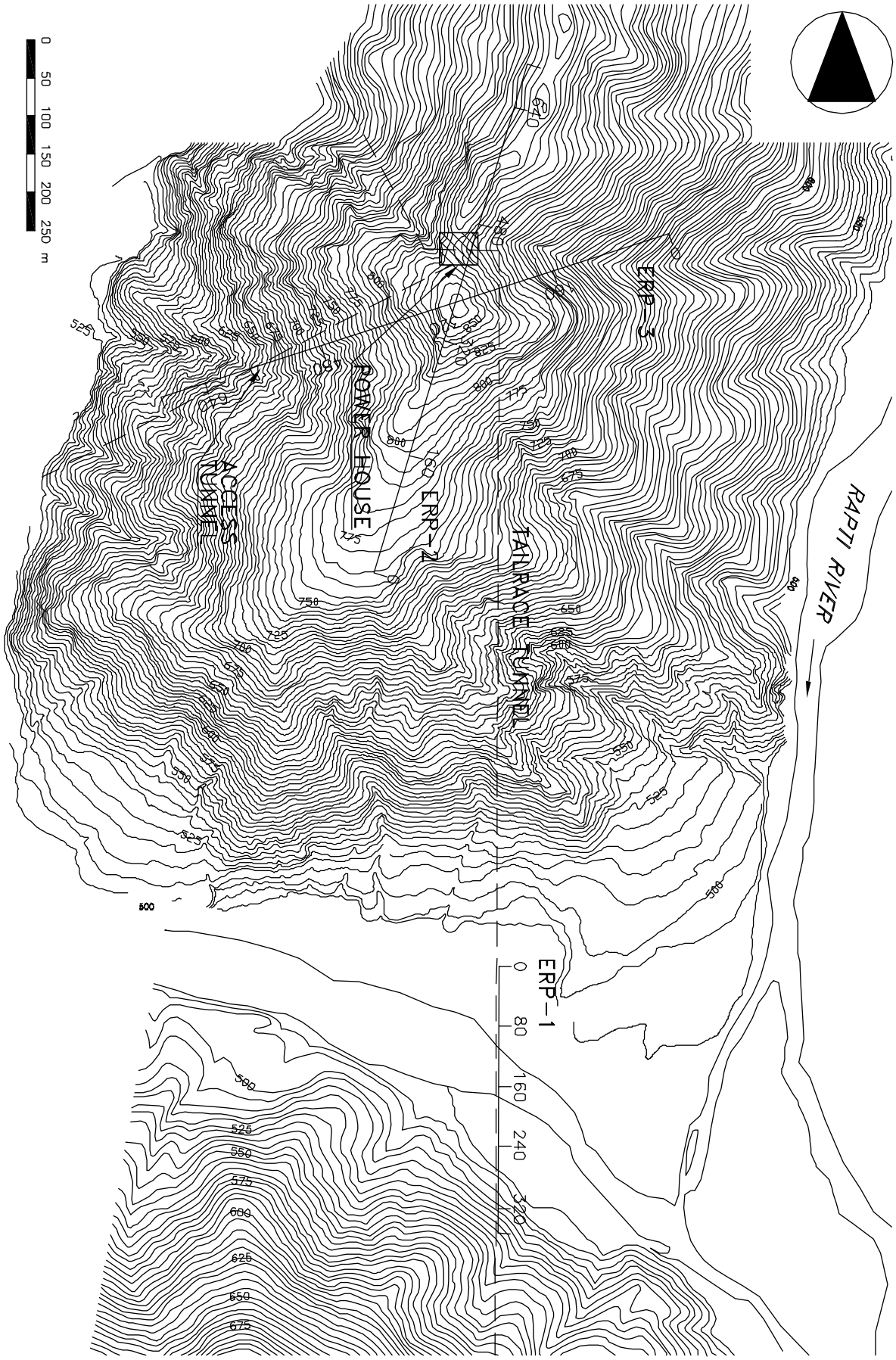

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Figure 3.3.6
Investigation Alignment of Electrical Resistivity Prospecting

