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

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

PRE-FEASIBILITY STUDY FOR PERMANENT COUNTERMEASURE AGAINST THE THUMANG CLIFF

APPENDIX

February 2017

KOKUSAI KOGYO CO., LTD.

EARTH SYSTEM SCIENCE CO., LTD.

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

OYO INTERNATIONAL CORPORATION

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Appendix 1

各種議事録

Minutes of Meeting in the Study

Record of Meetings/Information collection

Serial Number Minutes of meetings memo number	Date	Objective	Location	Name/Position of C/P participants	JET participants
No1	11-Oct	Meeting before traveling	JICA Headquarters	Mr. Kuge	Mr. Murata, Mr. Hara, Mr. Tozawa
No2	14-Oct	Meeting in office after arrival	JICA Bhutan Office	Mr. Yamada, Mr. Kono, Ms. Miyata	Mr. Murata, Mr. Hara, Mr. Tozawa
No3	17-Oct	First meeting with C/P	DOR	Lungten Jamtso, Chief Engineer and other 4 members	Mr. Murata, Mr. Hara, Mr. Tozawa
No4	18-Oct	Courtesy call to the minister of the Ministry of Works and Human Settlement	Ministry of Works and Human Settlement	Minister of the Ministry of Works and Human Settlement	Mr. Murata, Mr. Hara, Mr. Tozawa
No5	20-Oct	Information sharing from the Chief Engineer	DOR regional office in Trongsa	Chief Engineer	Mr. Murata, Mr. Hara, Mr. Tozawa
No6	21-Oct	Information sharing from the Tangsibji Hydro Power Energy General Construction Manager	Tangsibji Construction Office in Trongsa	Mr. Karma Choppel, General Manager	Mr. Murata, Mr. Hara, Mr. Tozawa
No7	25-Oct	Information sharing from Tangsibji Hydro Power Energy Construction Manager	Tangsibiji Local Office in Tshangka	Mr. Tshering, Construction Manager	Mr. Murata, Mr. Hara, Mr. Tozawa
—	26-Oct	DAI NIPPON CONSTRUCTION	Tangsibiji Local Office	Mr. Mizushima	Mr. Murata, Mr. Hara, Mr. Tozawa
No8	27-Oct	Courtesy call before Tunnel Information Collection in Punatsangchhu Hydro Power Energy Business	DOR Robeysa Local Office	Chief Engineer, Robeysa Local Office	Mr. Murata, Mr. Hara, Mr. Tozawa
No9	27-Oct	Road tunnel related information collection in Punatsangchhu Hydro Power Energy Business	Punatsangchhu Hydro Power Authhority	Mr. Khangzi, Managing Director	Mr. Murata, Mr. Hara, Mr. Tozawa
No10	28-Oct	Information collection for construction materials and its supply	Gravel company in Wangdi	President of the company	Mr. Murata, Mr. Hara, Mr. Tozawa
No11	31-Oct	Field study interim reporting	JICA Bhutan Office	Mr. Kono, Ms. Miyata	Mr. Murata, Mr. Hara, Mr. Tozawa
No12	2-Nov	Field study interim reporting	Ministry of Works and Human Settlement	Phuntso Wangdi, Deputy Chief and others	Mr. Hara, Mr. Tozawa
No13	1-Dec	Meeting in study site for soil dump	Study site	Mr. Kingzan, Staff in charge DOR	Mr. Tozawa
No14	2-Dec	Meeting in study site for soil dump	Study site	DOR staff and Department of Forests and Park Services staff	Mr. Tozawa
No15	3-Dec	Information Exchange with Construction Company	Study site	Hindustan Construction Company engineer	Mr. Tozawa
No16	8-Dec	Information Exchange	Study site	DOR staff	Mr. Tozawa
No17	13-Dec	Reporting before departure	JICA Bhutan Office	Mr. Yamada, Mr. Kono, Ms. Miyata	Mr. Tozawa
No18	14-Dec	Reporting before departure	DOR	Chief Engineer of the Design Department	Mr. Tozawa

Appendix 2

机上検討における評価表

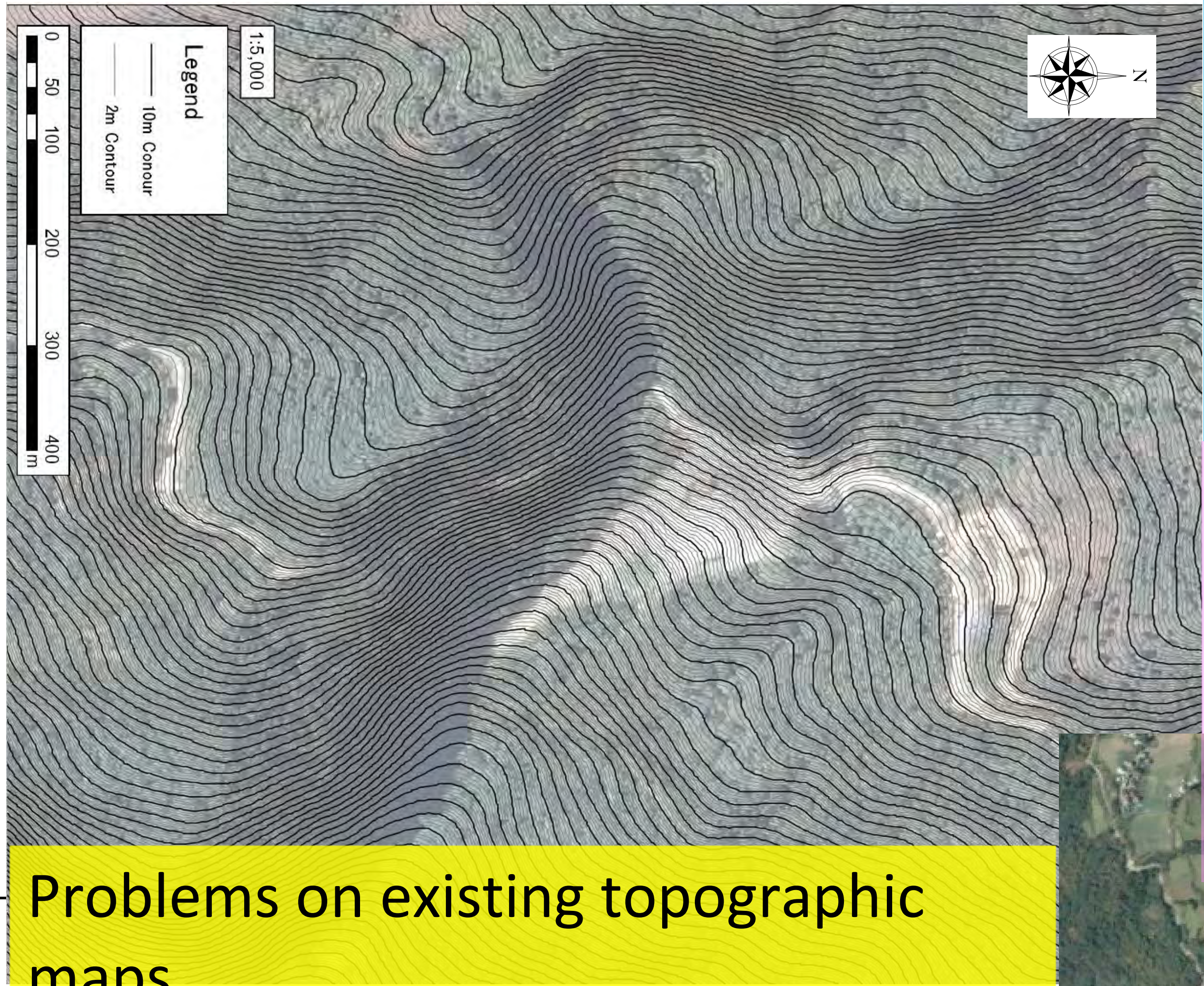
Evaluation Sheets
in the Desk Top Study

Route comparison and consideration from the existing data

History This route plan was made on 3 Oct 2016

Remarks This route overview plan was made before a field survey by using existing topographic maps with a low accuracy. It was therefore assumed with a highly probability that this plan would be re-considered.

It was considered extremely difficult to maintain high accuracy regarding any route plans made by using existing topographic maps with low accuracy.



Measures for topographic maps accurate enough to consider route option plans

→ Making DEM (Digital Elevation Model) data from satellite images, correcting numeric values of the terrain by field surveys and then converting to the CAD data for data sharing. (At the time, the satellite images were being purchased)

Observations from Google Earth :

・ Erosions of valleys are deep → Assumedly bedrocks are deep → Estimating and securing an appropriate overburden of a tunnel (3D and more) is crucial.

・ Necessary to confirm the alignment of the current road.

・ Necessary to make DEM from satellite images.

Problems on existing topographic maps,

・Contour lines of the maps do not comply with the site terrain conditions→Necessary to grasp terrains of Valleys/Cliffs → Necessary to identify with certainty the overburden of the tunnel.

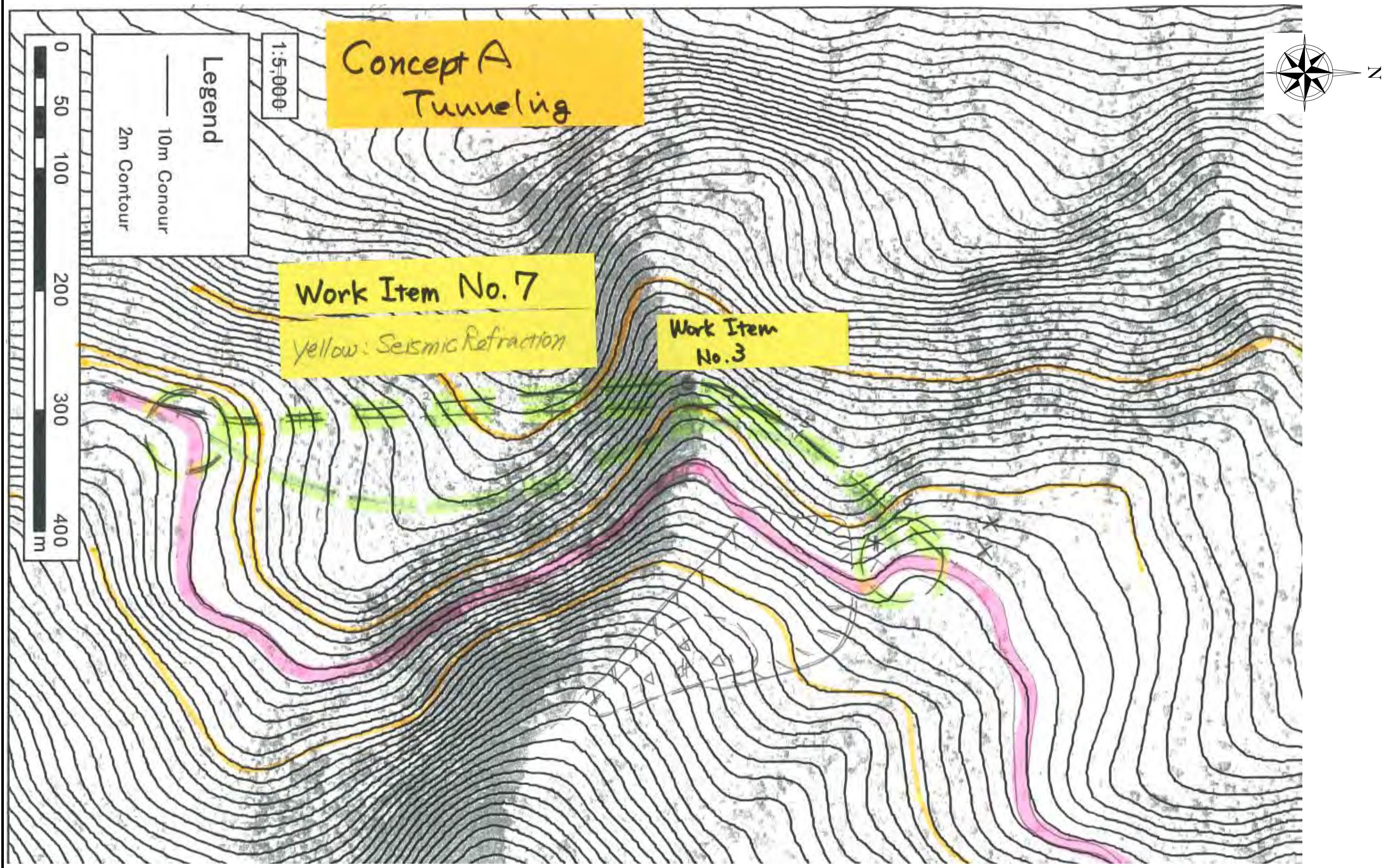
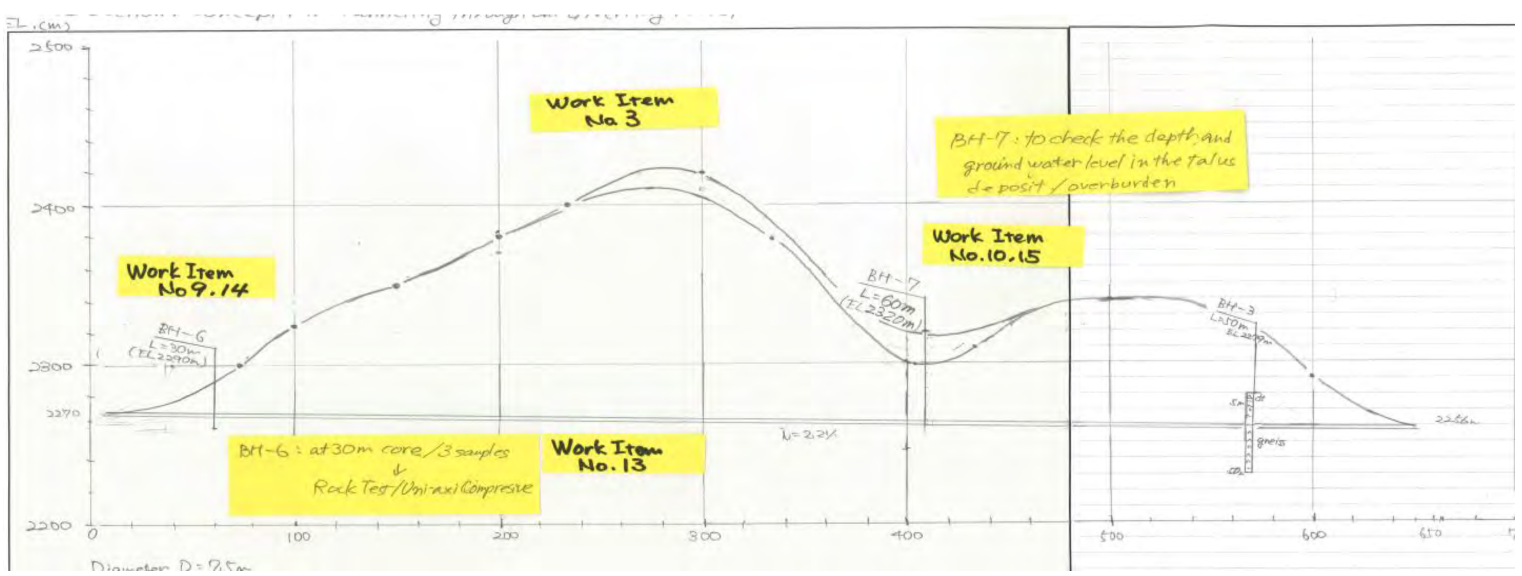
・Current road is not in the maps→Necessary to

Route comparison and consideration from the existing data

11 Oct 2016: KOKUSAI KOGYO/OYO INTERNATIONAL

History This route plan was made on 3 Oct 2016

Remarks This route overview plan was made before a field survey by using existing topographic maps with a low accuracy. It was therefore assumed with a high probability that this plan would be re-considered.

Plan A	Plan based on a Tunnel at the entire target section：To connect the beginning point to the end point of the target section with a tunnel as straight as possible.	Conditions / Comments / Remarks	
Plane view		Natural conditions: Geographical/ geological issues	・ Distribution and depths of talus deposits near the tunnel portals are unclear and they will be significantly influential in the tunnel construction. ・ Terrains and sediment loads in the valley at the middle of the target section have not been revealed clearly. → It is necessary to clarify the depths of the talus deposits and levels of the ground water with a borehole survey and to verify whether or not tunnel arch effects can be realized. ・ It is required to comprehend structures of columnar joints of metamorphic rocks as it will be significantly influential in the work efficiency for the tunnel drilling. ・ It is required to comprehend the presence/absence of a fault sheared zone in the valley site. This will be influential in selecting construction methods such as considering the applicability of auxiliary methods. ・ It is crucial to classify bedrocks based on the ground classification for an appropriate tunnel design. To do that, it is required to make efforts to improve the accuracy by means of elastic wave exploration.
		Construction work conditions: Issues of concern: Designing, Construction management and Cost estimate	・ Information of design conditions/criteria of the road are required such as design speed, width configuration, the tunnel clearance limit and so on. ・ It is preferable to adopt a plane road alignment without requiring road widening. ・ Tradeoff relationships may occur between the viewing distance and the plane curve radius:R. ・ It is required to examine whether the longitudinal alignment of the route connecting both sides of the tunnel portals is appropriate or not. ・ It is required to consider methods to adjust tunnel portals to connect with terrains and conditions of road widening areas. ・ It is required to consider securing spaces for construction yards and maintaining current traffic conditions during the construction period. ・ It is required to collect information of electric facilities for the construction and also for the maintenance after the construction. ・ It is required to examine the availability to procure construction machinery in the region and the country such as drilling machines, other heavy machinery and so on.
Longitudinal section		Social, economic and other conditions	・ It can be expected to provide a sense of security for road passers-by by implementing a road route inside the mountain by tunneling and by avoiding dangers of rock collapses from Thomang Cliff. ・ It can be also expected to fundamentally isolate itself from dangers of rock collapses at the steep cliff of the south side of Thomang Cliff. ・ By securing the road width, it can be expected to realize vehicle passage of large scale vehicles through the road with ample space. It will help to improve the efficiency and the safety of the transportation of equipment and materials for the hydro-power construction, too. ・ It is expected to shorten the traffic time of the road. This will also be helpful for the local society, especially for emergency activities.
		Issues to be examined in the field survey based on the above assumed conditions	・ To clarify contents of a road improvement plan of DoR at the target road section. ・ To identify depths of the surface soil and bedrocks around the tunnel portal at the south side of the tunnel. ・ To confirm the depths of the bedrocks at the valley site to check whether or not a tunnel arch formation can be secured sufficiently. If the arch can not be formed, it is necessary to move the plane alignment to a position where the depth of the overburden can be obtained for the arch effect. ・ It is necessary to take appropriate samplings of boring cores, to evaluate RQD (Rock Quality Designation) and to confirm the velocity distributions of the earth and rocks by the elastic wave exploration just above the tunnel route. From the analysis of those results, it is crucial to confirm the properties of the ground and to utilize them for the appropriate tunnel design. ・ A detailed topological survey around the tunnel route is required.

