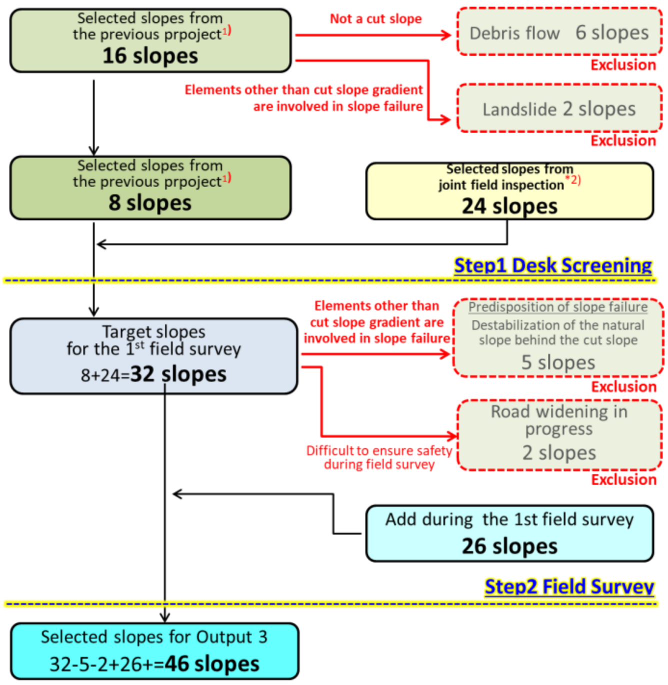
3.4 Output 3: Standards for cut slope angles for "debris slope failure" and "rock slope failure" are revised.

Activity 3-1: Select target sections and slopes based on the results of slope disaster inspections.

In order to study standard cut slope slopes, cut slopes under various conditions (geological conditions and stability) need to be included in the study. The selection process consists of two steps: 1) desk screening and 2) field survey.



(Source: JET)

Figure. 3.4-1 Output 3: Selection flow of target slope

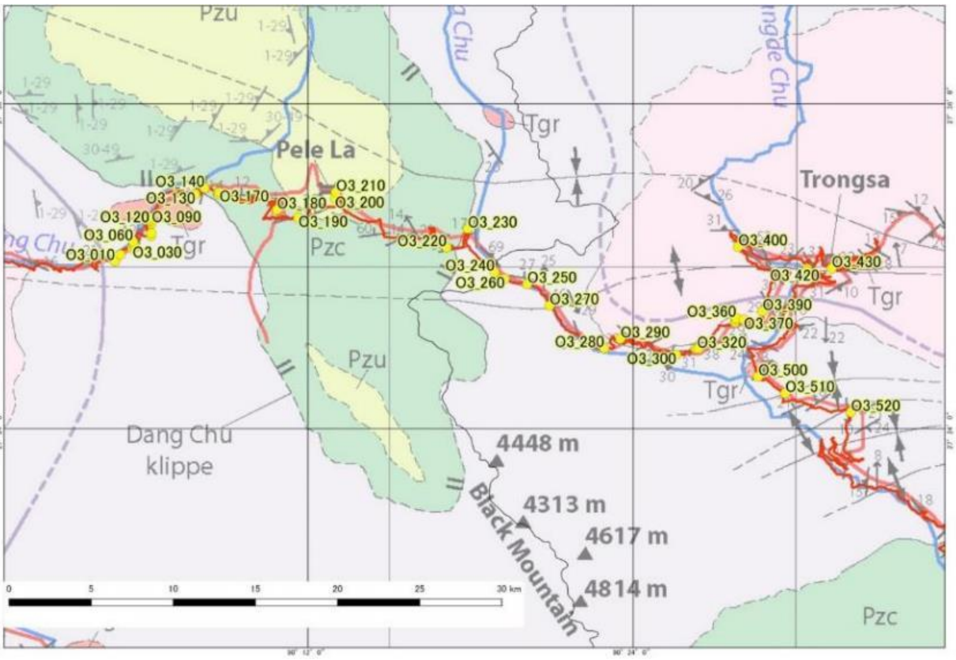
In the desk screening, in addition to the slopes with high priority for countermeasures identified in the previous project " Project for Master Plan Study on Road Slope Management in Bhutan," the results of the field inspection conducted jointly with the C/P at the start of this project (The target slopes were selected based on the results of the field inspection conducted jointly with the C/P at the start of this project (hereafter referred to as "joint field inspection").

Next, field inspection was then carried out to confirm the actual location and to discuss the applicability of the selected cut slopes for this activity, moreover, the cut slopes not selected during the joint field inspection were added to the list of target areas for this activity. The next table shows the results of the selection.

Table 3.4-1 List of target routes and cut slopes selected for Output 3

Jurisdiction	Rout ID	Cut slope ID	Cut slope specifications		Slope ID in previous project	Joint field inspection	Jurisdiction	Rout name	Cut slope ID	Cut slope specifications		Slope ID in previous project	Joint field inspection
			Height (m)	Angle (°)						Height (m)	Angle (°)		
Lobesa Regional Office	PNH1	O3_10	14	70		○	Trongsa Regional Office	PNH1	O3_240	17	60		○
		O3_20	14	85	WPP0120980				O3_250	20	55		
		O3_30	22	55		○			O3_260	16	65		○
		O3_40	13	68					O3_270	16	60		○
		O3_50	28	90		○			O3_280	14	70		
		O3_60	8	58					O3_290	25	80	TPP0122160	
		O3_70	14	90		○			O3_300	7	68		
		O3_80	21	70		○			O3_310	17	70		○
		O3_90	19	70		○			O3_320	15	60		○
		O3_100	17	90		○			O3_330	29	80		
		O3_110	10	60		○			O3_340	12	63		
		O3_120	18	60		○			O3_350	20	58		○
		O3_130	11	80		○			O3_360	7	55		○
		O3_140	9	58					O3_370	21	68		○
		O3_150	20	65					O3_380	12	62		○
		O3_160	7.5	72		○			O3_390	20	45	TPP0120850	
		O3_170	6	65					O3_400	15	72	TPP0120370	
		O3_180	35	65					O3_410	13	70		
		O3_190	20	50					O3_420	21	60		
		O3_200	13	60					O3_430	8	63		
		O3_210	12	68				PNH4	O3_500	12	90		
		O3_220	11	60		○			O3_510	22	60		
		O3_230	10	63					O3_520	8	65		

(Source: JET)



(Source : S.P. Long et al., Geological Map of Bhutan, Journal of Maps, 2011, Addendum: JET)

Figure. 3.4-2 Selected cut slopes on Output 3

Activity 3-2: Evaluate geology and slope stability by reconnaissance, etc.

In order to evaluate the geological properties and slope stability of cut slope in the current conditions, geological survey and hearing investigation were carried out.

For the former, there were organized and analyzed the geological survey results conducted with C/P.

For the latter. using the information obtained from interviews with C/P, it has been organized the correlation between each. A summary of each survey is provided below.

(1) Evaluation of geological properties

The survey equipment shown in the table below was used to collect and organize the physical properties of the various types of ground, which were then used as data for comparing with the slope stability and slope surface properties, and as basic data for soil/rock mass classification. Technical seminars on the handling of the survey equipment are held before the survey is conducted in each area.

Table 3.4-2 Provided geotechnical survey equipment used in the survey

Name	Application	Obtained Information / Physical Properties	Survey Quantity
Handy Dynamic Cone Penetrator	Soil and Highly weather rock	Tightness of a ground / Nc value	25 points 19 slopes ×1～6points
Handy Elastic Wave Meter	Weathered rock – Fresh rock	Weathering degree of rock / P-wave velocity	102 points 46 slopes ×1～6points

(Source: JET)

Seminar on handling geological survey equipment
Trongsa regional office (November 4, 2019)

Seminar on handling geological survey equipment
Lobeysa regional office (November 18,2019)

Conduct of Handy Dynamic Cone Penetration Test by C/P
Tronsa regional office jurisdiction (November 6, 2019)

Measuring a Vp velocity using simplified method by C/P
Lobeysa regional office jurisdiction (November 28, 2019)

(Source: JET)

Photo 3.4-1 Status of activities using provided geological survey equipment

The evaluation of geological properties was focused on common and easily applicable soil/rock classifications, as they are also relevant to the Rock Quality and Geology Classification Manual and activities related to the revision of cut slope.

In this activity, four categories are used to classify the soil: 1) Hard Rock, 2) Soft Rock, 3) Hard soil, and 4) Ordinary soil, which are defined in the current standards in Bhutan and are familiar to C/Ps.

The various threshold values used for classification are based on a comparison of existing data in Japan, as shown below, and values obtained from outcrop conditions and surveys in Bhutan, and an effort was made to follow the geological distribution conditions in Bhutan. The classification methods are also utilized in the manual on classification of rocks and geology described below.

Table 3.4-3 List of documents used in the study (Existing documents)

Title / Item	Publisher (Publication Year)
Rock Classification from the Perspective of Excavation Constructability - Especially regarding the classification of soil, soft rock, and hard rock -	Keiji Adachi (1987) Japan Society of Engineering Geology Rock Classification, Engineering Geology special issue
Guidelines for Road Earthworks Cut Slope Work/ Slope Stability Work	Japan Road Association（2009）
Study on the estimation of collapsible layer thickness using the HDCP test	Oyamauchi et al.（2005） Ministry of Land, Infrastructure, Transport and Tourism NILIM Document No.261

(Source: JET)

Table 3.4-4 List of materials used for consideration (Data obtained from geological surveys in this activity)

Data Type	Acquisition Method and others
Characteristics of Outcrops (Mainly Hardness)	・Sound , rock fragility, and shape of fragment during hammer strikes
Elastic Wave Velocity / Vp Velocity	・Measured values obtained using a handheld elastic wave meter conducted by C/P and JET.
Cone Penetration Test Value / Nc Value	・Measured values obtained using a Handy Dynamic Cone Penetration Test (HDCP) conducted by C/P and JET.

（Source：JET）

(2) Evaluation of slope stability

Since DoST does not have the record of slope disasters through the year, interviews with C/Ps were conducted as an alternative. The following table shows the items that were interviewed.

The occurrence of disasters and the degree of slope stability of the target slope were scored, and efforts were made to make the evaluation as quantitative as possible. stability of the target slope was scored, and efforts were made to make the evaluation as quantitative as possible.

(Source: JET)
Photo3.4-2 Status of hearing investigation
Lobesa regional office jurisdiction (May 5, 2019)

Table 3.4-5 List of interview items for slope stability assessment

Item (main)	Item (Subdivision)		Examples of description, selection, etc. The figures in parentheses ( ) indicate the grade.
Frequency of occurrence	a	Seasons to occurred	All periods (3 points) / rainy season (1 point) / during snowfall (1 point)
	b	frequency of occurrence	Number of occurrences during the outbreak period (1-8 points depending on frequency)
Disaster scale	c	Scale of road blocked	Whole lane (3 points) / Half lane (2 points) / Not blocked (1 point)
	d	Time of removal	Time to remove debris on the road (1-4 points depending on time)
	e	Method of removal	Heavy equipment (2 points) Human power (1 point)
Calculation for slope stability evaluation score = frequency of disaster occurrence + disaster occurrence scale = (a x b) + (c x d x e)			

(Source: JET)

The scores obtained for each item were organized by frequency of occurrence and disaster scale, and a grade for each slope was calculated. The threshold values shown in the following table were used to evaluate the stability of the slopes.

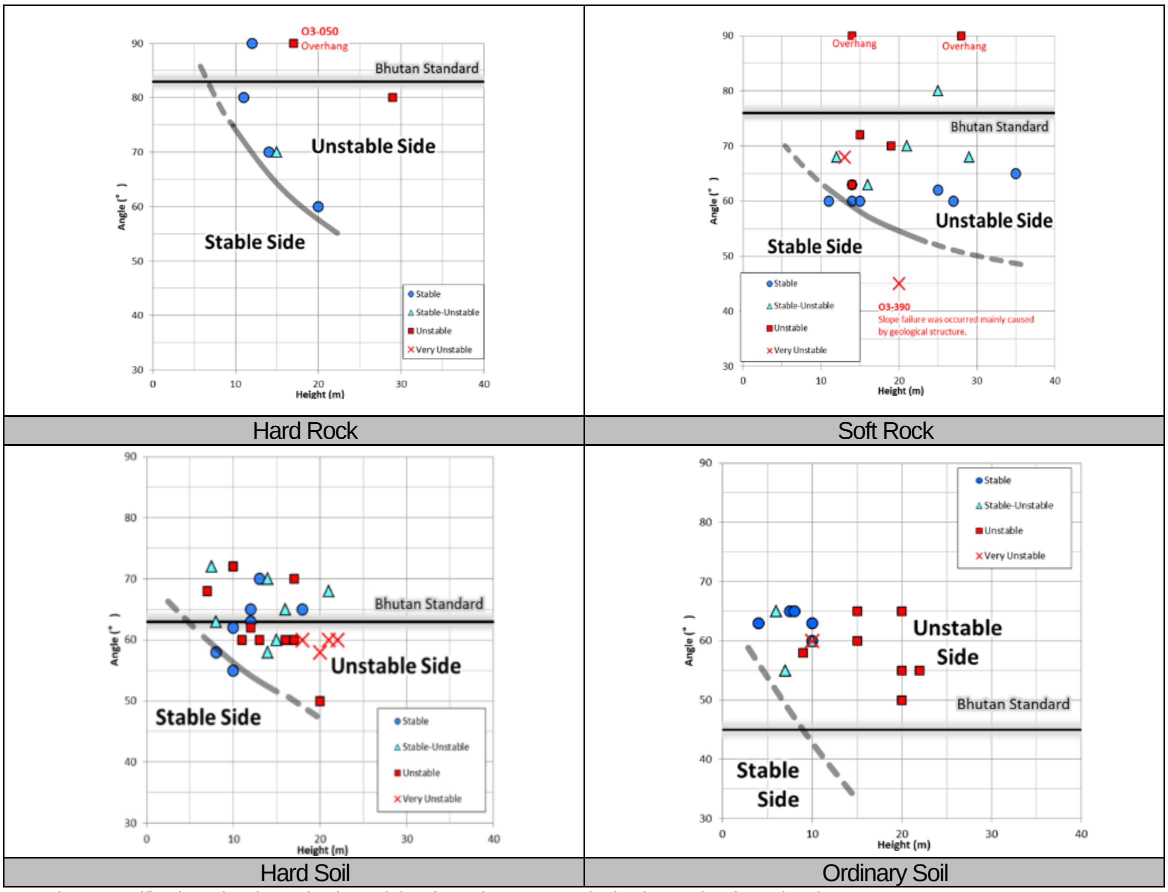
Table 3.4-6 Thresholds used to evaluate slope stability

Total score	Evaluation	Condition of a cut slope	Number of applicable cut slopes
0	Stability	･Slope failure is not occurred till present	10
10 or less	Stability - Unstable	･Occurrence frequency is low(1time /year～few year) / ･Disaster scale is not so big (Maximum : half lane was blocked)	11
20 or less	Unstable	･Occurrence frequency is few.(1times / few year) ･Disaster scale is medium～huge. (Most of disaster scale is half lane blocked)	19
More than 20	Very Unstable	･Slope failure has been occurred 1 times / year at least . ･Disaster scale is huge (Whole lane was blocked, time of removal : over 24 hours)	6
		Total	46

(Source: JET)

(3) Relationship between geological properties and slope stability

For each of the four categories in the evaluation of geological properties, a correlation map of cut slope on the vertical axis and cut height on the horizontal axis is created. By adding the stability assessment of the cut slope obtained from the interviews to these correlation charts, it is possible to estimate the stable/unstable areas of the cut slope for each geological feature. The correlation graphs are shown below, and the problems with the current cut slope standards in Bhutan are summarized.



*1 Slope specifications (Horizontal axis: Height of cut slope Vertical axis: Angle of cut slope)
*2 Stability (circle: stable, triangle::stable-unstable, square: unstable, ×: very unstable)
(Source: JET)

Figure.3.4-3 Correlation chart of slope stability in each classification category
– cut slope specifications (height and angle)

The problems with the current cut slope standards for each category that can be read from the correlation chart above are as follows.

[Hard Rock]

- As long as the cut slope height is at least 15 m or less, stability is considered to be ensured. On the other hand, the Bhutan Standard has no provisions regarding the cut slope height.

[Soft Rock]

- Unstable cut slopes were observed even at cut slope gradients gentler than the current Bhutan standard, suggesting that the cut slope gradients in the current standard are steeper than the appropriate gradient.
- There are some unstable one on cut slopes over 10 m high, but there is not specified the slope height in the current standard as with other classifications.
- All of the cut slopes with overhangs are unstable.
- Collapse occurs even when the slope gradients is gentle, but this is due to the geological structure, such as the dip slope, and can be considered an anomaly. However, it is an important factor for stability and should be considered when constructing cut slope.

[Hard Soil]

- Unstable cut slopes were observed even at cut slope gradients gentler than the current Bhutan standard, suggesting that the cut slope gradients in the current standard are steeper than the appropriate gradient.
- Unlike the above two categories, unstable conditions were observed even in areas with low slope heights of 10 m or less, and stable conditions could not be observed in areas with slope heights exceeding 20 m. As in the other category, there is no standard for slope height in the current standard.

[Ordinary Soil]

- Any cut slopes exceed the current Bhutan standard of 45°. This confirms the situation where this classification “Ordinary Soil” and “Hard soil” are not classified due to the difficulty of classification.
- Despite the relative fragility of this classification, most of the slope is in a state of instability when the slope is greater than 10 m because it is constructed at the same slope as “Hard soil”.
- As mentioned above, it is difficult to estimate the boundary between "stable" and "unstable" because there is no cut slope constructed as this classification, but at least there is no data to deny the current Bhutan standard.

In consideration of these issues, the criteria related to cut slope standards were reviewed in Activity 3-4 below.

Activity 3-3: Develop a manual on classification of rocks and geology.

This activity consists of three components: (1) development of Manual on Classification of Rocks and Geology, (2) application of the Manual, and (3) revision of the Manual.

Each item is described below.

1) Development of manual on classification of rocks and geology

Considering the geological characteristics in Bhutan obtained through the activities, a rock and geological classification manual was prepared and shared with C/P.

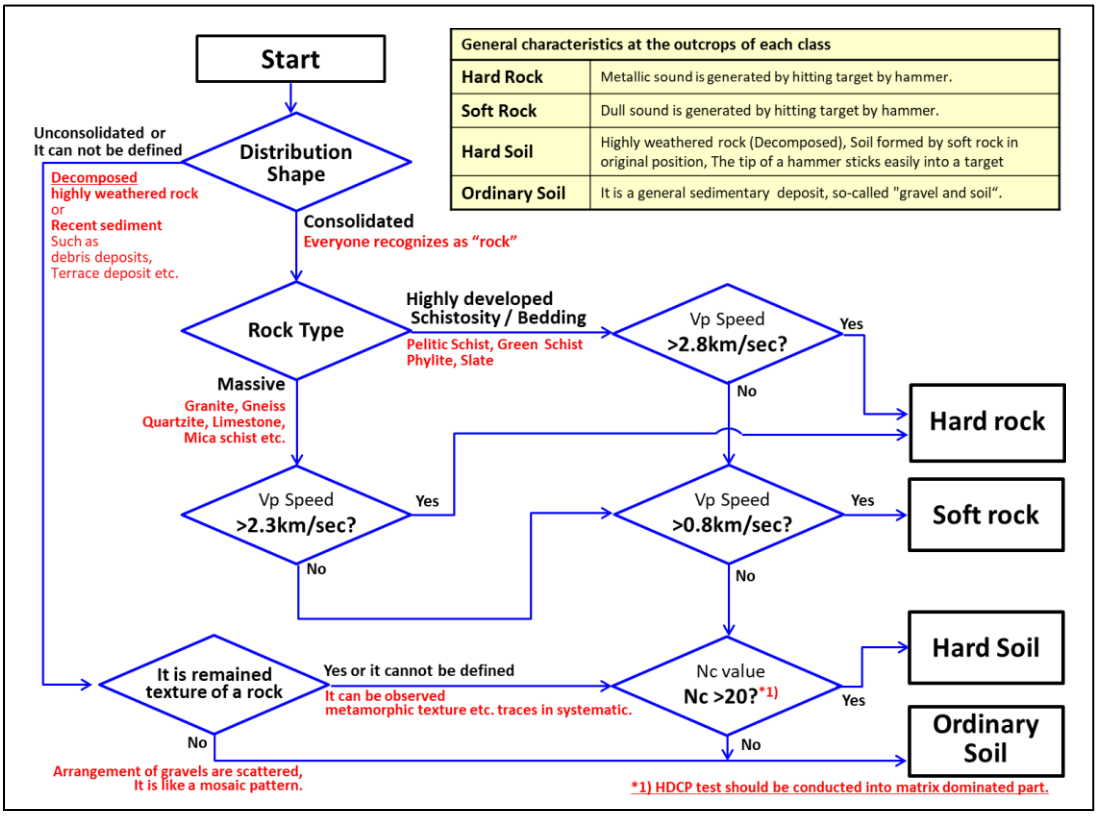
The manual is an overview of the geology distributed in Bhutan, the handling of geological survey equipment, and the methods of rock and geological classification utilizing these equipment.

The table of contents of the manual is shown in Table 3.4-7, and the classification flow diagram for rock and geology included in the manual is shown in the following figure.

Table 3.4-7 Table of contents of the Manual on classification of rock and geology

1	Basic knowledge of geology in Bhutan
1.1	General
2	Engineering geology in a cut slope construction
2.1	What are the Rock / Soil Classification?
2.2	The relationship between the rock / soil classification and the cut slope specifications
3	Geological survey for rock/soil classification
3.1	Type of survey and the Methodology
3.1.1	General geological survey equipment
3.1.2	Handy dynamic cone penetration test
3.1.3	Handy elastic wave meter
3.1.4	Seismic Refraction Tomography
Appendix:	The actual example of geological survey in cut slope construction

(Source : JET)



(Source: JET)

Figure. 3.4-4 Flow diagram for classification of rock and geology

As noted earlier, this manual describes survey and analysis methods for four categories: 1) Hard Rock, 2) Soft Rock, 3) Hard Soil, and 4) Ordinary Soil.

2) Application of the manual

A geological survey was conducted at the construction site, applying this manual. The purpose of the investigation was to collect basic data for detailed design and to apply the manual in practice. This geological investigation is a practical investigation that allows the client to experience a series of steps from planning to design and is expected to increase the client's understanding of and interest in the manual.

With the above background, JET invited engineers from other results to participate in the survey and provided technical guidance.

Handy Dynamic Cone Penetration Test Described in manual 3.1.2	Handy elastic wave meter Described in manual 3.1.3.	Seismic Refraction Tomography Described in manual 3.1.4
		
Geological Survey conducted by C/P survey team Trongsa office jurisdiction (June 3, 2022)	Field survey training for C/P of Output 4 Trongsa Office jurisdiction (June 16, 2022)	Field survey training for C/P of Output 4 Trongsa Office jurisdiction (June 16, 2022)

(Source: JET)

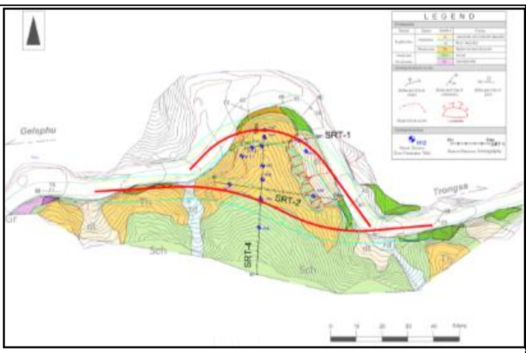
Photo 3.4-3 Status of field training for geological survey

The survey results obtained from this activity were used as basic data for detailed design and were also explained as the agenda for the third technical seminar. It is believed that this seminar contributed to share with many DoST engineers the basic knowledge of rock quality and geological classification and the existence of manuals.

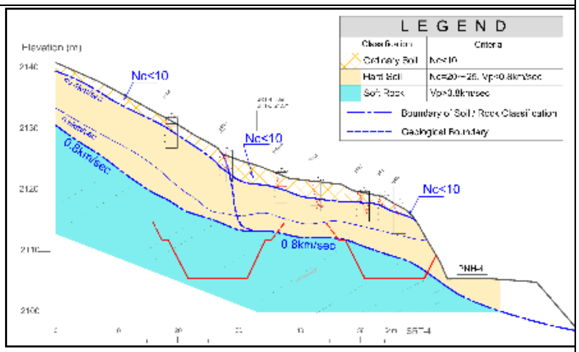
Output- 3 3rd Technical seminar

Agenda

1. Analysis of soil and rock classification at the pilot site with reference to the manual
2. Cut slope design at pilot site according to revised standard
3. Schedule of the construction site



Geological survey results / Plan view



Geological survey results / Cross-section
The results of rock and soil classification

(Source: JET)

Figure. 3.4-5 Example of handout from the 3rd technical seminar

(Source: JET)

Photo 3.4-4 Status of the 3rd technical seminar (Trongsa regional office, September 21, 2022)

In addition, technical seminars were conducted for DoST regional office staff with the aim of broadening the base of survey technicians.

The technical seminar consists of 1) "classroom training on basic knowledge," 2) "conducting a geological survey by participants," and 3) "organizing the results of the geological survey.

This was intended to give participants a more concrete image of the application of this survey method. After the seminar, Handy Dynamic Cone Penetrator is highly practical evaluated by some of the participants, and asked for the additional provision of the HDCP tester.

In addition, the survey results obtained from the training were used as basic materials for subsequent seminars on design. This was intended to make the training more practical by simulating the process from actual survey to design.

Although some of them were supported by Japanese experts, the trainer for this technical seminar are mainly DoST engineers. This indicates that C/Ps have acquired skills related to geological survey through the activities to date.

Table 3.4--8 4th technical seminar / Content and Lecturers

(Green cells: Output 3 WG members , Pink cells: Geo-tech section / Output 4 WG members)

Seminar Contents			Trongsa Regional Office	DoST Headquarters
1	Activities of Outputs 3 up to the present		Tshewang Dorji *Output 3 Leader	
2	Geological Survey	Overview of methodology on geological survey methods covered in Output 3	Ohashi	
		Handy dynamic Cone Penetration Test	Aita Tenzin Doya	Yonten Phuntsho
		Handy Elastic Wave Meter	Kinzang Chophel	Sangay Ngedup
		Seismic Refraction Tomography	Sangay Ngedup	
			Yonten Phuntsho	
				Sonam Tshering
3	Design of cut slope applying the revised standard		Hirose	
4	Supervision of cut slope construction (role of the cut point marker / how to install)		Sugihara	Hirose
* Explanation of construction site Trongsa Regional Office: on-site , DoST HQ : slide show			Kinzang Chophel	Yonten Phuntsho
			Aita Tenzin Doya	
* Support for overall			Yonten Phuntsho	Yonten Phuntsho
			Umesh Baniya *Local staff	

(Source: JET)

		
Output 3 Description of survey instruments by C/P Trongsa Reginal Office (April 17,2023)	Output 3 On-site training by C/P Trongsa Regional Office jurisdiction (April 18 ,2023)	Output 3: Practical training for analysis by C/P Trongsa Reginal Office (April 19, 2023)
		
Outputs 3,4 Description of survey instruments by C/P DoST Headquarters (April 25, 2023)	Output 4 On-site training by C/P Suburbs of Thimphu (April 26, 2023)	Output 3,4 Analysis practice by C/P DoST Headquarters (April 27, 2023)

(Source: JET)

Photo 3.4-5 Status of 4th technical seminar

An additional technical seminar was conducted in April 2024 at the request of DoST. As with the fourth technical seminar, the workshop was taught by DoST technicians who had mastered the technology.

		
Description of survey equipment by C/P DoST Headquarters (April 1, 2024)	On-site training by C/P Suburbs of Thimphu (April 1,2024)	Practical training for analysis by C/P DoST Headquarters (April 2,2024)

(Source: JET)

Photo 3.4-6 Status of additional technical training

3) Revision of the manual

The manual was revised after collecting requests from the C/P side. The content of the revision is the addition of a section on the "How to use Seismic Refraction Tomography equipment” owned by DoST. The request was made because DoST was aware of the usefulness of seismic refraction tomography equipment for geological surveys but had previously given up using it due to a lack of engineers who could operate it. The equipment was provided by the ADB (Asian Development Bank) around 2017.

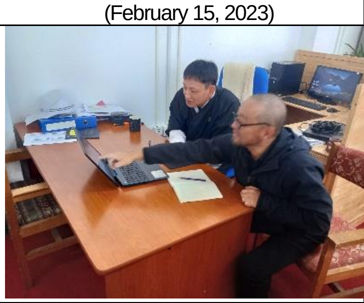
The following table lists the equipment and peripherals owned by DoST.

Table 3.4-9 Specifications of SRT equipment owned by DoST

Item	Name of equipment	Quantity	Specifications, etc.	remarks
Multichannel elastic wave measuring Instruments	ES-3000	1 unit	Max. 24ch	-
Software for measurement	Seis module Controller ESOS	1 set	Control measurement equipment on a Laptop PC	Installed from the beginning
Observation Cable/Seismograph	-	1 roll	12ch 5m spacing	-
Source of elastic wave	-	1 set	Hammer switch and 10 kg hammer	Repair by JET (May 2022)
Analysis Software	Seisimager 2D	1 set	Software for Seismic refraction tomography	License Renewal by DoST (September 2022)

(Source: JET)

Following the confirmation of the functionality of the exploration equipment, field training was conducted at the construction site, including elementary training for analysis. Additionally, materials created through these activities were incorporated into the manual. Furthermore, at the request of the Geo-Tech section engineers in charge of geological surveys at DoST, JET conducted supplementary technical training for practitioners.

		
1. Consultation on seismic survey equipment DoST Headquarters (May 12 , 2022)	2. Repair of peripherals DoST Headquarters (May 18, 2022)	3. Operation check and on-site practice Thimphu (May 24, 2022)
		
4-1. Field training to C/P of Output 3 Trongsa office jurisdiction (June 3, 2022)	4-2. Field training to C/P of Output 4 Trongsa Office jurisdiction (June 17, 2022)	5. Training related to analysis DoST Headquarters (September 19, 2022)
		
6. Additional on-site training Thimphu (February 14, 2023)	7. Additional training for analysis DoST Headquarters (February 15, 2023)	8. Inspection of geological survey sites by DoST Jurisdiction of Phuntsholing Reginal Office (April 11, 2023)
		
9. Additional equipment handling instructions DoST Headquarters (March 26, 2024)	10. Additional training for analysis DoST Headquarters (April 5, 2024)	11. Practical exercises in the field Reotara Landslide (April 11, 2024)

(Source: JET)

Photo 3.4-7 Status of activities related to additional requested contents from the DoST side (handling of seismic refraction tomography equipment)

The following table summarizes the total number of people who participated in this activity.

Table 3.4-10 Activities and number of participants related to the manual on classification of rocks and geology

Activity (The figures in parentheses indicate the time of implementation.	Contents	Number of participants (total persons/day)			
		Output 3 C/P	Other Output C/P	Other engineer	Total
2nd Technical Seminar (November 2019, December 2019)	▪ Overview of the methodology of geological survey listed in the manual ▪ How to handle survey equipment	6	5	17	28
Activity 3-2 : Geotechnical Survey for Information Collection (November 2019)	▪ On-site training on the methodology of geological survey listed in the manual	17	0	0	17
Geological survey at construction site (June 2022)	▪ Conducting geological surveys using the method of geological survey listed in the manual	17	4	1	22
3rd Technical Seminar (September 2022)	▪ Explanation of examples of geological survey results according to the manual	3	5	14	22
Technical training for Seismic Refraction Tomography (May 2022, September 2022)	▪ How to use the DoST-owned SRT equipment	2	1	0	3
Additional Technical training for Seismic Refraction Tomography (February 2023)	▪ How to use the DoST-owned SRT equipment	2	4	0	6
4th Technical Seminar (April 2023)	▪ Basic knowledge of geological survey methods in the manual ▪ On-site technical training of the above ▪ Practice analyzing the above	6	3	29	38
Join to the geological surveys conducted by Geo-Tech section (April 2023)	▪ Competence verification and advice on geological surveys for DoST	0	1	2	3
Additional technical training for the handling of geological survey equipment (April 2024)	▪ Basic knowledge of geological survey techniques in the manual ▪ On-site technical training of the above ▪ Practice analyzing the above	0	2	14	16
Join to the geological surveys conducted by Geo-Tech section (April 2024)	▪ Confirmation of the status of the Reotara landslide and advice on the results of the geological surveys. ▪ Exercises in the handling of geological survey equipment	3	3	9	15
	Total	56	28	86	170

(Source: JET)

4) Approval of the manual

The Manual was approved by the DoST at the DCC in April 2024.

Activity 3-4: Examine standards for cut slope angles on each geological type

Based on the evaluation results of Activity 3-2 and the materials collected in Activity 3-5, the standard gradient of cut slopes in Bhutan (Road Survey & Design Manual, June 2005, MoIT Department Roads) was reviewed. In addition, a geological survey of cut slopes, examples of slope failures, and interviews with road maintenance personnel were conducted in the field, and the correlation diagram shown in Figure 3.4-3 was developed for the four soil types. Based on the correlation diagram, the current standard cut slope in Bhutan was revised. The proposed revisions are shown below.

Table 3.4-11 Comparison of current and proposed revised the standard gradient of cut slopes

Soil and Rock classification	Current Bhutan standards[1)]	Revised
Hard Rock	1:0.12 (83°) Cut slope height: not specified	1:0.26 (75°) Cut slope height : less than 10m
Soft Rock	1:0.25 (76°) Cut slope height: not specified	1:0.46 (65°) Cut slope height : less than 10m
Hard soil	1:0.50 (64°) Cut slope height: not specified	1:0.70 (55°) Cut slope height : less than 7m
Ordinary soil	1:1.0 (45°) Cut slope height: not specified	1:1.0 (45°) Cut slope height : less than 7m

(Source: JET) 1) DoR Road Survey & Design Manual, 2005

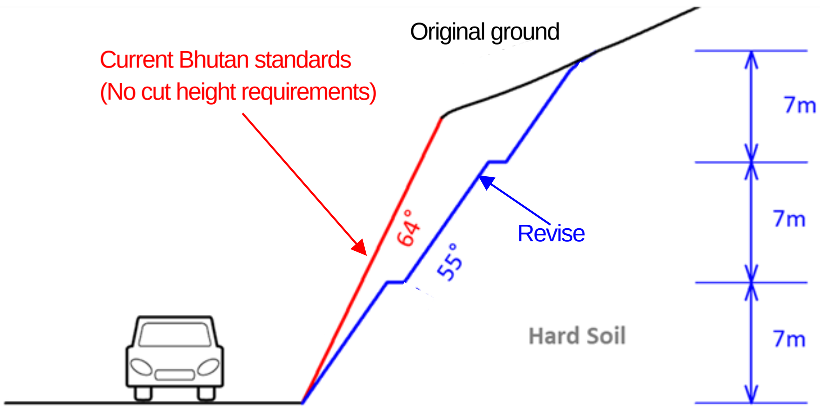
There are two points of revision from the current standard gradient of cut slopes: 1) cut slopes, 2) cut slope heights. The details of each item are described below.

1) Gradient of cut slopes

The standard gradient of cut slopes resulted in a slightly looser slope than the current slope.

2) Cut slope heights

During the field investigation, it was found that the higher the height of the cut slope, the greater the likelihood of collapse, regardless of slope or geology. Based on these findings, it was determined that the cut slope height needed to be revised to stabilize the cut slope and cut slope height standards were included in the proposed revision.



(Source: JET)

Figure. 3.4-6 Standard Cut Slope Comparison of Current and Proposed Revisions (for Hard Soil)

Consultation with the DoST, which is responsible for road construction in Bhutan, is required in order to apply the revised standard gradient of cut slopes in Bhutan. To this end, a technical consultation meeting was held with experts from the DoST side to discuss and exchange views on operational feasibility and other issues. The table below shows the experts from the DoST side who conducted the technical consultation meeting and the schedule of discussions.

Table 3.4-12 Conducted the technical consultation meeting

Name	Position	Contents	Date/Location
Karma Tenzin	Chief Engineer Lobeysa Regional Office	･Current Bhutan cut slope standards were developed.	March 10, 2020 Lobeysa Regional Office
Tempa Thinley	Deputy Executive Engineer / Geo-Tech and Research Section	･Leader of Geo-tech section ･Leader of Output 4	March 12, 2020 DoST Headquarters

(Source: JET)

Lobeysa RO March 10, 2020
(Back of center in photo: Mr. Karma Tenzin)

DoST HQ March 12, 2020
(Left in photo: Mr. Tempa Thinley)

(Source: JET)

Photo 3.4-8 The technical consultation meeting on the revision of the standard cut slope

After technical discussions, the proposed revisions to the standard gradient of cut slopes prepared by the JET side were accepted. On the other hand, the DoST side requested the transfer and expansion of technology related to the operation of various manuals, and the 4th to 7th technical seminars were held in all DoST regional offices and headquarters. In addition, through consultation with C/P and the DCC, it was finalized as the Design Guideline for Standard Gradient of Cut Slopes.

Activity 3-5: Develop a design/implementation guideline and a standard unit price table on the standards for cut slope angles in Bhutan.

This activity consists of the following three activities related to cut slope construction: 1) Design Guideline for Standard Gradient of Cut Slopes, 2) Standard Unit Price List, and 3) Construction Management Procedure. The following is a summary of each activity.

1) Design guideline for standard gradient of cut slopes

a) Collection and analysis of existing materials

In addition to collecting and analyzing the standards in use in the DoST listed in Table 3.4-13, interviews were conducted with C/P regarding cut slope construction.

Table 3.4-13 DoST Design Guidelines

Title.	year of issue
Guideline-to-Road-Drainage-System	November 2021
Guidelines on the use of Standard Work Items for Common Road Works	August 2010
Road Survey & Design Manual	June 2005
Road Maintenance Manual	May 2005
Design and Construction of Stone Masonry Retaining Walls - A Quick Guide	-

(Source: JET)

As noted in Activity 3-4, the current standard gradient of cut slopes are specified by four different geologic classifications. In addition, since the cut slope height is not specified, beams has not installed on the cut slope of the existing road.

According to interviews with the design department in charge of road design, the road cross section in the bid book shows two types of cut slope, 1V: 0.12H and 1V: 0.50H. During construction, the cut slope was modified as directed by the site engineer based on the actual geologic conditions encountered during construction. However, the cut slope of 1V: 0.50H, which is the standard for hard soil, was applied even in areas corresponding to ordinary soil during the field survey, and the cut slopes ware not properly managed in a series of operations from geological survey to design and construction management.

This activity developed the Design Guideline for Standard Gradient of Cut Slopes procedure for the standard gradient of cut slopes proposed in Activity 3-4, incorporating the elements necessary for the designer, contractor, and construction supervisor. In addition, the Design Guideline for Standard Gradient of Cut Slopes Procedure was approved by the DoST at the DCC on April 16, 2024.

Table 3.4-14 Current Bhutan standard

Soil classification	Slope angle
Hard rock	1V: 0.12H
Soft rock	1V: 0.25H
Hard soil	1V: 0.50H
Ordinary soil	1V: 1H

(Source: DoST Road Survey & Design Manual 2005)

Table 3.4-15 Comparison of current and proposed revised the standard gradient of cut slopes

Soil and Rock classification	Current Bhutan standards[1)]	Revised
Hard Rock	1:0.12 (83°) Cut slope height: not specified	1:0.26 (75°) Cut slope height : less than 10m
Soft Rock	1:0.25 (76°) Cut slope height: not specified	1:0.46 (65°) Cut slope height : less than 10m
Hard soil	1:0.50 (64°) Cut slope height: not specified	1:0.70 (55°) Cut slope height : less than 7m
Ordinary soil	1:1.0 (45°) Cut slope height: not specified	1:1.0 (45°) Cut slope height : less than 7m

(Source: JET)

b) Preparation of the guidelines

The Design Guideline for Standard Gradient of Cut Slopes is based on the standard gradient of cut slopes for the four soil types described in Activity 3-4, and includes examples of berms, drainage facilities, and drainage calculations.

	
Discussions with Output3 Bhutanese team leader (December 19, 2023)	Discussions with Output3 Bhutanese team leader (March 4, 2024)

(Source: JET)

Photo 3.4-9 Discussions with Output3 Bhutanese team leader for the design guideline

The following table shows the structure of the standard cut slope design guidelines.

Table 3.4-16 Cover and table of contents the design guideline

Design Guideline for

Standard Slope Gradient of Cut Slopes

March 2024

JAPAN INTERNATIONAL COOPERATION AGENCY

THE PROJECT FOR CAPACITY DEVELOPMENT ON COUNTERMEASURES OF SLOPE DISASTER ON ROADS IN BHUTAN

Contents

(Source: JET)

c) Operation of the guidelines

The Design Guideline for Standard Gradient of Cut Slopes and existing DoST standards were used to design a road with cut slopes as the primary. The table below shows the design items and the reference documents applied.

Table 3.4-17 Cut slope design items and applied standards

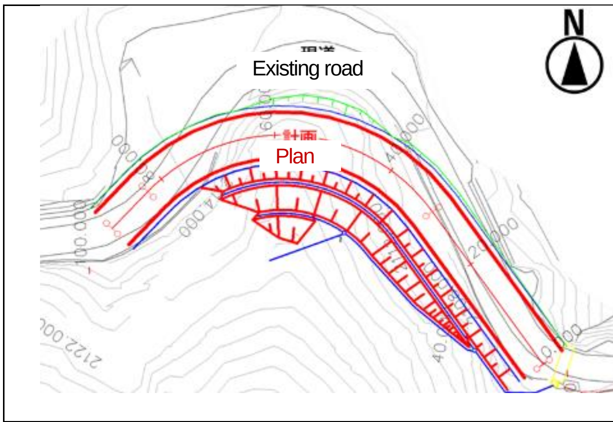
design specifications	Criteria applied	Design Manager
Road alignment	Road Survey & Design Manual	DoST Engineers
Road regulations		
Cut slopes	Design Guideline for Standard Gradient of Cut Slopes	DoST Engineers and JET (Technical support)
Drainage facilities		

(Source: JET)

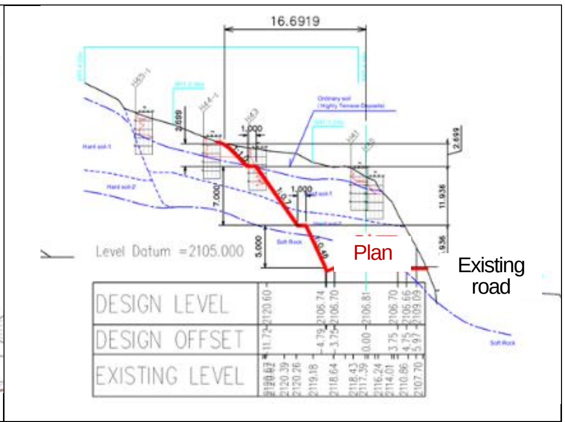
Items performed in DoST's design work, such as roadway alignment, were designed by DoST's engineers.

On the other hand, the JET provided technical assistance on items that DoST engineers had not previously experienced, such as the design of cut slopes, berms, and drainage facilities, and conducted the road design together with DoST engineers.

(Source: JET)
Photo 3.4–10 Technical assistance by JET, DoST HQ (September 12,2022)



Plan



Cross section

(Source: JET)

Figure. 3.4-7 Example of cut slope design drawing for Output 3 site

In this activity, the Guidelines were disseminated through the information meetings and various technical seminars shown in the following table. In particular, the 5th technical seminars were held at all DoST regional offices and headquarters to disseminate the Design Guideline for Standard Slope Gradient of Cut Slopes to a wider audience. The technical seminar covered the following three topics.

① Explanation of the Design Guideline for Standard Slope Gradient of Cut Slopes.

② Exercise on creating road cross section using geological survey data.

③ Exercising to Calculate Drainage.

Table 3.4-18 Held technical seminar

Activates	Contents	Participants			
		Member of Output3	Member of other Outputs	Others	Total
3rd Technical Seminar (September 2022) (Selected Engineers of ※1RO)	▪ Description of revised standards for cut slope design.	3	5	14	22
4thTechnical Seminar (April 2023) (Selected Engineers of RO)	▪ Description of revised standards for cut slope design. ▪ Exercise on creating road cross section using geological survey data.	6	3	29	38
5th Technical Seminar (1/3) (September & October 2023) (Sarpang RO,Tingtibi RO, Lingmethang RO Trashigang Samdrup Jongkhar RO)	▪ Description of revised standards for cut slope design. ▪ Exercise on creating road cross section using geological survey data. ▪ Exercising to Calculate Drainage.	3	0	40	43
5th Technical Seminar (2/3) (December 2023) (Thimphu RO, Lobeysa RO, Trongsa RO, Phuntsholing RO)	▪ Description of revised standards for cut slope design. ▪ Exercise on creating road cross section using geological survey data. ▪ Exercising to Calculate Drainage.	3	2	40	45
5th Technical Seminar (3/3) (March 2024), (Thimphu ※2HQ)	▪ Description of revised standards for cut slope design. ▪ Exercise on creating road cross section using geological survey data. ▪ Exercising to Calculate Drainage.	0	0	15	15
	Total	15	10	138	163

(Source: JET)
※1:DoST Regional Office, ※2:DoST Headquarter


Trashigang Regional Office (September 27, 2023)


Trongsa Regional Office (December 19, 2023)


DoST Headquarters (March 7,2024)

(Source: JET)

Photo 3.4--11 Status of the 5th technical seminar

2) Creation of standard unit price list

The standard unit price list to be prepared in this activity is based on the current standard unit price list (Bhutan schedule or rates-2021) and Laboure and material coefficients 2021 Civil served as the framework. The standard unit price list was created by incorporating the knowledge gained through the construction site work that preceded the project and the revision of the cut slope standards. The following table summarizes and details the costing items and considerations for the cut slope construction.

(Source: JET)

Photo 3.4-12 Discussion on the cost estimation of cut slope construction Trongsa Regional Office (September 21, 2022)

[Knowledge from prior cut slope construction]

The preceding case studies are the cut slope construction at the Output 2 construction site in the Lobesa Reginal Office and the cut slope construction at Output 4 in the Trongsa Reginal Office jurisdiction. Reference was made to manual construction in Output 2 and mechanical construction in Output 4. During the course of this work, the actual conditions of cut slope construction in Bhutan were clarified, and problems that needed to be improved, including cost estimation, were extracted. The main problems are items related to safety and quality control of cut slopes construction, and this activity presents improvement plans and estimation items that should be added.

[Revision of cut slope standards]

New standard unit prices were established for new construction types and methods that emerged with the revision of the cut slope standard, with technical support from Japanese experts.

The standard unit price list developed through the above activities was applied to the construction site in Output 3 to calculate the construction cost for the cut slope construction.

Table 3.4-19 Estimation items and considerations for construction of cut slope at the construction site

Main items of calculation		Suggestions from Japanese experts	
Item	Contents	Proposal Type	Purpose of Proposal, etc.
Temporary facility cost *Temporary facilities*	▪ Installation of water supply facilities, toilets, and temporary living facilities ▪ Disposal of waste from demolition of existing structures, etc.	new	**[Compliance with the Environmental Code of Conduct]** ▪ New standard unit prices were established based on examples from prior sites.
	▪ Site preparation and installation of a cut pont marker	new	**[New construction type/quality assurance of construction work due to the revision of the slope standard]** ▪ Since there are no items for site preparation (felling and rooting) and tree removal in the previous Bhutan's cost estimation standard, a standard unit price was set based on examples of prior sites, etc.
Excavation	▪ Excavation work (soil and soft rock)	-	-
	▪ Construction of temporary access road for heavy equipment delivery	add	**[Ensuring safe construction/construction quality]** ▪ Added to apply reverse winding construction.
	▪ Disposal cost for excavated soil	add	**[Compliance with the environmental code of conduct]** ▪ Added the cost of disposal of excavated soil.
Trim and clear slope	▪ Shaping of cut soil by heavy equipment, compaction of slopes, etc.	new	**[New construction types due to the revision of the cut slope standards / Ensuring quality of construction]** ▪ Although the current unit price list for pre-cut soil compaction and slope compaction has been existed , the compaction machine and frequency of compaction have not been selected in accordance with the soil type and scale of work, new standard unit price is added.
Drainage	▪ Shoulders and berm drainage facilities	new	**[New construction type due to the revision of the slope standard]** ▪ New standard unit prices were established with reference to existing standard unit price tables and examples from prior sites.
	▪ Road drainage	-	-
Pavement	▪ Roadbed / Base layer / Surface layer	-	-
Temporary facility cost **Safety measures cost*	▪ Materials and installation cost of entry prevention fence	new	**[Ensuring safe construction]** ▪ In Bhutan is defined as 4% of the direct construction cost, which is insufficient in some cases, so the required safety cost per site was recorded as a temporary construction cost.
	▪ Preventing falls by using a rope, etc.	new	
Site expenses	▪ On-site management in accordance with Japanese construction standards	add	**[Ensure labor environment and proper site management]** ▪ In Bhutan, site management costs (transportation costs for site supervisors, insurance premiums, office supplies, construction drawings, etc.) added as a percentage in Japan are not included. Therefore, it is unclear whether appropriate profits are being secured for the contractor, a percentage of site expenses was raised based on examples of prior sites, etc.

(Source: JET)

3) Development of construction management guidelines

As with the preparation of the standard unit price list, a construction management guideline for cut slope construction was prepared based on the experience gained at the pilot site where the work was performed earlier. This construction management guideline is now in operation at the three construction sites. The following table shows the construction management guidelines.

Table 3.4-20 Contents of construction management guideline for cut slope

Design/Implementation Guideline for Standard Cut Slope Angles in Bhutan Ⅱ: Construction Management (Ver.1)
Chapter-1 Construction Plan 1 Description 2 Requirement Chapter-2 Quality Control 1 Quality Control for each work 2 Field Checklist 3 As Built Control 4 Progress Control Chapter-3 Safety Control 1 Preface 2 Prevention of occupational accidents due to slope failure in cut slope construction 3 Safety Plan 4 Meeting with the Client 5 Dairy Works 6 Work Item 7 Field Checklist Appendix-1: Sample of Construction Plan Appendix-2: A Field Checklist on Quality Control for Construction (DRAFT) Appendix-3: Sample of Weekly Meeting Report Appendix-4: Sample of Daily Construction Report

(Source: JET)

Activity 3-6: Supervise based on developed design/implementation guideline.

The main purpose of this activity is to test the various procedures developed through this activity at actual construction sites to confirm their effectiveness and applicability, and to transfer technology related to safe and stable construction of cut slopes.

This activity consists of two steps: 1) selection of a construction site for construction supervision, and 2) construction supervision at the construction site based on various guidelines.

1) Selection of construction site

A poorly visible section of PNH5 in the Trongsa regional office Jurisdiction was selected as a construction site.

The background and conditions for selection are described below.

[Background of selection]

The reason for selecting this route was that the narrow road runs through mountainous terrain and has many visibility problems, resulting in a high risk of road traffic accidents. The objective of the construction project was to eliminate these visibility problems.

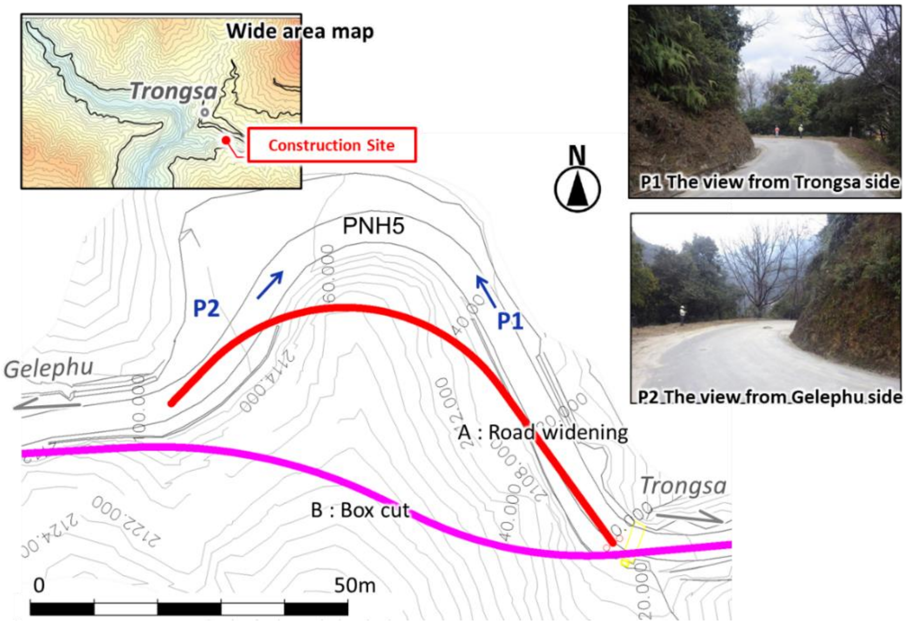
[Criteria of selection]

The purpose of this activity is to "revise the current cut slope standard to ensure the stability of the cut slope".

Sites where instability factors other than cut slope gradient and height are involved were judged to be unsuitable construction sites, for example, if floating rocks scattered on a cut slope cause falling rocks and safe traffic cannot be ensured.

Furthermore, this project has been allocated funding by the DoST. Therefore, it is not feasible to select sites that would require a significant construction cost, such as large-scale cut slopes, as it would not be possible to guarantee the feasibility of such sites.

The location of the construction site is shown in the following figure, and the reasons for selection are summarized in the following table.



(Source: JET)

Figure. 3.4-8 Output 3 Location map of construction site and photographs of current conditions

Table 3.4-21 Output 3: Candidate sites for construction

Site Photo			
Place ID	**01 (Selected site)**	02	03
Slope conditions	The area of cut required to ensure visibility is not very large and is not a problem for the budget.	If the revised cut slope is applied, a large-scale cut slope must be planned. Difficult to implement from a budgetary standpoint	The area of cut required to ensure visibility is not very large and is not a problem for the budget.
	The hinterland slope is gentle and there is no need to use rockfall protection in combination. Suitable for determining the effect of revised cut slopes.	High possibility that unstable rock remains on the surface of the cut slope; it does not ensure traffic safety. A rockfall prevention measure is required, so factors other than "revision of the cut slope gradient" is involved.	There is concern about falling rocks from the behind slope remaining after the cut slope construction. Unstable rock over 2m was observed from the road. It was assumed that rockfall countermeasures on the site would be necessary, and factors other than "revision of the cut slope gradient" is involved.