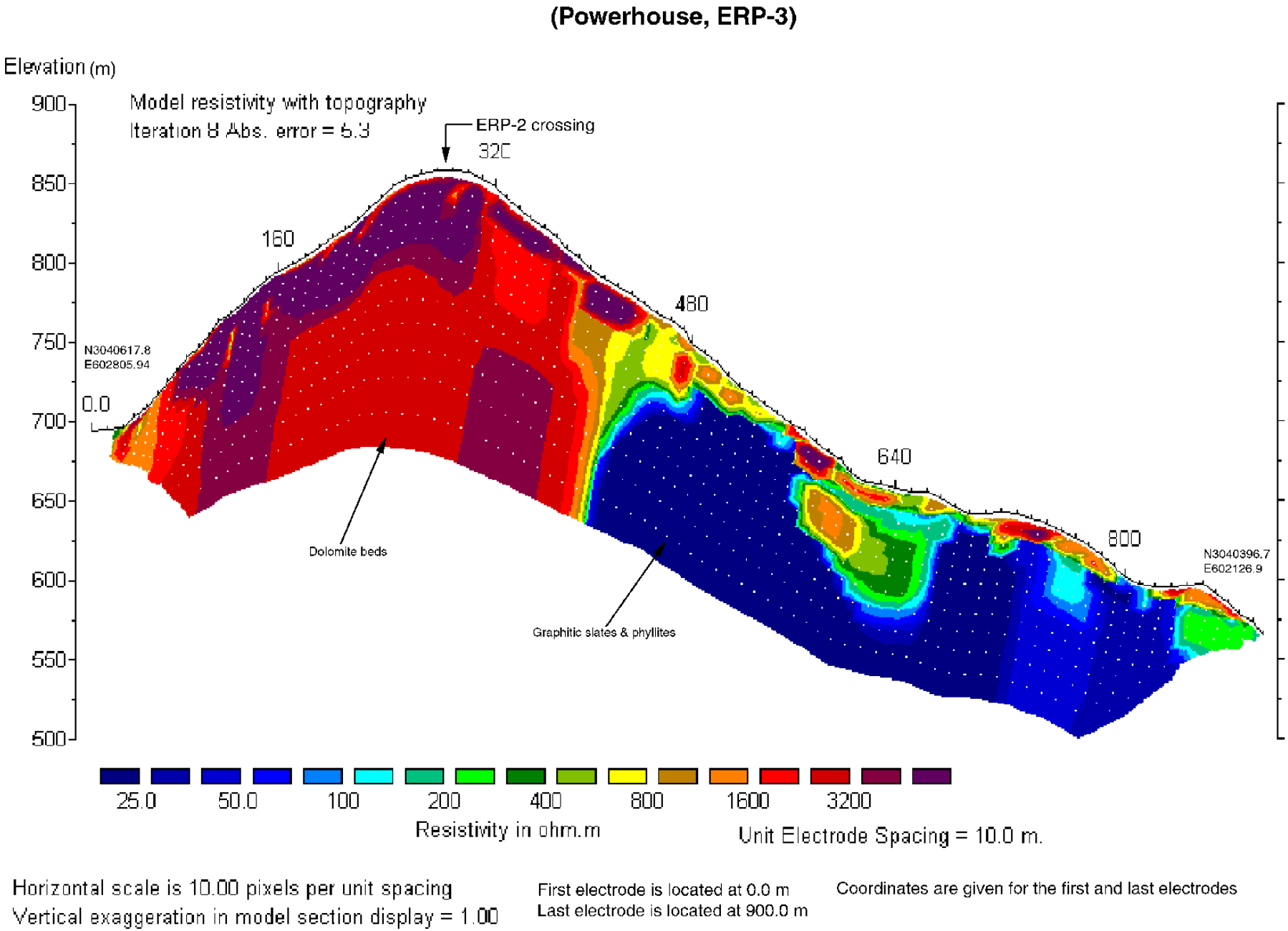

Figure 3.3.7
Electrical Resistivity Profiles around
Underground Structure Site (ERP 3)

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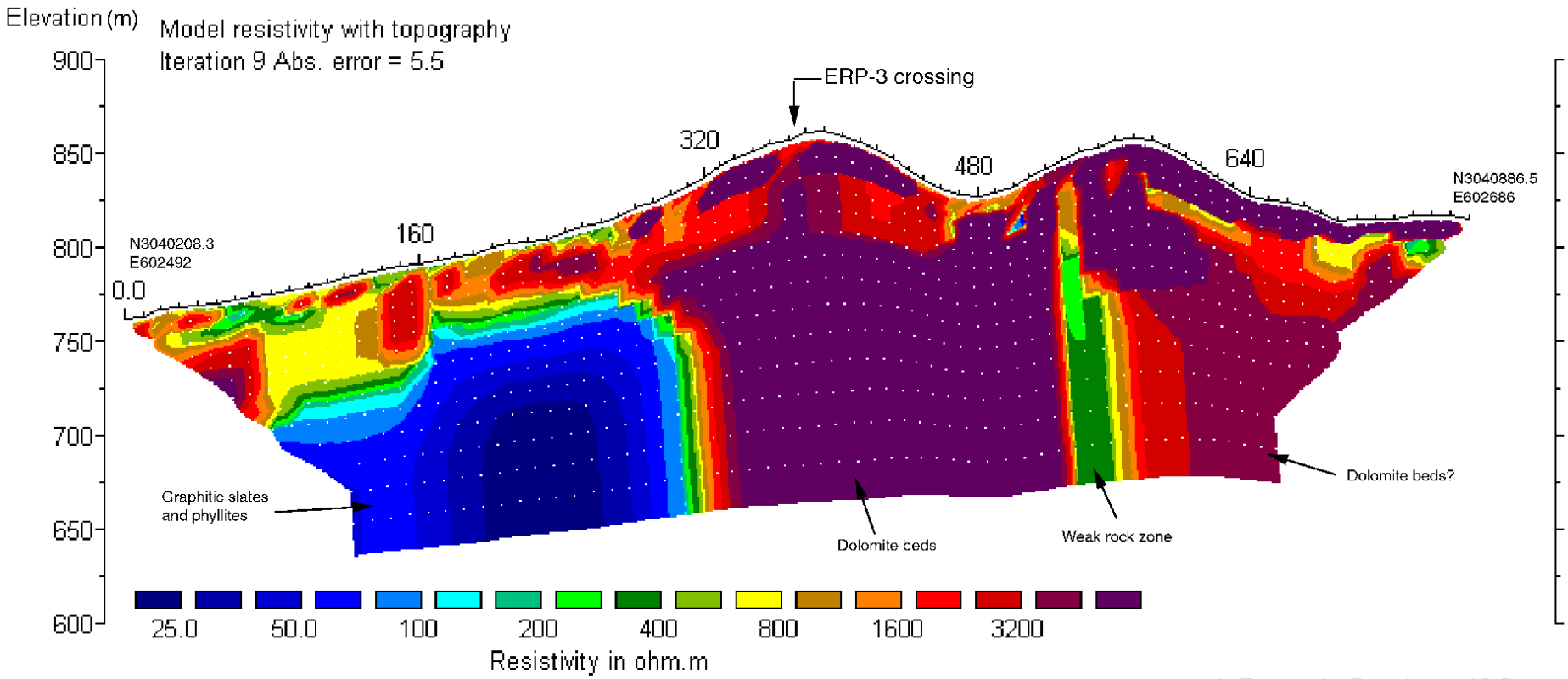
(Powerhouse, ERP-2)