Route comparison and consideration from the existing data

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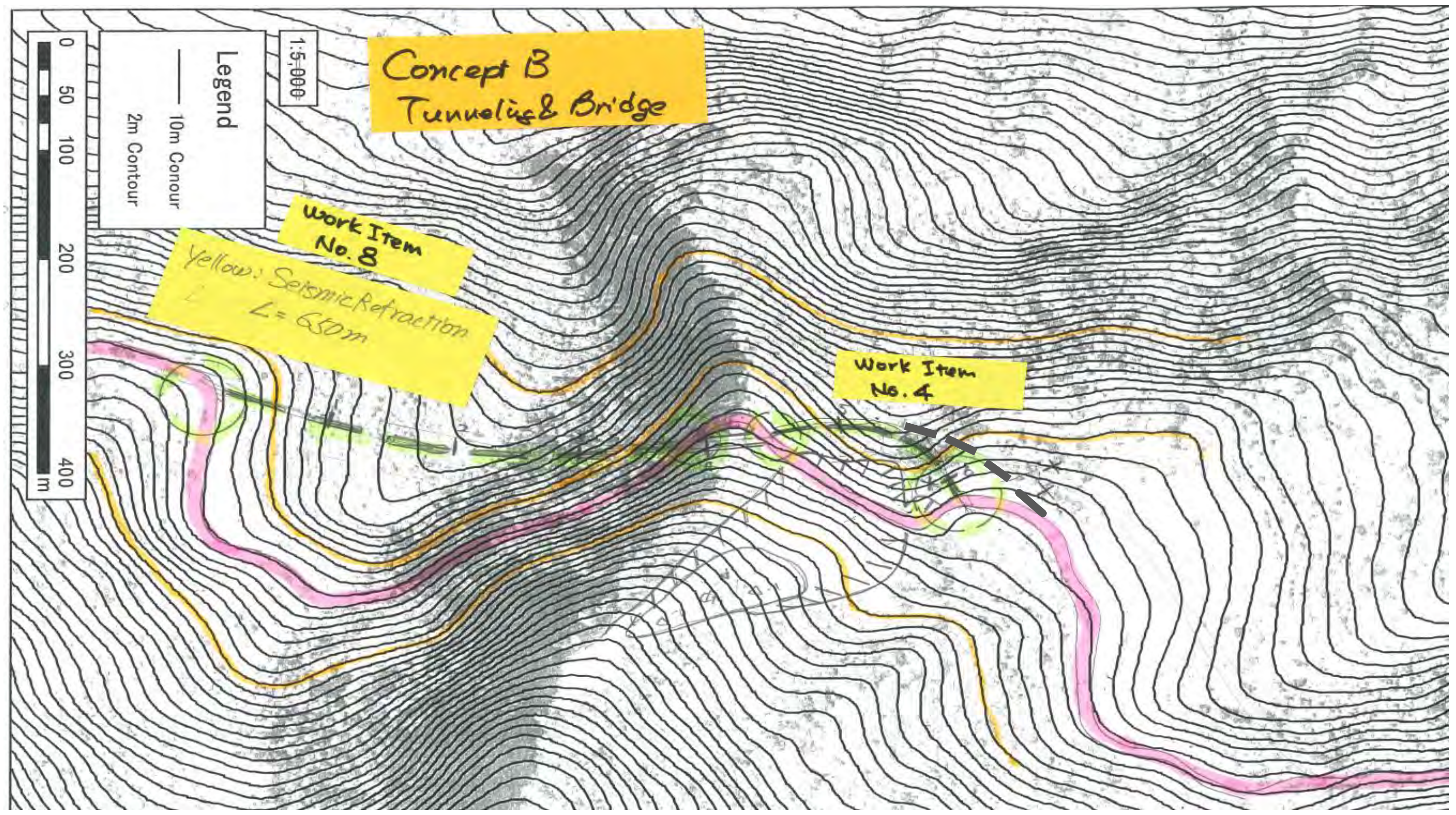
C — This route plan was made on 6 Oct 2016

Remarks — This route overview plan was made before a field survey by using existing topographic maps with a low accuracy. It was therefore assumed with a high probability that this plan would be re-considered.

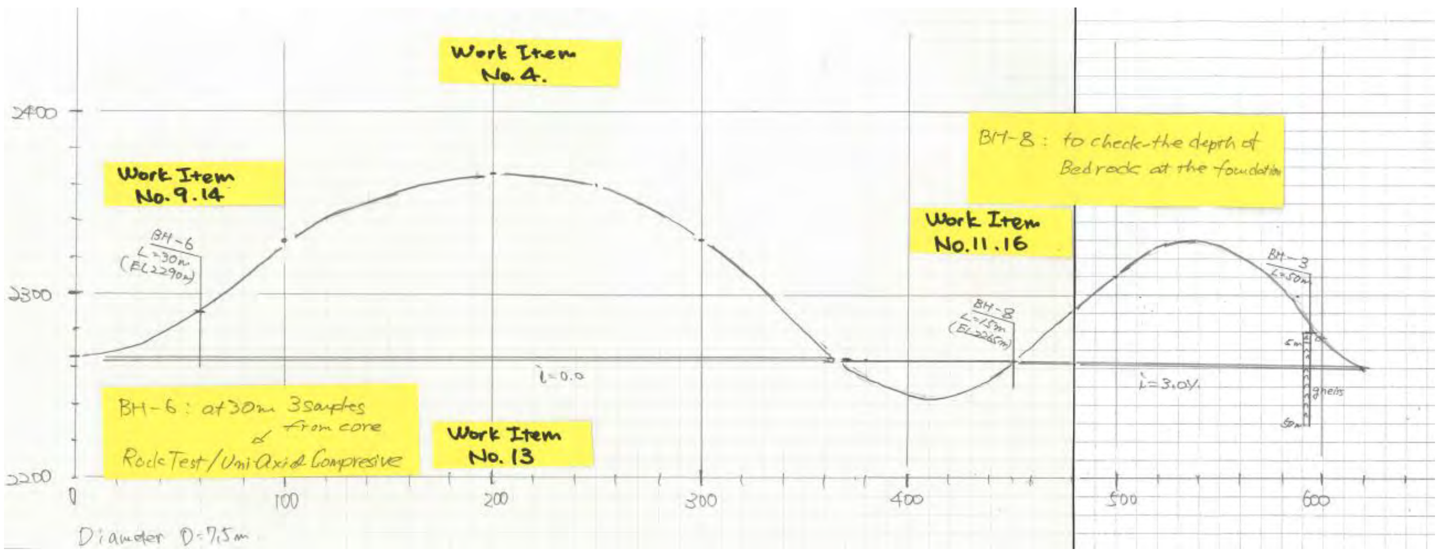
Plan B

Intergaration plan, a tunnel(s) with a bridge: To connect the beginning point to the end point of the target section with a tunnel and a bridge making the route as short as possible. A key issue of concern is the depth of bedrocks.

Plane view



Longitudinal section



Conditions / Comments / Remarks

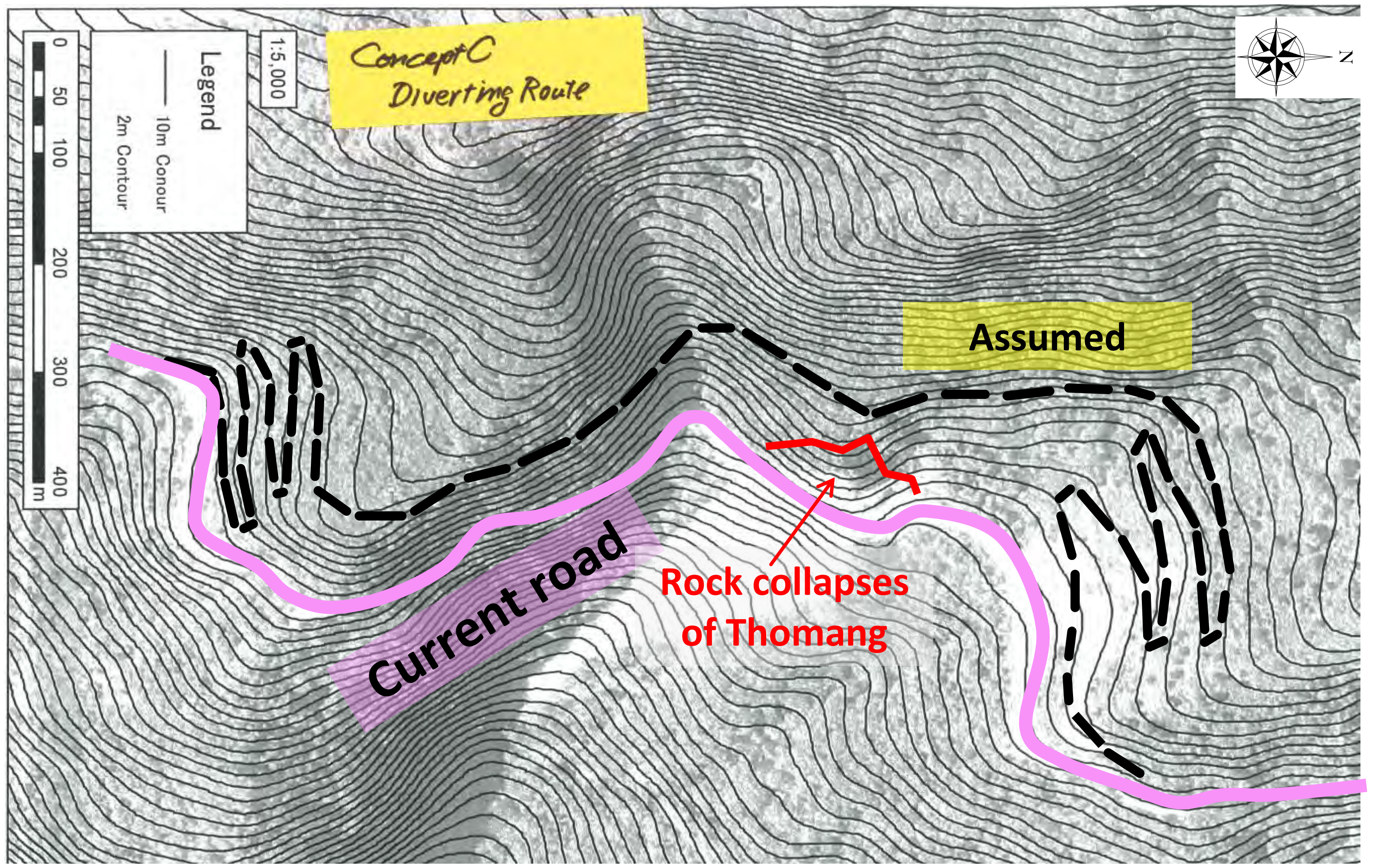
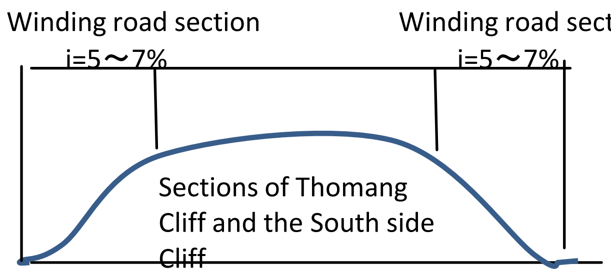
Natural conditions: Geographical/ geological	・ It may be possible to find the shortest route from this plan depending on conditions of the overburden of the tunnel and properties of the bedrocks of the rock-slopes. ・ It is crucial to comprehend the geographical and geological properties of the valley site, such as sediments and bedrock conditions, to clarify whether the sediments can be flown down under the bridge. ・ It is necessary to identify properties of bedrocks at bridge abutment positions. This will be dealt with through borehole surveys. ・ Distributions of sediments and talus deposits are influential in deciding positions and construction methods of tunnel portals and slope stability methods at the portal sites. ・ It is necessary to identify the depths of the bedrocks at the bridge abutment positions.
Construction work conditions: Issues of concern : Designing, Construction management and Cost estimate	・ It is requierd to confirm the design speed of the road. ・ It is required to consider the relationships between view distances and curve radius: R. ・ It is required to consider methods to adjust tunnel portal structures to connect with terrains of the sites and conditions of current road widening areas. ・ It is required to confirm the tunnel clearance limit from regulations and natural conditions. ・ Depths and hardness of bedrocks at bridge abutments are significantly influential in deciding the foundation types of the abutments. ・ It is required to examine and decide bridge supporting types. ・ It is required to judge in the field survey the availability of construction working spaces at narrow locations. Maintaining the current road traffic is the issue to be concerned about.
Social, economic and other conditions	・ It can be considered that implementing a road route inside the mountain by tunneling will avoid dangers of rock collapses from the Thomang Cliff. ・ It is possible to fundamentally isolate from dangers of rock collapse at the steep cliff of the south side of Thomang Cliff by avoiding the area through tunneling. ・ For the route of the South part of the target section, implementing a route to use the current road dealing with steep slopes combining with slope stability measures can be considered. In that case, it is required to conduct financial analysis to compare the costs with other optional routes. ・ It can be expected that this plan (with a tunnel, a bridge and current road improvement) is superior from a financial point of view compared with Plan A to construct a tunnel through the entire target section. ・ It is necessary to consider securing the road width to maintain the alternative vehicle traffic. ・ It is expected to shorten the traffic time of the road. ・ It is expected that large scale vehicles will be able to take the alternative traffic.
Issues to be examined in the field survey based on the above assumed conditions	・ To clarify contents of a road improvement plan of DoR at the target road section. ・ To identify properties of bedrocks around the tunnel portals. ・ To consider methods to make it available for waves of elastic wave exploration to penetrate into the tunnel depth in order to identify the ground rock classification appropriately. ・ To identify the columnar joint directions of metamorphic rocks appropriately from the observations of boring cores and reconnaissance in the field. They are significantly influential in the efficiency of tunnel excavation work. ・ To design a plane road alignment according to the prediction of rock collapses of Thomang Cliff based on long term probability.

Route comparison and consideration from the existing data

11 Oct 2016: KOKUSAI KOGYO/OYO INTERNATIONAL

History This route plan was made on 6 Oct 2016

Remarks This route overview plan was made before a field survey by using existing topographic maps with a low accuracy. It was therefore assumed with a high probability that this plan would be re-considered.

Plan C	Plan to make new road routes to avoid Thomang Cliff : To search and change road routes to avoid the Cliff.
Plane view	
Longitudinal section	A Photo Image of winding road From: Nikkan Kensetsu Kogyo Shimbun blog: Sindhuli road in Nepal Design speed V=30km  

Conditions / Comments / Remarks

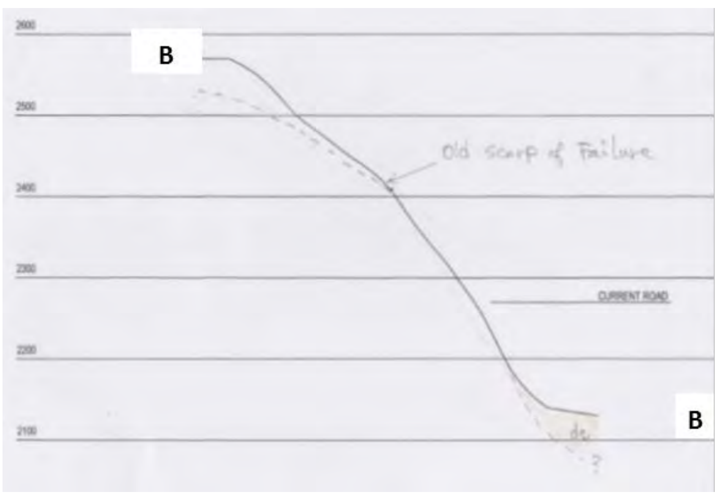
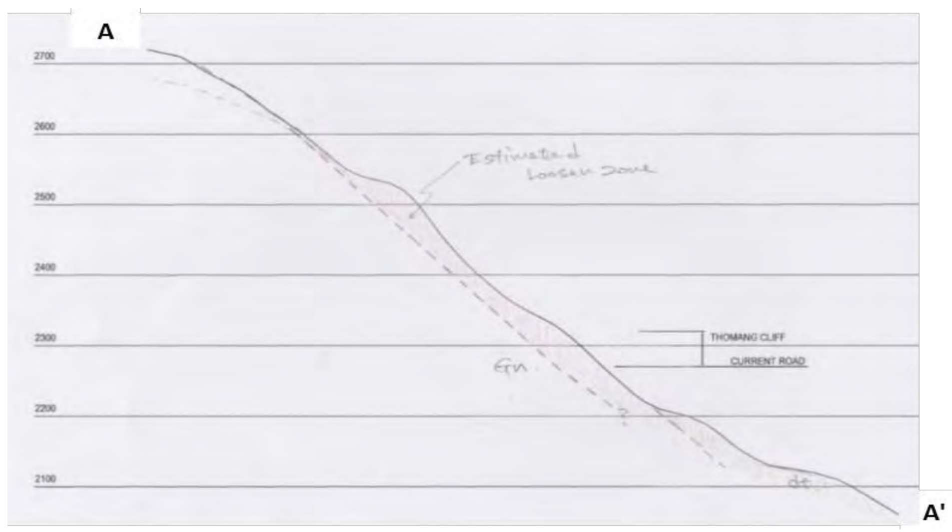
Natural conditions: Geographical/ geological issues	・ This route passes through the upper side of Thomang Cliff to avoid the Cliff. ・ Conditions of valleys and steep cliffs are unclear from the existing topographic maps and other existing information. ・ No current road alignment is shown on the maps. ・ It is difficult to grasp conditions of distributions of talus deposits from the existing data. ・ It is impossible to design a specific road alignment by using existing topo maps and information due to their lack of accuracy.
Construction work conditions: Issues of concern: Designing, Construction management and Cost estimate	・ It can be assumed that the design speed of the target road is V=30km/h, minimum curve radius is R=30m and Maximum road longitudinal gradient is 7 % according to the Type S road classification. This is because this is the primary National Highway with very steep terrains and it can be classified as Type S in the Road Design Standards. ・ It is an issue to be considered whether the structure can be planned with small scale structures of Gabion retaining walls or reinforced soil retaining walls, which are similar to Sindhuli Road in Nepal.
Social, economic and other conditions	・ By passing through above the cliffs can be considered a way to avoid dangers of rock collapses from Thomang Cliff and the steep slopes of the south side cliff. → New risks of other collapses in the new route may occur depending on the unknown geological/topographical conditions of the new route. ・ Securing sufficient road width for the new route is considered though it may be difficult to secure sufficient road width for traffic of large vehicles at hairpin curves in the winding road sections. ・ It can not be expected to shorten the traffic time. ・ Successive maintenance and management costs, such as maintaining tunnel lights, will not be required.
Issues to be examined in the field survey based on the above assumed conditions	・ To clarify contents of a road improvement plan of the target road section of DoR. ・ To identify locational relationships between hillside slopes and roads. ・ To grasp precise terrain features of the upper side slopes of the current road. ・ To grasp geological structures and distributions in the vicinity of the planned route. ・ To grasp loose rock conditions of the loose area of Thomnag Cliff and to estimate ranges of the loose area, especially at the ridge range on the upper side of the Cliff.

