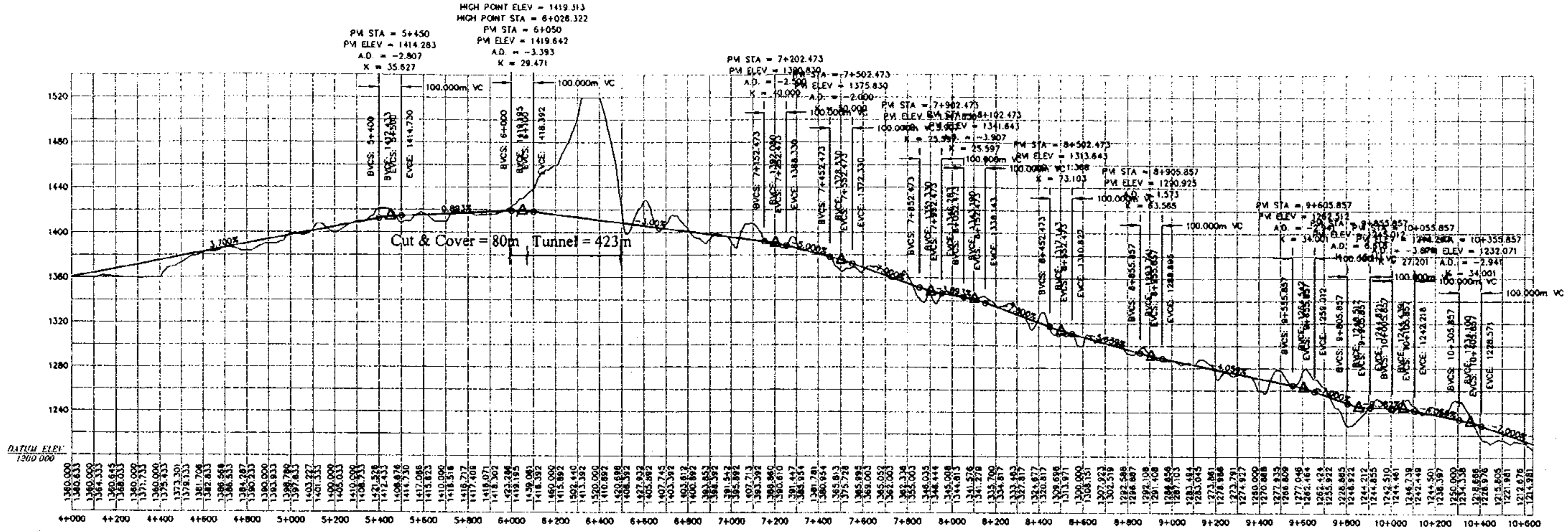
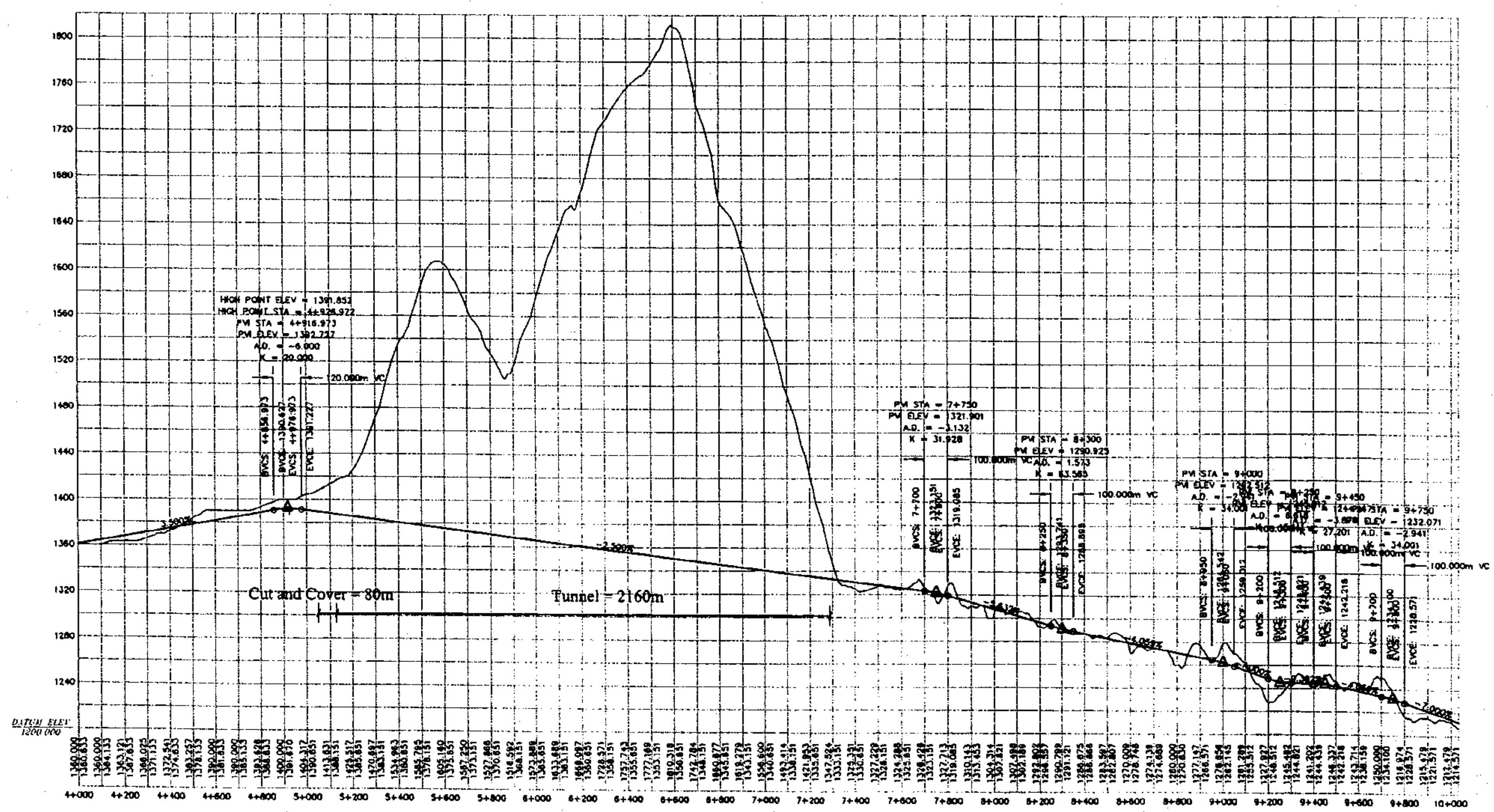


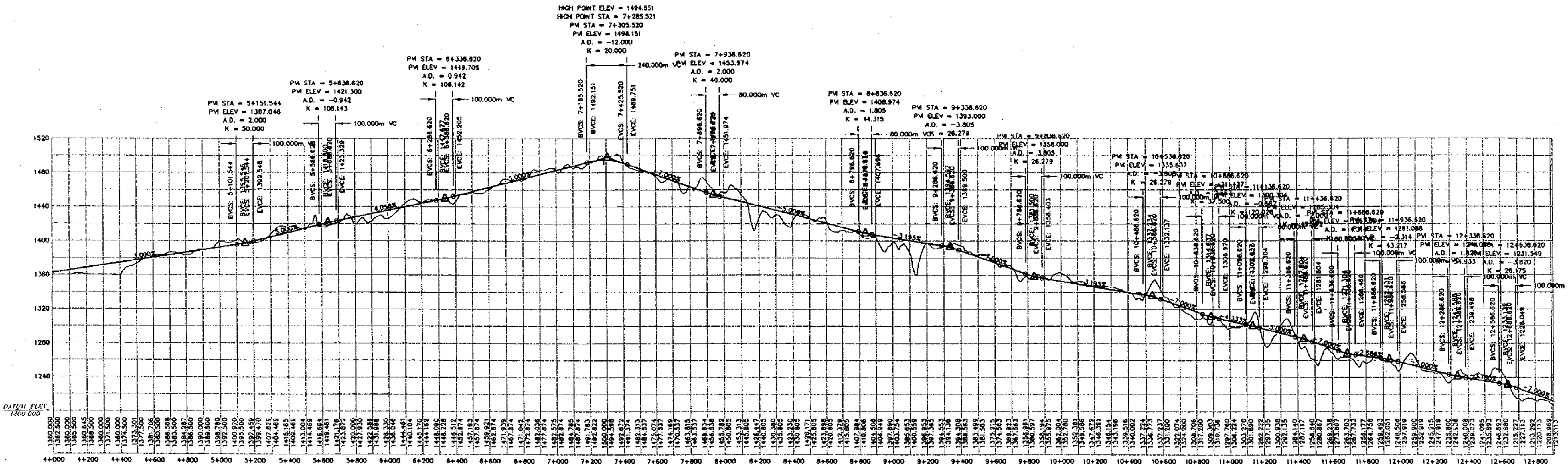
Alternative C-2 (Short Tunnel)



Alternative C-1 (Long Tunnel)

Scale : 1/25,000

Figure 10.4 (1/2) Vertical Profile of Alternatives in Section C



Alternative C-3N (Open Option)