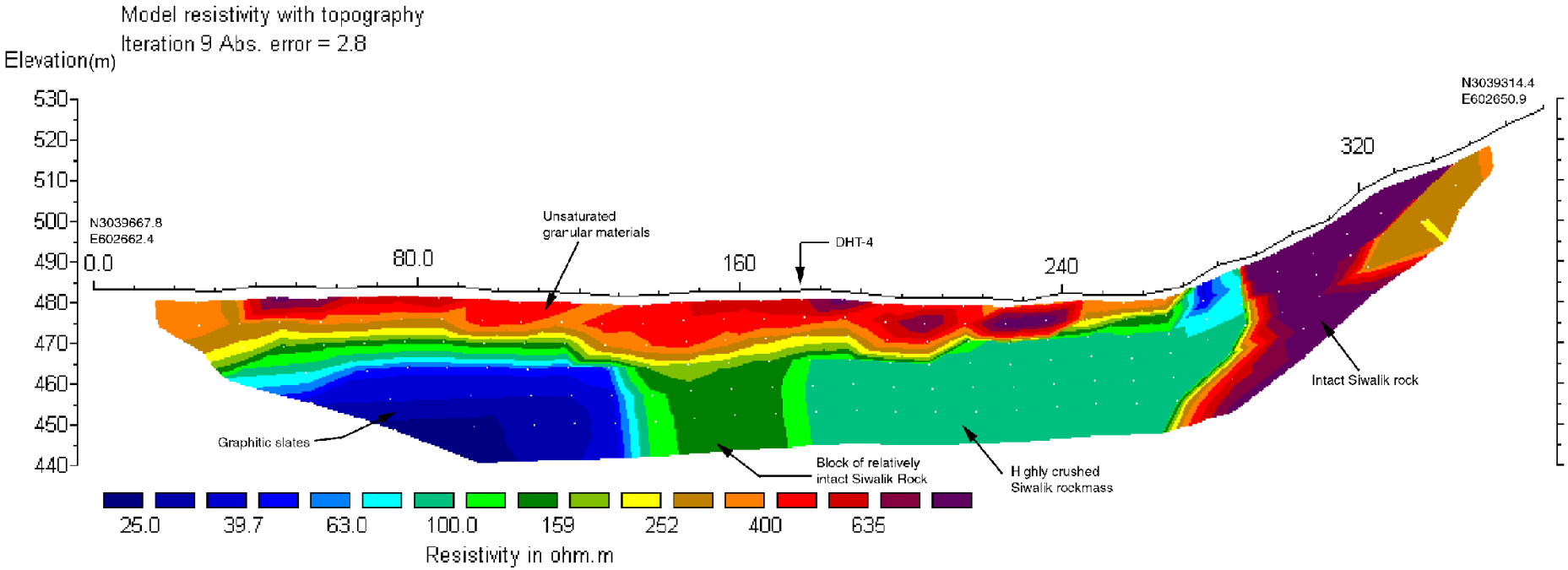
Unit Electrode Spacing = 10.0 m.

Horizontal scale is 10.00 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 m.
Last electrode is located at 760.0 m.

Coordinates are given for the first and last electrodes

Figure 3.3.8
Electrical Resistivity Profiles around
Underground Structure Site (ERP 2)

(Tailrace, ERP-1)

