

Exploratory Adit
(Alignment and Geological Sketch)

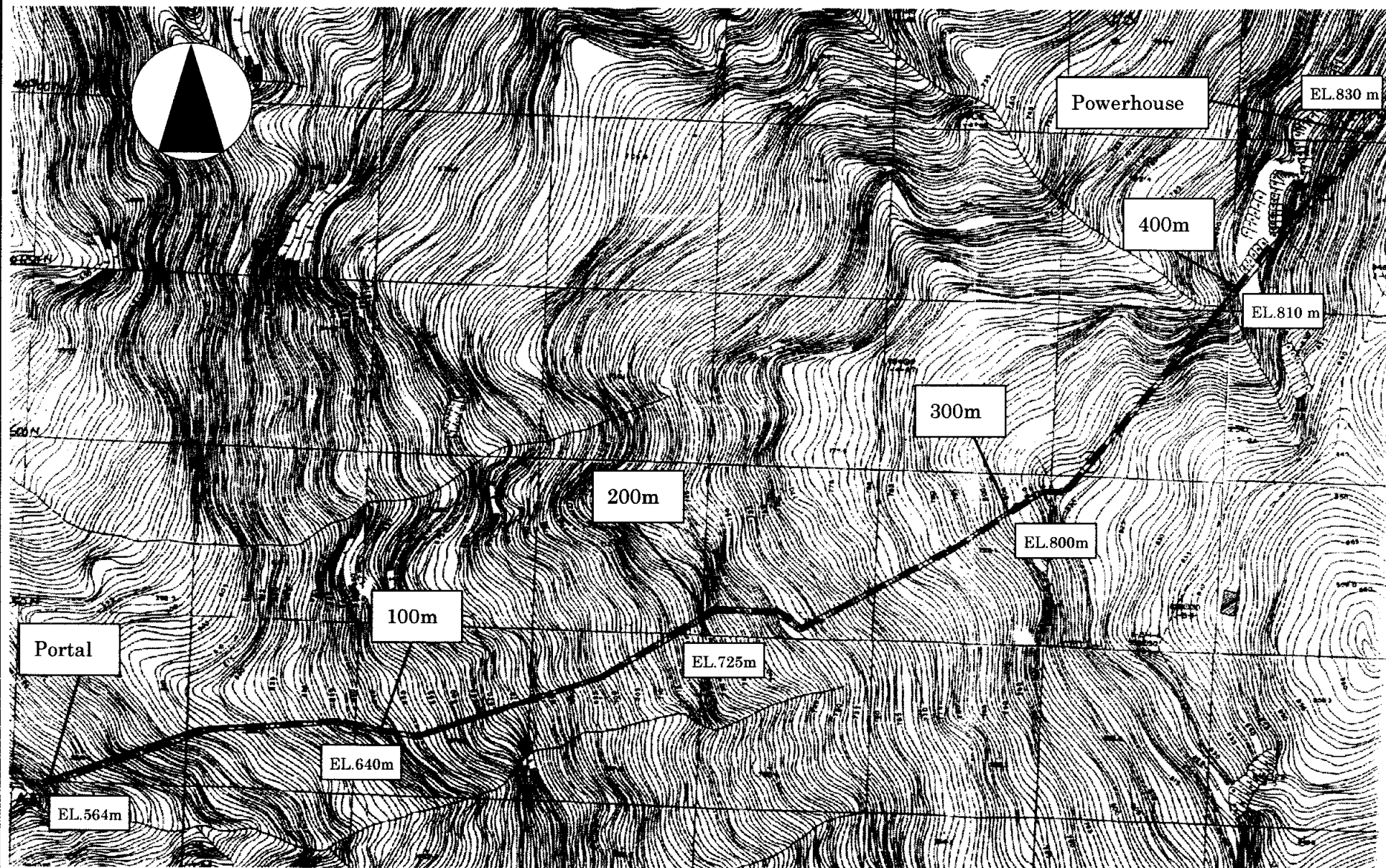
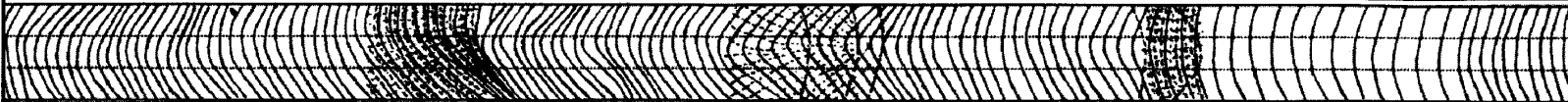
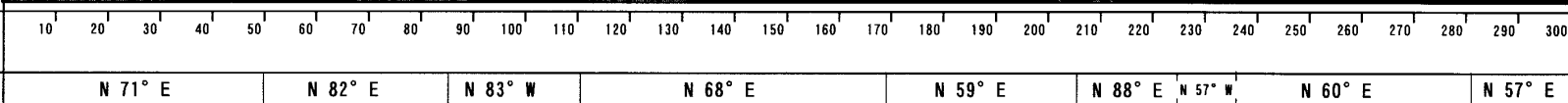
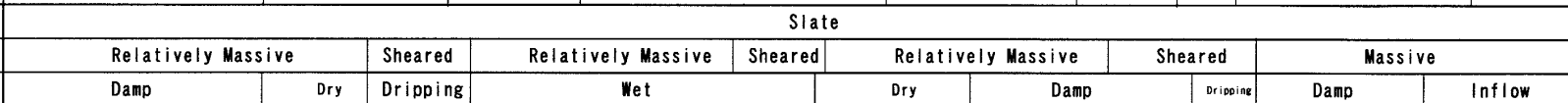
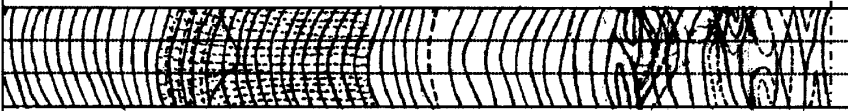
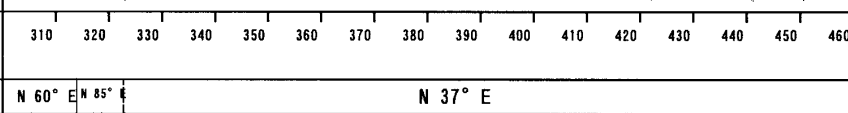
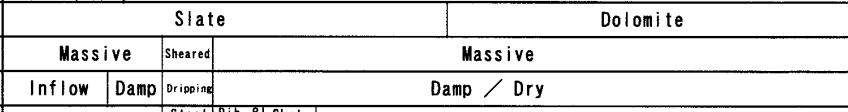


Figure B3.9.1 Alignment of Exploratory Adit

Geologic Sketch	Left Wall																																														
	Crown																																														
	Right Wall																																														
Chainage		<div><div></div><div>102030405060708090100110120130140150160170180190200210220230240250260270280290300</div></div>																																													
Direction		N 71° E					N 82° E					N 83° W					N 68° E					N 59° E					N 88° E					N 57° W					N 60° E					N 57° E					
Rock Type		Slate																																													
Rock Condition		Relatively Massive					Sheared					Relatively Massive					Sheared					Relatively Massive					Sheared					Massive															
Groundwater		Damp					Dry					Dripping					Wet					Dry					Damp					Dripping					Damp					Inflow					
Support		Steel Ribs					Rock Bolts					Steel Ribs					Rock Bolts + Shotcrete					Steel Ribs					Rock Bolts + Shotcrete					Steel Ribs		Rib & Shotcr		Steel Ribs		Rock Bolts + Shotcrete					Steel Ribs				
Rock Grade		Q3 - Q4					Q4 - Q5					Q3 - Q4					Q4					Q3 - Q4					Q4					Q3															
Remarks		EL563.6m at portal																														High groundwater inflow are seen around 280 m point															