(Source: JET)

C/P side proposed two construction methods, A) road widening and B) box cut, and conducted a schematic design and project cost estimation for each.

Based on the results of these discussions with DoST, the A) road widening n method was adopted due to its economic efficiency.

After that, detailed design and cost estimation were conducted using the design guidelines and standard unit price list, and bidding was conducted by DoST. The table below shows the construction details, construction cost, and the contractor who won the bid.

Table 3.4-22 Summary of construction work and costs at the sites, etc.

Summary of Construction	Construction period	Contract price	Contractor
▪ Construction length ≒ 90m ▪ Maximum 3-step cut slope ▪ Maximum height ≈ 15m ▪ Top of cut slope with bio-engineering (according to Output 2) ▪ Shoulder/berm /road drainage works	Feb 1, 2023 ~ May ,15 2023	Nu. 4,481,256.20	Blue Heaven Construction Private Limited

(Source: JET)

2) Supervise construction at the construction site based on the guidelines

Construction supervision was based on the guidelines developed in Activity 3-3 and Activity 3-5. This construction was the first project to apply the revised cut slope standard, it includes new construction methods such as the installation of a berm and the different gradient on each slope etc. which were first experiences for C/P. In addition, since quality of construction supervision equivalent to Japan is required, it is essential to support by Japanese engineers.

From above reasons, a system was set up for Japanese experts and C/P to work together to supervise the construction.

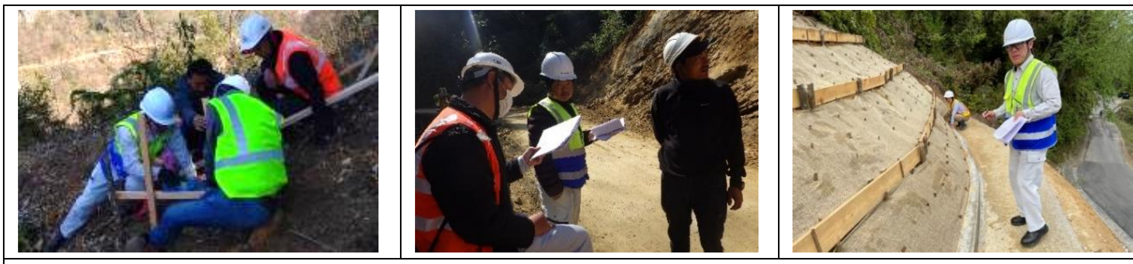
		
Multiple cut slopes with different gradient		
		
Bio- engineering work	Berm drainage	Shoulder drainage

(Source: JET)

Photo 3.4-13 New construction method added from revised cut slope standards

C/Ps participated in the supervision of the cut slope construction, from the installation of the cut point markers prior to the start of construction to the completion inspection. It is believed that the technology transfer was carried out in line with actual practice.

In addition, in accordance with the construction management guidelines, the construction management was carried out paying attention to safety management, such as hazard prediction activities before work and appropriate traffic control.



Status of the construction management by C/P
Left: Installation of the cut point marker (February 1, 2023)
Middle: Confirmation of progress of cut slope construction (February 17,2023) Right: Completion inspection (April 28, 2023)

Status of the discussions regarding cut slope construction by C/P
Left: Discussion with contractor (February 9, 2023)
Middle: Discussion at Trongsa Regional Office (February 17, 2023) Right: Discussion at DoST headquarters (February 20,2023)

Status of the safety control
Left: Preparatory exercise before the work (February 1, 2023)
Middle: Preparation of traffic control signboard (January 31, 2023) Right: Traffic control in progress (February 1, 2023)

(Source: JET)

Photo 3.4-14 Status of construction management

During the construction period, technical guidance and technical seminars related to this activity were held. The technical seminar was held at the request of the Trongsa regional office, which has jurisdiction over the construction site, and it was evident that there was a high level of interest in this construction site.

In addition, C/Ps from Output 3 served as lecturers at technical guidance and seminars. This is the result of C/Ps acquiring skills and knowledge through their activities, and this is one of evidence for successful technology transfer.

Left & Middle: Explanation of a cut point marker and field practice by C/P
(Trongsa regional office and around the construction site on Output 3, February 16, 2023)
Right: Explanation of the overview of cut slope work by C/P (Construction site on Output 3 April 19,2023)

(Source: JET)

Photo 3.4-15 Status of technical guidance and seminars for construction management

Panoramic view from the front

Panoramic view from Gelephu side
Slope of slope / Bottom: 65°, Middle: 55°, Top: 45° Side: Bio-engineering work and management pathway

Top cut slope : bio-engineering work and berm drainage

(Source: JET)

Photo 3.4-16 Cut slope construction on output 3 / post-completion and current conditions

The cut slope construction in this site is consisted of a series of work related to cut work (from geological survey, design and actual construction), it was carried out together with the C/Ps in accordance with the guidelines developed for this project.

By experiencing the entire construction process, it was possible to gain a more practical understanding of the various procedures, while also demonstrating the effectiveness of these procedures

3.5 Output 4: Suitable countermeasure works are implemented for "rock slope failure (rock fall)."

Activity 4-1: Select target sections and slopes based on the results of slope disaster inspections.

<Pilot site 1>

Following the confirmation of Output 4 activities with the Bhutanese side during the first JCC, the selection process for the first pilot site was conducted. The selected site was the slopes to be studied and constructed in FY2020 (FY 2019-2020 of Bhutan). The selection criteria for the pilot site were as follows.

1) Selected slopes to be constructed in 2020
2) Rated Rank 1 for slope inspections conducted in the 2016 Road Disaster Prevention Master Plan study.
3) Target type of disaster should be rockfall
4) Possible to use the type of rockfall prevention work that can be implemented in Bhutan.

The selection of target sites was conducted through the following steps

Extraction of potential rockfall hazards from 16 hazardous slopes proposed in the detailed planning study (desk work)

↓

Field inspections were conducted at 25 sites, including 8 sites identified in the previous step plus sites that DoST considered to be dangerous at the time. As a result, two slopes were selected that were at risk of rockfall hazards and of an appropriate size for the test construction. (Field work)

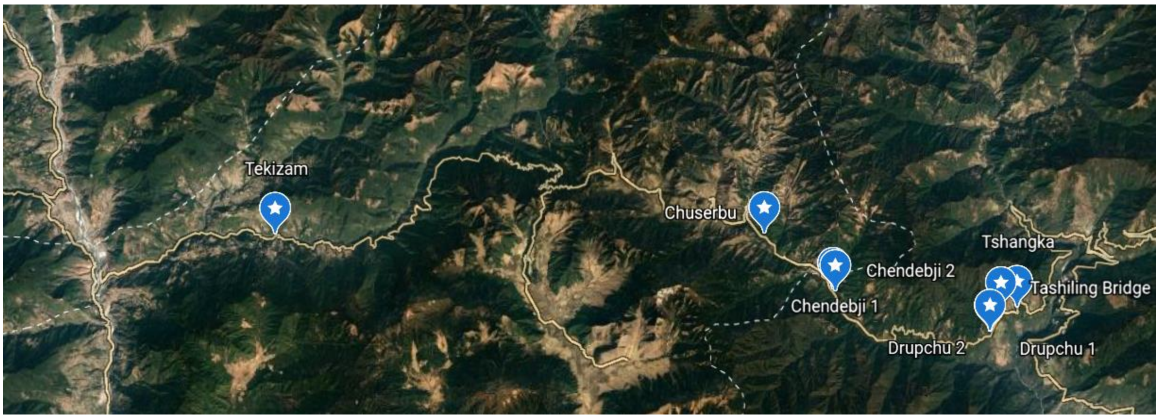
↓

The target slope is determined based on the slope selected in the previous step, taking into consideration whether the applicable countermeasure can be applied to the slope, workability, impact on traffic, and other factors.

In discussions during the detailed planning study for this project, it was decided that the type of rockfall protection work for the Output 4 trial construction would be a rockfall protection wall. Suitable slopes for this method include: high risk of rockfall hazards with acceptable rockfall energy for the structure, sufficient space for the structure, and low potential for major slope hazards such as landslides. Based on the results of the selection process according to the above steps, it was determined that the potential site of Chendebji meets these conditions. Therefore, the Chendebji site was selected as the first site for the rockfall test at Output 4.

<Pilot sites 2 and 3>

Although the target of Output 4 was rockfall countermeasures, a request was raised by DoST to include slope failure as a target of countermeasure works. In response, it was decided that Pilot Sites 2 and 3 would be selected not only from rockfall slopes but also from slope failure areas. Therefore, in order to select the remaining two pilot sites, the members of the working group for Output 4 conducted field inspections and road slope disaster prevention inspections at eight candidate sites proposed by the DoST. The degree of danger and urgency based on the results of the disaster prevention inspections at each candidate site were estimated, as well as the expected countermeasure work types, estimated construction costs, and construction period.



(Source: JET, base map: Google Earth)

Figure. 3.5-1 Potential Pilot Sites 2 and 3

Table 3.5-1 List of potential pilot sites survey results

	Tekizampa	Chuserbu	Chendebji 1	Chendebji 2	Drupchu1	Drupchu2	Tashiling bridge	Tshangka
Slope Inspection	**Rank 1** (100/78)	**Rank 1** (100/79)	**Rank 2** (70/58)	**Rank 2** (70/55)	**Rank 1** (100/62)	**Rank 1** (100/62)	**Rank 1** (100/78)	**Rank 2** (70/41)
Type of disaster	Slope failure	Slope failure	Slope failure, Rockfall	Slope failure	Rockfall/Rockslide	Rockfall	Slope failure	Rockfall
Type of work	SC, ECM	SC+RB, ECM	SC+CW, RPN, ECM	SC+CW, RPN, ECM	WRN	WRN	SC+CW, RPN, WRN, ECM, FN	SC+ RB, RPN
Cost (Mil. BTN)	33	141	39	43	38	128	50	33
Const. period (Month)	8.9 (by 2 parties)	48	7	8	6	11	10	6

The construction cost is estimated as the direct cost of the works + 20% of DC for overhead. The construction period is estimated when the works are conduced by one party.

Type of work:
SC: Shotcrete work, ECM: Erosion Control Mat work, RB: Rock-bolt work, CW: Concrete Crib work, RPN: Rockfall Prevention Net work, WRN: Wire Rope Net work, FN: Fence work:

(Source: JET)

The results of this study were discussed at the Directorate Coordinate Committee (DCC) meeting held on May 13, 2022, and it was decided that the Tekizampa, Tashiling Bridge, and Drupchu areas would be the final candidate sites in the DCC meeting. Based on this result, at the 5th JCC meeting held on May 17, 2022, two pilot sites were selected from the three final candidate sites: Tekizampa District (under the jurisdiction of Lobesa District Office) and Tashiling Bridge District (under the jurisdiction of Trongsa District Office), The JCC approved the selection of two pilot sites.

In the Tashiling Bridge area selected at that time, DoST was planning to replace the bridge destroyed by the 2020 disaster, and this collapsed slope was included in the scope of this replacement work. The project team conducted a field survey, prepared a geological map and a slope failure distribution map, and provided geological advice to the DoST. The Project included investigation, design, and construction of the failed slopes in the Tekizampa area.

Below are the locations of the three pilot sites that were ultimately selected.

(Source: JET, base map: Google Earth)

Figure. 3.5-2 Location map of the three pilot sites for Output 4

Activity 4-2: Investigate, analyze and evaluate on topography and geology for selection of countermeasure works.

<Pilot site: Chendebji district>

Activities were conducted with C/P on the slopes in the Chendebji area, which were selected as the target slopes for the first test construction in Activity 4-1. In the field work, field investigations were conducted to assess the stability of the slopes on the mountain side and valley side in order to provide the basic data for the design work in Activity 4-3. Since this was the first time for C/P to conduct such analyses and evaluations, the JET side took the lead in organizing the analyses and evaluations, and shared the methods and results with C/P.

Table 3.5 2 shows a summary of the main studies, analyses, and evaluations conducted. A summary of the results of each survey is provided below.

Table 3.5-2 Summary of studies, analyses and evaluations conducted at the target site (Chendebji)

Survey item		Contents
Field work	1. Interviews	Check past damage (timing, scale, frequency, and location).
	2. Ground surface survey	The deformation, spring water, etc. were confirmed in a wide area including the subject site.
	3. Observation of slope and road surface	Check the condition (location and size) of floating stones/boulders located on the slope (especially on the mountain side), as well as the presence or absence of deformations and water springs.
	4. Simple penetration test	Check the layer thickness and strength of the sediment deposited on the slope.
Indoor work	5. Organize field survey results	The results of the field work, observations, and tests are plotted in plan and cross-sectional views.
	6. Analysis work	The size and location of boulders/floating rocks measured in the field are arranged, and the energy of falling rocks is calculated *1
	7. Evaluation work	Based on the results of the field and analytical work, the disaster type classification and rockfall/floating rock stability evaluation of the local slope are conducted.

*1 Using the formula in "Rockfall Prevention Handbook, December 2009, Japan Road Association

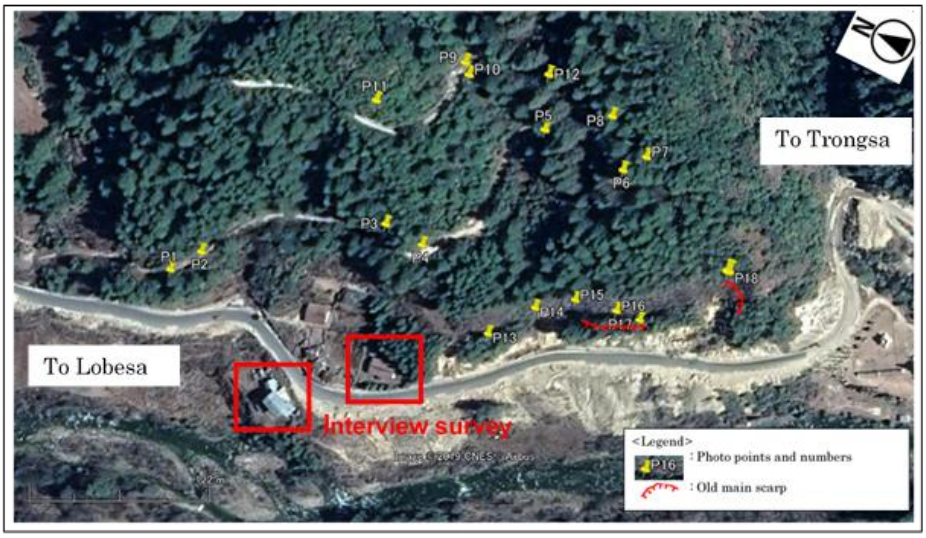
(Source: JET)

(1) Interview survey

Interviews were conducted with residents living in close proximity to the subject site and Park Range officers in Chendebji. The results of the interviews indicated that slope failures and rockfalls in the subject area occur from June to September during the rainy season and are confirmed after rainfall, and that no major slope failures or rockfalls have occurred since the road widening project in 2018.

(2) Site reconnaissance: investigation

Surface exploration was conducted in the surrounding area including the subject slope. The surrounding area, including the subject site, consists of metamorphic rocks such as gneiss, quartzite, and schist. No fresh cracks or deformations were observed on the mountain slope behind the cut slope. There were no signs of tree root bends or deformation to the road in the mountainside. There were no fresh cracks behind the cut slope, but an old continuous terrace topography was observed Figure 3.5-3. This terraced topography was presumed to have been caused by the road widening project, but was determined to be stable at that time because it was covered by vegetation and the terraced surface was not fresh.

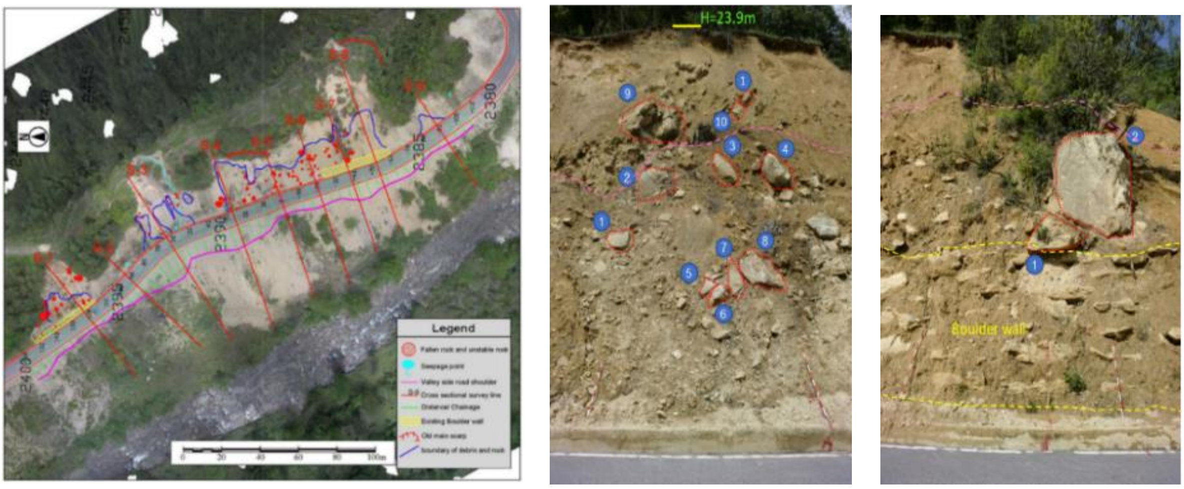


(Source: JET, base map : Google Earth)

Figure. 3.5-3 Location of Interviews and Scope of Surface Exploration

(3) Observation of glue and road surface

Observations of the mountain side slope surfaces confirmed the presence of a total of approximately 220 detached and unstabel boulder stones on the slope. In addition, six springs were identified within the subject site. Along the shoulder of the valley side road, settlement steps of approximately 0.50 m to 0.80 m from the road surface were observed at several locations. Potholes were also observed along some of the valley side road shoulders due to erosion by surface water. This suggests that the valley side slope is in a poor condition.

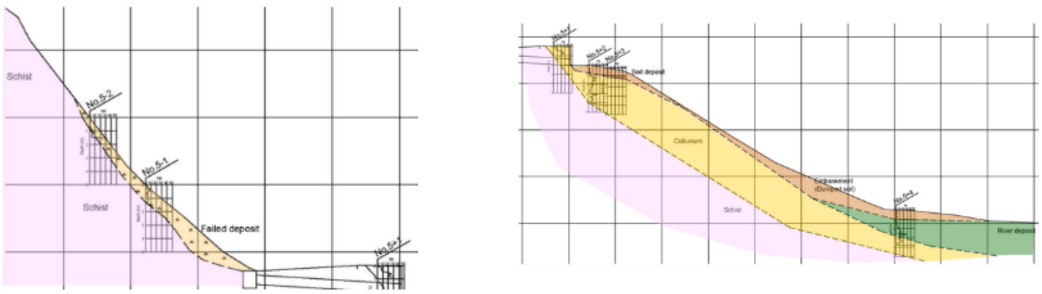


(Source : JET, base map : Google Earth)

Figure. 3.5-4 Slope observation result map (left figure) and floating stones on the slope (center and right figures)

(4) Simplified Penetration Test

Simple cone penetration tests were conducted on the survey lines of representative cross sections at the site to determine the thickness and strength of the cliff cone deposits on the cut slope, road surface, and valley side slope. The results of the tests at each site were reflected in the cross-sectional survey map conducted by the DoST survey team, and an estimated cross-sectional map was prepared..



(Source: JET)

Figure. 3.5-5 Simplified penetration test results (left: mountain side, right: valley side)

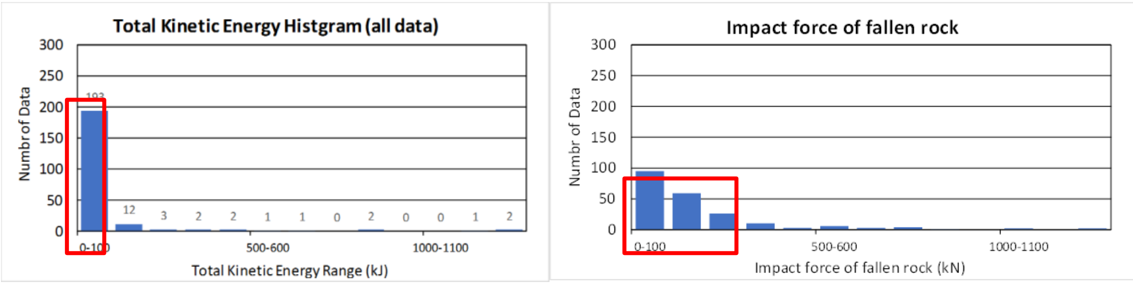
(5) Compilation of field survey results

The results of the field surveys conducted to date are summarized in the aforementioned chart. JET has also compiled photographs of the site conditions.

(6) Analysis work

Prior to the study of countermeasures, the total kinetic energy of falling rocks was calculated based on the location (height) and size of unstable rocks and boulders identified at the subject site and the results of cross-sectional surveys. Based on these results, JET determined the trend of kinetic energy of falling rocks occurring on the subject slope. The total kinetic energy of falling rocks was calculated using the equation published in the "Handbook for Prevention of Falling Rocks, December 2009, Japan Road Association.

The frequency distribution map of the total kinetic energy of each unstable rock and boulder fall identified in the field survey is shown in Figure 3.5-6.



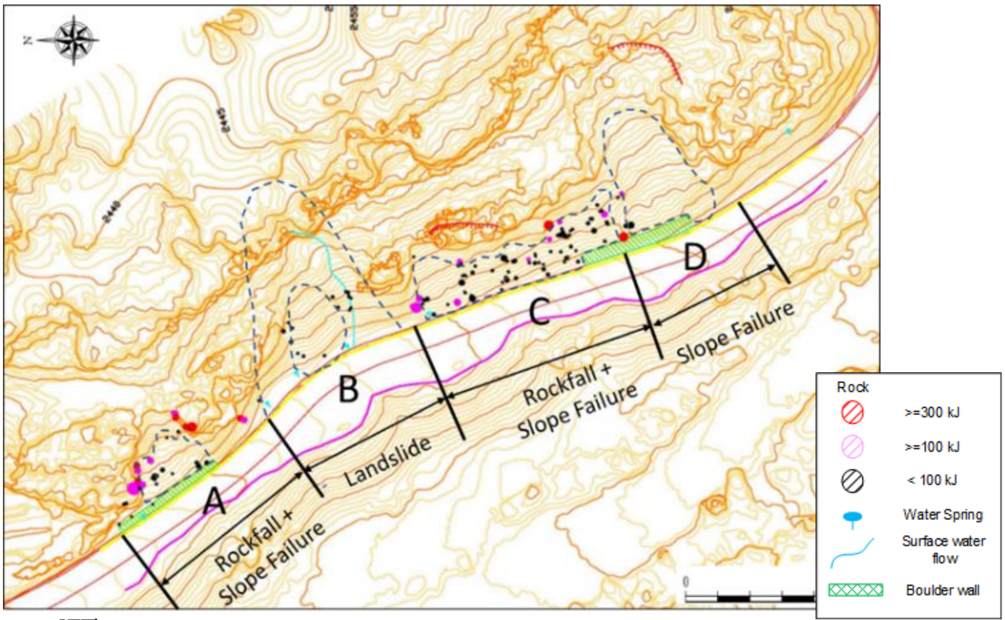
(Source: JET)

Figure. 3.5-6 Frequency distribution of rockfall energy

The figure shows that the total kinetic energy of boulders and boulders on the subject site is generally less than 100 kJ, and the impact force of falling boulders and boulders on more than 80% of the subject site is less than 300 kN.

(7) Evaluation work

Based on the results of the field survey and the analysis of the energy of falling rocks, JET has compiled the distribution of unstable rocks on the slopes of the target area, taking into account the expected disaster form and the total kinetic energy of the unstable rocks. The target area is shown in Figure 3.5-7 shows the four categories A to D. As can be seen in the figure below, boulders and boulders are particularly concentrated in two sections, A and C.



(Source: JET)

Figure. 3.5-7 Disaster Type Classification Chart of Subject Land

<Pilot sites: Tekizampa and Tashiling Bridge districts>

Activities were conducted with C/P on the following two slopes selected as Pilot Site 2 and Pilot Site 3.

- Tekizampa District (under the jurisdiction of Lobesa Regional Office)
- Tashiling bridge area (under the jurisdiction of Tongsa Regional Office)

As mentioned above, since the DoST's Bridge Division is planning to survey and construct a new bridge for the Tashiling bridge, the Project conducts surface exploration and provide geological advice to the DoST as necessary.

In the field work up to this point, surface exploration was conducted in the target area to identify geological distribution and areas at risk of slope failure, and to gather basic information to elucidate the mechanism of disaster occurrence. In addition, a borehole survey and seismic survey were conducted in the Tekizampa area by a consultant contracted by DoST from the end of November to the beginning of December 2022.

The table below shows a summary of the surveys conducted.

Table 3.5-3 Summary of surveys conducted in the target areas (Tekizampa and Tashiling bridge districts)

survey item		Contents
local	Topographic surveying	DoST's surveying team and the Output 6 Working Group prepared topographic maps of the target area using UAVs. The topography not captured by the drone due to overgrowth of vegetation was supplemented to a plan using a total station or other equipment on site. (Tekizampa and Tashiling bridge districts)
	2. Ground surface survey	Confirmation of collapsed landforms, cracks and other deformations, springs, etc., in a wide area including the subject site. Geological distribution and geological structure measurements Obtained additional data on collapsed areas in Tekizampa.
	3. Longitudinal and cross-sectional surveying	A simple cross-sectional drawing was prepared by DoST's survey team to study the temporary construction plan and placement of countermeasure works. (Tekizampa area only)
	4. Boring survey	The soil composition and thickness of the sediment deposited on the collapsed slope are confirmed. (Tekizampa area only)
	5. Seismic survey	The extent of distribution and thickness of collapsed sediment deposited on the slope are confirmed together with the results of the borehole investigation. (Tekizampa area only)
indoor	6. Geotechnical investigation (outsourced)	Assist in preparing technical specifications for DoST's ordering of geotechnical investigations, including borings and seismic surveys (Tekizampa area only).
	7. Organize field survey results	The results of the surface survey conducted in the field are organized and plotted on the drawings. Also, organize photographs of the site conditions.
	8. Analysis work	Reviewed the results of borings and seismic surveys conducted by the local survey company and prepared disaster geological plan and cross-sectional maps. (Tekizampa District)
	9. Evaluation work	The stability of the slopes are evaluated in the field and by analysis. (Tekizampa area only)

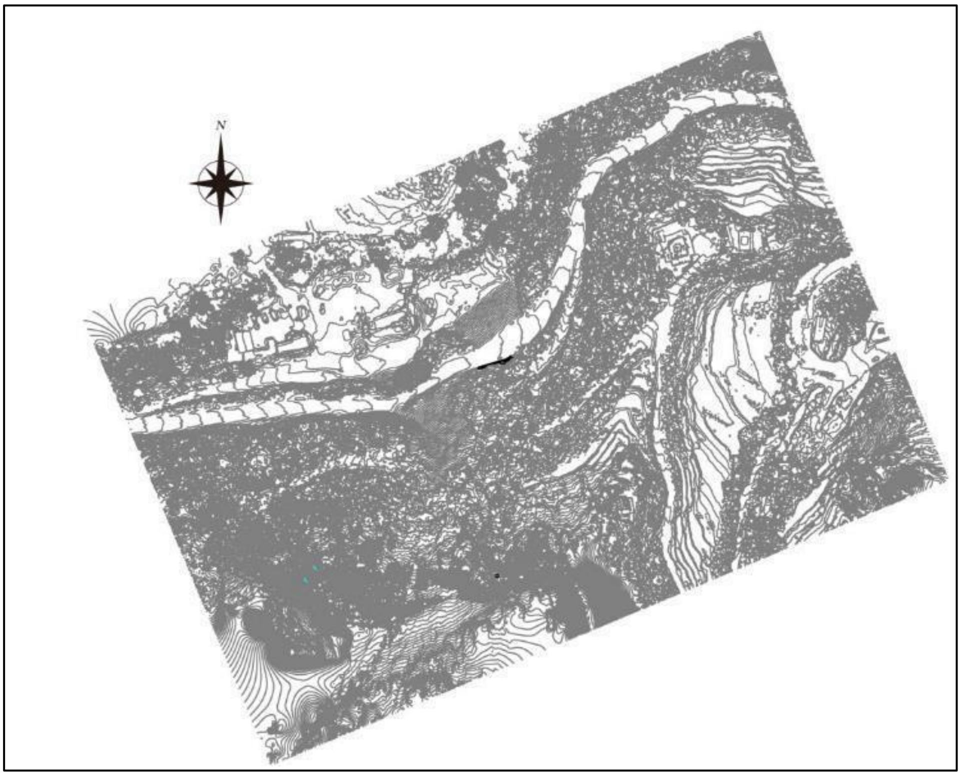
Survey items 1 and 2 were conducted mainly by the DoST survey team. Survey items 3 to 8 were conducted by the JICA expert team and members of the DoST's Results 4 Working Group.

The results of the survey for each pilot site are described below.

<Pilot site: Tekizampa district>

(1) Topographical survey

Prior to the surface survey and on-site ground investigation, topographical surveying was conducted around the subject slope. The surveying area included the target site and the mountain road to be used for the countermeasure work. However, it was difficult to determine the actual height and shape of vegetation, roads, and structures, so DoST's survey team used a total station to survey the ground surface. The final topographic map was created by combining the survey results from JET and DoST.



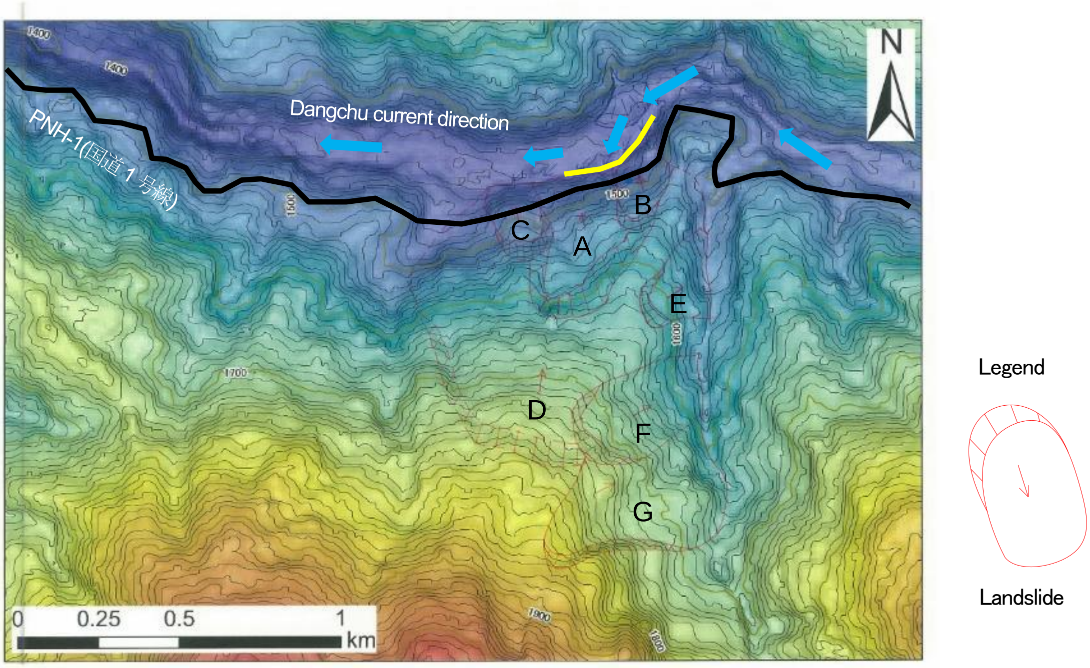
(Source: JET)

Figure. 3.5-8 Topographic map of Tekizampa area created using UAV

(2) Site reconnaissance

a) Topographic Analysis

Topographic decipherment was performed from a topographic map of the area around the subject district, which was created based on Google Earth data. As a result, seven landslide landforms were identified in the surrounding area, including the subject slope.



(Source: JET)

Figure. 3.5-9 Landslide topographic decipherment map around Tekizampa area

The landslide topography deciphered here is where the landslide exhibits characteristic landforms, and a detailed geologic investigation is required to determine if it is a true landslide. If the landslide slides, the landslides that directly affect PNH-1, the conservation target, are landslide blocks A, B, C, and D. The collapsed slopes in this case are located in the middle to lower part of Landslide Block A. The following items were identified by the decipherment.

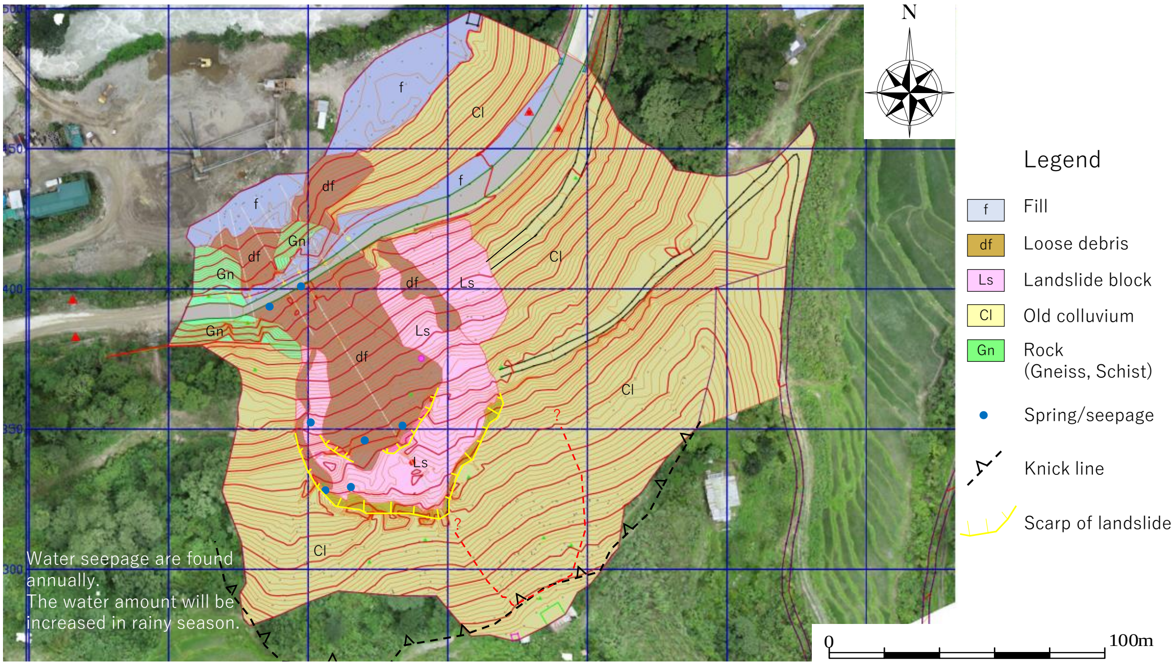
- The subject slope is part of a giant landslide block. However, the upper shape of the giant landslide block is unclear.
- The slope footing is the attack slope of the Dangchu River. The topography of the site is such that the slope foot is always prone to erosion, and erosion of the slope foot by the river is generally one of the main causes of landslide occurrence. In addition, cut-and-fill (+ widening) projects due to road construction and vibrations from stone crushing plants next to rivers can also destabilize slopes.
- The slide cliffs of landslide blocks A and B are continuous along the ridge extending in a south-southwest direction. The slopes on the ridge are under cultivated land use, and the environment is considered to be conducive to water inflow.

b) Site investigation

First, JET conducted a surface inspection of the landslide landforms extracted by topographic decipherment. Although it is difficult to determine whether the landslides are actual landslides from the field survey, at least no fresh landslide cliffs, cracks, springs, or other phenomena suggesting landslide activity were observed in these areas, except for the collapsed slopes that are the subject of this study. On the other hand, if these were actual landslides, on the other hand, the landslide terminus (yellow line in the above figure) may be eroded by river erosion and become unstable. The observation of the site revealed that the landslide terminus along the river has a quarry, and the area bordering the river is protected by a revetment made of huge gravels, which is considered to play a sufficient role in preventing erosion by the river. Based on the above, the landslide topography extracted by topographic interpretation shows no evidence of destabilization, at least at present, and there is little concern about erosion of the terminus, which could be caused by landslide activity, so the slope that is currently failing is targeted for countermeasure work.

The geology of the area including the subject slope consists of gneiss and schist metamorphic rocks. Gneiss is recognized in the bedrock outcrop on the Trongsa side along the national highway. The gneiss is of the NE strike-slope type and has a north-dipping structure with an inclination of about 30 degrees. On the other hand, outcrops of crystalline schist are observed on the Lobesa side along the national highway. The outcrops of the schist are of N70W strike with a southward dip of about 30 degrees, although the structure of the schist is variable. The outcrops of bedrock above the slope are of N40W type with a westward dip of about 20 degrees, which differs from the geological structure observed along the national highway. This suggests that the ground structure may have been disturbed by an old landslide, since variations in the structure were observed. The degree of weathering of the bedrock is moderate, and the rock texture is partially soft due to weathering along the fractures, but the geologic structure remains.

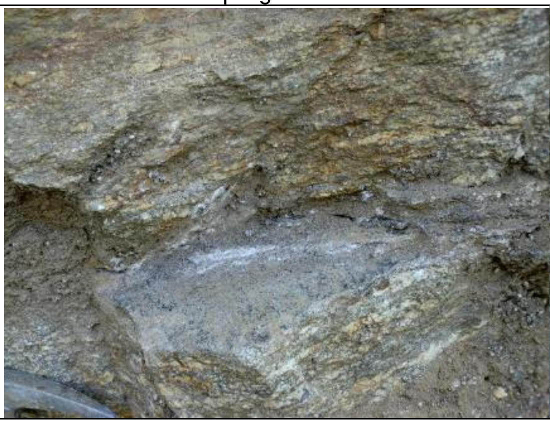
A few water springs were observed at the boundary between sediment and bedrock on the collapsed slope on the east side (Lobesa side) of the subject slope, and at the edge of the road, which is the edge of the collapsed slope. Since the observation was made in November, which is a dry season, it can be inferred that the amount of these springs increases during the monsoon season and that the number of springs increases.



(Source: JET, base map: Google Earth)

Figure. 3.5-10 Surface geological Map


Spring water from the end of the cut slope along the national highway




Gneissic structure: N16W, 4W

Spring water locations. The surrounding ground is extremely soft.

3m crack in the shoulder of the old road

(Source: JET)

Photo 3.5-1 Excerpts from a collection of local photos of the Tekizampa area

(3) Sectional surveying

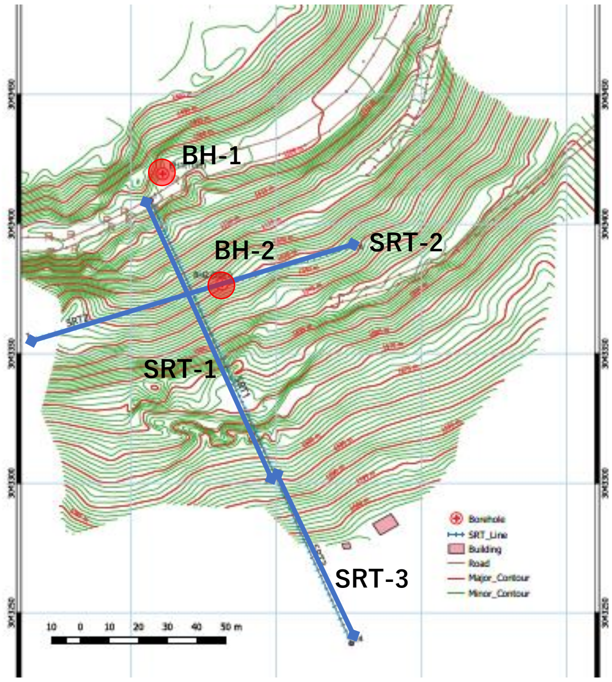
In front of the collapsed slope in the Tekizampa area is National Highway 1 (PNH 1), and the road section in the collapsed area has a partial road width of about 5 m, which allows for one lane. Therefore, it is necessary to prevent sediments and rocks generated by the construction work on the slope from falling onto the road. Therefore, a cross-sectional survey of the road was conducted to determine temporary rockfall protection measures while maintaining the width of the road. The survey team from DoST's Lobesa Regional Office conducted the cross-sectional survey. In preparing the transect map from the results of the transect survey, the team provided guidance on the specifications of the transect map required for the design of slope protection measures.

(4) Geotechnical survey (Outsourcing)

Borehole investigations and seismic surveys were planned to determine the geological conditions, distribution of unstable layers, and geological properties of the Tekizampa area. The DoST ordered these surveys to a private contractor, and JET assisted in the preparation of technical specifications for the ordered surveys.

The survey items and objectives are as follows

- ■ Boring survey: 2 locations
  - ✓ Core sample collection
  - ✓ Confirmation of geologic structure and depth
  - ✓ groundwater level
- ■ Standard penetration test: 2 locations
  - ✓ Confirmation of the degree of hardness and softness of the ground
- ■ Seismic survey: 3 lines
  - ✓ Distribution of hard and soft areas of the ground



(Source: JET, base map: Google Earth)
Figure. 3.5-11 Planned ground investigation plan in Tekizampa area

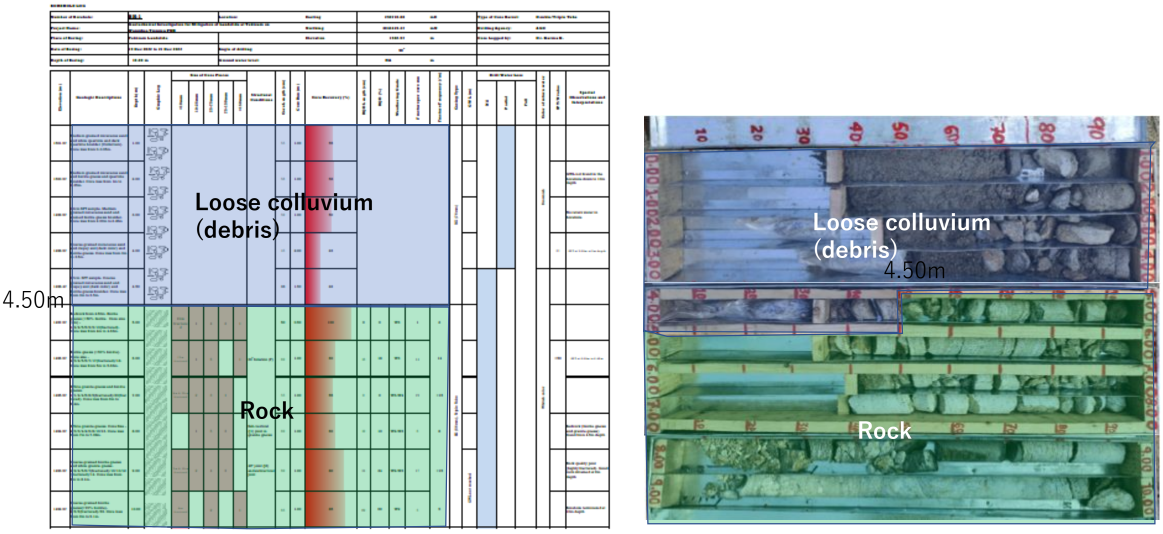
(5) Organize field survey results

The following is a summary of the results of the field surveys conducted to date.

- ■ Boring survey

The boreholes were placed at the two locations shown in the figure above. The drilling depths were 10 m in borehole BH-1 and 20 m in borehole BH-2. Core samples were taken at all depths during this borehole investigation to confirm the geologic type and depth of distribution.

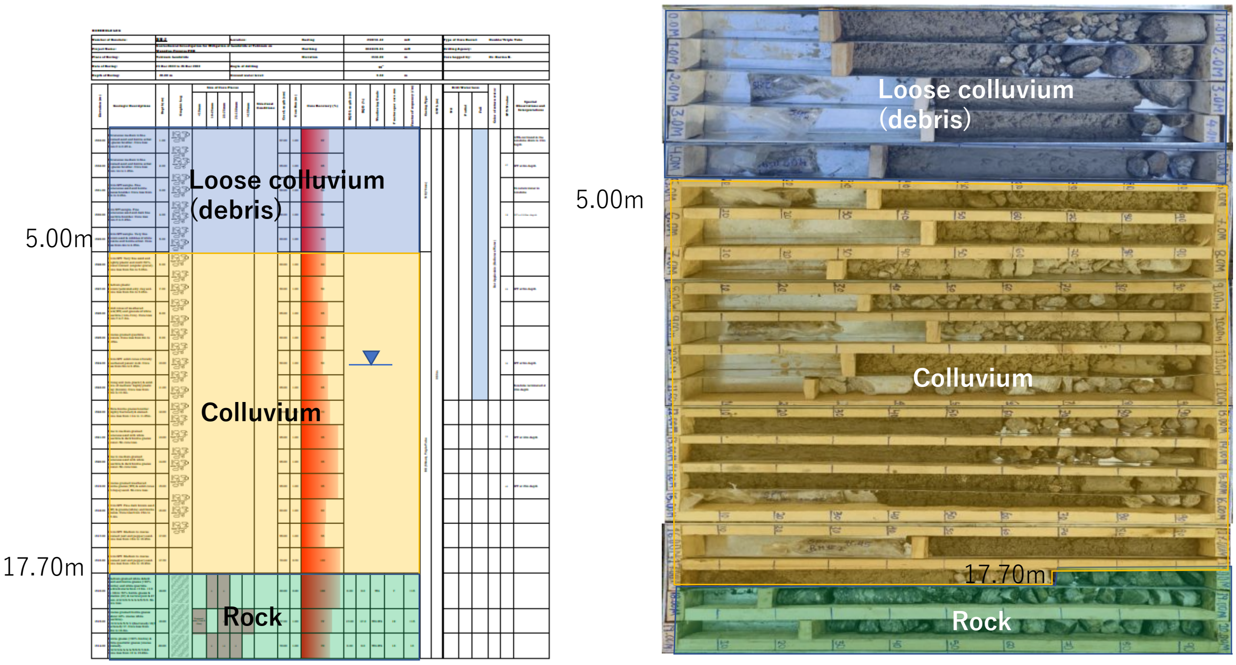
Based on the observation of these cores and the geological conditions confirmed during the field transects, a geological classification was made for each borehole. The results are shown in the figure below.



(Source: JET)

Figure. 3.5-12 Borehole core and columnar view of hole BH-1

The core observations indicate that the boundary between the loose soil and basement rock generated by the slope failure is located at a depth of 4.5 m.



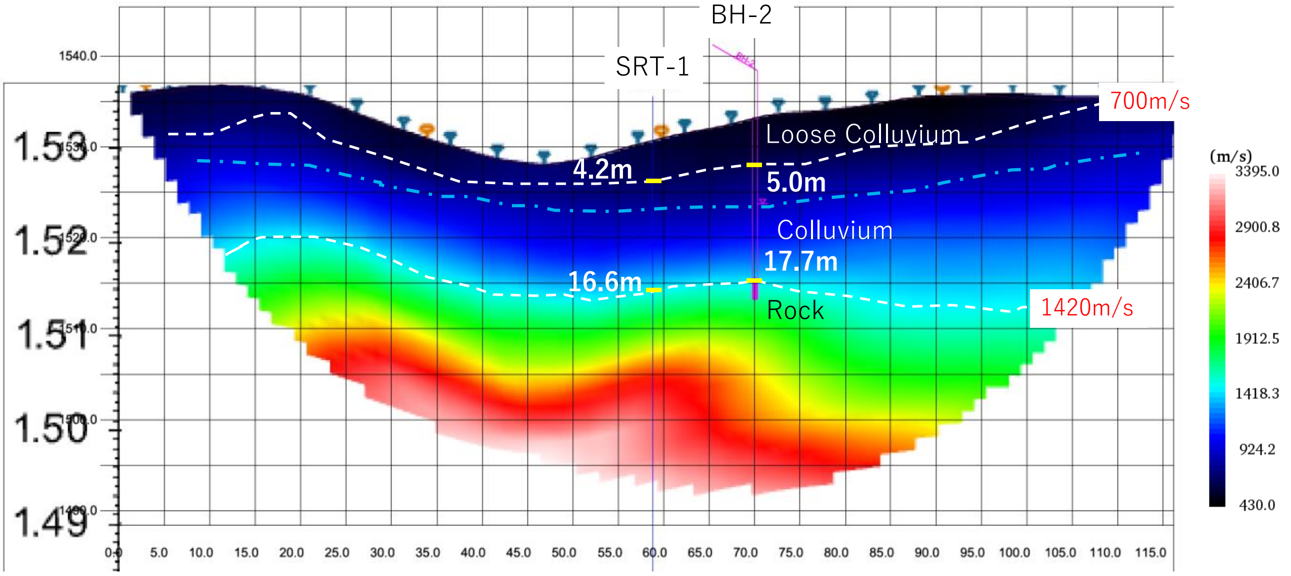
(Source: JET)

Figure. 3.5-13 Borehole core and columnar map of hole BH-2

The core observations identified three main geologic formations at this borehole site: loose colluvium resulting from slope failure, gravelly sandy soil cemented by older slope deposits, and basement rock, starting from the top. The boundaries of each are located at depths of 5 m and 17.7 m, respectively.

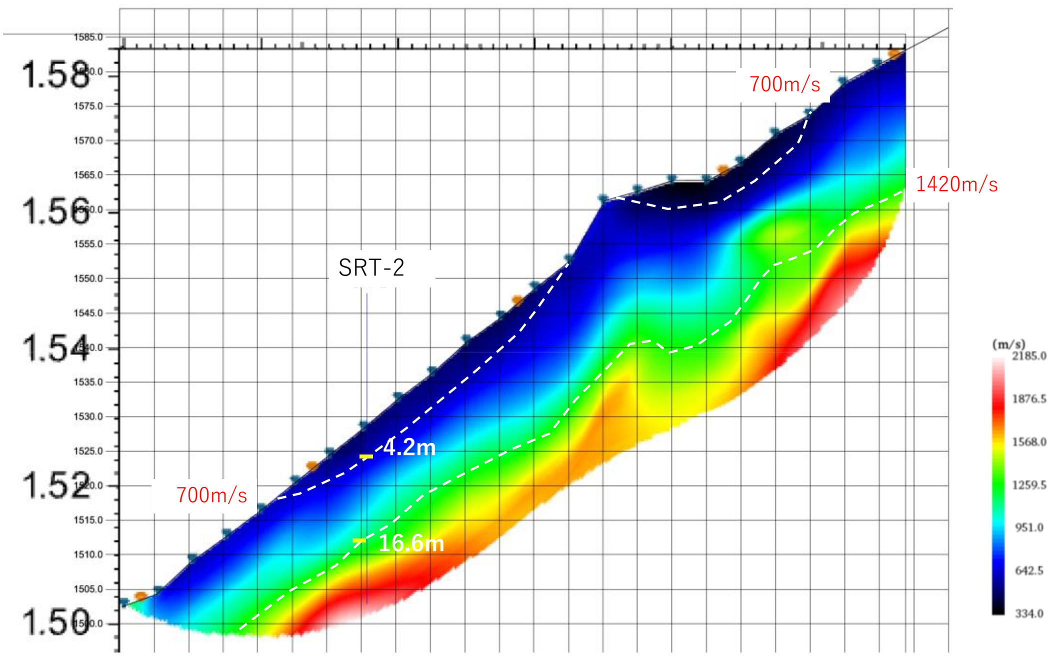
■ Seismic exloration

The seismic exploratioin was conducted on a survey line that passes through or near the borehole investigation site. In this way, a velocity layer analysis of seismic waves can be performed to estimate the distribution of each layer identified in the borehole survey and the groundwater level. Below is a diagram of the seismic velocity layer analysis, taking into account the results of the borehole survey.