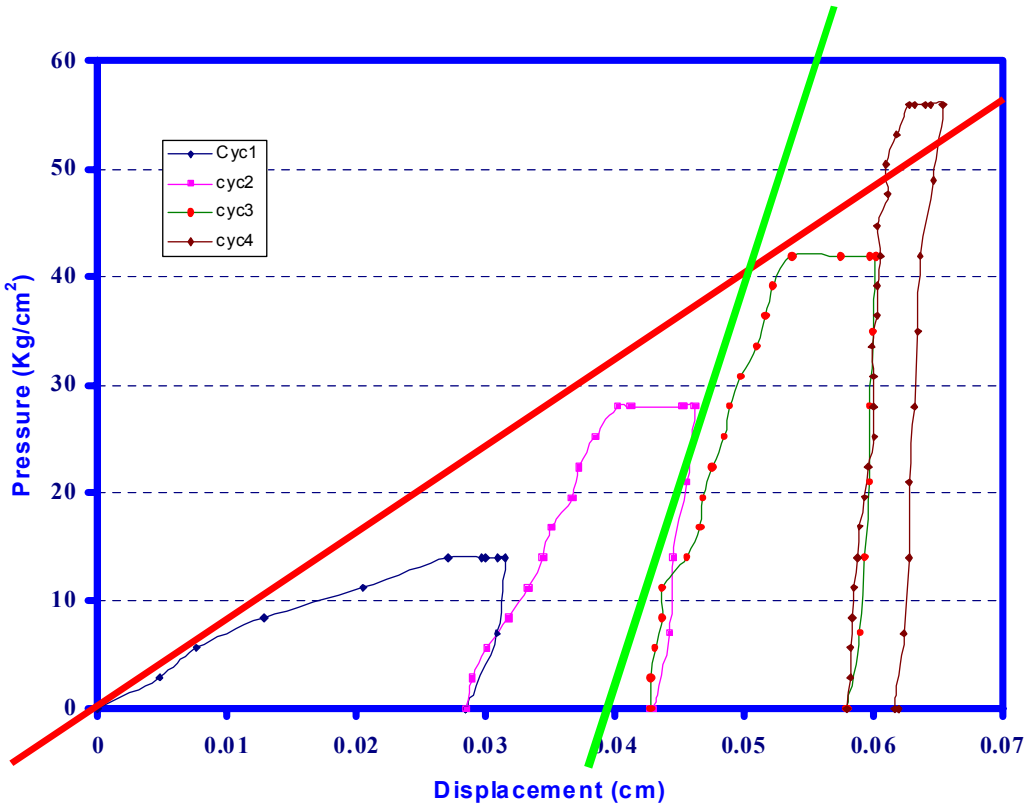


Horizontal scale is 25.00 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 m.
Last electrode is located at 370.0 m.

Coordinates are given for the zero and thirty six pegs

Unit Electrode Spacing = 10.0 m.

Figure 3.3.9
Electrical Resistivity Profiles around
Underground Structure Site (ERP 1)



Kulekhani site 1, pressure vs, displacement curves

Legend:

Modulus of Deformation

Modulus of Elasticity

PL-1

$D = (1-\mu^2) \times \Delta F / \Delta S \times 0.5\ a$

$= (1-0.2^2) \times (9.686 \times 10^4) / (0.0531-0.00) \times 1/(2 \times 27.5)$

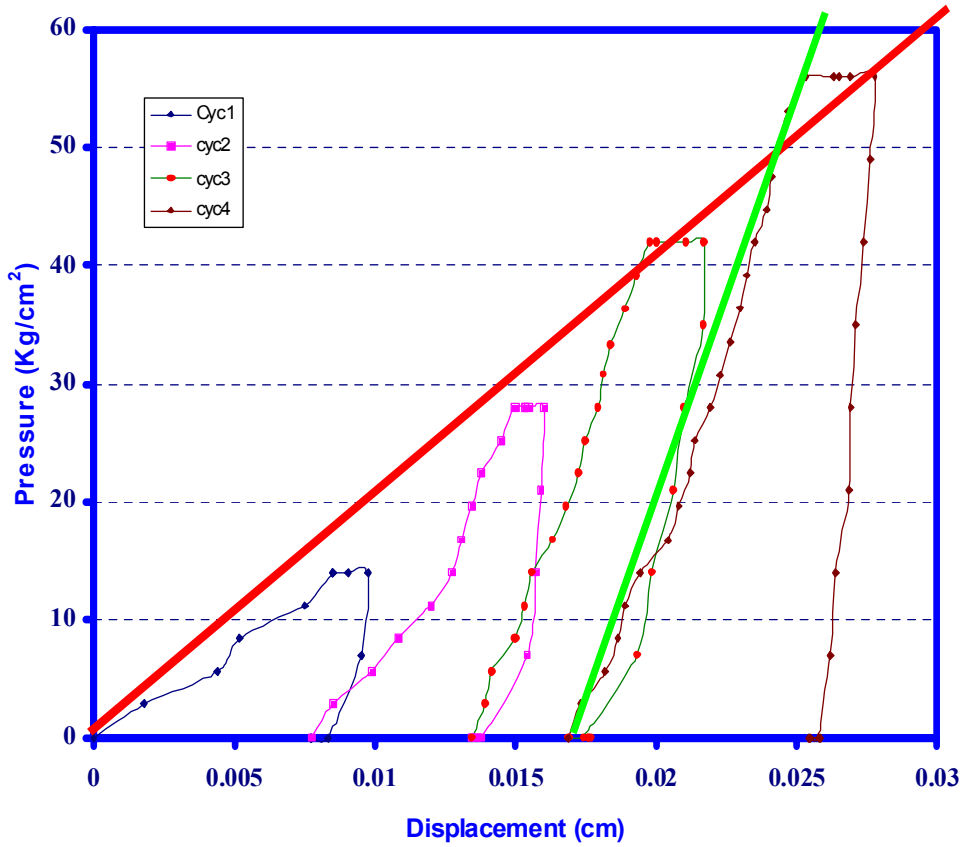
$= 3{,}183.9$ Mpa

$E = (1-\mu^2) \times \Delta F / \Delta S \times 0.5\ a$

$= (1-0.2^2) \times (9.686 \times 10^4) / (0.0531-0.0.04156) \times 1/(2 \times 27.5)$

$= 14{,}650.3$ Mpa

THE UPGRADING FEASIBILITY STUDY ON THE DEVELOPMENT OF THE KULEKHANI III HYDROPOWER PROJECT IN THE KINGDOM OF NEPAL	Figure 3.3.10 Test Result of Plate Load Test (1/3)
JAPAN INTERNATIONAL COOPERATION AGENCY	



Kulekhani site 2, pressure vs. displacement curves

Legend:

Modulus of Deformation

Modulus of Elasticity

PL-2

$D = (1-\mu^2) \times \Delta F / \Delta S \times 0.5\,a$

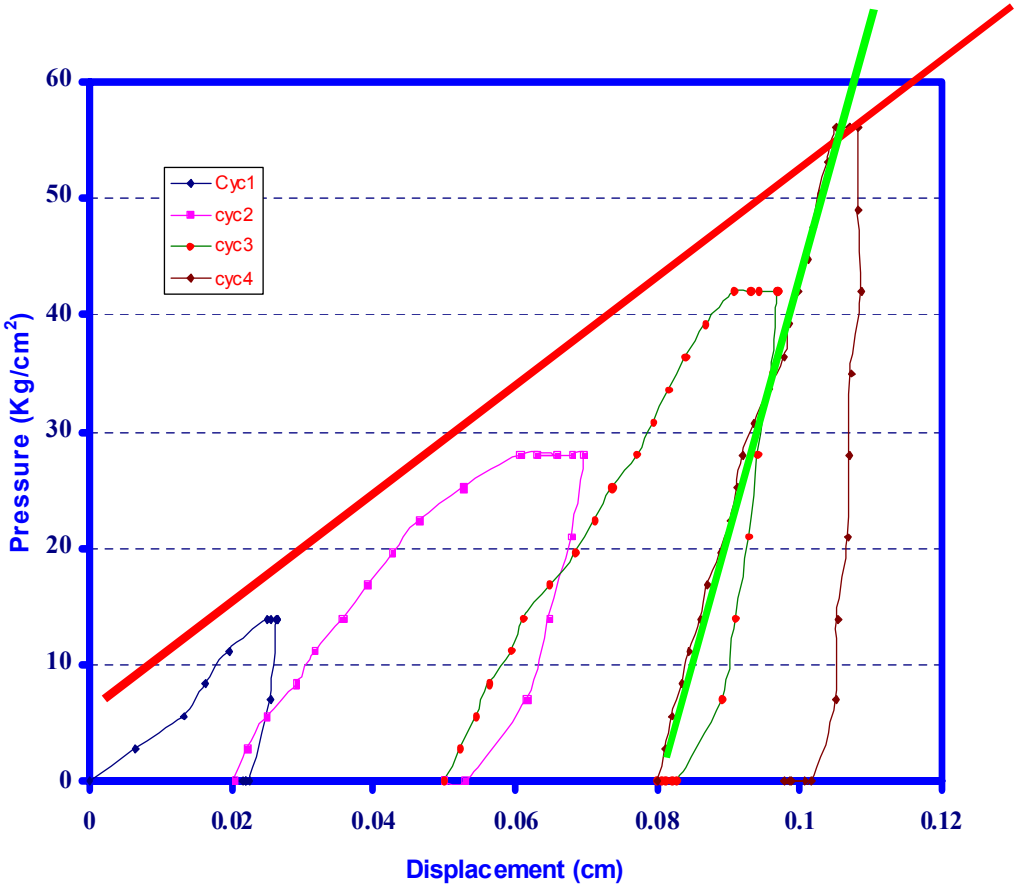
$= (1-0.2^2) \times (11.9672 \times 10^4) / (0.025-0.00) \times 1/(2 \times 27.5)$

$= 9{,}366.9$ Mpa

$E = (1-\mu^2) \times \Delta F / \Delta S \times 0.5\,a$

$= (1-0.2^2) \times (11.9672 \times 10^4) / (0.025-0.0027) \times 1/(2 \times 27.5)$

$= 25{,}340.5$ Mpa



Kulekhani site 3, pressure vs. displacement curves

Legend:

Modulus of Deformation

Modulus of Elasticity

PL-3

$D = (1-\mu^2) \times \Delta F / \Delta S \times 0.5\ a$

$= (1-0.2^2) \times (11.17522 \times 10^4) / (0.10270 - 0.00) \times 1/(2 \times 27.5)$