Scale : 1/25,000

Figure 10.4 (2/2) Vertical Profile of Alternatives in Section C

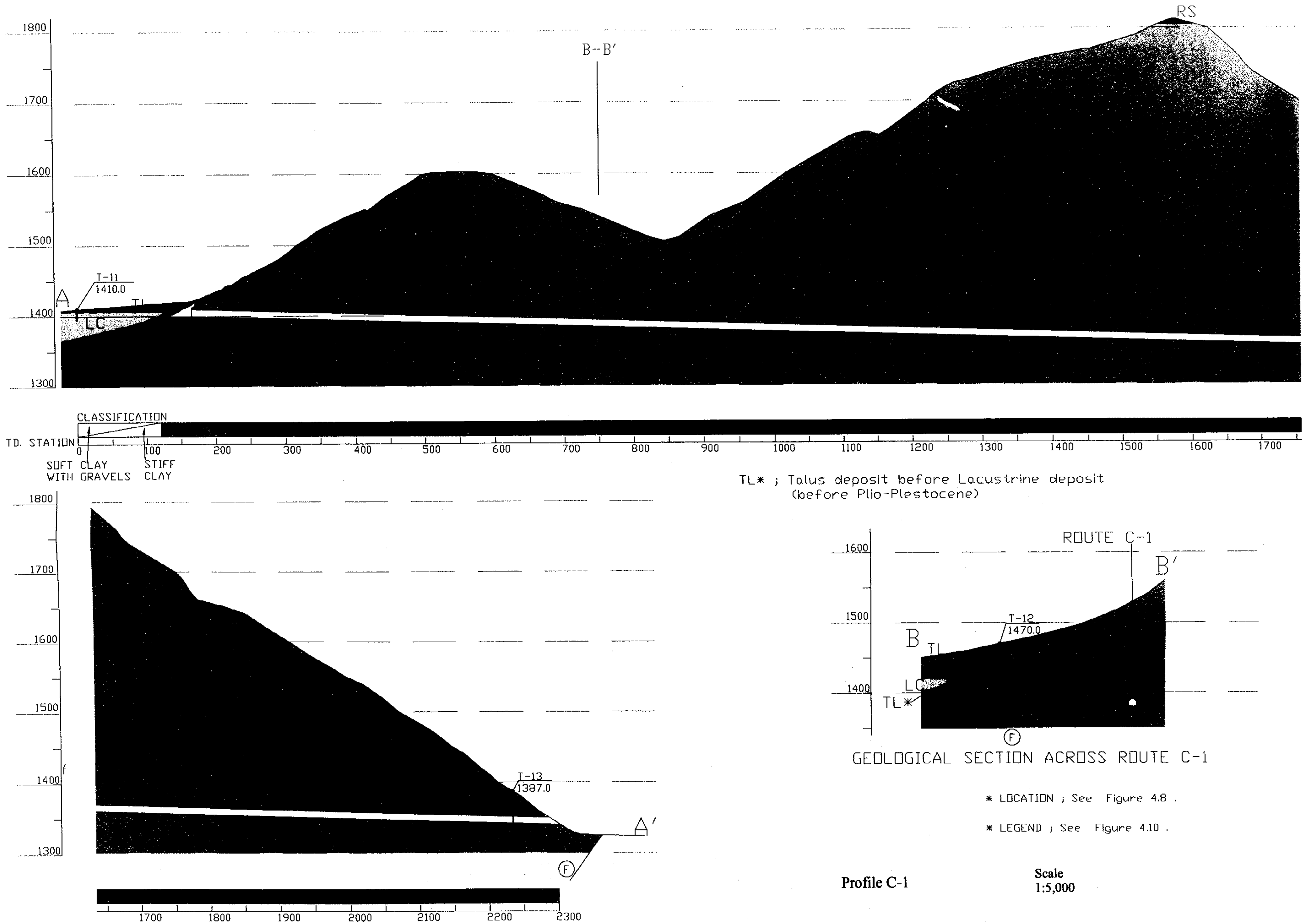


Figure 10.5 (1/2) Geological Profile Along Tunnel Routes

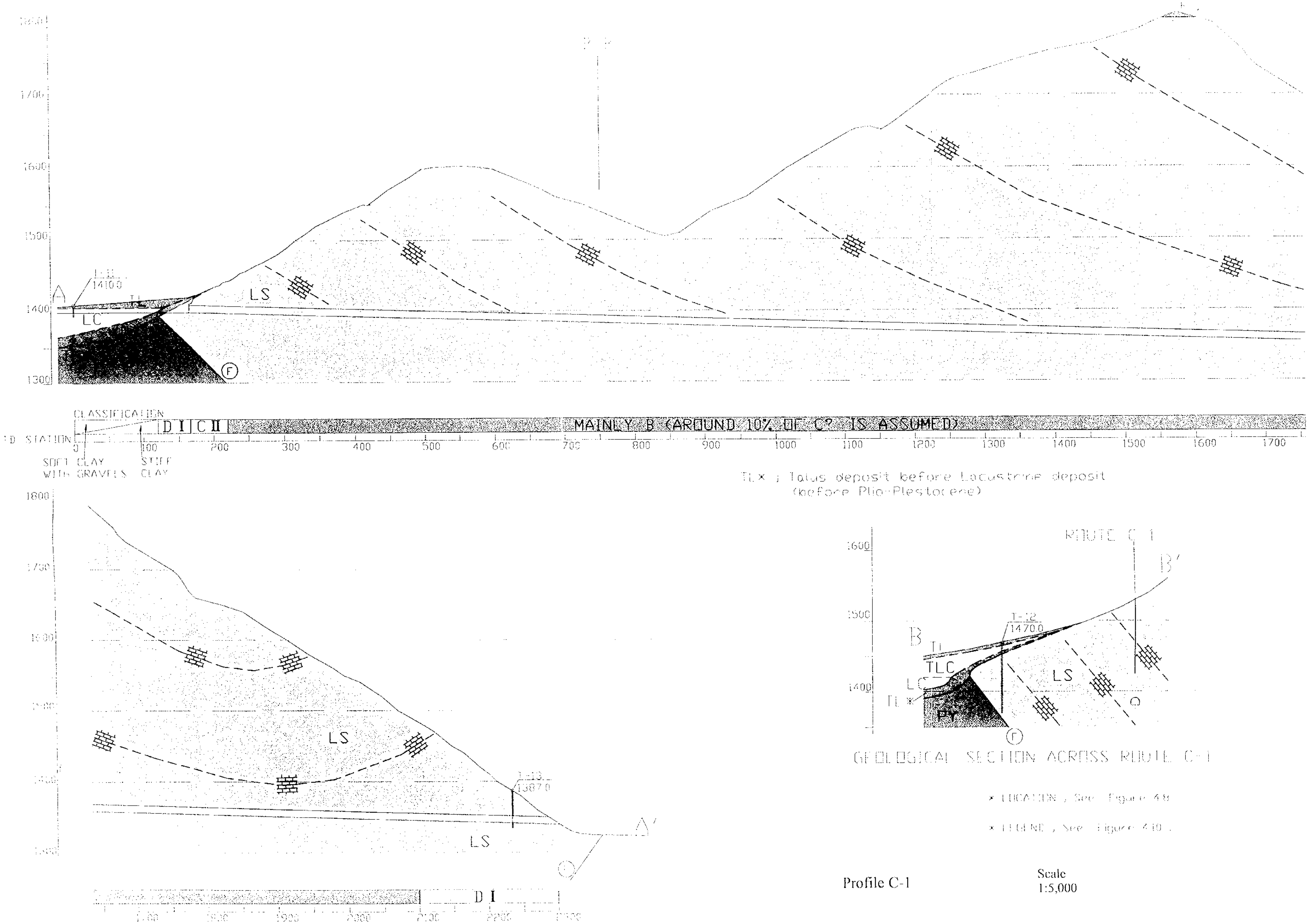
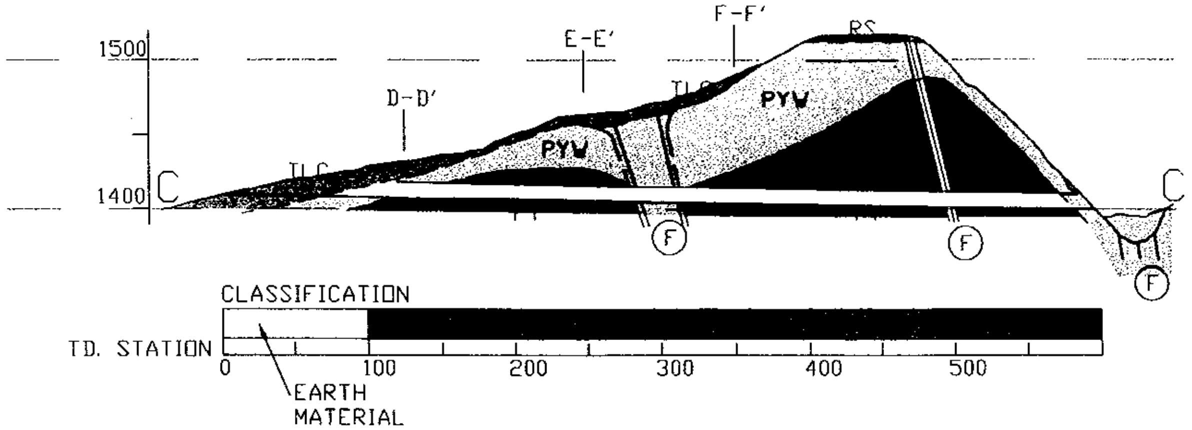
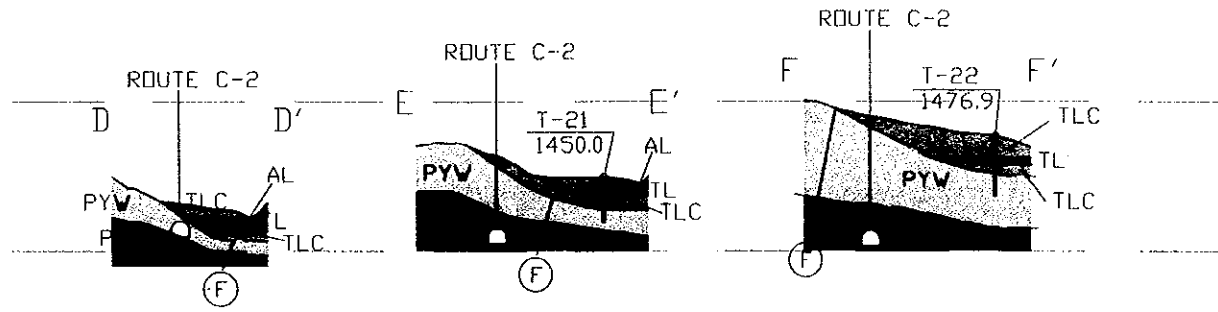


Figure 10.5 (1/2) Geological Profile Along Tunnel Routes



Profile C-2



GEOLOGICAL SECTIONS ACROSS ROUTE C-2

* LOCATION ; See Figure 4.8 .