Route comparison and consideration from the existing data

11 Oct 2016: KOKUSAI KOGYO/OYO INTERNATIONAL

History This route plan was made on 3 Oct 2016

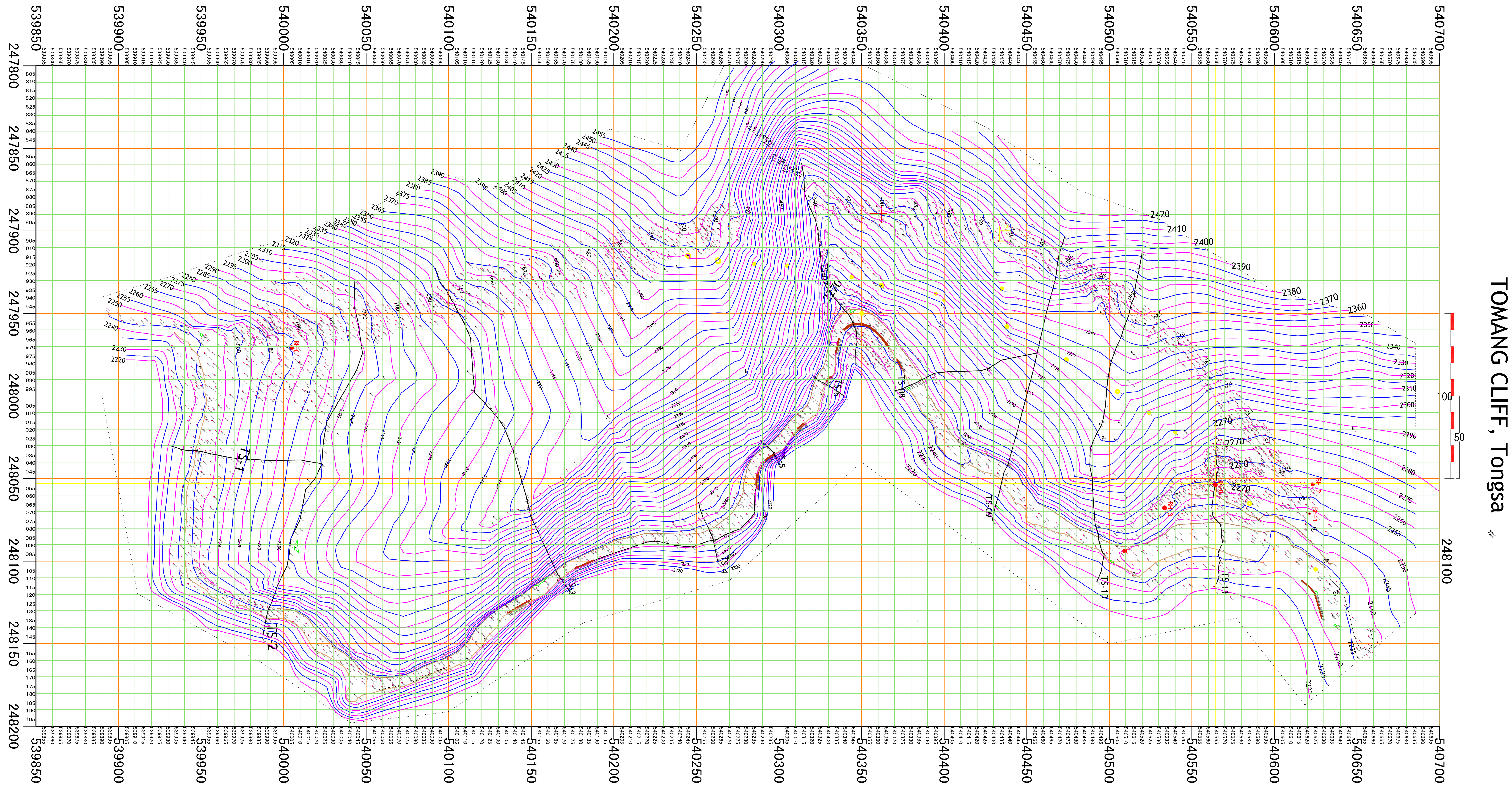
Remarks This route overview plan was made before a field survey by using existing topographic maps with a low accuracy. It was therefore assumed with a high probability that this plan would be re-considered.

Plan D	Plan to maintain and protect the current road route with slope stability measures: To maintain the safety of the target road with slope stability work at Thomang Cliff based on utilizing the current road route.	Conditions / Comments / Remarks	
Plane view		Natural conditions: Geographical/ geological issues	・ Paleozoic Gneiss rocks of metamorphic rocks are exposed along the road. ・ Steep, partly overhung, slopes of cut surfaces are almost all on the upper side of the road of the target section. Steep slopes with more than 45 degrees are also on the lower side of the road. ・ The road crosses several terrains of old collapses. ・ Around the middle of the section, a valley terrain crosses the road. Since the downward erosion of the valley is larger than the amount assumed from the catchment area, geological weak lines such as fracture zones may pass along the valley. ・ It was observed that low and high angles of columnar joints are significantly developed in the exposed rocks along the road side and it can be assumed from the rock structure that rocks are easily collapsed due to toppling and falling out. ・ The columnar joints of the exposed rocks are open widely and the rock structure seems loosened significantly.
		Construction work conditions: Issues of concern: Designing, Construction management and Cost estimate	・ It is necessary to excavate slopes of the upper side of the current road or to construct retaining walls to the lower side in order to secure the width of PNH standards as the current road widths are only around 4 m. ・ In the case of widening the width to the lower side of the road, it is necessary to confirm whether retaining wall work is applicable or not. ・ In the case of excavating to the upper side, it is necessary to find space for a temporal construction road and to secure the safety of workers under the excavating construction work. ・ It is also necessary to maintain the usual road traffic during the construction period, time regulations, etc., because there is no alternative route to use during the construction.
Longitudinal section	 	Social, economic and other conditions	・ The construction cost of this plan may be economically more advantageous over other proposals. ・ It can be expected to decrease road disasters caused by slope collapses (improving traffic safety). ・ In case of widening the road width to the upper side of the road, it needs a large scale of excavation of the slopes and it will have significant influence on the environment and the landscape of the vicinity. ・ Maintenance and management will be required depending on selected construction methods, such as maintenance of the surface slopes of cutting work.
		Issues to be examined in the field survey based on the above assumed conditions	・ To clarify contents of a road improvement plan of DoR at the target road section. ・ To identify locational relationships between hillside slopes and roads. ・ To grasp precise terrain features of the upper side slopes of the current road. ・ To grasp geological structures and distributions in the vicinity of the road. ・ To grasp loosened rock conditions of the loose area of Thomnag Cliff and to estimate the range of the loose area, especially at the ridge range on the upper side of the Cliff. ・ To consider stabilities of slopes covered with sediments and talus deposits. ・ To precisely grasp conditions of slopes on the lower side of the road such as slope gradients, vegetation and sediments covering the slopes, depth of bedrocks and so on. ・ To confirm circumstances of the construction work such as traffic regulation methods during the work and so on. ・ To consider construction roads and passages during the construction work. ・ To find and confirm sites for borrow pits, landfill for earth dump and stock yards as necessary.

Appendix 3

測量成果（平面図）

Topographical Survey Map



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PROJECT NAME
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TITLE
TOPOGRAPHIC MAP

DRAWING No.
SCALE 1:1500 —(A1)

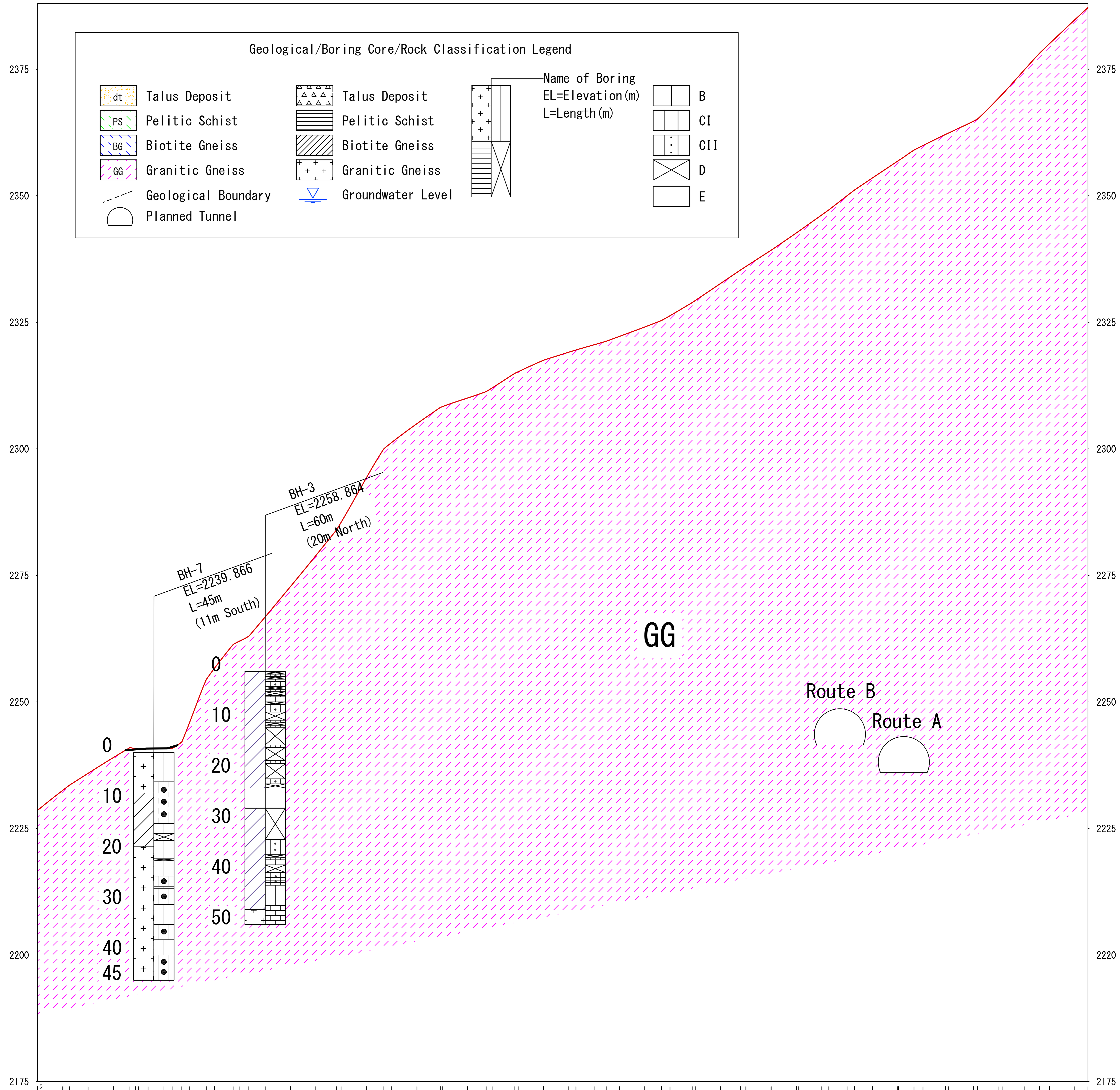
Appendix 4

地質平面・横断図

Geological Plane Map

Geological Traverse Section

THUMANG ROAD SECTION - TS-10 GEOLOGICAL TRANSVERSE PROFILE



Distance	TS 10 - Elevation
0.000	2228.559
5.000	2232.508
6.294	2233.530
10.000	2235.824
15.000	2238.920
18.264	2240.941
19.398	2240.750
20.000	2240.759
21.852	2240.785
25.000	2240.845
26.753	2240.879
28.521	2242.108
30.000	2245.869
33.365	2254.427
35.000	2256.556
38.667	2261.331
40.000	2262.046
41.764	2262.992
45.000	2266.913
50.000	2272.972
55.000	2279.032
59.136	2284.044
60.000	2285.524
65.000	2294.089
68.452	2300.002
70.000	2301.135
75.000	2304.796
79.618	2308.177
80.000	2308.309
85.000	2310.039
88.671	2311.309
90.000	2312.156
94.340	2314.920
95.000	2315.222
99.951	2317.491
100.000	2317.507
105.000	2319.085
106.415	2319.532
110.000	2320.569
112.510	2321.296
115.000	2322.230
120.000	2324.106
123.322	2325.352
125.000	2326.333
129.392	2328.901
130.000	2329.312
135.000	2332.682
138.946	2335.342
140.000	2336.021
144.961	2339.219
145.000	2339.246
150.000	2342.679
150.444	2342.984
155.000	2346.225
156.394	2347.216
160.000	2350.007
161.447	2351.127
165.000	2353.505
170.000	2356.851
170.142	2356.946
173.218	2359.017
175.000	2359.902
179.437	2362.106
180.000	2362.378
185.000	2364.789
185.785	2365.167
190.000	2369.379
190.787	2370.165
195.000	2374.816
198.036	2378.168
200.000	2380.018
205.000	2384.727
207.590	2387.167

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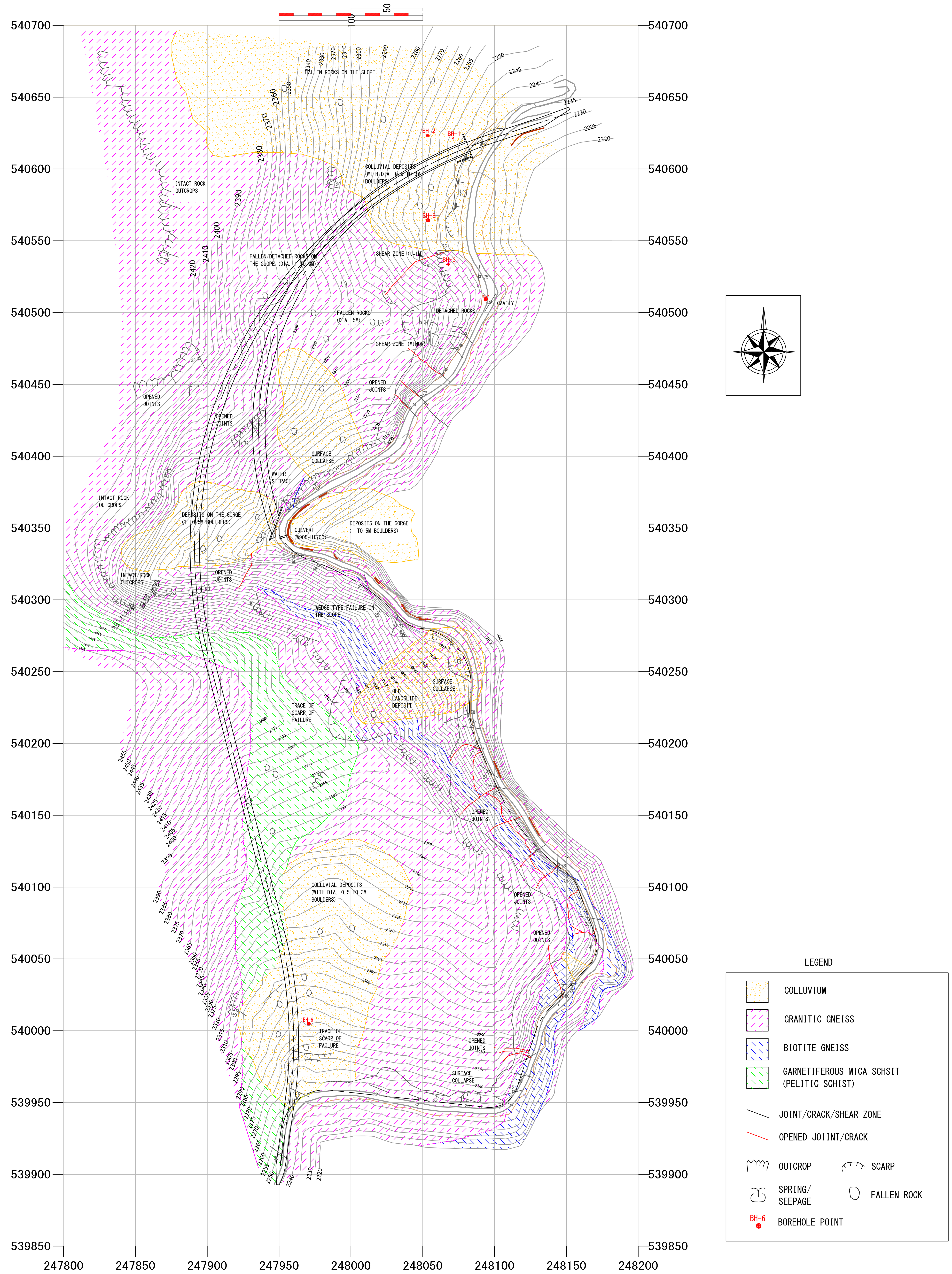
PROJECT NAME
THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN, JICA

TITLE
THUMANG ROAD SECTION - TS-10
GEOLOGICAL TRANSVERSE PROFILE

DRAWING No.
SCALE 1:500 —(A1)



TITLE

GEOLOGICAL MAP

DRAWING No.