Geologic Sketch	Left Wall																																					
	Crown																																					
	Right Wall																																					
Chainage		310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460																																				
Direction		N 60° E					N 85° E					N 37° E																										
Rock Type		Slate														Dolomite																						
Rock Condition		Massive					Sheared					Massive																										
Groundwater		Inflow					Damp					Dripping					Damp / Dry																					
Support		No Support					Steel Ribs					Rib & Shotcrete					No Support																					
Tunnel Condition		Q 3					Q 4 - Q 5										Q 2 - Q 3																					
Remarks		Rock faces change from dolomitic slate to scillicious dolomite at the lithological																																				

Rock Grade	Modulus of Deformation (MPa)	Shear Strength (MPa)	Friction Degree (degree)	Q value by Q system	CRIEPI classification system
Q1	> 3,000	> 2.5	> 50	> 40	B
Q2	3,000	2.5	50	10 to 40	CH
Q3	1,000	1.2	45	4 to 10	CM
Q4	500	0.6	40	1 to 4	CL
Q5	250	0.1	35	1 >	D

Figure B3.9.2 Geological Condition of Exploratory Adit

RESULT OF IN-SITU TESTING

Plate Loading Test (See ①, ②, ③)

LOCATION	MODULUS OF DEFORMATION (MPa)
PL-1	3,183.9
PL-2	9,366.9
PL-3	1,869.5

Block Shear Test (See ④)

$$\tau = 0.3 \text{ to } 0.5 \text{ MPa}, \quad \phi = 40 \text{ to } 50^\circ$$

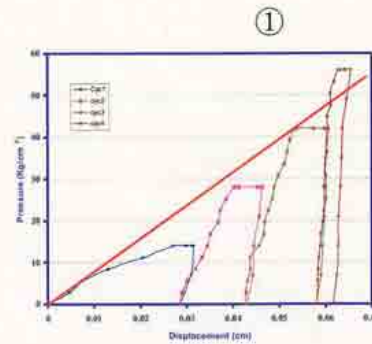


Plate Load Test (PL-1)

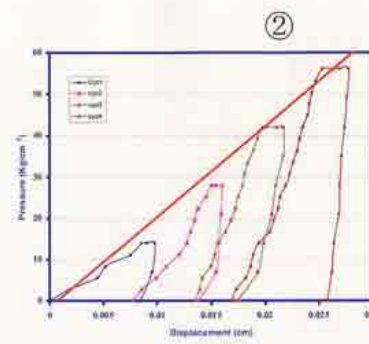


Plate Load Test (PL-2)

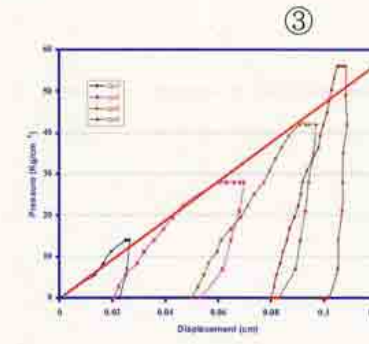
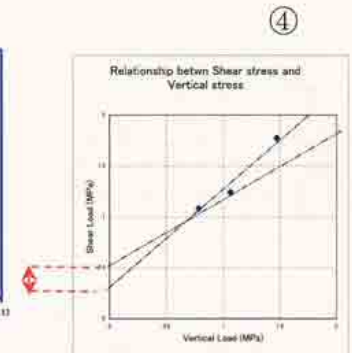


Plate Load Test (PL-3)



Block Shear Test

RESULTS OF LABORATORY TEST

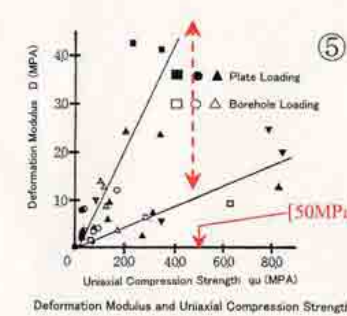
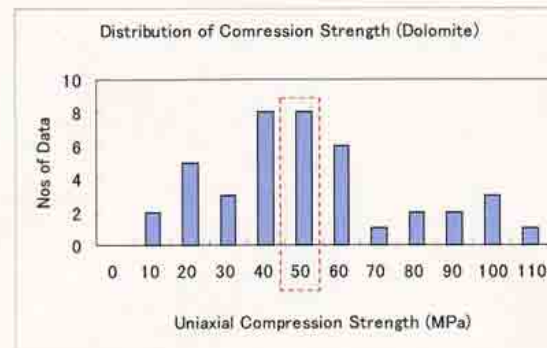
Modulus of Deformation (See ⑤)

2,000 to 3,500 MPa
(when $q_u = 50 \text{ MPa}$)

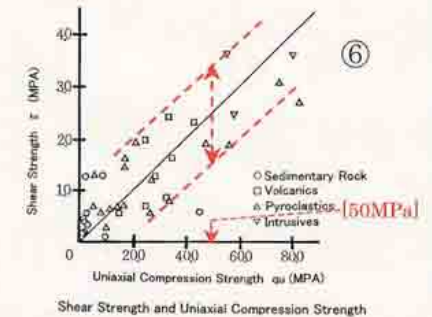
Shear Strength (See ⑥)

2 to 3 MPa
(when $q_u = 50 \text{ MPa}$)

[q_u : uniaxial compression strength]



[Ref: Rock Classification by Uniaxial Compression Strength etc. (K.Kuwabara; Japan Society of Engineering Geology, 1984)]



CHARACTERISTICS OF ROCKS

(at location of In-situ Rock Testing spot in Branch Adit)

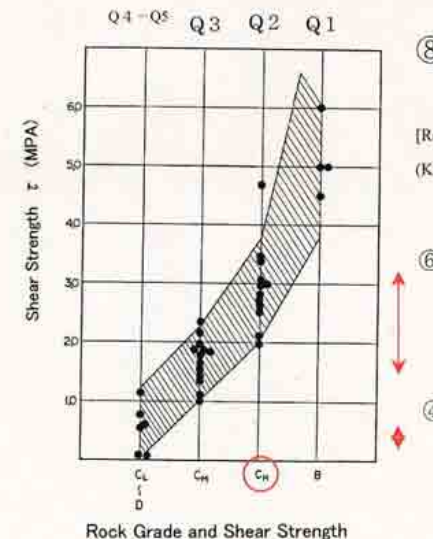
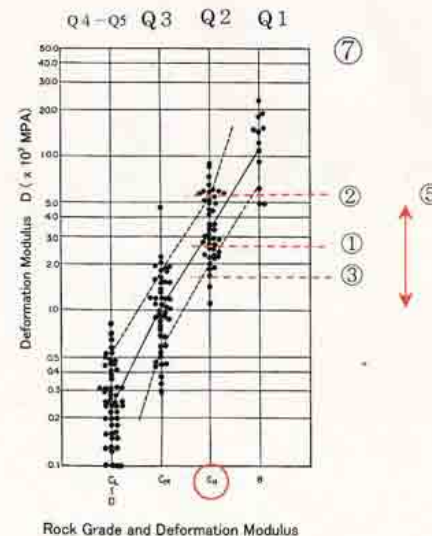
Modulus of Deformation (See ⑦)

3,000 to 5,000 MPa

Shear Strength (See ⑧)

2 to 3 MPa

(Friction angle
45 to 50 degrees)