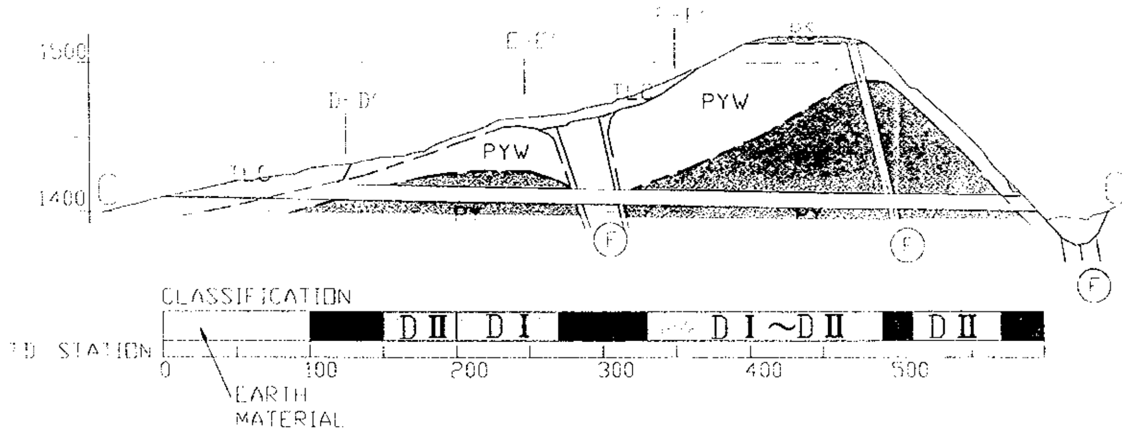
Scale
1:5,000

LEGEND

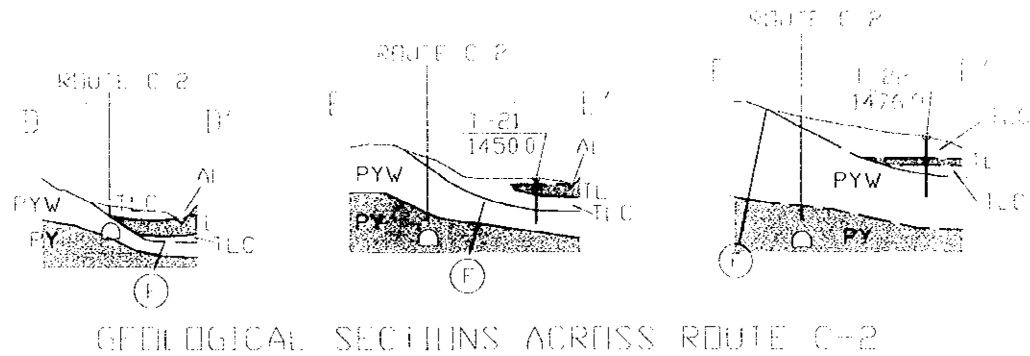
SYMBOL	FORMATION		DETAILED DESCRIPTION AND ENGINEERING PROPERTIES	GEOLOGICAL AGE
	Alluvial deposit	AL	Boulders,gravel,sandy gravel,sand and silt. Low bearing capacity ,midium dense to loose.	Holocene
	Talus to debris flow deposit with big boulders.	TL	Inhomogeneous deposit at foot-slopes with clay,silt and sand at places boulders. Low to moderate bearing capacity ,loose to slightly dense and soft to firm.	Holocene
	Talus to debris flow deposit without boulders.	TLC	Inhomogeneous deposit, without boulders mainly lateratic clayey material.	Holocene
	Residual soil	RS	Thin cover of lateratic soil and gray to brown silty clay and soil on ridge top.	Holocene
	Lacustrine deposit	LC	Semi-consolidated sandy,clayey carbonatceous silt interbeded with gravels and clayey sand. Peat and lignitic fray upto 3m is common. Medium to high bearing capacity.	Plio-Plestocene
	Limestone group	LS	Pale brown to bluish gray, medium to thick bedded massive and finely crystalline limestone, at places phyllite, locally sileceous and dolomites thinly bedded at the bottom.	Lower Paleozoic
	Phyllite group weathered	PYW	Greenish gray to brown, fine grained phyllite and slate interbedded with thin bands of argillaceous limestone. Moderate to heavily weathered. Remarkable anisotropy.	Pre-Cambrian
	Phyllite group unweathered	PY	Greenish gray to brown, fine grained phyllite with thin bands of argillaceous limestone, unweathered, Remarkable anisotropy.	Pre-Cambrian

Ⓕ Ⓕ	Fault
	Anticline
	Synecline

Figure 10.5 (2/2) Geological Profile Along Tunnel Routes



Profile C-2



Scale
1:5,000

× LOCATION , See Figure 4.8

LEGEND

SYMBOL	FORMATION		DETAILED DESCRIPTION AND ENGINEERING PROPERTIES	GEOLOGICAL AGE
	Alluvial deposit	AL	Boulders,gravel,sandy gravel,sand and silt Low bearing capacity ,midium dense to loose.	Holocene
	Talus to debris flow deposit with big boulders	TL	Inhomogeneous deposit at foot-slopes with clay,silt and sand at places boulders. Low to moderate bearing capacity ,loose to slightly dense and soft to firm	Holocene
	Talus to debris flow deposit without boulders	TLC	Inhomogeneous deposit, without boulders mainly lateratic clayey material	Holocene
	Residual soil	RS	Thin cover of lateratic soil and gray to brown silty clay and soil on ridge top	Holocene
	Lacustrine deposit	LC	Semi-consolidated sandy,clayey carbonatceous silt inter-beded with gravels and clayey sand. Peat and lignitic fray upto 3m is common. Medium to high bearing capacity	Plio-Plestocene
	Limestone group	LS	Pale brown to bluish gray, medium to thick bedded massive and finely crystalline limestone, at places phyllite, locally siliceous and dolomites thinly bedded at the botton.	Lower Paleozoic
	Phyllite group weathered	PYW	Greenish gray to brown, fine grained phyllite and slate interbedded with thin bands of argillaceous limestone Moderate to heavily weathered. Remarkable anisotropy	Pre-Cambrian
	Phyllite group unweathered	PY	Greenish gray to brown, fine grained phyllite with thin bands of argillaceous limestone, unweathered. Remarkable anisotropy	Pre Cambrian
	Fault			
	Anticline			
	Syncline			

Figure 10.5 (2/2) Geological Profile Along Tunnel Routes

10.4.2 Cost estimates of Possible Alternative Routes

1) General

The main features and policy to be considered in the approximate cost estimate are as follows:

- Approximate construction cost is calculated based on major construction works. Other minor works are included as miscellaneous, the cost of which is assumed to be 5 % of the total cost of major works.
- Unit Prices of major works, except tunnel, are temporarily referred to that of past study and contract unit prices of similar projects in Nepal.
- Construction cost of tunnels is computed based on the Japanese construction rate analysis. However, that is adjusted by using available Nepalese unit prices as far as possible.
- Cost of installation of power transmission line from sub-station to the Project site is based on the quotation of the Nepal Electricity Authority (NEA)

2) Construction cost estimate

Based on the above policy, construction cost of each alternative is estimated. Result of estimation is shown in Table 10.10.

Table 10.10 Approximate Cost Estimate

Major Item	Unit	Unit Cost (NRs)	Quantity Alt.-1	Quantity Alt.-2	Quantity Alt.-3	Total Cost (NRs) Alt.-1	Total Cost (NRs) Alt.-2	Total Cost (NRs) Alt.-3	Remarks
1.Preparation Work									
1-1 Clearing	m2	31	-	-	-				
2.Earthwork						446,986,000	503,375,000	656,976,000	*120%
2-1 Excavation (Common Soil)	m3	153	868,260	930,322	1,100,442	132,844,000	142,339,000	168,368,000	
2-2 Excavation (Rock)	m3	785	217,065	232,580	275,111	170,396,000	182,575,000	215,962,000	
2-3 Excavation (Spoil)	m3	257	0	0	0	0	0	0	
2-4 Embankment	m3	79	876,562	1,009,282	1,126,458	69,248,000	79,733,000	88,990,000	
2-5 Borrow Embankment	m3	824		18,000	90,000	0	14,832,000	74,160,000	
2-6 Excavation for Structure	m3	171				0	0	0	
3.Drainage						120,600,000	132,461,000	152,011,000	
3-1 Side Ditch	m	2,400	45,708	49,715	57,193	109,699,000	119,316,000	137,263,000	
3-2 Box Culvert (2m*2m)	m	21,374	510	615	690	10,901,000	13,145,000	14,748,000	
4.Slope Protection						149,084,000	207,505,000	346,484,000	*120%
4-1 Wet Masonry Wall	m2	2,500	13,150	19,450	20,150	32,875,000	48,625,000	50,375,000	
4-2 Gabion Wall	m3	3,000	30,454	41,432	79,454	91,362,000	124,296,000	238,362,000	
5.Bridge						365,135,000	453,951,000	532,899,000	
5-1 Bridge	m2	91,375	3,996	4,968	5,832	365,135,000	453,951,000	532,899,000	
6.Land Slide Countermeasure						16,050,000	35,404,000	71,346,000	
6-1 Wet Masonry Wall	m2	2,500				0	0	0	
6-2 Counterweight Embankment	m3	128		151,200	432,000	0	19,354,000	55,296,000	
6-3 Revetment	m2	2,500	2,100	2,100	2,100	5,250,000	5,250,000	5,250,000	
6-4 Gabion work	m3	3,000	3,600	3,600	3,600	10,800,000	10,800,000	10,800,000	
7.Pavement						371,607,000	404,181,000	464,982,000	
7-1 Subbase Course	m3	1,200	68,562	74,572	85,790	82,274,000	89,486,000	102,948,000	
7-2 Base Course	m3	1,400	68,562	74,572	85,790	95,987,000	104,401,000	120,106,000	
7-3 Asphalt Concrete	m2	846	228,541	248,575	285,967	193,346,000	210,294,000	241,928,000	
8.Tunnel						1,862,653,000	586,905,000	0	
8-1 Tunnel	L.S.					1,500,706,000	493,116,000		
8-2 Ventilation	L.S.					53,421,000			
8-3 Lighting	L.S.					73,684,000	36,842,000		
8-4 M&E	L.S.					153,158,000	38,421,000		
8-5 Emergency Facilities	L.S.					73,684,000	10,526,000		
8-6 Wiring Works	L.S.					8,000,000	8,000,000		
9.Miscellaneous	%	5				166,606,000	116,189,000	111,235,000	5%of 1-8
10.Total Direct Construction Cost						3,498,726,000	2,439,969,000	2,335,935,000	
11.Indirect Construction Cost						1,224,555,000	853,989,000	817,578,000	
11-1 Common Temporary Works & Site expenses	%	15				524,809,000	365,995,000	350,390,000	15% of 10
11-2 Overhead & Profit	%	10				349,873,000	243,997,000	233,594,000	10% of 10
11-3 Tax	%	10				349,873,000	243,997,000	233,594,000	10% of 10
12.Total Construction Cost						4,723,281,000	3,293,958,000	3,153,513,000	
13.Contingency	%	10				472,328,000	329,396,000	315,351,000	10% of 12
14.Design & Supervision	%	10				472,328,000	329,396,000	315,351,000	10% of 12
15.Sub Total						5,667,937,000	3,952,750,000	3,784,215,000	
16.Land Acquisition	m2					62,200,000	65,400,000	72,000,000	
Total						5,730,137,000	4,018,150,000	3,856,215,000	

Note: Unit price of each land type by Nepalese Revenue Office is applied for estimation of land acquisition cost.
Width of ROW is settled as 30 meters for estimation of land acquisition cost.

10.4.3 Construction plan and schedule

1) Alternative-1 (Long Tunnel Option)

The critical path of this alternative will be the construction of the long tunnel. The net construction period required for the construction of the tunnel, which includes cut-and-cover at tunnel approach, tunnel excavation, concrete lining, pavement and other incidental works, will be 37 months and overall construction period will be 39 months including mobilization period of 2 months.

The major issues of assumed construction plan are as follows.

- Construction of Section-A, B, E and F will be commenced from the beginning simultaneously.
- Construction of Section-D will be commenced after completion of earth work construction of Section-E and construction from Kathmandu side will follow later after completion of earth work of Section-C.
- The tunnel excavation will be commenced from west portal first. The tunnel excavation from east portal will be commenced after completion of construction of cut-and-cover works at east approach. Two parties of the tunnel construction equipment will be required.
- New Austrian Tunneling Method (NATM), which uses rock bolts and shot-crete for major supports of excavation surface, is assumed to be applied.
- Tunnel excavation will be carried out mainly by the full-face excavation method with blasting. Drilling for the blasting will be done by two of three-boom hydraulic drill jumbo. In case of the poor geological portion, the top heading and bench method will be adopted.

2) Alternative-2 (Short Tunnel Option)

In this alternative, tunnel construction is not the critical path but the road construction of Section-D will be the critical path. The overall construction period of this alternative is estimated at 34 months including mobilization period and site cleaning period.

The major issues of assumed construction plan are as follows.

- Construction of Section-A, B, E and F will be commenced from the beginning simultaneously.
- Construction of Section-D will be commenced after completion of earth work construction of Section-E and construction from Kathmandu side will follow later after completion of earth work of Section-C.
- The tunnel excavation will be done from west portal only. The cut-and-cover works at east approach will be done in parallel with the tunnel excavation.
- New Austrian Tunneling Method (NATM) is assumed to be applied.

- Tunnel excavation will be carried out mainly by the side drift tunnel excavation method with road header and/or giant breaker.

3) Alternative-3 (No-tunnel Option)

Road construction of Section-C and Section-D will be the critical path in this alternative. It will take time for the construction of Section-C, since this section has the steepest topographic feature and is the most difficult construction section. Consequently the construction of Section-D, which follows construction of Section-C, will require longer time than that of Alternative-2.