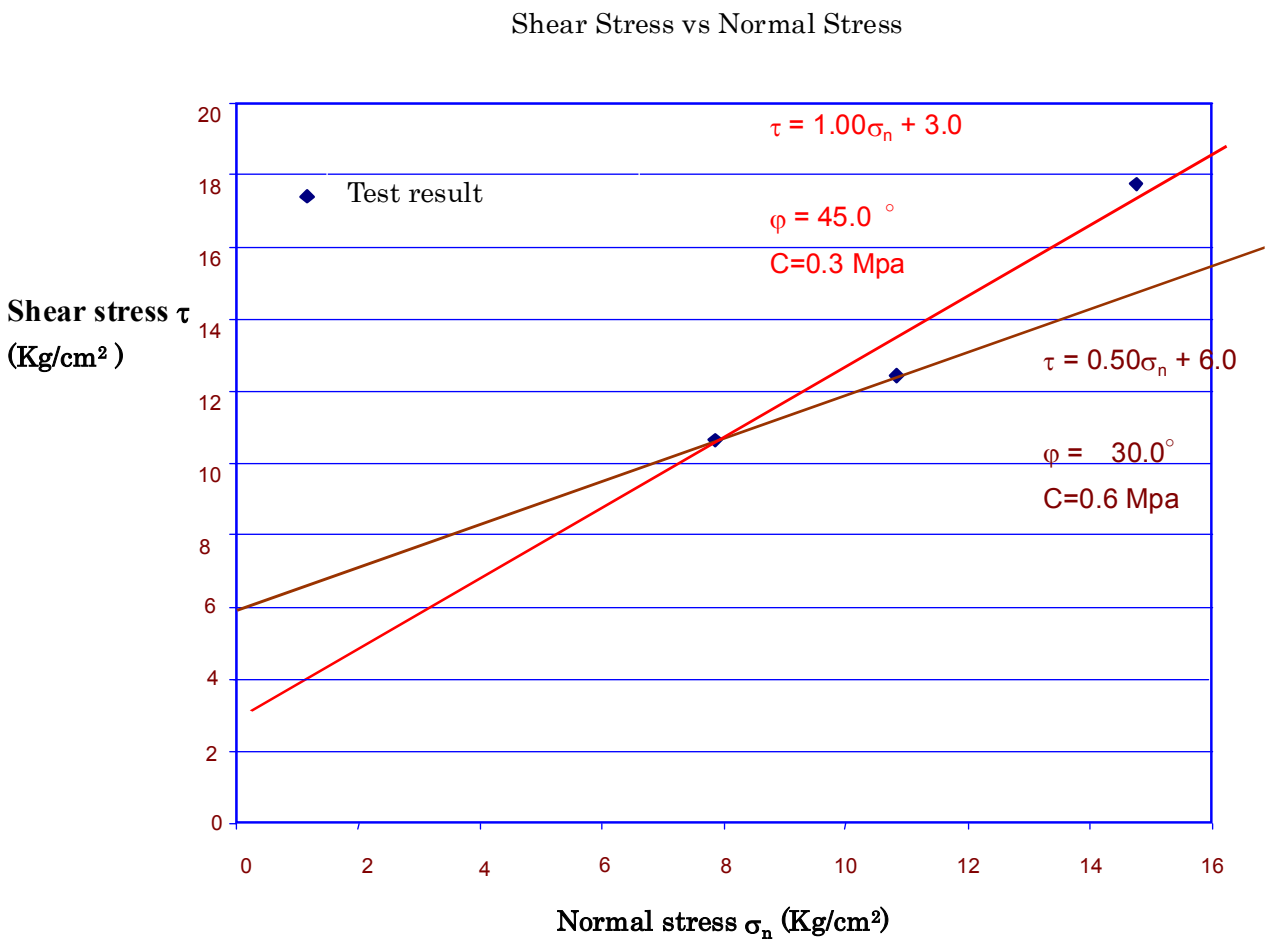
$= 1{,}869.5$ Mpa

$E = (1-\mu^2) \times \Delta F / \Delta S \times 0.5\ a$

$= (1-0.2^2) \times (11.17522 \times 10^4) / (0.10270-0.00973) \times 1/(2 \times 27.5)$

$= 8{,}392.9$ Mpa

THE UPGRADING FEASIBILITY STUDY ON THE DEVELOPMENT OF THE KULEKHANI III HYDROPOWER PROJECT IN THE KINGDOM OF NEPAL	Figure 3.3.12 Test Result of Plate Load Test (3/3)
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE UPGRADING FEASIBILITY STUDY ON THE DEVELOPMENT OF THE KULEKHANI III HYDROPOWER PROJECT IN THE KINGDOM OF NEPAL	Figure 3.3.13 Test Result of Rock Shear Test
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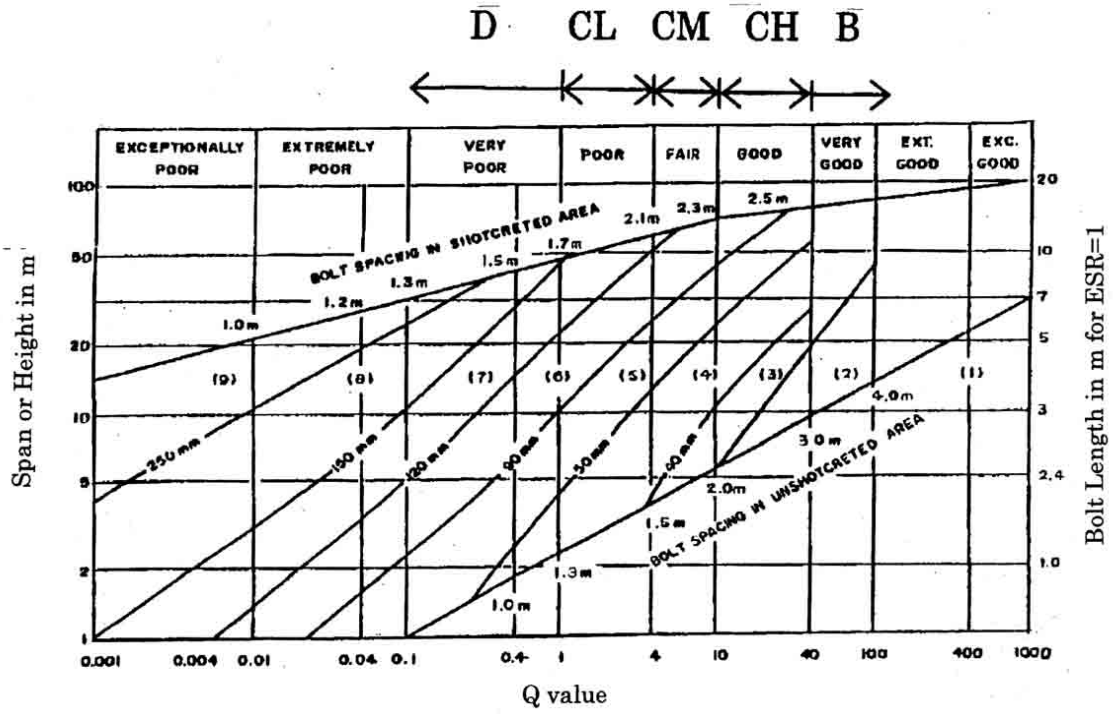
ROCK CLASSIFICATION AND REINFORCEMENT CATERGORIES BY CRIEPI ROCK CLASSIFICATION(1991)

