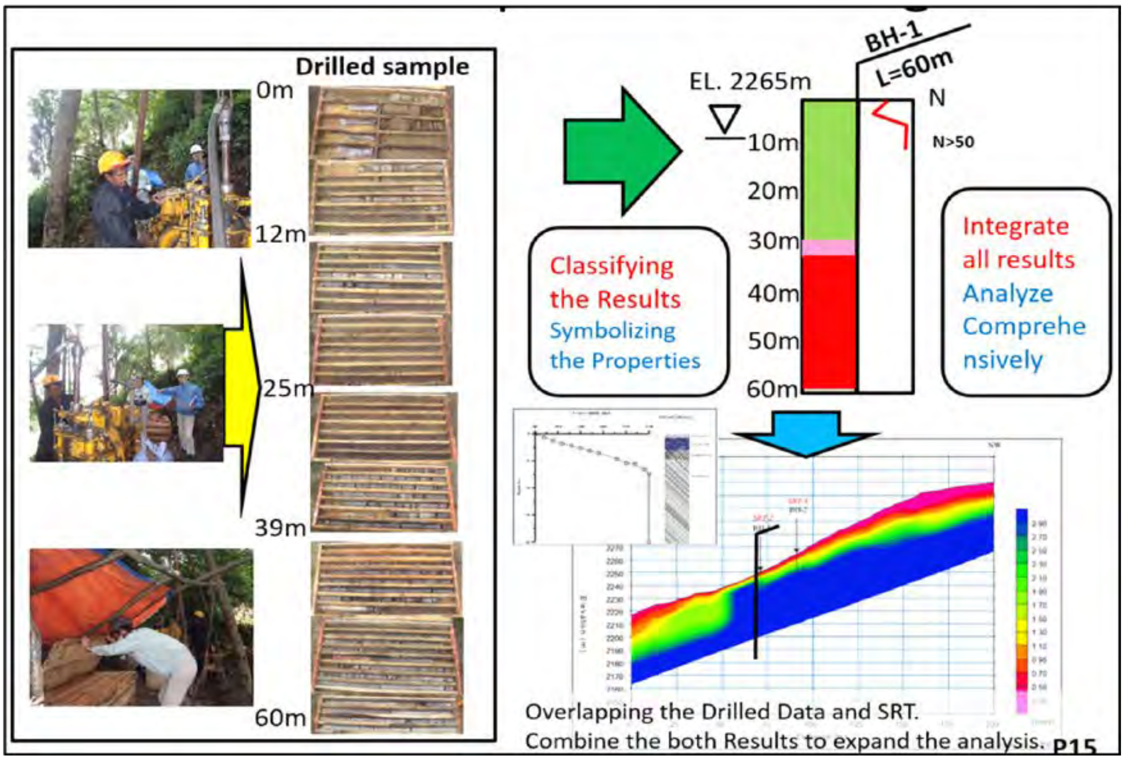


Figure 3.6.4 Comparison between the boring results and elastic wave exploration at site1 (Source JET)

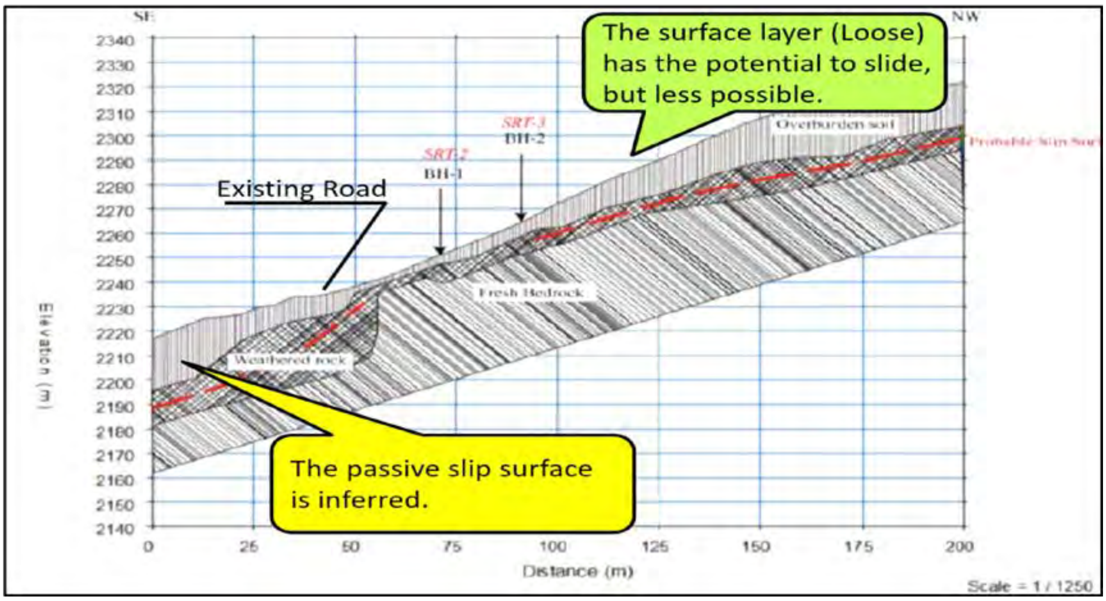


Figure 3.6.5 Geological cross section along the SRT-1 in Figure.3.6.1 (Source: JET)

As for the results obtained from the investigation implemented at Site 2, the sub-surface condition is clarified as follows:

➢ Analysis of the topographic map revealed several surface slip-like morphologies above and below the current road, which, therefore, have the potential to jeopardise the sustainability of the road (Figure 3.6.6).

- The elastic wave exploration results showed that the loosened layer that could be judged as the landslide mass, with its low traveling velocity of the seismic wave, is situated in the shallower area from the ground surface with a maximum depth of 5 m on both sides of (above and below) the road Figure 3.6.7).

- The observation of the boring core retrieved from the drilling supported the above idea that the potential mass movement layer is underlain by the subsequent bedrock of weathered gneiss (Figure 3.6.8 and Figure 3.6.9).

The effects from these observed landslide mass movements toward the current road can be considered to be minimal when the landslide scale (size, volume and inclination) is taken into account.

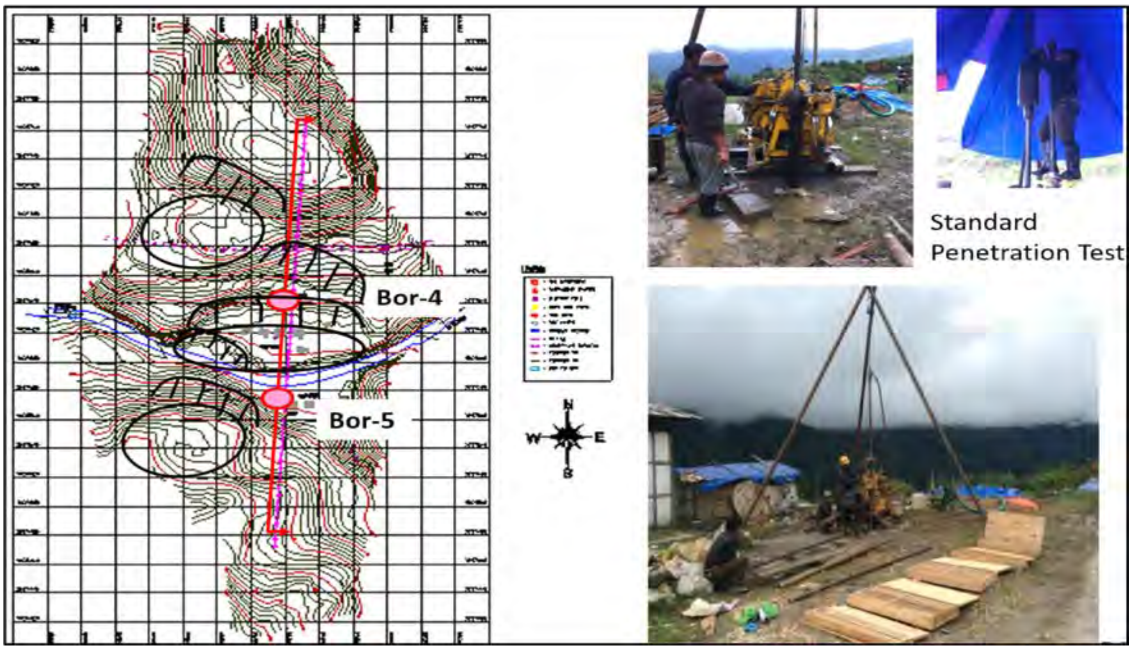


Figure 3.6.6 Topography and boring activity at Site 2 (Source JET)