SCALE 1:1500 (A1)

PROJECT NAME

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

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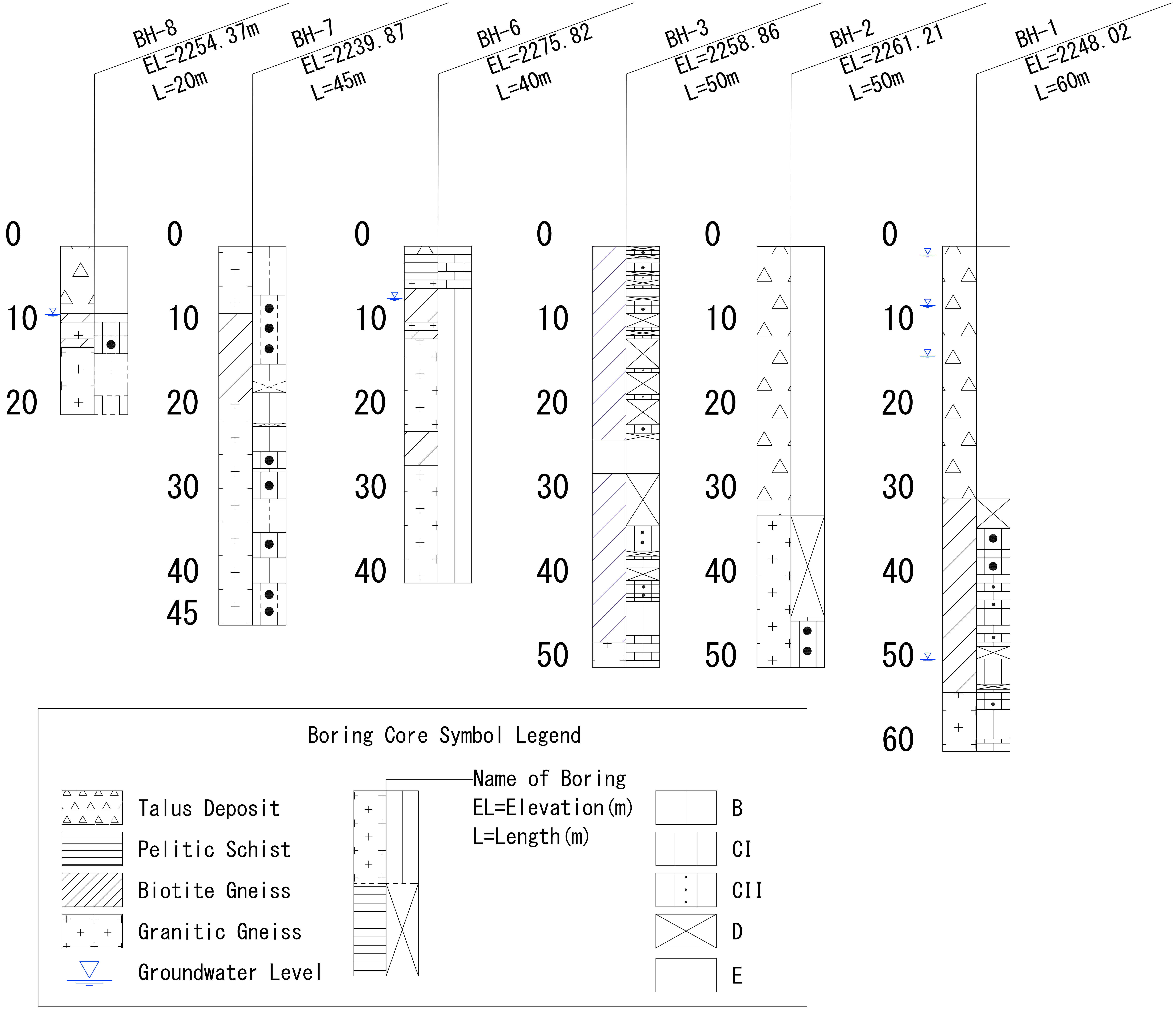
Appendix 5

ボーリング柱状図

Columnar Charts for Drilled Cores



KOKUSAI KOGYO CO., LTD. EARTH SYSTEM SCIENCE CO., LTD.	ORIENTAL CONSULTANTS GLOBAL CO., LTD. OYO INTERNATIONAL CORPORATION	PROJECT NAME THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN, JICA	TITLE BORING CORE COLUMN SYMBOL DRAWING No. SCALE 1:250 —(A1)

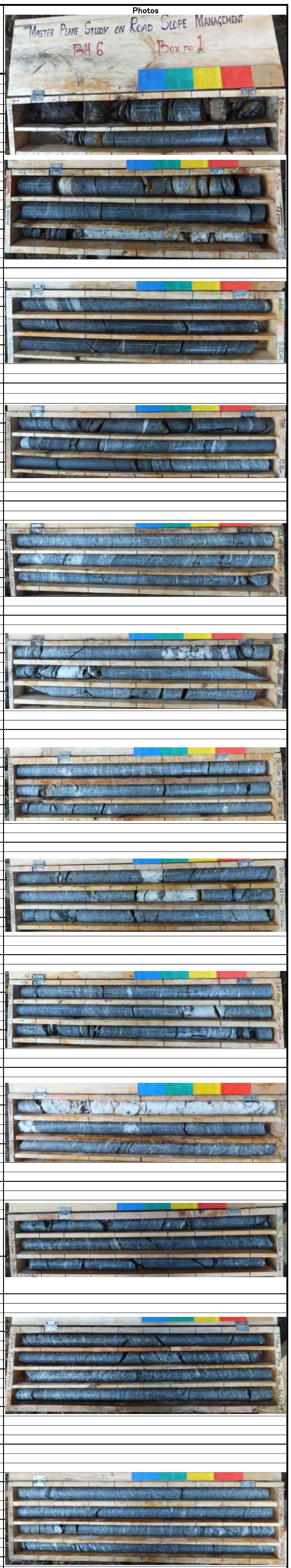
Columnal Chart of Borehole

Name of Boring	BH-6	Drilling Company Name	Karachakra Consultancy pv ltd.
Project Name	Road Slope Management Master Plan Project by JICA/Pre-F/S Study for Permanent Countermeasure against Tomang Cliff	Person in Charge	Krishna Basnet/phone 1764 9477
Place of Boring	In the southern portal area, about 3km to the north of Tsangkha Village	Drilling Machine Name	TOHO ADF20Engine
Date of Boring	From 30th October 2016 To 3rd November 2016	Hieght of mouth of boring	2275.821m
Length of Boring	40 [m]	Describer/Observer of the bored core	Japanese Experts Team

Elevation From [m]	Elevation To [m]	Depth From [m]	Depth To [m]	Progress Date	Drilling [m]	Casing Monitoring	GWL [m]	Classification Soil/Geology	Description	Weathering 1;None 2;Weak 3;Medium 4;Strong	Alteration α;None β;Weak γ;Strong	Rock Class	Maximum Core Length [cm]	Core Recovery Rate [%]	RQD [%]
2275.82		0.00	0.20					Overburden	0.0 – 0.2m; Overburden/Organic soil (peat)	–	–	–	–	80	–
		0.20	0.60												
		0.60	0.75						0.6 – 0.75; Soil/Sand intersection						
	2274.82	0.75	1.00						Porosity 10cm; Gravel (Pelitic Schist)						
2274.82		1.00	1.20					Schist	1.0 – 1.2m; Loss of core	3	γ	B	42	75	57
		1.20	1.35						1.2 – 1.8m; Dip angle 20° (Foliation)		β				
		1.35	1.80						1.35m Dip 30° (Joint)						
	2273.82	1.80	2.00						1.8m Dip 30° (Joint) Grade of weathering 2						
2273.82		2.00	2.15						2.15m, 2.25m, 2.6m, 2.8m; Dip 20° (Joint)			CI	20	95	45
		2.15	2.60			HX									
		2.60	2.80			11月13日									
	2272.82	2.80	3.00												
2272.82		3.00	3.35						3.35m; Dip 20° (Joint)			B	55	95	90
	2271.82	3.35	4.00							2					
2271.82		4.00	4.10					Granitic Gneiss	4.0 – 4.1m; Loss of core			CI	42	95	70
		4.10	4.70	13th NOV					Porosity 2–3cm (Biotite Gneiss)						
	2270.82	4.70	5.00					Biotite Gneiss	4.7m; Fragmentation of quartz in blocks	1	α				
2270.82		5.00	5.30						5.3 – 6.0m; Dip 20° – 30° (Foliation/Biotite)			B	100	100	100
							11月18日								
	2269.82	5.30	6.00												
2269.82		6.00	6.15			HXからNX	11月11日		6.15m; Dip 30° (Joint) Grade of weathering 2				30	95	95
		6.15	6.50			11月14日	11月16日		6.5m; Dip 20° (Foliation)	2	β				
	2268.82	6.50	7.00												
2268.82		7.00	7.30						7.3m;Dip 60° (Vein of quartz through joint)	1	α		30	95	82
	2267.82	7.30	8.00												
2267.82		8.00	8.40						8.0 – 8.4m; Dip 30° (Foliation)			CI	25	95	47
									Dip 30° (Joint) Grade of weathering 2	2	β	B			
									Continuation of 30° Joints in an						
	2266.82	8.40	9.00						interval of 5–6cm						
2266.82		9.00	9.50						9.0 – 9.5m; Dip 20–30° (Foliation/Joints)	1	α		35	100	68
								Granitic Gneiss	Porosity 5cm interval						
	2265.82	9.50	10.00					Biotite Gneiss							
2265.82		10.00	10.50						10.5m; Dip 20° (Joint) Degree of weathering 2				35	100	85
		10.50	10.60						10.6 – 11,0m; Core fragmentation						
									(Granite gneiss)						
	2264.82	10.60	11.00												
2264.82		11.00						Granitic Gneiss	11.0 – 12.0m; Dip 20–30° (Foliation)				85	100	100
	2263.82		12.00	14th NOV											
2263.82		12.00	12.70										50	100	100
		12.70	12.80						12.7 – 12.8m; Dip 20° (Joint)						
	2262.82	12.80	13.00						Degree of weathering 1						
2262.82		13.00	13.35						13.35m; Dip 20° (Joint) Degree of weathering 1				45	100	85
		13.35	13.80												
		13.80	13.90						13.8 – 13.9m; Dip 20–30° (Biotite)						
	2261.82	13.90	14.00												
2261.82		14.00	14.20						14.2m; Dip 50° (Joint)				45	95	85
		14.20	14.40						14.4m; Dip 20° (Foliation)						
		14.40	14.60						14.4 – 14.6m; Combination of quartz and						
	2260.82	14.60	15.00						biotite gneiss fractured like sheets						
2260.82		15.00	15.50						15.5m; Dip 80° (Joint)			CI	60	90	72
	2259.82	15.50	16.00									B			
2259.82		16.00	16.30						16.3m; Dip 50° (Joint) Degree of weathering 2				30	85	55
		16.30	16.70						Joints are brownish red	2	β				
									16.7m; Dip 20° (Joint) Degree of weathering 1						
	2258.82	16.70	17.00												
2258.82		17.00								1	α		52	100	100
	2257.82		18.00							2	β				80
2257.82		18.00	18.20						18.2m; Dip 80° (Joint) Degree of weathering 2				45	100	100
									Joints are yellowish brown	1	α				
	2256.82	18.20	19.00	15th NOV											
2256.82		19.00	19.40						19.4m; Dip 20° (Joint)				64	100	87
					Water										
	2255.82	19.40	20.00												
2255.82		20.00	20.60						20.6m; Dip 60° (Joint) Degree of weathering 2	2	β		32	100	78
	2254.82	20.60	21.00					Biotite Gneiss							
2254.82		21.00	21.30						21.3m; Dip 30° (Joint) Degree of weathering 2				33	95	83
		21.30	21.70												
									21.7m; Dip 0° (Joint) Degree of weathering 2						
	2253.82	21.70	22.00						Disking						
2253.82		22.00							22m – 23m; Dip 20–30° (Foliation)	1	α		42	95	66
	2252.82		23.00												
2252.82		23.00	23.30						23.3 – 23.4m; Dip 10°	2	β		32	100	90
		23.30	23.40												
		23.40	23.70							1	α				
	2251.82	23.70	24.00						23.7m; Dip 20° (Joint) Degree of weathering 2						
2251.82		24.00	24.50						24.5m; Dip 20° (Joint) Degree of weathering 1				50	100	95
	2250.82	24.50	25.00												
2250.82		25.00	25.10						25.1 – 25.4; Dip 30° (Joint)	2	β		35	95	45
		25.10	25.40						Degree of weathering 2						
										1	α				
	2249.82	25.40	26.00												
2249.82		26.00	26.10					Granitic Gneiss	26.1 – 27.0; Quartz (Pegmatite)		β	CII	38	85	50
		26.10	26.50						26.1 – 26.5m; Fragmentation in blocks, Porosity 2–3cm						
		26.50	26.70						26.7m; Dip 20° (Joint)						
	2248.82	26.70	27.00												
2248.82		27.00	27.70									B	67	95	100
										2	β				
	2247.82	27.70	28.00						27.7m; Dip 30° (Joint) Grade of weathering 2						
2247.82		28.00	28.40						28.4m; Dip 30° (Joint) Grade of weathering 2	1	α		55	100	95
										2	β				
	2246.82	28.40	29.00												
2246.82		29.00	29.35						29.35m; Dip 40° (Joint) Grade of weathering 2	1	α		22	100	75
		29.35	29.60						29.6m; Dip 20° (Joint) Grade of weathering 2						
										2	β				
	2245.82	29.60	30.00							1	α				
2245.82		30.00	30.30						30.3 – 30.6; Dip 70° (Joint) Grade of weathering				38	100	85
		30.30	30.60	16th NOV						2	β	B			
	2244.82	30.60	31.00												
2244.82		31.00	31.30						31.3m; Dip 60° (Joint) Grade of weathering 2				22	95	85
		31.30	31.80						31.8m; Dip 70° (Joint) Grade of weathering 2						
	2243.82	31.80	32.00												
2243.82		32.00	32.45						32.45m; Dip 50° (Joint) Grade of weathering 2				27	100	90
		32.45	32.55						32.55m; Dip 40° (Joint) Grade of weathering 2						
		32.55	32.65						32.65m; Dip 30° (Joint) Grade of weathering 1						
	2242.82	32.65	33.00						Dip 30° (Foliation)						
2242.82		33.00	33.20						33.2 – 33.7m; Fragmentation in blocks			CI	25	100	40
		33.20	33.70						Porosity 5cm, Dip 30° (Joint)						
										1	α				
	2241.82	33.70	34.00												
2241.82		34.00	34.50						34.5m; Dip 20° (Foliation)			B	58	100	95
		34.50	34.80						34.8m; Dip 40° (Joint)						
	2240.82	34.80	35.00												
2240.82		35.00											52	100	100
	2239.82		36.00												
2239.82		36.00	36.50						36.5m; Dip 60° (Foliation)				52	100	90
	2238.82	36.50	37.00												
2238.82		37.00	37.35						37.35m; Dip 30° (Joint) Degree of weathering 1				64	100	90
	2237.82	37.35	38.00												
2237.82		38.00	38.10						38.1m; Dip 30° (Joint) Degree of weathering 1				56	100	80
		38.10	38.20						38,1 – 38.2m; Fragmentation in blocks Porosity 3–5cm						
		38.20	38.80						38.8m; Dip 60° (Joint) Degree of weathering 1						
	2236.82	38.80	39.00	18th NOV											
2236.82		39.00	39.40						39.4m; Dip 40° (Joint) Degree of weathering 1				52	100	95
		39.40	39.60						39.6m; Dip 30° (Foliation)						
	2235.82	39.60	40.00												

Standard Penetration Test: On Site Data (First 15cm, Second 15cm, Last 15cm); Graph (10, 20, 30, 40, 50 以上, N [ ])

Photos



Columnal Chart of Borehole

Name of Boring	BH-7	Drilling Company Name	Karachakra Consultancy pv ltd.
Project Name	Road Slope Management Master Plan Project by JICA/Pre-F/S Study for Permanent Countermeasure against Tomang Cliff	Person in Charge	Krishna Basnet/phone no. 1764 9477
Place of Boring	At the road edge in front of Thumang Cliff	Drilling Machine Name	TOHO ADF20Engine
Date of Boring	From 29th October 2016 To 6th November 2016	Height of Mouth of Boring	2239.866m
Length of Boring	45 [m]	Describer/Observer of the Bored Core	Japanese Expert Team

Elevation From [m]	Elevation To [m]	Depth From [m]	Depth To [m]	Progress Date	Drilling [m]	Casing Monitoring	GWL [m]	Classification on Soil/Geology	Description	Weathering 1;None 2;Weak 3;Medium 4;Strong	Alteration α;None β;Weak γ;Strong	Rock Class	Maximum Core Length [cm]	Core Recovery Rate [%]	RQD [%]	Standard Penetration Test On Site Data (First 15cm, Second 15cm, Last 15cm) / Graph (10 20 30 40 50 More N [ ])
2239.86		0.00	0.80									CI	16	60	52	
	2238.86	0.80	1.00						0.8m; Bedding 30°							
2238.86		1.00	1.35						1.35m; Dip of Joint 30°				32	85	80	
	2237.86	1.35	2.00													
2237.86		2.00	2.50										80	85	80	
	2236.86	2.50	3.00	29th OCT								B				
2236.86		3.00	3.50										83	85	83	
	2235.86	3.50	4.00					Quartz Gneiss		1	α					
2235.86		4.00	4.80										70	95	95	
	2234.86	4.80	5.00				4.9 (31stOCT)		4.8m; Dip of Joint 60° (Grade of weathering 2)							
2234.86		5.00	5.60			NX 29th OCT							33	80	55	
		5.60	5.80						5.6 – 5.8m; Fragmentation in blocks			D				
	2233.86	5.80	6.00									CI				
2233.86		6.00	6.50										44	95	90	
	2232.86	6.50	7.00									B				
2232.86		7.00	7.40						7.35; Dip of joint 20° (Grade of weathering 2)			D	42	95	71	
		7.40	7.50							2	β	B				
	2231.86	7.50	8.00									CII / B				
2231.86		8.00	8.10										21	75	54	
		8.10	8.50	31st OCT				Mica Gneiss	8.1 – 8.5m; Fragmentation in rocks (Grade of weathering 2)		α	CII				
	2230.86	8.50	9.00													
2230.86		9.00	9.70							1		B	33	70	46	
	2229.86	9.70	10.00						9.7 – 10.00; Fragmentation in sand (fragile rock)		γ	D				
2229.86		10.00	10.30										38	95	90	
	2228.86	10.30	11.00						10.3 – 11.1m; Fragmentation in rocks		α	B				
2228.86		11.00	11.10								β	D	17	65	27	
		11.10	11.60							2						
		11.60	11.90					Quartz Gneiss	11.6 –11.9m; Blocks of quartz, Porosity 3–5cm		α					
	2227.86	11.90	12.00													
2227.86		12.00	12.30						12 – 12.3m; Fragmentation in blocks, Porosity 1- Loss of core		β		36	75	63	
	2226.86	12.30	13.00	1st NOV							α	CII / B				
2226.86	2225.86	13.00	14.00									D / CII	19	65	48	
2225.86	2224.86	14.00	15.00					Mica Gneiss		1		B	57	85	85	
2224.86		15.00	15.80								β		51	95	95	
	2223.86	15.80	16.00						15.8m; Dip of joint 30°							
2223.86		16.00	16.10								α		12	65	12	
		16.10	16.70						16.1 – 16.7m; Fragmentation in blocks (Rocks～Blocks), Porosity 5mm–2cm		β	D				
	2222.86	16.70	17.00	2nd NOV		NX 2nd NOV										
2222.86		17.00	17.80										45	70	65	
	2221.86	17.80	18.00						17.8m; Dip of the joint 70°							
2221.86		18.00	18.50						(Grade of weathering 1)	2			45	90	83	
	2220.86	18.50	19.00		Dry						α					
2220.86		19.00	19.70									B	47	100	100	
	2219.86	19.70	20.00						19.7m; Dip of the joint 20° (Grade of weathering 2)							
2219.86	2218.86	20.00	21.00										75	90	90	
2218.86		21.00	21.30						21 – 21.3m; Fragmentation in exfoliated state	1	β	D	42	80	64	
	2217.86	21.30	22.00													
2217.86		22.00	22.20										48	100	95	
	2216.86	22.20	23.00						22.2m; Dip of joint 60° (Grade of weathering 2)			B				
2216.86		23.00	23.80										28	100	92	
	2215.86	23.80	24.00						23.8m; Dip of joint 60° (Grade of weathering 2)							
2215.86		24.00	24.70										39	95	81	
	2214.86	24.70	25.00						24.7m; Dip of joint 70° (Grade of weathering 2)			D				
2214.86		25.00	25.90						25.9m; Dip of joint 80° (Grade of weathering 2)			B	43	100	92	
	2213.86	25.90	26.00									CII				
2213.86		26.00	26.80	3rd NOV					26.8m; Mica (exfoliated state)	2			60	95	70	
	2212.86	26.80	27.00									B / D				
2212.86	2211.86	27.00	28.00					Quartz Gneiss		1		B / D	62	80	62	
2211.86		28.00	28.30									CI	24	95	83	
	2210.86	28.30	29.00						28.3m; Quartz, Mica		α					
2210.86		29.00	29.70									B	30	85	67	
	2209.86	29.70	30.00						29.7m; Dip of joint 40° (Grade of weathering 1)			D				
2209.86	2208.86	30.00	31.00										32	90	80	
2208.86		31.00	31.30						31.3m; Dip of joint 30°				30	100	88	
	2207.86	31.30	32.00													
2207.86		32.00	32.30						32.3m; Dip of joint 40°			B	25	85	80	
	2206.86	32.30	33.00													
2206.86		33.00	33.30						33.3m; Bedding 30°	2			80	100	100	
	2205.86	33.30	34.00													
2205.86		34.00	34.30						34 – 34.3m; Fragmentation in blocks of mica				24	65	34	
		34.30	34.40													
		34.40	34.60						34.4 – 34.6m; Sheet like fragmentation Porosity			D				
	2204.86	34.60	35.00													
2204.86	2203.86	35.00	36.00	4th NOV							β	CI	49	75	49	
2203.86		36.00	36.30										27	50	27	
	2202.86	36.30	37.00					Mica Gneiss	36.3 – 37m; Fragmentation in fragile rocks							
2202.86		37.00	37.50						Porosity 2–3cm				30	95	79	
	2201.86	37.50	38.00									B				
2201.86	2200.86	38.00	39.00										41	85	74	
2200.86	2199.86	39.00	40.00								α		65	90	85	
2199.86		40.00	40.30						40 – 40.3m;Fragmentation in blocks, Porosity 3–			D	47	70	57	
	2198.86	40.30	41.00									B				
2198.86		41.00	41.40										21	65	41	
		41.40	41.70						41.4 – 41.7m; Mica fragmentation	1		D				
	2197.86	41.70	42.00								γ					
2197.86		42.00	42.10						42 – 42.1m; Inflow from silt to sand			CII	45	70	57	
		42.10	42.30	5th NOV				Quartz Gneiss								
	2196.86	42.30	43.00						42.3 – 43.0m; Fragmentation, Porosity 5–10mm			B / D				
2196.86	2195.86	43.00	44.00								α		56	100	90	
2195.86		44.00	44.27						44.27m; Inflow of silt			B	61	100	100	
	2194.86	44.27	45.00													