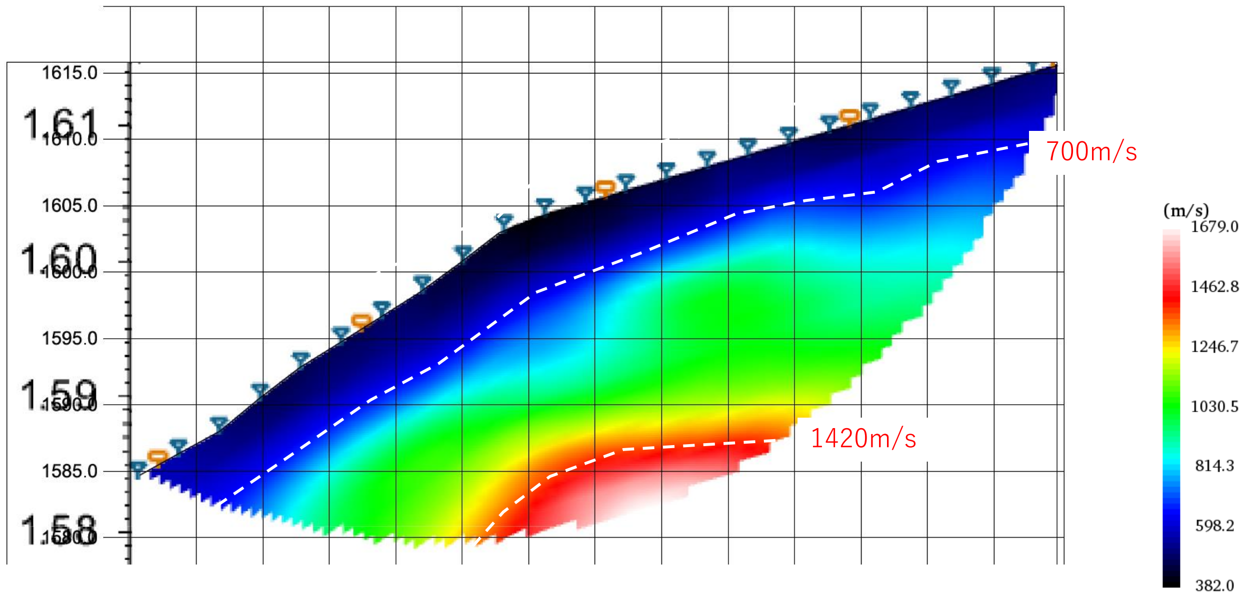
(Source: JET)

Figure. 3.5-14 Analytical cross section of SRT-2 seismic survey results



(Source: JET)

Figure. 3.5-15 Analytical cross section of SRT-1 seismic survey results

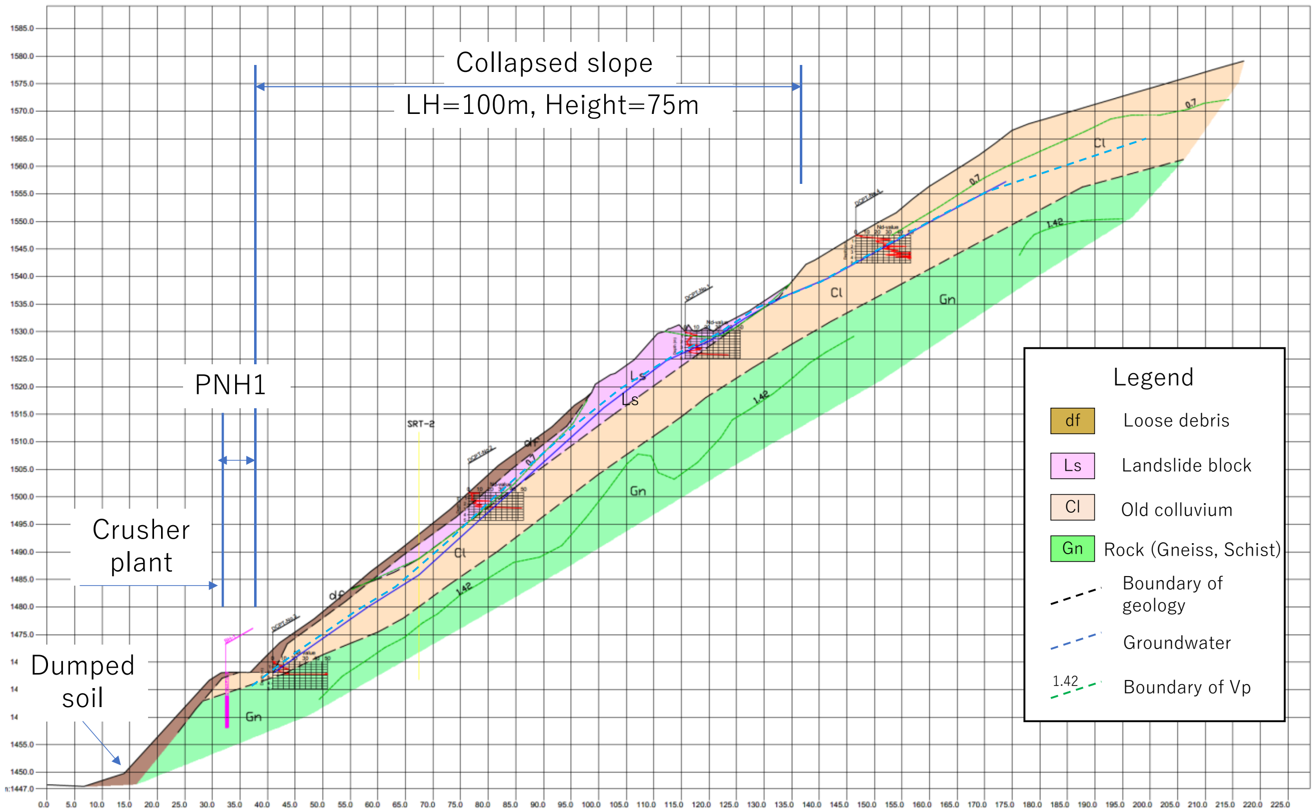


(Source: JET)

Figure. 3.5-16 Analytical cross section of SRT-3 seismic survey results

■ Geological analysis cross section

A geologic cross section of the subject slope was prepared based on the results of the field transects, borehole investigations, and seismic surveys.



(Source: JET)

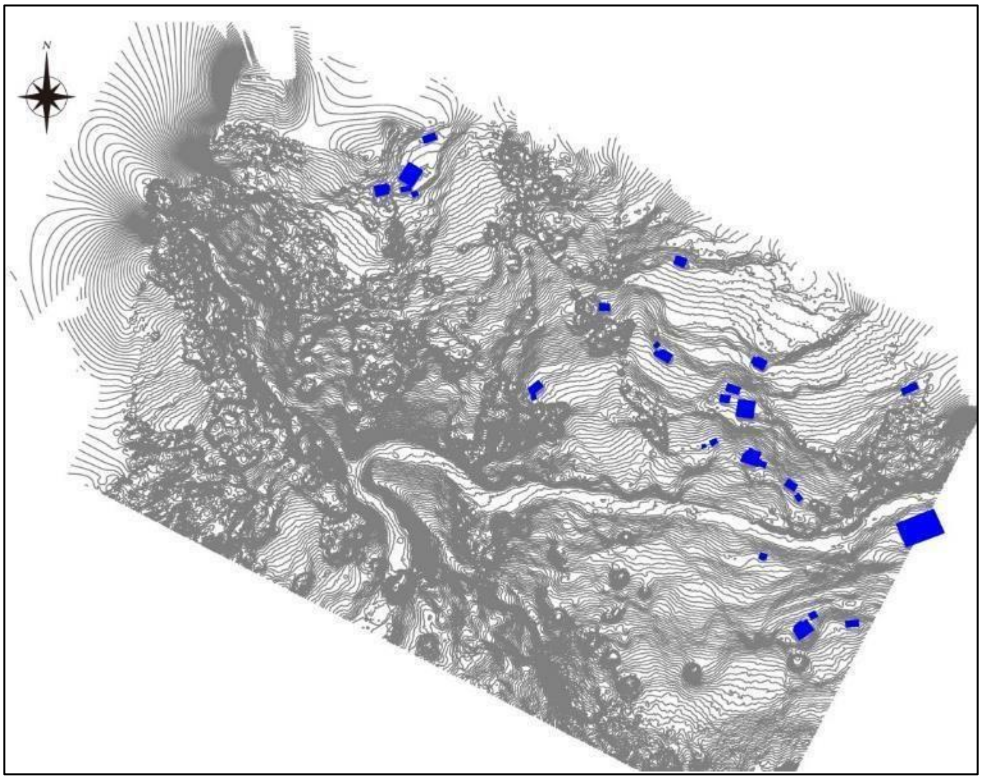
Figure. 3.5-17 Geologic Analysis Cross Section

Based on this, countermeasure construction was considered.

<Pilot site: Tashiling bridge area>

(1) Topographical survey

Prior to the surface survey and on-site ground investigation, topographical surveying was conducted around the subject slope. The surveying area included the target site and the mountain road to be used for the countermeasure work. However, it was difficult to determine the actual height and shape of the vegetation, roads, and structures, so DoST's survey team used a total station to survey the surface. The final topographic map was created by combining the survey results from JET and DoST.



(Source: JET)

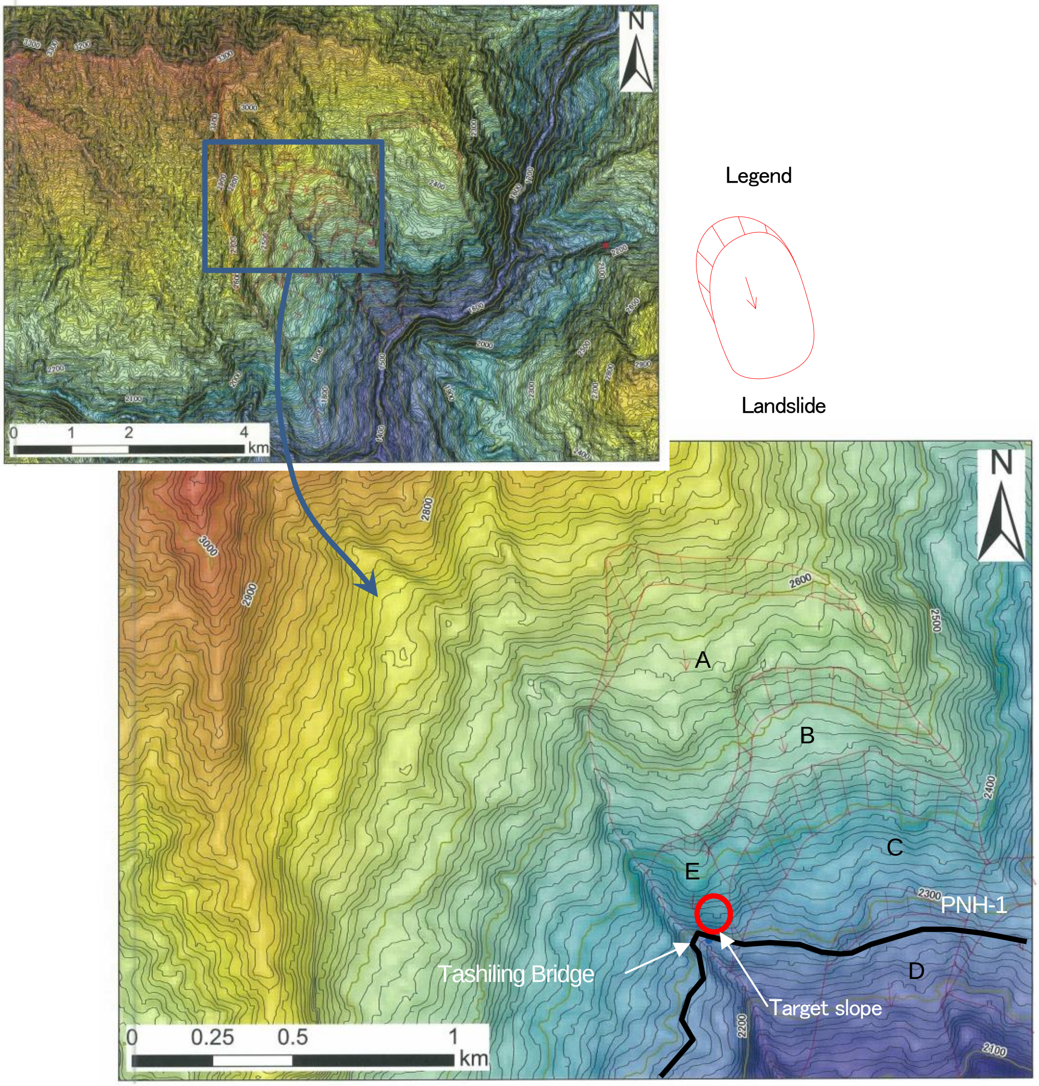
Figure. 3.5-18 Topographic map of the Tashiling Bridge area created using UAV

(2) Site reconnaissance

a) Topographic Analysis

Topographic decipherment was performed from a topographic map of the subject area based on Google Earth data; the Tashiling area has long been known as a landslide-prone area, and DoST frequently repairs roads in the area. As a result of the topographic interpretation, the target slope was found to be located within a large landslide topography.

The landslide landforms deciphered here are areas that exhibit characteristic landslide topography, and a detailed geological investigation is needed to determine if they are true landslides. However, since road deformations have been observed intermittently so far, it is highly likely that the decoded landslide topography is a relatively active landslide. As indicated by the decipherment results, the eastern road segment that includes the subject slope runs through the landslide block. The decipherment revealed the following



(Source: JET)

Figure. 3.5-19 Landslide topographic decipherment map of Tashiling Bridge area

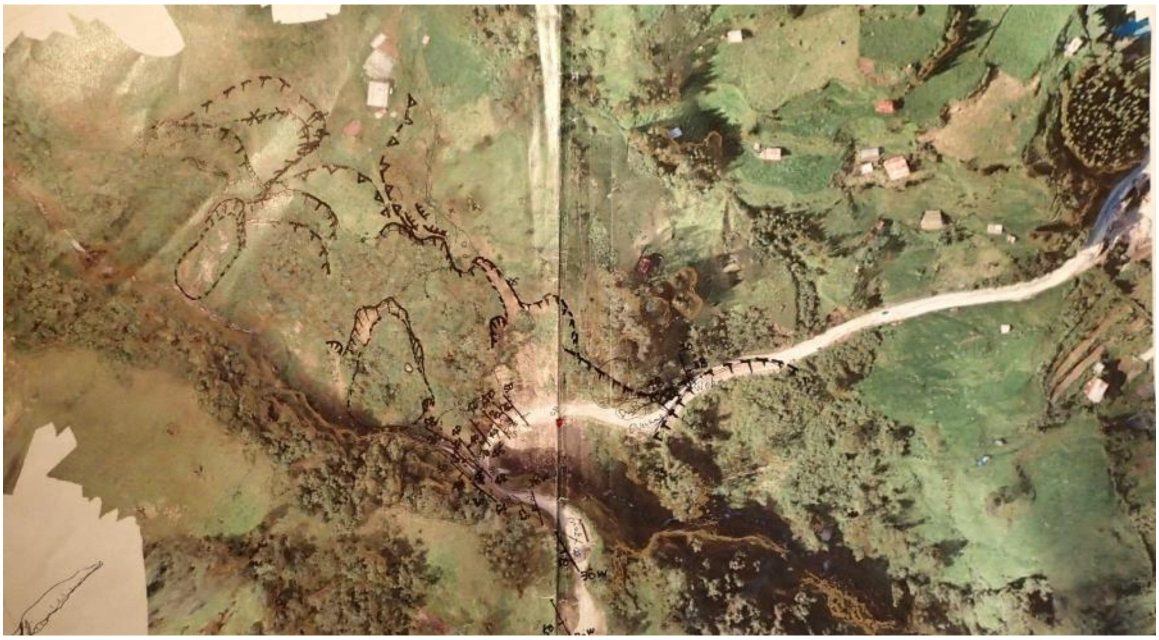
- From the main ridge at 3300m elevation to Mangdechu at 1500m elevation (see Figure 3-13 upper figure). Huge landslide blocks are densely packed. The topography of the upper and lower edges of the huge blocks is unclear.
- The subject slope is lateral to the main landslide block A. This landslide block is a landslide block that was destabilized by the progression of valley erosion caused by the stream on the west side of the subject slope. In particular, the side of landslide block A on the left bank of the stream appears to be secondarily active (landslide block E). In addition to this, the slope is thought to have been further destabilized by the cut-and-cover construction associated with the widening of the national road.
- The slope on the left side of the stream is extremely unstable with many new cracks developed and slope failure toward the stream.

b) Site recconnaissance

Surface exploration was conducted in the surrounding area including the subject slope. The area including the subject site is composed of metamorphic rocks (crystalline schist). Bedrock outcrops were observed along the national highway and along the mountain stream on the west side of the slope. The outcrops along the stream and near the outlet of the stream have a strike of N30-50W and a dip of 50° W, based on the direction of schist development in the crystalline schist. On the other hand, the outcrops on the east side of the stream, including the subject slope, differ from this structural direction and are dominated by an east-falling structure with strike N20W-10E and dip 30-70 degrees. The outcrops along the stream are relatively hard, but the outcrops on the east side of the stream are weathered, softening and loosening.

The topographic interpretation revealed that the slopes in the area including the subject slope are located within a landslide topography. Fresh cracks have developed on the surrounding slopes, including the subject slope, indicating an unstable situation.

Based on the results of the field transects and previous observations of deformation in the vicinity, it is possible that partial landslides are present and that they are also intermittently active.



(Source: JET, base map: Google Earth)

Figure. 3.5-20 Drawing of ground surface exploration

There are residual collapsed sediments and rock masses on the subject slope, which may become unstable and collapse in the future. In addition, a constant spring is observed on the slope, which is thought to have softened the slope ground and is supplying groundwater through seepage into the ground.

On the west side of the failed slope, the slope on the right bank (west side) of the stream is a near-vertical bedrock slope with no failure points, and the slope is considered to be stable. On the other hand, the slope slope on the left bank (east side) is 30 to 40 degrees, and many surface failures were observed, with collapsed sediments reaching the stream. Based on the strike and dip indicated by the aforementioned Katari, the bedrock structure on the left bank slope is inclined toward the stream (streambed), which is considered to be a collapse-prone condition. On the other hand, the bedrock structure on the right bank slopes in the opposite direction (catchment), forming a high-angle slope that is less prone to slope failure.

	
Open crack Depth: 0.6m, Width: 0.5m, Step: 0.4m	avalanche of sandstone cliffs
	
Spring from collapsed boundary	Spring from collapsed boundary
	
Crystalline schist: strike strike-slope N48W, 29W (right bank side)	

(Source: JET)

Photo 3.5-2 Excerpts from field photographs of the Tashiling bridge area (deformation locations and strike and dip results)

(3) Organize field survey results

The results of the field surveys conducted to date are summarized in the figure shown before. JET has also compiled photographs of the site conditions.

b) Comments on the content of the existing report

A draft report on the survey and design work ordered by the Bridge Division of the DoST was submitted. JET reviewed this survey report. Mainly, JET commented on the following points, which were shared and explained to the Bridge Division staff.

- Confirmation of the extent and distribution location of collapsed areas
- Results of borehole investigations and interpretation of the strata in which they are distributed
- Consistency with seismic survey results

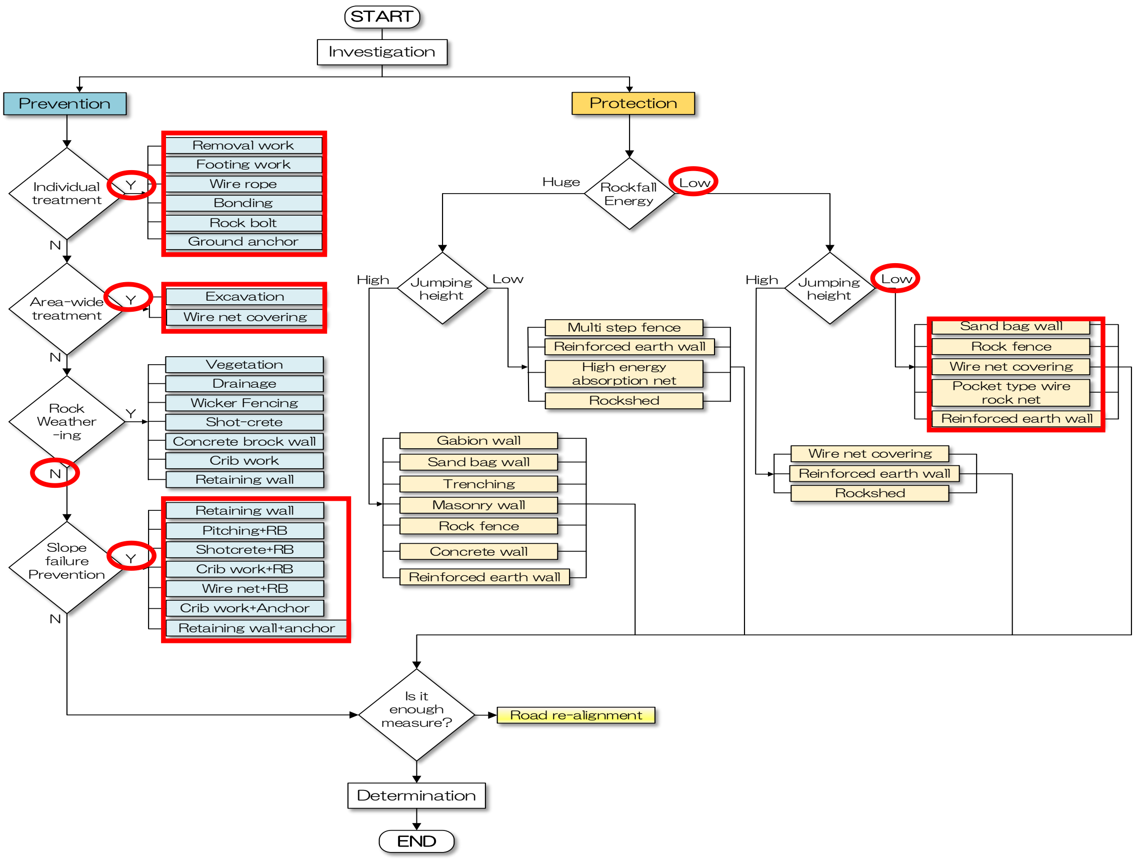
Activity 4-3. Select suitable countermeasure works for the target sections and slopes

<Pilot site: Chendebji district>

In the process of selecting the site for the countermeasure, JET had another discussion with the DoST side regarding the installation of a rockfall protection wall, which had been decided in the detailed planning study, and obtained their consent to apply a wall type rockfall protection work for the first traial construction. However, the DoST side decided to consider the application of a rockfall protection method using materials other than large sandbags due to difficulties in securing installation space, appearance that would spoil the landscape, and the fact that the sandbags would be imported from overseas (Japan), making the method less economical than the conventional method. The decision was made to consider a method of protecting against falling rocks using materials other than large sandbags. Based on the results of the investigation, the following policy for selecting countermeasure works was decided upon in consultation with the DoST.

1) Countermeasure works shall target rockfall and minor surface failures. This does not include reactive landslides.
2) Materials available in Bhutan is used as much as possible.
3) Current road alignment is not changed.
4) Existing countermeasure (Boulder wall) is not be touched.
5) The structure shall be capable of handling an impact force of 300 kN or less from falling rocks.
6) Unstable stones with more falling rock energy than that should be removed whenever possible
7) Also consider ensuring stability at the end of the slope
8) The construction method should minimize the impact of construction on slope stability.
9) Use drainage countermeasure construction in combination.

Based on these conditions and the results of the investigation, it was decided to consider countermeasure works for Sections A and C. The selection of countermeasure works was based on the following flow chart, which is commonly used in Japan. The selection of countermeasure works was based on the selection flow for rockfall countermeasures generally used in Japan, as shown below.

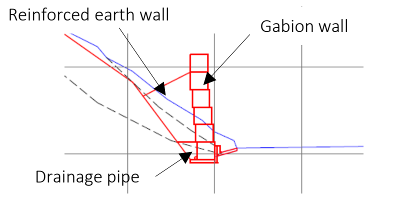
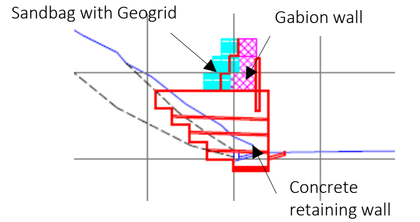
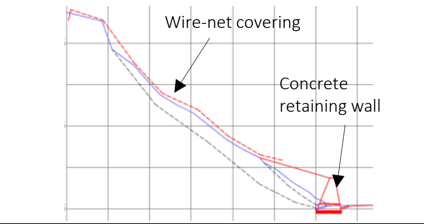


(Source: Rockfall Prevention Handbook, Japan Road Association)

Figure. 3.5-21 Selection Flow of Countermeasure Works

Based on the discussed countermeasure construction selection policy and the selection flow described above, three options were selected for countermeasure construction at this pilot site and compared. A table for selecting countermeasure works is shown below. The three selected plans are "Plan 1: Rockfall protection wall with reinforced soil wall using geogrid," "Plan 2: Concrete retaining wall + rockfall protection wall with sandbags," and "Plan 3: Concrete retaining wall + rockfall protection netting. The three points of comparison were "effectiveness of countermeasure construction," "workability," and "economic efficiency. As a result of the comparative study, it was concluded that the first proposal was the most advantageous in terms of workability, the degree of influence of the construction on slope stability, and the specification of materials that are easily available in Bhutan. Therefore, it was decided to adopt a geogrid reinforced soil wall to protect falling rocks as the countermeasure construction for the first pilot site.

Table 3.5-4 Selection Table for Countermeasure Works

	PLAN 1	PLAN 2	PLAN 3
Schematic drawing of Planed countermeasure			
Purpose of method	The plan is to retain the unstable slope and to protect from rockfall by absorption of rockfall energy by reinforced earth wall.	The plan is to retain the unstable slope by retaining wall, and to protect from rockfall sandbag wall with geogrid. Gabion wall is support of sandbag.	The plan is to retain the unstable slope by retaining wall and backfill as counter-weight. The unstable rocks on the slope are settled by the wire-net.
Feature of Measure	■ The reinforced earth wall using geotextile absorbs the impact of falling rocks without greatly expanding the road on the valley side and contributes to the stability of the back slope itself. ■ A pocket for falling rocks is secured by inclining the upper surface to the mountain side. ■ Since the amount of excavation is relatively small, there is small impact on slope stability. ■ It is difficult to treat high-energy rockfalls. ■ It can be constructed with materials available almost in Bhutan	■ By making a concrete base, it can be secured a space and pocket for the rock fall protection wall in the upper part without greatly expanding the road on the valley side. The concrete base also contributes to slope stability. ■ The rockfall protection wall itself uses a sandbag, so it is easy to be constructed and maintained. ■ It is difficult to treat high-energy rockfalls. ■ It will affect landscape relatively due to large concrete structure. ■ It can be constructed with materials available almost in Bhutan	■ Adopt wire net work with protective and preventive functions. Therefore, the rocks on the slope can be kept on the original position, or rockfall kinetic energy can be reduced. ■ The effectiveness for rockfalls with relatively large kinetic energy can be expected. ■ The work can contribute to the stability of the debris on the slope surface. ■ Material costs and construction costs for wire nets will be expensive. ■ Periodic maintenance to removal of debris behind the net is required.
Validity/Effectiveness	By removing rocks that are assumed to be high energy, it can be expected to protect against most rocks on the slope. It is also expected to prevent the collapse of unstable sediment on the slope.	By removing rocks that are assumed to be high energy, it can be expected to protect against most rocks on the slope. It is also expected to prevent the collapse of unstable sediment on the slope.	Wire net covering work can be expected to have effectiveness of protective and preventive work. Stabilization of rockfall and slope surface can be expected.
Workability	It is more lightweight than a concrete structure and can be constructed with ordinal machineries. Since slope excavation required, excavation and embankment laying must be done carefully and by stages.	Since the amount of excavated soil at the lower part of the slope is the largest in the three plans, excavation and concrete placement work must be done carefully and by stages. Quality control of concrete is important.	Since the excavation area on the slope is small, there is little impact on slope stability, and it is easy to ensure safety during work under the slope. On the other hand, wire net work requires work in high places, so safety must be ensured.
Economic efficiency	80,000 BTN/m The plan is the cheapest method among the three plans. Imported geotextile is a relatively expensive material, but other materials can be procured in Bhutan.	210,000 BTN/m The materials can be procured in Bhutan. Although the expected effectiveness is almost the same as PLAN 1, but the unit price is higher than PLAN 1 due to the large amount of concrete work.	1,100,000 BTN/m Although the concrete retaining wall construction cost for slope countermeasures is cheaper than PLAN2, the material cost and construction cost of the wire net are expensive.
Evaluation	○	△	×

(Source: JET)

○: Reasonable, △: Moderate, ×: Poor

<Pilot site Tekizampa district>

Through investigation and analysis, JET identified the unstable points on the subject slope. Countermeasure works were considered for these unstable areas. In considering countermeasure construction, two options were considered: (1) remove the unstable soil mass, and (2) fix at original position.

These two plans were reviewed and compared in terms of specific countermeasure types, advantages, challenges, and estimated construction costs. A summary of each plan is provided below.

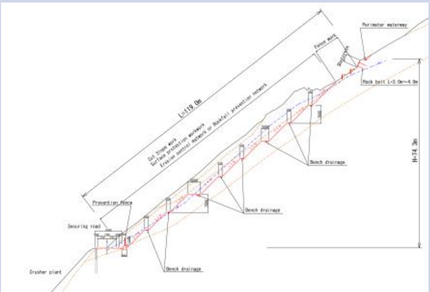
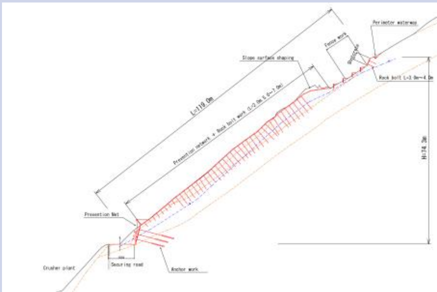
■ Plan1

Unstable soil masses are removed by cut-and-fill works, and appropriate cut-and-fill slopes are formed according to the geological conditions. The head of the cliff is reinforced by mortar spraying and reinforcing bars. After the cut, a drainage channel is constructed on the slope to properly remove surface water from the slope.

■ Plan2

The unstable soil mass is held in place by structures (anchors and rebar inserts) and secured in place. The head of the cliff is reinforced by mortar spraying and reinforcing bars. Drainage channels are laid around the target slope to prevent inflow into the slope from outside the slope.

Table 3.5-5 Selection Table of Countermeasure Works

	Plan 1 To stabilize by changing to stable shape (remove all unstable part)	Plan 2 To stabilize by structural force (mechanical countermeasure)
Standard cross section		
Advantage	• Stability of the slope can be secure after countermeasures due to removing all unstable part. • Maintenance after work is easy.	• Reduce the risk of secondary slope failure during construction due to minimal removal of unstable part
Issue	• A long-term construction period will be required. • It is difficult to ensure the safety of the national highway during cutting work (road closure measures are required)	• Material and machinery may be brought from out of country (construction costs will increase) • Maintenance of the structures is required regularly after completion of the construction
Rough cost	**51,000,000 (Nu)**	**250,000,000 (Nu)**

(Source: JET)

After comparative study, it was proposed that Plan 2 be adopted, as it is a construction method with which Bhutanese contractors have little experience, and the construction cost is approximately five times higher than Plan 1, and the DCC decided on January 31, 2023 to adopt Plan 1.

Activity 4-4: Plan and design the selected countermeasure works.

Design of countermeasure works selected through comparative study in Activity 4-3 was performed.

<Pilot site: Chendebji district>

(1) Adopted countermeasure construction

1) Removal of unstable rocks

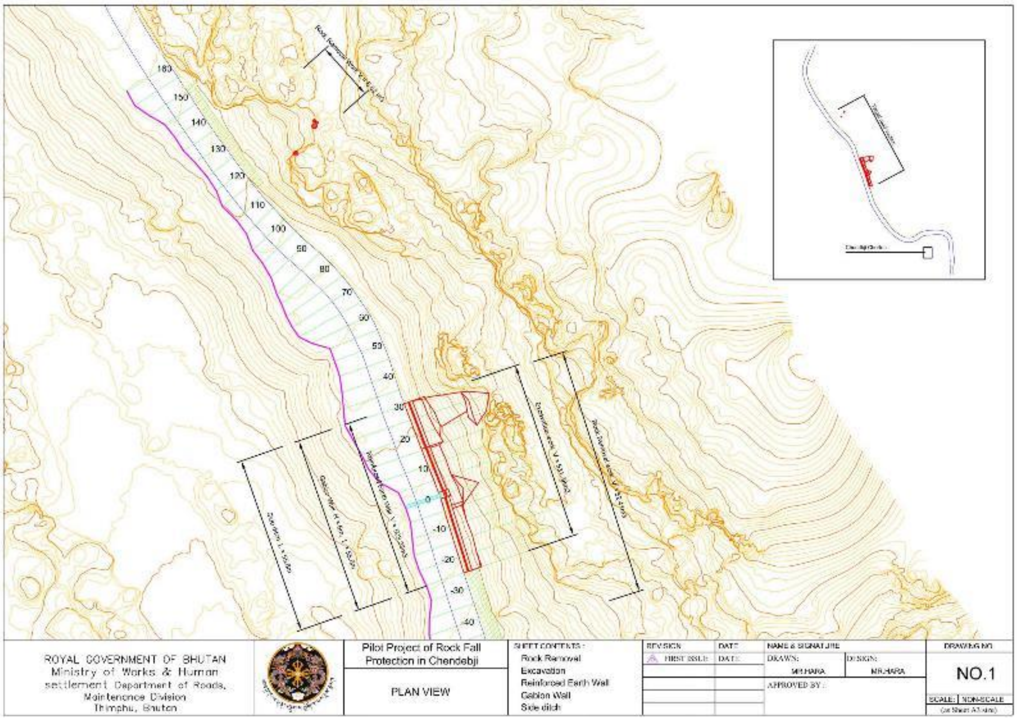
Unstable rock removal is basically performed to remove unstable rocks on the slope. Removal of unstable rocks is basically carried out using heavy equipment, and in places where heavy equipment cannot reach, removal is carried out manually. Unstable stones that are difficult to remove even with excavators are broken up using a Silent Blaster, and the small pieces of broken rock are removed.

2) Reinforced earth wall + Gabion wall

This retaining wall is a combination of a reinforced earth wall and a gabion. This structure is expected to function as a rockfall protection wall that is installed at the end of a slope to retain the slope behind it, including the surface, and to protect the road from falling rocks from the slope behind it. The reinforced soil wall absorbs the kinetic energy of falling rocks by means of a geogrid laid and compacted at intervals of 1 m in thickness. A permeable, flexible, and flexible cage will be placed in front of the reinforced soil wall. The geogrid can be procured from Indian manufacturers, and DoST has procured similar materials in the past.

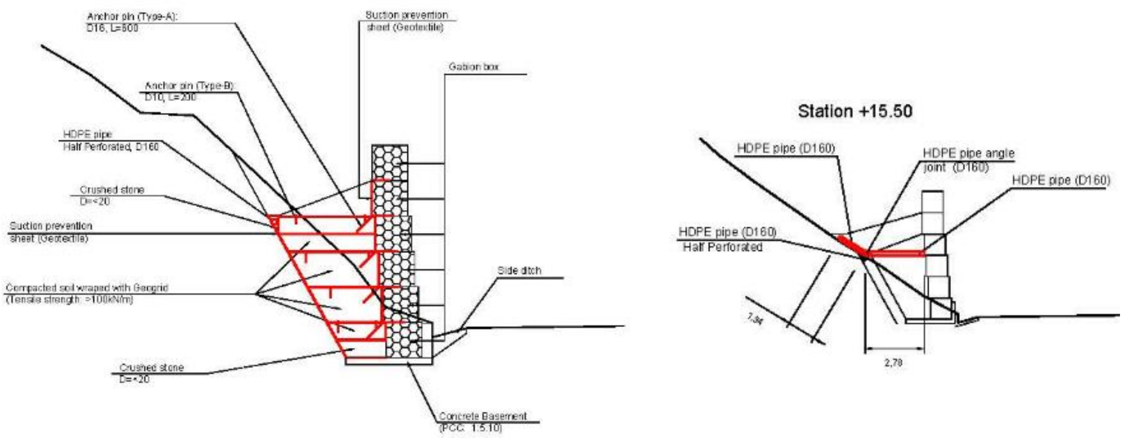
3) Drainage works

A geotextile and perforated pipe drainage system was installed in conjunction with a rockfall protection wall to properly drain spring water and surface water from the slope behind the wall. Water discharged from the drainage pipe drainage works installed in the protection wall is directed to the roadside ditch, while groundwater collected from behind the protection wall is designed to drain directly into the roadside ditch.



(Source: JET)

Figure. 3.5-22 Design drawings of countermeasure works at the pilot site (excerpt) (1)



Left: Standard cross section of reinforced soil wall, Right: Drainage work
(Source: JET)

Figure. 3.5-23 Design drawings of countermeasure works at the pilot site (excerpts) (2)

(2) Design standards and technical guidelines applied

The following design criteria and technical guidelines were applied in the design of this project.

1) Specifications for Building and Road works: DoES, MoIT
2) Guidelines on use of standard work item on common road work: DoST, MoIT
3) Handbook for rockfall prevention, Japan Road Association
4) Guidelines for Road Earthworks - Guidelines for cut-and-cover and slope stabilization works, Japan Road Association
5) Design and Construction Manual for Reinforced Soil Protection Retaining Wall Method for Steep Slope Protection, Reinforced Soil Protection Retaining Wall and Geo-Rock Wall Association

(3) Structural Calculation of Falling Rock Protection Wall with Earth Reinforcement

Among the countermeasure structures applied in this project, structural calculations were performed for a rockfall prevention wall (reinforced soil wall + gabion). The calculation items were to examine the stability against earth pressure from the slope behind and the impact strength against the assumed energy of falling rocks. Based on the results of the structural calculations, a design was drafted. In addition, technical specifications and cost estimates were prepared for the procurement of a contractor.

(4) Construction Precautions

A technical specification has been prepared that includes points to be considered in carrying out the designed countermeasure works. The following are some particularly important points to consider in carrying out the works

1) Excavation of the backslope should be done carefully to minimize the impact on slope stability.
2) The cut slope shall be thoroughly compacted with a bucket of heavy equipment prior to the installation of the reinforced soil wall.
3) Adequate safety measures should be taken during the work, especially while working on and near slopes, including enhanced monitoring.

During the construction period, one slope on each side of the road shall be closed to provide work space, and traffic guides shall be posted at all times.

<Pilot site: Tekizampa district>

(1) Adopted countermeasure construction

1) Earthwork

Recut the slope to a stable slope. Provide small steps at every 7 m slope elevation. Cuttings shall be excavated by machine.

2) Slope protection works

Prevent surface erosion by stretching jute nets over cut slope surfaces.

3) Berm ditch

Horizontal channels are provided on the small steps formed by the cut and earthwork to supplement surface water from the cut slope and discharge it off the slope. These small channels are connected to vertical drainage channels within the slope, collecting water and conducting it to roadside ditches.

4) Shotcrete + Soil nailing work

Mortar spraying + reinforcing bar insertion are applied to the cliff area at the head of the slope. This prevents erosion of the cliff surface and surface collapse of the slope.

5) Groundwater drainage work

A perforated pipe is inserted horizontally from near the point of water inflow within the slope to drain the groundwater underground. This reduces instability within the slope.

6) Wooden fence work

To ensure the stability of the natural slope below the slide cliff area, several levels of wooden fence construction should be installed horizontally.

7) Rockfall protection fence

Install rockfall protection fences along the road. After construction, protect falling rocks from the slope to the road.

8) Road widening works

Widen Route 1 road, which has become narrower due to slope failure.

(2) Construction issues

- Construction of works that are not common in Bhutan

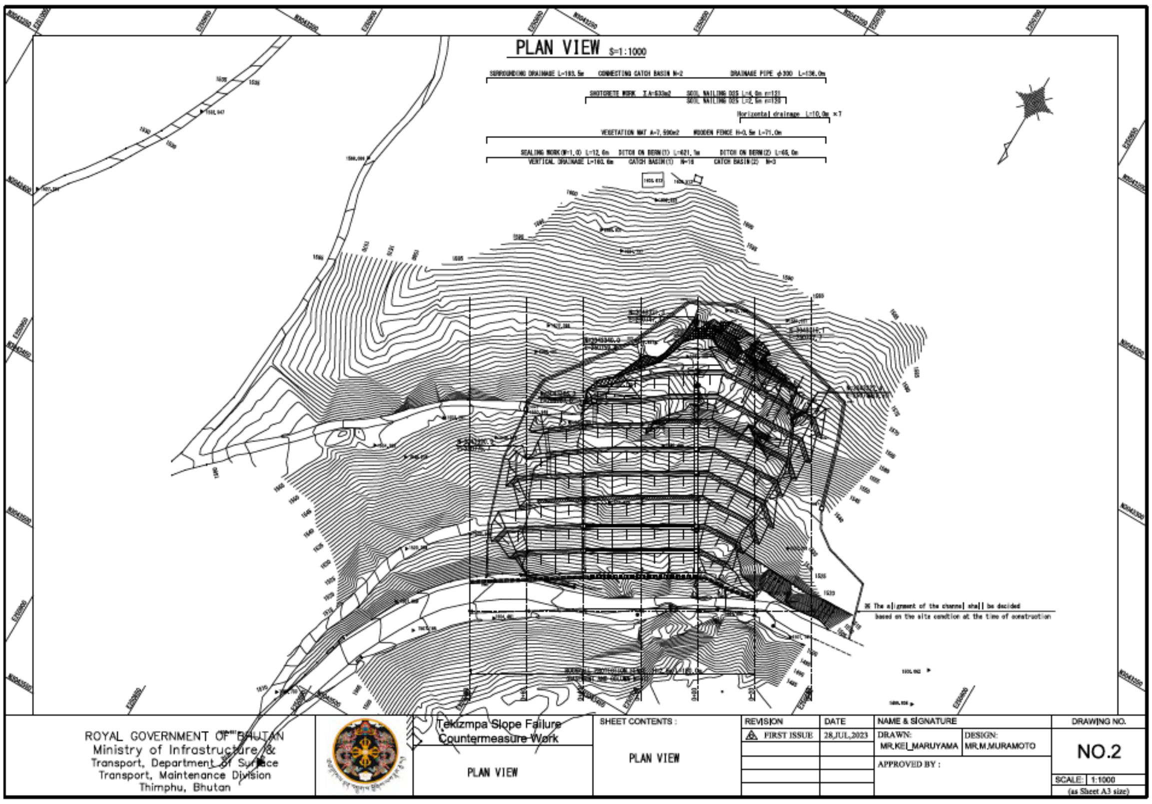
Of the construction types adopted for this project, mortar spraying, reinforcing bar insertion, and groundwater exclusion have been performed in Japan, but not many of them, and most of them were performed by foreign contractors. However, materials for construction can be obtained relatively easily in Japan or imported, and there are domestic contractors who own construction machinery, so it was determined that implementation would be possible by providing construction guidance to contractors for each type of construction.

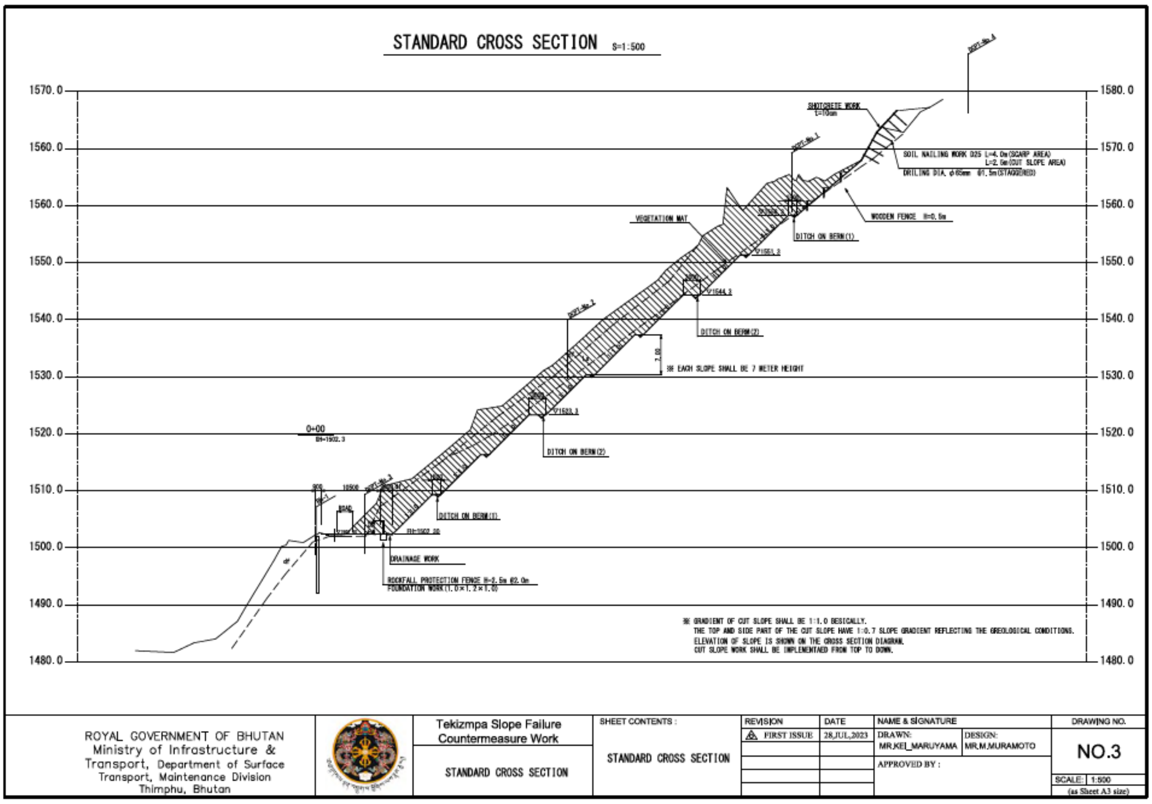
- Long-term construction period

The pilot site is expected to take at least two years to construct due to the larger area and volume of work compared to previous pilot sites.

- Securing soil dumping sites

The main part of this construction work was cut and fill. The amount of soil generated by this work was approximately 30,000 m3, so it is important to secure an earth dumping site to discharge this earth and sand. At present, a road slope located approximately 900 m from the construction site has been secured, and permission for soil dumping has been obtained from the Forestry Bureau.





(Source: JET)

Figure. 3.5-24 Design drawing of countermeasure works at pilot site Tekizapma

Activity 4-5: Implement the selected countermeasure works.

<Pilot site: Chendebji district>

As a result of this bidding, Druk Rabgyal Construction won the bid and the construction contract with DoST as the contractor was signed in early February 2020. The construction supervision system consisted of a supervisor from DoST's Trongsa regional office, a Japanese expert team in charge of construction management, and a locally hired site representative. The Japanese expert returned to Japan in mid-March due to COVID-19 pandemic, and the local management team consisted of the DoST supervisor, and a field representative hired by the Japanese expert team. The Japanese experts communicated with the local management via the Internet to keep abreast of the local situation. During the construction period, the supervisor and site representative held regular weekly meetings with the contractor to check the progress of the work and discuss problems, and then discussed with the Japanese side the issues raised in the progress checks and discussions with the contractor or provided guidance as necessary.

The construction work was initially expected to take 4.5 months, but due to the spread of COVID-19 pandemic, materials could not be procured from India, and a curfew was also imposed in Bhutan, which caused delays in the construction process. These delays caused the construction period to fall during the monsoon season, which further slowed down the construction progress. The materials to be procured from India were carried out using materials with equivalent specifications that were in the possession of DoST. This construction was completed in November 2020. During the construction period, events that were not anticipated during design were identified and occurred. Three design changes were made to address these situations.

1) Addition of side wall of rockfall protection wall (1st design modification)

After excavation for the installation of the rockfall protection wall, it was found that the originally assumed distribution area of the boulder wall was different from that of the original design. Therefore, a side wall of the boulder wall was added, which was not included in the design.

2) Shape change of rockfall protection wall (2nd design change)

A series of heavy monsoon rains caused the surface of the back slope on the Thimphu side to collapse, changing the shape of the back slope. The shape of the rockfall protection wall was changed due to this change in slope profile and the unstable rock mass on the slope.

3) Shape change of rockfall protection wall (3rd design change)

Monsoon rains caused the back slope on the Trongsa side to collapse, and the collapsed sediment caused the gabion in front of the protection wall to collapse. On-site inspection revealed that the reinforced earth wall itself was not damaged, only the cage placed in front of it. The slope collapse changed the shape of the slope behind the cage and caused unstable rocks on the slope, so the gabion was reinstalled and the shape of the rockfall protection wall was changed. This change was made as a temporary measure, taking into account the shortage of materials due to the Indian lockdown. In addition, since rainfall continued after the occurrence of the disaster, there was a possibility of further slope failure, so emergency measures were taken, such as cutting trees on the shoulder of the slope to reduce the load on the shoulder and covering the top of the slope with blue sheets to reduce the impact of precipitation on the slope. Since no new slope failure occurred and no movement of the slope was observed in the observation of cracks behind the slope, the slope was tentatively judged to be in a stable condition. There was no traffic or personal injury as a result of this event.

(Source: JET)

Photo 3.5-3 Reinforced Soil Wall Falling Rock Protection Wall Completed (2020/11/5)

Based on the results of field inspections and field tests conducted by the DoST supervisor and JET's field representative, JET submitted an approval document to DoST in November 2020 regarding the completion of the work. In this acknowledgment document, JET confirmed the unstable rock mass on the slope due to the change in slope conditions caused by the slope failure, verified the adequacy of the newly installed structures, and recommended that some countermeasures against slope failure should be implemented before the next monsoon.

<Pilot site: Tekizampa district>

As a result of the bidding, Rigsar Construction Private Limited won the bid and the construction contract with DoST as the contractor was signed on November 7, 2023. The construction supervision system consisted of a supervisor from DoST's Lobesa Regional Office, a team of Japanese experts in charge of construction management and construction guidance, and a locally hired site representative.

Construction of access roads

Temporary rock fall protection fence

Photo 3.5-4 Tekizmapa Preparatory Work Status

Activity 4-6: Implement safety management activities on the construction for the selected countermeasure works.

The safety management activities implemented during the remedial work at the pilot site are as follows.

(1) Mandatory wearing of helmets

JET made it mandatory for all workers to properly wear helmets while working on site to ensure worker safety.


(Source: JET)

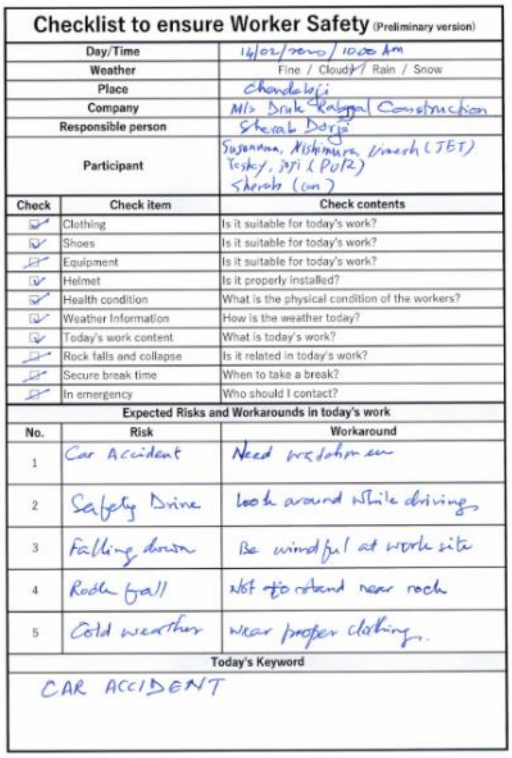
Figure. 3.5-25 Mandatory Helmet Wear (11/5/2020)

(2) Hazard prediction activities (KY activities)

KY activities are activities to anticipate safety by identifying potential hazards in the work and discussing countermeasures with all workers while observing the work methods, machinery, and work environment at the work site. The results of KY activities were compiled into a safety checklist prepared by the survey team.

(Source: JET)

Photo 3.5-5 KY activity on site (3/8/2020)



Checklist to ensure Worker Safety (Preliminary version)

Day/Time	14/02/2020 / 10:00 Am
Weather	Fine / Cloudy / Rain / Snow
Place	Chendebji
Company	M/s Druk Rabgyal Construction
Responsible person	Sherab Dorji
Participant	Susanna, Nishimura, Vinesh (JET) Yeshey, Jigi (PoR) Sherab (Con)

Check	Check item	Check contents
✓	Clothing	Is it suitable for today's work?
✓	Shoes	Is it suitable for today's work?
✓	Equipment	Is it suitable for today's work?
✓	Helmet	Is it properly installed?
✓	Health condition	What is the physical condition of the workers?
✓	Weather Information	How is the weather today?
✓	Today's work content	What is today's work?
✓	Rock falls and collapse	Is it related in today's work?
✓	Secure break time	When to take a break?
✓	In emergency	Who should I contact?

Expected Risks and Workarounds in today's work

No.	Risk	Workaround
1	Car Accident	Need watchmen
2	Safety Drive	look around while driving
3	Falling down	Be mindful at work site
4	Rock fall	Not to stand near rock
5	Cold weather	wear proper clothing.

Today's Keyword

CAR ACCIDENT

(Source: JET)

Figure. 3.5-26 Safety Checklist

(3) Assignment of traffic guides (Watchman)

When removing rocks from the slope, traffic guides (Watchmen) were placed on both sides of the construction section to ensure the safety of road users. Sign boards were placed to warn of the danger of falling rocks, and workers were instructed to suspend work on the slope when road users were passing by.

(Source: JET)

Photo 3.5-6 Safety Management by Traffic Guides (2/29/2020)

(4) Protection of slopes with blue sheets

Heavy rains during the rainy season caused several slope failures, which posed the risk of workers and road users being caught in the collapses. Efforts were made to mitigate the risk of collapse and reduce the risk of accidents by covering the tops of slopes at high risk of collapse with blue tarpaulins. During periods of concentrated rainfall, it is effective to cover slopes, especially shoulders and mid-slopes, with blue tarps to prevent rainwater and surface water from infiltrating into the slopes.

. (Source: JET)

Photo 3.5-7 Slope protection with blue sheets (10/8/2020)

Activity 4-7: Develop a design/implementation guideline and a standard unit price table on the selected countermeasure works.

The design and construction management guideline and standard unit price list for rockfall countermeasure works were prepared based on the construction procedures, design drawings, books, and construction supervision instructions prepared for the rockfall countermeasure works to be implemented at three sites. The table of contents and preparation policy of this technical guideline were reviewed and the design and construction management guideline was prepared. This guideline was divided into two parts: the planning, investigation and design section and the construction supervision section. The table of contents for the design and construction management guideline is described below.

Table 3.5-6 Table of Contents of Design and Construction Supervision Guidelines and Standard Unit Price List for Rockfall Prevention Work

Design/Implementation Guideline for Rock Slope Failure Countermeasure Works in Bhutan Ⅰ: Planning, Investigation and Design (Ver.1)	
1	Basic study procedure
2	Investigation and Analysis for Rock slope
2.1.	Topographical survey and Cross-sectional survey
2.1.1.	Topographical survey
2.1.2.	Cross-sectional survey
2.2.	Investigation method for Rock slope
2.2.1.	Interview survey
2.2.2.	Site reconnaissance
3	Design for rock slope countermeasure
3.1.	Calculation method of kinetic energy of rockfall
3.2.	Calculation method of Impact force of rockfall
3.3.	Selection of countermeasure for Rockfall disaster
3.4.	Design of countermeasure construction of rock protection wall
3.4.1.	General
3.4.2.	Material
3.4.3.	Procedure of design of geogrid reinforced earth wall
3.4.4.	Set the conditions and structural calculation
Appendix 1: Structural calculation sheet of the reinforced earth wall in case of Slope in Chendebji	
Appendix 2: Design drawings of rockfall countermeasure work in case of Slope in Chendebji	
Appendix 3: Quantity survey for the construction of Rockfall countermeasure work on the slope in Chendebji	
Appendix 4: Cost Estimation for the Rockfall countermeasure work on the slope in Chendebji	

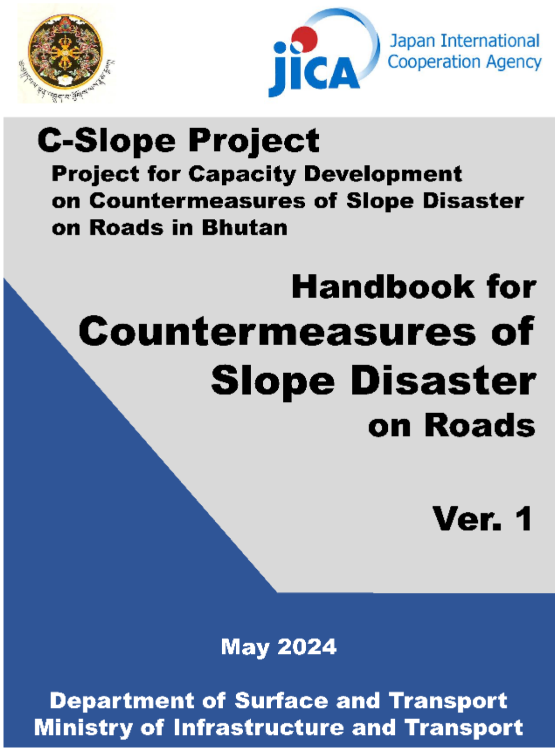
Design/Implementation Guideline for Rock Slope Failure Countermeasure Works in Bhutan Ⅱ: Construction Management (Ver.1)		
Chapter-1		Construction Plan
	1	Description
	2	Requirement
Chapter-2		Quality Control
	1	Quality Control for each work
	2	Field Checklist
	3	As Built Control
	4	Progress Control
Chapter-3		Safety Control
	1	Preface
	2	Prevention of occupational accidents due to slope failure in cut slope construction
	3	Safety Plan
	4	Meeting with the Client
	5	Dairy Works
	6	Work Item
	7	Field Checklist
Appendix-1: Sample of Construction Plan		
Appendix-2: A Field Checklist on Quality Control for Construction (DRAFT)		
Appendix-3: Sample of Weekly Meeting Report		
Appendix-4: Sample of Daily Construction Report		

(Source: JET)

Activity 4-8: Develop a countermeasure handbook for slope failures.