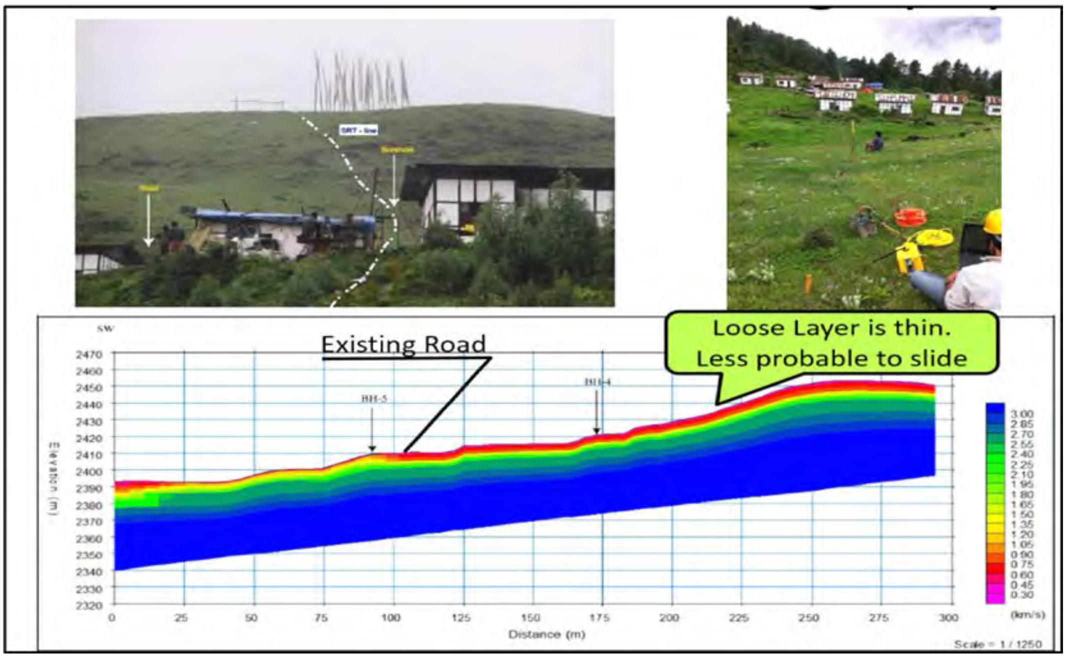


Figure 3.6.7 Elastic wave exploration (Seismic Refraction Tomography) at Site 2 (Source JET)

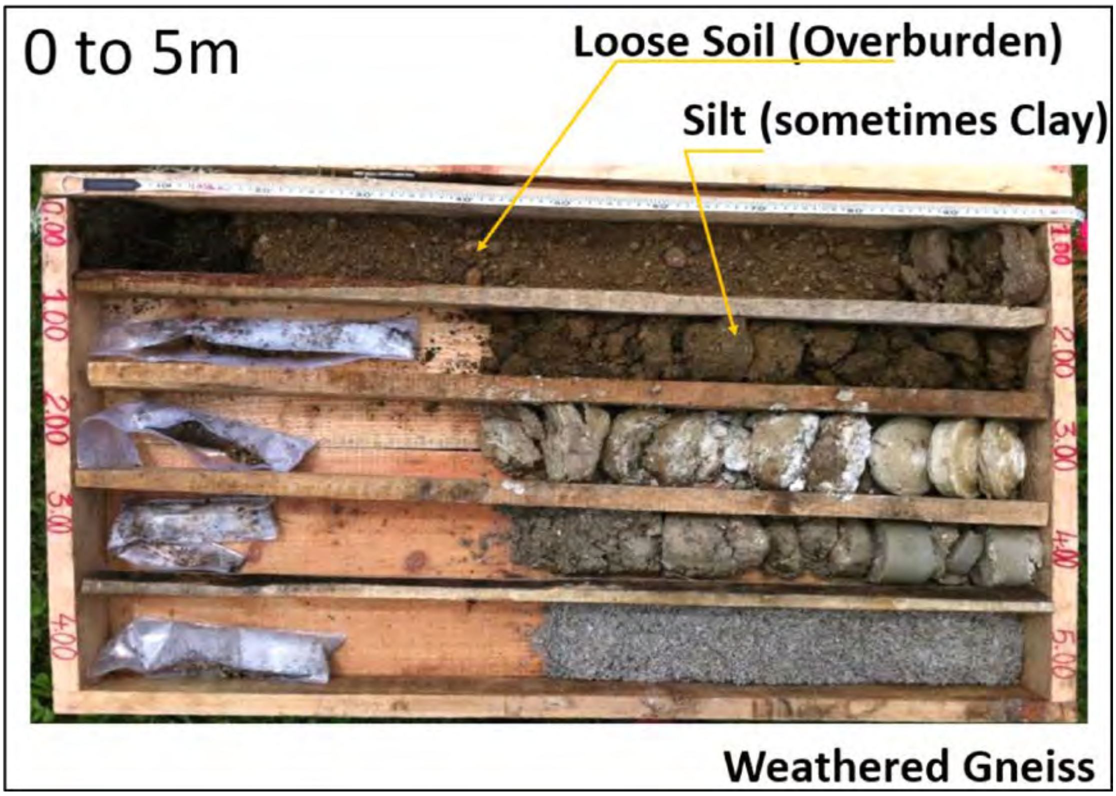


Figure 3.6.8 Drilled core at BH-4 at Site 2 (Source JET)

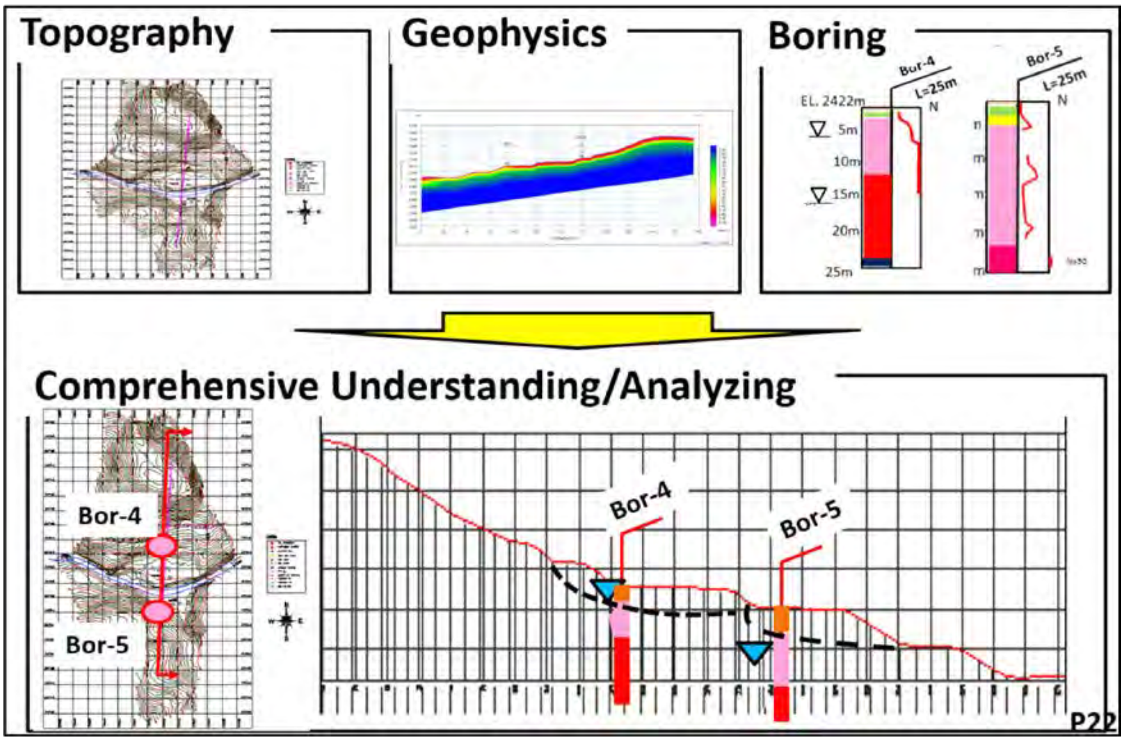


Figure 3.6.9 Organized geological cross section at Site 2 (Source JET)

The geological investigation will provide technical information to reduce the uncertainty the road planner will face in the course of road development. For example, in the case of a "landslide" area, the road planner can select the appropriate countermeasure in relation with efficient route selection based on the obtained data from the results of geological investigation, as below (Figure 3.6.10).