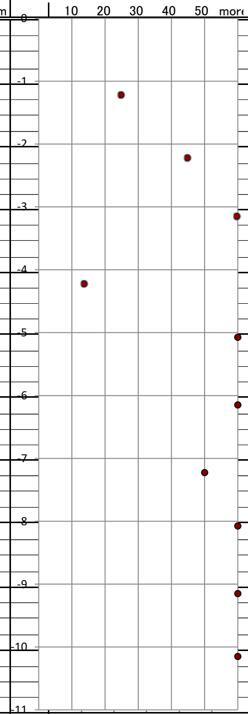
Photos

Columnal Chart of Borehole

Name of Boring	BH-8	Drilling Company Name	Karachakra Consultancy pv ltd.
Project Name	Road Slope Management Master Plan Project by JICA/Pre-F/S Study for Permanent Countermeasure against Thomang Cliff	Person in Charge	Krishna Basnet/phone no. 1764 9477
Place of Boring	In the Talus Deposit at the north of Thumang Cliff	Drilling Machine Name	TOHO ADF20Engine
Date of Boring	From 30th October 2016 To 3rd November 2016	Height of mouth of boring	2254.373m
Length of Boring	20 [m]	Describer/Observer of the bored core	Japanese Experts Team

Elevation From [m]	Elevation To [m]	Depth From [m]	Depth To [m]	Progress Date	Drilling [m]	Casing Monitoring	GWL [m]	Classification Soil/Geology	Description	Weathering (1;None 2;Weak 3;Medium 4;Strong)	Alteration (α;None β;weak γ;Strong)	Rock Class	Maximum Core Length [cm]	Core Recovery Rate [%]	RQD [%]	SPT First 15cm	SPT Second 15cm	SPT Last 15cm	N [ ]
2254.37		0.00	0.75	30th OCT	Dry	Perfolation to 8.5m from 8th NOv.		Overburden/Landslide	0.0 - 0.75m; Organic Soil with plant roots/Black sticky core				8	70	8				
	2253.37	0.75	1.00				31st OCT		0.75 - 1.00m; gneiss pebble with phai 5 to 8cm										
2253.37		1.00	1.45						1.00 - 1.45; SPT sample is clayey sand.				25	55	-	2	9	16	N=25
	2252.37	1.45	2.00						1.70 - 2.00m; Gneiss pebble with phai 3 to 5cm.										
2252.37		2.00	2.45	31st OCT					2.00 - 2.45m; SPT sample with gravel phai 2-3mm				29	90	67	1	16	29	N=45
	2251.37	2.45	3.00				1st NOV		2.50 - 2.60m; Gneiss pebble phai 10cm	2									
									2.70- 3.00m; Gneiss boulder phai 30cm										
2251.37		3.00	3.30						3.00 - 3.45m; SPT sample				27	45	55	23	>50		N>50
	2250.37	3.30	4.00						3.45 - 3.80m; Gneiss boulder phai 20cm.										
									3.80 - 4.00m; Clay with sand										
2250.37		4.00	4.45						4.00 - 4.45m; SPT sample				-	70	-	7	7	7	N=14
	2249.37	4.45	5.00						4.45 - 4.90m; sand										
									4.90 - 5.00m; sand with clay										
2249.37		5.00	5.15	1st NOV					5.00 - 5.15m; SPT sanple				13	30	15	>50			N>50
	2248.37	5.15	6.00						5.50 -5.60m; Gneiss pebble phai 10cm	2									
									5.60 - 5.70m; sand with silt										
2248.37		6.00	6.30						6.00 6.30m; SPT sanple				-	0	-	34	>50		N>50
	2247.37	6.30	7.00						6.50 - 6.90m; sand with clay										
2247.37		7.00	7.45						7.00 7.45m; SPT sample, homogenous sand/yellow bwon -> SPT sample may be from slime.				-	0	-	34	32	18	N=50
	2246.37	7.45	8.00				2nd NOV		7.45 - 7.80m; Slime core (Homogenous grain size)										
2246.37		8.00	8.15	2nd NOV	Water	HX 1st NOV		Biotite Gneiss	8.00 - 8.15m; SPT sample <- Slime SPT (N>50) bounced backed by Bec	1	α～β	B	43	50	50	>50			N>50
	2245.37	8.15	9.00						8.40 - 8.90; Dip 20° (Foliation)										
2245.37		9.00	9.30					Granitic Gneiss	9.00 - 9.15m; SPT sample <- Slime (Homogenous			CI 9.0-10.7m	20	30	30	30	>50		N>50
	2244.37	9.30	10.00																
2244.37		10.00	10.30						10.0 - 10.3; SPT sample <- Slime				28	90	90	17	>50		N>50
	2243.37	10.30	11.00						10.75 - 11.0m; Dip 20° (Foliation)			CII 10.7-12.4m							
									10.80m; Dip 40° (Joint)										
2243.37	2242.37	11.00	12.00					Biotite Gneiss	11.0 - 12.0m; Fragile Disk-like Cores l=10 to 15cı Dip 20 to 30° (Foliation), Biotite crystalize	2	β		15	70	15				
2242.37	2241.37	12.00	13.00			BX 2nd NOV		Granitic Gneiss	12.0 - 12.4m; Cores severely broken l=5cm.		α	B 12.4-19.2m	41	65	56				
2241.37	2240.37	13.00	14.00						13.4m; Dip 60° (Joint), Dip 20° (Foliation)				40	80	77				
2240.37	2239.37	14.00	15.00			Cementation upto 8.5m from 7th NOv.	3rd NOV		14.2m; Dip 20° (Joint) -> Face weathered with H Dip 20° (Foliation)				39	65	50				
2239.37	2238.37	15.00	16.00	3rd NOV					15.0m; Dip 60° (Joint) Weathering level 2				24	90	85				
2238.37	2237.37	16.00	17.00						16.3m; Dip 50° (Joint) Weathered 2, Dip 50° (Fol		β 16.1-16.3		20	95	66				
									16.5m; Dip 80° (Joint) Weathered 2										
2237.37	2236.37	17.00	18.00							1	α		80	90	80				
2236.37	2235.37	18.00	19.00						18 -19m; No Joints observed/ Core is hard itself				52	90	85				
2235.37	2234.37	19.00	20.00						19.2 - 19.4m; Biotite/Quarts blocked		β 19.2-19.5 ?	CI	21	90	21				

Standard Penetration Test/N value — Graph

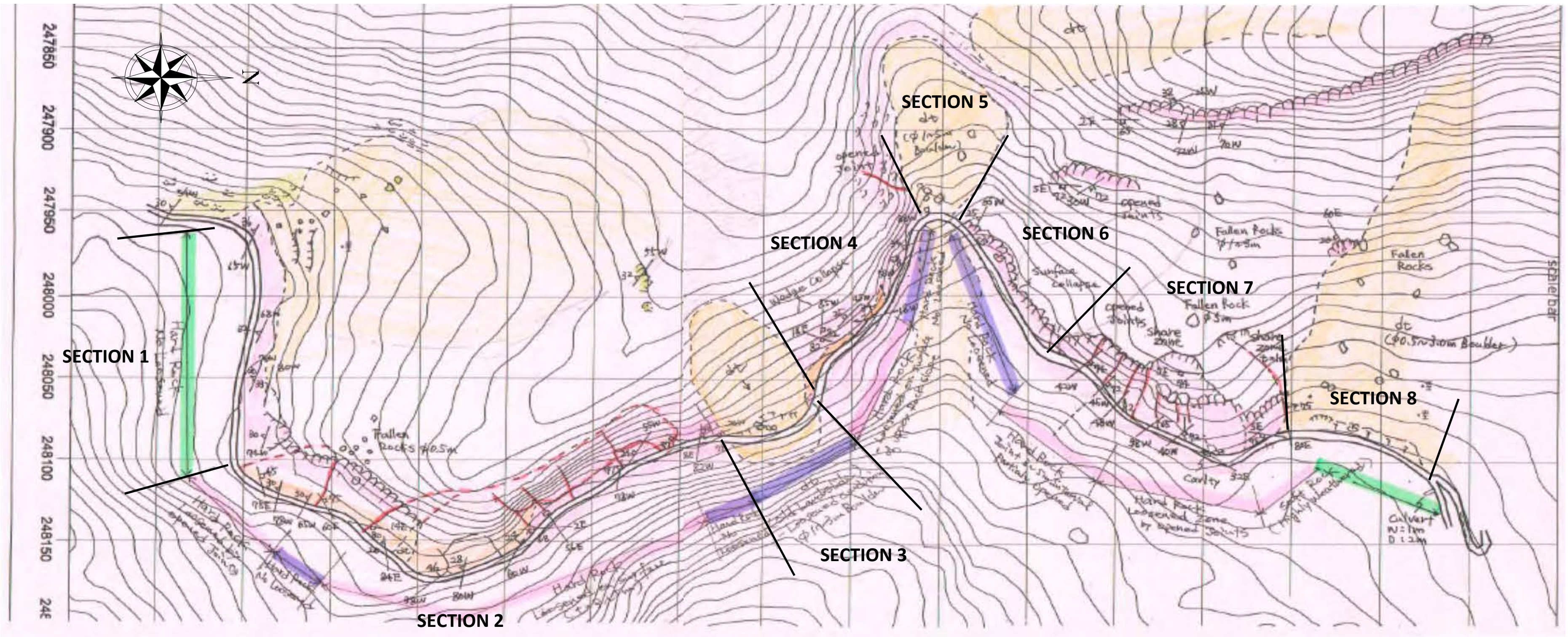


Appendix 6

道路斜面調査結果

Survey Results for Road Slopes Countermeasures

Site Reconnaissance Map



LEGEND (凡例)

dt Talus Deposit (崖錐堆積物)
Biotite Gneiss (黒雲母片麻岩)
Pelitic Schist (泥質片岩)
Granitic Gneiss (花崗片麻岩)
Geological boundary (地質境界)
Opened joint (開口節理)
Outcrop (露頭)
Fallen/Detached Rock (転石・浮石)
Dip and Strike (走向傾斜)
Joint (節理)
Schistosity (片理)
Bedding (層理)
Fault (断層/破砕帯)
Spring/Seepage (湧水)

<Stability Evaluation (安定度評価)>

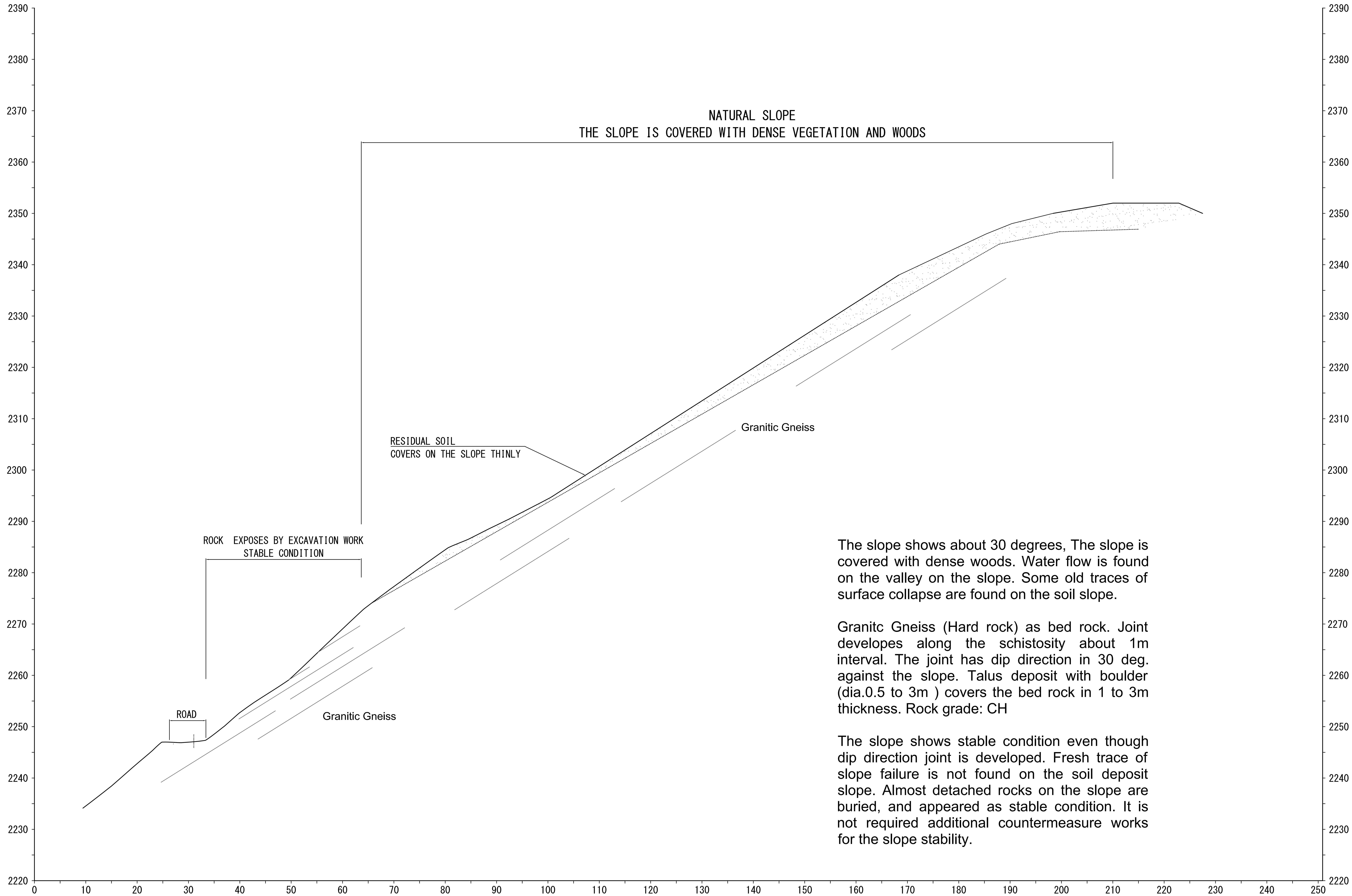
Loosened/Unstable (緩み大/不安定)
Loosened partially (部分的に緩む/やや不安定)
Stable (安定)

50m grid on the Figure

The Project for Master Plan Study on Road Slope Management in Bhutan, JICA
Road Slope Evaluation Table

	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	SECTION 7	SECTION 8
Length	140m	335m	78m	110m	30m	98m	168m	95m
Topography	The slope shows about 30 degrees, The slope is covered with dense woods. Water flow is found on the valley on the slope. Some old traces of surface collapse are found on the soil slope.	The both sides slope of the road show more than 70 deg. The rock slope on mountain side shows overhanging by excavation to secure traffic space. A natural slope about 25 deg. appears above the rock slope with dense woods. Detached rocks (dia. 0.5m) are found on the natural slope.	The topography and road alignment indicated possibility of landslide occurrence in past times. The slope coved by dense vegetation. The natural slope shows more than 45 deg. Slope failure is found at toe of the slope. The failed slope surface is wed condition even in the dry season.	The both side slope of the road show more than 70 deg. The rock slope on mountain side shows overhanging. Wedge type of rock failure are found at some part of the upper slope. Small terrace in 10m width is found 30m above from road, and the steep rock slope continue after the terrace.	The valley surrounded by cliffs crosses the road. Water flow is found on the valley. Debris and boulders deposit on the valley bed with dense vegetation. Downstream side also is covered by debris and boulders about 80m away from road. After the debris area, the slope shows steep angle more than 70 deg.	Natural slope exists behind rock slope (10m height and more than 70 deg.) along the road. The natural slope shows 50 deg. Slope on valley side shows 50 deg. natural slope. Both slopes are covered with dense vegetation.	The both side slope of the road show more than 70 deg. The height of rock exposed slope is 40 to 60m. The natural slope of the rock slope shows ridge province, and is covered with dense vegetation.	The natural slope shows 30 to 40 deg. Angle. The whole slope is covered with dense vegetation and trees. Detached rocks more than 5m are found on the slope. South part of the slope shows landslide feature. Water flow is found on the valley shape line on the slope.
Geology	Granitic Gneiss (Hard rock) as bed rock. Joint develops along the schistosity about 1m interval. The joint has dip direction in 30 deg. against the slope. Talus deposit with boulder (dia.0.5 to 3m) covers the bed rock in 1 to 3m thickness. Rock grade: C_H	Granitic Gneiss and Biotite Gneiss (Hard rock both) as bed rock. Biotite Gneiss shows undip direction schistosity against slope less than10 deg. Generally, more than 70 deg. (dip) and 20 deg. (undip) joints are found. Rock grade: C_M	The slope consists of debris of landslide. Boulders of Granitic Gneiss (dia 1 to 2m) are found on the debris. Since the rock on the outcrop at toe of the slope shows loosen and soft condition, the rock part might be the part of debris of the landslide. Rock grade: C_L～D	Granitic Gneiss (Hard rock) as bed rock. Biotite Gneiss exists in the bed rock in lens-shape partially. Several sense of steep angle joints are developed, and gentle undip direction joint about 25 deg. is found as well. Rock grade: C_M	Granitic Gneiss (Hard rock) as bed rock. River deposit material with boulder (dia. 1 to 3m) cover on the valley bed. Thickness of the deposit layer will be more than 5m. Rock grade: C_H	Granitic Gneiss (Hard rock) as bed rock. The rock has schistosity in 15 deg dip direction against slope. Joint is not prominence. Debris with boulder (dia. 0.5 to 1m) covers on the natural slope. The thickness of the debris layer will be about 3m. Rock grade: C_H	Granitic Gneiss as bed rock of this section. Even some parts of rock is soft, the bed rock is hard in general. The schistosity is not developed. Joints with high angle more than 70 deg. are developed. Shear zone is found at some parts along the joint. Rock grade: C_M～C_L	Talus deposit with boulder (dia. 1 to 3m) covers on the bed rock, Granitic Gneiss (estimated). Outcrop of bed rock is not found on the slope.
Stability	The slope shows stable condition even though dip direction joint is developed. Fresh trace of slope failure is not found on the soil deposit slope. Almost detached rocks on the slope are buried, and appeared as stable condition. It is not required additional countermeasure works for the slope stability.	The rock slope shows unstable condition due to opened joint with steep angle developed behind overhanging parts. The thickness of unstable parts will be 3 to 10m. Many opened joints with steep angle are found. Since the valley side slope shows steep angle, road widening shall be executed on mountain side slope.	At the present, activity of the old landslide is not detected. Area of the failed slope will be extended in the coming rainy season unless the slope is treated. Since the valley side slope shows steep angle, the excavation for road widening shall be executed on mountain side slope. In that case, stability of the old landslide shall be studied, and put some measures as required.	Some parts on/around overhanging and wedge-type failure show loosened condition by opened joints. Thickness of loosened parts will be about 3m. Since valley side slope shows steep angle (almost vertical), excavation for road widening shall be executed on mountain side slope. The loosened area will be extended due to excavation by blasting. The slope protection work will be required.	Since dense vegetation is found on the valley deposit, and boulder covered in moss are found, trace of major debris flow are not found, but minor debris flow. Since it will be difficult to secure firm foundation of on downstream side, the road shall be extended to mountain side. Culvert shall be installed (2000W*2000D) at cross point of road and valley .	The slope on mountain side appears stable condition even though minor surface collapse is found on the cut slope. Fallen rock (dia.1m) is found beside the road. Since the valley side slope is steep angle, the road widening shall be executed on mountain side slope. Some measure for rockfall and water treatment shall be required after excavation.	The slope area is unstable condition. Opened joints and shear zones are found on the rock slope. Some cavities are found by drilling survey. According to the study, the both side rock slopes of the road consist of detached rock blocks including the road. The loosened zone can be estimated more than 50m deep from the slope surface. It will be difficult to deal with the slope protection by structure measure.	Even though landslide topographical feature is found at south part of the slope, any trace of landslide activity is not found. At the present, trace of fallen rocks and slope failure are not found as well. The toe of the slope has been excavated to extend the road width. Minor surface collapse is found on the cut slope. The additional slope protection measure is not required at the present.
Cross Section	TS-01	TS-02 TS-03	TS-04	TS-05	TS-07	TS-08	TS-09 TS-10	TS-11
Photo								