The major issues of assumed construction plan are as follows.

- Construction of Section-A, B, E and F will be commenced from the beginning simultaneously.
- Construction of Section-D will be commenced after completion of earth work construction of Section-E and construction from Kathmandu side will follow later after completion of earth work of Section-C

10.4.4 Comparison by environmental criteria

All the sections excluding Section C have only one alternative selected after screening process. Thus, Alternatives 1, 2, and 3 have common routes in these sections excluding Section C. So it is considered that the environmental effect in these common routes are same in all the three alternatives and, the comparison is done based on the differences arising due to the different alternatives in Section C alone.

Table 10.11 shows the environmental elements with type of impacts as criteria for comparison, and the magnitude of impacts by each alternative of Section C.

Table 10.11 Comparison of each Alternatives in Section C by Environmental Criteria

Environmental elements		Type of impact	Magnitude of impact		
			C-1	C-2	C-3N
Bio-physical environment	Land use	Change of land use pattern due to road construction	++	++	+++
	Landscape	Changes of the topography or deterioration of harmonious landscape	++	++	+++
	Land stability	Increment of risk of slope collapse, land slide, and soil erosion due to the cutting and embankment work	++	++	++
	Air pollution	Change in air quality caused by gaseous emission from vehicles	+	+	++
	Noise	Generation of noise due to the vehicle traveling	+	+	+
	Vibration	Generation of vibration due to the vehicle traveling	-	-	-
	Water quality and sedimentation	Change in water quality and impact on river system by sedimentation	++	++	++
	Water resource	Reduction or depletion of water supply volume due to drawdown of groundwater table	+++	++	+
	Waste	Generation of construction waste such as surplus soil and debris	+	+	+
	Offensive odor	Generation of offensive odor	-	-	-
	Forest	Loss of forest area due to site clearance along the road alignment	+	++	+++
	Flora and fauna	Impact on habitat of flora and fauna, and extinction of species due to construction work or due to change of habitat condition	+	++	+++
	Meteorology	Changes in microclimate such as temperature and wind due to large-scale reclamation or construction	-	-	-
Socio-cultural environment	Resettlement	Resettlement due to road construction (Transfer of residence/land ownership)	+ ~50	++ ~100	+++ ~150
	Economic activities	Loss of production base such as agricultural land, and change of economic structure	+++	+++	+++
	Social/living facilities	Impact on social or living facilities such as schools, medical posts, and irrigation system	+	+	+
	Cultural/ religious sites	Loss or deterioration of cultural/religious properties such as temples and historic assets	+	+	+
	Health and sanitation	Deterioration of health or sanitary conditions due to the population gathered	++	++	++

+++: Relatively high magnitude of impact is expected. ++: Relatively medium magnitude of impact is expected.
+ : Relatively low magnitude of impact is expected. - : No magnitude is expected.

The characteristics of each alternative from an environmental point of view are summarized as follows.

- Land use

A certain magnitude of impact of change on the existing land use is expected due to cutting and embankment work, with regard to each alternative. However, the construction of Alternative C-3N will cause far more serious impact on the existing land use, since its total length amounts to about 10 km comparing with Alternative C-1 and C-2 of 6.0 and 6.5 km, respectively, and only open cut and embankment work is applied to constructing Alternative C-3N.

- Landscape

As well as change of the existing land use, relatively serious magnitude of impact on the landscape due to the change of topography caused by constructing Alternative C-3N is expected, because of the longest alignment. Moreover, in comparison with two other routes, much more change of landscape is caused by the construction of artificial structures such as bridges and gabion walls.

- Land stability

According to the earthwork of the long alignment of Alternative C-3N, the potential risks of slope failures and/or soil erosion of cutting/embankment slopes are increased, whereas the increment of these potential risks in case of constructing two other routes is relatively low.

On the other hand, there are dormant landslides around the Kathmandu side portals of both the long and short tunnel regarding Alternative C-1 and C-2. The risk of occurrence of landslide disaster may be increased, although both alignments can properly avoid the identified risk of landslide by the detail survey and examination.

- Air pollution

Alternative C-3N has the longest alignment, and the longitudinal gradient is the steepest. Therefore, the largest amount of exhaust emission by vehicle traveling of this alternative is expected, comparing with two other routes.

- Water resource

The construction of the long tunnel in Alternative C-1 may cause the drawdown of groundwater table in the surrounding area. This may result in the reduction or depletion of well/spring water volume supplied to and used by local people as drinking and miscellaneous water. Besides, the hydrological regime of Triveni Khola system may be changed due to the reduction of groundwater recharge volume, since the downward gradient from Kathmandu side is designed in this tunnel.

- Forest, flora and fauna

The likely lost areas of forest due to the construction of Alternative C-3N are more than five times of those of Alternative C-1 and C-2. The construction of Alternative C-3N splits the extensive forest located from Sotigau to Jhanglejhiti, whereas the forests affected by the construction of Alternative C-1 and C-2 are small-scale with low density, which are scattered on their ROWs. Therefore, considerably high magnitude not only of quantitative impact of deforestation but also of impact on habitat condition of wildlife is expected, due to the construction of Alternative C-3N.

- Resettlement

In the case of ROW width of approximate 30 m, the magnitude of resettlement caused by constructing each alternative in Section C is anticipated roughly as shown in Table 10.11, based on the quick field reconnaissance and the aerial photograph reading.

Although occurrence of resettlement will not be avoidable by any alternative, the magnitude of it due to constructing Alternative C-3N is presumed the highest.

10.4.5 Economic evaluation

1) Methodology

For the purpose of the selection of optimum route, the following procedure for the economic evaluation by each alternative was conducted:

- Calculation of economic benefits for each alternative routes
- Calculation of project cost for each alternative routes
- Comparison of EIRR, NPV and B/C

2) Economic Benefits

Vehicle operating cost savings and travel time costs savings of passengers were estimated quantitatively in this economic evaluation:

The vehicles adopted for calculation of the economic benefits were motorcycles, passenger cars, trucks, mini trucks, buses, and mini buses.

The future traffic volume and the travel speed presented in Chapter 7 were used for calculation of the economic benefits. Both existing and projected road conditions such as width, length, alignment, and roughness were taken into consideration for the benefits calculation.

The road network in 2020 was without Kathmandu-Terrai new road due to limited information for the future development plan.

The economic vehicle operating costs were estimated by using Highway Design Maintenance Standards Model (HDM) which is a computer model developed by the World Bank.

Price data and technical parameters of VOCs in the Fourth Road Improvement Project were updated by using the recent economic growth.

The time values for cars and buses are NRs 35.1 per hour and NRs 282.0, respectively, applying the results of the Fourth Road Improvement Project. Based on the occupancy rate of motorcycles and mini buses, the time values for motorcycles and mini buses are NRs 14.8 per hour and NRs 99.8 per hour, respectively.

The travel time costs by the alternative routes were calculated based on the traffic volume and the travel speed which were obtained from the results of the traffic assignment.

Based on the VOCs and travel time costs the economic benefits by the alternative routes were calculated and are presented in Table 10.12.

Table 10.12 Economic Benefits by Alternative Routes

unit: million NRs

	Economic Benefits	
	2010	**2020**
Alternative 1	387.9	985.7
Alternative 2	380.7	971.0
Alternative 3	338.3	882.7

3) Economic Costs

The economic costs were estimated based on the financial costs and conversion factors of financial prices to an economic basis. These are 0.88 in the case of construction costs and 0.9 in the case of maintenance costs.

All alternative route was assumed to be implemented with a start of construction in 2002. Construction period was assumed 3 years for each alternative route. Preliminary cost disbursement is shown in Table 10.13.

Table 10.13 Economic Cost Stream

unit: million NRs

	2002	2003	2004
Alternative 1	2,017.0	2,017.0	1,008.5
Alternative 2	1,414.4	1,414.4	702.2
Alternative 3	1,357.4	1,357.4	678.7

4) EIRR, NPV and B/C

In calculation of EIRR, NPV, and B/C, the following conditions were assumed:

- Opening year : 2005
- Evaluation period : 25
- Standard discount rate : 12 per cent

- Residual value : 75% of the construction cost at the end of the evaluation period
- Annual maintenance costs : 1% of the initial construction cost
- Benefit streams are estimated by means of interpolation and extrapolation between each benchmark years (2010 and 2020)

The results of calculation of EIRR, NPV and B/C are shown in Table 10.14.

Table 10.14 EIRR, NPV and B/C Calculation

	EIRR (%)	NPV (million NRs)	B/C
Alternative 1	9.4	-1225.1	0.71
Alternative 2	12.1	2.9	1.01
Alternative 3	11.6	-143.2	0.95

10.4.6 Result of optimum route selection

The optimum route was selected synthetically taking the following factors into consideration by rating.

1. Project Cost
2. Construction Period
3. Social Impact
4. Bio-physical Impact
5. Economic Feasibility

Rating results are presented in Table 10.15, in which the figures are given in order of preference.

Table 10.15 Results of Rating of Alternative Routes

No.	Item	Alternatives					
		Alternative 1		Alternative 2		Alternative 3	
		Long Tunnel Option		Short Tunnel Option		No-Tunnel Option	
	Road Length	24.8 km		25.4 km		28.6 km	
1.	Project Cost	③	5.7 Billion NRs. (78.1 million US$)	②	4.0 Billion NRs. (54.5 million US$)	①	3.7 Billion NRs. (52.2 million US$)
2.	Construction Period	③	39 months	①	34 months	②	37 months
3.	Social Impact	①		②		③	
	Land Acquisition Cost		62.2 million NRs (0.9 million US$)		65.4 million NRs (0.9 million US$)		72.0 million NRs (1.0 million US$)
	Resettlement		~ 450 houses		~ 500 houses		~ 550 houses
4.	Bio-physical Impact (Major Issue)	②	Drawdown of groundwater (relatively big scale)	①	Drawdown of groundwater (relatively small scale)	③	Loss of forest area and impact on the habitat of fauna and flora
5.	Economic Evaluation	③		①		②	
	EIRR		9.4%		12.1%		11.6%
	NPV		-1,225 mill.NRs		23 mill.NRs		-143 mill.NRs
	B/C		0.71		1.01		0.95
Total Evaluation		③		①	Recommended	②	

NOTE :
1. Rating : ①=most favorable (best), ② =second best, ③ =worst
2. Width of Row is settled as 30m for estimation of resettled houses and land acquisition cost.
3. Unit price for each land type by Nepalese Revenue Office is applied for estimation of land acquisition cost.
4. Houses to be resettled in Section A are excluded from estimation.

Alternative-1, Long Tunnel Option, will generate the biggest benefit and minimum social impact, however it requires the highest cost and shows the lowest economic feasibility.

Alternative-2, Short Tunnel Option, although its project cost is slightly higher than that of Alternative-3, it shows highest economic feasibility. Furthermore this alternative has advantages against the other alternatives in viewpoints of bio-physical impact and construction period.

Alternative-3, No-tunnel Option, will require the lowest cost, however it shows lower economic feasibility than that of Alternative-2. This alternative has disadvantages in viewpoints of social and bio-physical impacts.