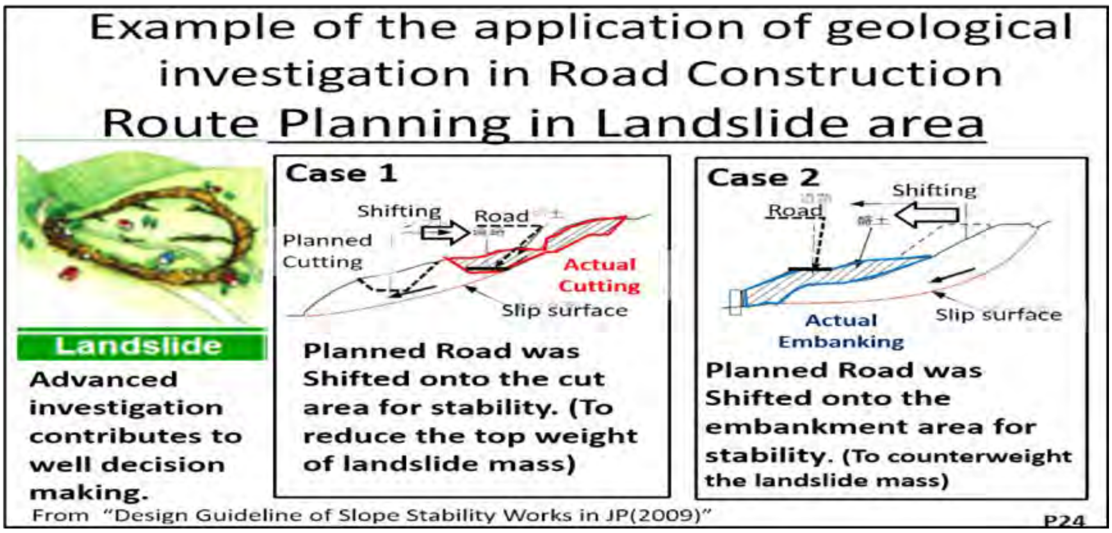


Figure 3.6.10 One Example of contribution from the geological investigation (Source JET)

3.7 Topographic Analysis

3.7.1 Development of Road Base Map using Existing Data

The topographic map and ortho-photo map based on satellite imagery in the southern part of Bhutan (9,870 km^2) have been developed by the technical corporation for the “Project on Establishment of National Geo-Spatial Data Infrastructure for Bhutan” from February 2015 to July 2016. The topographic map will be available from September 2017 (only the project area of the southern part of Bhutan is available). Also in recent years, the development of map and GIS data sharing with relative organization are progressing through the Center for GIS Co-ordination (CGISC) activities.

The road information under the jurisdiction of DoR has been updated every few years for the new road construction and the progress of upgrade. However, a road base map, which is updated based on the latest road information, has not been developed yet. This Project conducted the topographic analysis using the existing satellite data and integrated these to the road base map, based on various types of information such as the latest road alignment, boundary, facilities, etc.

This Project provides a road base map including each Dzongkhag and a 10,000 scale map along the major roads (Asian Highway and Primary Highway). The targets are used to make the 10,000 scale map, and have been selected based on the priority of grid which was created for each Dzongkhag (referred as Figure 3.7.1 therefore the grid including "Level 1" is selected as a target area.

According to this selection process, Gasa and Yangtse Dzongkhag do not qualify as “Level 1”, which is the target classification of grid to make the map. Therefore, these are subsequently categorized as “Level 2”, which is included in the target area. The total area of the road base map is around 7,158 km^2 and that will cover 18% of the entire land of Bhutan. The cover area and amount of the grid for road base maps are shown in Figure 3.7.2 and Table 3.7.1.

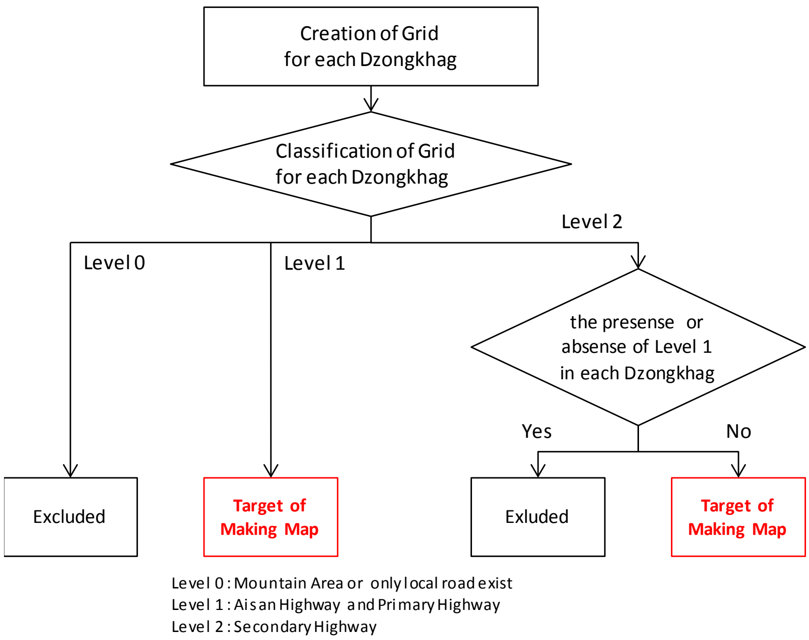


Figure 3.7.1 Flow of Selection of Target Area (Source: JET)

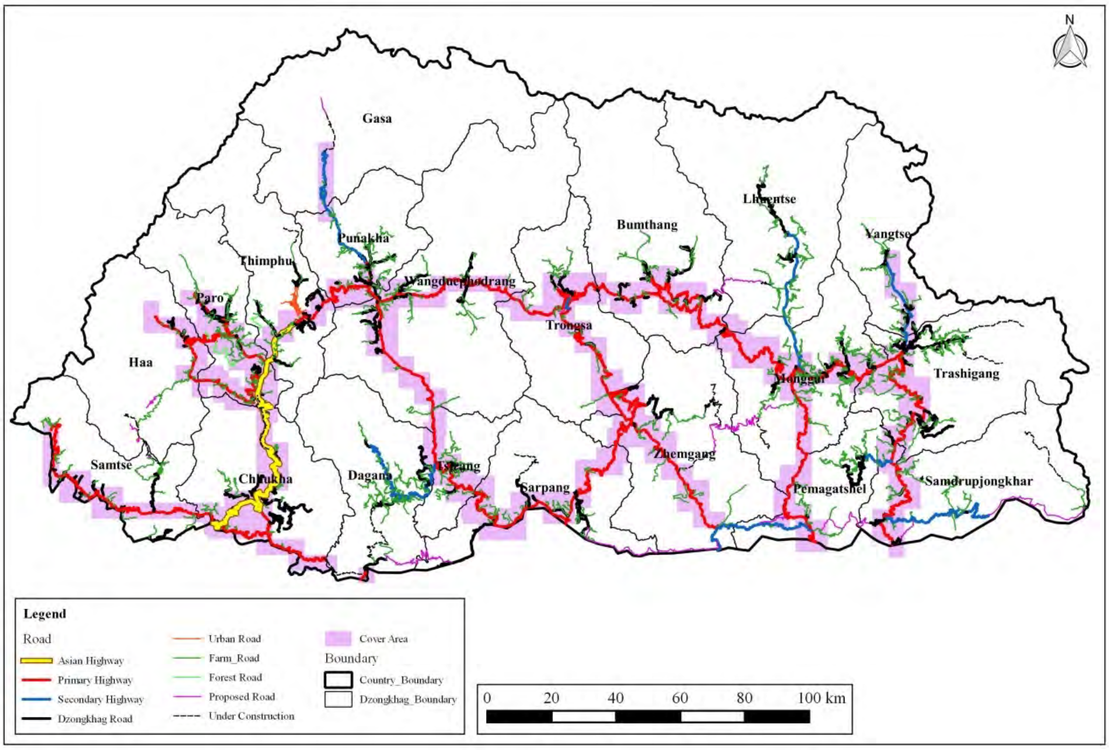


Figure 3.7.2 Cover Area of the Road Base Map (Source: JET)