The countermeasures handbook summarizes activities and countermeasure construction for Output 1 through 5. The handbook is intended to serve as a reference for DoST engineers in implementing slope control measures. It is also intended to provide hints on activities that should be implemented in the implementation of slope control measures. Therefore, the contents are not detailed descriptions from investigation to design and selection of countermeasure works, but rather broad and general contents. For more detailed information, please refer to the guidelines prepared for each outcome.

The cover and table of contents of the handbook are shown.


Japan International Cooperation Agency
C-Slope Project
Project for Capacity Development on Countermeasures of Slope Disaster on Roads in Bhutan
Handbook for Countermeasures of Slope Disaster on Roads
Ver. 1
May 2024
Department of Surface and Transport
Ministry of Infrastructure and Transport

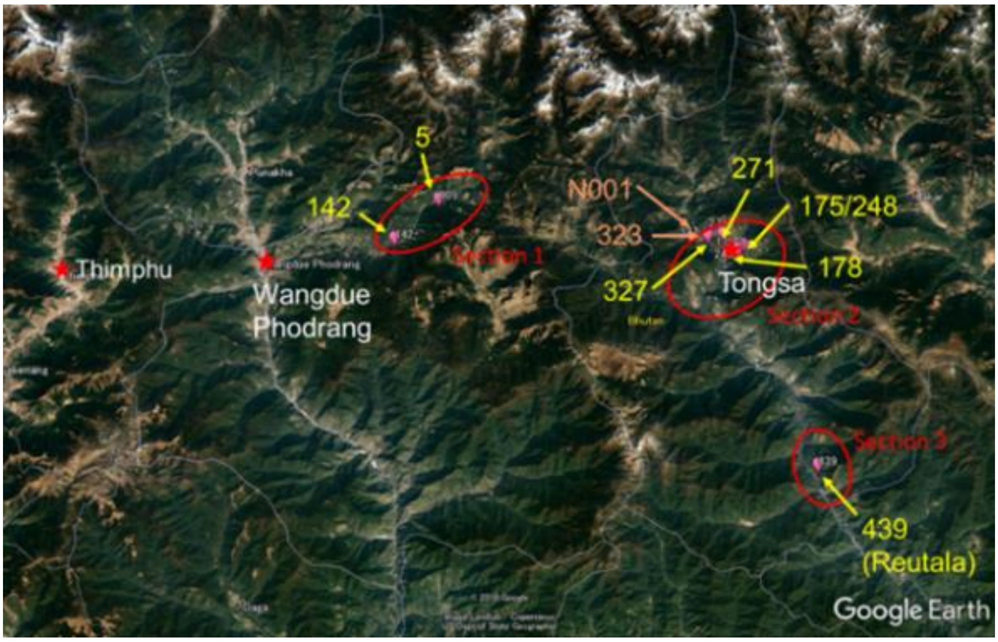
Contents

3.6 Output 5: Suitable drainage works and facilities are installed for "debris flow."

Activity 5-1: Select target sections and slopes based on the results of slope disaster inspections.

1) Selection of 1st pilot site

In the master plan survey for the preceding project, six streams were identified as candidate sites for pilot construction of debris flow counrtermeasure works within Lobesa and Trongsa ROs. In addition, information was obtained that four streams in these ROs had recently experienced debris flows along routes where DoST was implementing or planning to implement road widening projects. In order to select pilot sites, JET classified 10 of these streams into stream types based on their catchment area, streambed slope, geology, and other characteristics. In addition, detailed field survey were conducted on all candidate streams, and target slopes were selected together with C/P. The following is a location map of the candidate pilot sites and a list of the various parameters used in the selection of the pilot sites.



(Source: JET)

Figure. 3.6-1 Location map of 1st pilot site candidates (Lobesa: 2, Trongsa: 8 slopes)

Table 3.6-1 Topography and geology of the first candidate pilot site and characteristics of the countermeasure facilities

No	Office	Sec.	ID No.	PNH	Cross Section Num	Max Channel Order	φ Max (m)	Maximun Volume of Unstable Soil (m3)	Volume of Soil that can be Eroded by Estimated volume of Rainfall (m3)	Estimate Volume of Debris Flow (m3)	Peak Flow Rate (m3/s)	Cross-Sectional shape of Debris Flow W (m)	Cross-Sectional shape of Debris Flow D (m)	Minimum Drainage Facility *1 W (m)	Minimum Drainage Facility *1 D (m)	Current Status *2 W (m)	Current Status *2 D (m)	Current Status *2 φ (m)	Current Status *2 L (m)	Current Status *2 Condition	2-1 Judge	Widening	Proposed site for Pilot Construction 17/Apr/2019
1	Lobesa	1	142	1	3	0	1.2	2,440	15,070	2,440	27.1	2.4	1.4	2.4	2.0	–	–	1.0	20.0	Erosion on the lower downstream side. 0.3 m sink.	NG	Complete	B
2	Lobesa	1	5	1	5	2	1.2	22,180	72,010	22,180	246.4	5.0	3.2	5.0	4.0	1.5	1.5	–	6.0	Half of the downstream side is a bridge	NG	Complete	B
3	Trongsa	2	327	1	1	0	1.2	1,000	5,510	1,000	11.1	2.4	0.8	2.4	1.4	1.0	1.5	–	8.0	2/3 on the upstream side is buried with soil	NG	In progress	B
4	Trongsa	2	323	1	9	2	1.6	28,910	151,240	28,910	321.2	6.0	3.9	6.0	4.7	3.0	3.0	–	8.0	Countermeasures to be implemented	NG	In progress	A
5	Trongsa	2	N001	1	1	0	0.8	1,000	25,790	1,000	11.1	2.0	0.9	2.0	1.5	–	–	–	–	Countermeasures to be implemented	NG	In progress	B
6	Trongsa	2	271	1	9	2	2.4	11,360	167,770	11,360	126.2	5.0	2.4	5.0	3.2	3.0	3.0	–	8.0	New construction	NG	In progress	C
7	Trongsa	2	248	4	2	0	1.0	2,540	19,400	2,540	28.2	2.0	1.6	2.0	2.2	1.8	3.0	–	7.0	1/2 on the upstream side is buried with soil	NG	Undecided	C
8	Trongsa	2	175	4	1	0	0.6	1,000	8,270	1,000	11.1	2.0	0.9	2.0	1.5	1.5	1.5	–	6.0	1/2 on the upstream side is buried with soil	NG	Undecided	C
9	Trongsa	2	178	4	3	1	1.4	7,590	59,510	7,590	84.3	4.0	2.1	4.0	2.7	1.5	1.5	–	5.0	1/2 on the upstream side is buried with soil	NG	Undecided	B
10	Trongsa	3	439	4	2	0	1.6	1,000	6,890	1,000	11.1	3.2	0.7	3.2	1.6	1.5	1.5	–	7.0	Most of the upstream side is buried with soil	NG	Undecided	C

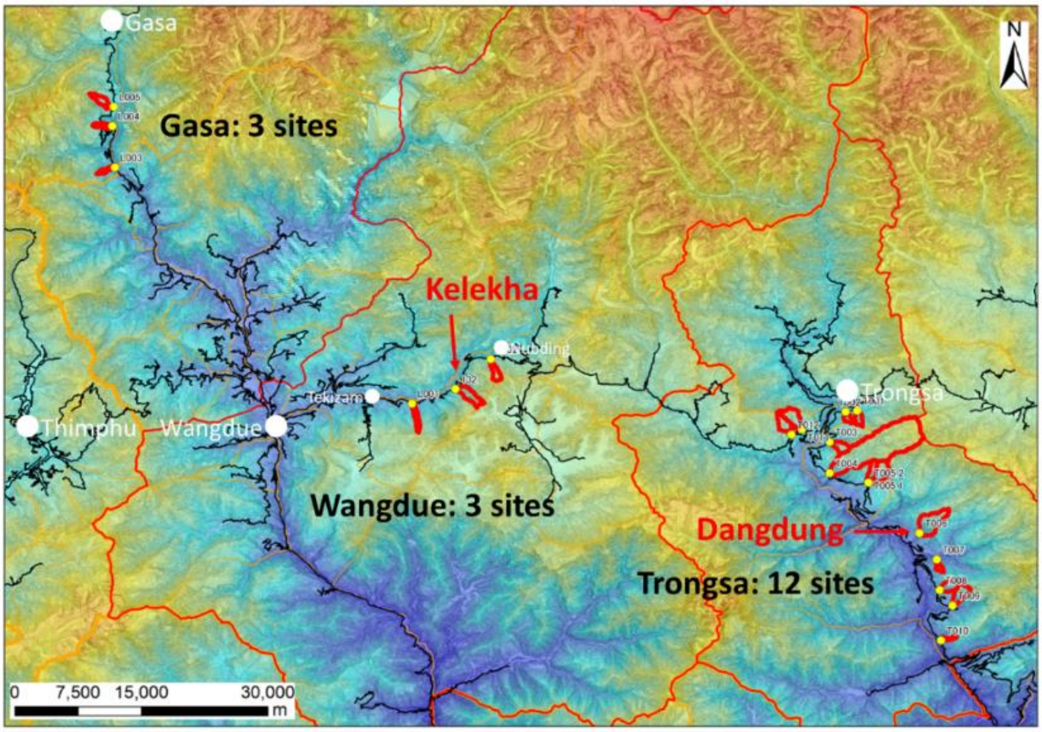
(orange)	Slope selected in the previous project
(yellow)	Slope that pointed as "Rank 1" in the previous project
(purple)	Slope where debris flow has occurred recently
Red	Conditions SUITABLE for pilot site
Blue	Conditions NOT SUITABLE for pilot site

(Source: JET)

As a result, No. 323 (Bjee site), located on a north-facing slope slightly on the Lobesa side from Trongsa, was determined to be the most suitable pilot site. A detailed survey of the amount of unstable soil deposited in the stream at the 10 candidate sites revealed that No. 323 is a secondery-order channel with an estimated soil discharge of 28,910 m3, a peak flow rate of 321.2 m3/s, and an estimated maximum boulder diameter of 1.6 m, all of which are the largest in the area, and that it would not be safe to carry out a debris flow at the road crossing. It is clear that a cross section of 6.0 m wide by 4.6 m high or more is necessary to allow the debris to flow down safely at the road crossing. In its current state, the box culvert is about 3.0 m wide by 3.0 m high, and this box culvert has become a bottleneck that has caused debris to spill onto the road on several occasions in the past. In addition, this section of road is currently undergoing road widening, and since safety assurance of the stream crossing was required, it was judged to be the most suitable pilot site for the first round of the project.

2) Selection of second pilot site

After the first pilot site selection, debris flows and debris discharges occurred in several streams while the project was suspended from April 2020 due to the impact of COVID-19. The second pilot site selection was based on these conditions and included 18 streams, including those that had been previously selected as candidates, and was classified into stream types based on a desk review of various parameters such as catchment area, streambed slope, and geology. The results of the field survey, the current condition of drainage facilities, the degree of impact in the event of a disaster, and the locations where surveys had already been conducted were taken into consideration. The following is a list of the various parameters that were taken into account in the selection of the second pilot site.



(Lobesa: 6, Trongsa: 12 Slopes, Source: JET)

Figure. 3.6-2 Location map of the second candidate pilot site

Table 3.6-2 Topography and geology of the second candidate pilot site, and characteristics of the countermeasure facilities.

Selection of Candidate Site for Debris Flow Countermeasure																			
Basic Information						Desk work					Field Survey						Result		
No	ID	Name/Place	RO	NH No	Selected by	Intersection point	Catchmnt Area	Channel Trace	Maximun Stream Order	No of Survey points	Priority of Survey	Intersection point	Current Culvert Size	Unstable soils on the channel	Photo for 3D-model	Note	Volume of expected debris flow (m3)	Cross-sectional shape of possible countermeasure facilities (Example)	Priority Order of Site Candidates (under consideration)
1	T001	Near Teleganchuu bridge	Trongsa	PNH6	Kinzang	Done	Done	Done	2	6	A	Done	1.6x1.8m	Done	Done	Requires special construction because it is directly under a waterfall	13,120	4.0x3.6m	B
2	T002	Near garbage disposal site	Trongsa	PNH5	Kinzang	Done	Done	Done	1	4	D	Done	1.5x1.2m	Done	Done	No space for inlet	7,590	4.0x2.7m	B
3	T003	Before Dam Colony,MHPA	Trongsa	PNH6	Kinzang	Done	Done	Done	2	6	A	Done	1.6x1.6m	Done	Done	Suitable for study	19,030	5.0x4.0m	A
4	T004	After Kungarapten (Truss Bridge)	Trongsa	PNH6	Kinzang	Done	Done	Done	4	20	C	Done	34x10m	Not planned	Done	Crossing by Truss Bridge			D
6	T005.1	Samcholing	Trongsa	PNH6	Kinzang	Done	Done	Done	1	3	B	Done	3.0x1.3m	Planning	Done	Merging after road crossing. Bridges are needed	No Data		B
6	T005.2	Samcholing	Trongsa	PNH6	Kinzang	Done	Done	Done	1	2	B	Done	2.8x1.2m	Planning	Done	Merging after road crossing. Bridges are needed	No Data		B
6	T006	2019 Debris flow at Tshongkhabg	Trongsa	PNH5	Kinzang	Done	Done	Done	2	13	D	Done	Hume pipe 0.9m	Done	Done	Hume pipe only	39,720	6.0x5.7m	A
7	T007	Opposite bank of Dangdung	Trongsa	PNH6	Kinzang	Done	Done	Done	0	1	C	Done	Hume pipe 0.9m	Not planned	Not Planned				C
8	T008	After DoR Koshala Office	Trongsa	PNH6	Kinzang	Done	Done	Done	2	6	A	Done	No culvert	Done	Done	No space for inlet	27,670	6.0x4.2m	B
9	T009	2019 Debris flow	Trongsa	PNH6	Kinzang	Done	Done	Done	1	5	D	Done	4.0x5.1m	Done	Done	There is a relatively large culvert Recommend removal of old culvert	11,510	4.0x3.6m	A
10	T010	Reutala	Trongsa	PNH5	Kinzang	Done	Done	Done	0	1	C	Done	2.4x1.2m	Done	Not Planned				C
11	T011	2020 Debris flow	Trongsa	PNH1	Nishimura	Done	Done	Done	2	12	B	Done	1.6x1.6m	Not planned	Done	Culverts are restored			C
12	T012	2020 Debris flow at Tashiling zam	Trongsa	PNH1	Nishimura	Done	Done	Done	2	8	B	Done	Hume pipe 0.9mx2	Done	Done	Bridge planning in progress	22,300	6.0x4.2m	D
13	L001	Big boulder	Lobesa	PNH1	Ashock	Done	Done	Done	1	6	A	Done	2.6x0.9m	Done	Done	Suitable for study	16,040	6.0x3.6m	B
14	L002	Near Quarry	Lobesa	PNH1	Ashock	Done	Done	Done	2	10	A	Done	1.4x2.4m	Done	Done	Suitable for study	22,500	6.0x4.1m	A
15	L003	before Nubding	Lobesa	PNH1	Ashock	Done	Done	Done	2	5	B	Done	1.5x1.6m	Planning	Done	Suitable for study	No Data		B
16	L004	Near Gasa gate	Lobesa	SNH	Ashock	Done	Done	Done	2	6	C	Planning	Hume pipe 1.2mx2	Not planned	Not Planned				C
17	L005	Barsha	Lobesa	SNH	Ashock	Done	Done	Done	2	6	C	Planning	Hume pipe 0.9mx1	Not planned	Not Planned				C
18	L006	Damji	Lobesa	SNH	Ashock	Done	Done	Done	3	7	C	Planning	Hume pipe 0.9mx1	Not planned	Not Planned				C
											A	High						High	A
											B	Middle						Middle	B
											C	Lo						Lo	C
											D	Done						No required	D

(Source: JET)

Of the 18 candidate sites, the amount of unstable soil deposited in the stream was surveyed in detail at 10 sites, excluding 8 sites that were excluded in the desk study phase as slopes outside the project area or slopes that did not include valleys larger than the primary-order channel (small-scale slopes). As a result of these surveys, L002 (Khelekha site) located between Wangdue and Nobuding in PNH1 and T006 (Dangdung site) located in the southern part of Trongsa in PNH5 have recently experienced large-scale disasters with road closures due to debris flow, and therefore, the improvement of drainage facilities as a pilot site should be considered. It was deemed urgent to study the improvement of drainage facilities as a pilot site.

L002 (Khelekha site) is a secondery-order channel sized stream with an estimated sediment discharge of 22,500 m3 , a peak flow rate of 250.3 m3/s, an estimated maximum boulder diameter of 2.0 m, and a cross section of at least 6.0 m wide by 4.1 m high to safely carry debris flow at the road crossing. The current condition is 1.0m wide and 4.1m high. In September 2021, this box culvert was blocked by a debris flow and overflowed onto the road, causing a major collapse at a point about 500 m on the Wangdue side of PNH1 and disrupting PNH1 for several days. This caused the PNH1 to be disrupted for several days.

T006 (Dangdung site) is a secondery-order channel sized stream with an estimated sediment discharge of 39,720 m3 , a peak flow of 441.3 m3/s, an estimated maximum boulder diameter of 1.6 m, and a cross section of at least 6.0 m wide by 5.7 m high is required to safely carry the debris flow at the road crossing. The only existing drainage facility is a 900 mm diameter hume pipe, and in 2019 a disaster occurred when a debris flow spilled and overflowed onto the road, temporarily disrupting a section of the newly constructed Refee-Kosala bypass.

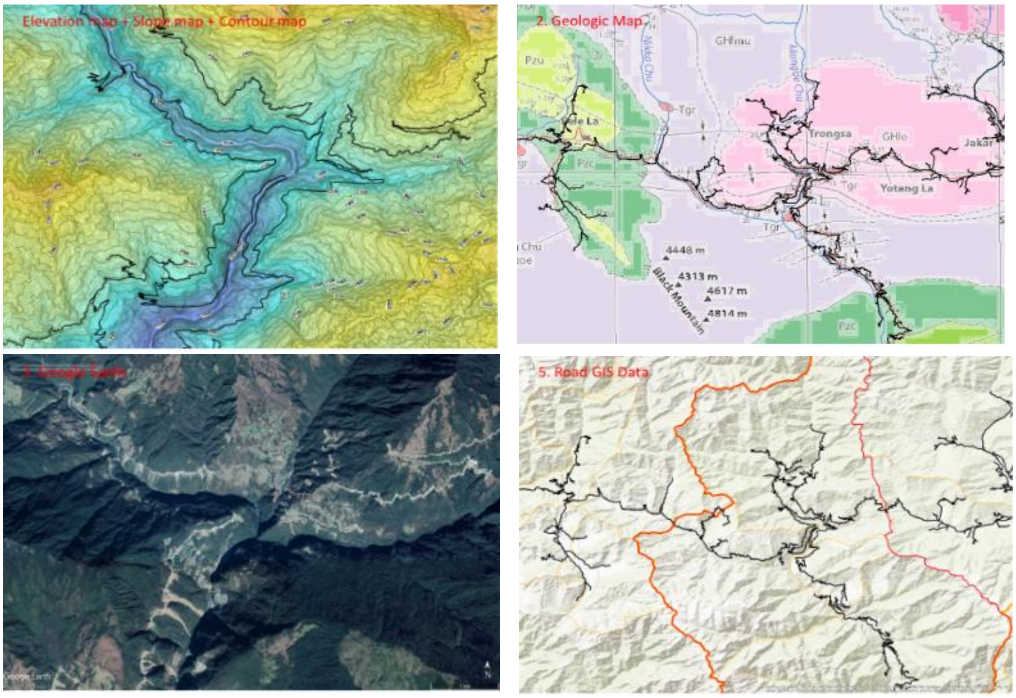
These two sites were discussed at the June 6, 2022 meeting of the DCC (a coordination meeting within the DoST), and it was determined that L002 (Khelekha site), which was damaged by the disaster and suffered roadbed washout, was a higher priority for improvement and was selected as the second pilot site.

As for T006 (Dangdung site), which was the runner-up, although it is not possible to construct countermeasure works with this year's budget, there is an intention to make improvements in the future, so the DoST proceeded with detailed design, cost estimation, and specifications within the project period, and JET provided advice on the results of the study to deepen technology transfer.

Activity 5-2: Survey and evaluate on topography and geology for the selected debris flow streams.

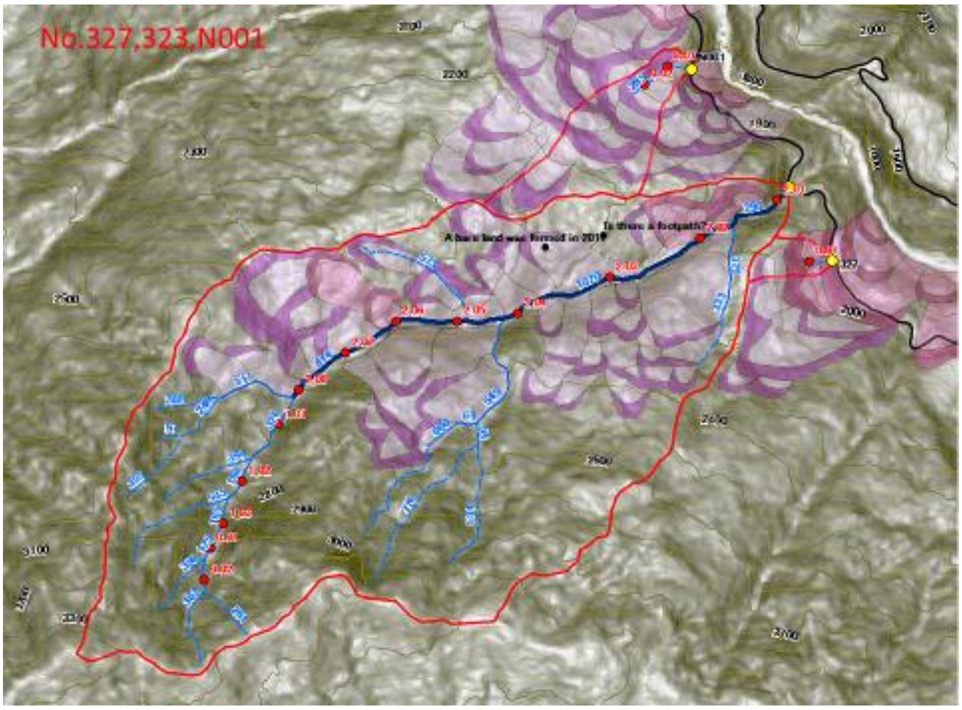
Detailed desk and field surveys were conducted to understand the topographical and geological conditions at 10 candidate sites for the first pilot site and 7 candidate sites for the second pilot site. In the desk study, JET obtained detailed information on the distribution of vegetation and collapsed areas in the catchment area, topographic divisions around the catchment area, and soil deposition in the streambeds from Google Earth imagery and other sources. In addition to confirming the results of the desk study, the cross-sectional shape and longitudinal slope of the stream were measured using a laser rangefinder, and the amount of sediment that could be eroded and transported was calculated to determine the amount of soil to be discharged. An Excel spreadsheet was created to calculate the sediment volume by simply entering the necessary parameters.

Based on the results of the cross-sectional surveys of 88 sites in 17 streams surveyed to date, the average cross-sectional shape of unstable soil by channel order was compiled. In collaboration with C/P, increase the number of surveys in the future, a method to calculate standard erodible soil volumes by classifying regions, catchment area types, and geology, etc. Developed an environment that is easy for C/P to understand and use and can easily be laterally developed in the future.



*1 Upper left: Elevation division map generated from high-resolution DEM + slope map + contour lines
*2 Upper right: Long-layer geological map
*3Bottom left: Satellite image (Google Earth)
*4Bottom right: Road GIS data

Figure 3.6-3 Examples of documents referred to in the desk works (Source: JET)



*1 Red line: Catchment area boundary
*2 Blue line: Channel order classification results and extension by section
*3 Black line: Route
*4 Yellow point: Intersection point between the route and the stream
(reference point for Debris flow volume calculation)
*5 Red points: Candidate sites for unstable soil volume survey
*6 Black points: bare ground, etc.
*7 Peach or purple polygons: Landslide topography (clear/obscure)
(Source: JET)

Figure. 3.6-4 Examples of results of desk studies (Nos. 323, 327 and N001 Streams)

(Source: JET)

Figure. 3.6-5 Example of a field survey (unstable soil volume survey in a stream) (2019/4/10)

Table 3.6-3 Example of unstable sediment volume calculation sheet (Excel) (No. 323 Stream) (Source: JET)

Calculation Sheet of the Volume of Unstable Soil in mountain channel (1)

Road No.	1	Distance Mark(km)	
Management Office	Trongsa		
Check List No.	323	Management No.	
Reference Point	Latitude		Longitude

Point Name	Stream Order	Width (m)	Depth (m)	Sectional Area (m2)	Stream Order	Average Sectional Area (m2)
2_01	2	8.2	1.5	12.0	4	0.00
2_02	2	11.2	1.7	19.4	3	0.00
2_03	2	7.8	1.1	8.5	2	10.13
2_04	2	4.2	0.7	2.7	1	7.05
2_05	2	12.0	0.9	10.9	0	1.40
2_06	2	7.0	1.0	7.2		Basic information
1_01	1	8.0	1.2	9.5		Field Work
1_02	1	4.0	1.2	4.6		Desk Work
0_03	0	2.4	0.6	1.4	Blue Letter	Japanese Standard
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		
				0.0		

Stream Order	Channel Length (m) Route A	Route B	Route C	Route D	Total
4					
3					
2	2,286	2,286	1,316		2,286
1	689	317	545		1,880
0	636	601	870		6,074
Volume of Unstable Soil(m3)	28,910	26,240	18,400	0	44,910
Maximun Volume of Unstable Soil in a Channel (m3:Min=1000)	28,910				Route A

Calculation Sheet of the Volume of Unstable Soil in mountain channel (2)

Road No.	1	Distance Mark(km)	0
Management Office	Trongsa		
Check List No.	323	Management No.	0
Reference Point	Latitude 0	Longitude	0

Top 10 Rock Diameter (m)

Data No	1	2	3	4	5	6	7	8	9	10
Point Name	2_01	2_02	2_03	2_04	2_05	2_06	1_01	1_02	0_03	0
Max_01	1.2	0.4	0.6	0.4	0.6	1.4	0.6	0.4	0.8	
Max_02	1.2	1.2	1.0	0.4	0.8	1.2	0.4	0.6	0.4	
Max_03	0.8	1.0	0.8	0.6	1.2	0.6	0.8	1.0	0.6	
Max_04	1.0	0.8	0.6	0.6	0.6	1.2	0.6	1.6	0.6	
Max_05	0.8	0.8	0.4	1.0	0.8	0.6	0.8	0.2	0.8	
Max_06	0.8	0.6	0.6	1.6	0.6	0.4	0.6	0.6	1.4	
Max_07	0.6	1.0	0.4	1.2	0.4	0.6	0.6	1.2	0.6	
Max_08	0.6	0.6	0.6	1.0	0.6	0.4	0.6	0.6	0.4	
Max_09	0.8	0.8	0.6	0.6	1.0	0.6	0.6	0.2	0.8	
Max_10	0.8	1.0	0.6	0.8	1.4	0.4	0.6	1.2	1.0	
Data No	11	12	13	14	15	16	17	18	19	20
Point Name	0	0	0	0	0	0	0	0	0	0
Max_01										
Max_02										
Max_03										
Max_04										
Max_05										
Max_06										
Max_07										
Max_08										
Max_09										
Max_10										

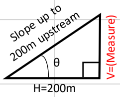
Maximun Rock Diameter (φMax)	1.6 m	2 x Maximum Rock Diameter (2φMax)	3.2 m

Calculation Sheet of the Volume of Unstable Soil in mountain channel (3)

Road No.	1	Distance Mark(km)	0
Management Office	Trongsa		
Check List No.	323	Management No.	0
Reference Point	Latitude 0	Longitude	0

Culculation of slope up to 200 m upstream

Horizontial Distance H(m)	Vertical Distance V(m)	tanθ	θ (rad)	Slope up to 200 m upstream θ(°)
200	70	0.35	0.34	19.29



Catchment Area A(km2)	Expected Daily Rainfall Pp (mm/Day)	Slope up to 200 m upstream θ(°)	Slope up to 200 m upstream (tanθ)	Water density ρ (t/m3)	Rock density σ (t/m3)	Internal friction angle of soil φ (°)
3.66	140.8	19.29	0.35	1.2	2.6	35

Soil Constant (Japanese Standard)

Coefficient (Japanese Standard)

Outflow rate Kf2	Outflow rate (Correction) Kf2'	Soil Concentration Cd	Soil Concentration (Correction) Cd'	Roughness factor n	Soil concentration per unit volume C*	Porosity Kv
0.15	0.15	0.86	0.54	0.1	0.6	0.4

Volume of soil that can be transported by Estimated volume of rainfall (m3)

151,240

Maximun Volume of Unstable Soil (m3)	28,910
Volume of soil that can be transported by Estimated volume of rainfall (m3)	151,240
Estimate volume of debris flow (m3)	**28,910**

$$V_{dy2}=\frac{10^3\cdot P_p\cdot A}{1-K_v}\left(\frac{C_d}{1-C_d}\right)K_{f2}$$

P_p: Expected Daily Rainfall (R24:mm) (Blue : Japanese Standard)
A: Catchment Area (km²)
K_v: Porosity (0.4)
C_d: Soil Concentration Rate
$C_d=\rho\tan\theta/(\sigma-\rho)(\tan\Phi-\tan\theta)$
ρ: Water density (1.2 t/m3)
σ: Rock density (2.6 t/m3)
Φ: Internal friction angle of soil (35°)
θ: Slope up to 200 m upstream (°)
K_{f2}: Outflow rate
$K_{f2}=0.05(\log A-2.0)^2+0.05$
(Max:0.5 - Min:0.1)

Calculation Sheet of the Volume of Unstable Soil in mountain channel (4)

Road No.	1	Distance Mark(km)	0
Management Office	Trongsa		
Check List No	323	Management No.	0
Reference Poi	Latitude 0	Longitude	0

Peak Flow Rate of debris flow

Concentration Rate per volume of Soil at Channel C*	Soil Concentration Rate Cd'	Volume of soil runoff by one debris flow Vdqp (m3, Min:1,000m3)	Total Volume of Debris Flow ΣQ (m3)	Peak Flow Rate of Debris Flow Qsp (m3/s)
0.6	0.54	28,910	32,122	321.2

Parameter

Roughness factor Kn(s*m-1/3)	Slope up to 200m upstream θ(°)	Slope up to 200m upstream sinθ
0.10	19.29	0.33

$$Q_p=0.01\cdot\sum Q$$

$$\sum Q=\frac{C_*\cdot V_{dqp}}{C_d}$$

Q_{sp}: Peak Flow Rate of Debris Flow (m³/s)
ΣQ: Total Volume of Debris Flow (m³)
V_{dqp}: Volume of soil runoff by one debris flow (m³, Min:1,000m³)
C_d: Soil Concentration Rate
C_*: Concentration Rate per volume of Soil at Channel (0.6)

Examination of cross-sectional shape that can flow peak flow

Flow width of the Bda(m)	Depth of debris flow Dr (m)	Area of Cross Ad (m2)	Velocity of debris flow U (m/s)	Peak flow rate that can flow down Qsp(m3/s)	Judge 2φMax	Judge Dr
1.0	11.2	11.20	28.8	322.2	NG	OK
2.0	7.4	14.80	21.8	323.0	NG	OK
3.0	5.8	17.40	18.6	322.8	NG	OK
4.0	4.9	19.60	16.6	325.0	OK	OK
5.0	4.3	21.50	15.2	326.8	OK	OK
6.0	3.9	23.40	14.2	333.2	OK	OK
7.0	3.5	24.50	13.2	324.6	OK	OK
8.0	3.3	26.40	12.7	336.3	OK	OK
9.0	3.0	27.00	12.0	322.8	OK	OK
10.0	2.9	29.00	11.7	339.0	OK	OK
3.2	5.6	17.92	18.1	324.8	OK	OK
		0.00	0.0	0.0	NG	NG
		0.00	0.0	0.0	NG	NG

Adjust the value and judge "OK" or "NG"

$$U=\frac{1}{K_n}D_r^{2/3}(\sin\theta)^{1/2}$$

U: Velocity at the front part of debris flow (m/s)
D_r: Depth of debris flow (m)
θ: Slope up to 200 m upstream (°)
K_n: Roughness factor ($s\cdot m^{-1/3}$, 0.10)

$$Q_{sp}=U\cdot A_d$$

A_d: Cross section of peak flow of debris flow (m³)

$$D_r=A_d/B_{da}$$

B_{da}: Flow width of debris flow (m)

Table 3.6-4 Average cross sectional area of unstable soil by channel order

Channel Order	Trongsa		Lobesa		Total	
	Number of Survey	Average Cross-Sectional Area (m2))	Number of Survey	Average Cross-Sectional Area (m2)	Number of Survey	Average Cross-Sectional Area (m2)
4	0	**-**	0	**-**	0	**-**
3	1	**17.40**	0	**-**	1	**17.40**
2	23	**8.65**	7	**8.43**	30	**8.60**
1	24	**7.14**	6	**9.58**	30	**7.63**
0	21	**4.50**	6	**4.65**	27	**4.54**

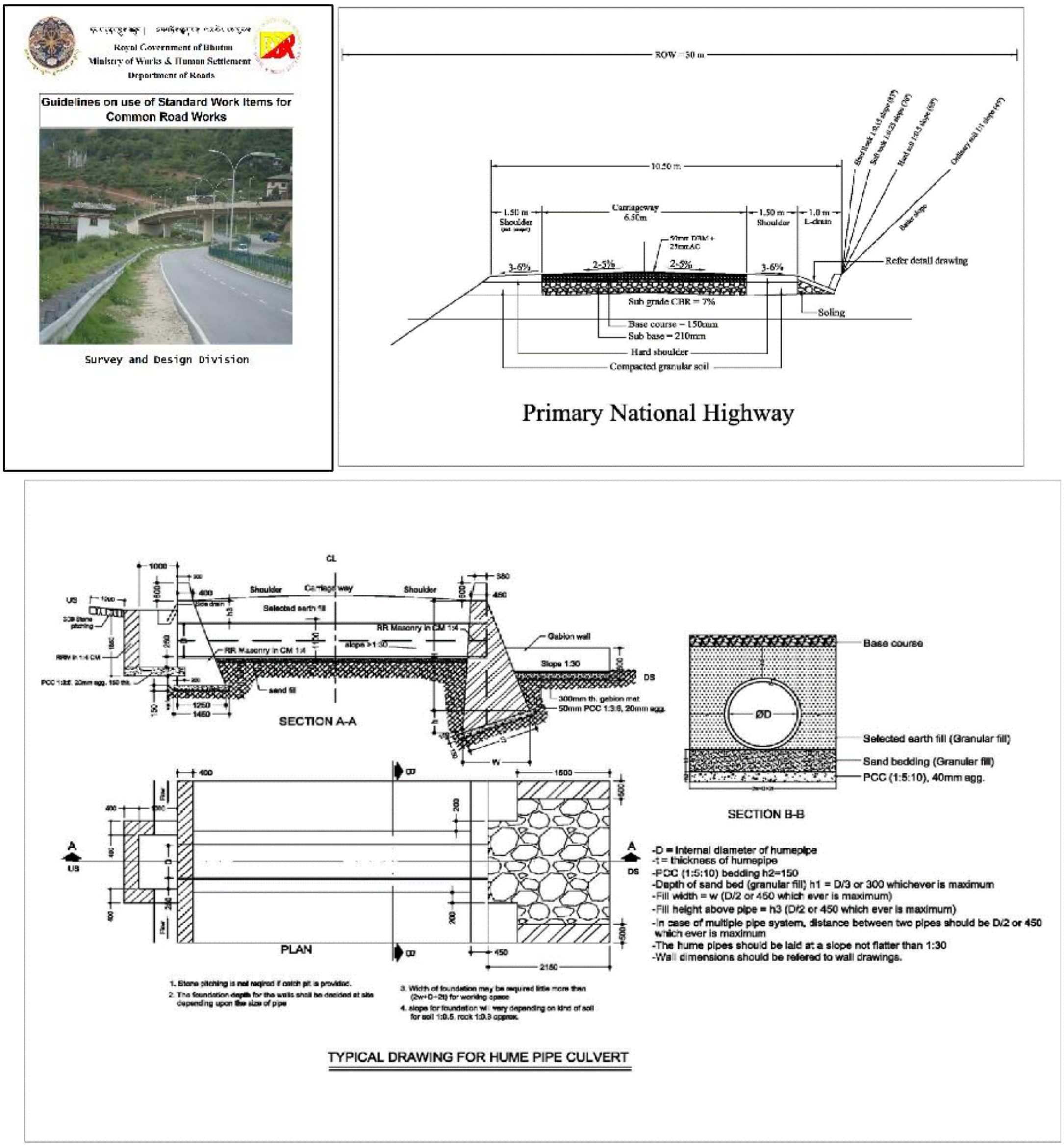
(Source: JET)

Activity 5-3: Collect and analyze information of drainage system on roads for the selected debris flow streams.

The Bhutanese standards (e.g., Road Design Manual) were carefully reviewed to understand the standard installation criteria for the drainage system.

In Bhutan, the "Guidelines on the use of Standard Work Items for Commom Road Works" developed by DoST is referred to for road design and construction, and standard drainage works are described in these guidelines. The guidelines provide a standard cross-section for PNH, which requires a full width of 10.50 m and an L-shaped drainage structure with a width of 1.0 m on the slope side. In addition, an example of construction using a hume pipe as a drainage work across the line is shown.

However, only the following standard cross-sections are included as examples, and there are no descriptions regarding the study of drainage volumes that vary depending on catchment area, slope, etc.



(Source: Guidelines on the use of Standard Work Items for Commom Road Works)

Figure. 3.6-6 Description of drainage works in "Guidelines on the use of Standard Work Items for Commom Road Works".

In addition, a field survey focusing on drainage works crossing roads confirmed that at least the following four types of works are applied in Bhutan.

*1 Upper left: Hume pipe *2 Upper right: Box culvert *3 Lower left: Arch culvert *4 Lower right: Bridge
(Source: JET)

Photo 3.6-1 Example of drainage works applied in Bhutan

Activity 5-4: Plan and design drainage works and facilities.

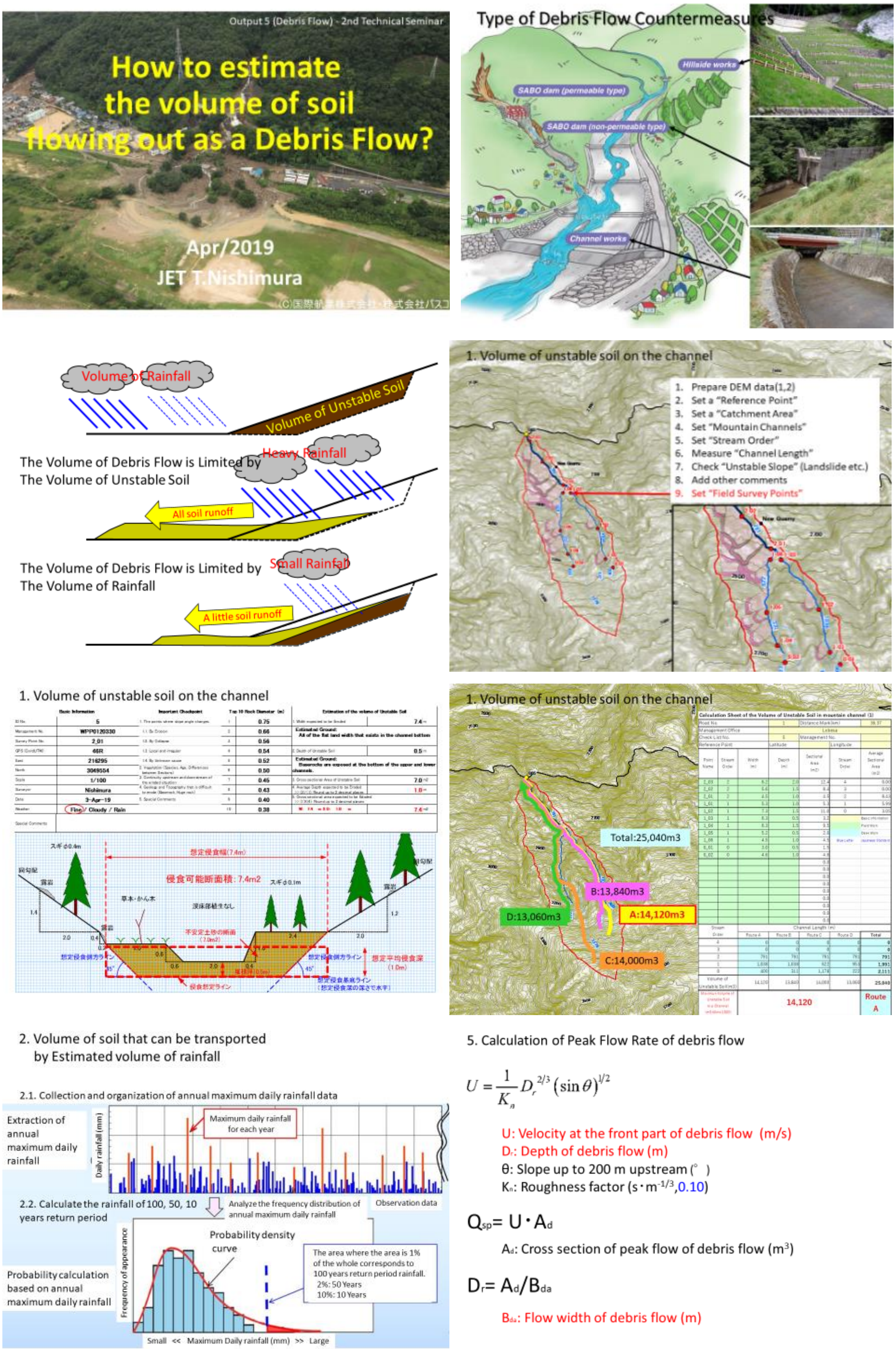
1) 1st pilot site (Bjee site)

For Stream No. 323, selected as the pilot site, planned and designed a channel and culvert (road crossing channel) with sufficient cross section for the peak flow of debris flow. In designing the channel and culvert works, JET applied the "Technical Guideline for the Design of Debris Flow Countermeasures (Sabo Department, Ministry of Land, Infrastructure, Transport and Tourism in Japan, revised in 2016)" and provided seminars and other opportunities for C/Ps to fully understand these concepts. In the planning and design of the project, sufficient attention was paid to the materials and equipment to be used so that local contractors would be able to handle the construction. In addition, to prevent the loss of original functions due to the accumulation of debris after the shared use, maintenance and management, such as inspection and maintenance, were also discussed, and opportunities were provided to deepen the knowledge of C/Ps and other related parties.

In Stream No. 323, a number of landslide landforms were identified in the catchment area at the desk study stage, but as a result of detailed field survey, the volume of soil discharged was estimated to be 28,910 m3 and the peak flow rate 321.2 m3/s. Based on the above, the schematic cross-sectional shape of the debris flow was assumed to be 6.0 m in width with a maximum depth of 3.8 m. However, considering the margin height of the countermeasure facility, a box culvert of 6.0 m in width and 4.6 m in height was planned and designed. In addition, there is a waterfall with a drop of about 15 m about 20 m upstream of the planned culvert location, and since the natural channel between the waterfall and the culvert is a large bend, a wing walls were planned in this section to ensure that the debris flow would flow into the culvert. The culverts and wing walls were constructed using masonry, which has been widely used in Bhutan, and reinforced concrete slabs, which can be constructed without using any special materials or techniques.

(Source: JET)

Photo 3.6-2 Seminars on debris flow countermeasure works
(29, March, 2019: DoST HQ, 1, April: Lobesa, 5, April: Trongsa)

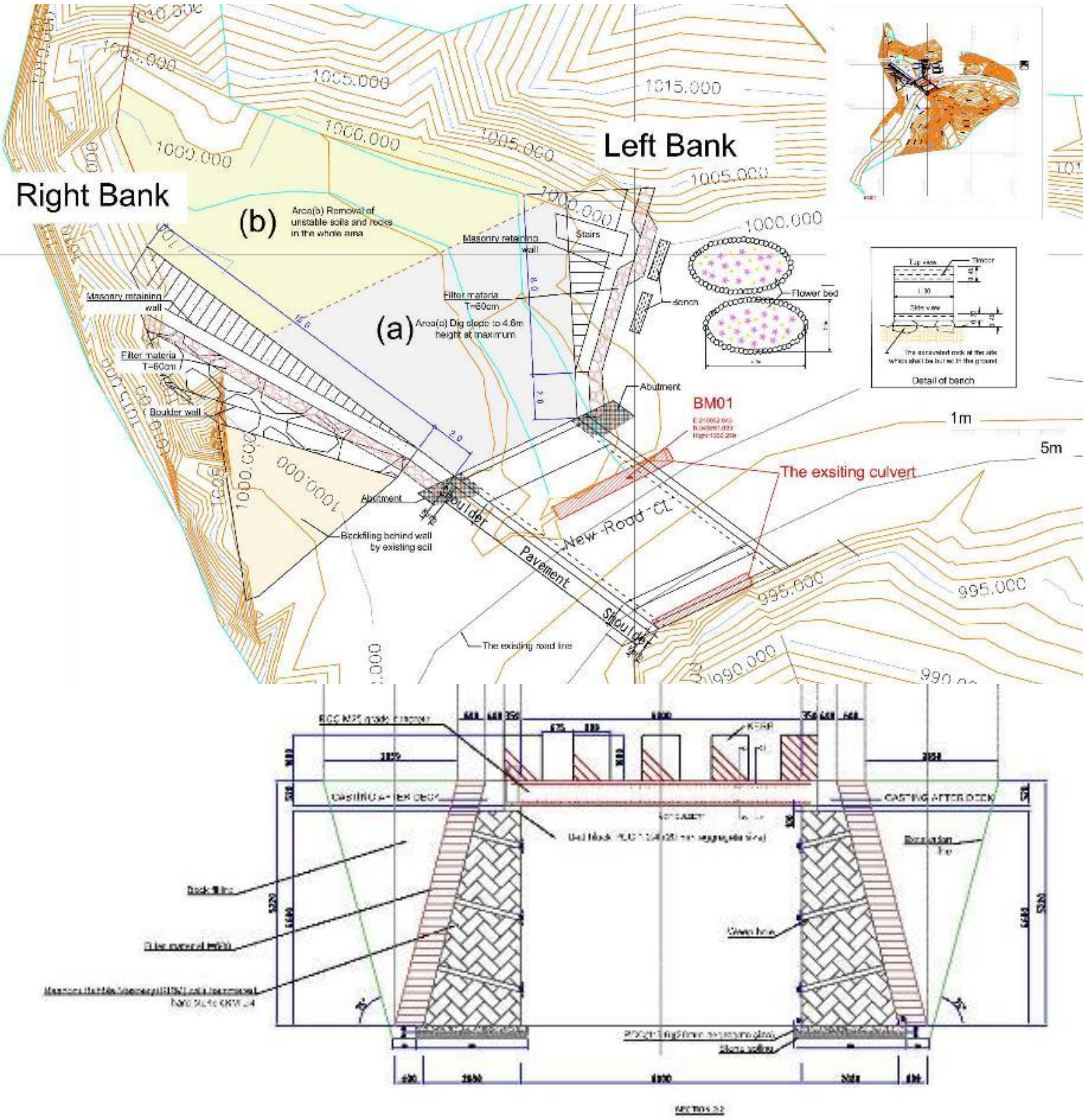


(Source: JET)

Figure. 3.6-7 Examples of materials used in seminars on debris flow countermeasure works

(Source: JET)

Photo 3.6-3 Bjee site before construction (left: from downstream, right: from upstream) (Apr/10/2019)



(Source: JET)

Figure. 3.6-8 Facility Layout and Front View of Culvert at Bjee Site

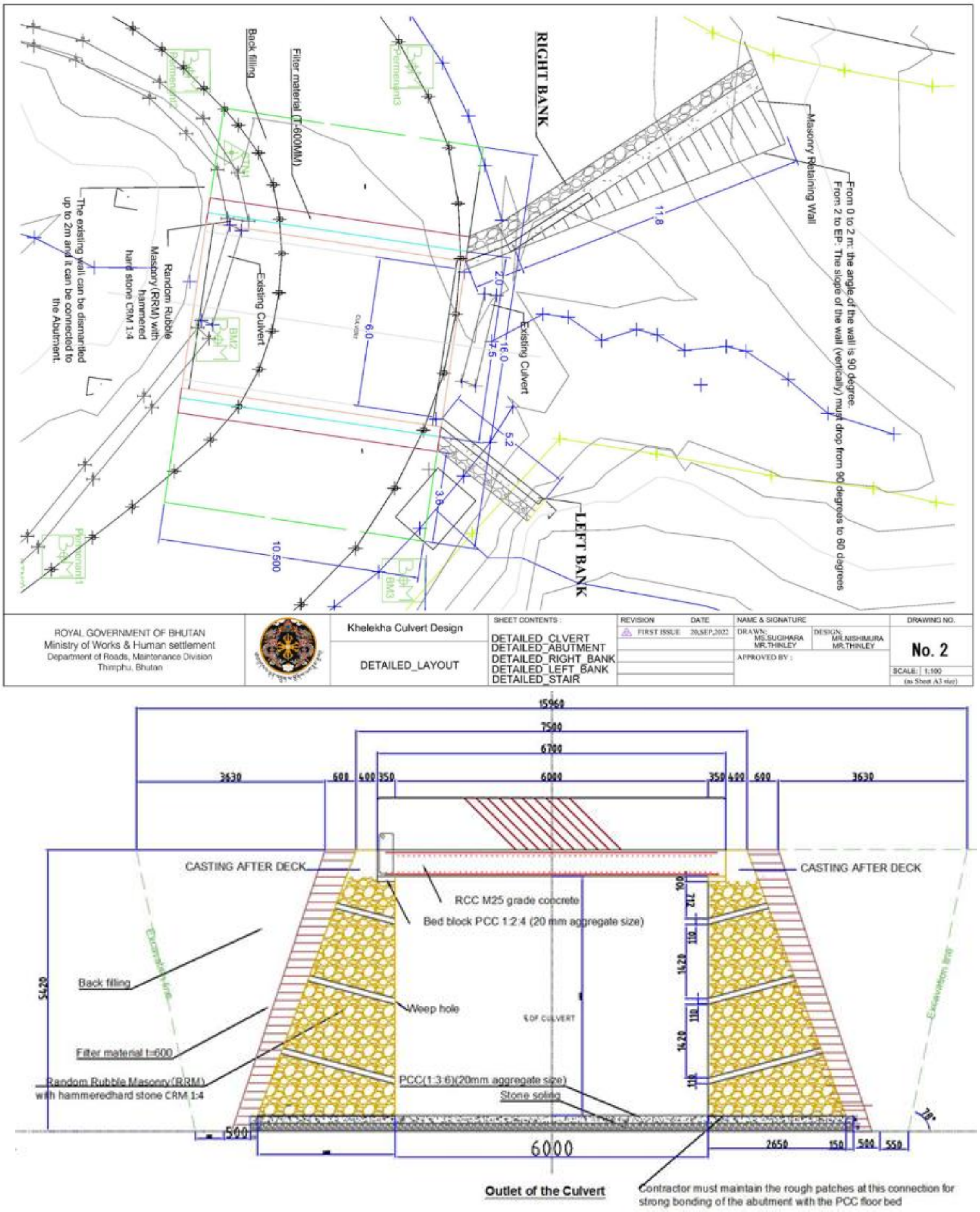
2) Second pilot site (Khelekha site)

For L002 stream selected as the pilot site, planned and designed a channel and culvert (road crossing channel) with sufficient cross section for the peak flow of debris flow. The design of the channel and culvert works was based on the "Technical Guidelines for the Design of Debris Flow Countermeasures (Sabo Department, Ministry of Land, Infrastructure, Transport and Tourism in Japan, revised in 2016)". In the planning and design of these works, sufficient attention was paid to the materials and equipment to be used so that local contractors would be able to handle the construction. In addition, to prevent the loss of original functionality due to the accumulation of soil and other materials after the shared use, maintenance and management, such as inspection and maintenance, were also studied. And opportunities were provided to deepen the knowledge of C/P and other related parties.

In the L002 stream, numerous landslide landforms were identified in the catchment area at the desk study stage, but as a result of detailed field surveys, the volume of sediment discharged was estimated to be 25,530 m3 and the peak flow rate 250.3 m3 /s. Based on the above, the schematic cross-sectional shape of the debris flow was assumed to be 6.0 m in width with a maximum depth of 3.3 m. However, considering the margin height of the countermeasure facility, it was decided to plan and design a box culvert with a width of 6.0 m and a height of 4.1 m. The upstream side of the culvert is a straight downstream section, but the valley width is rather wide (approximately 20 m), so JET planned a flow-diverting structure in this section to ensure that the debris flow would flow into the culvert. As in the second pilot site, the culvert and wing walls were constructed using masonry, which has been widely used in Bhutan, and a reinforced concrete slab, which can be constructed without using special materials and techniques.