Firstly Alternative-1 (Long-Tunnel Option) is screened out because of its highest cost and lowest economic feasibility, of which extents in difference between the other alternatives are considered not to balance with its advantages of smaller social impact.

As regards to the Alternative-2 (Short-Tunnel Option) and Alternative-3 (No-Tunnel Option), there is no significant difference in all aspects shown in Table 10.15. The JICA Study Team, however, recommends Alternative-2 (Short Tunnel Option) as the Optimum Route based on the following considerations.

1) Reliability of the Road

The tunnel itself can be recognized as a disaster-proof structure against heavy rain and earthquake, which are critical issues in Nepal. Since the Short-Tunnel Option can avoid the steepest topographic and poorest geological section in western side of the Bhimdhunga saddle, it should have higher reliability against the road disaster than the No-Tunnel Option. From the economic point of view, high reliability against the road disaster will decrease the maintenance cost for the restoration of the disasters and increase economical benefit due to the decrease in traffic interruption by the disasters.

2) Project Implementation

The Alternaive-3, No-Tunnel Option, causes loss of the remaining precious forest in Bindhunga and requires larger amount of land acquisition and number of resettlement of houses. On the other hand, Alternative-2, Short-Tunnel Option, can mitigate such environmental and social impacts and will be more acceptable for the environmental authority of the Nepalese government and local people. These are the advantages of the Short-Tunnel Option not only from viewpoints of the environmental and social impacts but also from the viewpoint of the smooth implementation of the Project.

3) Decrease in Traffic Accident Rate

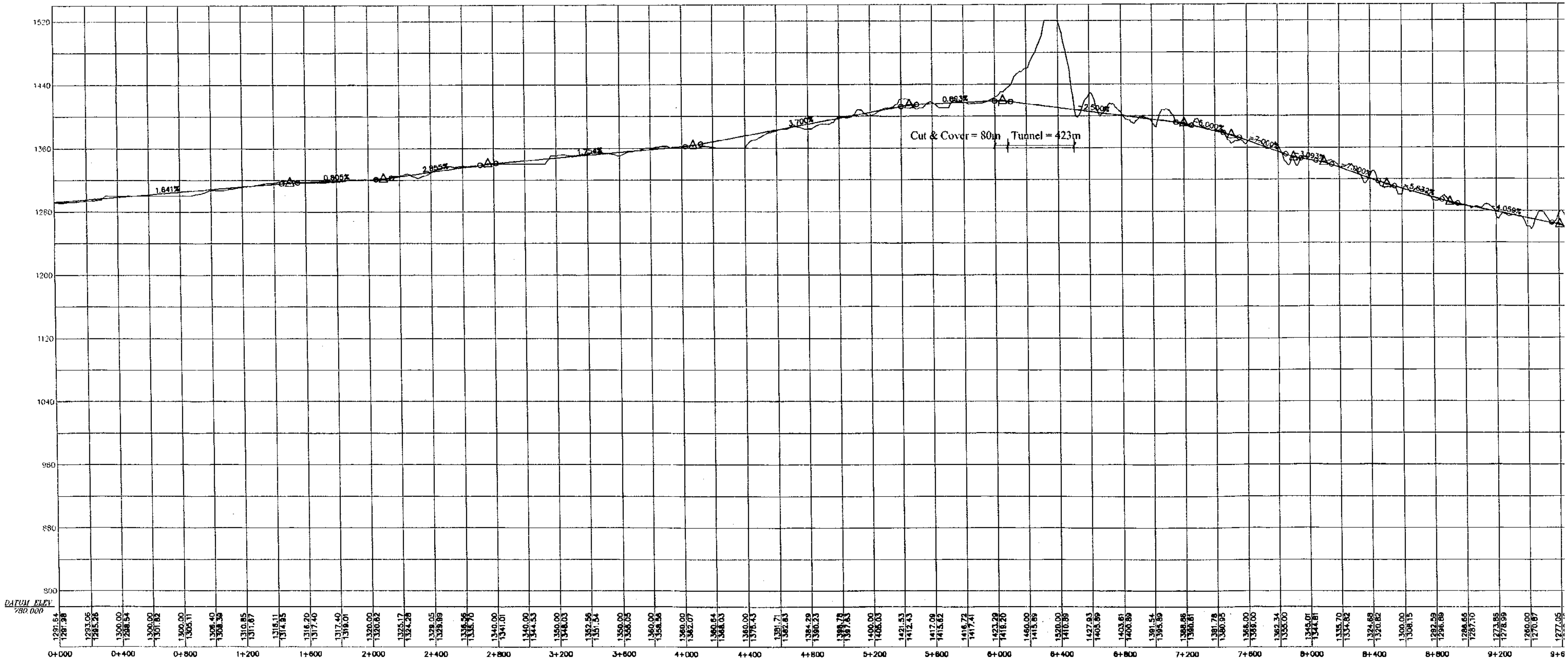
Generally, traffic accidents occur more frequently at such critical alignment sections as sharp horizontal curve and steep gradient portions. The road length in the critical alignment section of the Short-Tunnel Option is shorter than that of the No-Tunnel Option by about 3 km, so it can be expected that the total traffic accident rate per whole road length of the Short-Tunnel Option will be lower than that of the No-Tunnel Option.

4) Necessity of the Highway Tunnel in Nepal

Nepal is one of the eminent mountainous countries in the world and when we think about the future road development in Nepal, it will be indispensable to furnish highway tunnels in the long run. Since the Project Route is the most important corridor, it would be highly worth introducing the highway tunnel from the viewpoint of future road network development, while the country is in a stage of its effort to strengthen the national road network. In other words, the introduction of the highway tunnel through the Project must have remarkable meaning in transfer of new technology for the future road network development in Nepal.

The Optimum Route is given in Figure 10.6.


SECTION - A
RING ROAD CONNECTION
SYUCHATAR
SITAPAILA
HARISIDDHI


1520
1440
1360
1280
1200
1120
1040
960
880
800
DATUM ELEV
780.000
1.641%
0.805%
2.855%
1.75%
3.700%
0.863%
-2.500%
-6.000%
-7.000%
-5.632%
-4.059%
Cut & Cover = 80m
Tunnel = 423m
0+000
0+400
0+800
1+200
1+600
2+000
2+400
2+800
3+200
3+600
4+000
4+400
4+800
5+200
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6+000
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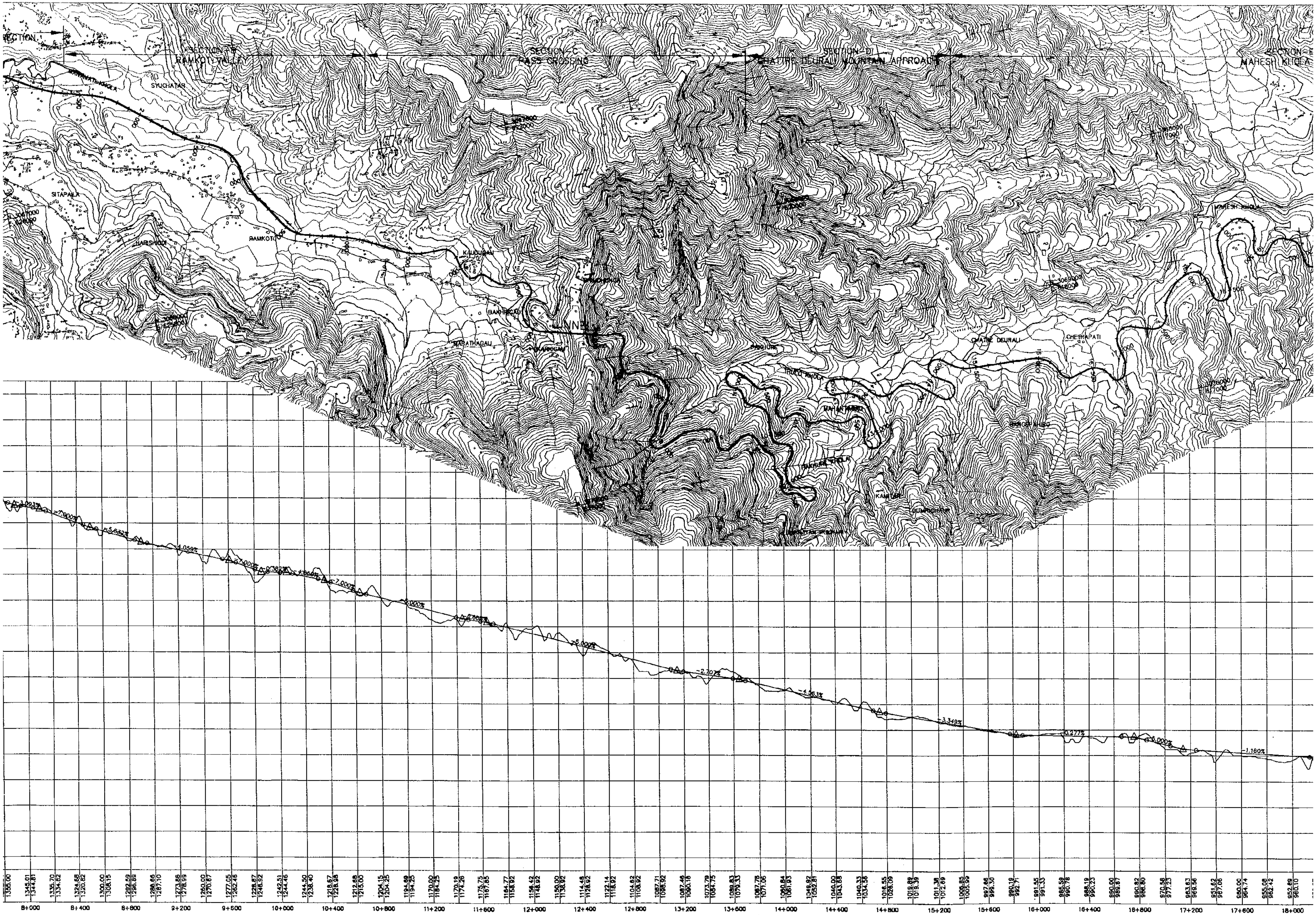
6+800
7+200
7+600
8+000
8+400
8+800
9+200