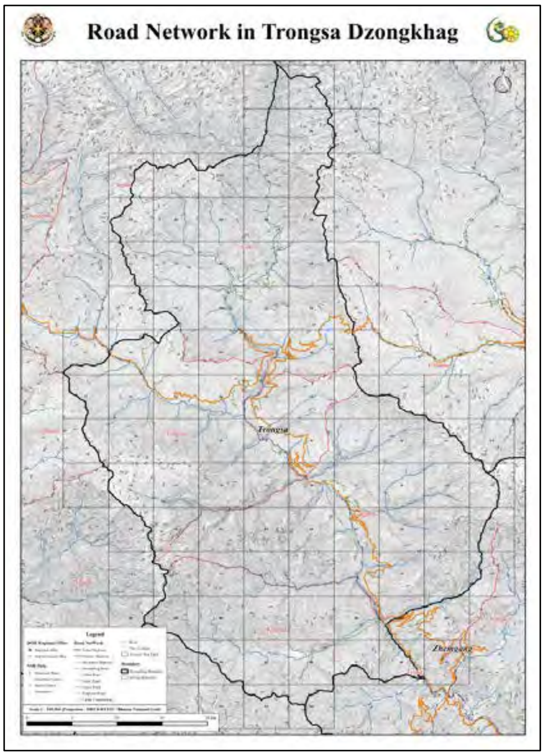
Table 3.7.1 Amount of the Grid for Road Base Maps (Source: JET)

No	Dzongkhag	Scale of Dzongkhag's Map	Amount of the Grid including each Level (Scale 1:10,000)			
			Data Source	Level 0	Level 1	Level 2
1	Bumthang	100,000	PRISM-DSM	119	**19**	0
2	Chhukha	100,000	PRISM-DSM	72	**32**	0
3	Dagana	100,000	PRISM-DSM	77	**4**	10
4	Gasa	100,000	SRTM	158	0	**5**
5	Haa	100,000	PRISM-DSM	86	**12**	0
6	Lhuentse	100,000	SRTM	135	**2**	8
7	Monggar	100,000	SRTM	68	**32**	4
8	Paro	100,000	SRTM	51	**23**	0
9	Pemagatshel	100,000	SRTM	38	**15**	6
10	Punakha	75,000	SRTM	49	**9**	7
11	Samdrupjonghar	100,000	SRTM	78	**11**	9
12	Samtse	100,000	SRTM	60	**19**	0
13	Sarpang	100,000	SRTM	75	**24**	0
14	Thimphu	100,000	PRISM-DSM	94	**13**	0
15	Treshigang	100,000	SRTM	97	**20**	1
16	Trongsa	100,000	SRTM	73	**26**	0
17	Tsirang	75,000	PRISM-DSM	24	**12**	2
18	Wanduephodrang	150,000	SRTM	181	**29**	0
19	Trashi Yangtse	100,000	SRTM	73	0	**7**
20	Zhemgang	100,000	SRTM	91	**28**	6
Total				1699	330	65
Amount of the Grid for Road Base Maps (Total of the bold character numbers)					**342**	

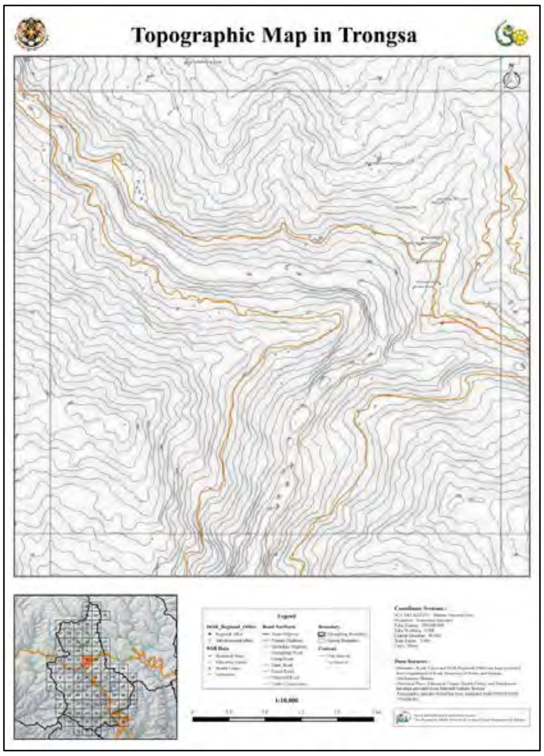
PRISM-DSM and SRTM version 3.0 (Shuttle Radar Topography Mission, 30 m resolution), which is provided free of charge by NASA, have been used for topographic analysis. It is better to apply PRSIM-DSM which has higher resolution to all of the areas. However, some errors have been confirmed at the eastern and southern parts of Bhutan. Therefore, those areas are complemented by SRTM and the various types of data collected from relative organizations during this Project. After necessary additions and editing, these data are integrated into the road base map. The collected data from DoR and relevant organizations is shown in Table 3.7.2. The road base map is shown in Figure 3.7.3. Also, these created maps were distributed to the regional DoR office.

Table 3.7.2 List of Collected Data for the Road Base Map (Source: JET)

No	Item	Data Format	Data Resources
1	PRISM-DSM	Raster	DGM
2	SRTM	Raster	NASA
3	Dzongkhag Boundary	Polygon	DoR
4	Gewog Boundary	Polygon	DoR
5	Road Network	Polyline	DoR
6	Settlement	Point	NSB
7	Historical Place	Point	NSB
8	Health Center	Point	NSB
9	Education Center	Point	NSB
10	DoR Regional Office	Point	DoR



Road Network in Trongsa Dzongkhag



Road Base Map at Section 2 (1/10,000 Scale)

Figure 3.7.3 Sample of the Road Base Map (Source: JET)

The topographic analysis and utilization of existing data using QGIS have been implemented through the OJT. The difficulty in conducting the OJT was taken into account for all of the work group members, including the regional office, and this led to the selection of three staff members who work in the DoR head office for the OJT. At first, technical transfer related to GIS and topographic analysis was carried out to those three staff members, then a technical seminar and workshop was held for promoting the dissemination of techniques to other DoR staff members. As mentioned in 2.6, the operations of GIS software and the method of topographic analysis, which are required to develop the topographic map, have been conducted through the OJT.

DoR generally uses Google Earth for their work on the confirmation of road alignment and disaster risk area, checking the current conditions. The usage of GIS data in Google Earth was introduced and practiced through the OJT and seminar because GIS data has good compatibility with Google Earth.

OJT Training

Technical Seminar in Thimphu

Technical Seminar in Thimphu

Discussion for the Road Base Map

Figure 3.7.4 Technical Transfer of the GIS Techniques (Source: JET)

3.7.2 Developing the Detailed Topographic Map

The satellite data such as PRISM-DSM and SRTM, which have constant accuracy, is useful data for developing a broad range of the road base map. On the other hand, the training for creating detailed topographic map conducted to use photo image from the opposite side. The project provided 3D analysis software (PhotoScan Pro, Agisoft LLC) for the photo mapping. The process of developing the detailed topographic map is shown in Figure 3.7.5.