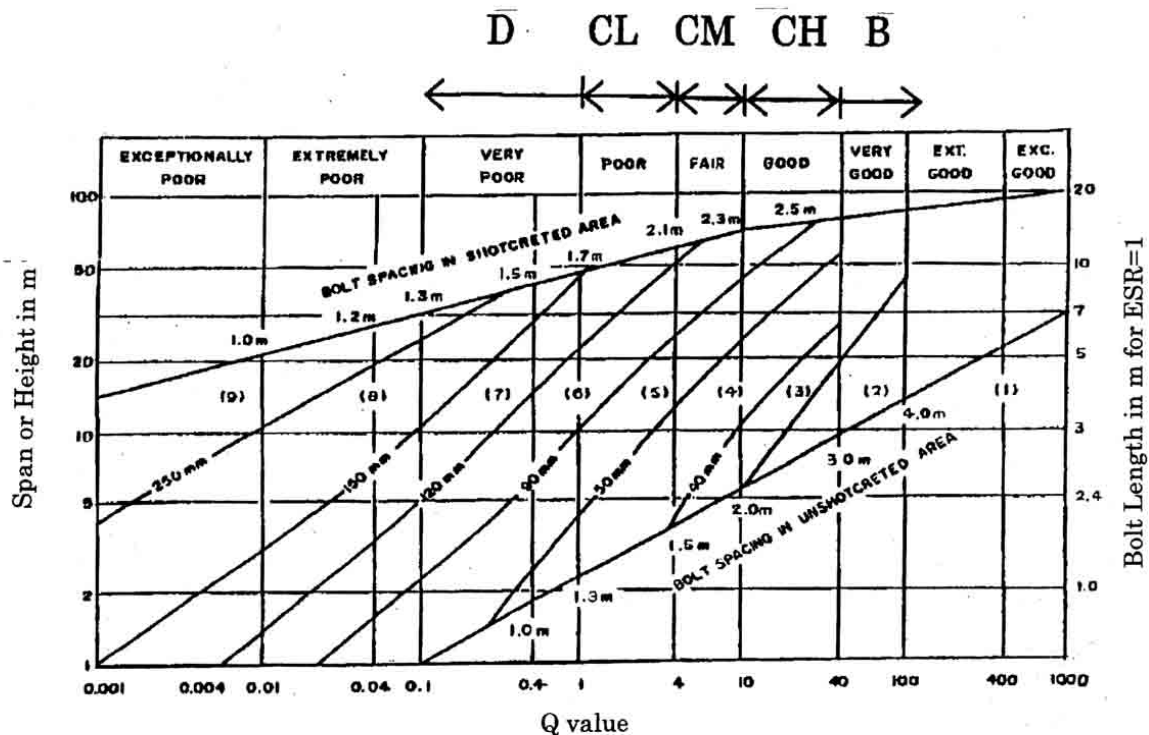
[Ref: Geotechnical Integrated Evaluation on the stability of Dam Foundation Rocks (K.Kikuchi; Japan Society of Engineering Geology, 1984)]

Figure B4.1.1 Discussion on Properties of Rocks

ROCK CLASSIFICATION AND REINFORCEMENT CATERGORIES BY CRIEPI ROCK CLASSIFICATION(1991)

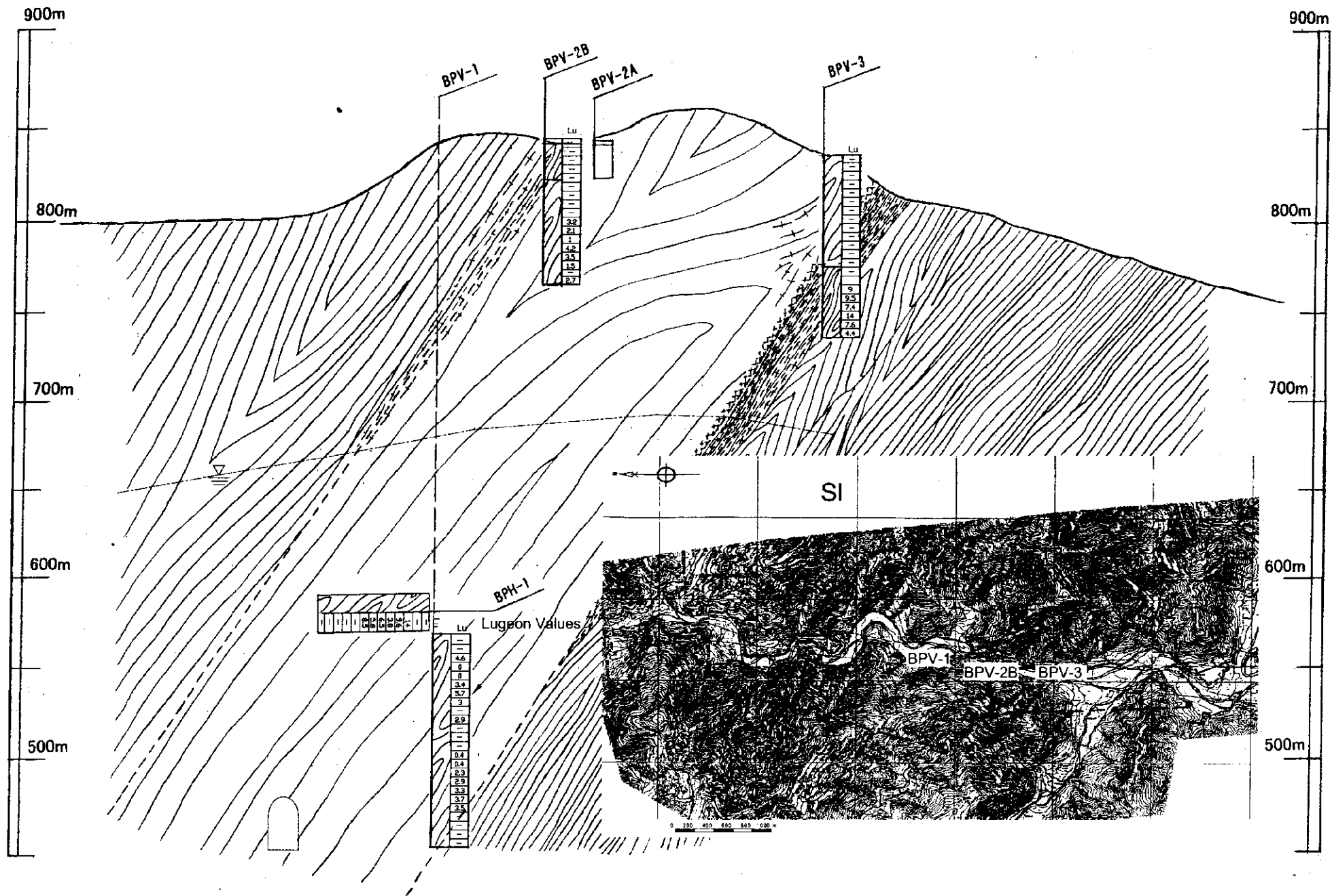
Rock Grade	Support Pattern	Shotcreting		Rock Bolting			Steel Support	
		Thickness (cm)	Area	Length (m)	Nos of bolts	Pitch (m)	Materialals	Pitch (m)
B	A	5	Arch	2	0 to 5	—	—	—
CH	B	5	Arch • Wall	2	7	1.5	—	—
CM	CI	10	Arch • Wall	2	10	1.5	—	—
	CII	15	Arch • Wall	2	12	1.2	—	—
CL	DI	15	Arch • Wall	3	12	1.2	—	—
	DII	15	Arch • Wall	3	12	1.2	(100H)	1.0 to 1.2
D	E	15 to 20	Arch • Wall	3	14	1.0 to 1.2	(125H)	1.0 to 1.2