SECTION-B
RAMKOT VALLEY
SECTION-C
PASS CROSSING
SECTION-D
CHATIRE DEURALI MOUNTAIN APPROACH
MAHESH KHOLA
SITAPAILA
RAMKOT
CHATRE DEURALI
CHETRAPATI
MAHESH KHOLA
-5.000%
-2.707%
-4.563%
-3.349%
-1.160%
8+000
8+400
8+800
9+200
9+600
10+000
10+400
10+800
11+200
11+600
12+000
12+400
12+800
13+200
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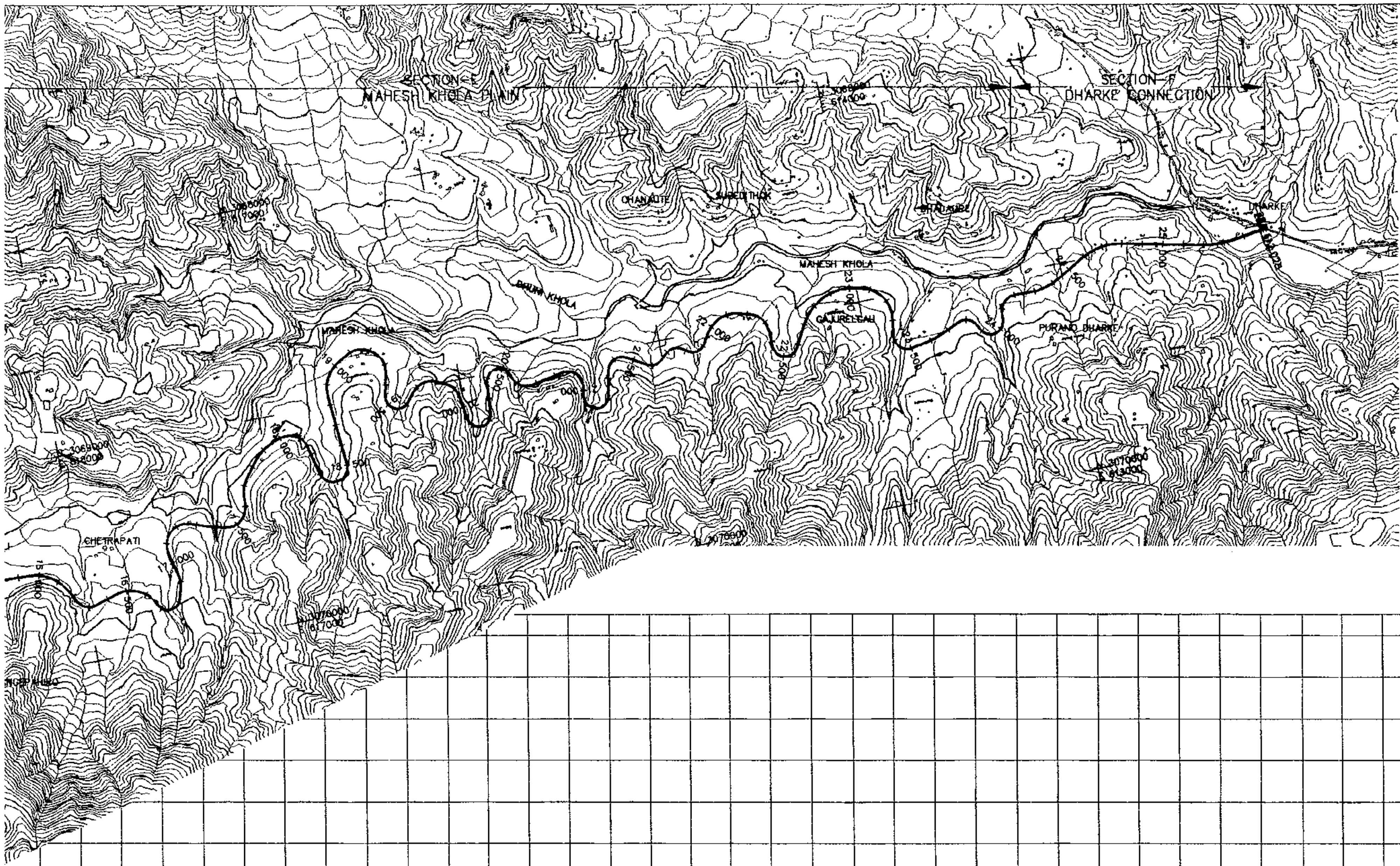
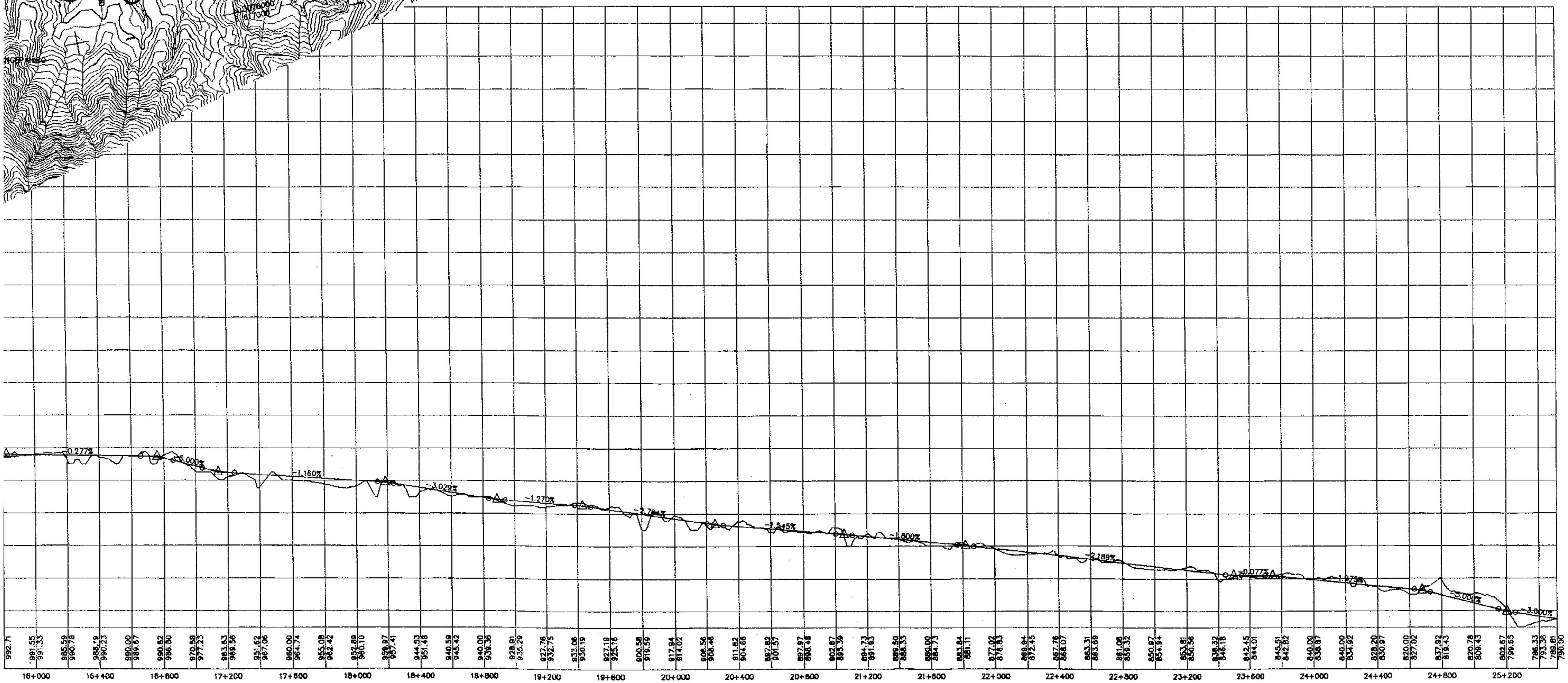
17+200
17+600
18+000





Scale: 1/25,000

Figure 10.6 The Optimum Route

10.5 Comparison with 4-lane Improvement of Existing Tribhuvan Highway Options

10.5.1 General

For the justification of the Project to construct a new alternate road in Kathmandu – Naubise Section, further comparison with other alternatives, which are 4-lane improvements of the existing Tribhuvan Highway, was conducted.

10.5.2 Possible Improvements of Existing Tribhuvan Highway (Kathmandu-Naubise Section)

Following improvement options for the existing Tribhuvan Highway can be formulated;

Option-1 4-lane widening of the whole section from Kathmandu – Naubise

Option-2 Partial 4-lane widening and partial 2-lane new construction
4-lane widening from Kathmandu to Nagdhunga pass, new 2-lane construction for the pass crossing and connection to the existing road, and 4-lane widening of the section to Naubise.

Option-3 Partial 4-lane widening and partial 2-lane new construction with tunnel
4-lane widening from Kathmandu to Nagdhunga pass, new 2-lane construction with tunnel for the pass-crossing, and 4-lane widening of the section to Naubise.

1) Option-1: 4-lane widening of the whole section from Kathmandu – Naubise

The existing Tribhuvan Highway was divided into three types of sections based on the topography.

i) Plan/Rolling Terrain Section – Type A
ii) Mountainous Terrain Section - Type B
iii) Steep Terrain Section – Type C

Typical cross sections of 4-lane widening applied to the above sections are shown in Figure 10.7 for respective cases.

a) Type A (Plan/Rolling Terrain Section)

This type of section is applied, where the terrain is rather gentle.

Small scale gravity wall for embankment and stone masonry wall for the cutting section is applied. All the road section in the Kathmandu Valley and the section with a length of about 5.5 km to Naubise belongs to this type. Generally, areas adjacent to the road in this type of cross section are built up, so land acquisition and compensation will be the critical issue.

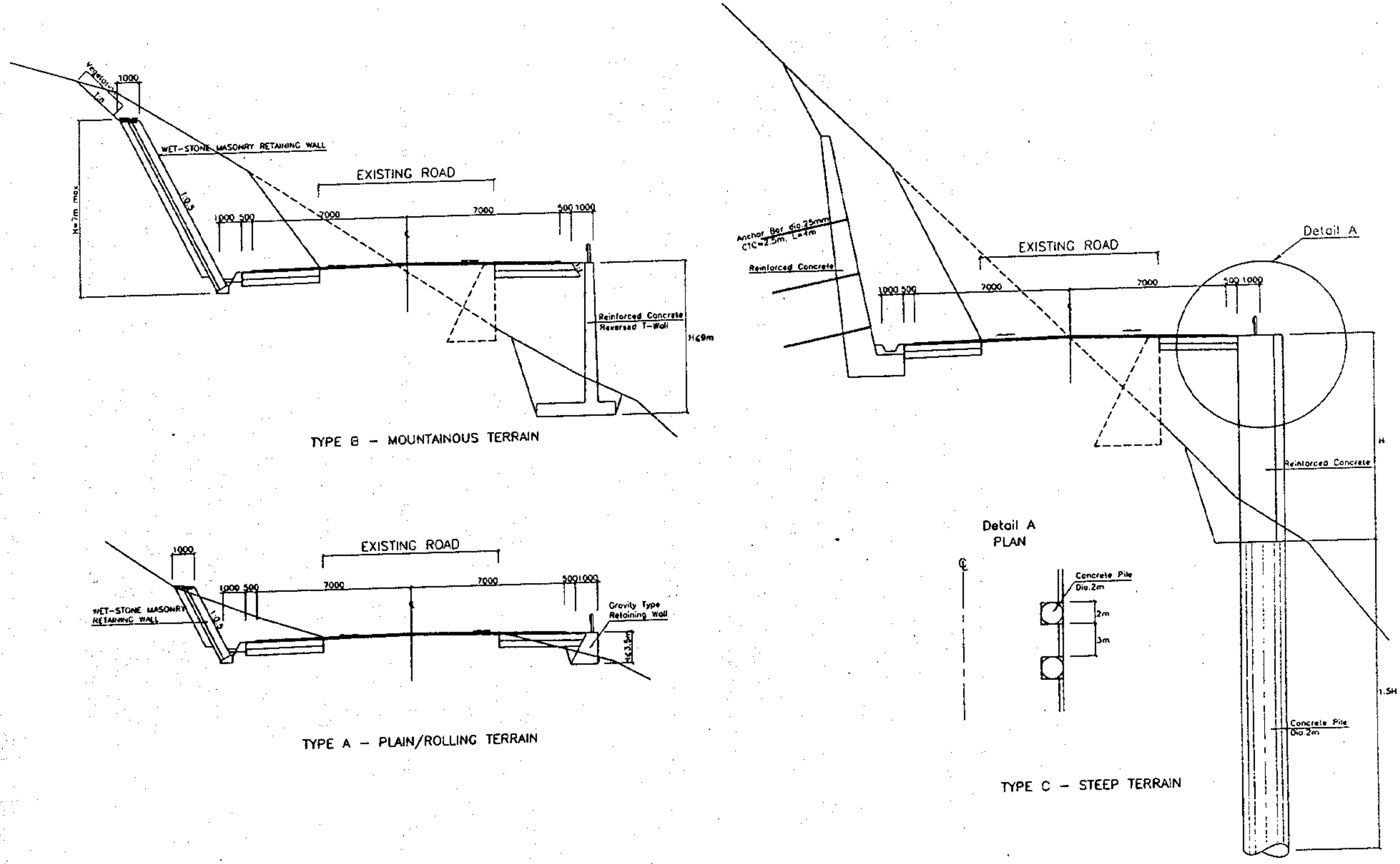


Figure 10.7 TYPICAL CROSS SECTIONS FOR WIDENING OF EXISTING TRIVUBAN HIGHWAY TO FOUR LANES

b) Type B (Mountainous Terrain Section)

The sections of the road, which pass through mountainous terrain, but not through steep terrain, are classified into this type.