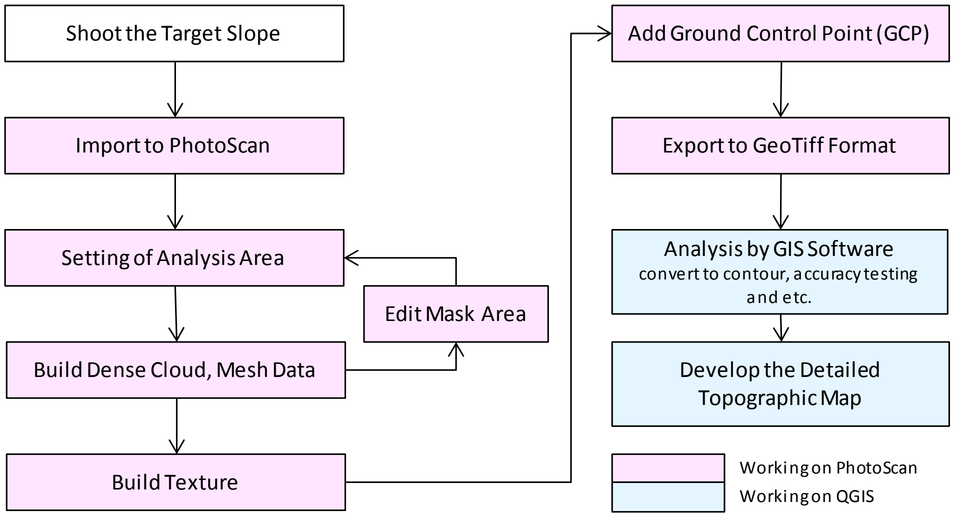


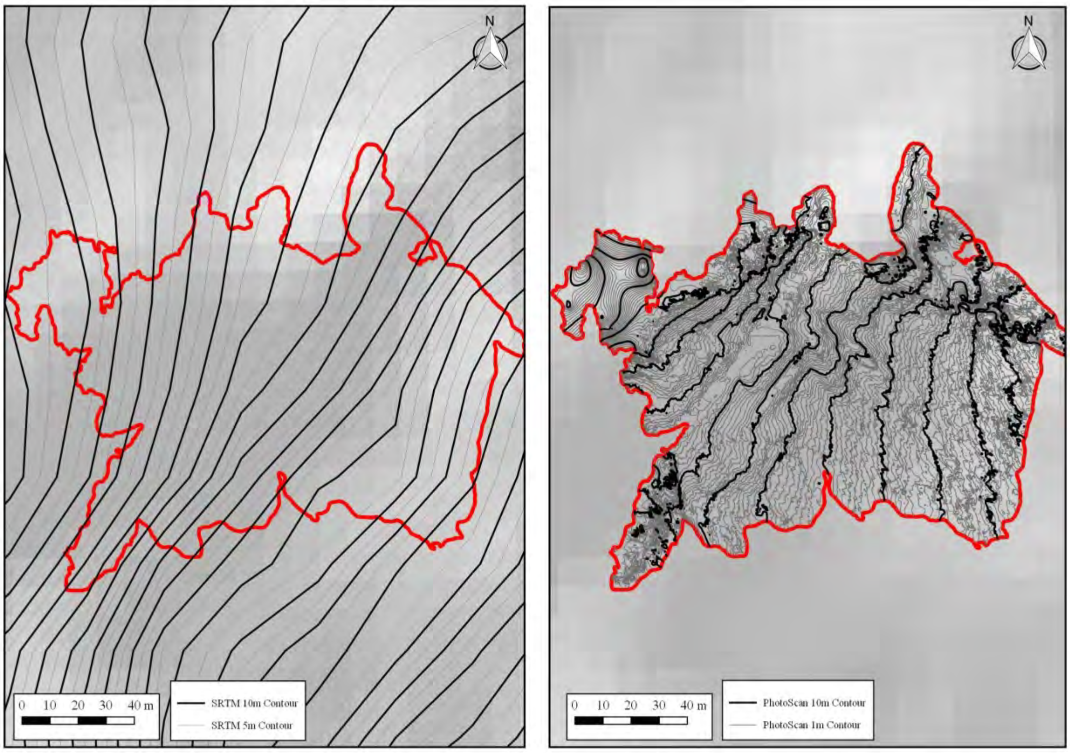
Figure 3.7.5 Process of Developing the Detailed Topographic Map (Source: JET)

Topographic analysis by PhotoScan enables to do high accuracy analysis. However, the analysis area is not so large and the calculation time depends on the computer specifications. For this reason, this method is mostly applied to collect the topographic information in a limited area or grasp actual conditions through brief data acquisition (photo shoot on the site). Accordingly, this Project was also subjected to slopes which are concerned with landslides, and the technical transfer was conducted for use as reference information when landslides occur.

When this method is applied to the road slope management, the following conditions are recommended to obtain good data:

- To be available to shoot the photo from good visibility from the opposite side
- Elevation of the photography spot is higher than the target slope
- The vegetation of the target slope is less, etc.

For the above, an understanding of the good and bad points of each data is important to select the data for different purposes. Advanced operation of GIS software is necessary to develop a detailed topographic map so that these processes also improve the GIS skills of the staff members. DoR activity like monitoring and grasping the conditions before and after the landslide are expected to be applied. And this method can contribute to the safety of the survey because it doesn’t require entering disaster risk areas.



Existing satellite data: SRTM　　　　Detailed data: Photo Scan

Figure 3.7.6 Comparison of Data Source of Topographic Analysis (Source: JET)

3.8 Infrastructure Development in Bhutan

3.8.1 Organization and System of the MoWHS

a. Background of the MoWHS

The Royal Government of Bhutan (GoB) has placed a strong emphasis on infrastructure development such as construction of buildings, roads, bridges, water supply and irrigation canals since the 1960s. The government has recognized the need for more and better infrastructure facilities to further economic growth. This was evident, when in 1961 it established Bhutan's first organization specifically focused on construction (infrastructure, public works), Bhutan Engineering Services. The chronology of organizational reform relevant to MoWHS is shown in Table 3.8.1.

Table 3.8.1 Chronology of Organizational Reform (Source: MoWHS Bhutan)

Year	Event
1961	**Bhutan Engineering Services** established. Responsible for construction of public infrastructure.
1966	Bhutan Engineering Services renamed as the **Public Works Department (PWD)**. PWD responsible for rural and urban infrastructure construction and management. Initially under the **Ministry of Development**, then under the **Ministry of Social Services** and later under the **Ministry of Communications**.
1999	Ministries restructured: Royal Government of Bhutan restructuring 'Enhancing Good Governance – Promoting Efficiency, Transparency and Accountability'.
2003	**Ministry of Works and Human Settlement** established (following ministry restructuring).

b. Organogram of the MoWHS

The MoWHS was established in 2003 as part of the GoB's restructuring effort: *Enhancing Good Governance: Promoting Efficiency, Transparency and Accountability*. It has three main technical departments as well as corporations and authorities, as follows:

<Main technical departments>

- Department of Roads
- Department of Urban Development and Engineering Services
- Department of Human Settlement

<Corporations and Authorities>

- Construction Development Board (CDB)
- National Housing Development Corporation (NHDC)
- Phuentsholing City Corporation (PCC)
- Thimphu City Corporation (TCC)

The figure below is an organogram of the MoWHS.

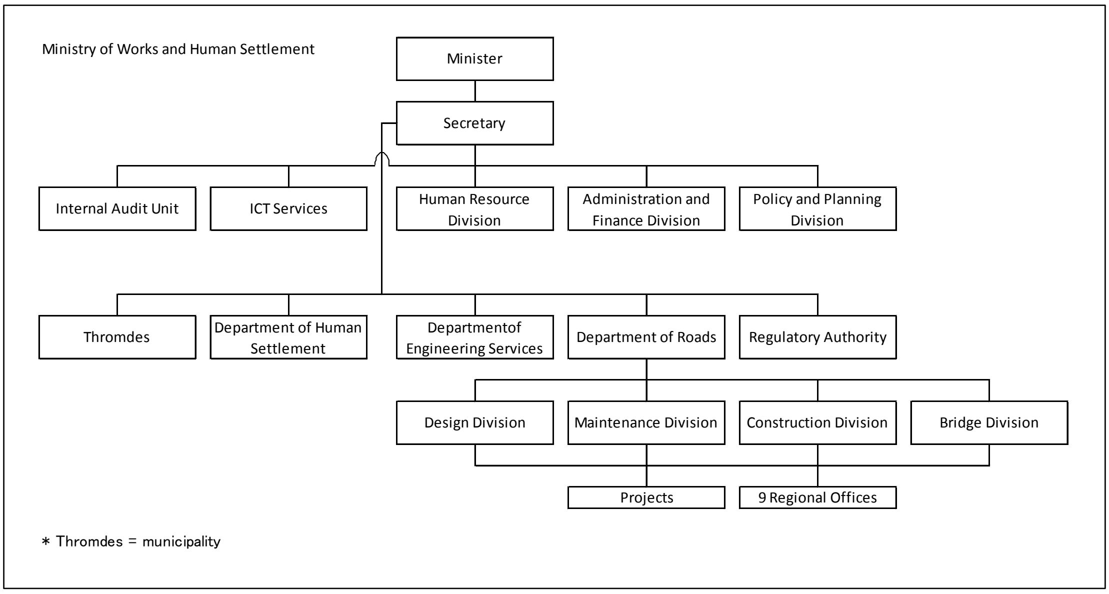


Figure 3.8.1 Organogram of the MoWHS (Source: MoWHS Bhutan)

c. Vision, Mission and Strategy of the MoWHS

The MoWHS defines its vision, mission and strategy as follows:

- Vision: A leading organization in the region in infrastructure development for human settlement and transportation
- Mission: To provide safe, reliable and sustainable infrastructure for human settlement and transportation leading towards a balanced regional development embodying the Bhutanese values
- Strategy: Development of a dynamic and highly motivated technical workforce

d. Function of the MoWHS

The MoWHS has the following functions:

- <u>Policies and plans</u>: Formulate policies and develop plans related to physical infrastructures;
- <u>Acts/regulations/standards</u>: Develop and implement acts/regulations/standards related to physical infrastructures;
- <u>Technical human resources</u>: Engage in and coordinate capacity building of technical human resources;
- <u>Construction industry management</u>: Set policies to promote a competent construction industry;
- <u>Research</u>: Promote research that will serve to maintain a synergy among technology,

environment and traditional values; and

- Human settlement: Develop plans and policies for proper human settlement through growth centers

3.8.2 Organization and System of the DoR

a. Background of the DoR

The GoB has pursued road development and has expanded the large networks of roads in the past several decades. Consequently, the department which is responsible for road construction has a long history in Bhutan. The concept of a separate institution was established in 1959 as the Bhutan Road Project, which was mandated to conduct the reconnaissance survey (feasibility study) for the Phuentsholing-Thimphu Highway. The Bhutan Road Project was renamed Bhutan Engineering Services in 1961 with a mandate to design and construct infrastructure, starting with the aforementioned highway. The organization was again renamed as the Public Works Department and then again as the DoR. Today, the DoR is one of the main technical departments under the Ministry of Works and Human Settlement.

b. Vision and Missions of the DoR

Vision and missions of the DoR are defined as follows:

- Vision: A professional and regulatory organization, competent and committed to enabling provision of road infrastructure that is adequate, efficient, reliable and safe
- Missions:
    - Up-grade, construct and maintain the national highways and roads
    - Ensure that more than 85 per cent of the population live within half a day's walk from the nearest motorable road by 2020
    - Capacity building of the employees
    - Improve construction/maintenance methodologies and quality
    - Introduce environmentally friendly and climate resilient techniques for road construction

c. Organogram of the DoR

The DoR has four divisions; Design Division, Maintenance Division, Construction Division and Bridge Division.