REINFORCEMENT CATEGORIES BASED ON Q SYSTEM AND ASSUMED CORRELATION WITH CRIEPI ROCK CLASSIFICATION



REINFORCEMENT CATERGORIES

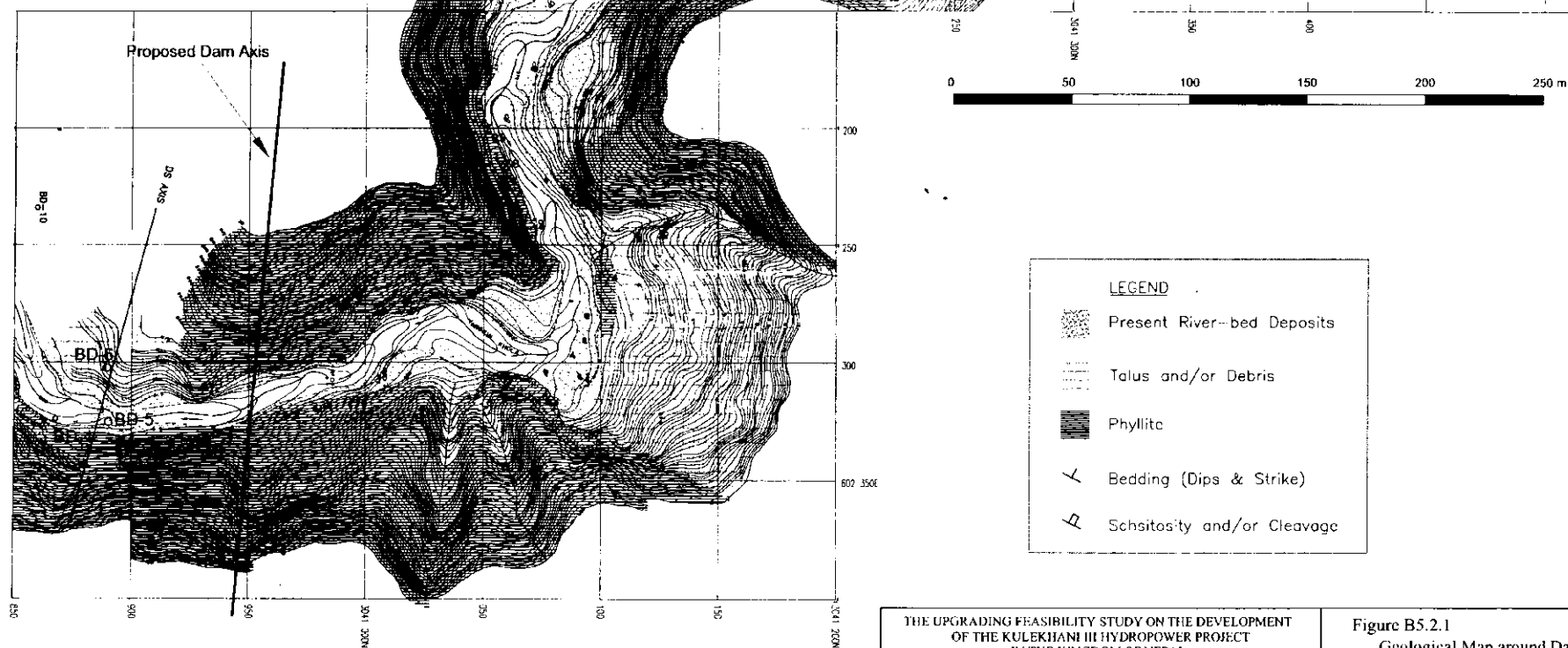
- | | |
|---|--|
| (1) Unsupported | (6) Fibre reinforced shotcrete, 90 - 120 mm and shotcrete |
| (2) Spot bolting | (7) Fibre reinforced shotcrete, 120 - 150 mm and shotcrete |
| (3) Systematic bolting | (8) Fibre reinforced shotcrete, >150 mm with reinforced ribs of shotcrete and bolting. |
| (4) Systematic bolting with
40 - 100 mm unreinforced shotcrete | (9) Cast concrete lining |
| (5) Fibre reinforced shotcrete, 50 - 90 mm
and shotcrete | |



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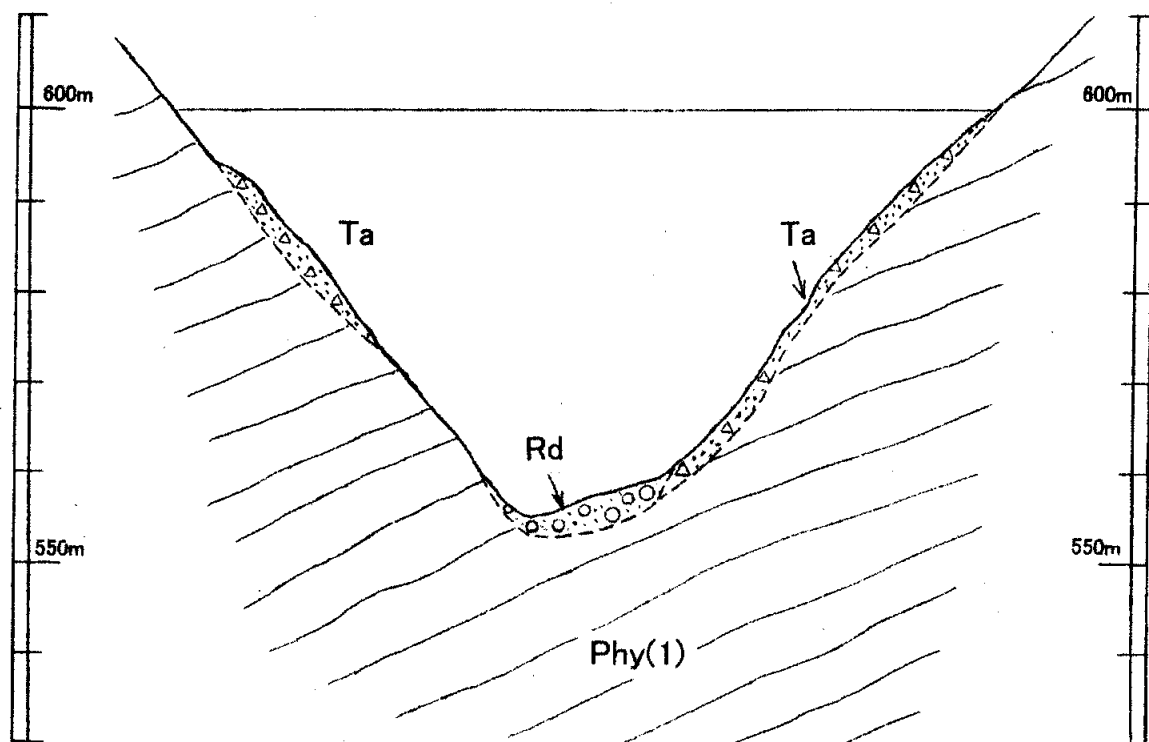
Figure B5.1.2
Permeability around Underground Structures