In this type, additional embankment is constructed by using retaining walls of R.C. reversed T-wall. The additional cutting required for widening towards the mountainside is done by using wet stone masonry wall. A total of about 5.5 km is estimated to be constructed by this type of cross section.

c) Type C (Steep Terrain Section)

The section of the road, in a length of about 5.5 km in the Nagdhunga pass, is through very steep terrain and, this type of cross section is applied to widen the existing road to 4-lane.

Due to very steep terrain condition and limited space available both in the embankment and cutting side, following retaining structures are considered.

- For embankment side : R.C. panel type wall and R.C. column supported by cast-in-situ well-type-pile.
- For cutting side : R.C. inclined wall supported by anchor bars.

2) Option-2: Partial 4-lane widening and partial 2-lane new construction

In this option, the section from Kathmandu to the Nagdhunga pass is considered to be widened to 4-lanes. The 4-lane widening is applied up to about 500 m before the existing first hairpin bend at Nagdhunga pass.

The existing road afterwards is considered as 2-lane one-way road for outbound traffic from Kathmandu to Naubise. Another 2-lane new route for inbound traffic to Kathmandu, with maximum vertical profile grade of 5%, has been investigated. After the Nagdhunga Pass crossing, the 2-lane new route meets the existing road, after which, 4-lane widening of the existing road is considered again up to Naubise.

The new route for 2-lane construction is shown in Figure 10.8 as the northern most route. The 2-lane new route passes through very steep topographical conditions and the total road length is increased by about 2.9km, compared to the existing road in this section. However, the horizontal alignment is improved to meet at least the design speed of 40km/hr and the vertical profile grade of less than 5%.

The construction of new 2-lane road through steep terrain conditions is considered similar to that of the project road through steep terrain conditions and similar typical cross sections have been applied. The alignment of 2-lane new route passes a dangerous stream of debris flow two times before and after the hairpin bend at STA.12+150 and STA.13+900. It passes other dangerous streams of debris flow at about STA.17+700 and STA.19+100. Bridges with enough clearance is considered for these stream crossings.

3) Option-3: Partial 4-lane widening and partial 2-lane new construction with tunnel

In this alternative, the section from Kathmandu to the Thankot is considered to be widened to 4-lanes. The existing road thereafter is utilized as 2-lane one-way road for outbound traffic from Kathmandu. The existing road is widened to 4-lanes up to about 700m from the Thankot check post and a new 2-lane road is investigated, which diverts slightly towards north.

A short tunnel of about 1200m is considered to cross the Nagdhunga Pass. The 2-lane new route passes through the mountainous section at the southern side of the existing road. The alignment meets the existing road near Khanikhola and 4-lane widening is again considered thereafter till Naubise. The alignment of the 2-lane new route with tunnel construction is given in Figure 10.8, which is the southern most route.

The total road length in the new 2-lane route section with tunnel is shortened by about 2.7km as compared to the existing road. Due to relatively flat terrain on the Kathmandu side of the Nagdhunga pass, the length of the tunnel becomes about 1200m, even after lowering the tunnel formation height with a cutting section of about 25m introduced at the tunnel portal of the Kathmandu side. Further increase in the length of the tunnel does not contribute to shortening of the total road length, because the topography of the Kathmandu side tunnel portal is plain.

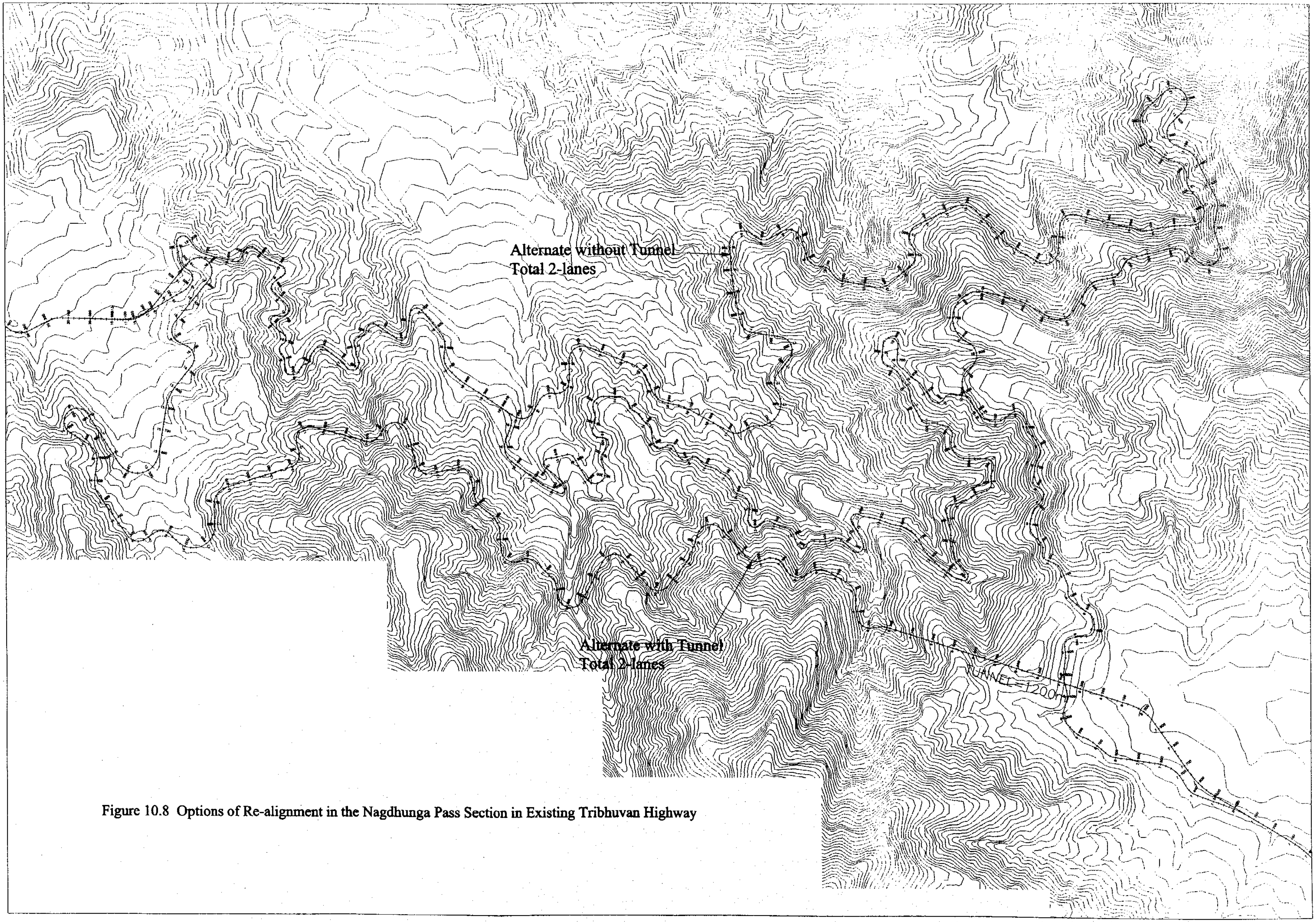


Figure 10.8 Options of Re-alignment in the Nagdhunga Pass Section in Existing Tribhuvan Highway

10.5.3 Cost Estimate of Different Options

Rough cost estimates were done for different options of improvement of the existing Tribhuvan Highway in Kathmandu – Naubise section. The costs have been summarized in Table 10.16.

Table 10.16 Cost Estimation for Possible Improvements of Existing Tribhuvan Highway

Items	Unit	Unit Cost (USD)	Option-1		Option-2		Option-3	
			Quantity	Total Cost (USD)	Quantity	Total Cost (USD)	Quantity	Total Cost (USD)
Excavation (Weathered Rock)	m3	10.0	511000	5,110,000	739857	7,398,566	436284	4,362,842
Filling	m3	1.2	262000	314,400	407679	489,215	220029	264,035
RC T-shaped Retaining Wall	m3	136.2	29000	3,949,800	49848	6,789,298	24013	3,270,543
Wet Masonry Wall	m2	21.7	129000	2,799,300	176500	3,830,050	141800	3,077,060
Gravity Wall	m3	37.2	22000	818,400	23088	858,874	24211	900,657
RC Retaining Wall	m3	96.4	64000	6,169,600	20880	2,012,832	0	0
Anchor Bar	Nos	367.0	7000	2,569,000	2160	792,720	0	0
RC Column	m3	96.2	41000	3,944,200	13528	1,301,401	0	0
RC Wall	m3	96.2	12000	1,154,400	4060	390,545	0	0
Concrete Pile	M	765.0	13000	9,945,000	500	382,500	0	0
Base Course	m3	18.1	36000	651,600	75930	1,374,333	61830	1,119,123
Subbase Course	m3	13.8	36000	496,800	75930	1,047,834	61830	853,254
Asphalt Concrete	m2	8.4	116000	974,400	276400	2,321,760	344500	2,893,800
Side Drainage	M	25.4	29500	749,300	32300	820,420	25800	655,320
Bridge	m2	1608.2	4392	7,063,214	5296	8,517,027	5196	8,356,207
Tunnel Structure	M	16064.5					1200	19,277,387
Ventilation	m	340.4					1200	408,433
Lighting	m	835.1					1200	1,002,067
M & E	m	1114.8					1200	1,337,743
Emergency	m	343.1					1200	411,740
Electric Installment	m	91.9					1200	110,238
Subtotal				**46,709,414**		**38,327,375**		**48,300,451**
Miscellaneous works	15% of road works			7,006,412		5,749,106		3,862,926
Total Direct Construction Cost				**53,715,827**		**44,076,481**		**52,163,377**
Land Acquisition Cost	**L.S.**			**19,911,296**		**20,654,565**		**18,552,514**
Compensation Cost	**L.S.**			**1,013,807**		**800,558**		**839,013**

The direct construction costs of Option-1 (4-lane widening of the whole road section from Kathmandu to Naubise), Option-2 (partial 4-lane widening and partial 2-lane new construction) and Option-3 (partial 4-lane widening and partial 2-lane new construction with tunnel) are 53.7 million US$, 44.1 million US$ and 52.2 million US$ respectively. The results showed that the 4-lane widening of the whole section gives the highest construction cost. The option with a short tunnel with partial new 2-lane construction is slightly cheaper than the 4-lane widening of the whole section.