Rock Grade	Support Pattern	Shotcreting		Rock Bolting			Steel Support	
		Thickness (cm)	Area	Length (m)	Nos of bolts	Pitch (m)	Materilals	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

(2) Spot bolting

(3) Systematic bolting

(4) Systematic bolting with 40 - 100 mm unreinforced shotcrete

(5) Fibre reinforced shotcrete, 50 - 90 mm and shotcrete

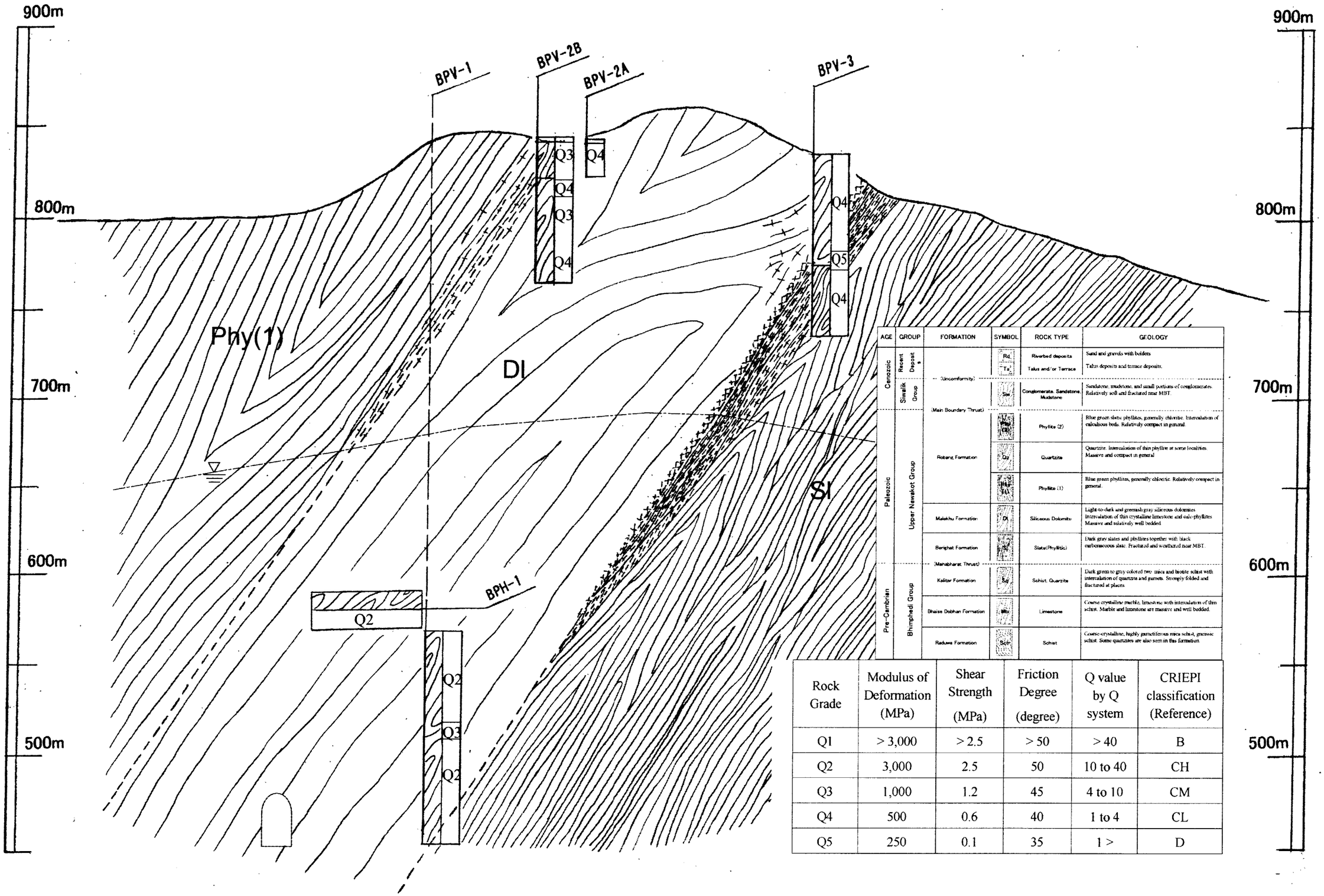
(6) Fibre reinforced shotcrete, 90 -120 mm and shotcrete

(7) Fibre reinforced shotcrete, 120 - 150 mm and shotcrete

(8) Fibre reinforced shotcrete, >150 mm with reinforced ribs of shotcrete and bolting.