AGE	GROUP	FORMATION	SYMBOL	ROCK TYPE	GEOLOGY
Cenozoic	Recent, Quaternary, Recent Deposits		Rd	Reverted deposits	Sand and gravel with boulders
			Ta	Talus and/or Debris	Talus deposits and debris deposits
			St	Conglomerate, Sandstone, Mudstone	Sandstone, mudstone and small pebbles of conglomerates. Relatively soft and fractured near MHT
Paleozoic	Upper Himalayas Group	(Main Boundary Thrust)		Phyllite (2)	Blue green phyllites, generally chloritic. Freely folded and calcareous beds. Relatively compact in general
		Popang Formation	Qp	Quartzite	Quartzite. Interbedded with phyllites at some locations. Massive and compact in general
				Phyllite (1)	Blue green phyllites, generally chloritic. Relatively compact in general
		Masina Formation	Ms	Schistose Gneiss	Light to dark and granitic gneiss with various accessories. Mineralization of iron, copper, zinc, lead and rare earths. Massive and relatively well bedded
		Bangpra Formation	Bp	Slate/Phyllite	Dark grey, black and phyllite layers with black calcareous siltstone. Fractured and weathered near MHT
Pre-Cambrian	Bhimgang Group	Mahabharat Thrust		Schist, Quartzite	Dark green to grey colored two mica and biotite schist with mineralization of quartzite and garnets. Strongly folded and sheared in places
		Kailash Formation	Kf	Schist	Coarse crystalline marble, limestone with mineralization of iron schist. Marble and limestone are massive and well bedded
		Rudra Formation	Rd	Schist	Coarse crystalline, highly garnetiferous mica schist, gneissic schist. Some quartzites are also seen in this formation



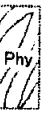


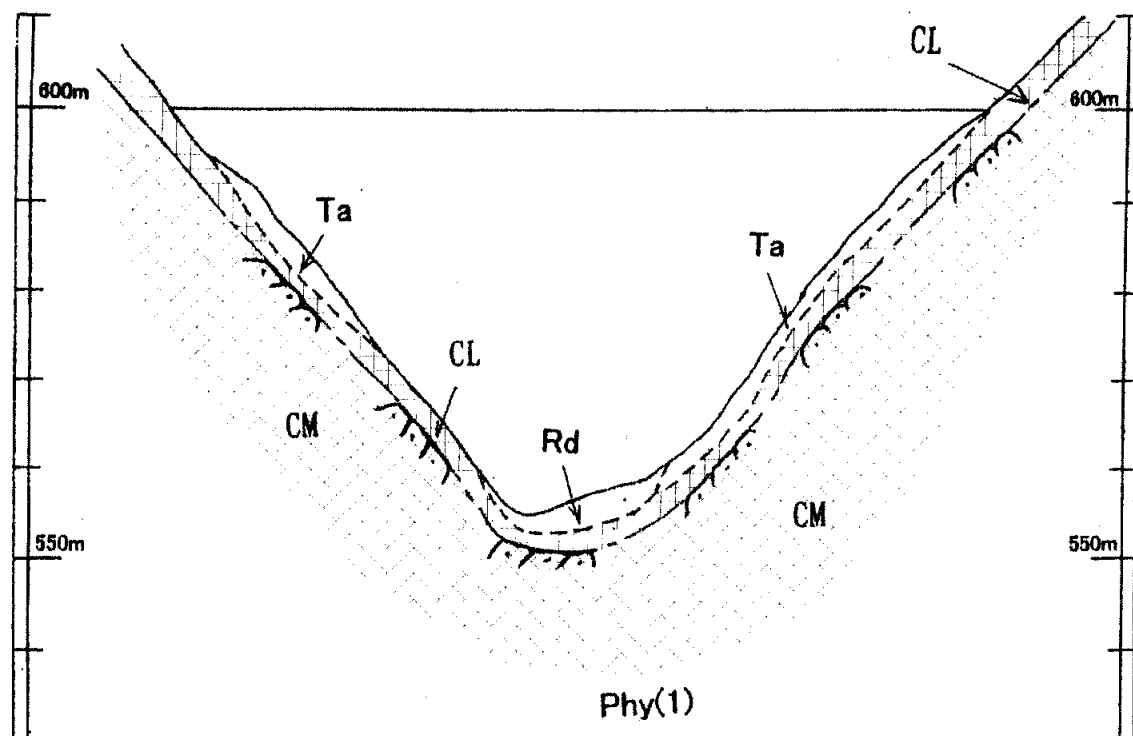
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Figure B5.2.1
Geological Map around Damsite and
Regulating Pond



Legend

AGE	GROUP	FORMATION	ROCKS	GEOLOGY
Cenozoic		Recent Deposits	 Rd Riverbed deposits	Sand, gravels and boulders of phyllites, limestone and schist are mainly distributed. Boulders and gravels and coarse materials are mainly distributed in the river due to high gradients of river-bed.
			 Ta Takus deposits	Sand, gravels and boulders of phyllites are generally distributed in the area.
		(Unconformity)		
Paleozoic	Upper Nawakot Group	Robang Formation	 Phy Phyllite (1)	Blue green phyllites, generally chloritic. Relatively compact in general.



Legend

[Hatched Box] CM

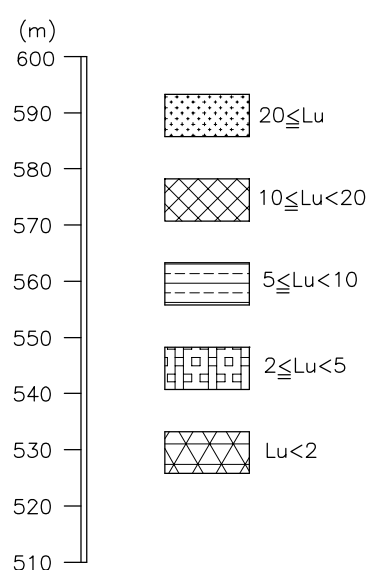
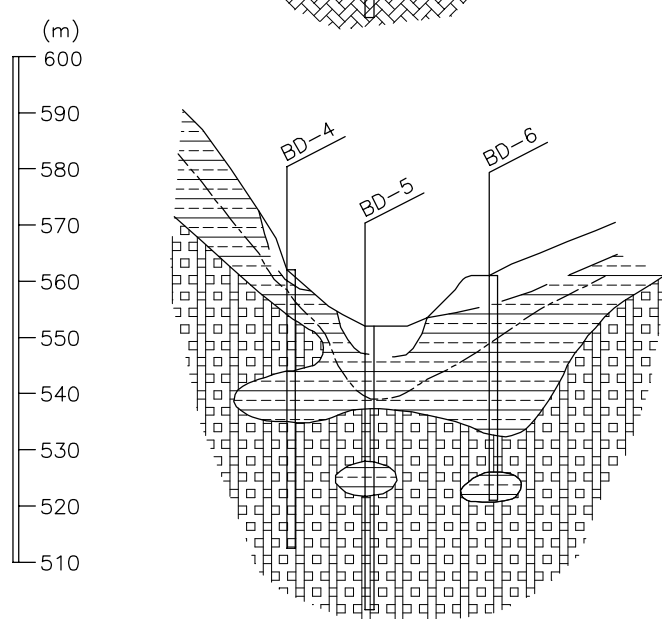
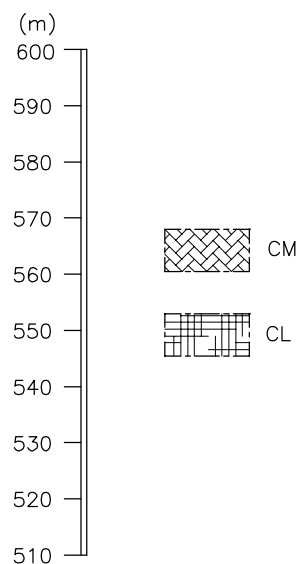
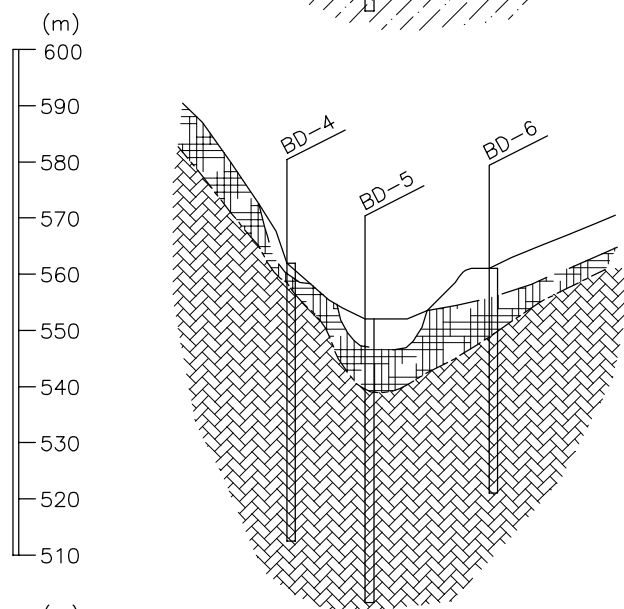
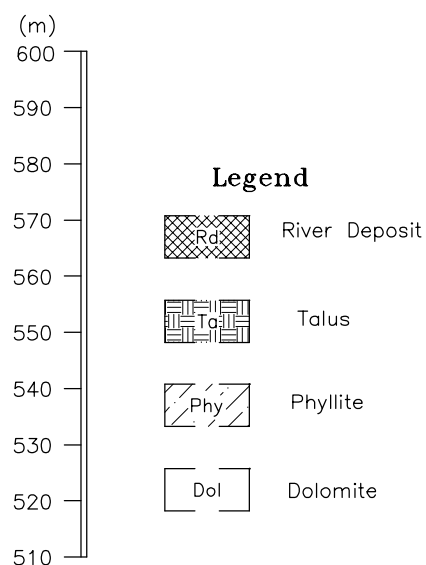
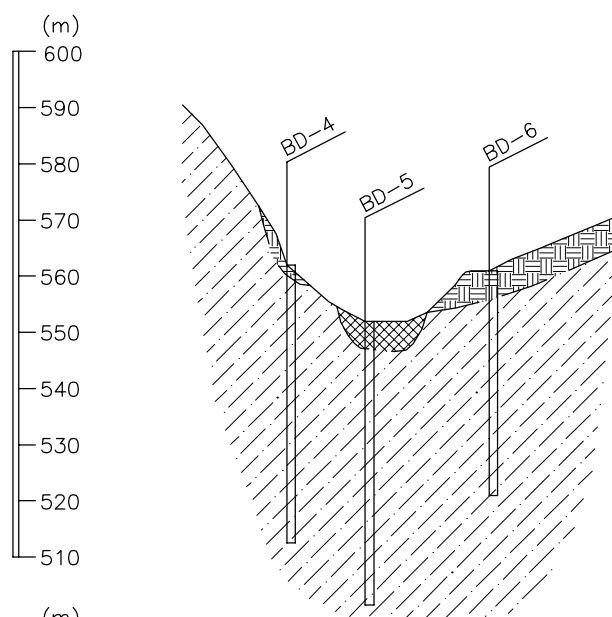
[Hatched Box] CL