(Source: JET)

Photo 3.6-4 Khelekha site before construction (left: from downstream, right: from upstream) (May/17/2022)



(Source: JET)

Figure. 3.6-9 Facility Layout and Front View of Culvert at Khelekha Site

Activity 5-5: Implement the drainage works and facilities.

1) 1st pilot site (Bjee site)

The culvert and wing wall works and other facilities planned and designed in Activity 5-4 were constructed using the opportunity of the PNH road widening project scheduled after October 2019. The construction was started in February 2020 during the dry season and completed in May of the same year, before the rainy season started. In supervising the construction, JET collaborated with the personnel in charge of "Construction Contract Management/Construction Supervision" as well as those in charge of Output 5 "Debris flow countermeasures" to transfer construction supervision techniques, which have been pointed out as a problem in Bhutan.

After the start of construction, on March 18, 2020, the JICA experts were instructed to return to Japan due to the global outbreak of COVID-19, so the direct supervision of the construction after that date was carried out by a local supervisor, and JETs managed the site from Japan through regular weekly web meetings and occasional chats.

The test excavation did not expose the bedrock that was expected to be exposed near the foundation, which resulted in changes to the foundation design after construction began. In addition, there were issues with the contractor's financial resources and ability to procure materials, as well as securing workers and heavy equipment. In addition to the many construction closure days during the work period, the process was significantly delayed due to the lockdown caused by the COVID-19 epidemic and damage to the construction site caused by rising water during the rainy season and its restoration.

The contractor's construction was generally completed in mid-November 2020. The progress of the construction is shown in the following photos.

On-site meeting before construction (Feb/13/2020)

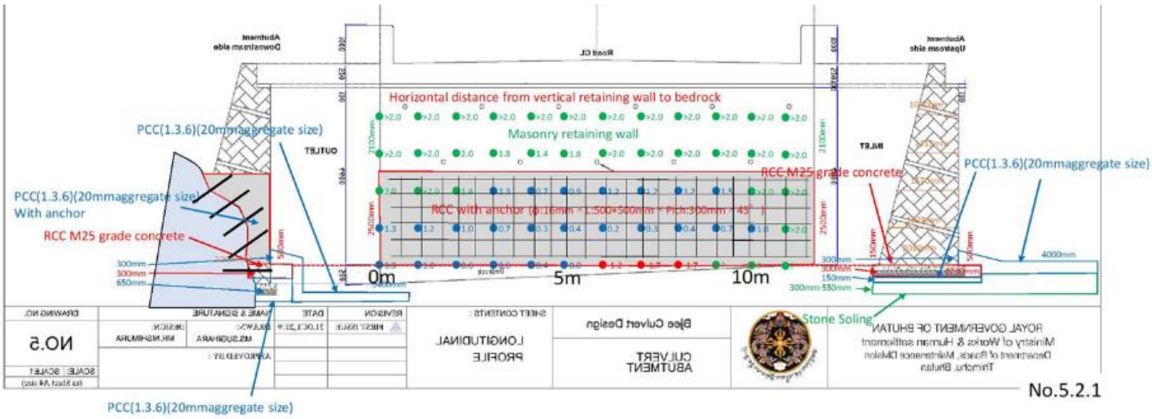
Start of temporary road construction (Feb/18/2020)

Removal of existing culvert (Feb/28/2020)

Excavation of culvert installation area completed (Mar/8/2020)

(Source: JET)

Photo 3.6-5 Progress of construction of culvert and wing wall works, etc. (1)



(Source: JET)

Figure. 3.6-10 Design Changes for Culvert Foundations (Mar/10/2020)

Anchor hole installation status at right bank foundation (Mar/17/2020)

Anchor hole installation status at right bank foundation (Mar/17/2020)

Confirmation of construction status via web meeting (Apr/2/2020)

Placement of concrete for abut foundation (Apr/12/2020)

(Source: JET)

Photo 3.6-6 Progress of construction of culvert and wing wall works, etc. (2)

Damage to right bank foundation (Apr/19/2020)

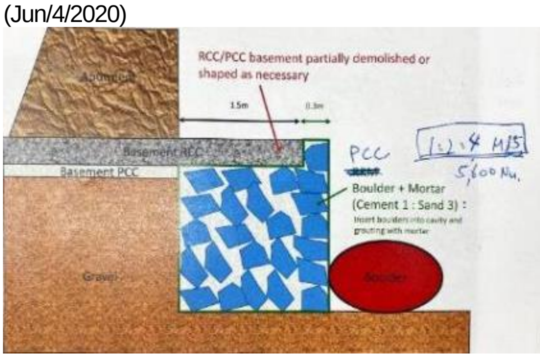
Start masonry work on left bank abutment(Apr/26/2020)

Concrete Poured for Right Bank Abutments
(May/23/2020)

Masonry Work on the Right Bank Abutment Begins
(May/26/2020)

Damage to right bank foundation due to rising water
(Jun/4/2020)

Culvert abutments completed on left and right bank
(Jun/12/2020)



Establishment of restoration plan for damaged areas
（Jun/17/2020）

Emergency restoration work for damaged areas
（Jun/19/2020）

(Source: JET)

Photo 3.6-7 Progress of construction of culvert and wing wall works, etc. (3)

Installation of Slab Shoring (Jun/29/2020)

Slab Concrete Placement (Jul/15/2020)

Construction of Parapet (Jul/18/2020)

Tentative opening of the culvert (Sep/7/2020)

Panoramic view of the culvert (Sep/8/2020)

Start of left-bank wing wall construction (Sep/26/2020)

Completion of left-bank wing wall construction (Oct/24/2020)

(Source: JET)

Photo 3.6-8 Progress of construction of culvert and wing wall works, etc. (4)

Start construction of right bank wing wall (night work) (Oct/10/2020)

Completion of right bank wing wall (Nov/11/2020)

Construction of the upper part of the right-bank wing wall (Nov/12/2020)

Construction of ancillary works (Nov/17/2020)

Completion Inspection (Nov/17/2020)

C/P, Local supervisor, Contractor (Nov/17/2020)

Overall view after completion (May/8/2022)

(Source: JET)

Photo 3.6-9 Progress of construction of culvert and wing wall works, etc. (5)

2) Second pilot site (Khelekha site)

Construction of the culvert and wing walls planned and designed in Activity 5-4 was carried out during the dry season from December 2022 to May 2023. In supervising the construction, JET worked not only with the personnel in charge of the countermeasures against debris flow, but also with the "Construction Contract Management/Construction Supervision" personnel and local supervisors to transfer construction supervision techniques and foster awareness of safety management, which have been pointed out as a problem in Bhutan.

The shape of the bedrock, which was expected to be exposed near the foundation during the test excavation, was somewhat deep, inclined, and uneven, so the design of the foundation was changed after construction began. The initial plan was to divide the culvert into two sections to ensure traffic flow during the construction period. However, the contractor proposed and implemented construction without dividing the culvert by installing a temporary road in an area separate from the construction area, thereby shortening the construction period.

As the irrigation facilities used by neighboring farmers would no longer be available due to the increased scale of the culvert (lowering of the riverbed), a new intake weir was constructed 50 m upstream of the culvert construction location, and a new canal was constructed in the section up to the existing canal.

The contractor's construction was completed and handed over to DoST in early May 2023. The progress of the construction is shown in the following photos.

(Source: DoST)

Culvert blocked by debris flow on Sep 15, 2021 and runoff onto road surface

Photo3.6-10 Progress of construction of culvert and sing wall works, etc. (1)

(Source: DoST)

Huge landslide in Khelekha area caused by debris flow that washed down the road surface (Sep/15/2021)

Technology transfer on facility design (Sep/7/2023)

Study on site (Sep/8/2023)

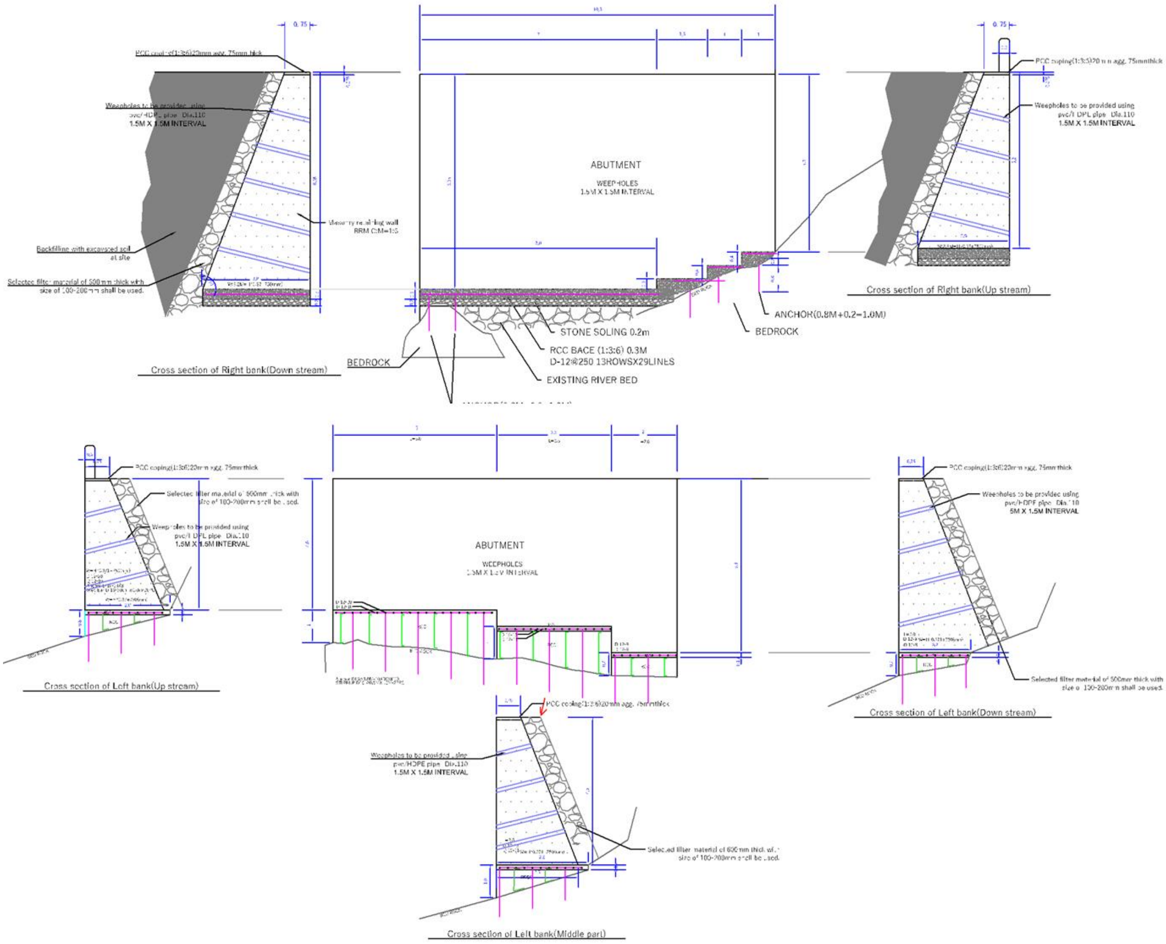
Start construction of bypass (Dec/24/2022)

Opening of bypass (Dec/31/2022)

(Source: JET)

Photo3.6-11 Progress of construction of culvert and wing wall works, etc. (2)

Start of removal of existing culvert (Jan/2/2023) Completion of removal of existing culvert (Jan/13/2023)



Design change of the abut foundation section according to the shape of the bedrock (Feb/16/2023)
(Source: JET)

Photo3.6-12 Progress of construction of culvert and wing wall works, etc. (3)


Construction of left bank abut foundation section (Jan/16-Feb/7/2023)


Construction of right bank abut foundation section (Jan/16-Feb/7/2023)


Construction of intake weir (Jan/13-20/2023)

(Source: JET)

Photo3.6-13 Progress of culvert works and wing wall works, etc. (4)

Construction of left bank abutments (Feb/8-12/2023)

Construction of right bank abutments (Feb/15-23/2023)

Slab shoring and slab construction (Feb/24-Mar/3/2023)

(Source: JET)

Photo3.6-14 Progress of culvert works and wing wall works, etc. (5)

Construction of agricultural canal (Mar/5-Apr/15/2023)

Roadbed grading and paving (Apr/23-May/4/2023)

Completion inspection and site handover (May/5/2023)

(Source: JET)

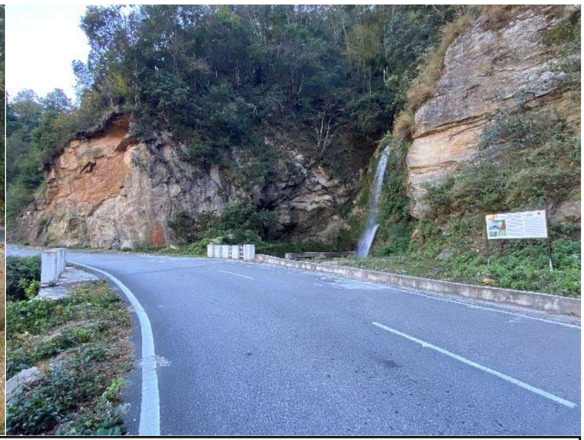
Photo3.6-15 Progress of culvert works and wing wall works, etc. (6)

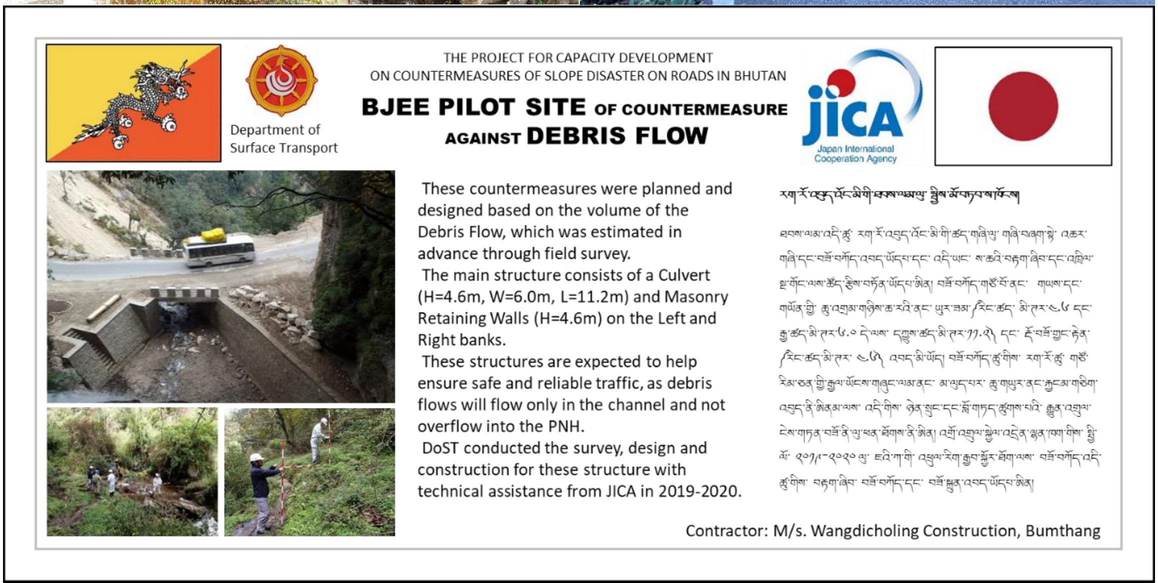
Overall view of the culvert after completion (left: from downstream, right: from upstream)

Overall view of the culvert after completion (3D model)

(Source: JET)

Photo3.6-16 Progress of culvert works and wing wall works, etc. (7)





Installation of information boards at Bjee and Khelekha sites (Jun/13/2023)

(Source: JET)

Photo3.6-17 Progress of culvert works and wing wall works, etc. (8)

Activity 5-6: Implement safety management activities on the construction for the drainage works and facilities.

When constructing countermeasures against debris flows, safety management is important, as it is necessary to pay attention to falling rocks and collapses around the construction site, and to debris flows from upstream during rainfall. In this project, additional construction supervisors were dispatched during key construction periods, and a local supervisor provided ongoing advice on safety management methods at the construction site.

In addition, simple rain gauges using plastic bottles were installed at the construction site to periodically check the amount of rainfall, and safety control was thoroughly implemented by temporarily suspending work when the hourly rainfall exceeded 5 mm. During winter construction, a thermometer was installed at the site to check the minimum temperature every morning for quality control of concrete placement, etc.


KY meeting before works


Preparatory exercises before works

Information board indicating under construction


Guidance and installation of simple rain gauge


Barricades on the bypass section to warn of loose shoulders

(Source: JET)
Photo3.6-18 Safety management activities related to drainage works and drainage facilities construction

Activity 5-7: Develop a design/implementation guideline and a standard unit price table on the drainage works and facilities.

Based on the results of the planning, design, construction, and safety management activities at the pilot site conducted up to Activity 5-6, a "Guideline for Debris flow countermeasures (Ver. 1)" was developed to enable horizontal deployment in Bhutan.

In addition, MoIT periodically publishes a standard unit price list, but it only includes general construction work. Therefore, standard unit prices and construction footprints for each construction method were prepared based on the actual results of debris flow countermeasure works to be carried out in this project. The table below shows the table of contents in Guideline.

These guidelines were approved and published at the DCC on April 16, 2024.

Table 3.6-5 Table of Contents of Guidelines for Debris Flow Coutermeasures (Ver. 1)

Design/Implementation Guideline for Debris Flow Countermeasure Works in Bhutan Ⅰ: Planning, Investigation and Design (Ver.1)
1 What's Debris Flow? 2 Type of Debris Flow Countermeasures 3 How to identify valleys with the potential for debris flow may flow down? 4 How to estimate the volume of Debris Flow? 5 Study of drainage facilities to safely flow down debris flow 6 Channel Works Reference Appendix 1. Cross Sectional Survey Data Recording Form 2. Excel sheet for volume and peak flow rate calculations for debris flow 3. Excel sheet for calculating probable annual maximum daily rainfall 4. Excel sheet for Channel work check sheet 5. Safety check list for field survey Endnotes 1. Specific examples related to the study of debris flow countermeasures in C-Slope project > 1st Pilot site: Bjee (Trongsa RO)
Design/Implementation Guideline for Debris Flow Countermeasure Works in Bhutan Ⅱ: Construction Management (Ver.1)
Chapter-1 Construction Plan 1 Description 2 Requirement Chapter-2 Quality Control 1 Quality Control for each work 2 Field Checklist 3 As Built Control 4 Progress Control Chapter-3 Safety Control 1 Preface 2 Prevention of occupational accidents due to slope failure in cut slope construction 3 Safety Plan 4 Meeting with the Client 5 Dairy Works 6 Work Item 7 Field Checklist Appendix-1: Sample of Construction Plan Appendix-2: A Field Checklist on Quality Control for Construction (DRAFT) Appendix-3: Sample of Weekly Meeting Report Appendix-4: Sample of Daily Construction Report

(Source: JET)

3.7 Output 6: Information system on slope disasters and traffic controls on roads is improved.

Activity 6-1: Conduct training on basics of GIS.

In the first through the third training sessions, a series of technical transfer has been conducted to enable regional office staff to acquire road information such as road alignment in the field using GPS devices and drive recorders, and to convert this information into GIS. In the fourth training session, training was provided on the use of the BRS application developed in this project. The contents of the training from the first to the fourth session are as follows.

Table 3.7-1 Basic GIS training (1st-3rd)

training round	Period	Subject C/P	Training Items	Results and deliverables from training
1st	May 17, 2019 (Trongsa Regional Office) May 21, 2019 (Lobeysa Regional Office)	DoST Maintenance Division Trongsa Regional Office Lobeysa Regional Office	Basic knowledge and basic operation of QGIS OJT training for acquiring road alignment using GPS and drive recorder Introduction to UAV aerial surveying	Pilot regional office staff to acquire basic knowledge of GIS Understanding of data collection methods using GPS devices and drive recorders by regional office staff Understanding of the method from UAV aerial photography to topographic mapping by DoST Maintenance Division staff and pilot regional office staff, and creation of a plan to introduce the method to the DoST.
2nd	Dec 2-4, 2019 (Lobeysa Regional Office) Dec 9-11, 2019 (Trongsa Regional Office)	DoST Maintence Division Trongsa Regional Office Lobeysa Regional Office	Exercise in acquiring road alignment using GPS and drive recorder How to import collected data to PC and display in GIS, etc.	Pilot regional office staff learning how to use GPS devices and drive recorders to collect data and import it into a PC.
3rd	Feb 10-11, 2019 (Trongsa Regional Office) Feb 12-13 , 2019 (Lobeysa Regional Office)	Trongsa Regional Office Lobeysa Regional Office	Creation of road alignment maps How to create cross sections using topographic data (DEM)	Creation of road alignment maps for the Tonsa-Robesa Pilot Regional Office Mastery of cross-sectional mapping using topographic data from the DoST Headquarters Maintenance Office and the Pilot Regional Office.
4th	May 13-14, 2024 (Trongsa Regional Office) May 16-17 , 2024 (Limitan Regional Office) May 20-21, 2024 (Phuentsholing Regional Office)	Trongsa Regional Office Ligmethang Regional Office Phuntsholing Regional Office	How to use BRS	All regional office staff

Basic GIS training was conducted for DoST Headquarters Maintenance Division staff beginning in March 2023. During this period, the staff of the DoST Maintenance Division conducted the tasks of importing the data collected by ROMDAS by the DoST Maintenance Division staff and the data collected by the DoST Regional Offices into the GIS database. In the process of implementing these tasks, there was a problem that the DoST maintenance staff could not convert the data into a suitable data format for storing in the GIS database by themselves, so under the guidance of JETs, they learned how to create a conversion format (Excel) and input the data into the GIS database, on-the-job training.

① Creation of data format for storing in GIS database and how to input data into GIS database

The Road Asset Management System (hereinafter referred as "RAMS") was created through a joint effort between DoST Maintenance Division staff and the regional office. This Excel sheet contains road information (distance markers, latitude and longitude location information, types of road structures, etc.) at 5-meter intervals, and rules and technical guidance were provided to extract only road structure information from RAMS to be imported into the GIS database (Road Asset Management GIS database). JET created rules and provided technical guidance to extract only road structure information from the RAMS and import it into the GIS database.

② How to retrieve data directly from ROMDAS and how to input data into the GIS database

JET provided on-the-job training on how to extract data from the ROMDAS vehicle and the GIS database. JET provided guidance on how to extract data from ROMDAS vehicles and how to transfer to the GIS database in the form of on-the-job training.

Guidance on data extraction from ROMDAS vehicles

Guidance on incorporating RAMS into GIS databases

(Source: JET)

Figure. 3.7-1 Technoical Transfer Landscape

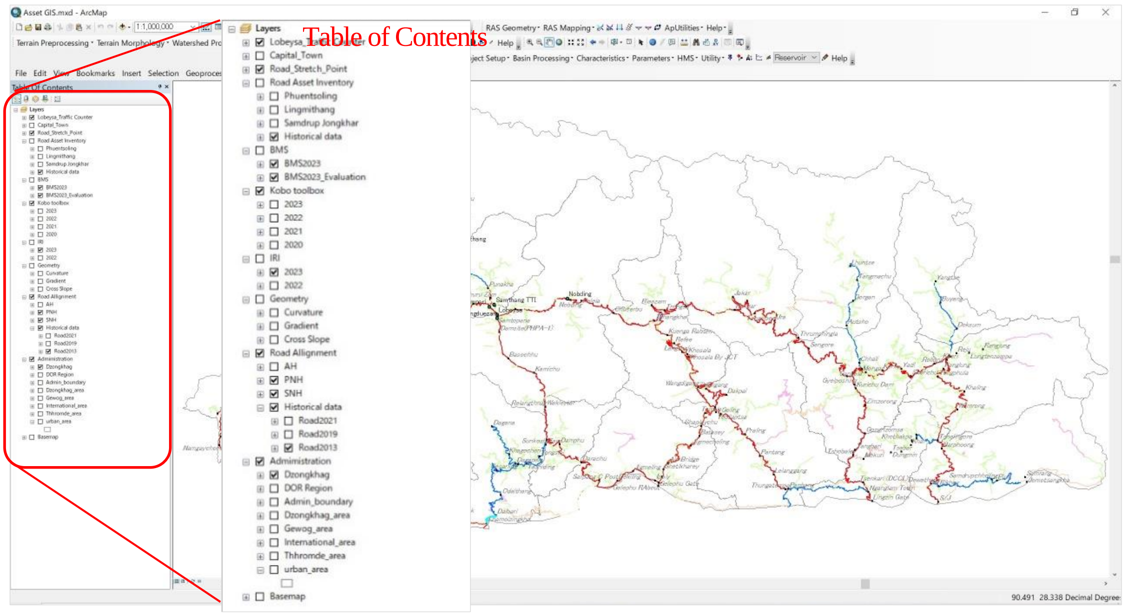
After January 2024, basic training on BRS and the GIS database established by the Headquarters Maintenance Division were provided to regional office staff.

Activity 6-2: Improve the existing DoR GIS database and information sharing mechanism between DoR headquarters and Regional Offices after clarifying the current situation and issues..

The Road Asset Management GIS database was constructed during this activity period. The information (layer structure) of each GIS database is described below. In the past activities, JET has collected RAMS and ROMDAS data, which are information for constructing GIS databases, together with the regional offices. Particularly in the process of creating RAMS, the division of roles between the DoST Headquarters Maintenance Division staff and the regional offices and the establishment of an information sharing system were important issues, which have been established through technical transfer in this project activity. In this activity period, as the next process, technical guidance and GIS database construction were provided on the procedures to process the data collected by the headquarters staff and regional offices and incorporate them into the GIS database.

■ Layers of GIS database and Table of Contents
Layer structure and information stored in the GIS database.

Figure. 3.7-2 and Table 3.7 2 show the layers and information stored in the GIS database. Each layer is composed of not only the latest information, but also data collected in the past and stored as "Historical Data.



(Source: JET)

Figure. 3.7-2 Layered structure of the GIS database

Table 3.7-2 Details of GIS database layer structure

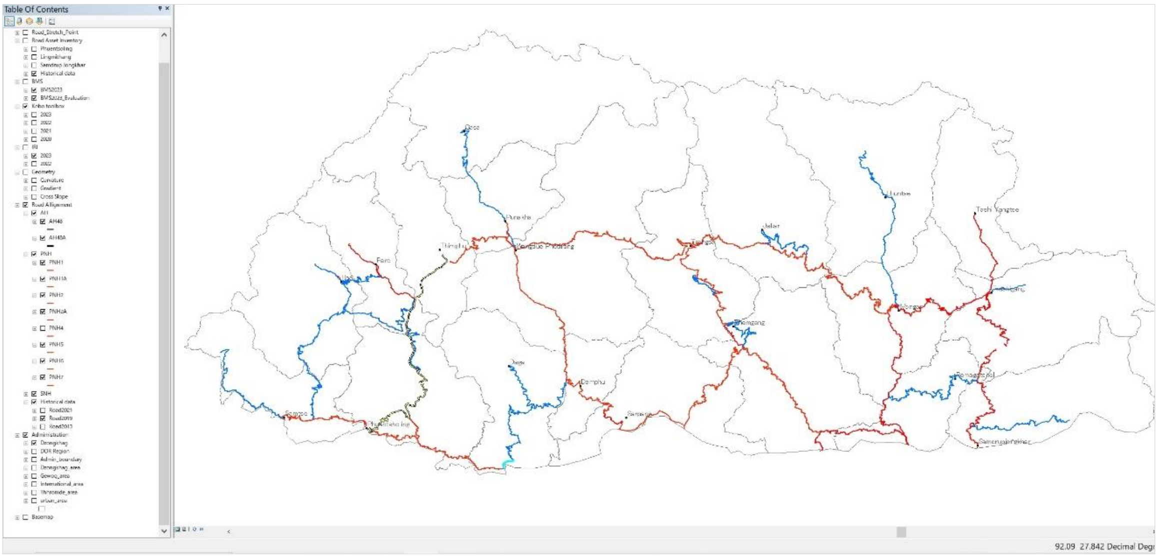
Layer	Data content	
Capital Town	Capital Town of Dzongkhag	Mapping point data of prefectural capitals
Road Strech Point	Starting and ending location of road management section	Mapped as point data based on road ledgers created and maintained by the DoST Design Division
Road Asset Inventory	Road Structure Information	Information on road structures (drainage, crossing pipes, slope protection works, etc.) collected by the Maintenance Division of the DoST Headquarters and regional offices
BMS	Bridge Management System	Bridge management database managed by DoST Bridge Division
Kobo toolbox	Record of disaster location	Disaster occurrence location records collected by DoST regional offices. Data is accumulated as disaster history.
IRI	International Roughness Index	Record of road surface irregularities measured by ROMDAS provided by the World Bank
Geometry	Road geometry data	Road geometry records measured by ROMDAS. Longitudinal gradient, cross-sectional gradient, R-value (curve radius)
Road Alignment	Road alignment	Road alignment data measured by ROMDAS and tablets provided by the project
Administration	administrative district	Administrative boundaries created by the National Land Commission (NLC)

(Source: JET)

A detailed description of each layer is given below.

Capital Town

The county capitals of all 20 Dzongkhags are shown. Each point contains the name of the Dzongkhag and the name of the city.

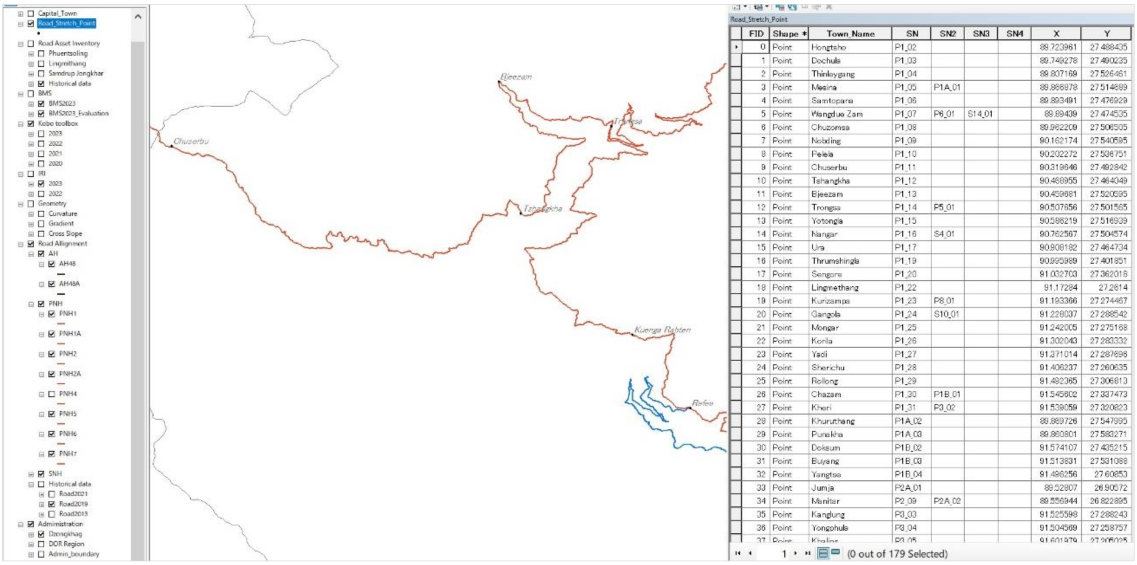


(Source: JET)

Figure. 3.7-3 GIS Database (Capital Town)

Road Strech Point

The starting and ending points of the road management section are mapped as point data, which were defined in the DoST Design Division's road ledger, but the information in the road ledger was in tabular form only, so they were mapped in this project. The attribute table contains the start and end point names, national road names, control numbers (SN) defined in Road Stretch Point, and location coordinate information.



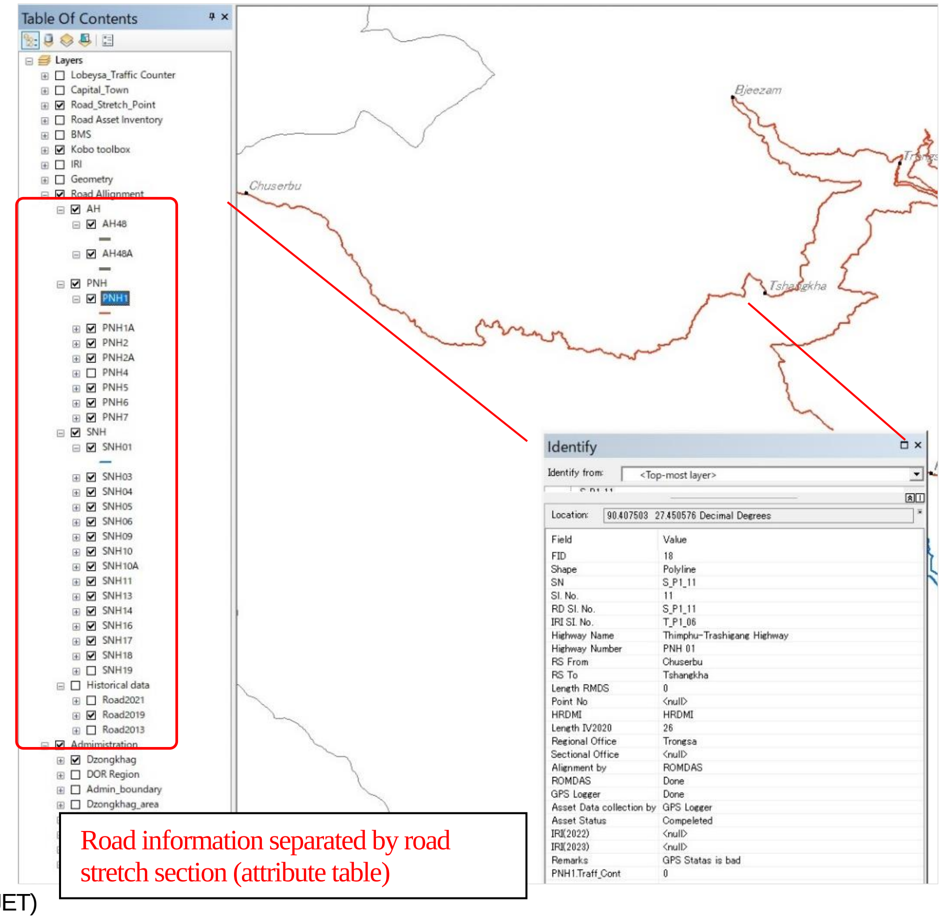
(Source: JET)

Figure. 3.7-4 GIS database (Road Strech Point)

Road Alignment

Asian Highway (AH), Primary National Highway (PNH), and Secondary National Highway (SNH) are shown as color-coded road alignments. These alignment data are collected by ROMDAS equipped with high accuracy GPS and stored in this GIS database as the latest road alignment data. In addition, each road alignment is managed as a database divided into sections by "Road Stretch", and the information for each section can be checked on the GIS database.

Linear data collected in the past for the years 2013, 2019, 2021, and 2023 (ROMDAS is after 2021) are also stored as historical information.

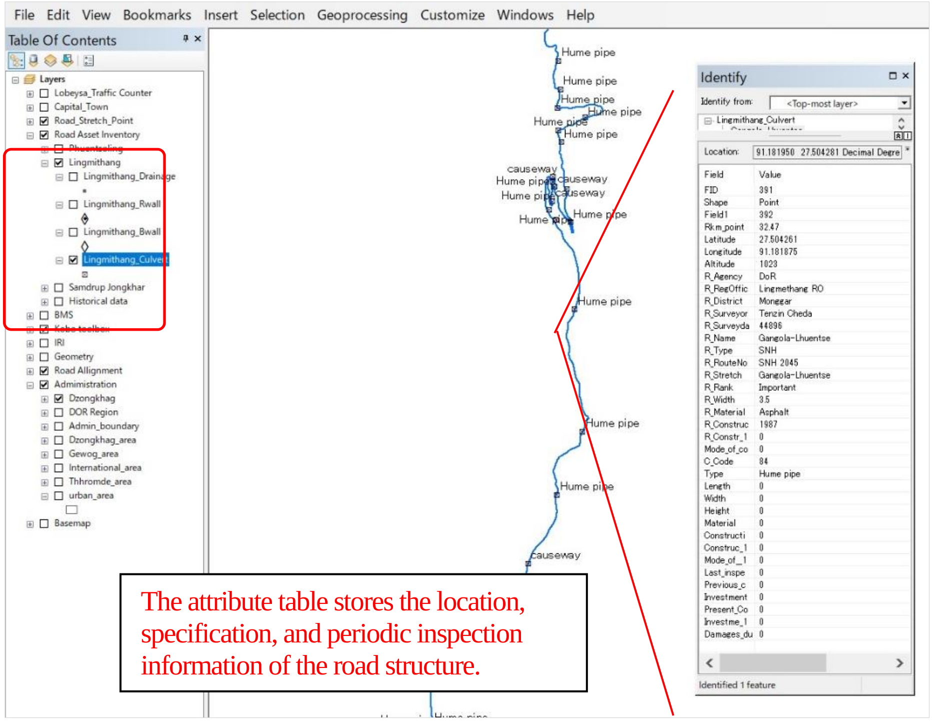


(Source: JET)

Figure. 3.7-5 GIS Database (Rood Alignment)

Road Asset Inventory

Information on road structures such as crosspipes (Culvert), drainage channels (Drainage), and slope protection works (Breast wall, Retaining wall) were stored in the GIS database as point data. This information is composed of "1) data from ROMDAS" and "2) various information based on the ROMDAS data, which was obtained by the regional office staff through field surveys. In addition, to enable management of the results of periodic inspections, an inspection information item is also included in the attribute table.

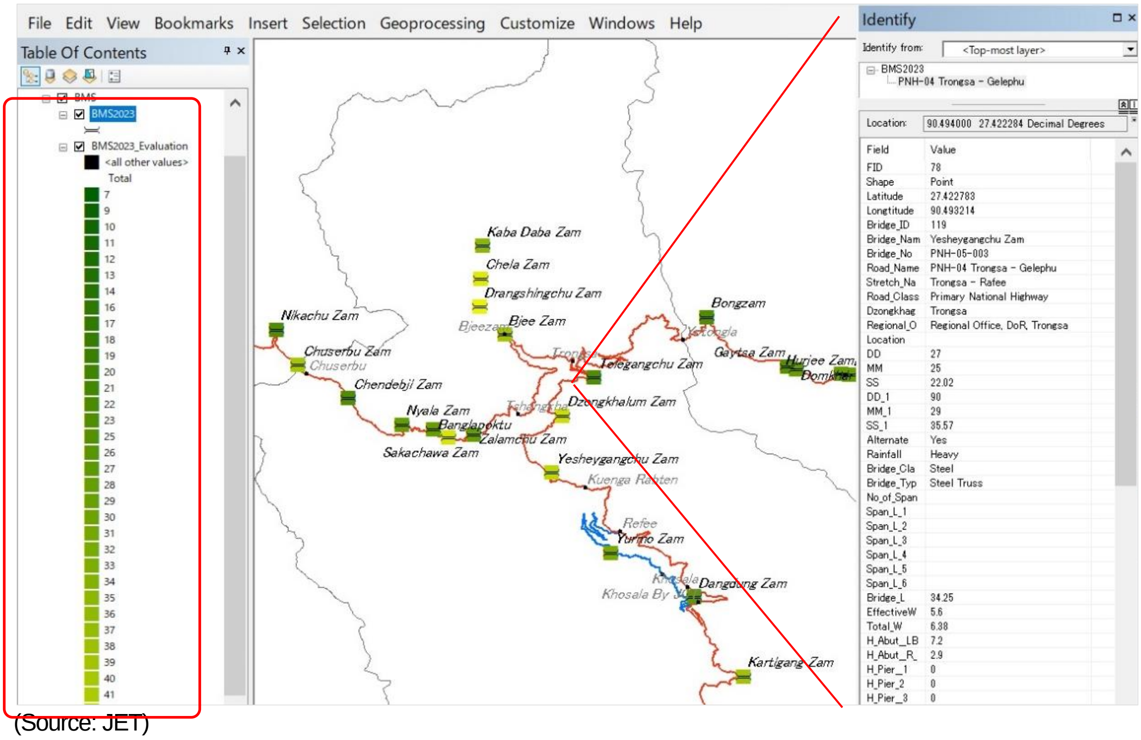


(Source: JET)

Figure. 3.7-6 GIS Database (Road Asset Inventory)

BMS (Bridge Management System)

The data is extracted from the Bridge Management System (BMS) managed by the DoST Bridge Division, which is a web-based viewing and editing system, but the data is extracted from the server PC that manages the BMS and incorporated into the GIS database. The information in the attribute table is the same as that stored in the BMS managed by the Bridge Division, and includes bridge specifications and inspection results. The map is set up in such a way that the repair and reinforcement priorities can be identified on the map.

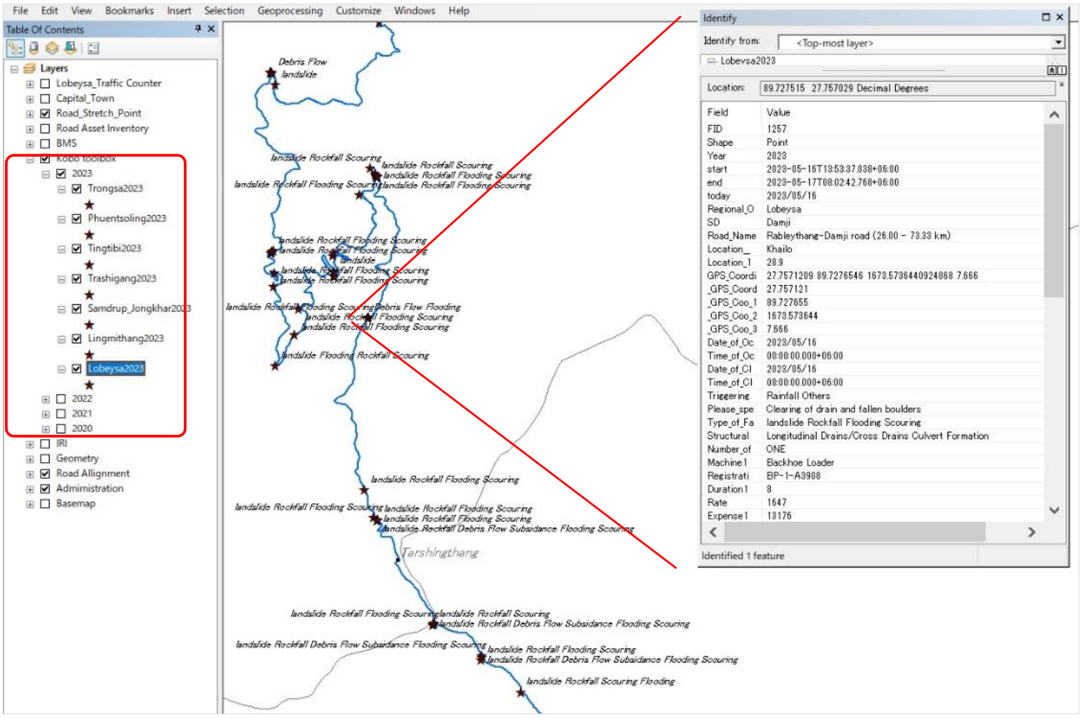


(Source: JET)

Figure. 3.7-7 GIS Database (BMS)

Kobo toolbox

Regional office staff keep records of disaster occurrence history across the country. Information such as time of disaster occurrence, type of disaster, cause, and what post-disaster response was implemented is stored, and records from 2019 to the present are maintained as Excel data. In this project, these data were set up so that they can be viewed on a map in the GIS database. JET expects that as the data is accumulated in the future, it will be possible to use the data in a more analytical way, such as being able to visually identify vulnerable areas.

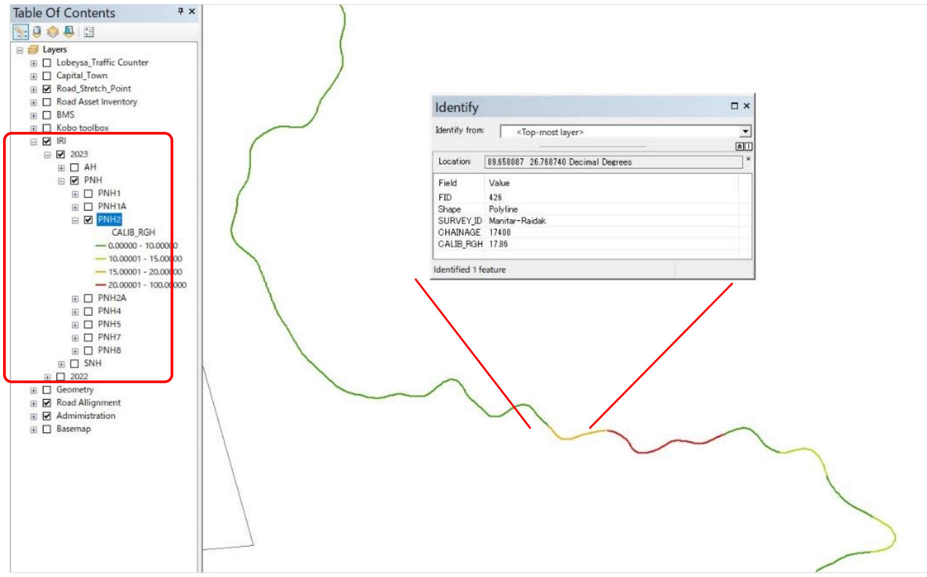


(Source: JET)

Figure. 3.7-8 GIS database (Kobo toolbox)

IRI (International Roughness Index)

This data was measured every 100 m by ROMDAS as an indicator of the degree of road surface unevenness. The data is displayed in a gradation of colors from green to red, from low (less uneven) to high (more uneven). In the case of Bhutan, since pavement maintenance and regular maintenance and repair have not progressed in many areas, the IRI indicator is often used to identify unpaved sections and sections with severe damage due to potholes, etc. on the map, rather than to plan repairs due to age-related deterioration. For this reason, the range of gradation colors shown on the map is set wider for larger values so that unpaved sections and sections with large damage can be recognized more easily.

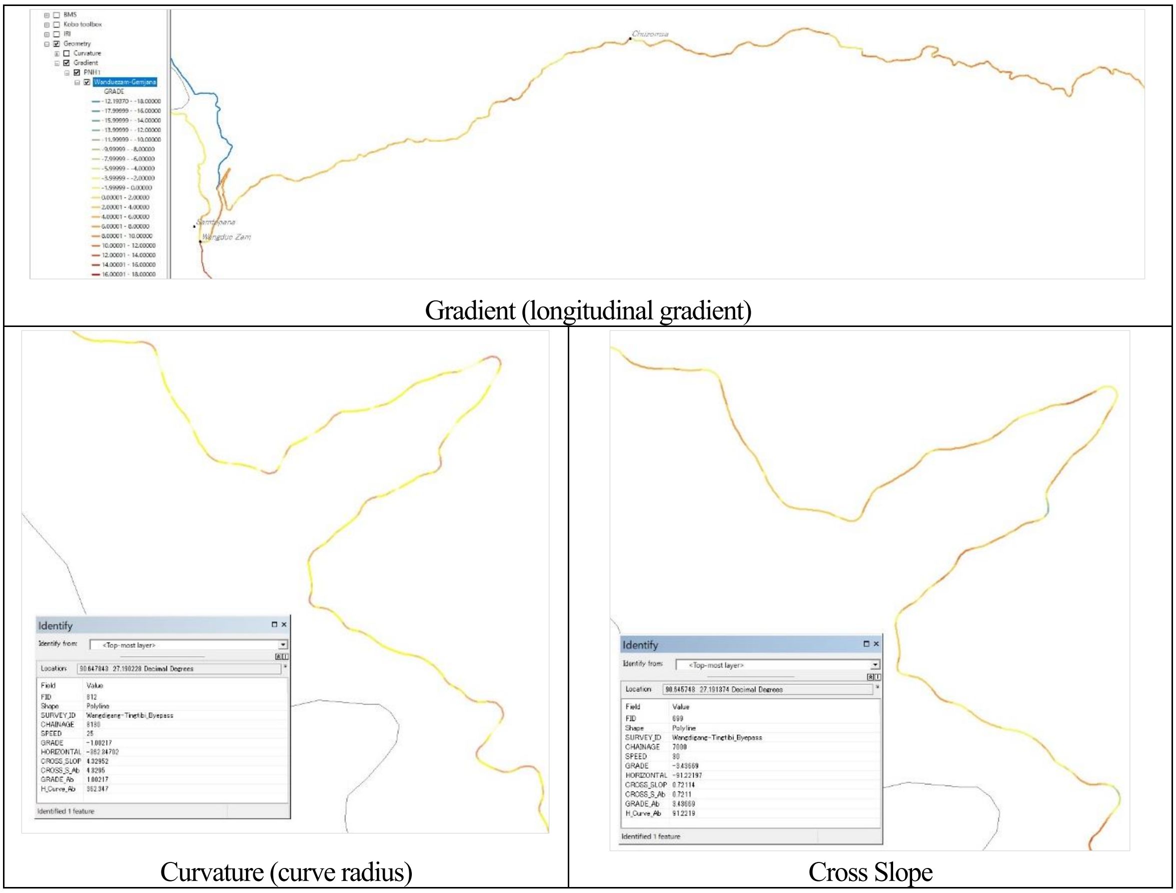


(Source: JET)

Figure. 3.7-9 GIS Database (IRI)

Geometry

The road geometry data is represented as Curvature (curve radius), Gradient (longitudinal gradient), and Cross Slope (cross-sectional gradient) for each 10m in each layer. The data is color-coded according to the size of the numerical value.



Gradient (longitudinal gradient)

Curvature (curve radius)

Cross Slope

(Source: JET)

Figure. 3.7-10 GIS Database (Geometry)

Activity 6-3: Improve data acquisition system for road information at the Regional Offices of the DoR.

1. Technical transfer of road information acquisition and establishment of an acquisition system

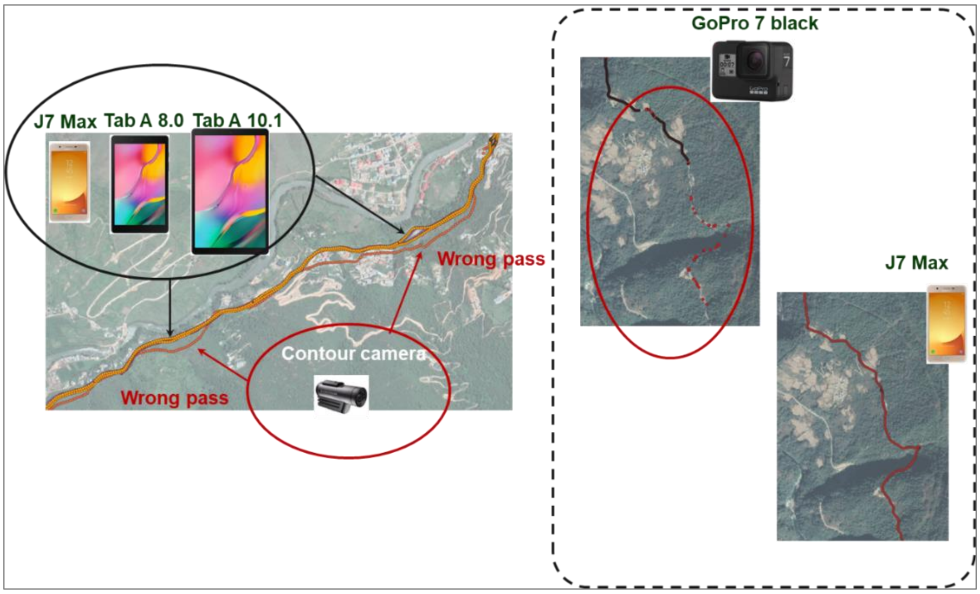
This activity was to enable DoST regional office staff to obtain road information data and to establish a system to implement road information collection operations in cooperation between DoST headquarters and each regional office. Taking into consideration the issues and improvement policies identified in Activity 6-2, a data collection method suited to the capabilities of DoST staff and the natural environment of Bhutan was proposed, and technical transfer was conducted.

Initially, JET proposed to use only the drive recorder (Transcend DrivePro 520) provided by the project to acquire road pavement conditions and structure locations, but the GPS accuracy was not well secured and the device was not compatible with the Road Asset Management System (RAMS), an Excel spreadsheet that is becoming established within the DoST. However, the GPS accuracy was not well secured, and the support for the Road Asset Management System (RAMS), an Excel spreadsheet that is becoming established within the DoST, was also insufficient.

1) Selection of equipment for acquiring road information data

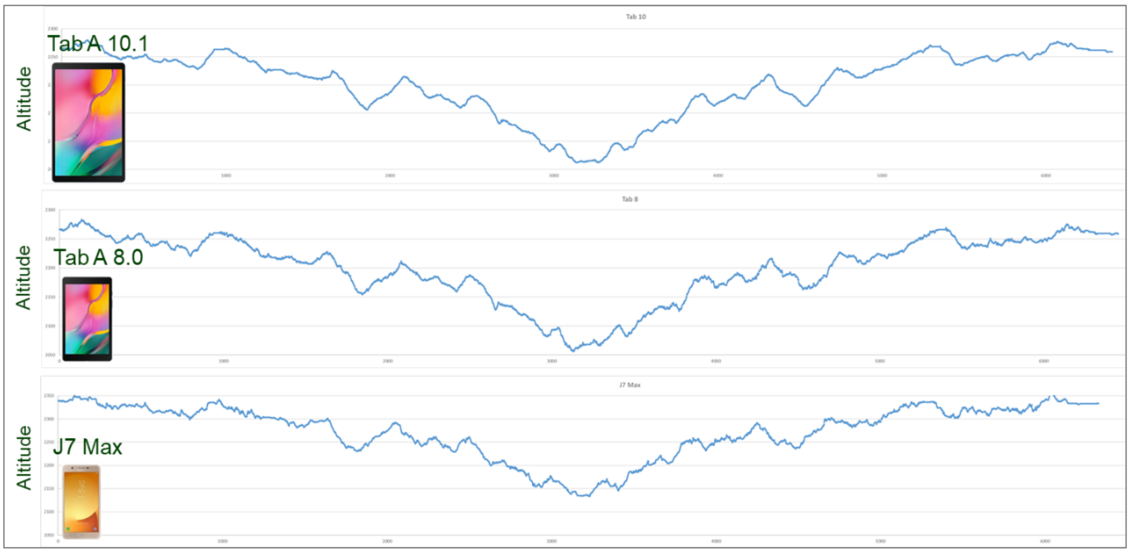
GPS accuracy verification

GPS accuracy tests were conducted using as many sample devices as possible. Considering that a certain degree of GPS accuracy is ensured even in mountainous areas, that the device should be readily available in Bhutan, and that it can be used in conjunction with other operations, JET decided to use the "Sumsung Galaxy Tab A 10.1" tablet as the recommended device for this project. Below is a sample of the results of the comparative study for the surface road alignment and elevation, respectively.