(9) Cast concrete lining

Figure 3.3.14 Correlation of Q System and CRIEPI Rock Classification



AGE	GROUP	FORMATION	SYMBOL	ROCK TYPE	GEOLOGY
Cenozoic	Recent Deposits		Rd	Riverbed deposits	Sand and gravels with boilders
			Ta	Talus and/or Terrace	Talus deposits and terrace deposits.
		(Unconformity)			
	Siwalik Group		Sw	Conglomerate, Sandstone, Mudstone	Sandstone, mudstone, and small portions of conglomerates. Relatively soft and fractured near MBT.
		(Main Boundary Thrust)			
Paleozoic	Upper Nawakot Group	Robang Formation	Phy (2)	Phyllite (2)	Blue green slate; phyllites, generally chloritic. Intercalation of calcalious beds. Relatively compact in general.
			Qz	Quartzite	Quartzite, intercalation of thin phyllite at some localities. Massive and compact in general
			Phy (1)	Phyllite (1)	Blue green phyllites, generally chloritic. Relatively compact in general.
		Malekhu Formation	DI	Siliceous Dolomite	Light-to-dark and greenish gray siliceous dolomites Intercalation of thin crystalline limestone and calc-phyllites Massive and relatively well bedded
		Benighat Formation	Sl	Slate(Phyllitic)	Dark gray slates and phyllites together with black carbonaceous slate. Fractured and weathered near MBT.
		(Mahabharat Thrust)			
Pre-Cambrian	Bhimphedi Group	Kalitar Formation	Sq	Schist, Quartzite	Dark green to gray colored two mica and biotite schist with intercalation of quartzite and garnets. Strongly folded and fractured at places
		Bhaise Dobhan Formation	Mbr	Limestone	Coarse crystalline marble, limestone with intercalation of thin schist. Marble and limestone are massive and well bedded.
		Raduwa Formation	Sch	Schist	Coarse-crystalline, highly garnetiferous mica schist, gneissic schist. Some quartzites are also seen in this formation.

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

0 25 50 75 100 125 m

THE UPGRADING FEASIBILITY STUDY ON THE DEVELOPMENT OF THE KULEKHANI III HYDROPOWER PROJECT IN THE KINGDOM OF NEPAL

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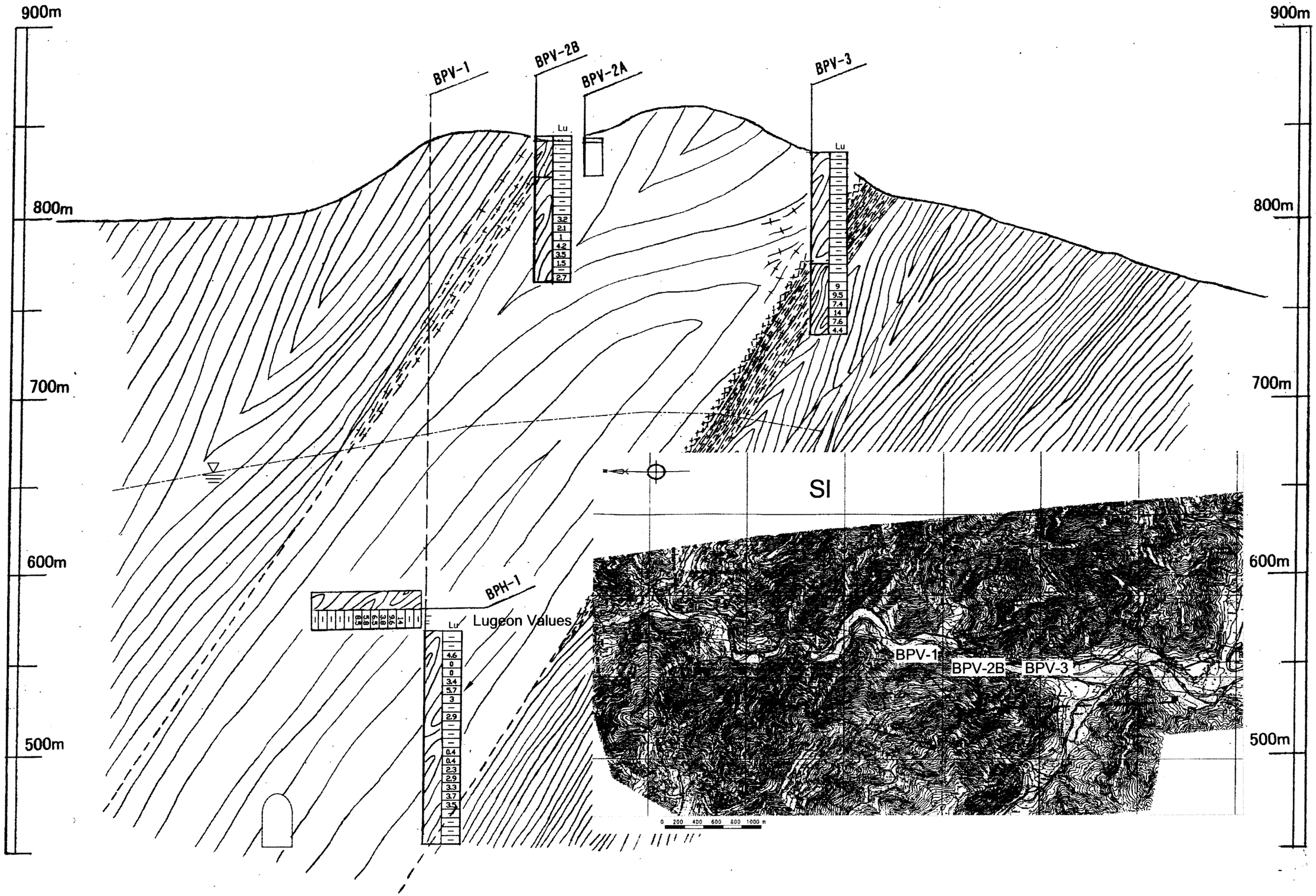
Figure 3.3.15
Geological Condition around Underground Structures



THE UPGRADING FEASIBILITY STUDY ON THE DEVELOPMENT OF THE KULEKHANI III HYDROPOWER PROJECT IN THE KINGDOM OF NEPAL	Figure 3.3.16
JAPAN INTERNATIONAL COOPERATION AGENCY	Permeability around Underground Structures