THOMANG ROAD SECTION - TS-01



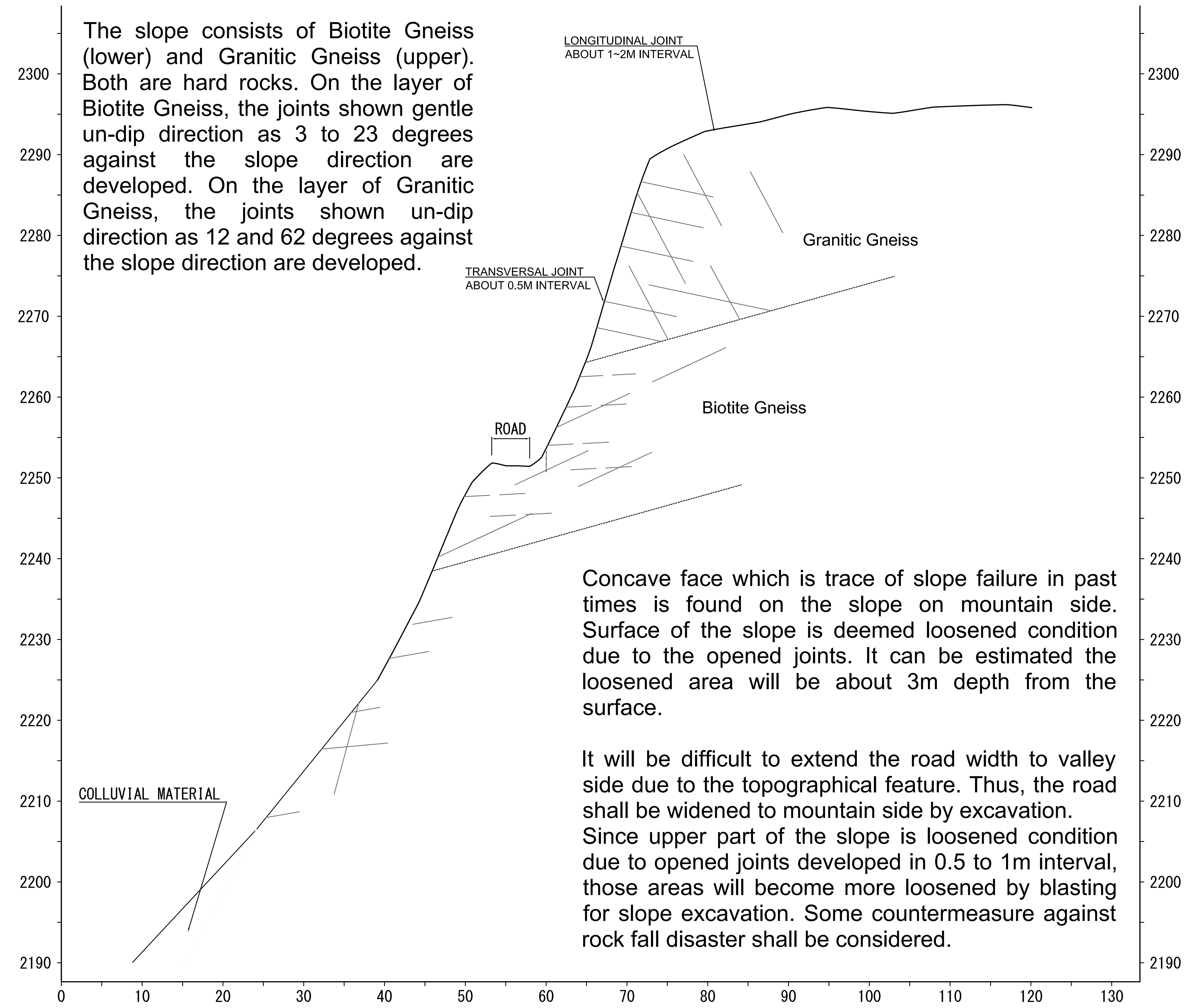
The slope shows about 30 degrees, The slope is covered with dense woods. Water flow is found on the valley on the slope. Some old traces of surface collapse are found on the soil slope.

Granitc Gneiss (Hard rock) as bed rock. Joint developes along the schistosity about 1m interval. The joint has dip direction in 30 deg. against the slope. Talus deposit with boulder (dia.0.5 to 3m) covers the bed rock in 1 to 3m thickness. Rock grade: CH

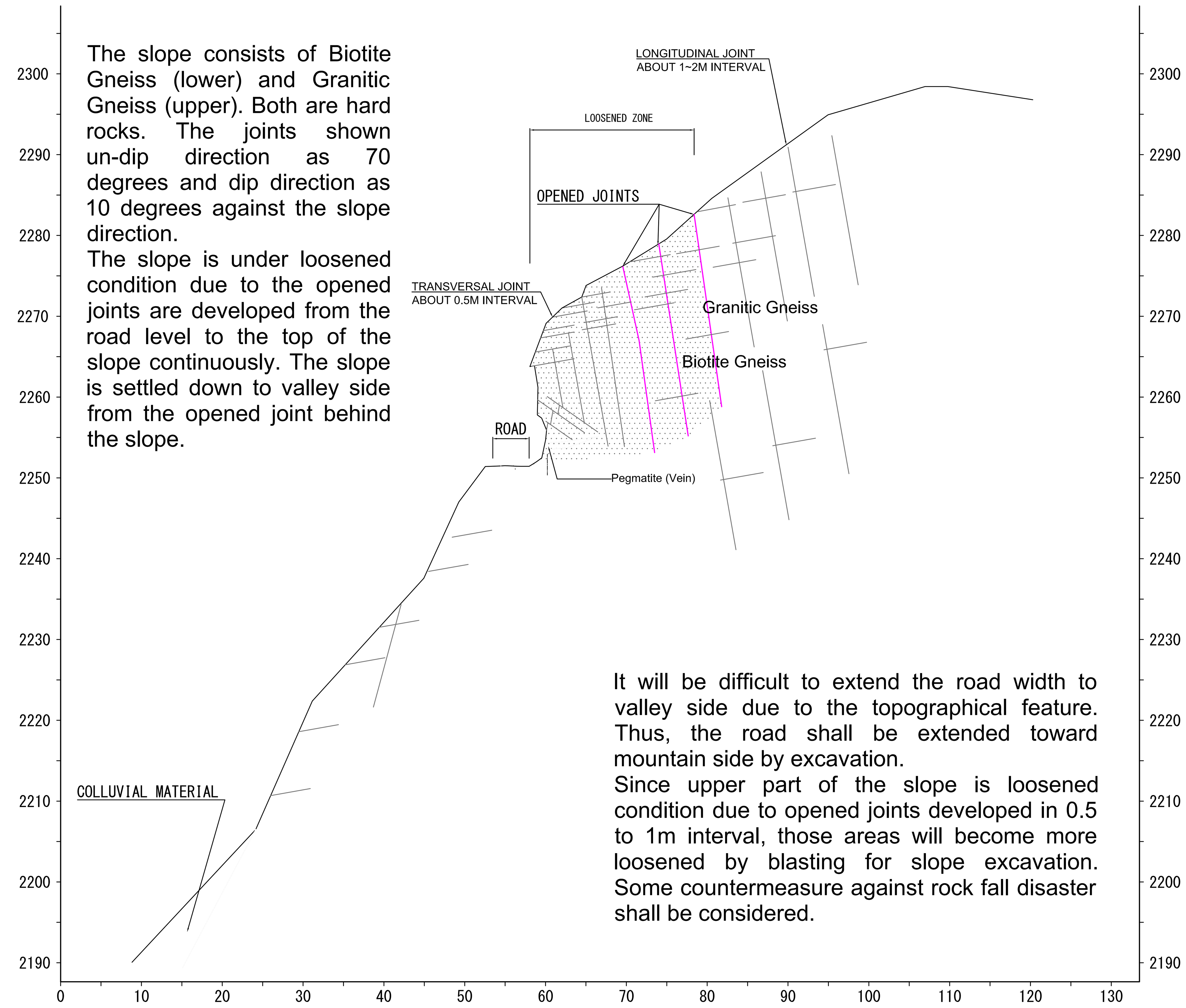
The slope shows stable condition even though dip direction joint is developed. Fresh trace of slope failure is not found on the soil deposit slope. Almost detached rocks on the slope are buried, and appeared as stable condition. It is not required additional countermeasure works for the slope stability.

KOKUSAI KOGYO CO., LTD. EARTH SYSTEM SCIENCE CO., LTD.	ORIENTAL CONSULTANTS GLOBAL CO., LTD. OYO INTERNATIONAL CORPORATION	PROJECT NAME **THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN, JICA**	TITLE GEOLOGICAL CROSS SECTION (TS-01) DRAWING No. SCALE 1:400 -(A1)

THOMANG ROAD SECTION - TS-2

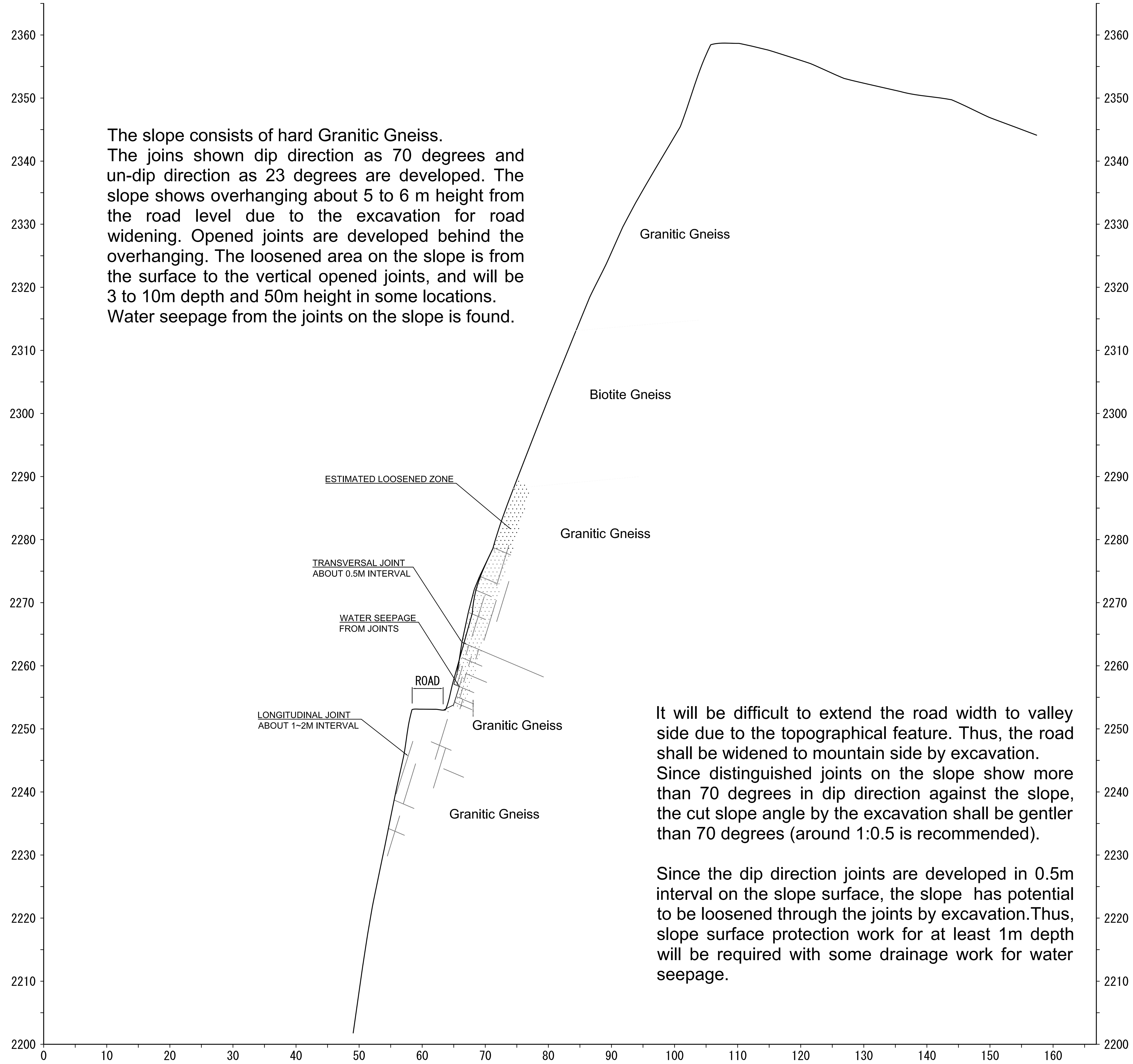


THOMANG ROAD SECTION - TS-02-1



KOKUSAI KOGYO CO., LTD. EARTH SYSTEM SCIENCE CO., LTD.	ORIENTAL CONSULTANTS GLOBAL CO., LTD. OYO INTERNATIONAL CORPORATION	PROJECT NAME **THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN, JICA**	TITLE GEOLOGICAL CROSS SECTION (TS-02, TS-02-1) DRAWING No. SCALE 1:400 -(A1)

THOMANG ROAD SECTION - TS-03



The slope consists of hard Granitic Gneiss.
The joins shown dip direction as 70 degrees and un-dip direction as 23 degrees are developed. The slope shows overhanging about 5 to 6 m height from the road level due to the excavation for road widening. Opened joints are developed behind the overhanging. The loosened area on the slope is from the surface to the vertical opened joints, and will be 3 to 10m depth and 50m height in some locations.
Water seepage from the joints on the slope is found.

It will be difficult to extend the road width to valley side due to the topographical feature. Thus, the road shall be widened to mountain side by excavation.
Since distinguished joints on the slope show more than 70 degrees in dip direction against the slope, the cut slope angle by the excavation shall be gentler than 70 degrees (around 1:0.5 is recommended).

Since the dip direction joints are developed in 0.5m interval on the slope surface, the slope has potential to be loosened through the joints by excavation.Thus, slope surface protection work for at least 1m depth will be required with some drainage work for water seepage.

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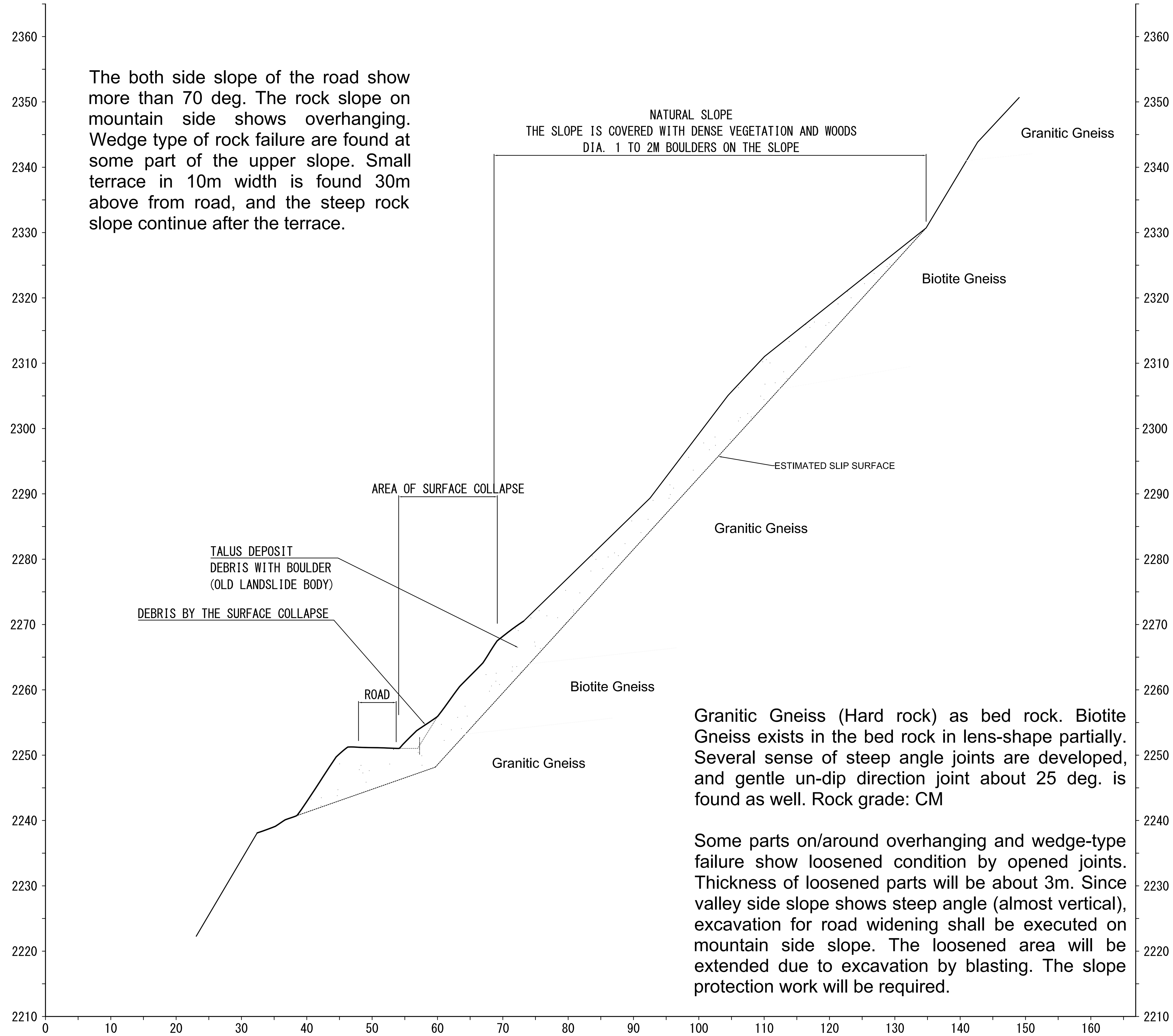
THOMANG ROAD SECTION - TS-04

The both side slope of the road show more than 70 deg. The rock slope on mountain side shows overhanging. Wedge type of rock failure are found at some part of the upper slope. Small terrace in 10m width is found 30m above from road, and the steep rock slope continue after the terrace.