(Source: JET)

Figure. 3.7-11 GPS accuracy test results for a flat road alignment (example)



(Source: JET)

Figure. 3.7-12 GPS accuracy test results for elevation (example)
(RSTA Parking ⇔ Chuzom approx. 25 km)

2) Data collection and organization using both tablet device and drive recorders

In this project, JET decided to use both a drive recorder and a tablet device. The drive recorder was to be used only for its function of taking video, while the tablet device was to be used for its function of collecting truck logs and other location information.

Drive recorder functionality

The drive recorder (Transcend DrivePro 520) provided by the project was used to collect video files that record road information as visual information.

Utilization of tablet device functionality

After confirming GPS accuracy, JET decided to use Samsung Tab A10.1 for this activity. The "GPS Logger" application installed on the device was used to obtain GPS location information, elevation, and time (GMT).

3) Data entry into RAMS (Excel sheet)

RAMS is an Excel-based road asset management database that records location information such as latitude and longitude, elevation, and distance markers, as well as pavement conditions, road structures, and damage conditions.

The RAMS used by DoST continued to be utilized in this project, but the sheet contents and formulas have been improved due to the change in data collection equipment.

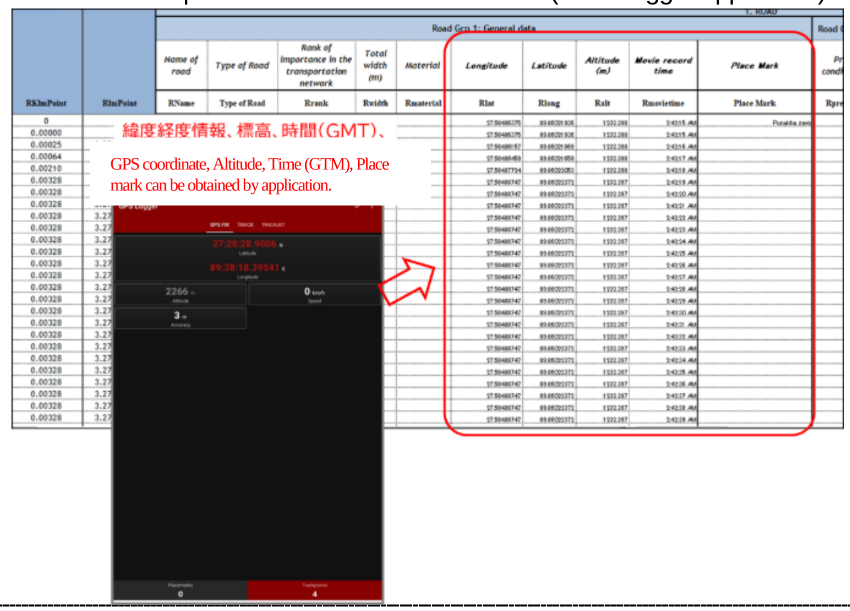
Location and time information

Latitude/longitude information, elevation, and time (GMT) information are entered into RAMS using data collected by the "GPS Logger" application on the tablet device.

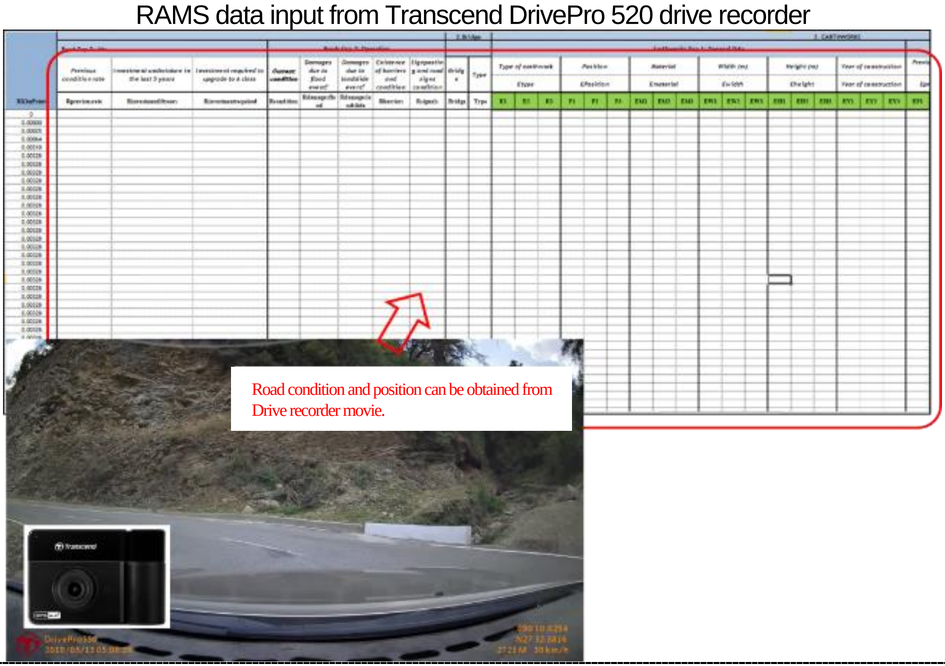
Road Structure Information

The road structure information visually obtained from the video is input into RAMS in a way that ties the RAMS time series (GMT) to the time displayed in the drive recorder video (GMT).

RAMS data input from Tab A 10.1 tablet device (GPS Logger application)



RAMS data input from Transcend DrivePro 520 drive recorder

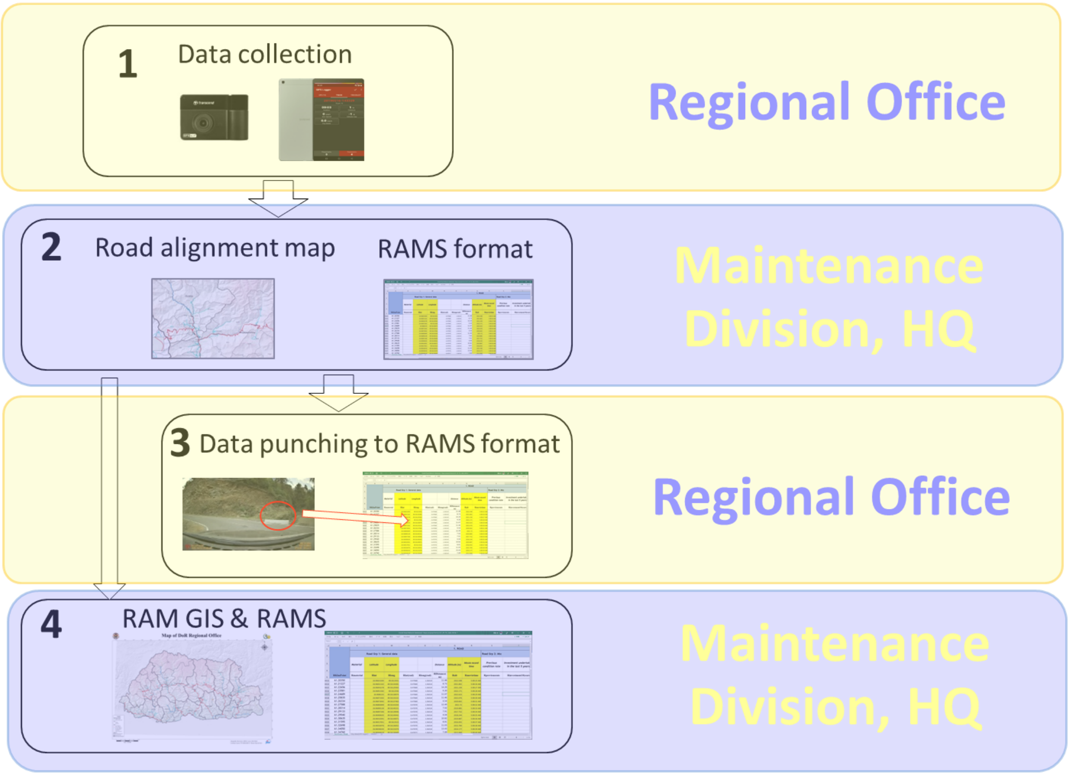


(Source: JET)

Figure. 3.7-13 Input information from each terminal

4) Establishment of a road information collection and sharing system between the Maintenance Division of the DoST Headquarters and the regional offices

Through the on-the-job training on road information data collection and the RAMS input technical transfer seminar, the roles related to road information collection were discussed between the DoST Headquarters Maintenance Division and the regional offices. Below is a tentative flowchart of the roles determined through the discussions. The following flowchart was improved and clarified through practical implementation in the future.



(Source: JET)

Figure. 3.7-14 Draft Flowchart of Road Information Collection and Sharing System

5) Construction of GIS database (QGIS)

- Road alignment and mapping

Road alignment maps for each regional office were created using data collected by the Trongsa-Lobeysa Regional Office for Primary National Highway, Secondary Highway, Dzongkak roads, and Gewog Center roads; the DoST has not revised road alignment maps since 2013, and starting with the road alignment maps to be updated at the Trongsa-Lobeysa Regional Office, the maps were used for all The maps were spread to the regional offices and reflected in the Road Asset Management GIS database constructed in Activity 6-2. The following is a comparison of the road alignment maps created at the Trongsa Lobeysa Pilot Regional Office before and after the update.

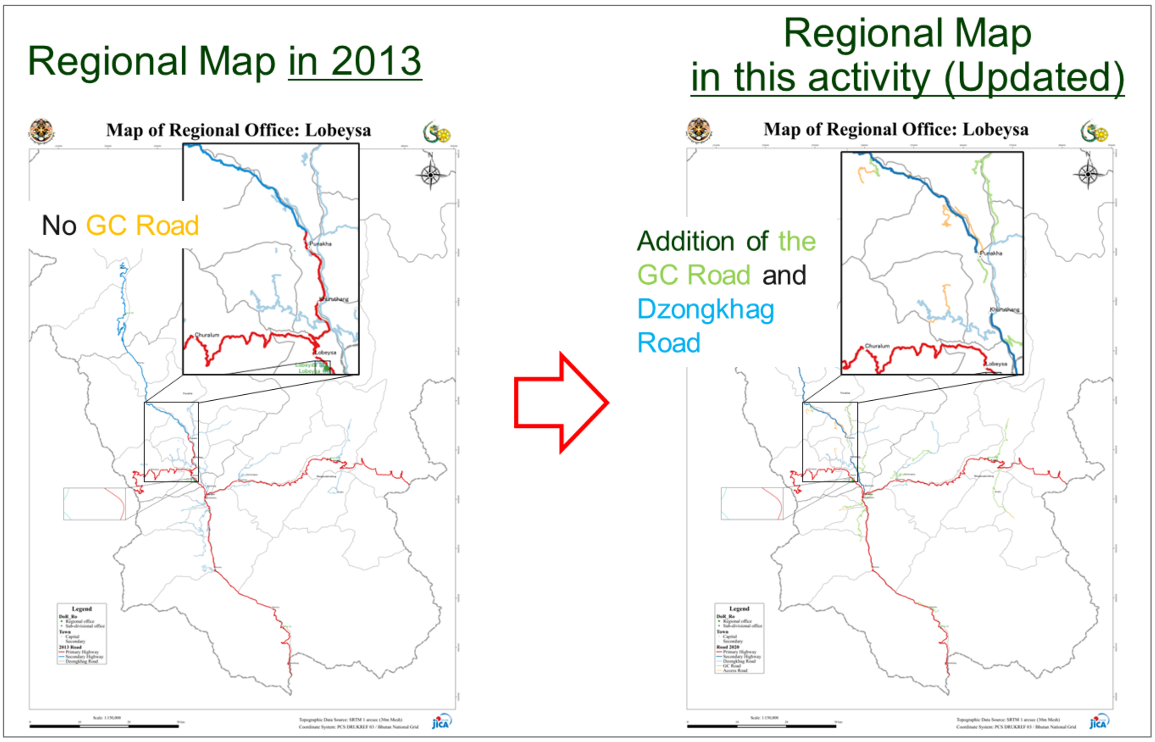
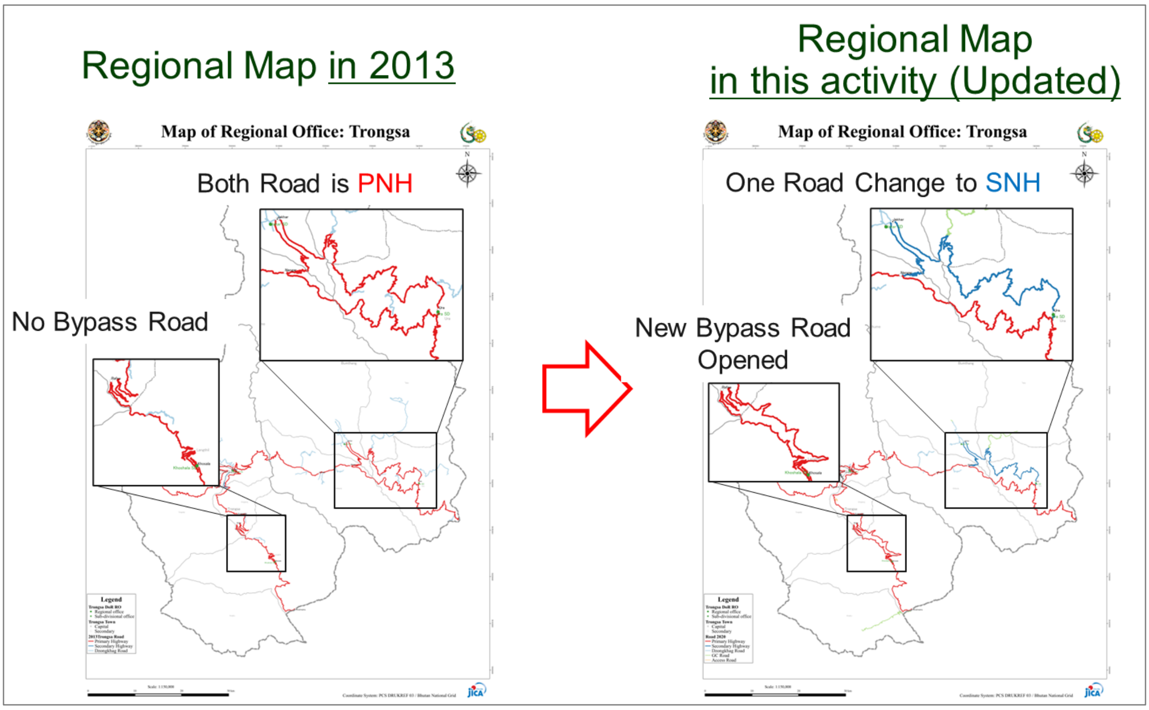


Figure. 3.7-15 Road alignment map of Lobesa Regional Office (left figure: 2013, right figure: prepared by this activity (2019))



(Source: JET)

Figure. 3.7-16 Road alignment maps of the Tonsa Regional Office (left: 2013, right: prepared by this activity (2019))

2. Technical transfer of aerial photogrammetric surveying methods using drones

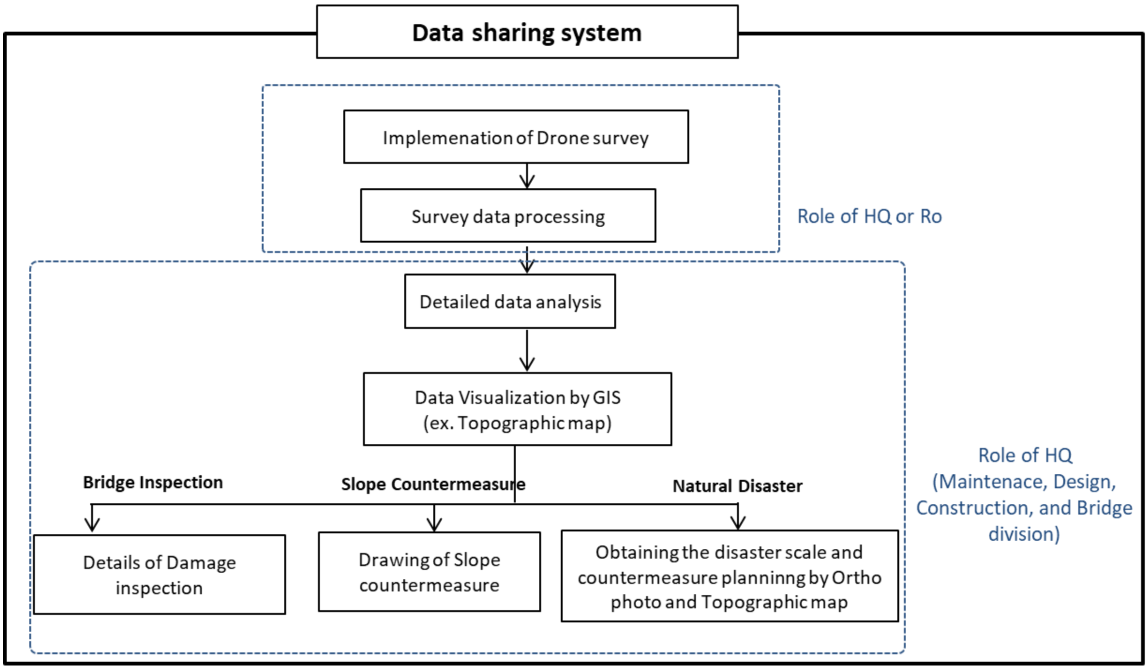
Technical transfer on aerial photogrammetry methods using drones as one of the methods used by DoST regional office staff to obtain road information was conducted.

■ Purpose of Drone Introduction

The technical transfer and provision of drone-related equipment for aerial photo surveying by drone were conducted to enable regional office staff to quickly conduct detailed topographic mapping for design of slope countermeasures, general survey for slope disaster occurrence, and inspection for bridge integrity survey by drone. In addition, a sharing system was established for DoST headquarters and regional offices to share survey data and output.

i) Data sharing system between DoST headquarters and regional offices

The DoST consists of the headquarters and nine regional offices, which work in cooperation with each other. Based on the system in which the regional offices collect data in the field and DoST headquarters staff analyze and evaluate the data, JET proposed a sharing system for drone aerial photo surveying operations that follows the basic system described above. The following flowchart shows the sharing system, which was discussed and shared with the DoST.



(Source: JET)

Figure. 3.7-17 Information Sharing System between Headquarters and Regional Offices

ii) Provision of equipment

In implementing this activity, drone equipment, analysis software and PC for analysis, and simulators for drone training were provided. Two drone and flight simulators were provided on the assumption that regional office staff would also be able to operate drone surveying, and one unit each of analysis software and PC for analysis was provided on the assumption that DoST headquarters would use them. In selecting a drone, the project team selected a DJI drone, which has distributors around the world and can provide support in case of problems, etc. The Phantom4 RTK drone, which specializes in surveying, was selected as the model. In addition, as the WB project also provided a DJI drone, DoST was advised to select a model purchased for the WB project that is operationally compatible with the equipment provided for this project, while at the same time taking advantage of the differences in functionality. The following is a list of equipment to be provided under this project.

Table 3.7-3 List of drone-related equipment

No	equipment	(technical) specification	volume
1	Drone	DJI Phantom 4 RTK with battery,. Flight Simulator (PC soft with Transmitter of RC Helicopter)	2
2	Desktop PC for analysis	I7 11th gen/Ram 32gb(ADD)Hdd-1tb+ 512ssd/DOS/19.5 MONITOR/3YRS WARRENTY KEBOARD+MOUSE	1
3	Drone Analysis Software	Agisoft Metashape (Software license) 3D Analysis software	1

(Source: JET)

■ Implementation of a drone aerial photogrammetry technology transfer program

Training was conducted in line with the Technology Transfer Program with the aim of enabling DoST headquarters and regional office staff to conduct aerial photogrammetric surveying using drones. The program aimed to develop drone operators through this training, and trainees who met the same level of the program content by accredited schools that met the technical accreditation standards set by the Ministry of Land, Infrastructure, Transport and Tourism's registered management organization were certified as having drone operation skills with a certificate of participation in this program's technology transfer program. The outline of the technical transfer program is as follows

i) Technical Transfer Program Overview

・ target group

Since the objective of this training was to enable the entire DoST organization to make effective use of drones, no restrictions were placed on DoST headquarters departments or regional offices, and trainees were selected equally from each organization.

- DoST Headquarters Staff

  Maintenance Division (4), Bridge Division (2), Design Division (2), Construction Division(1)

- DoST Regional Office

  One from each of the nine regional offices nationwide

・ Training Programs

The program was conducted at the Trongsa, Lobeysa, and Phuntsholing DoST regional offices as a 5-

day program for each office. Pilot slopes and bridges were selected at each regional office to incorporate a practical on-site format, and a series of processes from drone operation, analysis, and GIS visualization were transferred using the surveying of pilot slopes and bridges as teaching materials.

Table 3.7-4 Training Programs (conducted at each regional office)

Number of days	Program	
	morning	afternoon
Day 1	Lecture: Drone Regulation Law and Operation in Bhutan Practical training: Operation training using a flight simulator	Practical skills: manual operation training
Day 2	Practical skills: hands-on manual and automatic operation exercises	Practical skills: hands-on manual operation exercises (bridge inspection)
Day 3	Practical skills: hands-on manual manipulation exercises (collapsed slopes, landslides)	Practical skills: hands-on manual operation exercises (bridge inspection)
Day 4	Practical skills: automatic operation exercises in the field (collapsed slopes, landslides)	Practical skills: automatic operation exercises in the field (collapsed slopes, landslides)
Day 5	Practical skills (indoor exercises): data analysis, GIS mapping training	Practical skills (indoor exercises): data analysis, GIS mapping training

(Source: JET)

- Training Schedule

The training location (regional office) and dates were as follows

Table 3.7-5 Training Schedule

Training Location	schedule	
	Training in regional offices	on-the-job training
Trongsa Regional Office	Nov 2, 8 2022 (2 days)	Nov 3,4 and 7, 2022 (3 days)
Lobeysa Regional Office	Nov 10, 18 2022 (2 days)	Nov 14, 16, and 17, 2022 (3 days)
Phuntsholing Regional Office	Nov 21, 25 2022 (2 days)	Nov 22 – 24 2022 (3 days)

(Source: JET)

ii) Outputs and Proficiency

- Drone operation and data collection

Trainees who participated in this program were able to perform basic manual operations, create flight routes, and perform automatic operations in accordance with the flight routes, and were deemed competent enough to perform operations at disaster sites and bridges without JET support.

- Data analysis, GIS and other visualization work

Since this program focused on improving the ability of DoST regional office staff to reliably perform drone flight operations with reference to the technical accreditation standards for registered management organizations of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), it is necessary to continue to follow up on the technical transfer for data analysis, visualization through GIS, etc. Since training was conducted in the form of on-the-job training on the series of steps from data analysis to visualization in accordance with the procedure manual, it can be evaluated that the participants acquired the ability to create visualized images, etc. by following the procedure manual. However, the setting of coefficients for noise reduction corresponding to surveyed areas, etc., requires a certain degree of trial and error, so it is necessary to follow up through practical surveying conducted by the DoSTs themselves.

On-the-job drone operation training (DoST Lobeysa Regional Office)

Data Analysis Training (DoST Lobeysa Regional Office)

(Source: JET)

Figure. 3.7-18 Training scene of drone aerial photo interpretation program

iii) Issuance of Certificate of Attendance

Certificates of participation were issued to trainees who have taken this program to certify that they have completed the program. This certificates were used for drone flights in Bhutan. Prior to conducting drone flights in Bhutan, it is necessary to apply for and obtain permission in accordance with the rules stipulated by the Bhutan Civil Aviation Authority (hereinafter referred to as BCAA). In the application process, the drone operator must either "be a participant in drone pilot training by an external organization" or "demonstrate his/her piloting ability by conducting a demonstration flight at the BCAA". The Certificate of Attendance issued under this activity was positioned as proof of "having attended drone pilot training by an external organization".

iv) Follow-up Activities

The procedure manual was prepared only for the general flow of analysis, and it is necessary to acquire some experience in setting up individual site conditions and coordinate reference points.

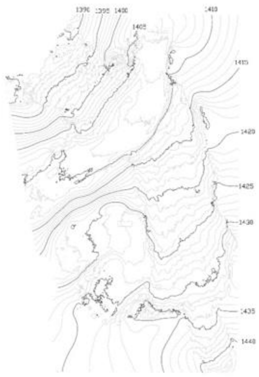
■ Drone aerial photogrammetry on slopes subject to pilot construction (within the output 2 activities)

Drone surveying was conducted on Gopini (in the jurisdiction of Phuntsholing), a slope subject to the pilot work for Output 2, and detailed topographic maps necessary for the design of countermeasure works were created. As a follow-up to the transfer of aerial photogrammetry technology using drones in 2022, this activity included on-the-job drone operation training, instruction on how to create flight routes, etc., analysis at DoST headquarters, and the creation of detailed topographic maps.

Specifications / Data Resolution

Ortho image: 0.02m/pix Detailed topographic map: DEM resolution 0.1m, contour interval 1.0m

i)Aerial photogrammetric survey in Gopini (within the jurisdiction of Phuntsholing Regional Office) (Implementation date: 12/12/2023)

	
Ortho image	Detailed topographic map

(Source: JET)

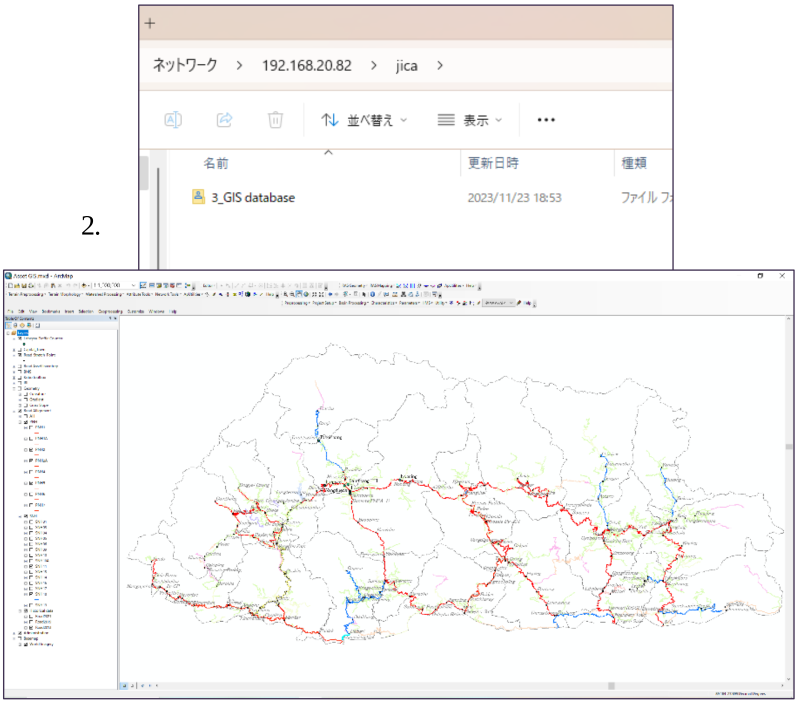
Figure. 3.7-19 Ortho image and detailed topographic map from drone survey (Phuntsholing site)

(Source: JET)

Figure. 3.7-20 Drone operations by DoST headquarters personnel and Phuentsoling Regional Office personnel (Phuntsholing site)

Activity 6-4: Improve systems at DoR headquarters used to input road information into and manage the GIS database.

A shared folder was created on the server PC managed by MoIT and the GIS database was stored in it so that other divisions of DoST (Construction Division, Bridge Division, and Design Division) could access the GIS database established by the DoST Maintenance Division and collect necessary information. This developed a system where necessary information could be accessed from each division. The shared folder on the server PC was set up as an intranet that can be accessed via the Internet line in the MoIT building. The data structure and usage of the GIS database were transferred to the GIS staff in other divisions through training. The technology transfer was conducted through training programs for GIS database data configuration and usage.

1.	Access to shared folders	Design Division, Construction Division Use of road alignment, IRI, road asset management information, and topographical information
2.		Bridge section Confirmation of BMS location (mapping) and various information

(Source: JET)

Figure. 3.7-21 Image of Shared Folder Access Usage on MoIT Server PC

Activity 6-5: Improve system for sharing road information utilizing the GIS database.

In this activity, a BRS Application with map functionality was developed based on the Asset Management GIS database constructed in Activity 6-2.

The structure of the BRS application in the GIS database is described below. In developing the application, the project was carried out from the system specification stage through repeated discussions with the DoST.

1. Basic application policy

- The system shall be designed to be used by general road users, and the information shall be made available via a smartphone interface (Android/iOS compatible).
- System that can be managed on the PC web is built to provide a function for data management by the DoST Headquarters Maintenance Division and for storing past information as a database.
- While the DoST staff actually operates and edit the BRS application, the Government Technology Agency (GovTech) is responsible for system management of the BRS application itself and the server

PC containing the system. This is because it has become the policy that GovTech manages all systems developed and managed by all government agencies in Bhutan, and the system to be developed in this project also follows this policy.

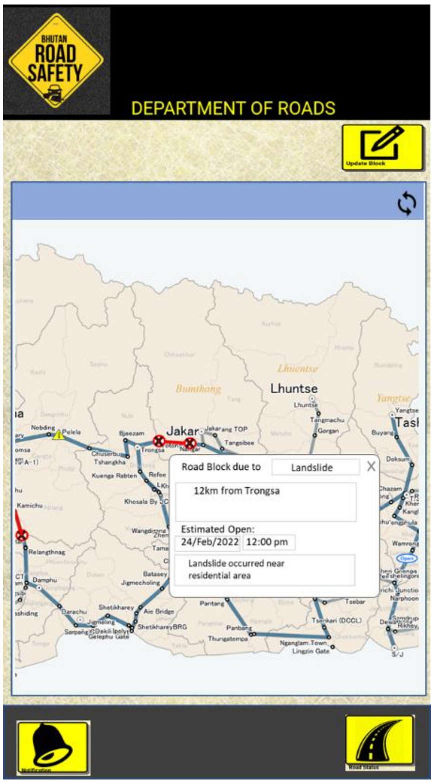
- The system is a web system that allows not only DoST headquarters staff but also regional office staff to access applications and PC systems, and system user registrants are able to view, edit, and add information. However, since access to all functions by all DoST staff members would cause problems in terms of data management, it was decided to establish access privileges by authority. The Web database defined here is a system that can be viewed and operated via a Web interface.

2. System configuration overview

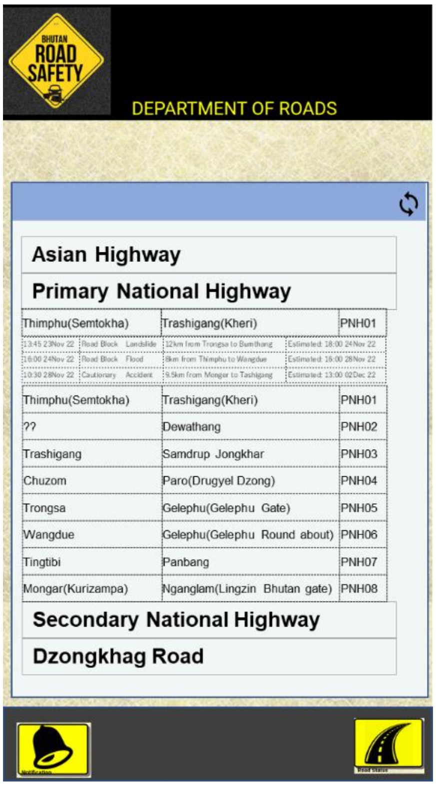
i) Interface

The interface is primarily a map function, with the objective of making it easy for general road users to obtain road information. However, to enable users who cannot read maps to use the system, a function to display road information in a list is provided. The map function should be designed so that even general road users can understand it. The following points should be considered when creating the map function.

- Since the information is used on a small screen on a smartphone, information on road curves along topography, etc., is cut off, and straight road lines connecting only major cities and towns are displayed. This method was adopted because general road users are interested in the distances and sections of major cities and towns, not in detailed road curves.
- Symbols are used to indicate road information so that it can be grasped at a glance. Clicking on a symbol displays detailed road information.
- For road users who cannot read maps, the system also includes a function to retrieve road information from a list.



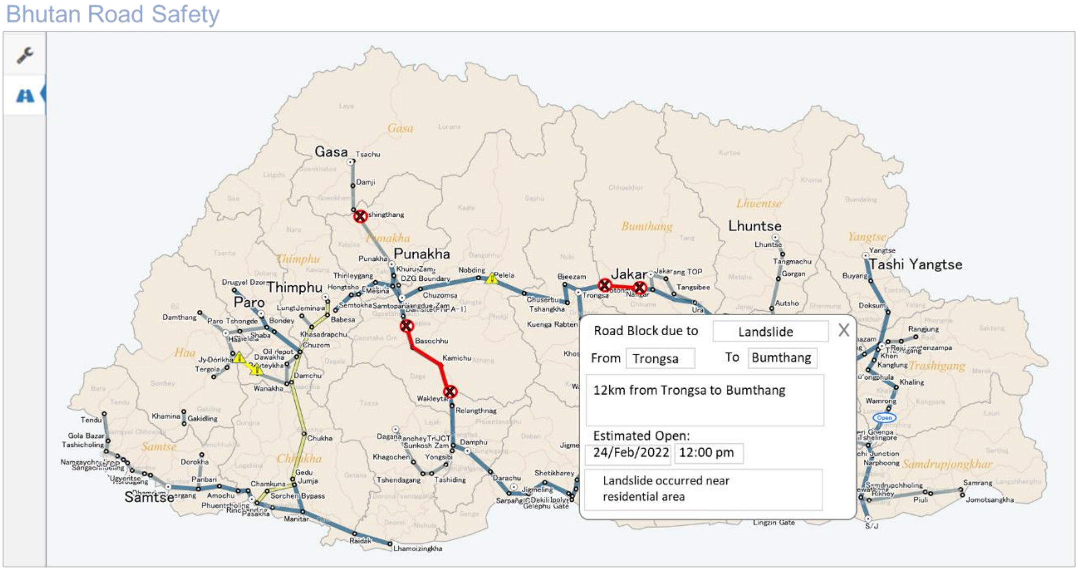
Map function (design)



List display function (design)

(Source: JET)

Figure. 3.7-22 Smartphone Interface



Map function (design)

(Source: JET)

Figure. 3.7-23 PC Web Interface

ii) Type of road information

Road information consists of three types of information: Road Block Information, Road Maintenance Activity, and Cautionary Information.

- Road Block Information

Road closures due to natural disasters associated with slope disasters, floods, bridge collapses, road collapses, etc.

- Road Maintenance Activity

Road closures for DoR maintenance and road repair work, often following a set schedule within a day, and often temporary and not lasting for a long period of time.

- Cautionary Information

This information is not a road closure, but it is necessary to be careful when passing through. This information is for sections where snow accumulation, falling rocks, etc. require attention.

iii) Road Information Items

It is important that the input information items for issuing the above road information be not only information items to be sent to road users, but also serve as a database for the DoST Maintenance Division to accumulate and evaluate data on disaster history. Through discussions with the DoST Maintenance Division, the following road information items were established.

Table 3.7-6 Input information items when issuing road information

(data) item	Contents	form (something takes)
Information Type	Type of road information	Select from "Road Block Information", "Road Maintenance Activity", and "Cautionary Information".
Type Category	Predisposition of road information	Information on natural disasters, road maintenance, strikes, etc. Items can be set from the configuration function. (Not set at this time)
Type		
Place Type	Symbol Display Type	Select "point", "section", or "point cloud
HW No	Road name	Select road names classified as "Asian National Highway," "Primary National Highway," "Secondary National Highway," or "Dzonghag road.
Section	Interval	Select a section of road information point
Nearest Chainage Point(km)	Distance markers in the section	Select distance markers within a section of road information points
GPS Coordinate	latitude and longitude information	Enter the latitude and longitude of a road information point. It can also help selecting a location from a map.
Location	Location Information	Manually enter location information
Date, Time of Occurrence	Date and time of event occurrence	Enter date and time
Expected Date, Open of Occurrence	Scheduled date and time of road information release	Enter date and time
Action Taken	What the DoR has done in response to the event	Listed manually
Remarks	remarks	Listed manually
Photo	situation photograph	Upload Photo

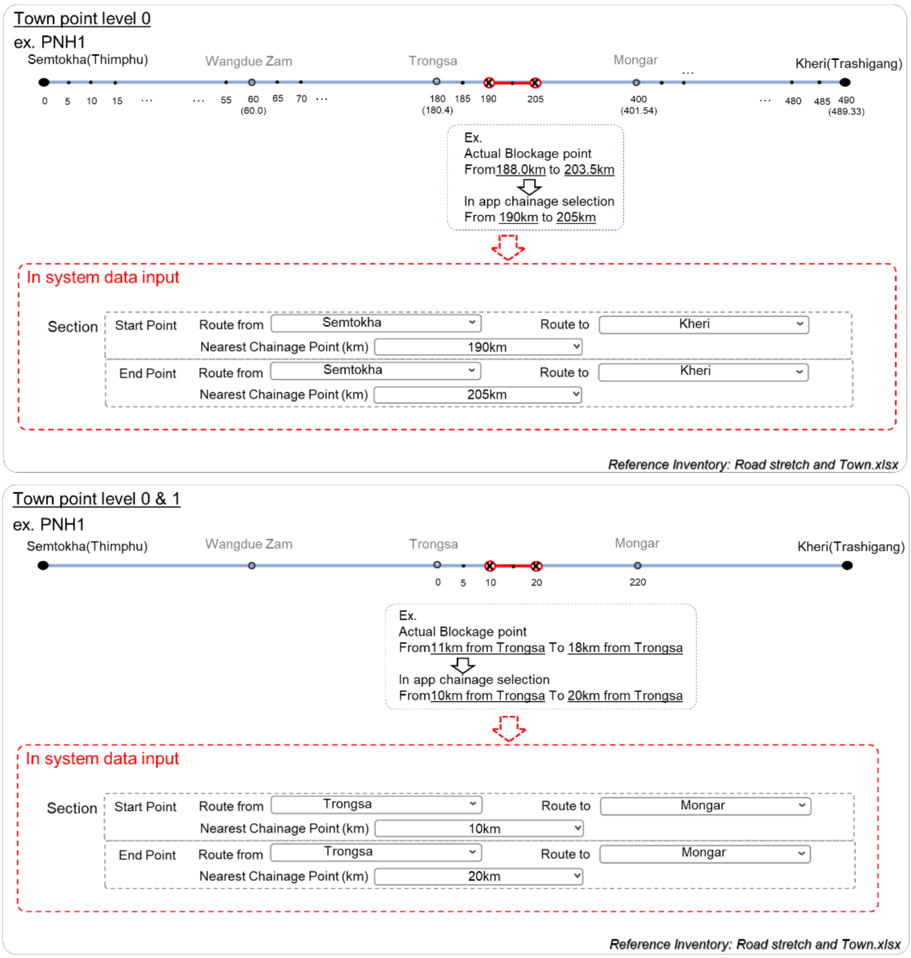
(Source: JET)

iv) Road Information Symbol Display

This map function displays road information symbols on the road lines in order to display straight road lines connecting only major cities and towns for easy understanding by general road users. All symbols are managed only by distance markers, and the system uses a method in which road lines are divided into 5-kilometer units and road information for each 5-kilometer unit is displayed as a symbol on the map.

Below are some points to keep in mind for distance marker management.

This application is to be input by DoST Regional Office staff who manage roads by region throughout the country, and a system of distance marker management that can be understood by DoST Regional Office staff is to be implemented. For example, National Highway PNH 1 is a 490-km east-west national road, and distance markers are maintained from the beginning to the end of the road. However, since it straddles several DoST regional offices, some of the regional offices manage the distance markers focusing on the distance marker from the prefectural capital.



(Source: JET)

Figure. 3.7-24 Image of the function to select a starting point and an ending point from multiple sections

The national road names, distance markers and sections to be used in the BRS application shall be in accordance with the road ledger "The Road Classification and Network information of Bhutan 2020" prepared by the DoST Design Division, and the BRS distance marker control ledger (BRS distance marker control ledger) prepared based on the above road ledger. The BRS distance marker control Inventory (Figure. 3.7-25). After the system is developed, when the road inventory is updated, the BRS distance marker control inventory is updated and the process is reflected in the system.

HW, No.	SN	Stretch Point	Town P Level	Chainage[km]	BRS Chainage from TPL 0	BRS Chainage from TPL 0&1				BRS Chainage from Town P Level0&1&2																		
AH48	A48_01	Lungtenzampa	0	0	0	0				0																		
AH48	A48_02	Babesa	2	6.2	5					5	0																	
AH48	A48_03	Khasadrapchu	2	13.7	15						10	0																
AH48	A48_04	Chuzom	2	26.7	25							10	0															
AH48	A48_05	Damchu	2	38.7	40								15	0														
AH48	A48_06	Chukha	1	62.9	65	65	0							25	0													
AH48	A48_07	Gedu	2	103.9	105										40	0												
AH48	A48_08	Rinchending	2	142.9	145											40	0											
AH48	A48_09	Phuentsholing	0	147.9	150		85										5											
AH48A	A48A_01	Sorchen Bypass	0	1.2	0	0				0																		
PNH 01	P1_01	Semtokha	0	0	0	0				0																		
PNH 01	P1_02	Hongtsho	2	11	10					10	0																	
PNH 01	P1_03	Dochula	2	17	15						5	0																
PNH 01	P1_04	Thinleygang	2	43	45							30	0															
PNH 01	P1_05	Mesina	2	53	55								10	0														
PNH 01	P1_06	Samtopana	2	58	60									5	0													
PNH 01	P1_07	Wangdue Zam	1	60	60	60	0								0	0												
PNH 01	P1_08	Chuzomsa	2	70	70											10	0											
PNH 01	P1_09	Nobding	2	100	100												30	0										
PNH 01	P1_10	Pelela	2	115	115													15	0									
PNH 01	P1_11	Chuserbu	2	136	135														20	0								
PNH 01	P1_12	Tshangkha	2	162	160															25	0							
PNH 01	P1_13	Bjeezam	2	173.7	175																15	0						
PNH 01	P1_14	Trongsa	1	180.4	180	180	120	0														5	0					
PNH 01	P1_15	Yotongla	2	207.7	210																		30	0				
PNH 01	P1_16	Nangar	1	232.98	235	235		55	0															25	0			
PNH 01	P1_17	Ura	2	265.48	265																				30	0		
PNH 01	P1_18	Serpang	2	294.48	295																					30	0	
PNH 01	P1_19	Thrumshingla	2	298.98	300																						5	0

... mation | Stretch point | Road Stretch

(Source: JET)

Figure. 3.7-25 BRS Distance Marker Control Ledger (partial sample)

4. Selection of re-contractor for BRS development

Work was performed on the preparation of bidding documents, bidding, contract negotiations with the successful bidder, and contract procedures for the development of the BRS. In particular, with regard to the system management system after the development of the system, JET worked with GovTech (Government Technology Agency), which was newly established in July 2023 following a major reorganization of the Bhutan government, to manage all systems developed by government agencies.

① Preparation of Bidding Documents

Bidding documents were prepared jointly with GovTech on the assumption that GovTech would manage the system after it was developed. The system design, including interfaces and functions, was set by DoST and JET, and system requirements were defined by GovTech. For the technical document portion of the bidding documents, an open briefing session (attended by 7 companies) was held in advance (Oct 31, 2023) for contractors to introduce the development details and discuss the technology.

② Publication of Bidding Documents

Bidding documents were sent to contractors who participated in the open bidding session on Nov 10, 2023. The bidding was publicly announced, with the upper limit of the bidding price set, and bids were evaluated on the basis of the total of technical and price points.

③ Application Deadline

Applications for bids were closed at 11:00 a.m. on Nov 27, 2023; three firms submitted bids.

④ Evaluation and determination of successful bidder

The application documents were reviewed on Nov 27, 2023 at 11:00 p.m. in the office of the Director of DoST Maintenance Division. Witnesses were the JICA Bhutan Office representative, the Director of the DoST Maintenance Division, the C/P, and the JET.

Bid documents were evaluated by DoST Maintenance Division staff, GovTech staff, and JETs on Nov 28, 2023 and Nov 29, 2023. After a comprehensive evaluation of technical and price points, NGN TECHNOLOGIES PRIVATE LIMITED was selected as the successful bidder on Nov 31, 2023.

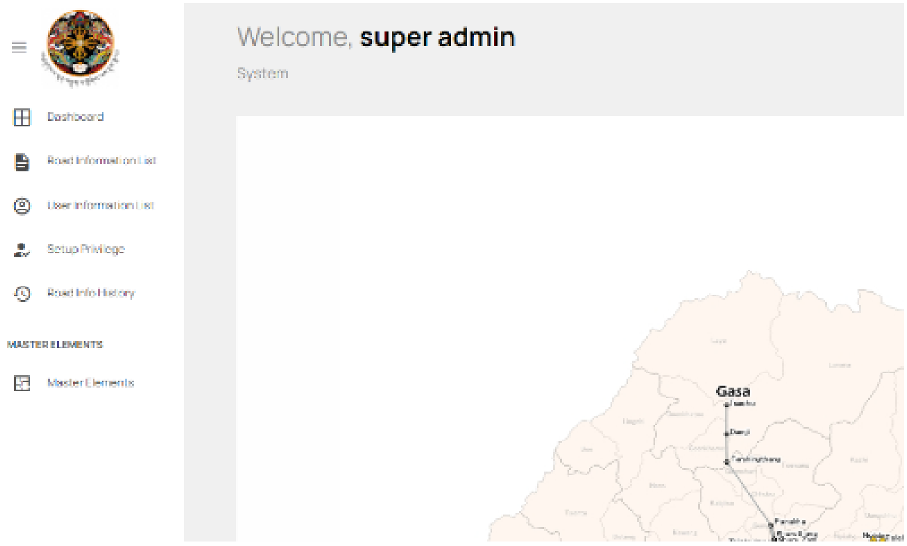
⑤ Contract negotiation

Contract negotiations and confirmation of specifications for application development were conducted with the successful bidder, NGN TECHNOLOGIES PRIVATE LIMITED, from December.

5. System configuration (completed system version)

1) Main Menu

The main menu is available in the PCWeb version and consists of "Road Information list", "User Information list", "Setup Privileges", "Road Information History", and "Master Element". The main menu consists of "Road Information list," "User Information list," "Setup Privileges," "Road Information History" and "Master Element.

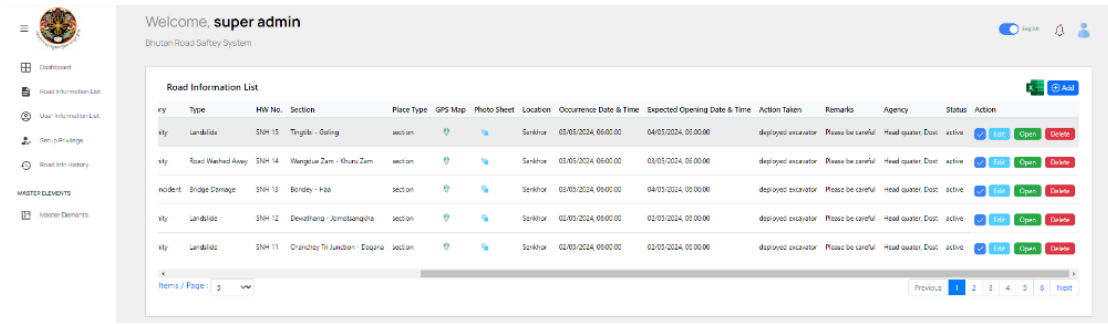


(Source: JET)

Figure. 3.7-26 BRS Main Menu (from PC Web version)

Road Information list

This function displays a list of road information that is currently available. If the system user is a regional office, only road information under the jurisdiction of the regional office is displayed in the system. The user can operate from this screen to add new road information, delete new road information, or Open information from this function page. When the road information in the field is opened, the system manually performs the opening and moves to the "Road Information History" function.

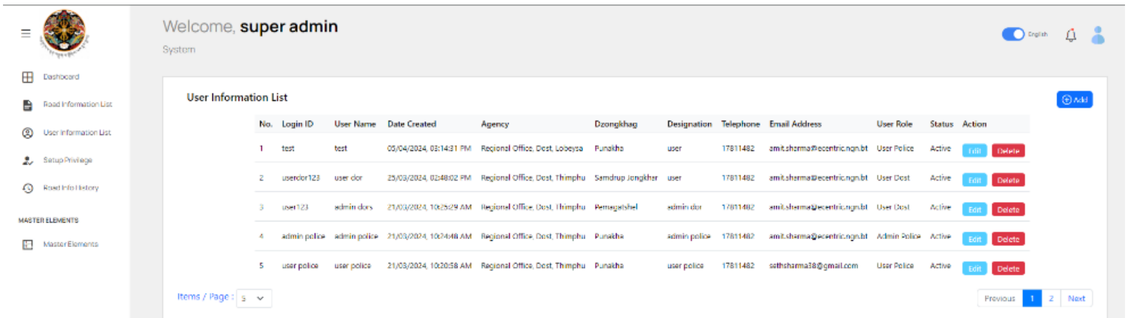


(Source: JET)

Figure. 3.7-27 BRS Road Information List Interface (from PCWeb version)

2) User Information list (User Information list)

A list of DoST staff users to access and operate the BRS, setting the usage level (User Role) to grant access privileges according to the DoST's jurisdiction.

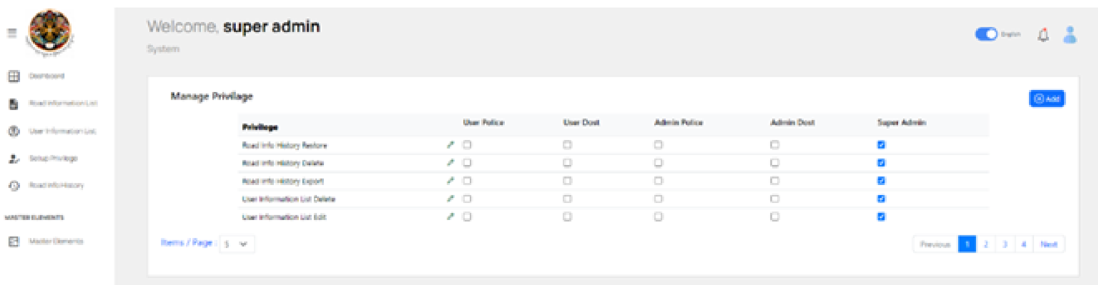


(Source: JET)

Figure. 3.7-28 BRS User Information List Interface (from PCWeb version)

3) Access authority setting function

This function sets access privileges in the system according to the user level set in the User Information list. Access privileges can be set for all functions in the system according to the user level (User Role).

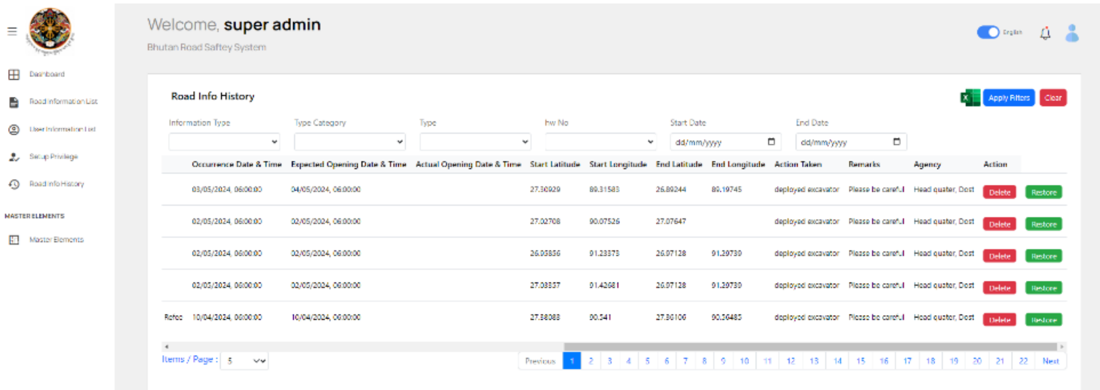


(Source: JET)

Figure. 3.7-29 BRS access authority setting function interface (from PCWeb version)

4) Road Information History function

This is a function to accumulate road information released in the Road Information list as a historical record. It is a function for DoST maintenance division staff to manage and analyze statistical data in the future, and is equipped with a filtering function for each road closure type and disaster type. The data can also be exported to Excel data, which can be used to prepare reports or as raw data to be input into GIS.



(Source: JET)

Figure. 3.7-30 BRS Road Information History Function Interface (from PCWeb version)

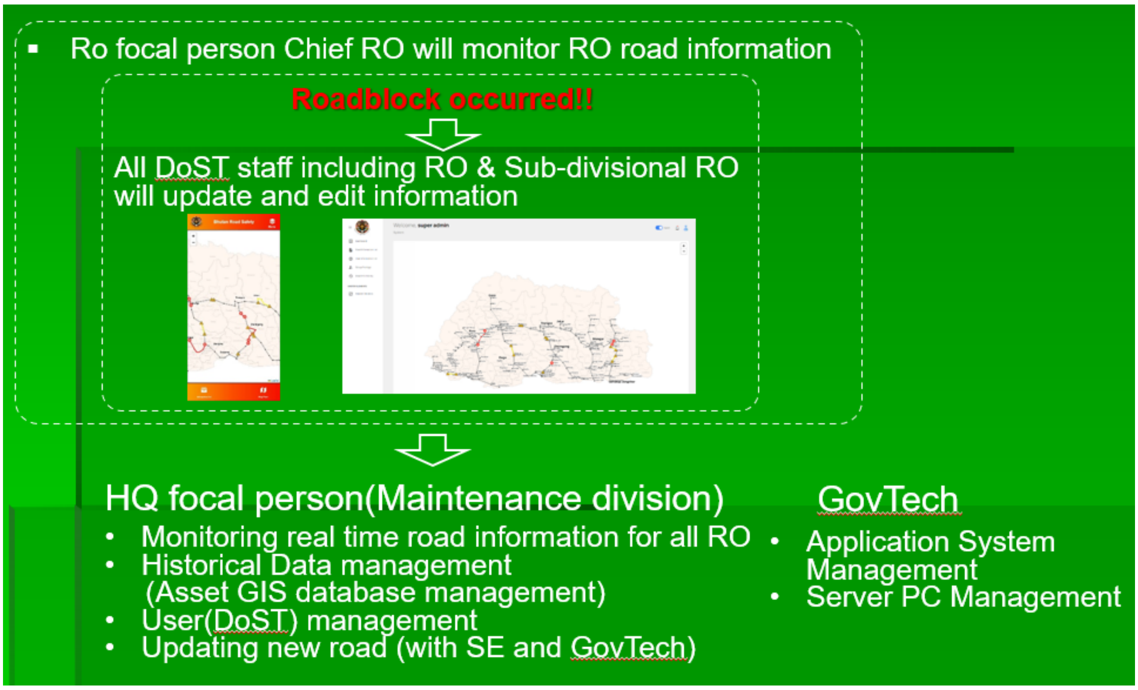
5) Various setting functions (Master Element)

This function is used to define the information to be formulated and input. The main formulas are road type, road number, regional office name, prefecture, road closure type, and disaster type. This function can only be operated by DoST Headquarters Maintenance Division staff.