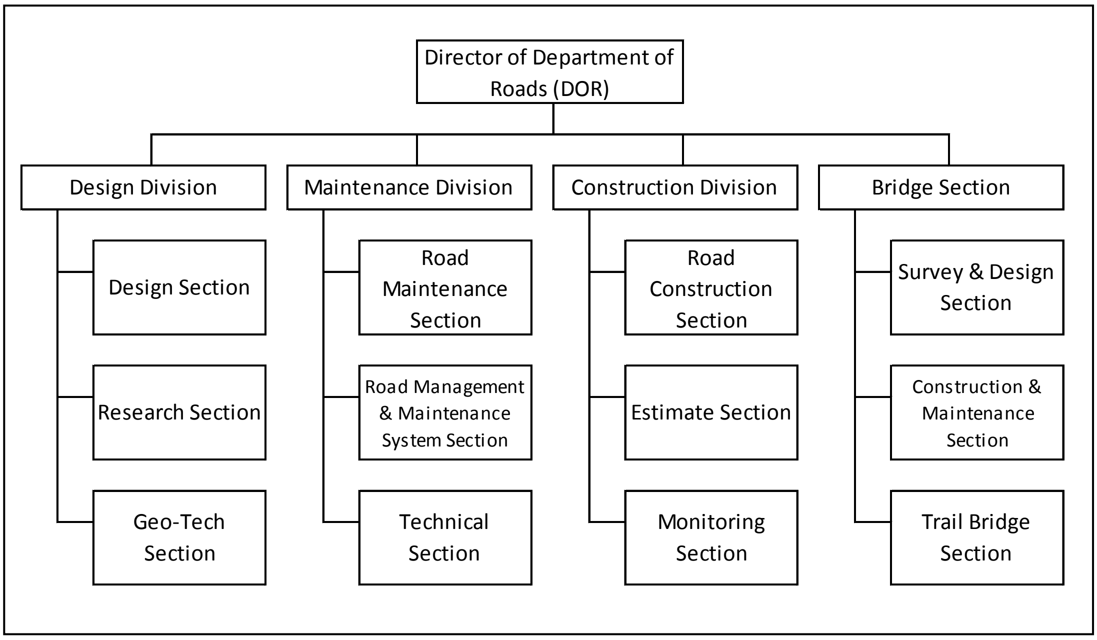


Figure 3.8.2 Organogram of the DoR (Source: DoR-MoWHS Bhutan)

The main tasks of each division and the number of staff are summarized below.

Table 3.8.2 Main tasks and staff number in each division (Source: DoR-MoWHS Bhutan)

Division	Main tasks	Engineer
Bridge Division	• Planning/design/construction supervision of bridge • Maintenance of existing bridges • Support of RO	8
Design Division	• Design of roads • Support of RO	5
Construction Division	• Construction of new roads and bridges • Support of RO	7
Maintenance Division	• Maintenance of existing roads • Slope management • Support of RO	6

d. GIS under the DoR

GIS has not been considered a main priority and there has been no engineer assigned to GIS in the DoR. However, the DoR has now realized the importance of GIS because of this JICA Project. The DoR has prioritized GIS work and has assigned one engineer to develop the digital road map of Gewog Road and define the locations of four types of landslides on the map for the whole area of Bhutan.

f. Foreign Support for the DoR

Apart from JICA's project, there have been no slope management projects supported by either foreign countries or international organizations. Rather, foreign countries and international organizations have supported construction or improvement of roads.

3.9 Road Maintenance in Bhutan

3.9.1 Maintenance Works under the DoR

As mentioned in the Table 3.8.2, the main tasks of the maintenance division are maintenance of the existing roads and bridges, slope management and support of the regional office (RO). The engineers in the maintenance section provide both monitoring for the regional offices and give technical advice to RO engineers.

The maintenance division is sub-divided into three sections; Road Maintenance Section, Bridge Maintenance Section, and Road Management and Maintenance System Section (RMMS).

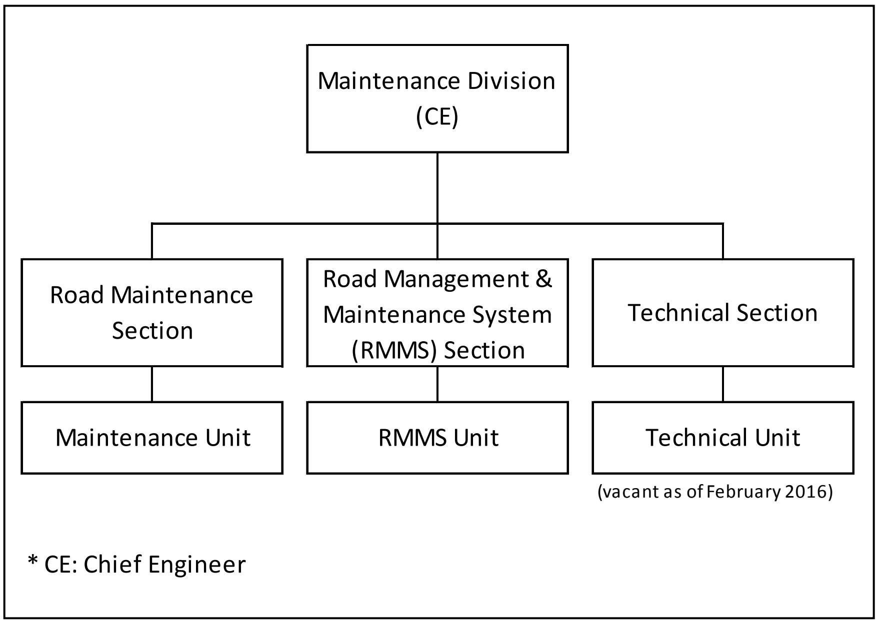


Figure 3.9.1 Organogram of the Maintenance Division (Source: DoR-MoWHS Bhutan)

The DoR controls most of the roads except some parts of Farm Road in Bhutan. Table 3.9.1 shows the road network in Bhutan by category, the length and per cent of each road type. Table 3.9.2 shows the annual changes of road length by category.

Table 3.9.1 Road Network by Category as of June 2015 (Source: DoR-MoWHS Bhutan)

Road type	Length (km)	Per cent
Expressway (Asian Highway)	6.20	0.06
Primary National Highway	1,974.64	17.66
Secondary National Highway	584.47	5.23
Dzongkhag Roads	1,504.32	13.46
Urban Road	396.78	3.55
Farm Road	5,240.32	46.88
Forest Road	684.51	6.12
Access Road	674.65	6.04
Other	111.10	0.99
TOTAL	11,176.99	100.00

Table 3.9.2 Annual Changes of Road Length by Category (Source: DoR-MoWHS)

Year	Expressway (Asian Highway)	Primary National Highway	Secondary National Highway	Dzongkhag Roads	Urban Road	Farm Road	Forest Road	Access Road	Other	Total
2004	—	1577.20	459.00	1213.21	117.42	244.27	542.60	Nil	Nil	**4153.70**
2005	—	1571.00	459.00	1278.26	125.11	388.54	570.60	Nil	Nil	**4392.50**
2006	—	1556.00	510.95	1246.91	130.22	525.85	574.80	Nil	Nil	**4544.73**
2007	6.2	1628.1	481.2	818.2	161.3	1012.3	559.6	534.7	148.1	**4946.6**
2008	6.2	1621.1	482.0	820.7	163.0	1045.6	528.9	554.2	140.8	**5362.4**
2009	6.2	1696.79	490.65	883.36	206.64	1395.62	536.80	562.64	203.60	**5982.31**
2010	6.2	1753.83	505.59	1066.09	295.00	1980.26	583.39	580.57	149.20	**6920.13**
2011	6.2	1757.19	516.35	1107.50	304.87	3236.41	630.75	619.87	134.90	**8314.04**
2012	6.2	1768.65	521.18	1050.94	326.91	4380.93	667.25	634.50	134.90	**9491.47**
2013	6.2	1860.12	578.26	1178.29	349.67	5255.19	667.25	563.18	120.10	**10578.26**
2014	6.2	1860.12	578.26	1178.29	349.67	5255.19	667.25	563.18	120.10	**10578.26**
2015	6.2	1974.64	584.47	1504.32	396.78	5240.32	684.51	674.65	111.10	**11176.99**

a. Maintenance Works

Maintenance Division under the DoR is currently responsible for the maintenance works as listed below.

a.1 Routine Maintenance Works

The DoR has conducted routine maintenance works following the *Road Maintenance Manual* developed in 2005 as well as the *Cost Estimate for Routine Maintenance of Roads under the Divisions for 2006-2007 for Administrative Approval and Financial Sanction* produced in 2006. These documents show the activities to be conducted such as routine maintenance work, frequency, and period.