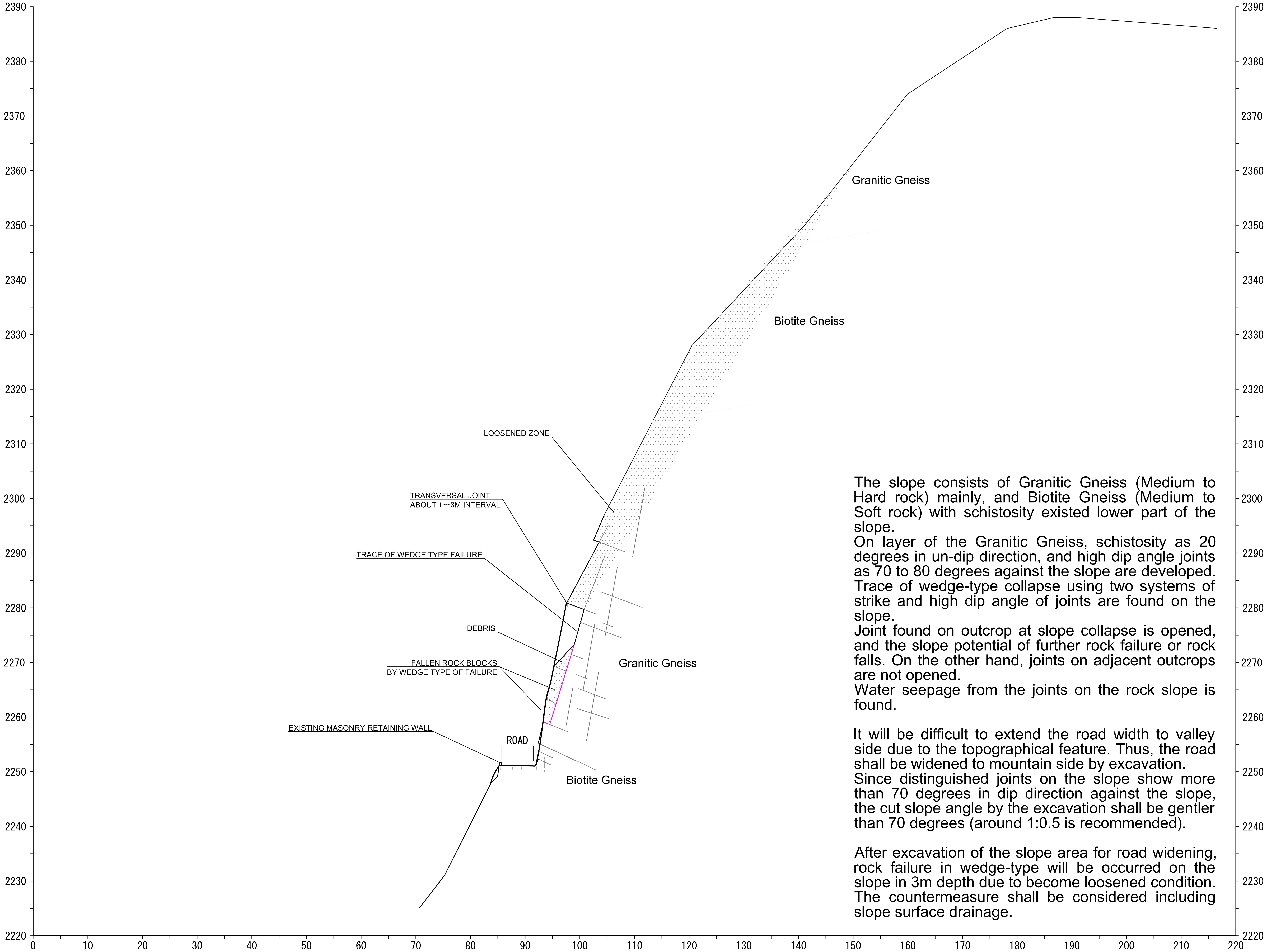


Granitic Gneiss (Hard rock) as bed rock. Biotite Gneiss exists in the bed rock in lens-shape partially. Several sense of steep angle joints are developed, and gentle un-dip direction joint about 25 deg. is found as well. Rock grade: CM

Some parts on/around overhanging and wedge-type failure show loosened condition by opened joints. Thickness of loosened parts will be about 3m. Since valley side slope shows steep angle (almost vertical), excavation for road widening shall be executed on mountain side slope. The loosened area will be extended due to excavation by blasting. The slope protection work will be required.

KOKUSAI KOGYO CO., LTD. EARTH SYSTEM SCIENCE CO., LTD.	ORIENTAL CONSULTANTS GLOBAL CO., LTD. OYO INTERNATIONAL CORPORATION	PROJECT NAME THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN, JICA	TITLE GEOLOGICAL CROSS SECTION (TS-04) DRAWING No. SCALE 1:400 -(A1)

THOMANG ROAD SECTION - TS-05



The slope consists of Granitic Gneiss (Medium to Hard rock) mainly, and Biotite Gneiss (Medium to Soft rock) with schistosity existed lower part of the slope.
On layer of the Granitic Gneiss, schistosity as 20 degrees in un-dip direction, and high dip angle joints as 70 to 80 degrees against the slope are developed.
Trace of wedge-type collapse using two systems of strike and high dip angle of joints are found on the slope.
Joint found on outcrop at slope collapse is opened, and the slope potential of further rock failure or rock falls. On the other hand, joints on adjacent outcrops are not opened.
Water seepage from the joints on the rock slope is found.

It will be difficult to extend the road width to valley side due to the topographical feature. Thus, the road shall be widened to mountain side by excavation.
Since distinguished joints on the slope show more than 70 degrees in dip direction against the slope, the cut slope angle by the excavation shall be gentler than 70 degrees (around 1:0.5 is recommended).

After excavation of the slope area for road widening, rock failure in wedge-type will be occurred on the slope in 3m depth due to become loosened condition. The countermeasure shall be considered including slope surface drainage.

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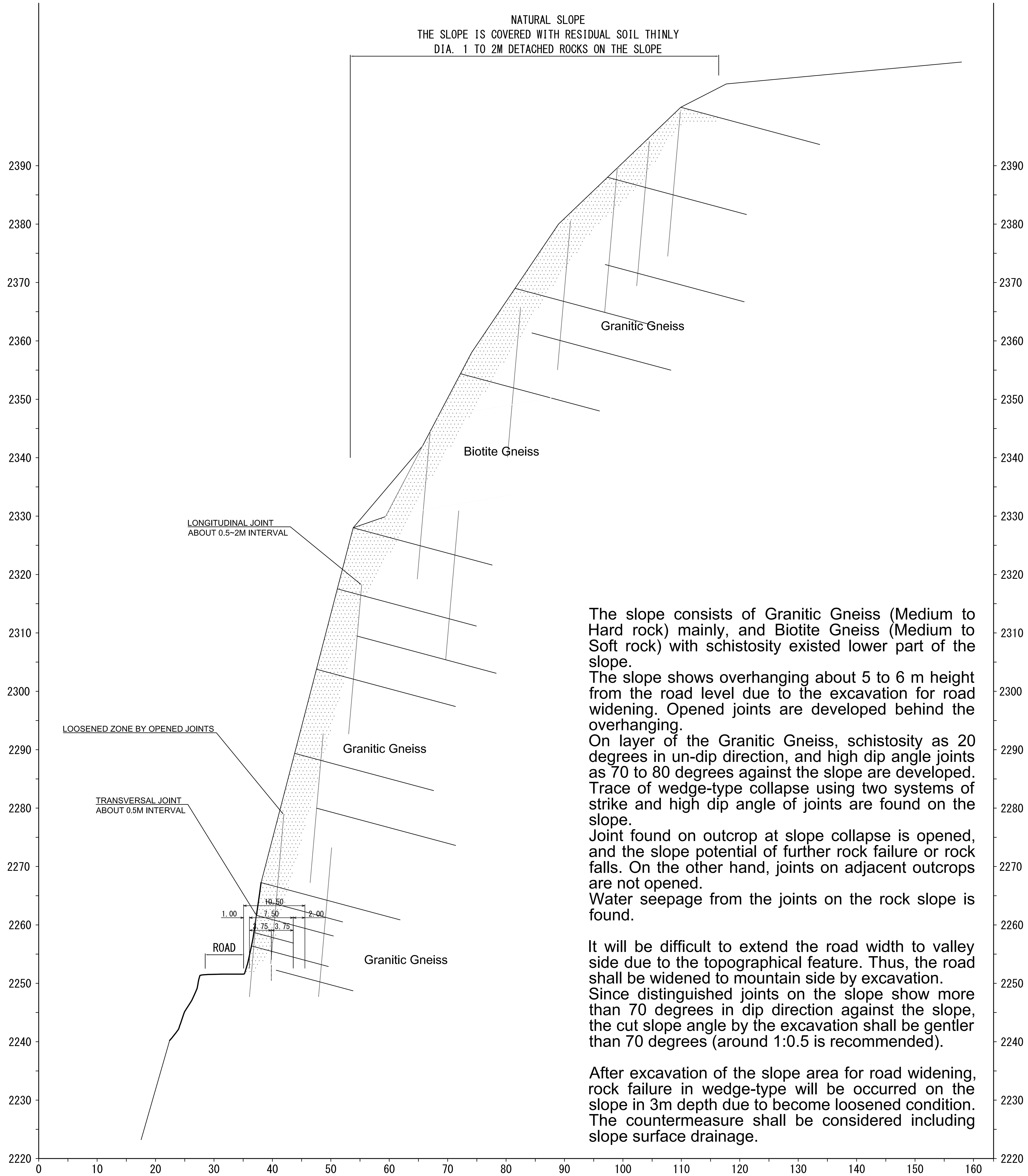
THOMANG ROAD SECTION - TS-06



The slope consists of Granitic Gneiss (Medium to Hard rock) mainly, and Biotite Gneiss (Medium to Soft rock) with schistosity existed lower part of the slope.
The slope shows overhanging about 5 to 6 m height from the road level due to the excavation for road widening. Opened joints are developed behind the overhanging.
On layer of the Granitic Gneiss, schistosity as 20 degrees in un-dip direction, and high dip angle joints as 70 to 80 degrees against the slope are developed.
Trace of wedge-type collapse using two systems of strike and high dip angle of joints are found on the slope.
Joint found on outcrop at slope collapse is opened, and the slope potential of further rock failure or rock falls. On the other hand, joints on adjacent outcrops are not opened.
Water seepage from the joints on the rock slope is found.

It will be difficult to extend the road width to valley side due to the topographical feature. Thus, the road shall be widened to mountain side by excavation.
Since distinguished joints on the slope show more than 70 degrees in dip direction against the slope, the cut slope angle by the excavation shall be gentler than 70 degrees (around 1:0.5 is recommended).

After excavation of the slope area for road widening, rock failure in wedge-type will be occurred on the slope in 3m depth due to become loosened condition. The countermeasure shall be considered including slope surface drainage.

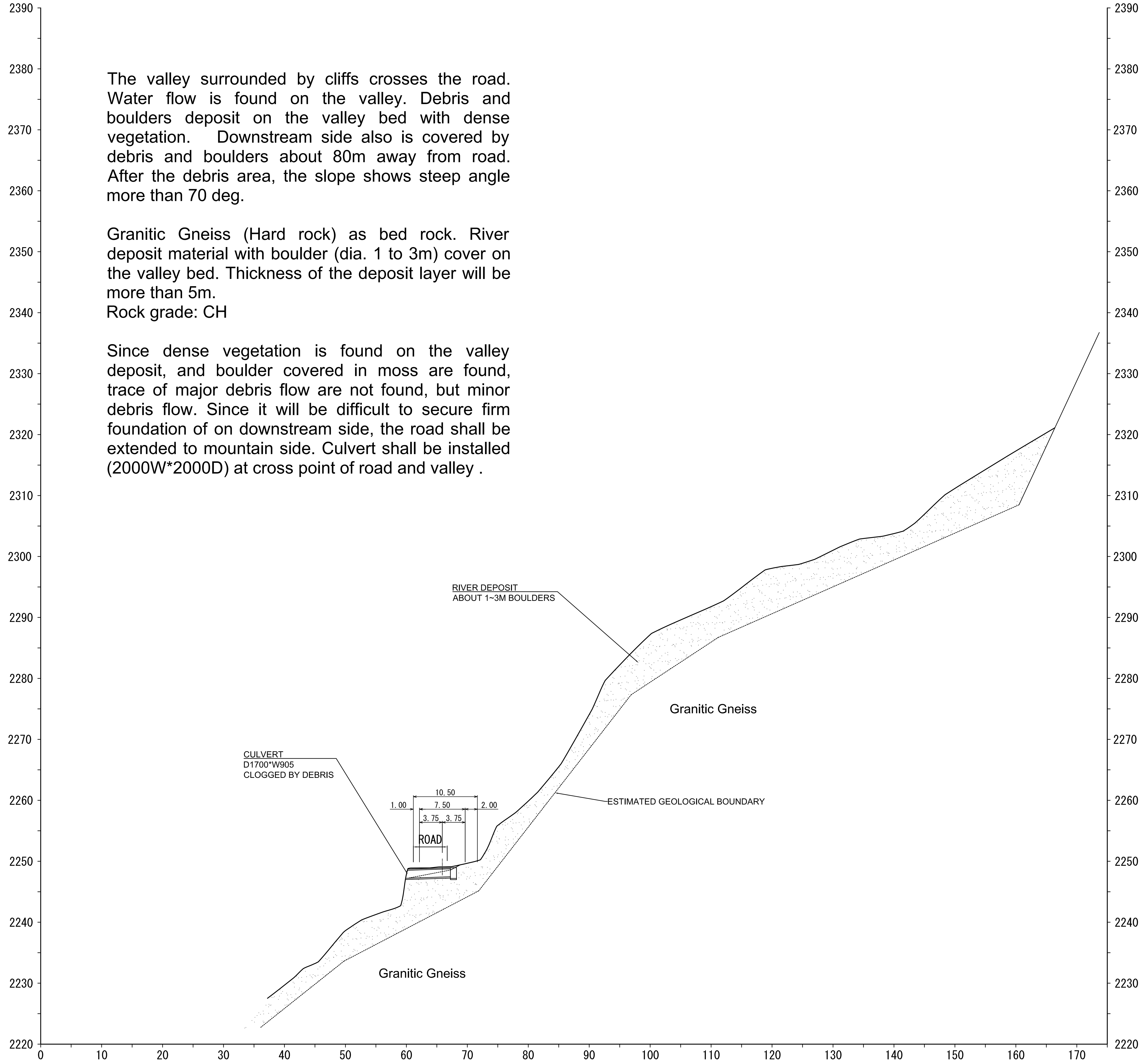
KOKUSAI KOGYO CO., LTD. EARTH SYSTEM SCIENCE CO., LTD.	ORIENTAL CONSULTANTS GLOBAL CO., LTD. OYO INTERNATIONAL CORPORATION	PROJECT NAME **THE PROJECT FOR MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN BHUTAN, JICA**	TITLE GEOLOGICAL CROSS SECTION (TS-06) DRAWING No. SCALE 1:400 —(A1)

THOMANG ROAD SECTION - TS-07

The valley surrounded by cliffs crosses the road. Water flow is found on the valley. Debris and boulders deposit on the valley bed with dense vegetation. Downstream side also is covered by debris and boulders about 80m away from road. After the debris area, the slope shows steep angle more than 70 deg.

Granitic Gneiss (Hard rock) as bed rock. River deposit material with boulder (dia. 1 to 3m) cover on the valley bed. Thickness of the deposit layer will be more than 5m.
Rock grade: CH

Since dense vegetation is found on the valley deposit, and boulder covered in moss are found, trace of major debris flow are not found, but minor debris flow. Since it will be difficult to secure firm foundation of on downstream side, the road shall be extended to mountain side. Culvert shall be installed (2000W*2000D) at cross point of road and valley .



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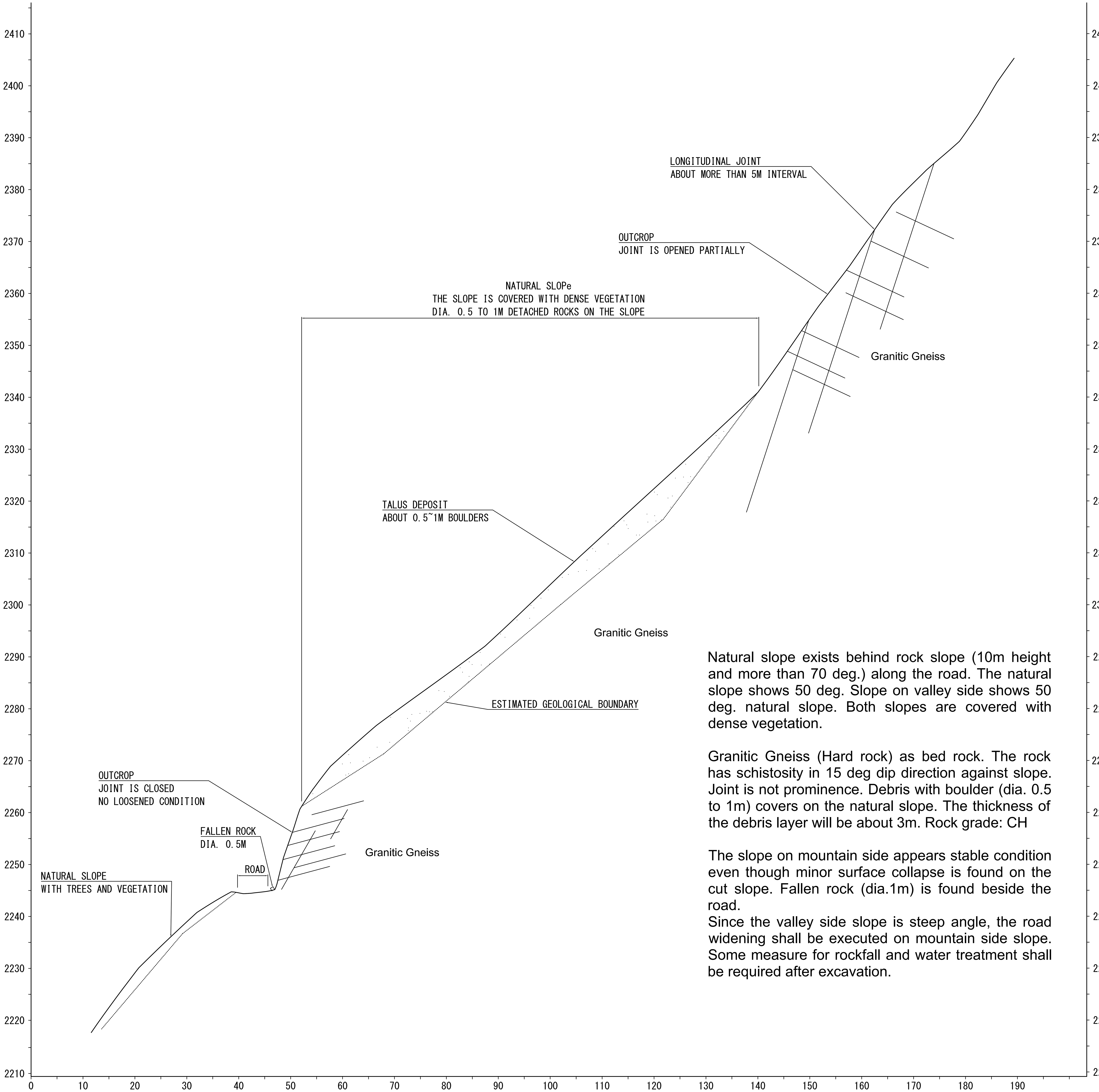
THOMANG ROAD SECTION - TS-08



Natural slope exists behind rock slope (10m height and more than 70 deg.) along the road. The natural slope shows 50 deg. Slope on valley side shows 50 deg. natural slope. Both slopes are covered with dense vegetation.