6) Conduct technology transfer seminars

Since the BRS application is used by all DoST staff, including those at the regional offices, a technology transfer seminar was held for all regional offices. The instruction was conducted on the premise that the application would be operated by the staff of the regional office and the sub-regional offices below it. In addition, the regional office with jurisdiction over the area is responsible for managing the road information that is currently displayed, and guidance was provided to ensure that the chief engineer or person in charge at the regional office is required to monitor the information.

The following is a conceptual diagram of the division of responsibilities in operating the BRS.



(Source: JET)

Figure. 3.7-31 BRS Operational Responsibility Assignment Summary Chart

The main contents of this technology transfer seminar are as follows

(1) Acquisition of BRS operation method

Seminar participants performed actual data entry tasks, with the objective of ensuring that all regional office staff members obtained operating procedures. All participants checked to see if the data was entered correctly, and if there were any input errors, they checked and corrected them on the spot, with the goal of acquiring the skills needed to enter data reliably.

(2) Data administrator settings

One Focal person (Focal person) was assigned to each regional office to manage road information in an overall manner. In accordance with the division of operational responsibility, it was confirmed that the regional offices would be responsible for managing road information under their jurisdiction.

(3) Final confirmation of BRS map

The names and locations of towns included in the map function of the BRS were prepared based on the integrated GIS database (Asset Management GIS databese) established at the DoST headquarters, but since the BRS is intended to be used by residents living in each region, even small errors are However, since the BRS is intended to be used by local user, even a small mistake can be sent out as incorrect information, and the BRS does not function. Through this seminar, JET confirmed that the information on the areas under the jurisdiction of each regional office was set up correctly, and corrected the BRS in the wrong town point and fed back into the integrated GIS database.

Activity 6-6: Develop a manual on the road information system utilizing the GIS database.

The project developed a Raod Asset Management GIS database and a manual on BRS.

1. Manual for Road Asset Management GIS database

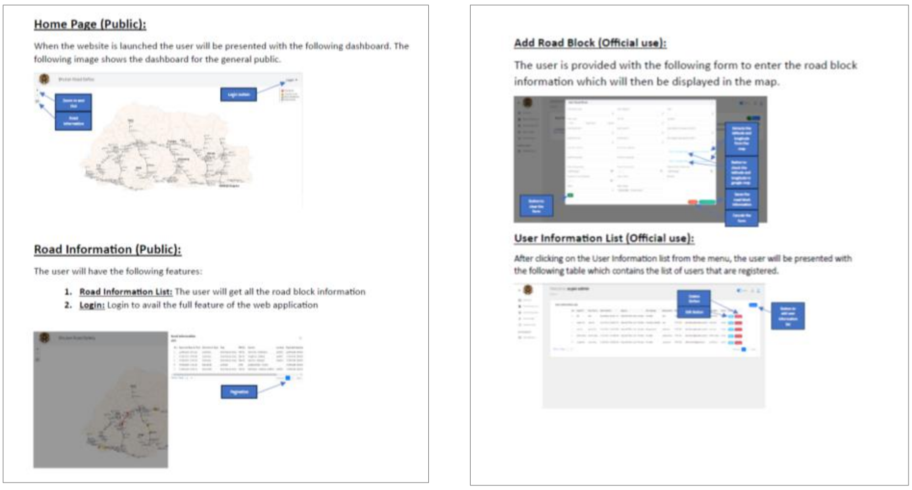
This manual is a manual for the GIS database established in Activity 6-2, but it is not limited to the GIS database only; it also describes the data collection methods necessary for creating the GIS database. In Activity 6-3, tablets and drive recorders were provided for on-site data collection, and instructions were given on how to organize road alignments and road structures into RAMS and how to import them into the GIS database. This manual covers the completion of the series of tasks.

2. Manual of Bhutan Road Safety

A manual on the BRS developed in Activity 6-5 was prepared. It consists of three types of content as follows.

(1) BRS Operation Manual

The content is intended for DoST staff to operate the BRS, from their role of entering data according to their DoST authority to the DoST Headquarters Maintenance Division staff who manage all BRS users.

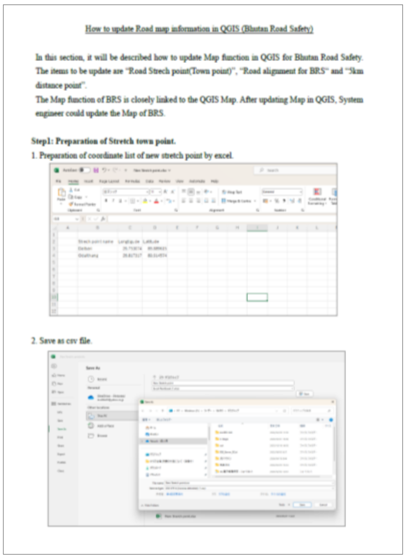


(Source: JET)

Figure. 3.7-32 DoST Staff Operating Manual (excerpts)

(2) Manual for updating BRS map function

The map function of the BRS is based on the Road Asset GIS database, and the map function of the BRS is developed in QGIS using the Road Asset GIS database as the base data, While updating the map display in BRS is done by an engineer specialized in system operation, updating the map function in QGIS needs to be done by DoST staff. This manual is designed for DoST to update the map functionality.



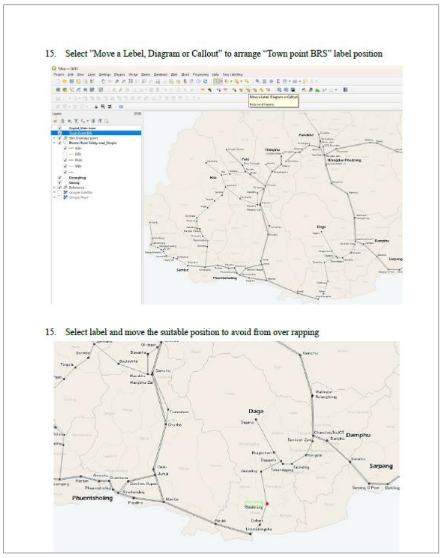
How to update Road map information in QGIS (Bhutan Road Safety)

In this section, it will be described how to update Map function in QGIS for Bhutan Road Safety. The items to be update are "Road Strech point(Town point)", "Road alignment for BRS" and "5km distance point".
The Map function of BRS is closely linked to the QGIS Map. After updating Map in QGIS, System engineer could update the Map of BRS.

Step1: Preparation of Stretch town point.

1. Preparation of coordinate list of new stretch point by excel.

2. Save as csv file.



15. Select "Move a Lebel, Diagram or Callout" to arrange "Town point BRS" label position

15. Select label and move the suitable position to avoid from over rapping

(Source: JET)

Figure. 3.7-33 DoST Staff Operating Manual (excerpts)

(3) Manual for updating the BRS system

The BRS system and server PCs are managed by GovTech, and modifications and updates to the system itself are carried out by GovTech's expert system engineers. The system is developed by NGN Technologies (NGN), a private company in Bhutan, as a sub-contracted project, and NGN prepares a Technical Document describing the system configuration, etc. and submit it to GovTech. After approval by GovTech, the document was submitted to the project team and GovTech.

3.8 Other activities: training in Japan, seminars, publicity activities

（1）Training in Japan

The purpose of this training program in Japan was to help trainees understand and master Japan's road management system and disaster countermeasure technologies, and to provide practical feedback in the project after returning to their home countries. Lectures, on-site training, lectures on the management system of expressways and national highways, and tours of road control centers were conducted.

The first training in Japan took place from September 15 to September 28, 2019. Since the content of the training was related to Outputs 1, 5, and 6, the total number of participants was 12, including DoST Director Tenzin, DoST Maintenance Division Chief Dorji Gyeltshen P, and 10 WG members in charge of Outputs 1, 5, and 6.

Table 3.8-1 Participants in the 1st training in Japan (conducted in September 2020)

No.	名前	所属
1	Mr. Tenzin	MoIT, DoST, DG
2	Mr. Dorji Gyeltshen P	MoIT, DoST, Maintenance Division, CE
3	Mr. Yeshey Penjor	MoIT, DoST, Maintenance Division
4	Mr. Tashi Tenzin	MoIT, DoST, Maintenance Division
5	Mr. Dhan Raj Chhetri	MoIT, DoST, Maintenance Division
6	Ms. Phuntsho Wangmo	MoIT, DoST, Maintenance Division
7	Mr. Rinchen Gyeltshen	MoIT, DoST, Maintenance Division
8	Mr. Áshok Rai	MoIT, DoST, Maintenance Division
9	Mr. Thinley Dorji	MoIT, DoST, Maintenance Division
10	Mr. Barun Kumar Sanyasi	MoIT, DoST, Maintenance Division
11	Mr. Phuntsho	MoIT, DoST, Maintenance Division
12	Mr. Sonam Dorji	MoIT, DoST, Maintenance Division

(Source: JET)

In the first training, participants visited the Kanto Regional Development Bureau of the MLIT, the Road Control Center of the Chugoku Branch of West Nippon Expressway Company Limited, and the Tokai-Hokuriku Expressway, where road slope monitoring is being conducted, in order to learn about road information acquisition, system management, and advance traffic control based on road information. The team also made a tour of the Tokai-Hokuriku Expressway, where road slope monitoring has been conducted. In addition, as a content related to Output 5, the participants inspected the Sanyo Expressway, which suffered damage from debris flows caused by the July 2018 torrential rains, to learn about on-site response to debris flow disasters. The participants also learned about slope disaster prevention technology in Japan through lectures at Gifu University and the Public Works Research Institute. The itinerary of the first training course in Japan is shown below.

Table 3.8-2 Schedule of the 1st Training Course in Japan

Day	Date	Training Destination	Method	Training Contents
1	9/15 (Sun.)			(Trainees visiting Japan)
2	9/16 (Mon.)			
3	9/17 (Tue.)	・ JICA Tokyo Center ・ JICA Headquarters		・ Briefing and program orientation ・ Courtesy visit to JICA Headquarters
4	9/18 (Wed.)	・ Kanto Regional Development Bureau, MLIT	Lecture Inspection	・ Disaster Prevention and Slope Protection Technologies in Japan ・ Road control and monitoring room
5	9/19 (Thu.)	・ Faculty of Engineering, Gifu University ・ E-MAC Technical Training Center	Lecture Inspection	・ Monitoring and control works ・ Infrastructure Management Technology Research Center ・ E-MAC Technical Training Center ・ Gifu Maintenance and Service Center
6	9/20 (Fri.)	・ Tokai-Hokuriku Expressway	inspection	・ Slope monitoring and countermeasure site visits1,2,3
7	9/21 (Sat.)			
8	9/22 (Sun.)			
9	9/23 (Mon.)	・ Itsukushima Shrine ・ Hiroshima Peace Memorial Park	inspection	・ Understanding Japanese Culture
10	9/24(Tue.)	・ Head Office, WESCO Central Nippon ・ Road Control Center, WESCO ・ Sanyo Expressway	Lecture Inspection	・ Overview of the July 2018 Torrential Rain Disaster ・ Slope Inspection on Expressways ・ Rainfall traffic restrictions ・ Tour of the Road Control Center ・ Visits to disaster recovery sites1,2
11	9/25 (Wed.)	・ Hiroshima-Kure Road ・ Honkawa Elementary School Peace Museum	Inspection	・ Inspection of disaster recovery sites ・ Tour of the Museum
12	9/26 (Thu.)	・ Public Works Research Institute. ・ JICA Tokyo Center	Lecture	・ Landslide Hazards and Mitigation Measures in Japan ・ Road Slope Disaster Prevention Management in Japan ・ Creating an Action Plan
13	Friday, 9/27	・ JICA Tokyo Center		・ Creating an Action Plan ・ Action Plan Presentation ・ Evaluation meeting
14	9/28 (Sat.)			(Returning)

(Source: JET)

During the orientation session, the Japanese road management system was explained, followed by an explanation of the objectives, itinerary, and schedule of the training, which enabled trainees to better understand the purpose and objectives of this training program. During the courtesy visit to JICA, a lecture on road asset management in Japan was provided, which helped the trainees to recognize the importance of road maintenance and management once again.

The curriculum of this training program covered everything from basic knowledge of slope hazards by experts affiliated with universities and research institutes to on-site response, leading to a comprehensive understanding of the knowledge that trainees needed to implement slope disaster prevention in Bhutan.

Throughout the training, DoST staff often asked questions about Japan's road management system, the role of each related organization, and other issues such as construction costs of countermeasure works and material costs, etc. Through these question-and-answer sessions, meaningful discussions were held at each destination on feasible initiatives in Bhutan.

Courtesy visit to JICA Headquarters
(2020/9/17)

Tour of the Gifu University Infrastructure Museum
(Sep 19, 2019)

Visit to the Road Control Center, Chugoku Branch Office, West Nippon Expressway Company Limited
(2019/9/24)

By West Nippon Expressway Engineering Chugoku Co. Explanation of the site where the debris flow occurred
(9/25/2019)

(Source: JET)

Photo 3.8-1 The first training session in Japan

The 2nd Training in Japan was conducted from October 20, 2023 to November 3, 2023. Since the content of the training was mainly related to the construction of road slope control measures in Outputs 2, 3, and 4, the total number of participants in the 2nd Japan Training Course was 10 engineers involved in the investigation, design, construction, and maintenance of slope control measures in DoST.

Table 3.8-3 Participants in the 2nd training in Japan (conducted in October- November 2023)

No.	名前	所属
1	Mr. Gyeltshen Wangdi	MoIT, DoST Lobesa RO, PE
2	Mr. Nar Bdr Jogi	MoIT, DoST Trongsa RO, AE
3	Mr. Tshewang Dorji	MoIT, DoST HQ, Design Division,CE (Leader of this Training)
4	Mr. Kinzang Chophel	MoIT, DoST Trongsa RO, EE
5	Mr. Aita Tenzin Doya	MoIT, DoST Trongsa RO, AE
6	Ms. Naley	MoIT, DoST Trongsa RO, AE
7	Mr. Leki Drakpa	MoIT, DoST Trongsa RO Engineer
8	Mr. Sangay Ngedup	MoIT, DoST HQ Design Division, Engineer
9	Mr. Thinley Wangchuk	MoIT, DoSTHQ Maintenance Division, Engineer
10	Mr. Yeshi Wangchuk	MoIT, DoST Lobesa RO, AE

（Source：JET）

In the second training, participants visited national roads of the MLIT, prefectural and municipal roads in Yamaguchi, Gifu and Nara prefectures, and expressways of the Chugoku Branch of WESCO to learn about the construction of road slope protection works and road maintenance management. Several lectures and site inspections related to the construction of road slope control works and road slope monitoring were provided during the training. In addition, at the Chugoku Branch Office of WESCO, the participants visited the Road Control Center, where they attended a lecture on the latest road control system in Japan and observed realtime road control. In addition, through lectures by professors from Gifu University and Yamaguchi University, the participants learned about Japan's slope disaster prevention technology. The outline of the second training course in Japan is shown below.

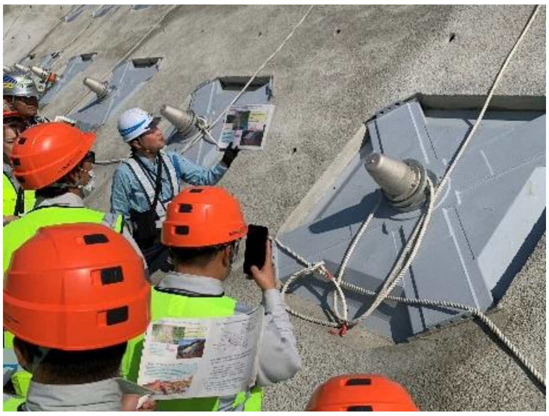
Table 3.8-4 Second Japanese Training Schedule

Day	Date	Training Destination	Method	Training Contents
1	10/20 (Fri.)	・ JICA Tsukuba Center		・ (Visiting Japan) Briefing, Program Orientation
2	10/21 (Sat.)	・		・
3	10/22 (Sun.)	・		・
4	10/23 (Mon.)	・ Shiraito River second erosion control dam	Inspection	・ Environmental friendly countermeasures against debris flows
5	10/24 (Tue.)	・ Hiroshima Peace Memorial Park ・ Head Office of WESCO ・ Road Control Center, Chugoku Branch Office, WESCO	Lecture and Inspection	・ Hiroshima Peace Study ・ Road Slope Stabilization Work ・ Road Control Center of NEXCO
6	10/25 (Wed.)	・ Sanyo Expressway Doo JCT	Inspection	・ Observation of slope disaster countermeasures construction site
7	10/26 (Thu.)	・ Tokiwa Consultant Co. ・ (Venue: Hotel COCOLAND)	Lecture and Inspection	・ Boring machines, tools, and survey equipment ・ Geology, core determination, etc.
8	10/27 (Fri.)	・ Ube City Road, Hikigawa-Oji Line Hagi Akiyoshi-route, a major prefectural road	Inspection	・ Slope disaster countermeasures construction site
9	10/28 (Sat.)	・		・
10	10/29 (Sun.)	・		・
11	10/30 (Mon.)	・ Gifu University Infrastructure Museum Omozan Tunnel Construction Site	Lecture and Inspection	・ Slope disaster countermeasures ・ Structures and construction methods of tunnels, bridges, and slope disaster countermeasures
12	10/31 (Tue.)	・ Tenshin shiragiku tour ・ Folding screen rock ・ Takayama Kiyomi Road Bogata Tunnel Construction Site	Inspection	・ Location of bus accident that led to the prior rainfall restrictions ・ Mitigation measures on a national highway

Day	Date	Training Destination	Method	Training Contents
				・ High-standard road construction and road slope disaster prevention measures
13	11/1 (Wed.)	・ Kokusai Kogyo Chubu Office		・ Review of the field trip and preparation of report materials
14	11/2 (Thu.)	・ JICA Tsukuba Center		・ Action Plan ・ Action Plan Presentation ・ Evaluation meeting
15	11/3 (Fri.)	・		・ (Returning)

In this training, the road management system in Japan was explained at the orientation ssession, followed by an explanation of the objectives, itinerary, and schedule, which helped the participants to understand the purpose and objectives of this training. The curriculum of the training covered everything from basic knowledge of slope disaster management by university and actual road management engineers to on-site response, leading to a comprehensive understanding of the knowledge required for future implementation of slope disaster prevention in Bhutan by the trainees. Throughout the training, DoST staff often asked technical questions about the construction cost, construction period, material cost, and other technical aspects of Japan's road countermeasure works, and through these question-and-answer sessions, meaningful discussions were held at each destination on feasible initiatives in Bhutan in the future.

On the other hand, some of the trainees commented that there were too many sites to visit and the time required to visit each site was too short, and that there were not enough sites related to Output 2: Vegetation Works, which JET would like to refer to when conducting similar training programs in Japan in the future.



Site visit on countermeasure works in Japan
（Oct 25, 2023）

Geological survey in Japan
（Oct 26, 2023）

Lectures on maintenance work at Gifu university
（Oct 30, 2023）

Final session at the training in Japan
(Nov 2, 2023）

(Source: JET)

Photo 3.8-2 Second Training in Japan Session

（2）Seminars and public relations activities

Technical transfer seminars

In the Project, technical transfer seminars were conducted in order to help C/P members to better understand project activities, and to strengthen cooperation with other organizations and public relations activities by incorporating relevant organizations such as the Bhutan National Police, RSTA, MoAF, and DGM as appropriate to the content of the seminars. From the start of the project to December 2023, a total of 29 seminars were held, including 26 seminars on Outputs 1~6 and 3 open seminars. The timing, participants, and agenda for each seminar are shown in following Table.

Table 3.8-5 Seminars Held

No.	Holding period		participant	Main Agenda	Output					
1	2019	February	DoST	Objective of the activity and overview of the survey methodology, selection of target streams for the survey					5	
2		February	DoST	Standard gradients and types of vegetation works, diagrammatic exercises, field practice		2				
3		April	DoST	Planning and design of drainage works and drainage facilities, and maintenance plans					5	
4		April	DoST, RSTA	Training on preliminary traffic control overview, monitoring plan, and equipment installation	1					
5		May	DoST, DGM	Summary of Activity Objectives and Survey Methodology			3			
6		May	DoST	Introduction of existing GISDB and GISDB construction implementation policy						6
7		October	DoST, MoAF	Selection method for vegetation work type, planning and design of the first test construction		2				
8		October	DoST, MoAF	Methods for selecting the type of rockfall prevention work, planning and design of the first construction				4		
9		October	DoST,	Drainage system, topography and geological situation information analysis, manual for countermeasures against debris flows					5	
10		Novembe r	DoST, DGM	Explanation of the Draft Manual of Rock Quality and Geological Classification, field exercises			3			
11		Decembe r	DoST	Basic training on how to obtain information from GISDB and view GISDB						6
12	2020	February	DoST, RSTA, CST, JNEC, WB, UNDP, BBS, Nor-Lha Construction, JICA	1st Open Seminar	whole					
13		February	DoST	How to obtain road information and create cross sections using GIS						6
14	2022	Septemb er	DoST	Soil and rock classification analysis, cut slope design			3			
15		Novembe r	DoST	Drone flight training and acquisition data analysis exercises						6
16		Decembe r	DoST	Planning and investigation of rockfall prevention				4		
17	2023	January	DoST	Types of Construction and Construction Notes		2				
18		February	DoST	Technical training for installation of hinges			3			
19		February	DoST	Investigation, planning, and design of countermeasure works against debris flows (subject to Western RO)					5	
20		April	DoST	Basic knowledge of geotechnical investigation, design, and construction management for cut slope construction			3			
21		April	DoST, RSTA, CST, JNEC, JICA	2nd Open Seminar	whole					
22		May	DoST	Investigation, planning, and design of countermeasure works against debris flows (subject to Eastern RO)					5	
23		May	DoST	Establishment of rainfall thresholds / advance traffic control methods / drill implementation procedures	1					
24		Sep. and Dec.	DoST	Description of Standard Cut Slope Design Guidelines			3			
25	2024	April	DoST	Output 3: Additional technical training for geological survey			3			
26		April	DoST	3rd Fundamentals of Construction Methods in Vegetation Works		2				
27		April	DoST	Conducting mock drills related to advance traffic control	1					
28		May	DoST、RSTA、CST、JNEC、WB、UNDP、BBS、Contructors、JICA	3rd Open Seminar	whole					
29		Jun	DoST	Operation Seminar for BRS System						6

(Source: JET)

The results of the seminars and open seminars for each Output are as follows

Output 1:

The first seminar was held at the timing of the installation of the slope monitoring equipment, and lectures were given on the outline of advance traffic control and the monitoring plan. In addition, onsite training was conducted at the site where the monitoring equipment was installed in order to explain how the equipment works and how to install it. C/Ps could understand the details of the activities and the function of installed equipment. Themes related to setting rainfall thresholds and ex-ante traffic control were explained in the second seminar, and as the third seminar, a hands-on training for advance traffic control was conducted in April 2024.

Output 2:

In order fro C/Ps to understand the activities in each phase of Output 2, the first seminar was held at the time of the selection of the pilot site. The second seminar was held at the time of preparing the bidding documents for the first pilot activity. The second seminar was attended by MoAF, which had knowledge of vegetation in Bhutan, and discussions were held among the participants including JET, DoST, and MoAF. In the fourth seminar, an overview of the vegetation work conducted in the Gopini area was explained through the indoor lecture and onsite training.

Output 3:

In the first seminar, the activities of Output 3 were explained and C/Ps were able to understand the activities and acquire the necessary basic knowledge. In the second seminar, the use of geological survey equipment was explained to the seminar participants. In the third seminar, the geological analysis and cut slope design at the construction site were explained in detail, with specific examples, in accordance with the Manual and the Bhutan Standard Cut Slope Revision Plan developed in the project.

Output 4:

The first seminar provided an overview of the investigation, planning, and design conducted for the first test construction, as well as a detailed explanation of the countermeasure construction techniques. In the second seminar, the planning and investigation of rockfall countermeasures were explained and the analysis techniques were transferred.

Output 5:

In order to ensure that C/Ps understand the contents of the activities in each phase of Output 5, three seminars were held in accordance with the progress of the activities: the first seminar was held at the time of the selection of the pilot construction site, the second seminar was held in conjunction with the topographical and geological survey to calculate the volume of runoff sediment, and the third seminar was held during the preparation of bidding documents for the pilot project. In conjunction with the construction of the second pilot site, study sessions (3 days each) on investigation, planning, and design of debris flow countermeasure works were held for the western 5 ROs and eastern 4 ROs in February and May 2023, respectively, to simulate specific fields, from field investigations to the assumption of debris flow scale and schematic design of culverts. The study sessions were conducted in a simulated field.

Output 6:

A total of three seminars focusing on GIS operation methods and one training course on aerial photogrammetry by drone were conducted. In addition, training has been conducted on road alignment acquisition using GPS and drive recorders, aerial photo surveying by drone, and methods for analyzing the data. In the drone photo training, DoST staff were able to experience on how to operate a drone for surveying and how to analyze the acquired data.

Output 1: First seminar Explanation of how to install monitoring equipment at construction site (4/17/2019)

Output 1: 2nd seminar Exercise of rainfall traffic pre-regulation (2023/6/6)

Output 2: 1st Seminar Explanation of the Basics of Vegetation Construction (2019/2/20)

Output 3: 2nd seminar by DoST staff Clinometer handling training (11/18/2019)

Output 3: Technical training on SRT (2023/2/14)

Output 3: The 5th Technical Seminar (2023/2/14)

Outputs 4 1st Seminar Explanation of detailed design of test construction (10/18/2019)

Output 5 1st Seminar: Practical training on stereo vision of aerial photographs (2/19/2019)

Output 5: Study group on earth and rock flow control works for western ROs.
(2/2/2023)

Output 5: Study session on countermeasure works against debris flows for the Eastern RO
(4/25/2023)

Output 6 First Seminar Demonstration of UAV Aerial Surveying (5/17/2019)

Output 6: Horizontal development of drone utilization
(2023/3/16)

(Source: JET)

Photo 3.8-3 Seminars on each Output

Open Seminar

The purpose of the Open Seminar is to make the project widely known in Bhutan and to promote close collaboration between JICA, DoST and other donors, universities, etc. The first Open Seminar was held in February 2020. The 2nd Open Seminar was held in April 2023. The 3rd Open Seminar was held in May 2024.

The 1st Open Seminar, presented by CST Sangey Pasang (2020/2/5)

Commemorative photo after the 1st Open Seminar (2020/2/5)

Opening remarks for 2nd Open Seminar by Director General Tenzin (2023/4/21)

Commemorative photo after the 2nd Open Seminar (4/21/2023)

Opening remarks for 3nd Open Seminar by Dasho Secretary Phuntsho Tobgay (May 28, 2024)

Commemorative photo in the 3nd Open Seminar (May 28, 2024)

(Source: JET)

Photo 3.8-4 Open Seminar

Public relations activities

The following public relations activities were conducted through the Project in order to ensure that the importance of the Project, activities, and Outputs are properly understood widely in Bhutan as well as in Japan.

i. Open seminars

The first open seminar was held on February 5, 2020, the second on April 21, 2023, and the third on May 28, 2024, with the participation of other donors such as WB and UNDP, and lecturers from CST and JNEC. Information was shared and opinions were exchanged.

ii. Information dissemination through the media

The first open seminar was reported for about 4 minutes in the news program of Bhutan Broadcasting Service (BBS) on February 8, 2020. The second training in Japan on October 31, 2023 was reported in the Chuken Nippo newspaper (a construction trade newspaper in the Chugoku region). A video of the mock drill was made available on Youtube with the aim of publicizing the activities related to ex-ante traffic control in Bhutan.

iii. Newsletter

The first issue of the newsletter, summarizing the project and its progress, was published on February 4, 2020. The second issue was published in conjunction with the 2nd Open Seminar in April 2023, the third issue in conjunction with Japan Week in Bhutan in October 2023, and the fourth issue in conjunction with the 3rd Open Seminar in May 2024.

iv. Dissemination of information through conferences, forums, journals, etc.

The following is a list of presentations made at conferences, forums, and in academic journals.

Table 3.8-6 Presentations at Conferences and Forums

No	name	date of issue	originator	Main contents
1	Environmental Council, 2019 (journal)	2019/9/5	Iwasaki	Introduction of this project
2	Social Infrastructure Tech 2019 (Conference)	2019/12/4	Iwasaki	Exhibit of posters introducing Output 1 Advance Traffic Control Technology
3	Journal of the Japan Society of Civil Engineers	2020/6/1	Iwasaki	Implementation of Japanese Technology in the Technical Assistance Project for Road Slope Disaster Prevention in Bhutan, Journal of Japan Society of Civil Engineers, June 2020, pp24-25
4	Understanding Risk Forum 2020 (academic conference)	2020/12/3	Hasegawa Iwasaki, Kuwano	Output 1Slope monitoring technology presented in a joint session with WB
5	CREST2020	2021/3/11	wide field	Presentation on the characteristics of the Bhutan National Highway 1 slope disaster
6	Fifth World Forum on Slope Disaster Mitigation	Nov. 4, 2021	Tempa Thinley	Description of road slope disaster in Bhutan and introduction of this project
7	Fifth World Forum on Slope Disaster Mitigation	Nov. 4, 2021	Hara	Introduction of rock slope remediation work performed under Output 4 of this project.
8	Landslide Society of Japan 2022	9/28/2022	Hirota, Nishimura, Sugihara, Iwasaki	Introduction to Bhutan's Slope Measures
9	2022 ICL-KLC Joint Conference	11/25/2022	Hirota	Presentation on remote vegetation engineering guidance
10	Erosion Control Society of Japan 2023 meeting for reading research papers	5/10/2023	Nishimura	Supervision of construction of earth and rock flow control facilities using 3D models
11	Landslide Society 2023	2023/9/20	Hirota	Introduction of Slope Disaster Prevention in Bhutan
12	Japan Week in Bhutan	10/30/2023	PJ	PJ Letter displayed at "Japan Week" in Bhutan
13	Zhongjian Nippo Newspaper Article	10/31/2023	PJ	Second Japanese training session was reported in a local newspaper.
14	CREST2023	11/22/2023	Nishimura	Introduction of a case study on countermeasure works against debris flow in Bhutan
15	5th Geotech-Hanoi	12/14-15 December 2023	PJ	Poster exhibition at the international conference held in Hanoi, Vietnam

(Source: JET)

v. Information dissemination via the Web, SNS, etc.

The table below shows the results of information dissemination on the Project via the Web, SNS, etc.

Table 3.8-7 Information Dissemination via Web and SNS

No	Medium	Date	Contents	URL
1	DoST HP	2/1/2019	Project Introduction	https://www.MoIT.gov.bt/en/capacity-development-on-countermeasures-of-slope-disaster-on-roads-in-bhutan/
2	JICA Bhutan Office Facebook	2019/9/13	The 1st meeting before the training trip to Japan	https://www.facebook.com/JICABhutan/posts/2254199754678496
3	JICA Tokyo Center Facebook	2019/9/18	Start of the first training program in Japan	https://www.facebook.com/jicatokyo/posts/2654171014602705
4	JICA Bhutan Office	10/22/2019	Detailed design of countermeasures 2, 4,	https://www.facebook.com/JICABhutan/posts/2328071900624614

	Facebook		and 5	
5	JICA Bhutan Office Facebook	2020/2/5	Holding of the 3rd JCC	https://www.facebook.com/JICABhutan/posts/2545517478880054
6	DoST Facebook	2020/2/5	Holding of the 3rd JCC	https://www.facebook.com/DoSTinfom/posts/3179916952234365
7	BBS HP	2020/2/8	First Open Seminar	http://www.bbs.bt/news/?p=128036&fbclid=IwAR2n0D0UKtNZt6grSx2fDSkk2VbO_h820rPQ7CiBEhyE5s7EchE24syjs5s
8	JICA Bhutan Office Facebook	2020/2/8	First Open Seminar	https://www.facebook.com/JICABhutan/posts/2555548574543611
9	JICA Bhutan Office Facebook	2020/7/13	Output 2: Completion of vegetation work	https://www.facebook.com/JICABhutan/posts/2907234172708381
10	DoST Facebook	2020/7/13	Output 2: Completion of vegetation work	https://www.facebook.com/DoSTinfom/posts/3343861042506621
11	JICA HP	2020/10/21	Project Introduction	https://www.jica.go.jp/oda/project/1802020/index.html?fbclid=IwAR3adheKWipGoXvLLDcbQjf5HeVG7qUjdhtywhBgvSavfANksiehjzUUdqY
12	JICA HP	2020/10/22	Output 1Introduction of Road Slope Monitoring Technology	https://www.jica.go.jp/activities/issues/transport/ramp/technical-cooperation.html
13	MoIT HP	5/18/2022	Holding of the 5th JCC	https://www.MoIT.gov.bt/en/5th-joint-coordination-committee-meeting/
14	DoST Facebook	5/18/2022	Holding of the 5th JCC	https://www.facebook.com/DoSTinfom/posts/310501174590347
15	KUENSEL HP	Nov. 1, 2022	Handover of drone equipment	https://kuenselonline.com/drones-to-be-used-for-surveying-slope-disaster/
16	MoIT HP	Nov. 2, 2022	The 6th JCC	https://www.MoIT.gov.bt/en/capacity-development-on-countermeasures-of-slope-disaster-on-roads-in-bhutan/
17	DoST Facebook	Nov. 2, 2022	The 6th JCC	https://www.facebook.com/DoSTinfom/posts/pfbid0BnWEccjd7yqqkJBnGfH4hCL7UPi4VxK7iWFGmyzfPfLwWSxNFMciVF5cbyuUyFxKl
18	BTTV (mobile app)	11/6/2022	Output 6: Hosting of drone training	Video in BBS Mobile App
19	BBS HP	11/7/2022	Output 6: Hosting of drone training	http://www.bbs.bt/news/?p=177036
20	JICA HP	11/9/2022	6th JCC held and handover of drone equipment	https://www.jica.go.jp/bhutan/office/information/20221109.html
21	Kuensel Online	Apr. 27, 2023	Holding of the 7th JCC	https://kuenselonline.com/japanese-expertise-to-help-reduce-slope-disasters-on-bhutanese-roads/?fbclid=IwAR2C2Ov1kB_-WYJzekbsHY0_jSZFRgGEgn80NUJeX3-BFTUxKKFXi822rbyQ
22	DoST Facebook	2023/05/10	Output 2: Site Introduction of Vegetation Works	https://www.facebook.com/rotrongsaDoR/posts/pfbid02aT3fPeestvgPZUi6umLhhUr2YgAvurH7Xt4ForWTUwP8itMP63xXcxwT9ZNGuSVKl
23	DoST Facebook	Jun 19, 2023	Output 1: Introduction of advance traffic control training	https://m.facebook.com/DoSTMoIT/posts/pcb.555334680105696/?photo_id=555333546772476&mds=%2Fphotos%2Fviewer%2F%3Fphotoset_token_%3Dpcb.555334680105696%26photo%3D555333546772476%26profileid%3D100053910961079%26eav%3DAfa2hO6l4l9rEdnxhT2XWcFeCrOzgyL4osX8h1eCO9G_3gKgyVYJLT8MRTCHII6hQXPk%26paipv%3D0%26source%3D48%26refid%3D52%26__tn__%3DEH-R%26cached_data%3Dtrue%26ftid%3D&mdp=1&mdf=1
24	DoST Facebook	Nov. 28, 2023	The 8th JCC	https://m.facebook.com/story.php?story_fbid=pfbid062CT4uTbF4RL7oUcnNfYXxpRrP3zUrNg1fm3CZzXaYnG5UPagcCSYWyFCPi9Fqhel&id=_100068914012059&mibextid=WC7FNe

25	DoST Facebook	5/1/2024	Output 1 Report on advance traffic control training (classroom and on-site implementation)	https://www.facebook.com/share/p/H11RveS3wZgT5og1/?mibextid=WC7FNe
26	Bhutan Broadcasting Service Facebook Official HP	5/1/2024	Output 1 Report on advance traffic control training (classroom and on-site implementation)	https://www.facebook.com/share/dpQ2Csy9rSvtmSCR/?mibextid=WC7FNe https://www.bbs.bt/news/?p=203024&fbclid=IwZXh0bgNhZW0CMTAAAR004kZb28jccgbmT6BoVUxg46c6hQBmiZbneb7k2yNwVdjQnkxefUpqNuo_aem__AaForkQXCZCQiYk15of0jLC0Yum2iRykp750B_R-qlu7z4sG1IuiGWkoX4HGDmCn-hqBkr-eZBtS0SgtPWHzAq-c
27	JET Youtube	2024/5/8	Educational materials to learn about advance traffic control training initiatives	https://www.youtube.com/watch?v=fCQ07ZIZSB4
28	Bhutan Broadcasting Service Facebook Official HP	2024/5/28	Third Open Seminar	https://www.bbs.bt/news/?p=204256&fbclid=IwZXh0bgNhZW0CMTEAAR1SD-N8gPFCZT07dAF_Ax7JG9RUtLZ-iebTJ1sFG0hQsDPO8DMZfsbdrOU_aem_ARUnN0ob89kGia1iG_84C7krsOZCk2jDuBz6CfRHvjBPMMTckxDMJrEQjLTnaKZyqJoTdwQhnSJYOv8rYOLI7NkG
29	Kuensel Online	2024/5/28	Third Open Seminar	https://kuenselonline.com/moit-to-start-website-and-app-for-real-time-roadblock-alerts/?fbclid=IwZXh0bgNhZW0CMTAAAR2ewZdb9K1msI5rgQOKY_IrSrtJT6HHNDxuqRa6WfSA_KjLneXWW3oHI-4_aem_AbUlCWM8q7T06QXM-_ccXqiHw-JyNf_VZ9zJviDU6orEYhEtiARjzeiNZwBY4SwiXz5e3Vcdj3s8Po1dG8IDYxML

(Source: JET)

3.9 Issues, Devicing, Lessons Learned, and Recommendations for project implementation

While issues have been identified and improved from time to time throughout the activities of this project, fundamental issues have also been highlighted. The following is a summary of the contents and recommendations that JET has devised with the C/Ps to improve these issues, in relation to the respective activities.

1) General

(1) Effects of COVID-19

Isuue: This project was initiated in December 2018 and completed in July 2024. During this period, the project was significantly affected by the global outbreak of COVID-19, which forced a travel interruption of over two years in the middle of the project (March 2020 to April 2022). For Outputs 2, 4, and 5, training opportunities for learning through the supervision of these construction activities and site visits during construction were severely compromised, as they were just after the start of the first pilot construction activities, respectively, at the beginning of the year 2020.

Devicing: On the other hand, since many meetings were held virtually due to COVID-19, and all C/Ps, young and old, were able to conduct web meetings without any resistance, JET made great use of this. The project decided to hold weekly construction supervision meetings via the Web prior to the emergency return to Japan in March 2020, and to continuously discuss and provide guidance on the status of the site and future work policies for each output. The local supervisor, who was stationed at the site as a construction supervisor, acted as an intermediary and played a major role in understanding the site situation and providing guidance.

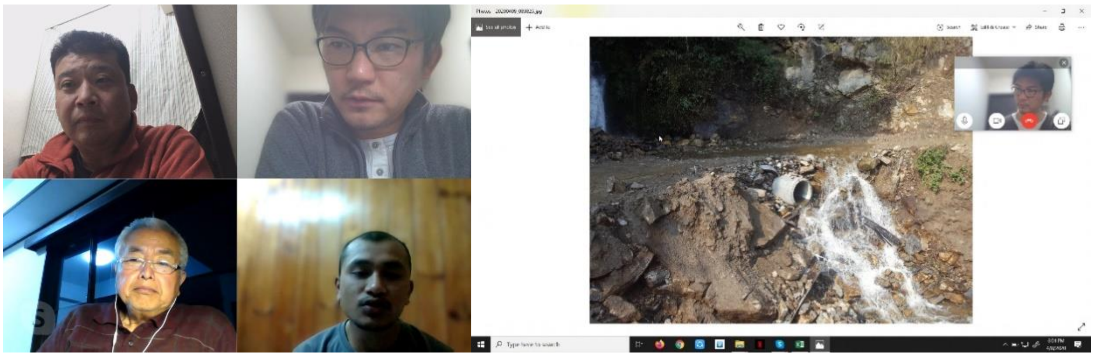


Figure. 3.9-1 Example of checking construction progress and site status via web meeting

Lessons learned and recommendations: The COVID-19 outbreak and the resulting travel restrictions were completely unforeseen at the outset of the project. Since the main purpose of technical cooperation projects is to develop human resources, restrictions on human contact and seminars were a major hindrance to the project's operations. However, by boldly adopting new technologies, such as web meetings, the project was able to continue without stopping.

JET believes that it is important to always seek the best possible method at the time of an unexpected situation, and to try it out while making improvements.

(2) Information sharing using Ggroup Chat

Isuue: During the construction period, the C/P of the regional office (RO) managing the construction site could easily obtain the latest site information and could visit the site frequently in the course of their duties. On the other hand, C/Ps from HQ and other ROs, their supervisors, and JICA experts had difficulty in being stationed in the site, making it difficult for them to monitor the site situation and work progress. This also led to a gradual decline in interest in the project and a loss of a sense of ownership.

Devicing: In addition to the morning meeting and weekly meetings, a group chat was formed with all construction-related personnel, including C/Ps, JICA experts, local supervisors, and contractors, to frequently exchange information on the status of the day's work, issues, and measures to address them. These exchanges were not limited to confirming and sharing the details of the day's work, but also provided valuable information as a record of the progress of the construction.

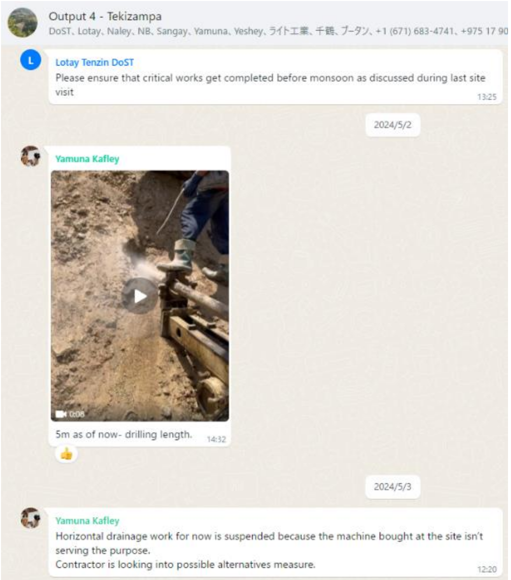


Figure3.9-2 Examples of group chat exchanges

Lessons learned and recommendations: However, by exchanging opinions on work progress, issues, and measures to deal with them in real time among many members and sharing the status, all parties involved were able to engage in the project with a sense of ownership. In addition, by looking back on the chat exchanges, it is possible to relive what kind of work was being done and when, and it is also effective as a record of the work.

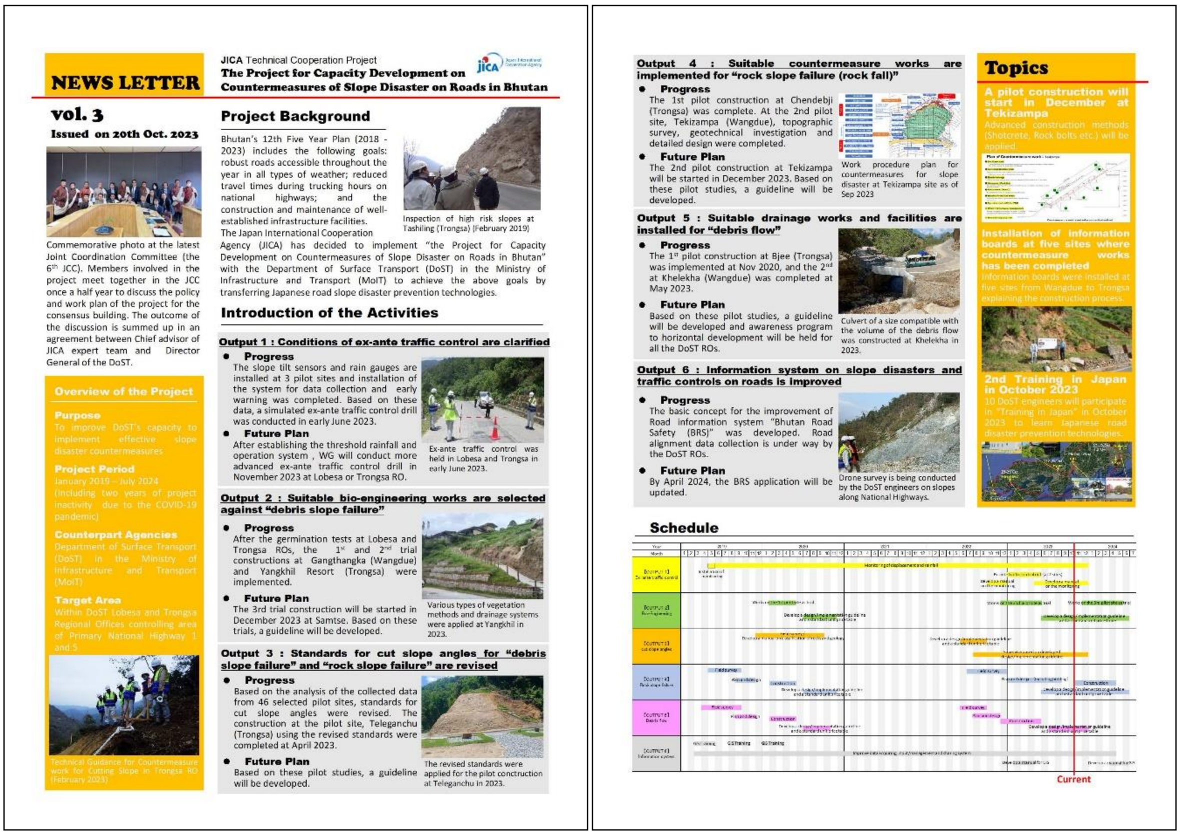
It is believed that SNS continues to be an effective tool for recording the actions and thoughts of those involved, along with photos, video, audio, and other realistic materials.

(3) Information dissemination through newsletters

Issue: Opportunities to communicate project activities to the outside were limited, such as when open seminars were held.

Devicing: The newsletter was distributed at open seminars and during publicity activities at the JICA Bhutan office. The newsletter were issued four times, and some of them were also posted on DoST's Facebook page.

Lessons learned and recommendations: It is important to actively utilize the newsletter as a publicity tool for the project by producing it on a regular basis and distributing it to relevant parties at every opportunity, as well as posting it on JICA's local offices and C/P websites to deepen understanding of the project and JICA's activities.



NEWS LETTER

JICA Technical Cooperation Project
The Project for Capacity Development on Countermeasures of Slope Disaster on Roads in Bhutan

vol. 3
Issued on 20th Oct. 2023

Commemorative photo at the latest Joint Coordination Committee (the 6th JCC). Members involved in the project meet together in the JCC once a half year to discuss the policy and work plan of the project for the consensus building. The outcome of the discussion is summed up in an agreement between Chief advisor of JICA expert team and Director General of the DoST.

Overview of the Project

Purpose
To improve DoST's capacity to implement effective slope disaster countermeasures

Project Period
January 2019 – July 2024 (including two years of project inactivity due to the COVID-19 pandemic)

Counterpart Agencies
Department of Surface Transport (DoST) in the Ministry of Infrastructure and Transport (MoIT)

Target Area
Within DoST Lobesa and Trongsa Regional Offices controlling area of Primary National Highway 1 and 5

Technical Guidance for Countermeasure work for Cutting Slope in Trongsa RO (February 2023)

Project Background

Bhutan's 12th Five Year Plan (2018 - 2023) includes the following goals: robust roads accessible throughout the year in all types of weather; reduced travel times during trucking hours on national highways; and the construction and maintenance of well-established infrastructure facilities.
The Japan International Cooperation Agency (JICA) has decided to implement "the Project for Capacity Development on Countermeasures of Slope Disaster on Roads in Bhutan" with the Department of Surface Transport (DoST) in the Ministry of Infrastructure and Transport (MoIT) to achieve the above goals by transferring Japanese road slope disaster prevention technologies.

Inspection of high risk slopes at Tashiling (Trongsa) (February 2019)

Introduction of the Activities

Output 1 : Conditions of ex-ante traffic control are clarified

- **Progress**
The slope tilt sensors and rain gauges are installed at 3 pilot sites and installation of the system for data collection and early warning was completed. Based on these data, a simulated ex-ante traffic control drill was conducted in early June 2023.
- **Future Plan**
After establishing the threshold rainfall and operation system , WG will conduct more advanced ex-ante traffic control drill in November 2023 at Lobesa or Trongsa RO.

Ex-ante traffic control was held in Lobesa and Trongsa in early June 2023.

Output 2 : Suitable bio-engineering works are selected against "debris slope failure"

- **Progress**
After the germination tests at Lobesa and Trongsa ROs, the 1st and 2nd trial constructions at Gangthangka (Wangdue) and Yangkhil Resort (Trongsa) were implemented.
- **Future Plan**
The 3rd trial construction will be started in December 2023 at Samtse. Based on these trials, a guideline will be developed.

Various types of vegetation methods and drainage systems were applied at Yangkhil in 2023.

Output 3 : Standards for cut slope angles for "debris slope failure" and "rock slope failure" are revised

- **Progress**
Based on the analysis of the collected data from 46 selected pilot sites, standards for cut slope angles were revised. The construction at the pilot site, Teleganchu (Trongsa) using the revised standards were completed at April 2023.
- **Future Plan**
Based on these pilot studies, a guideline will be developed.

The revised standards were applied for the pilot conctruction at Teleganchu in 2023.

Output 4 : Suitable countermeasure works are implemented for "rock slope failure (rock fall)"

- **Progress**
The 1st pilot construction at Chendebji (Trongsa) was complete. At the 2nd pilot site, Tekizampa (Wangdue), topographic survey, geotechnical investigation and detailed design were completed.
- **Future Plan**
The 2nd pilot construction at Tekizampa will be started in December 2023. Based on these pilot studies, a guideline will be developed.

Work procedure plan for countermeasures for slope disaster at Tekizampa site as of Sep 2023

Output 5 : Suitable drainage works and facilities are installed for "debris flow"

- **Progress**
The 1st pilot construction at Bjee (Trongsa) was implemented at Nov 2020, and the 2nd at Khelekha (Wangdue) was completed at May 2023.
- **Future Plan**
Based on these pilot studies, a guideline will be developed and awareness program to horizontal development will be held for all the DoST ROs.

Culvert of a size compatible with the volume of the debris flow was constructed at Khelekha in 2023.

Output 6 : Information system on slope disasters and traffic controls on roads is improved

- **Progress**
The basic concept for the improvement of Road information system "Bhutan Road Safety (BRS)" was developed. Road alignment data collection is under way by the DoST ROs.
- **Future Plan**
By April 2024, the BRS application will be updated.

Drone survey is being conducted by the DoST engineers on slopes along National Highways.

Topics

A pilot construction will start in December at Tekizampa
Advanced construction methods (Shotcrete, Rock bolts etc.) will be applied.

Installation of information boards at five sites where countermeasure works has been completed
Information boards were installed at five sites from Wangdue to Trongsa explaining the construction process.

2nd Training in Japan in October 2023
10 DoST engineers will participate in "Training in Japan" in October 2023 to learn Japanese road disaster prevention technologies.

Schedule

Current

Figure. 3.9-3 Example of Newsletter

(4) Provision of equipment

Issue: C-Slope project provided a large number of equipment for use in the field survey. This included high-specification drones, which are still rare in Bhutan. However, due to the high cost of the equipment, the number of drones provided was limited to two, and only a limited of HQ members within C/P had the opportunity to operate them. This also limited the opportunities to use the drones for filming and measurement.

Figure 3.9-4 Example of drone training in RO

Devicing: Seminars on basic knowledge of drones, piloting practice, and basic aerial photography were held for representatives of all ROs. As a result, all ROs now have technicians with drone piloting skills. In addition, a certificate of participation was issued to those who attended the seminar, and an application was filed with the Civil Aviation Department in Bhutan to establish a system that allows official operation of the drone.

Lessons learned and recommendations: The limited amount of equipment available limited the number of C/Ps who could operate the drone. It is considered that providing a large number of inexpensive drone with only basic functions would have provided more C/Ps with opportunities to fly and operate the drone and led to a broad improvement in basic technology.

(5) Outflow of human resources

Issue: During the project period, a large number of C/Ps and project staff left Bhutan due to exodus, job transfers, and other reasons. In particular, since the outbreak of COVID-19, there have been many cases of people leaving Bhutan to study or work in Australia, which has become a social problem not only for this project but also for Bhutan as a whole. The outflow of C/Ps, to whom technology transfer had been promoted over a long period of time, was a major obstacle to the progress of the project.

Devicing: When the second training program in Japan was implemented, a written pledge was made within the DoST to ensure that the participants would not leave their jobs for a period of one year after participating in the training program. The Bhutanese government has also begun to tighten VISA requirements in order to curb the outflow of excellent human resources.

In order to ensure that the results of technology transfer through the project are sustained, past educational materials and seminar content were archived and compiled into manuals, which were used to explain the project content to newly appointed C/Ps. In addition, the results of project activities were compiled into guidelines and handbook so that technology could be appropriately transferred by referring to these guidelines and handbook.