The DoR consigns the routine maintenance work to the locals due to a limited budget and a reliance on cheap labor.

The routine maintenance work on the slopes has not been conducted.

Table 3.9.3 Activities of Routine Maintenance Work and Schedule
(Source: Road Maintenance Manual[*4])

Sl#	Activity	Month											
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	Vegetation Clearing	—	—	—	—							—	—
2	Brooming of road surface	—	—	—	—	—	—	—	—	—	—	—	—
3	Clearing of Side Drains	—	—	—	—	—	—	—	—	—	—	—	—
4	Berms/Edge Clearing/Repairing			—	—	—					—	—	—
5	Minor Slip Clearance up to 1.5 cu.m	—	—	—	—							—	—
6	White washing				—	—	—	—	—	—			
7	Repair/Maintenance/Painting of road furniture				—	—	—	—	—	—			
8	Road marking				—	—	—	—	—	—			
9	Clearing of cross drainage	—	—	—	—					—	—	—	—
10	Snow Clearance						—	—	—	—			
11	Patches/Potholes repairing				—	—	—	—	—	—	—	—	
12	Nursery maintenance	—	—	—						—	—	—	—
13	Bio-engineering maintenance	—	—	—						—	—	—	—

Table 3.9.4 Frequency of the Activities (Source: Cost Estimate for Routine Maintenance of Roads under the Divisions[*5])

No	Activities	Frequency
1	Drain cleaning	4 times/year
2	Culvert cleaning	2 times/year
3	Scrub cutting/Jungle clearance	3 times/year
4	Potholes repair	1 time/year
5	Berm/Shoulder reshaping	1 time/year
6	Parapet repair and other structure	1 time/year
7	White washing & painting	1 time/year
8	Sweeping	2 times/year
9	Minor slip clearance	1 time/year
10	Tipper truck	1 day/year
11	Road marking	1 time/year
12	Tools & Plants	- (lump sum)

a.2 Periodic Maintenance Works

Periodic maintenance works refer to the resurfacing work which is subcontracted to the private companies. The RO manage the data of the repair records and future repair plan, and engineers from the DoR inspect the sites based on the data. As the data is managed in an Excel spread sheet, it is not shared online.

The periodic maintenance work on the slopes has not been conducted.

a.3 Emergency Works (monsoon restoration works)

The emergency works are the restoration works such as road clearance, retaining wall instalment and drainage construction after floods or slope failures during the monsoon season. Most of the emergency works are subcontracted to private companies.

b. Organogram of Regional Offices

There are nine RO under the DoR. The RO are responsible for road maintenance work within their jurisdiction.

Table 3.9.5 List of Regional Offices (Source: DoR-MoWHS Bhutan)

No	Regional Office
1	Samdrupjongkhar
2	Lingmethang
3	Thimphu
4	Trongsa
5	Trashigang
6	Phuentsholing
7	Lobeysa
8	Sarpang
9	Zhemgang

Each RO is headed by a chief engineer (CE), followed by three to five executive engineers (EE) or assistant engineers (AE) and three to five junior engineers (JE) under each EE or AE. Each JE is assigned to one section of 20 km to 50 km of road under its RO's control. Each EE or AE supervises three to five JE and their sections, and the CE supervises the entire section of roads under the RO.

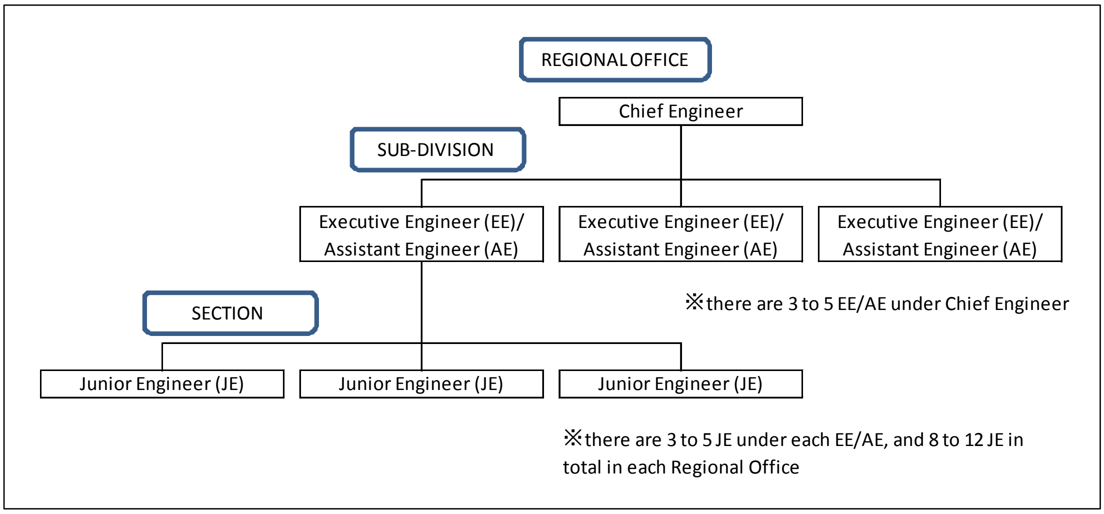


Figure 3.9.2 Organogram of Regional Offices (Source: DoR-MoWHS Bhutan)

The number of engineers and administrative staff in each RO is shown in Table 3.9.1.

Table 3.9.6 Number of Staff in Each Division/Office (as of June 2015)
(Source: DoR-MoWHS Bhutan)

No	Regional Office	Engineer							Other	Admin Staff	Total
		CE	PE	EE	Dy EE	E	AE	JE			
1	Samdrupjongkhar	1	0	1	1	1	5	8	4	7	28
2	Lingmethang	1	0	0	0	1	9	8	6	11	36
3	Thimphu	1	0	1	0	4	8	6	11	13	44
4	Trongsa	1	0	2	2	1	10	7	11	9	43
5	Trashigang	1	0	1	0	2	6	11	10	11	42
6	Phuentsholing	1	0	2	1	0	12	7	10	16	49
7	Lobeysa	0	1	4	0	1	4	8	11	10	39
8	Sarpang	1	0	4	1	1	7	8	4	14	40
9	Zhemgang	0	1	2	2	2	7	13	6	13	46
	TOTAL	7	2	17	7	13	68	76	73	104	367

The followings are abbreviations used in

Table 3.9.6, as well as an explanation of what “other” and administrative staff entails.

- CE: chief engineer, PE: principle engineer, EE: executive engineer, Dy EE: deputy executive engineer, E: engineer, AE: assistant engineer, and JE: junior engineer
- “Other” includes project managers, surveyors, road inspectors, architects, and technicians
- Administration staff includes accountants, dispatchers, and drivers

b.1 Mandate of Regional Offices

The following are the mandates of the regional offices:

- Management of roads and bridges:
  - Oversee routine, periodic and emergency maintenance of roads and bridges
  - Monitor and report conditions of roads on a daily basis during monsoon season and snowfall wherever applicable
  - Maintain and submit road inventory
- Construction activities:
  - Review field data, annual budget proposal and annual work plan for maintenance and construction activities
  - Review drawings and estimates
  - Issue administrative, financial and technical approvals
  - Review rate analysis and quantity surveying for various maintenance and construction activities
  - Review and prepare contract documents, invite and evaluate bids and process awarding work
  - Conduct field level tender committee meetings
- Project management:
  - Oversee the overall contract and project management
  - Supervise and monitor progress of works and ensure quality
  - Certify bills for payments
- Administrative management:
  - Review and submit progress reports, labor reports, explosives reports and other reports submitted by the field offices
  - Liaise with the other agencies on issues concerning the road sector

c. Budget

The DoR via MoWHS submits the budget proposal to the Ministry of Finance every February. The budget is approved by the cabinet in June and Bhutan’s fiscal year starts from July to June in the following year.