Granitic Gneiss (Hard rock) as bed rock. The rock has schistosity in 15 deg dip direction against slope. Joint is not prominence. Debris with boulder (dia. 0.5 to 1m) covers on the natural slope. The thickness of the debris layer will be about 3m. Rock grade: CH

The slope on mountain side appears stable condition even though minor surface collapse is found on the cut slope. Fallen rock (dia.1m) is found beside the road.
Since the valley side slope is steep angle, the road widening shall be executed on mountain side slope. Some measure for rockfall and water treatment shall be required after excavation.

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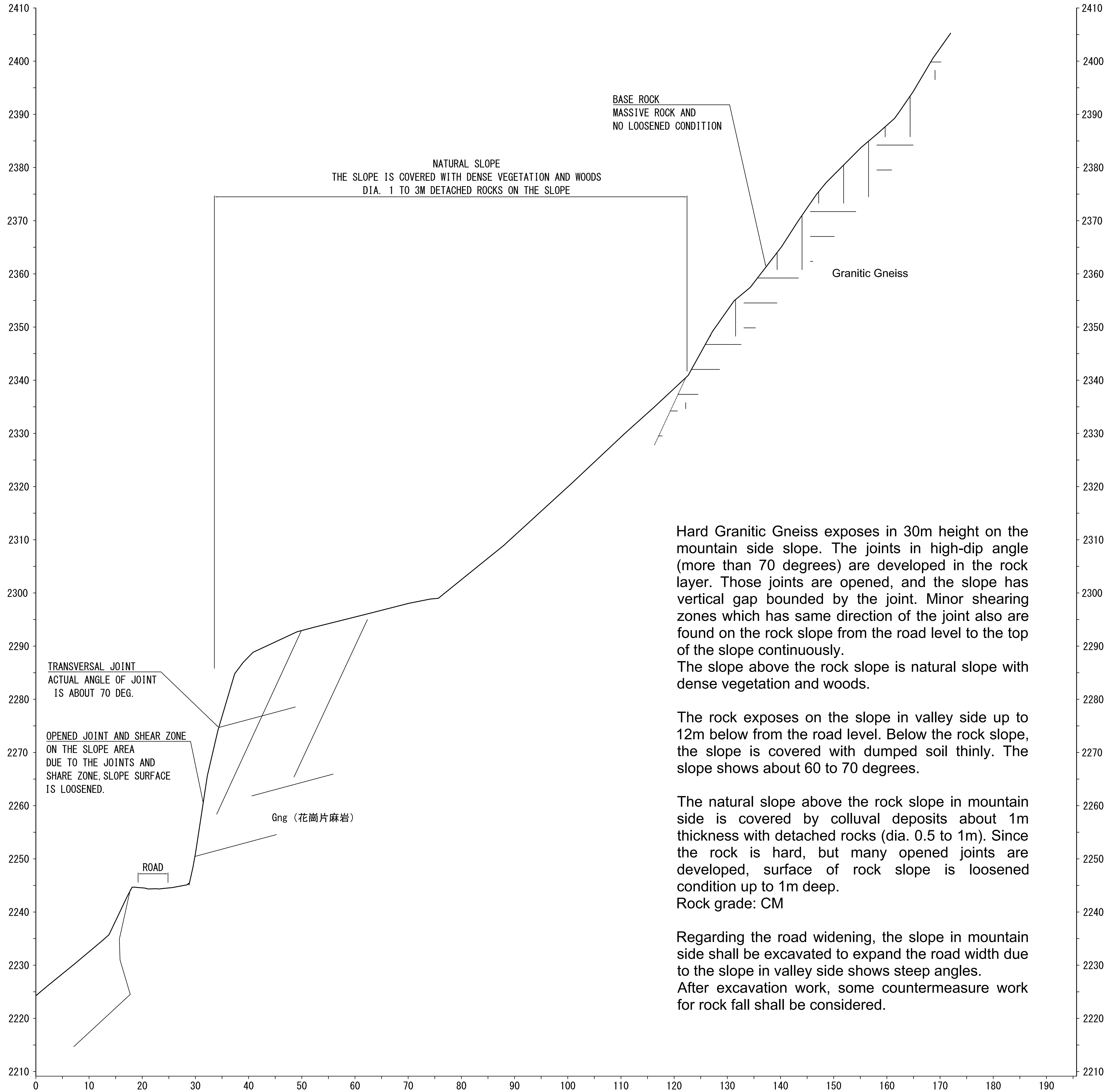
THOMANG ROAD SECTION - TS-09



Hard Granitic Gneiss exposes in 30m height on the mountain side slope. The joints in high-dip angle (more than 70 degrees) are developed in the rock layer. Those joints are opened, and the slope has vertical gap bounded by the joint. Minor shearing zones which has same direction of the joint also are found on the rock slope from the road level to the top of the slope continuously.
The slope above the rock slope is natural slope with dense vegetation and woods.

The rock exposes on the slope in valley side up to 12m below from the road level. Below the rock slope, the slope is covered with dumped soil thinly. The slope shows about 60 to 70 degrees.

The natural slope above the rock slope in mountain side is covered by colluval deposits about 1m thickness with detached rocks (dia. 0.5 to 1m). Since the rock is hard, but many opened joints are developed, surface of rock slope is loosened condition up to 1m deep.
Rock grade: CM

Regarding the road widening, the slope in mountain side shall be excavated to expand the road width due to the slope in valley side shows steep angles.
After excavation work, some countermeasure work for rock fall shall be considered.

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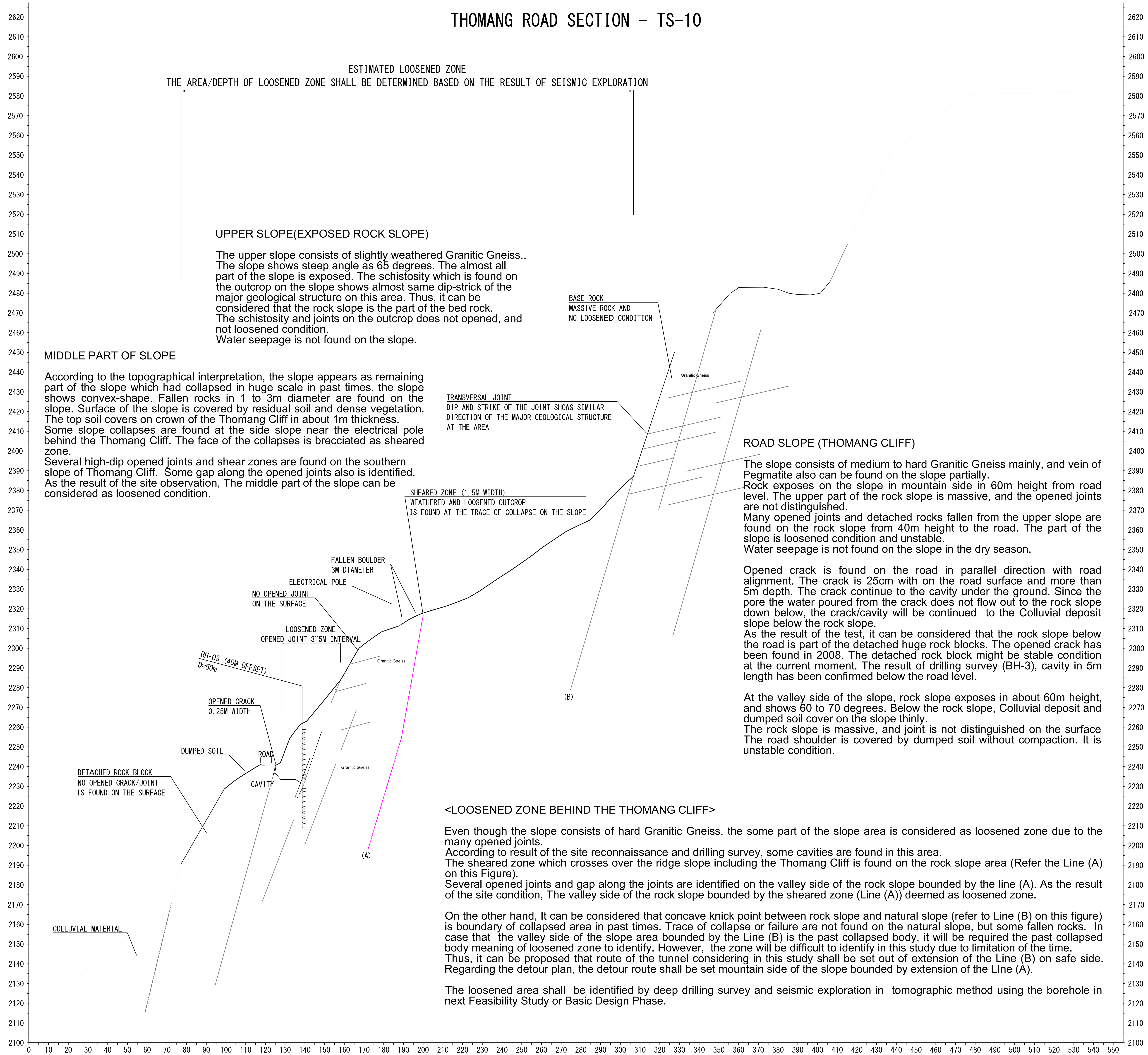
THOMANG ROAD SECTION - TS-10



UPPER SLOPE(EXPOSED ROCK SLOPE)

The upper slope consists of slightly weathered Granitic Gneiss.. The slope shows steep angle as 65 degrees. The almost all part of the slope is exposed. The schistosity which is found on the outcrop on the slope shows almost same dip-strick of the major geological structure on this area. Thus, it can be considered that the rock slope is the part of the bed rock. The schistosity and joints on the outcrop does not opened, and not loosened condition.
Water seepage is not found on the slope.

MIDDLE PART OF SLOPE

According to the topographical interpretation, the slope appears as remaining part of the slope which had collapsed in huge scale in past times. the slope shows convex-shape. Fallen rocks in 1 to 3m diameter are found on the slope. Surface of the slope is covered by residual soil and dense vegetation. The top soil covers on crown of the Thomang Cliff in about 1m thickness.
Some slope collapses are found at the side slope near the electrical pole behind the Thomang Cliff. The face of the collapses is brecciated as sheared zone.
Several high-dip opened joints and shear zones are found on the southern slope of Thomang Cliff. Some gap along the opened joints also is identified.
As the result of the site observation, The middle part of the slope can be considered as loosened condition.

ROAD SLOPE (THOMANG CLIFF)

The slope consists of medium to hard Granitic Gneiss mainly, and vein of Pegmatite also can be found on the slope partially.
Rock exposes on the slope in mountain side in 60m height from road level. The upper part of the rock slope is massive, and the opened joints are not distinguished.
Many opened joints and detached rocks fallen from the upper slope are found on the rock slope from 40m height to the road. The part of the slope is loosened condition and unstable.
Water seepage is not found on the slope in the dry season.

Opened crack is found on the road in parallel direction with road alignment. The crack is 25cm with on the road surface and more than 5m depth. The crack continue to the cavity under the ground. Since the pore the water poured from the crack does not flow out to the rock slope down below, the crack/cavity will be continued to the Colluvial deposit slope below the rock slope.
As the result of the test, it can be considered that the rock slope below the road is part of the detached huge rock blocks. The opened crack has been found in 2008. The detached rock block might be stable condition at the current moment. The result of drilling survey (BH-3), cavity in 5m length has been confirmed below the road level.

At the valley side of the slope, rock slope exposes in about 60m height, and shows 60 to 70 degrees. Below the rock slope, Colluvial deposit and dumped soil cover on the slope thinly.
The rock slope is massive, and joint is not distinguished on the surface
The road shoulder is covered by dumped soil without compaction. It is unstable condition.

<LOOSENED ZONE BEHIND THE THOMANG CLIFF>

Even though the slope consists of hard Granitic Gneiss, the some part of the slope area is considered as loosened zone due to the many opened joints.
According to result of the site reconnaissance and drilling survey, some cavities are found in this area.
The sheared zone which crosses over the ridge slope including the Thomang Cliff is found on the rock slope area (Refer the Line (A) on this Figure).
Several opened joints and gap along the joints are identified on the valley side of the rock slope bounded by the line (A). As the result of the site condition, The valley side of the rock slope bounded by the sheared zone (Line (A)) deemed as loosened zone.

On the other hand, It can be considered that concave knick point between rock slope and natural slope (refer to Line (B) on this figure) is boundary of collapsed area in past times. Trace of collapse or failure are not found on the natural slope, but some fallen rocks. In case that the valley side of the slope area bounded by the Line (B) is the past collapsed body, it will be required the past collapsed body meaning of loosened zone to identify. However, the zone will be difficult to identify in this study due to limitation of the time.
Thus, it can be proposed that route of the tunnel considering in this study shall be set out of extension of the Line (B) on safe side.
Regarding the detour plan, the detour route shall be set mountain side of the slope bounded by extension of the LIne (A).

The loosened area shall be identified by deep drilling survey and seismic exploration in tomographic method using the borehole in next Feasibility Study or Basic Design Phase.

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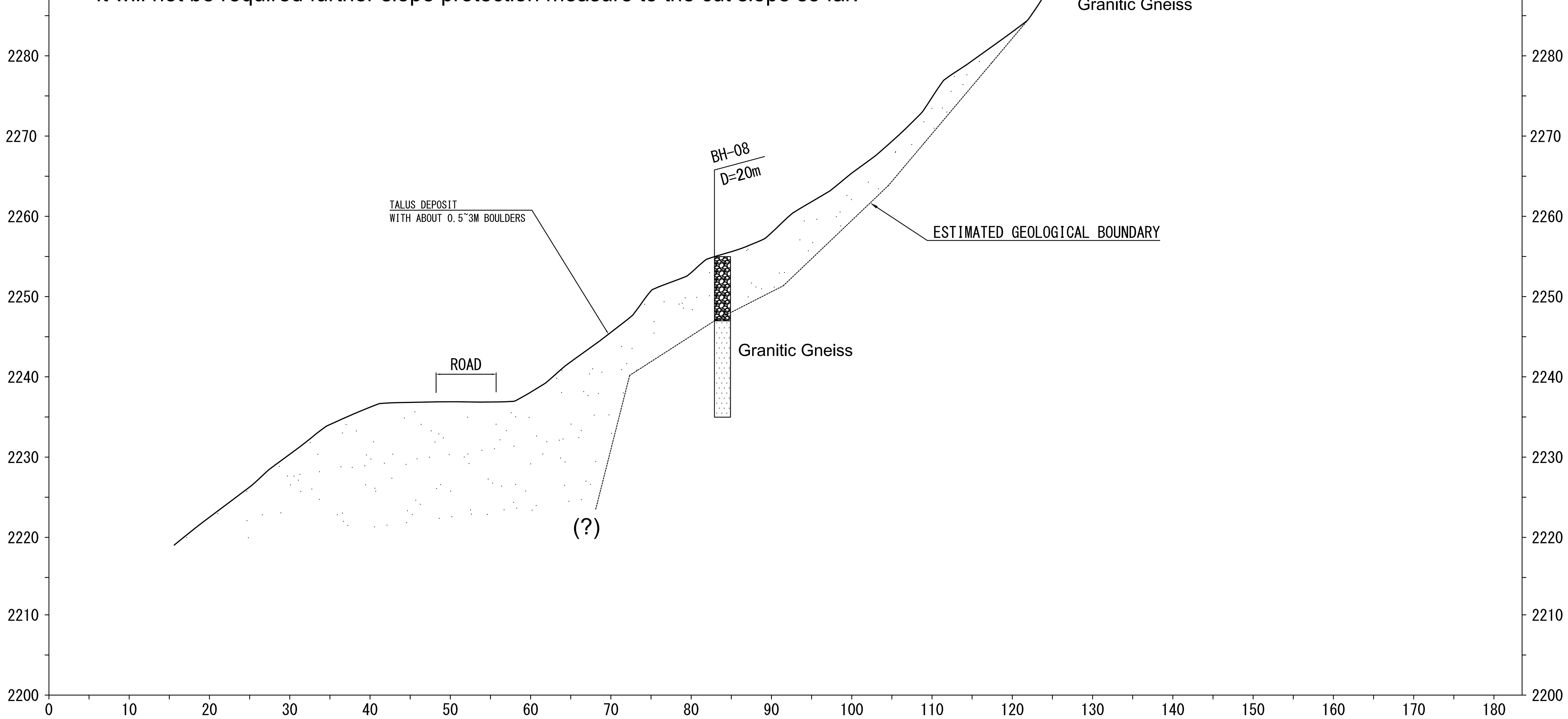
THOMANG ROAD SECTION - TS-11

It is the natural slope in 30 to 40 degrees.
Dense vegetation and woods cover a whole slope area.
Some detached rock blocks (5m) are found on the slope partially.
Part of the slope shows landslide topographic feature.
There is a stream on on the slope.

The slope consists of colluvial deposits with boulder (1 to 3m diameter).
Outcrop is not found on the colluvial slope.
According to the result of seismic explocation on the slope, gap of the velocity layer of P-wave at lower part of the slope. It can be considered that the gap shows boundary of base rock and loosened zone.

Even though landslide topographical feature is identified on the slope, trace or evidence of landslide activity are not found on the area. Since no trace of rock fall or slope failure is found, the slope deems as stable condition at the present.
The lower part of the slope was excavated to expand the road width.
It will not be required further slope protection measure to the cut slope so far.



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