Option-2 with partial 2-lane new construction (without tunnel) for the Nagdhunga Pass crossing is the cheapest option. However, considerations for geometric improvements of the existing 2-lane road in the pass crossing have not been considered in this option. Besides, considerations for preventive countermeasures against landslides have not been included, which are required for one-way operation of the existing road in this section of Nagdhunga pass crossing. This consideration will definitely escalate the construction cost of this option further.

10.5.4 Evaluation of 4-lane Improvement of Existing Tribhuvan Highway Alternatives

Following Table 10.17 shows the results of the cost estimate. As shown in the table, direct construction cost together with land acquisition cost of all options are higher than that of the Project road, so it could be concluded that the Project road - a new alternate road via Bindhunga - is more advantageous from economical point of view.

Table 10.17 Cost Comparison between 4-lane Improvement of Existing Tribhuvan Highway and Kathmandu – Naubise Alternate Road Project

Unit: million US$

	Cost of Alternatives (million US$)			
	4-lane Improvement of Existing Tribhuvan Highway Option			New Kathmandu – Naubise Alternate Road
	Option-1	Option-2	Option-3	
Direct Construction Cost	53.7	44.1	52.2	33.6
Land Acquisition Cost	2.5	2.6	2.3	0.9

Furthermore, it must be preferable from the viewpoint of the national security to have plural alternatives route in Kathmandu – Naubise section, where the existing Tribhuvan highway is the sole route at present.

In addition, the new alternate road construction via Bhindhunga shall have an advantage to extend possibility of regional development in surrounding area of the Kathmandu valley.

According to the above results and consideration, it was concluded that the Project road is the most viable option as the highway improvement of Kathmandu – Naubise section.

CHAPTER 11 STUDY ON LOCATION AND FORMATION OF TUNNEL

11.1 General

The optimum route selected in the previous chapter was studied with the help of the existing topographic map of 1:25,000 scale that was digitally converted to a scale of 1:10,000.

Three major routes were analysed in the previous chapter regarding the pass crossing. A short tunnel option with 500m length (the geological condition is relatively poor), a long tunnel option with 2000m length (the geological condition is sound), and one no-tunnel option, were finally discussed. Ultimately, it was concluded that the alternative with short tunnel option is the optimum route.

However, the 500m length, the location and formation height of the tunnel itself were still to be studied in detail after the detailed topographic survey. Seismic refraction survey was also carried out using blasting to obtain the geo-physical characteristics of the tunnel area.

Furthermore, the location and formation height of the tunnel affects the whole alignment after the tunnel portal in Naubise side. The locations of the hairpin bends are also affected by the formation height and location of the tunnel. So, it was desirable to study this issue before commencing the preliminary design stage.

11.2 Initial Study Based on Topographic Survey

After the completion of the detailed topographic survey, the location of the tunnel portal based on the Optimum Route was studied. *During the initial study, the seismic refraction survey was still being carried out.*

Towards the north side of the tunnel portal (Kathmandu side), a dormant landslide area at Dhansar exists, as shown in the Hazard Map. The formation height of the tunnel at this location cannot be lowered much as that will ultimately accelerate the landslide activity due to large cut. A full-scale landslide countermeasure will be required in such case. So, cut and cover portion of about 80m was introduced in this alternative.

For this reason, another alternative location for the short tunnel in the vicinity was studied such that the formation height of the tunnel can be lowered further to shorten the total length of the Project Road. The studied alignment is shown in Figure 11.1, along with the short tunnel option (C2) for comparison. The profile of this alignment has been given in Figure 11.2.

This alternative alignment for Section C has been named as "C4".

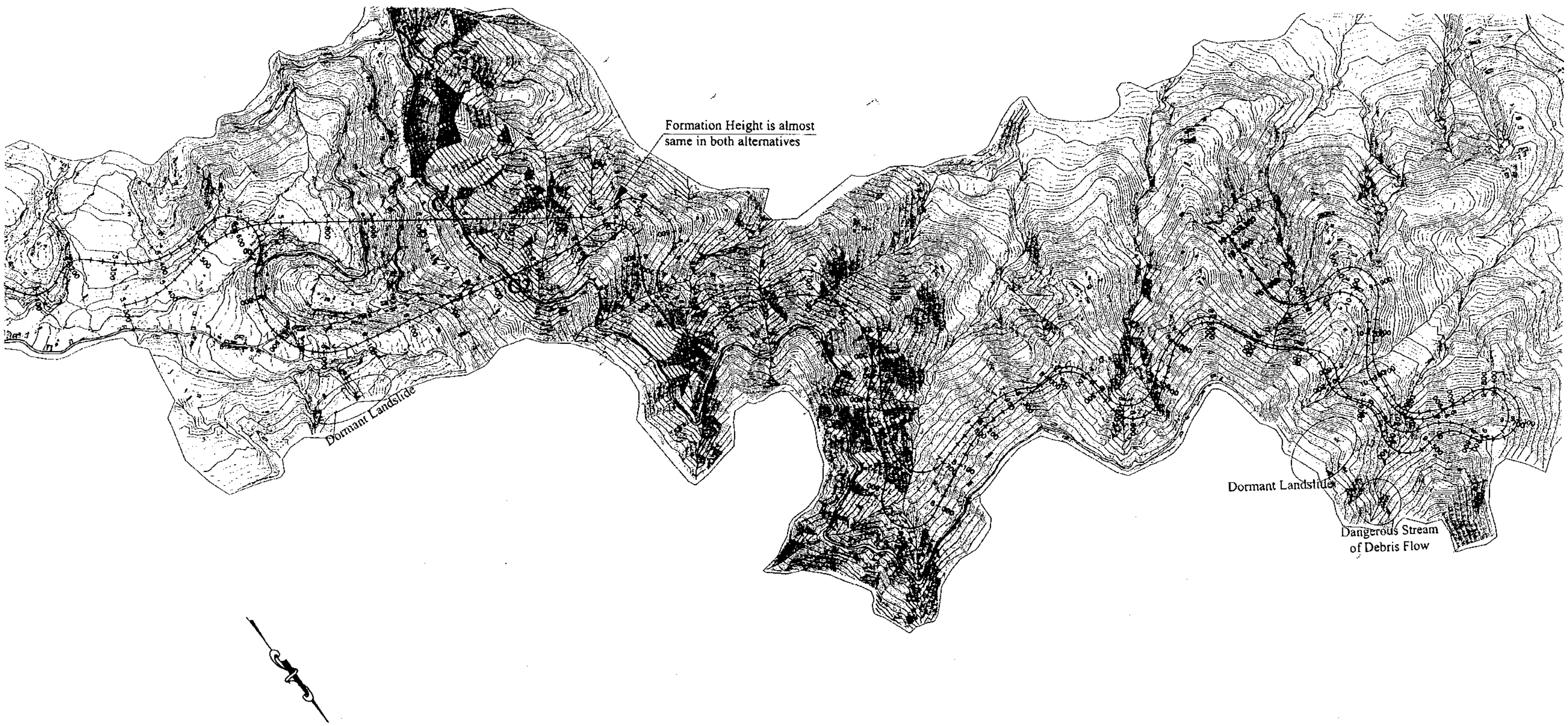


Figure 11.1 Alternative Alignment C4 of Short Tunnel
Scale 1:10,000

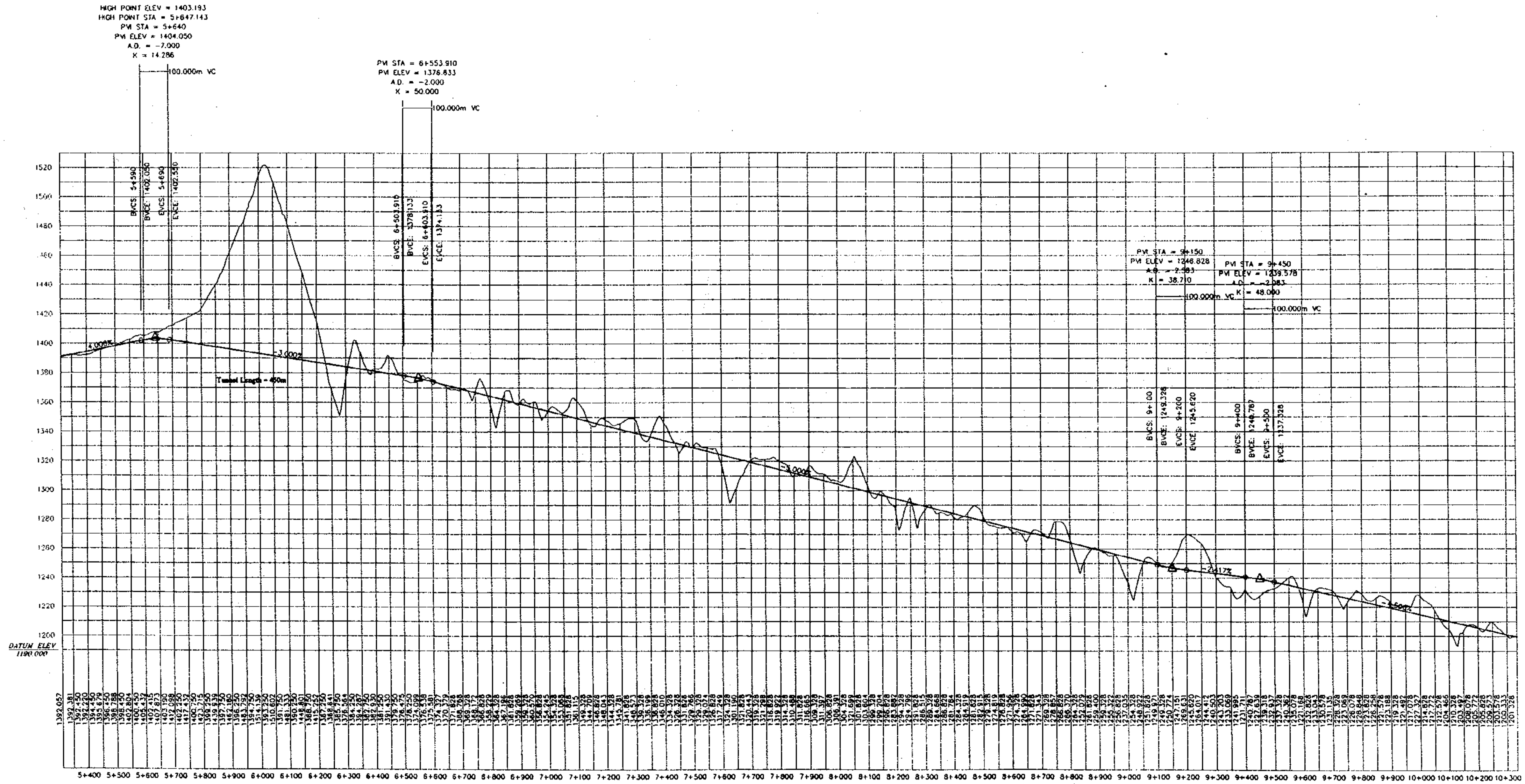


Figure 11.2 Profile of Alternative Alignment C4
Scale 1:15,000