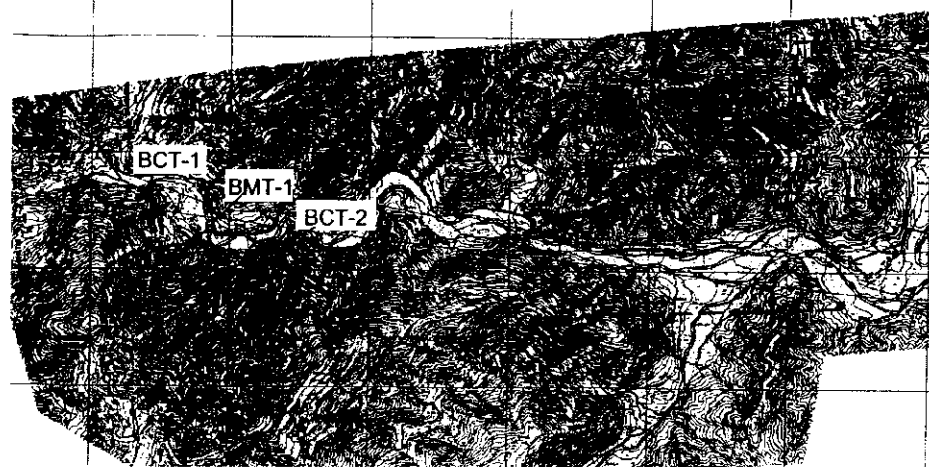
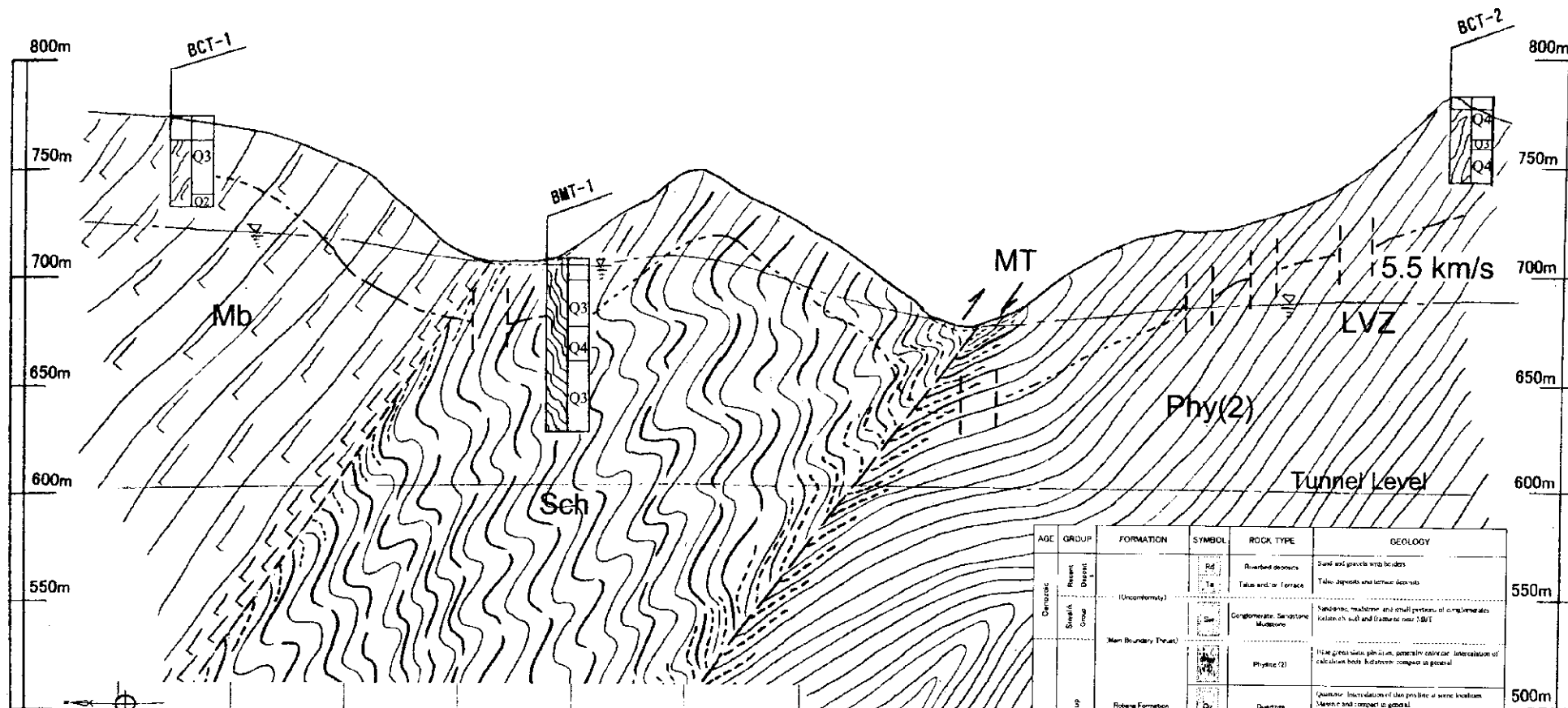
[Dashed Line with Circles] Excavation Line