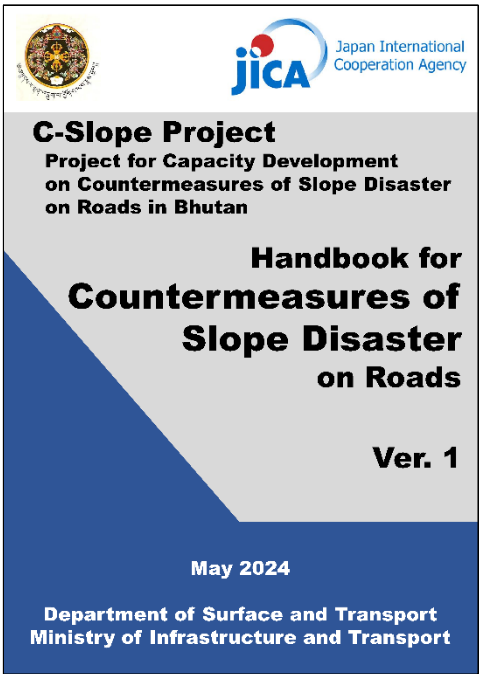


Figure 3.9-5 Cover of the handbook developed by this project

Lessons learned and recommendations: Taking into account personnel transfers and retirements during the project period, the contents of educational materials and seminars should be archived and manualized as needed. In addition, the results of technology transfer should be compiled into guidelines and handbooks that can be referred to even after the project is completed.

In this project, technology transfer was conducted for various countermeasure methods related to road slope disaster countermeasures. However, in many cases, standardized countermeasures are not sufficient for slope disaster countermeasures, and flexible responses must be considered according to the site topographical and geological conditions and rainfall.

Based on the basic knowledge gained in this project, it is necessary to study the technology in a more practical, developmental, and continuous manner.

2) Output 1 (Ex-ante traffic control)

Based on rainfall observations and records of the occurrence of collapses, a threshold of rainfall at which collapses may occur was established, and the threshold of rainfall is used to implement ex-ante traffic control in the future.

In this project, rainfall and collapse data were collected over a five-year period after a rainfall and collapse observation system was installed. Based on these records, a rainfall threshold was set, an information communication system for ex-ante traffic control was established, and a series of procedures for implementing ex-ante traffic control was learned through mock drills.

Table 3.9-1 Issues, innovations and lessons learned/recommendations related to Output 1

Issue	(1) It is unknown whether road users accept the operation of closing roads only by the amount of rainfall before a disaster occurs, instead of the current operation in which roads are closed only after a disaster occurs and become impassable, and then opened as soon as the road reopening activities are completed. (2) Sufficient rainfall data and disaster records are not available to establish a threshold for the amount of rainfall that could cause a disaster. (3) There is no budget set aside for maintenance of rainfall observation equipment.
Devicing	(1) In the discussion before and after the mock drill, JET also discussed the possibility of using the Japanese approach to close roads to traffic when rainfall exceeds a threshold level. In the discussion, JET also considered the following options; Only alerting passing vehicles or closing longer sections to traffic uniformly to avoid identifying dangerous points, depending on the actual conditions in Bhutan. (2) In the project, tilt sensors were installed in the slopes where collapse was expected and data was obtained on the relationship between rainfall and slope behavior. DoST has begun operating its own Kobo system and is developing a database of road maintenance information. In the future, disaster information is also stored in the BRS system developed in this project. (3) Basically, maintenance-free equipment was installed, and the equipment was maintained and upkept by JICA experts throughout the project period. Full maintenance, including battery replacement was performed prior to handover.
Lessons learned and recommendations	(1) It is necessary to continue activities to increase public awareness and understanding of the importance and effectiveness of advance traffic control (preventive measures) in Bhutan. And it is necessary to inform the public on a regular basis by setting up signs and other information about the restricted areas. (2) It is necessary to record not only disaster data but also rainfall information at the time of the disaster, and to establish a system to collect long-term data on the relationship between rainfall and the occurrence of disasters. (3) When installing continuous equipment and instruments, it is necessary to encourage the C/P agency to secure a budget for maintenance to ensure that the equipment is properly maintained after the project is completed.

3) Output 2 (Bio-engineering works)

Bio-engineering works control erosion of slopes and infiltration of surface water, and stabilize slopes.

In this project, three pilot sites were constructed at Lobesa, Trongsa, and Samtse, each with different types of Bio-engineering works.

Table 3.9-2 Issues, innovations and lessons learned/recommendations related to Output 2

Issue	(1) Bio-engineering work alone is not effective enough to stabilize slopes. (2) The effectiveness of the Bio-engineering work has not been fully verified, as it was not possible to fully confirm that the Bio-engineering thrived and recovered within the project period alone. (3) It has not been possible to present Bio-engineering works applicable to extremely steep and rocky slopes and slopes in high-elevation areas, which are numerous in Bhutan.
Devicing	(1) In the pilot construction at the three sites, various drainage works and gabions, which contribute to slope stability, were constructed prior to the installation of Bio-engineering works. Since the application limit of ordinary Bio-engineering works is up to a slope of about 45 degrees, pilot construction was conducted on a slope with a sloping angle of less than 45 degrees. In the pilot construction sites of Outputs 3 and 4, when slopes were found where the Bio-engineering works could be applied, the techniques studied in Output 2 were applied and the Bio-engineering works were constructed. (2) Some areas of Bio-engineering construction were not seeded, but were constructed with the intent of natural restoration of Bio-engineering by seeds from outside sources. Continuous observation of these areas was requested from the C/P. (3) In this project, priority was given to slopes of a type that frequently occurs in Bhutan to conduct pilot construction of Bio-engineering works.
Lessons learned and recommendations	(1) Through the guidelines and handbooks, instruct for users to consider combining Bio-engineering works with cutting, rock slope and rockfall protection works, drainage works, etc., rather than Bio-engineering works by itself. (2) For construction types that require evaluation through long-term observation, it is necessary to establish a system that enables long-term monitoring of vegetation recovery and thriving conditions, such as requesting the C/P to periodically observe and report the results of such observations. (3) Since the number of pilot construction sites was limited for the main patterns of slopes requiring Bio-engineering work in Bhutan, priority was given to the most frequently occurring types, but it is necessary to continue to study variations of Bio-engineering work applicable to all regions, using this project as a reference.

4) Output 3 (Cut Slope)

Create stable cut slopes by placing cuttings and small steps at appropriate slopes reflecting site geological conditions.

In this project, pilot construction was conducted at one site in Trongsa, where cutting works of different slopes were constructed for different geologies.

Table 3.9-3 Issues, innovations and lessons learned/recommendations related to Output 3

Issue	(1) In Bhutan, cut slope standards had been established prior to the project, but the standards have not been adhered to due to steep terrain conditions and prioritizing construction efficiency and other factors. (2) Although there were regulations for cut slope, there was no custom to check the slope on site, and the slope was determined by the experience and intuition of the heavy equipment operators. (3) Drainage around the cut slope was not considered.
Devicing	(1) In this project, a detailed geological survey was conducted, a notional geological cross-section map was prepared, and cutting gradients were set for each geological classification. (2) For cut slope slopes, the team was instructed on how to check the slope of the cut slopes by installing a hinge. In addition, a system was established to check the slope of the cut slope using slants to confirm that construction was being performed at the appropriate slope. (3) When cut slopes exceed a certain height, criteria for stabilization by installing small steps and drainage works were developed and included in the guidelines.
Lessons learned and recommendations	(1) In Bhutan, there are not so many gentle slopes that can be handled by cutting alone, and construction is mainly done in combination with other countermeasures. Technology transfer for survey, design, and construction of countermeasure works combining cutting works and other countermeasures is needed. (2) However, there is a lack of equipment to accurately measure the slope, and a system has not yet been established to ensure that the slope can always be checked at the construction site. Efforts should be made to disseminate the concept down to the end of the line, for example, by providing additional equipment. (3) Although the standards for cut slope, etc. have been compiled as guidelines, there should be opportunities to continuously and iteratively disseminate the concept to RO site engineers, contractors, and operators to ensure that construction is carried out in compliance with these standards.

5) Output 4 (Rock Slope Failure and Rockfall Countermeasures)

Safe passage was ensured by constructing appropriate rock slope failure countermeasures or rockfall countermeasures that reflected the site topography and geological conditions.

In this project, one rock slope failure/rockfall coutermeasure works was constructed in each of Trongsa and Lobesa RO. Although the initial plan was to pilot construction at three sites, after the first site in Trongsa, the C/P requested that the remaining construction be concentrated on one difficult slope rather than two small slopes, so construction was concentrated on one medium-size slope in Lobesa RO.

Table 3.9-4 Issues, innovations, lessons learned, and recommendations related to Output 4

Issue	(1) In Bhutan, no rockfall countermeasure works had ever been constructed to survey unstable boulders in the slope and to take into account the impact forces caused by their fall. (2) Highly accurate topographic maps or topographic data did not exist for conducting the slope survey. In addition, topographic surveying by DoST had not reached the level to design slope countermeasure works. (iii) Slope disaster prevention work was designed with high expectations for the strength and durability of the materials, but they were not adequately managed, and the possibility of rusting and loss of strength due to repeated flexion and extension of rebars were considered.
Devicing	(1) JET conducted a survey of unstable boulders on the slope, calculated the impact force considering their size, height, slope gradient, etc., and designed and constructed countermeasures to withstand the impact force. Any boulders that could not be covered by the countermeasures were removed prior to construction. (2) The survey was conducted on some of the slopes by specifying the line spacing and location, and detailed topographic data was obtained. Aerial photographs were also taken using a drone introduced in this project, and a 3D topographic model was constructed from the images obtained to understand the microtopography around the target slopes. (3) When accepting materials for use at the construction site, inspected the materials and refused to accept any materials that might not have the required strength, such as rusted or bent rebars or cement that had been manufactured too long, to ensure quality. The accepted materials were also thoroughly managed, and those members whose rusting was to be controlled were given instructions on how to apply rust-preventive treatment.
Lessons learned and recommendations	(1) Technical transfer of a method for considering impacts due to unstable boulders in slopes was conducted. By continuously conducting survey and design on similar slopes, the technology can be established and horizontally deployed. (2) The importance of detailed topographical information in survey and design was reaffirmed. Since various methods of data acquisition were presented, it is desirable to repeat the same process repeatedly and acquire the skills to acquire appropriate topographic data according to site conditions. (3) Materials used at the site should be properly accepted and managed so that they continue to be effective not only upon completion of construction but also over the long term.

6) Output 5 (Construction of countermeasures against debris flow)

Safe passage was ensured by constructing countermeasure works of a scale that would allow for the safe flow of debris flows of the anticipated scale.

In this project, one debris flow coutermeasure works was constructed in each of Trongsa and Lobesa RO.

Table 3.9-5 Issues, innovations and lessons learned/recommendations related to Output 5

Issue	(1) In Bhutan, no debris flow cuntermesure works had ever been constructed to survey unstable soil in the stream and the volume of debris flows. (2) In conducting the stream survey, there were no accurate topographic maps and topographic data. (3) The construction of the culvert and its ancillary facilities was a small-scale project, and a small-class contractor was responsible for the order and construction. The small class contractors did not have sufficient capacity to procure equipment and personnel, causing significant delays in the work progress.
Devicing	(1) Based on a survey of unstable soil in the stream bed upstream from the road and the amount of rainfall in the area, the volume of debris flow that could occur in the future was estimated, and the size of the necessary countermeasure facilities was established. These survey methods were compiled into a set of guidelines. (2) DEMs generated from satellite imagery developed in prior projects were used to determine the distribution of topography and unstable slopes around the stream. (3) For the second pilot construction, DoST introduced several medium-sized contractors with experience in construction, and JET conducted bids.
Lessons learned and recommendations	(1) The guidelines are being horizontally deployed within DoST, and construction of new debris flow coutermeasure works has begun with DoST's budget. It is necessary to continue to support these trends (technical and budgetary). (2) Efforts should be made to disseminate the use of topographic data developed in prior projects, and the ability to decipher disaster-related information from detailed topographic data should be developed. (3) In order to instill the habit of adhering to process plans (especially construction that avoids rainy seasons), it is necessary to provide continuous and extensive opportunities to make people understand the importance of developing construction plans and supervising construction according to those plans.

7) Output 6 (Information Systems)

A Data Base was built to centrally manage road information collected independently by DoST and road information from equipment provided by some donors, and a system was built to manage location information on a GIS. BRS application was developed to release information on road traffic restrictions. In addition, equipment and technology for acquiring topographical data and information on disaster conditions using drones were introduced.

Table 3.9-6 Issues, innovations and lessons learned/recommendations related to Output 6

Issue	(1) Bhutan government's policy for the development and management of information and communication related applications has changed significantly, and the authority for development and management has been handed over from DoST to GovTech. (2) DoST has accumulated a variety of information on road management, but it has not been in a position to integrate and manage it because it has been developed by various donors' projects. (3) Even in the event of a disaster such as slope failure, the survey system was far from ensuring safe and secure passage because countermeasures were being considered only by confirming the situation at the roadside, which led to another collapse from the upper slope.
Devicing	(1) The design and construction of the system proceeded smoothly through discussions with GovTech from the system study stage. (2) The DB integrates information on roads by linking various types of information using road location information as a key. (3) The project introduced a drone and provided guidance on drone operation, aerial photogrammetric surveying, and topographic modeling. In the event of a disaster, etc., the upper part of the slope and the surrounding area can now be checked from a safe location.
Lessons learned and recommendations	(1) When updating or revising applications that have been developed, it is necessary to constantly consult with GovTech. It is necessary to properly manage the design and specification documents at the time of development, and establish a system that can be taken over even if the administrator changes. (2) A vast amount of information has been maintained as a DB, but in order to use this information continuously, it must be properly operated and managed, which requires specialized staff and a certain budget. (3) Knowledge and skills that are different from those normally handled by DoST, such as safe operation of drones, photography methods for building appropriate terrain models, and procedures for building terrain models, are required. Ongoing technical training should be provided so that more members can be involved in these tasks.

Chapter 4. Project Evaluation

4.1 Summary of Internal Endline Evaluation

1) Purpose and Method

The purpose of the Internal Endline Evaluation is to "evaluate a technical cooperation project near its ending from the viewpoints of achievement of project objectives, efficiency of the project, and prospects for self-sustaining development," to conduct a self-evaluation of the project, and to "determine the appropriateness of termination of cooperation or the need for follow-up such as extension of cooperation" based on the results (see “JICA Project Evaluation Handbook (Ver. 2.0)”, March 2021: hereinafter referred to as "Project Evaluation Handbook"). It is also used as a point of consideration when the counterpart side continues the project and for lessons learned for similar projects.

According to the Project Evaluation Handbook, in the Endline Evaluation, "the achievement of Outputs, which are the direct benefits of the project, is evaluated using one of the six DAC evaluation criteria (relevance, consistency, effectiveness, impact, efficiency, and sustainability), particularly "effectiveness. In the evaluation of effectiveness, "the degree of achievement of the expected project effects at the target level in the target year (including the use of facilities and equipment)" is required to be verified with attention to "whether there are differences in the degree of achievement or results among beneficiaries.

Therefore, the Endline Evaluation in the Project examines the achievement of the project objective "The capacity of the DoST for road slope control is improved." is examined mainly from the evaluation criteria of effectiveness, paying attention to the degree of achievement and differences in capacity building of the engineers at the DoST headquarters and regional offices as beneficiaries. The results, implementation process, and causality of the project inputs (human, material, and budgetary), whether they were implemented as planned, whether the outputs (capital goods and services generated by the project) were produced as expected, and whether the Output, the project goal, was achieved, are also examined based on the PDM, The results, implementation process, and causal relationships were verified based on the PDM.

As for the survey methodology for the Endline Evaluation, as indicated in the Means of Verification of PDM Indicators, JET analyzed the results of previous reports, BL and EL surveys, and the utilization of various guidelines and handbook developed by this project, as well as conducted interviews with the beneficiaries, the DoST in addition, interviews were conducted with engineers of DoST, the beneficiary of the project, to evaluate this project.

2) Verification of PDM

Regarding logframe (PDM) and evaluation, the Project Evaluation Handbook states that there are matters that can be evaluated based on logframe/PDM and matters that cannot be evaluated based on logframe/PDM. The items that can be evaluated based on the log frame/PDM include project results, comparative study of planned and actual results, and appropriateness of project design, while the items that cannot be judged based on the log frame/PDM include project process, implementation structure, and impact and sustainability beyond the top goals. The items that cannot be determined based on the logframe/PDM are the project process, implementation structure, and impact and sustainability other than the top goals. This section examines the logframe/PDM prior to the evaluation based on the logframe/PDM. The logframe/PDM for this project is shown in Table 4.1-1.

Table 4.1-1 List of PDM indicators set (indicators and deadlines set after the start of work in **bold)**

Objectives and Outputs	indicator
Overall Goal: Slopes on roads in Bhutan are properly developed and managed by using countermeasures improved in the Project.	More than 4 countermeasures by using the technology installed/improved in the Project are implemented in the 2 target regional offices (Lobesa and Trongsa).
	More than 7 countermeasures by using the technology installed/improved in the Project are implemented in all of the other 7 regional offices.
Project Purpose: Capacity of DoST for countermeasures of slope disaster on roads is improved.	More than 4 countermeasure works by using the technology installed/improved in the Project are implemented by DoST.
	More than 70% of DoST engineers is able to implement ex-ante traffic control according to the developed manuals.
	Budget for countermeasures by using the technology installed/improved in the Project is incorporated into the annual budget plan in DoST.
Output 1: Clarification of conditions for ex-ante traffic control	Sections of ex-ante traffic control are selected **(by December 2022)**
	Threshold rainfall of ex-ante traffic control is established.
	A manual on the monitoring of displacement/rainfall and the ex-ante traffic control is developed and approved by DoST (MoIT) **(by December 2023)**
Output 2: Suitable bio-engineering works are selected against "debris slope failure".	At least two engineers in the DoST headquarters and each regional office are able to select suitable bio-engineering works and to supervise implementation of the works
	A design/implementation guideline and a standard unit price table on the bio-engineering works are developed and approved by DoST (MoIT) **(by June,2024)**
Output 3: Standards for cut slope angles for "debris slope failure" and "rock slope failure" are revised.	At least two engineers in the DoST headquarters and each regional office are able to select suitable cut slope angle on each geological type and to supervise implementation of the works
	A design/implementation guideline and a standard unit price table on the standards for cut slope angles are developed and approved by DoST (MoIT) **(by December, 2023)**
Output 4: Suitable countermeasure works are implemented for "rock slope failure (rock fall)".	At least two engineers in the DoST headquarters and each regional office are able to select suitable countermeasure works for "rock slope failure (rock fall)".
	At least two engineers in the DoST headquarters and each regional office are able to understand the selected countermeasure works and to supervise implementation of the works.
	A design/implementation guideline, a standard unit price table on the countermeasure works for "rock slope failure (rock fall)" and a countermeasure Handbook are developed and approved by DoST (MoIT) **(by June,2024)**.
Output 5: Suitable drainage works and facilities are installed for "debris flow".	At least two engineers in the DoST headquarters and each regional office are able to investigate and design suitable drainage works and facilities and to supervise implementation of the works.
	A design/implementation guideline and a standard unit price table on the drainage works and facilities are developed and approved by DoST (MoIT) **(by December, 2023).**
Output 6: Information system on slope disasters and traffic controls on roads is improved.	Road information system with the existing GIS database is improved.
	Necessary data for maintenance and traffic control on roads are periodically collected by regional offices.
	Manual on the road information system utilizing the GIS database is developed and approved by DoST (MoIT) **(by June,2024)**

(Source: JET)

With regard to the vertical logic that is the framework of the logframe/PDM, the expected outputs and the logical flow to the project goals and to the overall goals are consistent during and at the end of project implementation, and as described below, the achievement of outputs contributes to the achievement of project goals, and the achievement of project goals contributes to the achievement of overall goals in the future, It can be predicted that the achievement of project goals lead to the achievement of overall goals in the future.

The indicators for each Output were generally set appropriately for achievement, and each Output could be evaluated using these indicators at the endline of the project.

On the other hand, some issues were observed regarding the indicators of the project goals. For "Indicator 2: 70% of DoST engineers are able to traffic control according to the manual." The guidelines, mock drills, and the viewing of a brief video of the event on Youtube were considered to have helped transfer the concept and procedures of ex-ante traffic control to a large number of DoST personnel. However, since the number of sections where ex-ante traffic control can be implemented based on actual observed rainfall is limited to only three sections in two ROs, it has not been possible to provide opportunities to deepen understanding through practical operation and to discuss operational methods suitable for Bhutan.

This project had to be suspended for a little more than two years from March 2020, in the middle of the project, due to the COVID-19 epidemic. During the suspension period, the pilot construction of the first site progressed, making it impossible to hold seminars and other events using the site under construction. However, after the project resumed in May 2022, technology transfer was promoted through pilot construction at the second and subsequent sites, and the development of the Output guidelines was vigorously pursued, so the indicators for each Output and project goal set at the beginning of the period were generally achieved.

The issues for the indicators of the overall goals are discussed in detail in "Chapter 5: Achieving the Overall Goals after the Project Completion".

4.2 Project Achievements

1) Confirmation of Achievements

(1) Status of achievements of each Output

Table 4.2.1 summarizes the achievement of each Output.

All six Output indicators were 100% achieved, although some outputs were slightly behind schedule. The guidelines for Outputs 1, 4, and 5 were scheduled to be approved and formalized by DoST by December 2023, but were delayed in terms of completion date because they were to be approved by DoST together with the guidelines for Outputs 2 and 4. However, the contents of these guidelines were largely completed by the end of 2023, and seminars using the draft guidelines were held at ROs in various regions to promote the technology.

Based on the evaluation of the above indicators, the achievement of all six Outputs is rated "High".

Table 4.2-1 Indicators of each Output and status of achievement and attainment

Indicator	Status of Achievement	Level of Achievement	Notes
Output 1: Clarification of conditions for ex-ante traffic control			
Sections of ex-ante traffic control are selected (by December 2022)	Three sections were selected.	100%.	
Threshold rainfall of ex-ante traffic control is established.	Threshold rainfall of ex-ante traffic control were set at three sites.	100%.	
A manual on the monitoring of displacement/rainfall and the ex-ante traffic control is developed and approved by DoST (MoIT) **(by December 2023)**	Manuals for displacement of Slope, rainfall monitoring and ex-ante traffic control were developed and approved by DoST in April 2024.	100%.	Approval was delayed because it was combined with other guidelines
Output 2: Suitable bio-engineering works are selected against "debris slope failure".			
At least two engineers in the DoST headquarters and each regional office are able to select suitable bio-engineering works and to supervise implementation of the works	Three DoST engineers were able to select and supervise the construction of appropriate Bio-engineering works.	100%.	
A design/implementation guideline and a standard unit price table on the bio-engineering works are developed and approved by DoST (MoIT) **(by June,2024)**	Design and construction supervision guidelines and standard unit price list for Bio-engineering works were developed and approved by DoST in April 2024.	100%.	
Output 3: Standards for cut slope angles for "debris slope failure" and "rock slope failure" are revised.			
At least two engineers in the DoST headquarters and each regional office are able to select suitable cut slope angle on each geological type and to supervise implementation of the works	Four DoST engineers were able to select the appropriate slope for each geological feature and supervise the construction.	100%.	
A design/implementation guideline and a standard unit price table on the standards for cut slope angles are developed and approved by DoST (MoIT) **(by December, 2023)**	Design and construction management guidelines and standard unit price list for standard cut slope were developed and approved by DoST in April 2024.	100%.	Approval was delayed because it was combined with other guidelines
Output 4: Suitable countermeasure works are implemented for "rock slope failure (rock fall)".			
At least two engineers in the DoST headquarters and each regional office are able to select suitable countermeasure works for "rock slope failure (rock fall)".	Four DoST engineers are now able to select suitable countermeasure methods for "rock slope failure (falling rocks)".	100%.	
At least two engineers in the DoST headquarters and each regional office are able to understand the selected	Four DoST engineers were able to understand and install the countermeasure works introduced	100%.	

countermeasure works and to supervise implementation of the works.	in this project.		
A design/implementation guideline, a standard unit price table on the countermeasure works for "rock slope failure (rock fall)" and a countermeasure Handbook are developed and approved by DoST (MoIT) **(by June,2024)**.	Design and Construction Management Guidelines for Rock Slope Failure (Rockfall) Countermeasures and Standard Unit Price List and Handbook were developed and approved by DoST in April 2024.	100%.	
Output 5: Suitable drainage works and facilities are installed for "debris flow".			
At least two engineers in the DoST headquarters and each regional office are able to investigate and design suitable drainage works and facilities and to supervise implementation of the works.	Four DoST engineers are now able to survey, design, and construct proper drainage works and drainage facilities.	100%.	
A design/implementation guideline and a standard unit price table on the drainage works and facilities are developed and approved by DoST (MoIT) **(by December, 2023).**	Design and construction management guidelines and standard unit price list for drainage works and drainage facilities were developed and approved by DoST in April 2024.	100%.	Approval was delayed because it was combined with other guidelines
Output 6: Information system on slope disasters and traffic controls on roads is improved.			
Road information system with the existing GIS database is improved.	The existing road information system BRS including GISDB has been improved and put into operation.	100%.	
Necessary data for maintenance and traffic control on roads are periodically collected by regional offices.	Through the operation of the RAMS system and guidance in registering data in the BRS, the necessary data acquisition is taking place.	100%.	
Manual on the road information system utilizing the GIS database is developed and approved by DoST (MoIT) **(by June,2024)**	A Road Information Management Manual was developed and approved by DoST in June 2024.	100%.	

(Source: JET)

(2) Status of achievement of Project Goals

The level of achievement of the project goals is evaluated based on each of the established indicators. The level of achievement for each indicator is shown below. Table 4.2-2 summarizes the level of achievement for each indicator.

(a) More than 4 countermeasure works by using the technology installed/improved in the Project are implemented by DoST.

In this project, two pilot ROs were set up and pilot construction of Output 2, 3, 4, and 5 was carried out within their jurisdiction. Three pilot sites for Output 2 (Bio-engineering works) were funded by JICA, while one site for Output 3 (cut slope), two sites for Output 4 (countermeasures against rock slope failure/rockfall), and two sites for Output 5 (debris flow) were funded by DoST, and DoST took the initiative in implementing the five sites.

In addition, DoST independently constructed a debris flow countermeasure works at one site in Samdrup Jongkhar RO, which was not covered by the project, in accordance with the guidelines developed by the project and funded by DoST.

Since DoST has already implemented 6 slope coutermeasure works using the countermeasure works improved/introduced in this project, this indicator is evaluated as 100% achievement.

(b) More than 70% of DoST engineers is able to implement ex-ante traffic control according to the developed manuals.

In April 2023, a total of 10 members of the WG of Output 1 and engineer of the pilot ROs were trained at Lobesa RO and Trongsa RO to confirm the procedures for ex-ante traffic control. In April 2024, a mock drill for ex-ante traffic control based on rainfall warnings was conducted at the Trongsa RO. About 30 engineers participated in the drill, including 1-2 representatives from each of the 9 ROs and HQs, engineers from the Trongsa RO and Maintenance Division, and traffic police. Through the full-day mock drill, they understood the concept of ex-ante traffic control and its actual operation. A 5-minute video of the day's mock drill was compiled and posted on Youtube. After returning to their respective ROs/HQs, the participants were encouraged to watch the video and, if they understood the content, to click the “Like” button. As a result of these efforts, the video received over 300 views and 47 “likes” as of the end of May 2024. In addition, mock drill participants were given mini-seminars at each RO and HQ using the handbook and video created by the project, with about 10 participants each at each RO (100 participants in total).

Through these activities, approximately 20% (40 person) of the DoST engineers (approximately 200 people) participated in the mock drill, and approximately 50% (100 person) deepened their understanding of ex-ante traffic control through lectures from the mock drill participants. Furthermore, it is believed that most of the engineers gained a certain level of knowledge about ex-ante traffic control methods by watching the video.

Based on the above, this indicator is evaluated as 100% achievement.

(c) Budget for countermeasures by using the technology installed/improved in the Project is incorporated into the annual budget plan in DoST.

At the beginning of the project, it was assumed that DoST would take the lead in implementing countermeasure works within the project at a cost of about 5,000,000 BTN per pilot site, with a budget of about 30,000,000 BTN (equivalent to an annual average of 7,500,000 BTN) for a total of 6 sites over the 4-year project period.

The first pilot construction of Output 4 (rockfall prevention works) and 5 (debris flow prevention works) in FY2020 and the cut slope works of Output 3 in FY2023, respectively, were generally implemented in accordance with the original budget.

On the other hand, for the second pilot construction of Output 4 that started in 2023, DoST requested to take on a more difficult slope, so the budgets for the second and third pilot construction were combined and increased to 30,000,000 BTN (equivalent to 15,000,000 BTN per year) for the two-year period from FY2023 to FY2024. The construction in FY2023 is carried out as an activity within the project, while the construction in FY2024 and beyond is carried out solely by DoST, with about half of the budget being allocated outside of the project. And Samdrup Jongkhar RO uses this budget as the basis for the design of the debris flow counterneasure works. Based on this budget, the design and construction of the debris flow countermeasure works were proceeded and completed at the end of May 2024.

Based on these facts, JET can confirm that DoST has incorporated the budget for the measures implemented in this project into its FY2023 and FY2024 budgets, and therefore, JET rate the achievement level for this indicator at 100%.

Table 4.2-2 Indicators of Project Goals and Status of Achievement

Indicator	Status of Achievement	level of Achievement	Notes
Project Goal: Capacity of DoST for countermeasures of slope disaster on roads is improved.			
More than 4 countermeasure works by using the technology installed/improved in the Project are implemented by DoST.	Slope countermeasure works improved/introduced in the project were implemented in six locations by DoST.	100%.	
More than 70% of DoST engineers is able to implement ex-ante traffic control according to the developed manuals.	More than 70% of DoST engineers understood the concept and procedures of ex-ante traffic control, including those who participated directly in the training (20% of all engineers) and those who understood the process of ex-ante traffic control by watching the video and attending the debriefing session (more than 50% of all engineers).	100%	
Budget for countermeasures by using the technology installed/improved in the Project is incorporated into the annual budget plan in DoST.	In addition to the budget for the countermeasure works planned for the project, a multi-year budget for rockf slope failure countermeasures (rockfall countermeasures) was incorporated for the 2023-2024 fiscal year, and a budget for two sites was incorporated for the 2023 fiscal year for the countermeasure works for debris flows.	100%.	

(Source: JET)

2) Transition of PDM

The finalization of the indicators listed in the PDM presented in the first JCC (January 2019) and the specific figures for the items not yet set were discussed with the C/P after consultation at JICA HQ and finalized in August 2019. After this, the deadline for the activity was revised to reflect the extension of the project period by 1.5 years, which was decided in May 2022.

3) Confirmation of implementation process

(1) Project management structure

The project management structure was a Joint Coordinating Committee (JCC) under the DoST Headquarters, chaired by DoST Director General (Director General) as Project Director. Under the JCC, the Cheef Engineer of Maintenance Division (CE, MD) led the group as Project Manager, and the Focal Persons at HQ and the Pilot ROs implemented the project as members of the WGs for Outputs 1 through 6.

The Japanese side consisted of a JICA Expert Team (JET) guiding the WGs for each Output; the JETs worked closely with the WGs, holding regular workshops/seminars, meetings, field training, etc. to review the progress and Outputs of the project.

Figure 4.2-1 shows the project management structure.

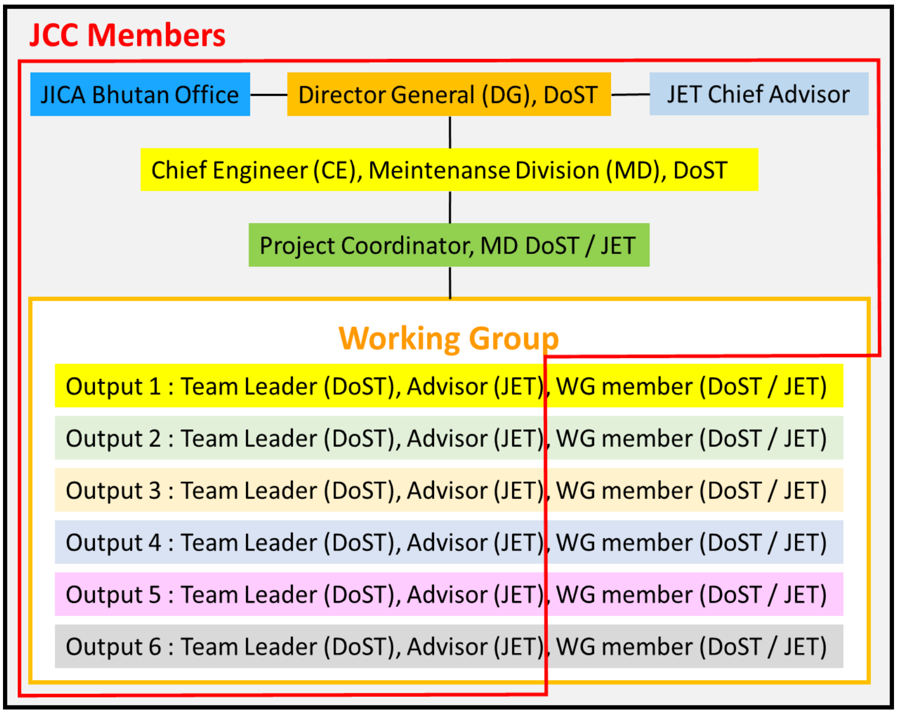


Figure. 4.2-1 Project Management Structure

(2) Status of sharing technology, knowledge, know-how, and experience

Through the activities of this project, engineers from DoST Headquarters (HQ) and DoST ROs (especially Trongsa and Lobesa ROs that served as pilot ROs) have been trained in topography and geology, which are the basic knowledge for slope disaster countermeasures, and practical training in survey, design, and cost estimation for Bio-engineering works, cut slope works, rock slope failure (rock fall) countermeasures works, and debris flow countermeasures works, as well as construction supervision, quality, and safety management at pilot construction sites under the guidance of JETs. In addition, they gained a wide range of skills, knowledge, and experience in the digitization of road management, including basic GIS and drone operations and the sharing of road management information through the BRS system.

The following is a summary of the status of sharing of technology, knowledge, know-how, and experience that DoST's engineers have developed to date.

With regard to the sharing of technology, it is considered that the WG members who participated in the project at HQ and the pilot ROs obtained the same level of technology. During the implementation of the pilot construction, a large amount of information on daily work progress and work-related issues were shared with the WG members via SNS, so that even those members who could not visit the sites frequently could understand the technical issues, their solutions, and the work progress. On the other hand, opportunities to share technical information to other engineers affiliated with these offices and ROs other than the pilot ROs were limited to the time of seminars, etc., and it is likely that this understanding remained fragmentary or limited. In some Outputs, such as Outputs 3 and 5, seminars were held for several days for all ROs (or some joint ROs) to provide practical technology transfer, including on-site training, while in other Outputs, only general seminars were held. In the future, it is expected that the core members of each WG take the lead in horizontal development and deepening of technology through more practical seminars and actual construction, using the guidelines for each Output developed in this project.

With regard to knowledge sharing, the project conducted pilot construction of slope disaster countermeasure works at eight sites. The first round of construction (3 sites starting in January 2020) was significantly affected by COVID-19, and travel and gatherings in the country were effectively prohibited immediately after the start of construction. In the second and subsequent rounds of construction (after December 2022), opportunities for site tours were proactively provided, but the number of engineers who could actually visit sites under construction was limited due to the poor accessibility of various sites unique to the country of Bhutan. During project design and pilot site selection, it may have been necessary to consider the possibility of locating pilot construction sites in various areas of Bhutan.

The Bhutanese national character and organizational characteristics are also reflected in the sharing of know-how and experience. They have acquired enough knowledge by observing various new Japanese technologies and construction sites of road slope disaster prevention works in mountainous areas similar to those in Bhutan. However, the sharing of experiences, new technologies, know-how, etc. gained from training in Japan upon their return to their home countries seems to have been limited to debriefing sessions at their home offices and reports at the JCC after their return to Japan. In this context, JET looks forward to the future of the opinion expressed during the visit to the Infrastructure Museum at Gifu University that "it is precisely in Bhutan, where construction sites are limited, that such a full-scale construction model should be set up.

4.3 Review of DAC6 Item Evaluation

The results of the implementation of the work are reviewed in terms of the six evaluation criteria of the DAC shown in Table 4.3-1.

Table 4.3-1 DAC6 evaluation items and evaluation of this project

Item	Evaluation Perspectives	**Evaluation of this project**
Validity	The degree to which the objectives and design of the intervention continue to respond to the needs, policies, and priorities of the beneficiaries and adapt to changing circumstances.	**(iii) High**
Consistency	Compatibility of the intervention in question with other interventions for the country, sector, or organization.	**(iii) High**
Effectiveness	The degree to which the objectives and Outputs of the intervention have been achieved or are likely to be achieved, including the different consequences for the various populations.	**(iii) High**
Impact	The degree of significant positive or negative, intended or unintended, higher-order effects produced or expected to be produced by the intervention.	**(iii) High**
Efficiency	The degree to which the implementation of the intervention produces or will produce results in an economical and timely manner.	**(iii) High**
Sustainability	The degree to which the net benefits of the intervention will continue or are likely to continue.	**(iii) High**

Source: "JICA Project Evaluation Handbook (Ver. 2.0), March 2021" with additions to the evaluation of this project.

1) Validity: (iii) "High"

The validity primarily evaluates the compatibility of the project goals, plan and approach with the development policies and plans of Bhutan and the needs of the target group, DoST.

The C-Slope project is consistent with Bhutan's national development policy. The Eleventh Five-Year Plan 2013-2018 indicates "road safety," "quality of construction," and "financial sustainability to maintain the extensive road network that has been built" as key issues for the road sector. The 12th Five-Year Plan 2019-2023 also identified "investment in a reliable transportation system for a growing population and increasing traffic" and called for strategies to improve the capacity to plan, build, and maintain the road network.

The project goal of this project, " Capacity of DoST for countermeasures of slope disaster on roads is improved." is one of the DoST's Key Performance Indicators (KPIs), which include: " More than 4 countermeasure works by using the technology installed/improved in the Project are implemented by DoST," " More than 70% of DoST engineers is able to implement ex-ante traffic control according to the developed manuals," and " Budget for countermeasures by using the technology installed/improved in the Project is incorporated into the annual budget plan in DoST".

C-Slope project was designed to address the need for improved capacity to cope with slope hazards by developing and improving the capacity of engineers involved in the construction and maintenance of road slope countermeasure works under the jurisdiction of DoST. Therefore, the project can be rated as "iii): High" in terms of validity from the perspective of addressing the development policies of Bhutan, the needs of the DoST, and the problems and challenges of the road maintenance sector.

2) Consistency: iii) "High"

The consistency evaluation section primarily examines consistency with development assistance policies, projects, and international frameworks of the Japanese government, JICA, and other donors and agencies.

The Japanese government's May 2015 development assistance policy for Bhutan that the basic policy of the government is to provide assistance for self-reliant and sustainable development with a balance between urban and rural areas, and in order to achieve sustainable economic development, one of the priority sectors, the need for road and bridge development to improve the quality of life in the region is the report points out. In addition, JICA's April 2018 Project Development Plan for Bhutan points out that the lack and poor quality of road infrastructure is a major constraint to development as it hinders social and market access and economic activities. The plan therefore states that JICA continues to support the government of Bhutan in capacity building for the design and construction, maintenance, and management of infrastructure. With regard to the second priority sector of reducing vulnerability to disasters, the plan aims to support the implementation of necessary measures for infrastructure against flooding and landslides during the rainy season.

C-Slope project was implemented in line with these development assistance policies of the Government of Japan and JICA's project development plan for basic infrastructure development and maintenance, including bridge replacement and bridge maintenance capacity improvement projects in PNH1 and PNH4 (changed to PNH5 during the project implementation period).

From an international framework perspective, the C-Slope project is consistent with Sustainable Development Goal (SDG) 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. In particular, the project can contribute to the achievement of "Target 9.A. Promote sustainable and resilient infrastructure development in developing countries through enhanced financial, technical, and technological assistance to African countries, least developed countries, landlocked developing countries, and small island developing countries.

Based on the above, the project can be evaluated as "iii): High" in terms of consistency with the policies of the Japanese government and JICA, as well as with international frameworks.

3) Effectiveness: iii) "High

The effectiveness item evaluates whether project goals were achieved as a result of project implementation.

In this section, JET evaluates whether the project goal of " Capacity of DoST for countermeasures of slope disaster on roads is improved." as a result of the implementation of each of the activities in Outputs 1 through 6 in this project, based on three indicators.

Analysis of three indicators: " More than 4 countermeasure works by using the technology installed/improved in the Project are implemented by DoST," " More than 70% of DoST engineers is able to implement ex-ante traffic control according to the developed manuals," and " Budget for countermeasures by using the technology installed/improved in the Project is incorporated into the annual budget plan in DoST". Results in the project objectives being achieved at a level of almost 100%, and therefore the effectiveness of the project is rated as "iii): High".

As described in "4.2 Project Achievements," slope countermeasure works were performed in more sites than originally planned, the majority of DoST engineers became familiar with ex-ante traffic control through mock drills and video recordings of the drills, and the budget for the countermeasure work was incorporated into DoST's annual budget. All outputs were achieved at a 100% level at the time of project completion, although there were some problems and delays in completion. As a result, the capacity of DoST's engineers with respect to slope hazard countermeasures was greatly enhanced.

In addition, four Outputs on slope disaster countermeasure works (Outputs 2, 3, 4, and 5), new guidelines were developed based on various manuals and guidelines in Japan and by adding the experience gained through pilot construction in Bhutan. These guidelines have been approved and formalized by DoST, and are expected to be used as a new standard for road slope disaster prevention in the future. The engineers who participated in this project as WG members are well versed in the contents of the guidelines, and it is hoped that while they are still in their current positions, they work to horizontally development their skills through the construction of new countermeasure facilities in various ROs of Bhutan.

4) Impact: iii) "High"

From the previous analysis, it can be said that the project has had a significant impact on improving the capacity and awareness of DoST organizations and engineers regarding slope disaster countermeasures, improving their awareness for ensuring construction quality and safety, improving their ability to collect and analyze road management data, introducing the new concept of ex-ante traffic control, and securing budgets related to road disaster countermeasures. The project changed the engineers' awareness of slope disaster preparedness and greatly improved the slope disaster preparedness capacity of the engineers who participated in the WGs of each Output from the DoST, especially HQ and the pilot ROs.

The various guidelines developed by this project have also had a significant impact on the technical standards for slope disaster countermeasure works in Bhutan, as they have been formalized by DoST and are expected to be revised and used in the implementation of slope disaster countermeasure works in the future.

These guidelines are applicable not only to road slope hazard countermeasures implemented by DoST, but also to roads managed by Dzongkhag and Gewog. It is also expected that the techniques related to geological survey methods and topographic information acquisition take root as highly versatile technologies that can be applied not only to road slope hazard countermeasures, but also to planning of new routes and schematic and detailed surveys.

There are no negative environmental, economic, or gender impacts of the project.

Assuming that these impacts are adequately maintained and enhanced after the project is completed and that the necessary resources and budget continue to be allocated, there is a great possibility that the overall goal " Slopes on roads in Bhutan are properly developed and managed by using countermeasures improved in the Project." is achieved.

On the other hand, continuous training and the creation of opportunities for step-by-step technical improvement are necessary to maintain the ability and motivation of engineers, and organizational efforts to reduce personnel turnover and ensure continuity of skills, knowledge, and experience are also considered necessary.

Based on these considerations, the impact of this project on Bhutan and DoST can be evaluated as "iii) : High".

5) Efficiency : iii) "High

The Japanese side's project cost increased by about 16%, due to the introduction of a drone and 3D model analysis software, geological survey equipment such as a Simple Penetration Tester and handheld elastic wave velocity meter, additional equipment costs such as rain gauge and ground surface tilt sensor, and pilot construction at three sites for Output 2 (Bio-engineering work). In addition, the global outbreak of COVID-19 forced the suspension of work for more than two years, which extended the project period by one and a half years (37.5%) to July 2024.

Expert input increased by about 7%, from 116.90 to 125.20 specialists/month. In addition, as indicated in Chapter 2, the input of several experts was changed. The reasons for the changes were due to the need to adjust assignments within the group due to changes in the progress and difficulty level of each Output from the initial assumption, as well as other supplementary work.

These changes in project costs, inputs, and duration are due to the inevitability of generating project outputs or due to the fact that this project was significantly affected by COVID-19.

Therefore, the efficiency of this project is rated as "3): High.

6) Sustainability : iii) "High”

The sustainability of the project's impact was evaluated from four perspectives: policy and institutional, implementing agency structure, capacity, and financial.

In terms of policy and institutions, PNH and SNH are recognized as critical infrastructure that forms the basis of transportation in Bhutan, and improving safety against road slope disasters is recognized as an important issue and one of the priorities for ensuring accessibility in rural areas, and therefore it is hoped that the project effectiveness is maintained.

From the organizational perspective of the implementing agencies, there are concerns about the sustainability of the project effects in terms of technical succession due to personnel transfers, job transfers to private companies, and the outflow of human resources overseas. Although the abilities of engineers and their awareness of slope disaster countermeasures have improved, the turnover of high-quality engineers is a serious problem for the DoST and Bhutan, and it is necessary to prevent the outflow of human resources or to expand them. In addition, the transfer of engineers who have received technology transfer through various seminars on behalf of ROs may have a negative impact on the technical capacity of ROs.

With regard to sustainability in terms of skills, knowledge, and techniques, continuous training and updating of knowledge on slope hazard countermeasures is necessary. In particular, it is necessary to raise the level of technical skills of the entire DoST by regularly holding seminars and other events using the various guidelines and handbook developed in this project, so that engineers from all ROs can survey, design, and construct slope disaster countermeasures with the same quality and standards.

Regarding the financial perspective, this is a major concern for the sustainability of project effects. In order to continuously implement slope disaster countermeasures and extend, even gradually, the length of sections that can be passed safely and securely, it is necessary to allocate a budget for slope disaster countermeasures on an ongoing basis. It is also necessary to have a budget for the appropriate maintenance and management of the slope disaster countermeasures already constructed. The financial aspect is of paramount importance for the sustainability of effectiveness. Although concerns were voiced about this point at the last JCC, it was confirmed that the DoST recognizes the importance of slope disaster countermeasures and continues to seek budget acquisition in the future.

Judging comprehensively from these perspectives, the sustainability of the effects of this project is judged to be iii): High.

Chapter 5. To achieve the Overall Goals after the project is completed

5.1 Prospects for achieving Overall Goals

The project has carried out various activities with the following overall goals

Table 5.1-1 Overall goals of PDM

Objectives and Outputs	indicator
Overall Goal: Slopes on roads in Bhutan are properly developed and managed by using countermeasures improved in the Project.	More than 4 countermeasures by using the technology installed/improved in the Project are implemented in the 2 target regional offices (Lobesa and Trongsa).
	More than 7 countermeasures by using the technology installed/improved in the Project are implemented in all of the other 7 regional offices.

(Source: JET)

Based on the analysis and evaluation, it can be inferred that the project has a great potential to achieve its overall goals, " Slopes on roads in Bhutan are properly developed and managed by using countermeasures improved in the Project." However, to ensure the achievement of the overall goals, follow-up is needed to address the challenges and risks mentioned in "4) Impact" and "6) Sustainability" in "4.3 Review of DAC6 Item Evaluation". Ongoing training needs to be provided to address issues such as maintenance of technical skills and motivation. At the same time, it is important to continuously secure a budget for slope disaster countermeasures while taking into account the external environment, and to take necessary measures to improve, accumulate, and pass on technical skills while accumulating actual experience in survey, design, and construction. These perceptions were reaffirmed at the last JCC.

Among the two indicators of the Overall Goals, " More than 4 countermeasures by using the technology installed/improved in the Project are implemented in the 2 target regional offices (Lobesa and Trongsa)"can be achieved by using countermeasures (countermeasure works, ex-ante traffic control) using technologies introduced in at least four sites within two target ROs (Lobesa and Trongsa RO), it is expected to be easy to achieve as long as budgetary measures are taken.

As for the other item, " More than 7 countermeasures by using the technology installed/improved in the Project are implemented in all of the other 7 regional offices," this can be achieved as long as budget are secured, since all ROs have already conducted several-day seminars, including field surveys, on cut slope works and countermeasures for debris flow, and the problem areas and model study areas in each RO have already been selected. As for the countermeasures against debris flow, budgets have already been secured for pilot projects in some ROs, and Samdrup Jongkhar RO is now constructing countermeasures against debris flow in accordance with the guidelines developed in this project. It can be said that efforts to achieve the overall goals have already begun.

5.2 Plan and implementation system to achieve the Overall Goals

1) Utilization and horizontal development of guidelines at new slope disaster countermeasure construction

In the future, new slope disaster countermeasure works to be constructed by DoST are surveyed, designed, and constructed in accordance with the new guidelines developed and formalized by this project. In these efforts, engineers from HQ and pilot ROs who participated in the WG of this project serve as instructors, and the content of the guidelines and details of actual work are horizontally developed.

2) Use of guidelines at disaster restoration sites

In Bhutan, roadblocks caused by slope failures occur every year, and disaster restoration work is carried out each time. Initially, the work is mainly for emergency restoration to ensure the passage of traffic, but for full-scale restoration work, appropriate countermeasures against slope disasters are taken, including survey, design, and construction in accordance with the guidelines established in this project.

3) Promote ex-ante traffic control and information provision based on rainfall observation

In this project, thresholds for ex-ante road block based on rainfall information were set at three sites. In Bhutan, there is an unresolved concern that road blocks prior to the occurrence of a failure may not be fully understood by local residents and road users. Therefore, the introduction of the system should be considered from the soft side. In addition, when the reliability of the threshold for the relationship between rainfall and occurrence of slope disasters becomes somewhat assured through long-term data collection, the operation is shifted to one involving traffic control, and other flexible operations are implemented according to the status of DoST engineers' and society's understanding of ex-ante traffic cotrol.

4) Collection and dissemination of road disaster information using BRS system

By consolidating road disaster information into the BRS system established in this project and identifying areas where disasters repeatedly occur, and then analyzing the topographical and geological characteristics of these areas and their relationship with rainfall, the project accumulates basic data for more efficient and effective slope disaster countermeasures.

In addition, the operational methods of the BRS system is brushed up as appropriate with regard to the collection and dissemination of road disaster information.

5) Ongoing Slope Disaster Preparedness Budget

In order to continue the above activities, a prerequisite is to secure a budget for slope disaster countermeasures to support them. DoST, which has recognized the importance of slope disaster countermeasures through this project, systematically and continuously secure a budget for this purpose.

5.3 Recommendations to the Bhutanese side

1) Consideration of countermeasures according to the topographical and geological characteristics of the slope

Most slope hazards occur in accordance with the topographic and geologic characteristics of the area surrounding the slope. Although the guidelines and handbook in this project introduced basic measures for a wide range of slope disaster countermeasure works, natural conditions vary widely, and a combination or application of various techniques is required depending on the situation at a given site.

It is desirable to consider the most appropriate countermeasure construction method after fully surveying and understanding the topographical and geological characteristics of the target slope in accordance with the survey method indicated in the guidelines. It is also important to carefully survey the topographical and geological conditions of the surrounding slope and select an appropriate construction method based on a thorough understanding of the slope characteristics in order to avoid slope instability in new road construction and road widening projects before using countermeasure works.

2) Effective use and updating of the guidelines and handbook developed by this project

In this project, guidelines and handbooks were developed based on various Japanese manuals and guidelines, as well as on the experience gained through surveys and pilot construction conducted at several sites in Bhutan. After the completion of the project, while the members who participated in the WG are still in the same positions, it is necessary to conduct seminars and study sessions using these guidelines and handbook to strongly promote horizontal development and technical deepening.

In addition, the guidelines developed in this project may not be applicable to all slopes, as Bhutan has a mixture of regions with widely different climatic and weather conditions, from low elevation to high elevation, from warm and humid regions to cold and dry regions, all within a small land area. In the future, as the survey, design, and construction proceed in accordance with the guidelines, if any event occurs that is not compatible with Bhutanese climate, customs, or technology, it is necessary to revise the guidelines to make them more suitable for Bhutan's slope disaster conditions by making additions or corrections as appropriate.

In addition, because slope disaster control technology is constantly evolving, the guidelines should be reviewed at least once every five years and constantly updated to incorporate the latest technology.

3) Dissemination of continuous and extensive survey, design, cost estimation, and construction techniques through small-scale slope disaster countermeasure works

The various guidelines developed for this project introduce a number of technologies that can be constructed using conventional construction methods in Bhutan. However, by implementing a large number of small-scale slope disaster countermeasure works that can be handled with basic techniques on a wide scale and on a continuous basis, it is possible to raise the level of technical skills and accumulate experience in survey, design, cost estimation, and construction. In particular, by having young engineers experience many such sites, it is expected that they develop an interest in the work and a sense of fulfillment, and that they grow up to become core engineers of DoST and remain active for a long time.

4) Study and accumulate experience in survey, design, cost estimation, and construction techniques at pilot sites in all ROs

The project provided intensive technology transfer mainly to the engineers from HQ and the two pilot ROs in Trongsa and Lobesa who participated in each WG of the project. These engineers participated in numerous seminars, workshops, and training in Japan during the project period, and by the end of the project, they had grown to the level of leading experts in slope disaster countermeasure works in Bhutan.

In order to impart their experience to a wider range of people, and to realize the benefits of the project throughout Bhutan, it is necessary to promote horizontal development with them as instructors promptly after the completion of the project. However, since these skills cannot be easily acquired through classroom learning alone, it is necessary to set up a pilot site based on the results of this project at all ROs and conduct a series of studies from survey, design, and cost estimation to construction, in order to study and accumulate experience in live technology.

5) Monitoring plan from project completion to ex-post evaluation

In JICA's technical cooperation projects, an "ex-post evaluation" is conducted several years after the completion of the project to assess the extent to which the project has been effective.

It is proposed that the implementation of slope disaster countermeasure works using the results of this project be monitored on a regular basis, not only for "ex-post evaluation" purposes, but also to ensure that all roads in Bhutan are safe and secure and passable at all times.

Possible monitoring indicators include:

(1) Number of slope disaster countermeasure works implemented (the greater the number, the greater the effect)

(2) Number of ROs that have implemented slope disaster countermeasures (the more, the greater the effectiveness)

(3) Number of slope hazards (the smaller the number, the greater the effect)

(4) Number of roadblocks (the fewer, the greater the effect)

(5) Number of ex-ante traffic control (the more, the greater the effect)

(6) Budget size related to slope disaster countermeasures (the larger the budget, the greater the effectiveness)

(7) Number of engineers engaged in the study of slope disaster countermeasures (the greater the number,

the greater the effectiveness)

Road slope disaster management in Bhutan has only just begun. JET hopes that the concepts and techniques introduced, experiences gained, and information collected through this project is put to good use, take root, and develop.