In the financial year 2014-2015, the budget request from the DoR was 3,321.509 million Nu whereas the actual budget distribution was 1,941,571 million Nu which is approximately 60 percent of the original amount requested.

Table 3.9.7 Annual Budget for DoR (Source: DoR-MoWHS Bhutan)

Programme/activity	July 2013- June 2014		July 2014- June 2015		July 2015- June 2016
	Request budget	Actual budget	Request budget	Actual budget	Request budget
Planned programme					
1 Construction, upgrading and improvement of roads	3,524.905	3,480.445	4,256.14	2,222.41	4,753.375
2 Construction of bridges under DoR	338.74	309.30	243.00	213.43	213.525
3 Road asset management and maintenance	823.08	843.78	570.89	365.29	530.799
Unplanned programme					
1 GC/Farm road construction	20.000	107.590	0.000	9.999	-
2 Improvement works	1.400	8.199	74.786	0	-
3 Bridge construction	1.24	10.84	18.60	11.24	-
GRAND TOTAL	**3,184.746**	**3,320.292**	**3,321.509**	**1,941.571**	**5,668.729**

(million Nu)

Table 3.9.8 Budget Comparison by Programme (Source: DoR-MoWHS Bhutan)

Construction and upgradation of roads and bridges	Maintenance of roads and bridges	Operation and management services	Total
4,966.90 (87.62 %)	530.799 (9.36 %)	171.03 (3.02 %)	5,668.729 (100 %)

(million Nu)

The budget for maintenance is about 30 per cent of construction, upgrading and improvement costs. While the source of construction, upgrading and improvement costs is mainly funded by grant aid or loans from international organizations such as the World Bank and Asia Development Bank, the maintenance cost is funded by the GoB.

The maintenance budget is divided into three categories; 1) monsoon restoration works, 2) routine maintenance works, and 3) periodic maintenance works. Table 3.9.9 is the monsoon restoration budget for the period of 2008 to 2013.

➢ Budget for monsoon restoration works

This is the budget for implanting the emergency maintenance works for slope failure after the monsoon season. The engineers from the DoR implement the site inspection in October and November, then submit the budget proposal in December. Each RO submits the budget proposal to the DoR and the proposals from all RO are collectively submitted to the MoF. The approved budget is normally less than the budget proposal. It is allocated from the MoF to the DoR and then distributed to each RO according to their budget proposal. Apart from the budget proposal from each RO, one million Nu is annually allocated to each RO as lump sum.

Table 3.9.9 Monsoon Restoration Budget (Source: DoR-MoWHS Bhutan)

Fiscal year	Request	Actual expenditure
2008-2009	135.951	135.41
2009-2010	185.546	145.91
2010-2011	197.209	138.43
2011-2012	115.419	96.12
2012-2013	237.121	158.05
Total	871.246	673.92

(Million Nu)

- Budget for routine maintenance works

The budget for routine maintenance works is fixed according to the road type as mentioned in Table 3.9.10. The budget below was set in January 2012. The budget has to be adjusted to reflect price increases, however, the GoB has not approved any such changes to the budget.

Table 3.9.10 Budget for Routine Maintenance Works (Source: DoR-MoWHS Bhutan)

Road type	Budget
Primary national highway	86,000Nu/km/year
Secondary national highway	80,000Nu/km/year
Dzongkhag roads	44,000Nu/km/year
Urban roads	89,000Nu/km/year
Bridge maintenance	26,000Nu/bridge/year

The breakdown of the maintenance budget is shown in Table 3.9.11. The budget for monsoon restoration works, routine maintenance works and periodic maintenance works is more or less the same.

Table 3.9.11 Breakdown of the Maintenance Budget 2014-2015
(Source: DoR-MoWHS Bhutan)

Item		Approved budget
Routine maintenance	Primary National Highway	109.244
	Secondary National Highway	39.344
	Dzongkhag Roads	29.382
	Urban roads	0.236
	Bridge maintenance	5.397
	Total	183.603 (33%)
Periodic maintenance		204.20 (37%)
Monsoon restoration works		160.684 (29%)
Snow clearance works		3.45 (1%)
Total		551.937 (100%)

(Million Nu)

The Table 3.9.12 shows the length of each road type and the length which can be covered by the approved maintenance budget. While the maintenance budget for primary national highway and secondary national highway covers approximately 70 % of its total length, the budget for dzongkhag road covers less than 60 per cent.

Table 3.9.12 Total Length of the Road and Length can be Covered by the Approved Maintenance Budget (Source: JET)

Road type	Total length (km)	Length can be covered by the approved maintenance budget	
		Km	%
Primary national highway	1,860.12	1,270.30	68
Secondary national highway	578.26	400.00	69
Dzongkhag road	1,178.29	667.80	57

3.9.2 Issues on Road Maintenance

Issues on road maintenance in Bhutan are as follows:

a. Maintenance System

Currently, only 6 engineers lead by the Chief Engineer belong to the Maintenance Division in DoR headquarter. The main tasks of the staff in headquarter are to monitor works done by regional offices and to provide technical advises as required. But those works such as creating slope karte and management of database etc. are necessary to be continued by DoR even after this technical cooperation project completed, therefore, it is required to increase the number of staff in DoR headquarter.

In case of estimating maintenance cost and prioritizing the rehabilitation location, it is preferable to develop not only a short-term (1 year) maintenance plan but also medium and long-term maintenance plan. However, currently medium and long-term maintenance plan is not prepared in DoR. Therefore, it is important to develop maintenance budget plan in the medium and long-term and implement road maintenance based on the detailed database. In order to achieve it, organizational expansion and capacity building of headquarter and DoR regional offices are essential.

b. Road Design

Road alignment passes following zone, where large-scale disaster can be generated. Route selection should be done considering future maintenance, therefore, the above mentioned zones should be avoided as much as possible.

- Fault/Fractured zone
- Landsliding zone
- Slope failure landscape/ Falling rocks zone/ Fractured rock zone

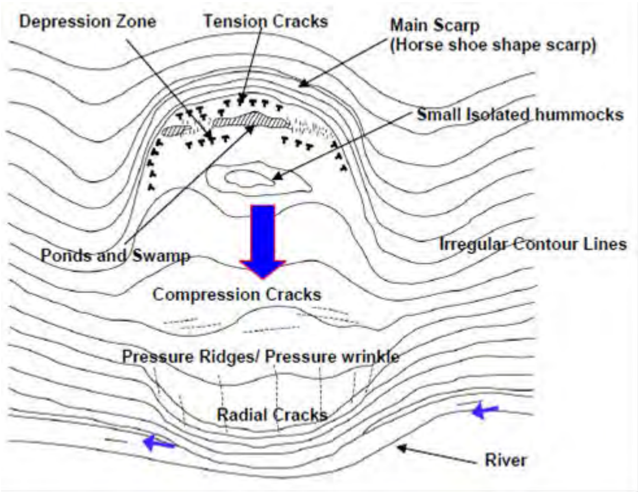


Figure 3.9.3 Characteristic Topographical Feature of Landslide (Source: JET)

c. Types and Contents of Maintenance Work

- Daily maintenance work is carried out by local residences, therefore, technical level is low.
- The contents of maintenance manual are poor as well as it actually to be mere facade since it is not actually exploited. At site, workers are conducting their tasks based on their personal experience. In particular, the contents related to slope inspection and maintenance are poorly described.
- The cost for slope inspection and maintenance is not appropriately included in cost for the daily maintenance work.
- There is no contract for carrying out the hybrid maintenance appropriately.
- So far, inspection and preventative maintenance for preventing slope failure has not been conducted at all.

d. Budget

- Unit cost for the work of routine maintenance has not been reviewed in the next five years after setting the Five- Year Plan. Since inflation during the period has not been taken into consideration, it has become inadequate to carry out the actual work. Therefore, equipment is also lacking.
- Maintenance budget proposal is prepared and submitted by DoR to the government every year, however, amount of the budget is always reduced by the government. Because it is difficult to make the government understood the actual situation at site and amount of work necessary only by document based reports. Therefore, it is necessary to describe damage states by using pictures and drawings for making explanation of the situation more reliable. In order to achieve it, development of the road inventory (database) which information can be centrally managed is required.

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