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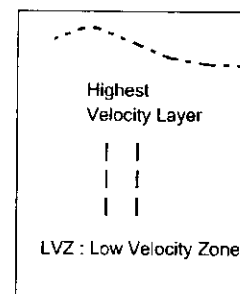
Figure B5.2.3
Geological Profile of Proposed Damsite
(Rock Grade)





0 250 500 750 1000 m

0 25 50 75 100 125 m



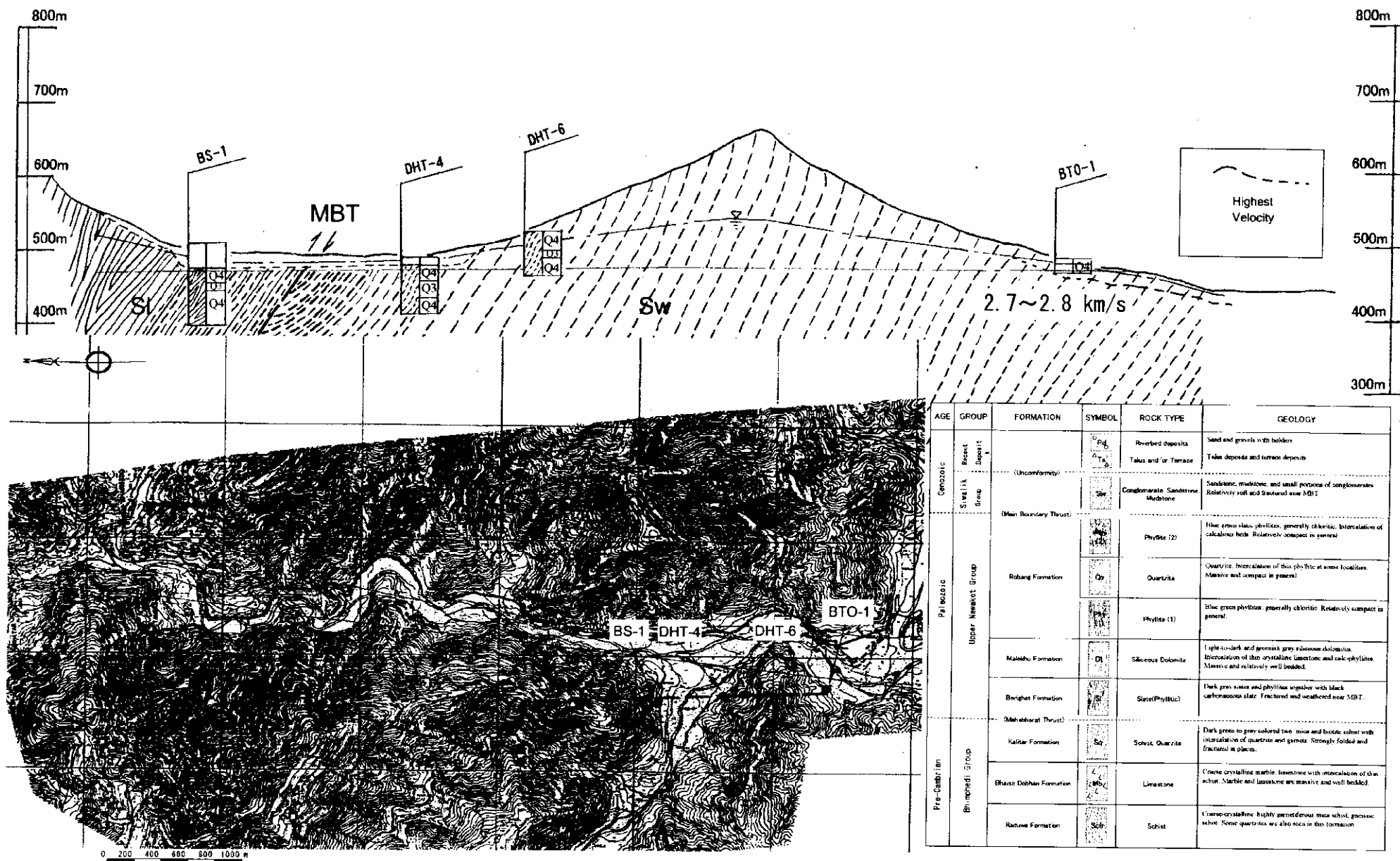
AGE	GROUP	FORMATION	SYMBOL	ROCK TYPE	GEOLOGY
Cenozoic	Recent Deposit Group		Rd	Fluvial deposits	Sand and gravel with boulders
			Ta	Talus and/or Terraces	Talus deposits and terrace deposits
		(Unconformity)	Un		
Paleozoic	Upper Nawakot Group		Co	Conglomerate, Sandstone, Mudstone	Sandstone, mudstone and small portions of conglomerates (relation with and to them is not clear)
		Main Boundary (Thrust)			
			Phy(2)	Phyllite (2)	Thin green phyllite, phyllite, alternating calcareous, intercalation of calcareous beds, relatively compact in general
		Robing Formation	Qu	Quartzite	Quartzite, intercalation of thin phyllite at some locations, massive and compact in general
			Phy(1)	Phyllite (1)	Thin green phyllite, generally chloritic, sometimes compact in general
		Meteolu Formation	Di	Siliceous Dolomite	Light to dark and greenish gray, micaceous dolomite, massive, siliceous, some crystalline, some micaceous and calc-phyllite, massive and relatively well bedded
Pre-Cambrian	Bhimgadevi Group	Bergant Formation	Sl	Slate/Phyllite	Dark gray slate and phyllite, generally thin bedded, fractured and weathered near MBT
		(Mahabharat Thrust)			
		Kalari Formation	Sg	Schist, Quartzite	Dark green to gray colored fine grained and biotite schist with intercalation of quartzite and garnet, strongly folded and fractured at places
		Bhase Dobhan Formation	Ms	Limestone	Thin to medium bedded, micaceous, with intercalation of thin schist, massive and laminar, etc. massive and well bedded
		Rabuni Formation	Sch	Schist	Thin to medium bedded, light greenish gray mica schist, generally, schist, some quartzite are also seen in this formation

* Mahabharat Thrust (MT):

Considered as an extension of Main Central Thrust (MCT), which forms the boundary between Higher and Lower Himalayas. Movement of MCT appears to be 5cm/year in recent years. MT is said to be basement thrust of Kathmandu Valley which includes Bhimgadevi Group.

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Figure B5.4.1
Geological Condition of Connection Tunnel



* Main Boundary Thrust (MBT) :

This thrust forms the boundary between Lower and Sub Himalayas. Siwalik sandstone of folded and faulted Tertiary sedimentary rock have been overthrust in the south of MBT.

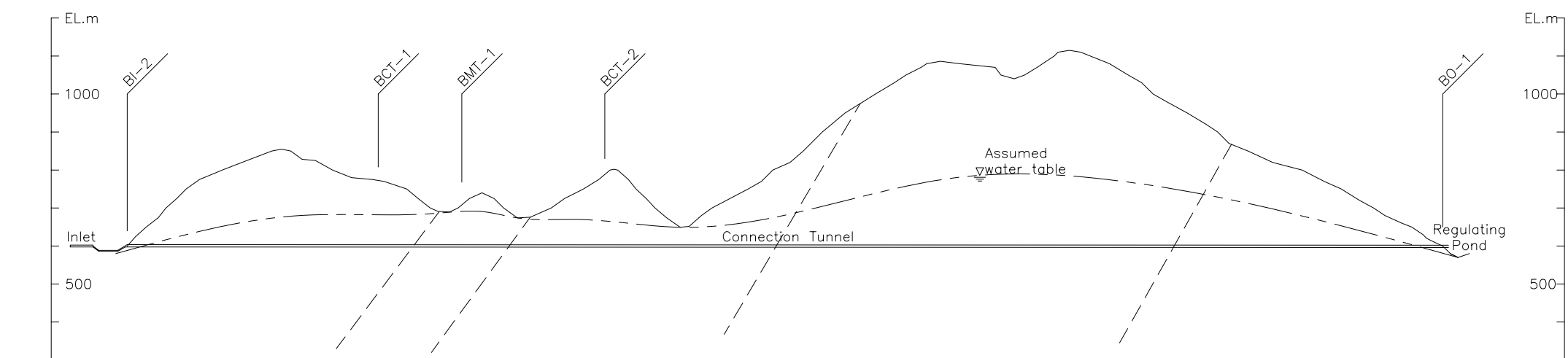
0 50 100 150 200 250 m

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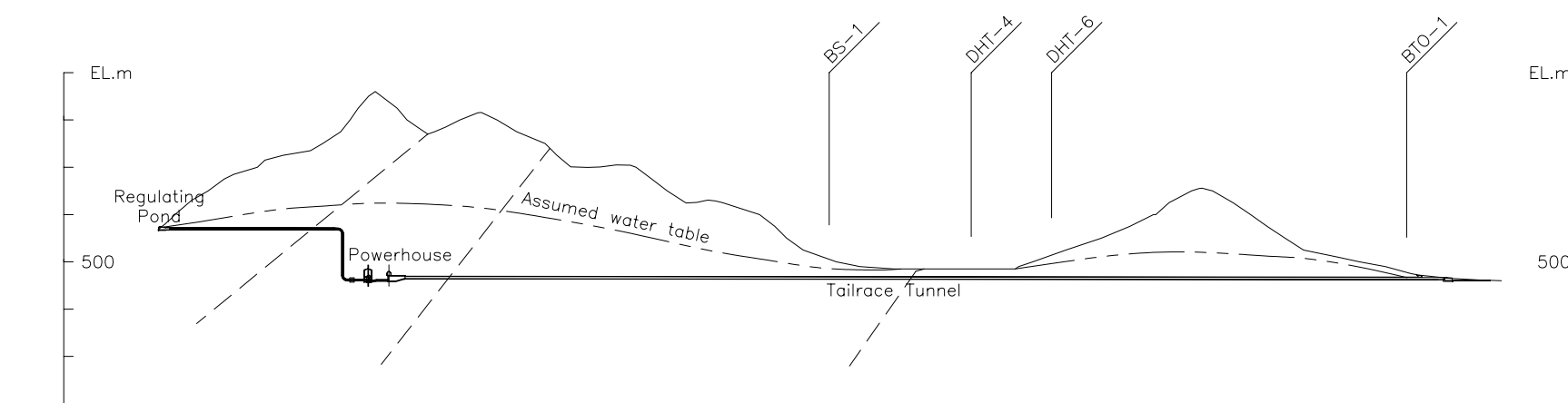
Figure B5.6.1

Geological Condition along Tailrace Tunnel



Additional Distance 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(Inlet To Regulating Pond)

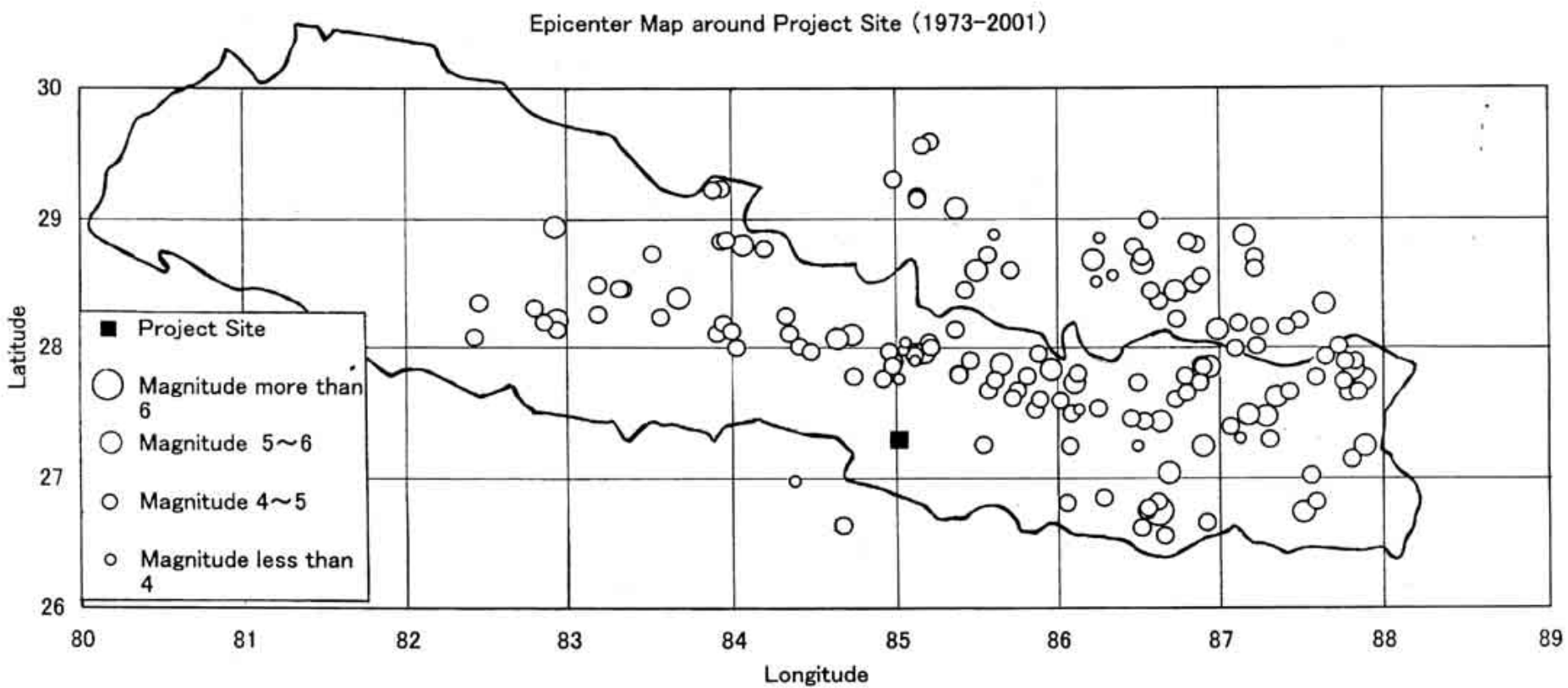


Additional Distance 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(Regulating Pond To Tailrace)

Rock Grade	Modulus of Deformation (MPa)	Shear Strength (MPa)	Friction Degree (degree)	Q value by Q system	CRIEPI classification (Reference)
Q1	> 3,000	> 2.5	> 50	> 40	B
Q2	3,000	2.5	50	10 to 40	CH
Q3	1,000	1.2	45	4 to 10	CM
Q4	500	0.6	40	1 to 4	CL
Q5	250	0.1	35	1 >	D





FREQUENCY-INTENSITY RELATION OF
EARTHQUAKE(By Cornell)

